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Forest floor: Mix, move or manage it?

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Highlights

- Harvesting has the general effect of increasing forest floor decomposition and often nitrogen and phosphorus availability but can also lead to nutrient losses.
- Mechanical site preparation methods such as blading can improve seedling growth by increasing soil temperature but possibly at the longer-term cost of nutrient loss.
- Site preparation methods that mix forest floor and mineral soil often increase nutrient availability and tree growth.

"The vitality of an ecosystem is connected to the energy and nutrient status of the forest floor which has the most biologically active portion of the soil and often the largest reservoir of nutrients."[12]

An overstatement? It depends on your point of view. Forest floor, that thick or thin organic layer overlying the mineral soil in forest ecosystems, has a mixed reputation. There is little dispute that forest floor is an important source of available nutrients for forest vegetation with a substantial proportion of site nutrient capital in some forest types. In peatland black spruce forests, for example, the forest floor represents the largest pool of available nutrients. Regardless of forest type, the forest floor represents the biggest reservoir of nitrogen (N). While nutrient supply is a major advantage of forest floor or humus, as it is commonly called, it also promotes water retention and can improve soil structure. It also buffers against disturbances that could lead to nutrient deficiencies. It's not all good news however. Sometimes, the forest floor is a nutrient sink that acts as a competitor for nutrients like N. This is especially true where forest floor accumulates as it does in forested peatlands. Here nutrients are progressively immobilized into humus, which over time leads to nutrient availability problems and, a decline in site productivity.

The availability of forest floor nutrients to vegetation is affected by any activity, such as harvesting and site preparation, that changes the rate of input and decomposition of forest litter. Although there is a significant body of research on the short-term effects of these activities on forest floor nutrient availability, tree nutrition and growth, less is known about the longer-term impacts. This research note summarizes the impacts of harvesting and site preparation practices on forest floor nutrients and provides some guidance about which practices are recommended for certain forest types.

The forest floor after harvest

Harvesting affects the forest floor nutrient cycle in a number of profound ways – both positive and negative. An increase in decomposition after harvest has been observed in many forest ecosystems due, in part, to a rise in soil temperature.[12] This can lead to greater nutrient availability, at least in the short term. The loss of trees, on the other hand, can lead to increased soil moisture (due to a decrease in evapotranspiration) to the point of anaerobic conditions, which, in turn lead to lower decomposition and nutrient availability. Reduced organic matter input in the first few years after tree harvest also results in a change in the quality and quantity of organic matter. How and whether such a change impacts tree nutrition is still unclear.

Studies comparing the effects of clearcutting, both full-tree and tree-length with uncut stands have found few differences in forest floor nutrient concentrations a few years after harvest.[7] What are the longer-term effects? They have not been well-studied.

Figure 1. Post-harvest cutover. Photo courtesy of Dave Morris, Ontario Ministry of Natural Resources

In terms of site nutrient capital management (removal vs returns), the length of the recovery period (return to pre-harvest levels) is a function of: 1) the degree of site depletion accompanying the harvest treatment, 2) the rate of nutrient input, and 3) the ability of the regenerating forest to retain these inputs. Research results indicate that recovery rates depend on the type of disturbance and the forest type and can range anywhere from less than 5 to at least 80 years.[12]

Careful logging and forest floor disturbance

Forest managers are increasingly interested in practices that emulate patterns of natural disturbance given the importance of disturbance in boreal forest regeneration.[11] Careful logging seeks to minimize soil disturbance while protecting regenerating growth and is practiced as an alternative, sustainable forest practice. Practices such as careful logging, however, do not generate a forest floor environment that resembles one left as a result of wildfire.

Site preparation

Effects of site preparation appear to vary with site properties and the intensity of the treatment. Studies have borne this out with variable and often only short-term results. Longer periods of study may be necessary to determine if impacts on site productivity intensify over the rotation. Effects of forest practices may well be cumulative and may become obvious over time with the nutrient demands of a growing plantation.

