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Influence of cover type and variable retention harvesting on soils in the EMEND Experiment

Highlights

- Soil profiles that reflect parent materials and other soil forming factors are fairly consistent over the study area, while forest floor properties differ under different overstory vegetation types.
- Although variable retention harvesting may provide other important ecological and silvicultural benefits, there were no advantages over clearcut harvesting, in terms of changes in nitrogen availability, during the time frame studied here.
- Stand composition appears to influence not only forest floor properties, but the associated microbial and understory ecological community as well, underlining the importance of maintaining heterogeneity in the boreal mixedwood forest.
- The low-impact harvesting applied on boreal mixedwood sites in the EMEND study resulted in very few changes in nutrient availability immediately following harvest, supporting the importance of practices that minimize soil disturbance on these sites.

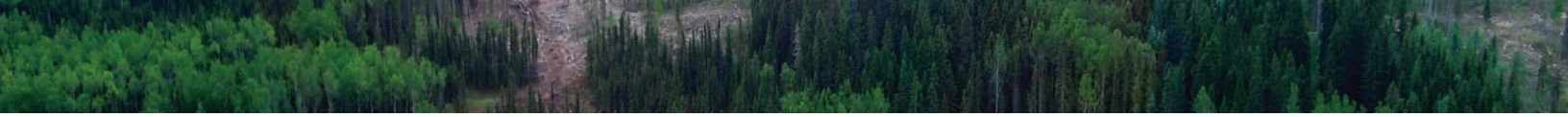
Soils and forest management

Soils are a critical component of any ecosystem and can directly affect forest management activities. For example, many soil processes and properties affect forest productivity in both the short and long term including:

- Chemical processes involved in the turnover of soil organic matter, which is essential for nutrient cycling and other aspects of soil health;

The Ecosystem 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 scheduled for an entire forest rotation (i.e. 80 years). Individual research projects evaluate which forest harvest and regenerative practices best maintain biotic communities, spatial patterns of forest structure, and functional ecosystem integrity, compared to mixedwood landscapes created by natural disturbances. Furthermore, economic and social analyses evaluate the long-term viability and acceptability of these practices. This research note is one of a series about the EMEND project.

View of a variable retention harvesting treatment at EMEND. Photo courtesy of B. Kishchuk.



- Physical properties affecting water movement and gas exchange;
- Biological conditions such as the structure and function of the soil microbial community.

To enhance opportunities for successful forest management, it is important that we understand the soil properties, processes, and functions specific to each site. This information in turn provides forest managers with several tools to help:

- Maintain or improve soil conditions under forest management;
- Predict possible management implications under specific site, soil and vegetation conditions;
- Use knowledge of fundamental soil processes to determine best practices;
- Prevent the need to mitigate or restore degraded soils, which can have both ecological and economic costs.

To provide managers with a better understanding of soil processes and functions, this research note looks at results from the first five years of soils research at the EMEND experiment. The note summarizes studies that looked at the impact of both stand type and variable retention harvesting on soil properties.

Treatments, stand types, and replication at EMEND

The EMEND experiment provides an experimental template where six levels of variable retention (VR) treatments (0-2%, 10%, 20%, 50%, 75% and 100% or uncut) were applied to forest stands 10 ha in size. These retention treatments were replicated 3 times over 4 dominant stand types (deciduous dominated canopy-primarily aspen and balsam poplar, deciduous canopy with developing understory of white spruce, mixed deciduous-conifer canopy and conifer dominated canopy-primarily white spruce). During harvesting operations, techniques such as winter logging and, in most cases, designated machine corridors were used to minimize soil disturbance. In total, 100 stands were sampled for characterization of soil properties before any treatment, and 72 stands are being monitored following harvesting treatments. An additional subset of stands subject to 10% retention with slash either left on site or burned is being monitored to determine fire effects.

Nature of soils research at EMEND

The design of the EMEND experiment allows two levels of soils research:

1) **Extensive** (i.e. experiment wide) research and monitoring of soil properties, specifically:
   - Changes over the long term;
   - Conditions under all treatments; and
   - Properties over the entire experimental area.

