EMEND

ECOSYSTEM-BASED MANAGEMENT EMULATING NATURAL DISTURBANCE

EMEND Insights #22

Ecological Messages:

- Temperature conditions are strong drivers of CO_2 production in boreal soils. Current rates of CO_2 output will likely increase with future climate warming.
- The amount of easily decomposable carbon is greater at lower topographical positions (i.e., downslope), which may serve as especially significant carbon sources in warming scenarios.

Management Implications:

- Harvesting did not alter the relationship between DTW and mineral soil carbon stocks, suggesting that the EMEND harvest design protected a more stable carbon pool.
- **Harvesting from the dry end of the DTW gradient is preferable for *conifer-dominated* stands** to avoid triggering a loss of forest floor carbon stocks.
- **In *deciduous-dominated* stands, harvesting from the wet end of the DTW gradient may be preferable** to promote increased forest floor carbon stocks.

Adapting harvest practices to climate change: how Wet Areas Mapping can help estimate soil carbon stocks

Research led by Paul Sewell, Sylvie Quideau, and Miles Dyck

The boreal forest accounts for nearly a quarter of all soil carbon stores in the world. Perhaps surprisingly, most of that carbon is not actually in the trees—it's in the soil. With climate change predicted to affect the boreal forest more severely than other terrestrial ecosystems, boreal soils may shift from being a carbon sink to a carbon source. Armed with knowledge about where carbon is stored in these important soils, ***forest managers may be able to adjust harvest practices to help reduce carbon losses from forest soils.***

We asked whether a tool used by forest operators, the depth-to-water (DTW) index, could be useful for predicting soil carbon stocks across varying levels of retention harvest. We also investigated the implications of topography, a rarely-considered feature of the boreal forest, for determining the distribution and stability of soil carbon and how this may shift with climate change.

In unharvested conifer-dominated stands, we found that forest floor carbon stocks increased towards the wet end of the DTW gradient. After harvest, there was no relationship between site wetness and forest floor carbon stocks, suggesting that ***carbon stocks were lost from sites at the wet end of the DTW gradient in conifer-dominated stands.*** In unharvested deciduous-dominated stands, we did not detect a relationship between DTW and forest floor carbon stocks. After harvest, forest floor carbon stocks increased at wetter sites, suggesting that ***long-term regeneration processes may increase forest floor carbon at the wet end of the DTW gradient in deciduous-dominated stands.***

Overall, the results of our study also show that temperature conditions are also strong drivers of soil CO_2 output and that ***soil CO_2 production will generally increase with future warming. Adjusting harvest practices based on the DTW gradient may be an important strategy for lessening this predicted increase.*** Future research will strive to increase the precision of soil carbon estimates derived from DTW, potentially by combining Wet Areas Mapping with mapping of the forest canopy.

Why Forest Soils?

Forest soils are an important carbon sink, but changes to soil moisture, temperature, and the forest itself (e.g., forest harvesting) can affect soil carbon dynamics. These changes may cause increases in soil respiration, meaning that more CO_2 is released into the atmosphere. We studied soil carbon stocks and respiration at EMEND to evaluate 1) the relationships between depth-to-water (DTW, see Box 1) and soil carbon stocks across a harvesting gradient, and 2) the relationships between actual and potential (e.g., under future warming) soil carbon respiration and hillslope position.

Study Design

We estimated DTW and measured soil carbon stocks throughout EMEND 17 years after harvest treatments were applied in 1998–99. These sites are currently dominated by aspen regeneration. We assessed two retention treatment levels (20% and 50%) and compared these to clear-cuts (2%) and unharvested controls to answer the questions: ***does DTW accurately predict soil carbon stocks? Do these relationships change depending on harvest treatments?***

We also measured soil CO_2 respiration across an unharvested hillslope (c. 140 year old boreal mixedwood) to assess these changes across a topographic gradient (drier deciduous forest upslope and wetter conifer forest downslope). We did this in the field to assess the current levels of CO_2 production, then took soil samples to the lab to measure how much carbon was labile (i.e., how much carbon could break down and be respired).

Box 1. What is depth-to-water (DTW)?

Aerial photo interpretation has typically been used to develop maps showing surface drainage networks, but these maps often lack the level of detail needed to plan forest operations. Following recent advancements in remote sensing, the Wet Areas Mapping project used LiDAR data to estimate the depth in metres to the water table. This measure was labeled the depth-to-water (DTW) index. A low DTW value, for example, means there is a high probability that water is near or even at the surface of the ground. It is important to note that DTW is not an empirical measure of site wetness, but rather represents the probability of encountering water at a given depth. Researchers can adjust the model to improve its performance at different sites and under different conditions (e.g., drought).