Many studies have shown that mechanical site preparation like mounding which mixes mineral soil with organic matter while leaving some portion of the organic horizon intact, improves seedbed conditions, seedling competition and increases decomposition. In aspen mixedwoods, it was found that nutrient and productivity losses were minimal when the forest floor was left largely undisturbed.[12]

More intense site preparation methods such as blading have varying effects. Very extreme disturbance of the forest floor of an aspen mixedwood (up to 80% of the forest floor displaced) caused a severe reduction in aspen productivity compared to site disturbance by harvest only. In contrast, blade scarification on medium-textured podzols can improve seedling growth considerably. This growth can come at a cost however; reduced forest floor nutrient capital and increased compaction occurred in central Ontario with outplanted white spruce and pine.[4] Studies that compared blading, slash burning and no site preparation found that although blading decreased soil nutrient content (due to forest floor removal), tree nutrition and growth 15-20 years after treatment increased. In the cold soils of the northern boreal forest, blading allows the soils to warm more quickly and does not have a negative effect on soil moisture.[3]

Figure 2. A jack pine stand 35 years after an extreme blading exercise. Early growth was good and now is in major decline. Photo courtesy of Dave Morris, Ontario Ministry of Natural Resources.

Fire and forest floor

Prescribed burns or wildfire can be beneficial to nutrient availability and thus, to forest productivity. By increasing decomposition, at least over the short-term, nutrients, particularly Magnesium (Mg), potassium (K) and calcium (Ca), become available, thus also raising the forest floor pH.[12] Nitrogen mineralization has also been shown to increase after fires. However, the effects of fire are not easily predictable and depend on fire intensity and, quantity and quality of organic matter. On dry, thin forest floor sites for example, nutrient losses are likely as the forest floor is consumed. In the boreal mixedwoods of Quebec, severe forest floor combustion is associated with K and possibly Mg and Ca depletion while N supply remains less affected.[2]

Figure 3. A jack pine stand immediately after fire. Photo courtesy of Dave Morris, Ontario Ministry of Natural Resources.

A look at some forest ecosystems

Jack pine forests on dry, coarse soil

Forest systems with shallow, dry and coarse soils, where the forest floor is thin depend on organic matter for new tree growth and continued growth of existing trees. An important consideration here is that after clearcut harvesting, the forest floor represents the most important pool of nutrients with up to 70% of the nutrient reserves in some sites. The mineral soil below the forest floor can supply a significant quantity of K, Ca and Mg but still relies on the forest floor and the decomposition process to load it's exchange sites.

Coarse shallow-soil sites also appear to benefit from site preparation. Scarification proved to be important for initial establishment on harvested jack pine on coarse-textured soils in northwestern Quebec.[1] Presumably the mixed forest floor and mineral soil improved nutrient availability for seedlings while also reducing competition with invasive weed species. Similarly, in northeastern Ontario, jack pine seedling survival five years after harvesting exceeded 85% on bladed sites on medium- to coarse- textured soils. This was attributed to the removal of the forest floor, which resulted in higher soil temperatures and modulation of soil surface temperatures.[6]

Upland black spruce

Research indicates that regenerating growth can be sustained on upland black spruce sites – at least in the short term.[15] Still needed, however, are studies of effects of both harvesting and site preparation on forest floor nutrient cycling over full rotations. In boreal Quebec, upland black spruce stands are thought to have sufficient reserves of N and other nutrients in the organic horizon for regenerating growth after full-tree harvest. In northern Quebec, upland black spruce on deep till soils with 5-10 cm of forest floor is vulnerable to K, Ca and N depletion under full-tree harvest. Here, fertilization or tree-length (i.e. slash left on-site) is recommended.[15] One study of boreal black spruce mixedwood on fine-textured soils in Quebec found no significant nutrient losses 25 years after clear-cutting and recorded a pulse of Ca, K and phosphorus (P) and higher N mineralization after cutting.[2]

When some, or all, of the forest floor in upland black spruce stands is removed during site preparation, there can be a significant improvement in tree growth. Studies of coarse-textured black spruce stands in northwestern Ontario found that seedling establishment and growth were significantly better in thin forest floor or at the mineral soil/humus interface compared to undisturbed, thick organic horizons.[5] This improved growth was associated with higher soil temperatures of the mineral soil and perhaps increased nutrient availability. Similarly, site preparation by bedding in black spruce mixedwoods on poorly-drained fine sands with 5-15 cm organic horizon showed greater decomposition and N mineralization as a result of improved aeration and an increase in microbial activity. Here 100% disturbance of the forest floor provided more favourable growing conditions than disk-trenched sites.[12]

However, the long-term effects of severe disturbance of the forest floor are not well-established and best practices still recommend minimal disturbance in order to reduce mineralization and hence, loss of nutrients and organic matter. [8]

Peatland black spruce

Thick organic layers are associated with black spruce stands with peaty phase soils occurring on toe positions along a toposequence and on some lacustrine deposits. In these systems, the soil represents the largest pool of carbon in the forest ecosystem. While sphagnum provides an excellent seedbed, early growth can be poor likely due to limitations of microclimate, soil moisture, nutrition and also severe problems with needle scale whose alternate host is labrador tea.