   Nutrient concentrations provide an indication of what nutrients are available to plants for growth and metabolism, while properties such as pH and CEC describe soil conditions that may influence nutrient availability.

   Examples of properties being monitored are concentrations of nutrients such as nitrogen (N), phosphorus (P), potassium (K) and calcium (Ca); other soil properties such as pH, cation exchange capacity (CEC) and total carbon (C) concentration, as well as the quantity of nutrients and C expressed on an area basis (e.g. kilograms of N or C per hectare).

2) More **intensive** process research furthers our understanding of the soil resource and allows us to use this information in predicting the effects of management activities and environmental change. Understanding these processes and how they differ from site to site allows us to better understand what specific conditions are being altered under forest management activities.

   Examples of this include soil organic matter composition, microbial community composition and structure; soil N and P availability; and litter decomposition rates.

What have we learned so far about soil properties at EMEND

Work to date at EMEND has enabled us to describe the soil properties across the experimental area and under the range of forest cover types within the study. This allows us to describe the pre-harvest baseline against which the effects of VR harvesting and burning can be evaluated. There are two important results to consider:

1) In terms of pedological properties (soil parent material, soil formation and soil classification) the soils are fairly consistent over the entire experimental area (Kishchuk 2004). This finding will assist in the interpretation of results from soils and other ecosystem components under harvest or burn treatments as results are less likely to be confounded by major spatial differences in soil parent material or soil forming processes across the study area.
2) There are clear differences in forest floor properties in the four cover types at EMEND, largely driven by the overstory vegetation in these stands through different types of litter inputs from canopy trees (the associated understory vegetation) and microclimatic differences under different cover types. These differences may result in an interaction between the forest floor conditions in a given stand type and the harvesting treatments applied to that stand type (i.e. treatments will have different effects on soil properties in different stand types).

Example of a soil profile used to study soil properties at the EMEND experiment. Photo courtesy of B. Kishchuk.

Lessons learned about soil processes

From the early work characterizing the entire study area, we found that soil properties related to organic matter, nitrogen cycling, and microbial processes were different because of either cover type or early treatment effect, and further research followed these lines of investigation. More focussed research has allowed us to examine impacts of forest harvesting and stand type differences in a subset of treatments.

Harvesting impacts on soil processes

The effects of clearcut harvesting on soil N dynamics have been investigated in a variety of forest types to address concerns such as N losses through leaching, or implications of changes in N availability for tree growth and productivity. Under the specific harvesting conditions applied at EMEND, N availability did not increase under harvesting, and nutritional concerns about increased N availability following clearcutting were not realized at this site (Jerabkova et al. 2006a). Effects of VR harvesting on N availability were not different from clearcuts, suggesting that there was no net benefit of VR in terms of N availability (Jerabkova et al. 2006a). We also found similar results when exploring the impacts of VR harvesting on the microbial community (Hannam et al. 2006). These results suggest that although VR harvesting may provide benefits in terms of other ecological functions, it may not be justified on the basis of preventing increases in N availability in comparison to clearcutting.

Value in maintaining different stand types

Each of the distinct stand types encountered at EMEND contributes unique attributes to the properties of the soil-plant ecosystem, highlighting the importance of maintaining heterogeneity of stand types in the boreal mixedwood.

EMEND core crew collecting soil data to better understand soil processes within boreal mixedwood stands. Photo courtesy of B. Kishchuk.

- In some cases the deciduous dominant stands showed different characteristics than mixed and conifer stands. For example, forest floor microbial community structure was different under deciduous stands than under coniferous or mixed cover types (Hannam et al. 2006; Swallow et al. 2009). Interestingly, Macdonald and Fenniak (2007) found a similar pattern in understory vegetation composition at EMEND, with deciduous stands being different than mixed and conifer stands. These studies indicate that the presence of coniferous species results in differences in both soil processes and plant community composition.

- Other results from our research showed that N mineralization rates were highest in mixed stands compared to dominantly deciduous or coniferous stands (Jerabkova et al. 2006b). Work on mixedwood stands in eastern Canada also indicates that coniferous and deciduous species have different effects on soil properties.