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).

Main Findings

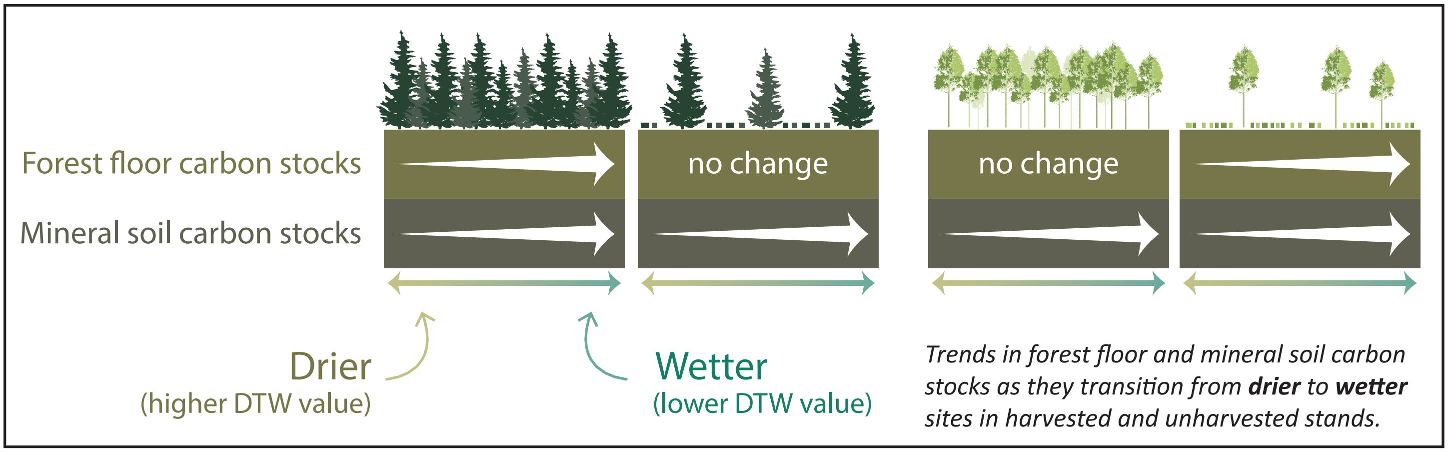
Depth-to-water: a tool that must be informed by stand type

Based on our findings, we suggest that ***harvesting from the dry end of the DTW gradient is preferable for conifer-dominated stands*** to avoid triggering a loss of forest floor carbon stocks. In contrast, ***harvesting from the wet end of the DTW gradient may be preferable in deciduous-dominated stands***, as this may promote increased carbon stocks.

In unharvested conifer-dominated stands, ***carbon stocks increased towards the wet end of the DTW gradient*** in both the mineral soil and the forest floor. After harvest, the relationship between DTW and forest floor carbon stocks became very weak in conifer-dominated stands, suggesting that carbon losses were greatest in the forest floor of wetter sites. ***By harvesting from the dry end of the DTW gradient in conifer-dominated stands, forest managers can conserve the higher forest floor carbon stocks that exist at the wet end of the gradient.***

Box 2. Harvesting had a significant effect, but there were few differences among treatments

While the relationship between forest floor carbon stocks and DTW changed before and after harvest, the relationships among the harvest treatments (clear-cuts, 20% and 50% retention) were not significantly different. This means that forest floor carbon stocks behaved in similar ways across the DTW gradient, regardless of retention level, 17 years post-harvest.



*Trends in forest floor and mineral soil carbon stocks as they transition from **drier** to **wetter** sites in harvested and unharvested stands.*

In deciduous-dominated stands, carbon stocks also increased towards the wet end of the DTW gradient in the mineral soil, but there was no obvious relationship between DTW and forest floor carbon stocks in unharvested stands. However, harvest led to an increase in forest floor carbon stocks at wetter sites. This suggests that ***it may be beneficial to harvest from the wet end of the DTW gradient in deciduous-dominated stands.***

Forecasting the future: where might soil carbon emissions increase?