Both harvesting and site preparation in forested peatlands increase soil aeration and temperature, which in turn accelerate organic matter decomposition. While increased organic matter decomposition increases nutrient availability to conifer seedlings, it may also increase nutrient leaching into nearby watercourses and turn what was a carbon sink into a carbon source (via the release of CO_2 during decomposition). A study that looked at careful (protects regenerating growth) and tree-length logging, suggested that careful logging could minimize the interruption in the nutrient cycling between vegetation and the forest floor and mineral soil.[14] By maintaining smaller trees on site, organic matter inputs in the forest floor are continued to some extent and could also avoid rising water tables and nutrient export.

The harvesting of peatland black spruce presents complicated management objectives with on the one hand, the benefits of disturbance and the resultant increase in decomposition (and nutrient release). On the other hand, are the unknown long-term effects of removal of organic matter inputs on the nutrient cycle given the slow rate of nutrient mineralization from peatlands particularly under anaerobic conditions.[14]

Aspen mixedwoods

Studies have shown that harvesting boreal mixedwoods can negatively affect forest floor nutrients over the short term but that this effect can disappear over time. For instance, harvesting reduced N and P availability, lowered the amount of exchangeable bases and increased acidity in a boreal aspen mixedwood in Alberta due to inputs of high- carbon, coarse woody debris and organic acid production from harvest residues.[13] Over time, though, the C:N ratio would likely decrease with ongoing decomposition and low C:N litter inputs from successional plants.

Three years after full-tree harvest of aspen mixedwood stands in central Ontario on shallow to deep outwash sands, forest floor N and K concentrations declined while Ca and Mg concentrations increased after tree-length logging, presumably as a result of logging slash.[7] In a boreal aspen stand on a luvisol in Saskatchewan, annual variation in forest floor chemistry was greater than any effect of patch cuts suggesting minimal impact of alternative harvesting strategies.[9]

Site preparation in aspen mixedwoods also has negative impacts on forest floor properties, at least in the short term. Fifteen months after mechanical site preparation (disc trenching, ripper plowing and blading) in the boreal aspen-white spruce stands of Alberta, researchers observed reduced N and P availability and increased pH and base saturation of the mixed forest floor/mineral soil.[13] Blade scarification after the harvest of an aspen mixedwood in Central Ontario resulted in significant loss of nutrients due to the loss in humus.[10] Such initial losses, however, may be compensated for with new organic matter input from regenerating vegetation in a few years. It is still unclear, however, what (or if there are any) the long-term impacts of initial reductions in nutrient availability are on tree productivity over the course of a rotation.

Summary

Full-tree and tree-length harvesting affect the forest floor nutrient cycle of distinct forest types differently with the most negative effects on shallow soil sites. For upland black spruce and aspen mixedwoods the short-term effects on the forest floor nutrient reservoir do not appear to be dramatic but long-term impacts remain inconclusive. Site preparation, particularly where mixing of forest floor and mineral soil occur tends to have positive effects in terms of nutrient cycling. At the same time, minimal forest floor disturbance is recommended for aspen mixedwood sites and those sites with shallow soils.

Implementation

- Full-tree harvesting of jack pine on dry, coarse soils with thin forest floors runs the risk of nutrient depletion over the course of the next crop of trees; logging residues are critical in mitigating this.
- Site preparation in dry, coarse-soil jack pine sites improves initial growth of seedlings by improving nutrient availability.
- Upland black spruce can be harvested with minimal impacts on tree nutrition for the initial 25 years of growth; thereafter tree growth should be monitored carefully to detect any nutritional problems.
- Disturbance of thick forest floor layers associated with upland black spruce is recommended for improved seedling establishment and initial growth.
- Lowland black spruce is sensitive to nutrient leaching after harvest; although logging residue left on-site will reduce this loss.
- In aspen mixedwoods, forest floor nutrient cycling will recover most rapidly with logging residue left on site and with site preparation methods that minimally disturb the forest floor.
- Prescribed burning of sites with thick forest floor allows for greater nutrient availability and helps in seedling establishment.

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