These results, taken together with associated work that identified specific chemical differences in forest floor material from coniferous and deciduous dominated stands (Hannam et al. 2004), suggest that the presence of individual tree species influences not only the properties of the forest floor material but the nature of the ecological community it supports. This demonstrates that stand type heterogeneity contributes to structure, function, and processes in the boreal mixedwood forest. It is too early for definitive results that are widely applicable to the entire study for the long term, but the influence of stand type on harvesting outcomes is important to note.

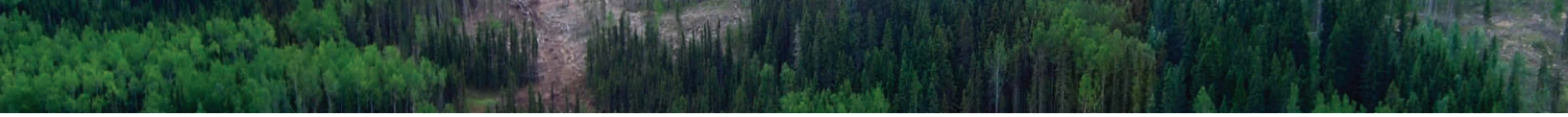
Thoughts for managers, and future research needs

At this stage of the experiment, these results raise some further issues and questions to be explored.

Harvesting operations: To date, our results show no advantage in soil nutritional conditions under VR harvesting on these sites, despite the other ecological benefits VR harvesting may provide. However, the harvesting operations at EMEND were done carefully with minimal soil disturbance, utilizing both winter logging and designated corridors. Avoiding soil disturbance by using the careful logging practices applied here may be required for maintaining healthy and productive soils on these sites.

Careful harvesting at EMEND resulted in minimal soil disturbance. Photo courtesy of B. Kishchuk.

Beyond evaluating direct harvesting impacts, several aspects of the harvesting cycle remain to be further examined. Mechanical site preparation was not applied operationally in this study. The soil disturbance associated with mechanical site preparation is known to alter nutrient availability, and the effects of site preparation under all site conditions in this study require examination. The



effect of the machine corridors on soil physical properties and the effect of the harvesting treatments on the nutritional status and growth of regenerating vegetation are also not yet known.

Heterogeneity of the boreal mixedwood forest: The results suggest that it may be necessary to recognize and plan around differences in stand type. Managers should consider whether the mixedwood forest should be treated as a homogeneous entity both in terms of spatial differences on the landscape and temporal differences through successional stages.

Comparisons with natural disturbance: One of the underlying research questions in the EMEND study is how harvesting disturbance compares with natural disturbance, such as wildfire. To date, direct comparisons of soil properties between fire and harvesting on these sites have been limited to comparisons of stands with unburned and burned slash (Swallow et al. 2009). Further work is required to characterize and systematically compare soils following fire and a range of harvesting intensities in boreal forest stands.

Further reading

Hannam, K., S.A. Quideau, S-W. Oh, B.E. Kishchuk and R.E. Wasylishen. 2004. *Forest floor composition in aspen- and spruce-dominated stands of the boreal mixedwood forest.* Soil Sci. Soc. Am. J. 68: 1735-1743.

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Macdonald, S.E. and T.E. Fenniak. 2007. *Understory plant communities of boreal mixedwood forests in western Canada: natural patterns and response to variable-retention harvesting.* For. Ecol. Manage. 242: 34-48.

Swallow, M, S.A. Quideau, M.D. MacKenzie and B.E. Kishchuk. 2009. *Microbial community structure and function: The effect of silvicultural burning and topographic variability in northern Alberta.* Soil Biol. Biochem. 41: 770-777.

Management Implications

- Careful, low-impact harvesting resulted in minimal soil disturbance and little change in soil N availability. Applying practices that minimize soil disturbance, such as winter logging, may increase the potential for maintaining post-harvest productivity. Further understanding of the implications of operationally applied practices such as site preparation is also required.
- Although VR harvesting has many other ecological benefits, to date we have not documented benefits to soil processes at EMEND in the properties we have measured.
- Managers should aim to maintain stand heterogeneity in the boreal mixedwood forest as this contributes to diverse soil communities and may contribute to the resiliency of soil processes.

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Ecosystem Management Emulating Natural Disturbance

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