We measured soil CO_2 respiration (output) along a hillslope to capture a range of soil moisture and tree cover types in a small area (i.e., drier, warmer aspen forest upslope and wetter, cooler white spruce forest downslope). Forest floor carbon respiration was much more variable than the mineral soil, much like we found with carbon stocks, suggesting that ***the forest floor is a major driver of total carbon outputs***. Harvest practices that protect the forest floor, such as winter harvesting, may help to mitigate this dynamic.

Soil temperature and moisture were both important drivers of soil CO_2 respiration. At downslope positions, low temperatures appeared to inhibit total soil carbon production, while at upslope positions, periodic drying appeared to reduce forest floor carbon production.

CO_2 production rates from forest floor samples from all topographic positions ***increased by a factor of ten in the lab when compared to the same topographic positions sampled in the field***. This means that under future warming, overall soil carbon production will likely increase regardless of slope position or stand type.

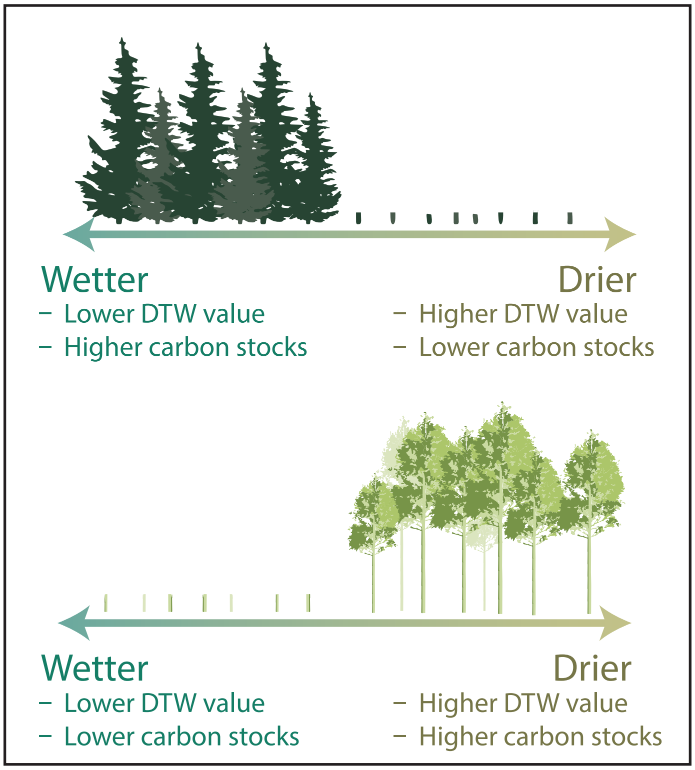
However, our findings suggest that ***the forest floor at lower slope positions (or in conifer-dominated stands) are likely to be a much larger future source of CO_2***. In the lab setting—i.e., no longer limited by soil moisture or temperature—these soil samples released almost twice as much CO_2, suggesting they held more carbon that can turn over quickly than upslope soils. Application of these findings to forest management should be a priority for future research, as there may be an opportunity to conserve soil carbon based on the topographical position of harvesting activities.

Management Implications

The results of our work suggest that harvesting from the dry end of the DTW gradient is preferable for conifer-dominated stands to avoid triggering a loss of forest floor carbon stocks, while harvesting from the wet end of the DTW gradient in deciduous-dominated stands may promote increased forest floor carbon stocks.

In the context of retention harvest, the above approach may work best when it comes to choosing the location of retention patches (aggregated retention) rather than the location of single trees (dispersed retention). A potential harvest pattern could be to leave patches of trees in conifer-dominated stands at relatively wet sites (i.e., low DTW value), and to apply the opposite for deciduous-dominated stands, leaving retention patches at relatively dry sites (i.e., high DTW value).

Because this study took place 17 years after retention harvest, it will be important for future studies to address the question: what happens in the soil directly after harvest? A similar study to ours, but conducted directly after harvest, would be useful to help answer this question. It may also be useful to incorporate LiDAR data to study forest canopy contributions to carbon in the forest floor. While the forest floor (e.g., leaf litter and debris from the canopy) appears to be a strong driver of soil carbon turnover, DTW does not correlate strongly with forest floor properties. By incorporating LiDAR, it may be possible to increase the accuracy of soil carbon estimates.



Potential retention patterns to promote conservation of soil carbon stocks in conifer-dominated stands (top) and deciduous-dominated stands (bottom).

Further reading

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WRITTEN BY:

S. Nason, MSc
S. Odsen, MSc

COORDINATING EDITOR: M. PYPER
GRAPHICS & LAYOUT: S. NASON & S. ODSEN

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