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Food for thought and for forests: A look at forest nutrition

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Highlights

- A stand's nutritional characteristics are important in constructing a picture of the current and future site productivity potential.
- Nutrient reserves in the mineral soil and forest floor are often sufficient in many boreal stands to allow for good early growth of one generation.
- Nutrient reserves are considerably less in sites with shallow, coarse soils compared to sites with deep mineral soils.

A mere glimpse at the young jack pine stand and you know that something is wrong. Needles on the upper branches are yellowing and the leaders are gnarled. There is a general lack of vigour. All you know is that this particular site was clear-cut and scarified about 25 years ago. It used to support a well-stocked, mature jack pine forest on a shallow, sandy soil. A closer look at the trees brings you no further insight. There is no insect damage and no apparent disease. This scenario would be very puzzling indeed—unless you happen to have some nutrient information for the site in your back pocket. With such information, you may learn that not all is well when it comes to the nitrogen (N) status of the soil underneath the stand. Not only is there very little N, but there is hardly any organic matter. Once you know something about both of those components and what they mean for forest growth, you can begin to think about solutions.

Let's talk forest nutrition

Some nutrition information and knowledge can go a long way in explaining certain mysteries in the forest. Forest nutrition refers to a forested or recently forested ecosystem's capacity to supply nutrients and its ability to utilize and retain those nutrients. Just as human nutrition is an all-encompassing concept for us, so is forest nutrition for trees and their ecosystem. In forest nutrition there is much to consider including the sources of nutrients, their usage and their losses.

Nutrition implies the availability and uptake of nutrients from the soil. In order for nutrients to be utilized by, say, a conifer seedling, several factors must work in concert. Not only must the nutrients be present in an available form (more about this later), but the plant roots must also be able to access these nutrients. Nutrient uptake requires a healthy root system (e.g. healthy plant), a good balance of air and water in the soil (i.e. minimal or no soil compaction/waterlogging) and limited or no disease or insect damage that may affect root function.

Why worry about forest nutrition?

Our reliance on forest products demands that forest stands grow and mature at a regular and predictable rate. Tree growth is directly related to tree nutrition, although nutrition is certainly not the only factor in stand productivity and health. An understanding of nutrient storage and cycling in forests is central to forest management practices. In order to avoid soil nutrient depletion, which could eventually limit forest growth, knowledge of nutrient pools – where nutrients reside in the system – and the effects of forest practices on these pools is needed. This, combined with information about nutrient sources, exports and losses, can provide us with the tools to come up with a nutrient budget. A nutrient

budget can tell us about current or potential nutrient deficits or accumulation in a given site. Nutritional information can then provide some of the pieces of the puzzle that is a poorly growing forest stand. It can also help to predict situations where we might encounter growth problems.

The nutrient story

When we talk about nutrients in relation to forest growth, we mean those that are essential to plant growth. They are generally divided into macro- and micro- nutrients. Macronutrients include N, phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg), which are 'macro' because they are taken up by plants in large quantities. Elements such as zinc (Zn), manganese (Mn), molybdenum (Mb) and iron (Fe) are equally essential but are taken up in comparatively 'micro' amounts.

Knowing which nutrients are important to plant growth is just the beginning of the story. Where they come from is important in determining potential deficits or surpluses that could affect tree growth. N, for example, comes in large part from the continual decay process or decomposition of dead plant and animal remains (organic matter) in forest ecosystems. Smaller quantities come from a process called N fixation (where N is taken up directly from the atmosphere by bacteria or fungi and converted to useable N. The other macronutrients are also made available through the process of decomposition as are many of the micronutrients. Some such as K, Ca and Fe are also products of mineral weathering. Several are deposited, although in small amounts, through rainfall and snowfall.

What happens to nutrients once they are circulating and 'available'? Plants and other forms of life take what they n eed while some 'mobile' nutrients (e.g. NO_{3}^{-}) trickle down through the soil to the groundwater table and are lost to plant roots. Still others bind to soil organic matter and soil particles (e.g. Ca, Mg and K). Some N is converted to gas and enters the atmosphere.

Rotting logs and carcasses and nutrients

The nutrient story is hardly complete without a closer glimpse at the process of decomposition. Decomposition is integral to all soil bound systems, such as forested and agricultural lands. As plants and animals die, they are literally broken down into increasingly smaller components by a host of soil organisms. Bacteria, fungi, earthworms and centipedes - to name only some of the players - all have their role in this process. Over time, what used to be the carcass of a ground beetle or a tree branch turns into carbon (C), N and other nutrients. These in turn are the building blocks for new generations of soil organisms and of course, for plant growth. And so the cycle continues.

Nutrient availability – key to forest nutrition

In talking about nutrients for plant growth, it is important to differentiate between total and available nutrients. While this distinction might sound trivial, it can mean the difference between a flourishing and a deteriorating second growth forest. Research reports and articles, for example, often refer to both total and available N pools in forest soil. The total amount stands for every last bit of N in the soil, including what is available and 'tied-up' in organic matter while the available amount refers only to the part that is immediately useable by plants (i.e. ammonium and nitrate). Total N can run in the order of 1500 kg/ha compared to 50 kg/ha of available N. Quite a difference - especially from a young tree's perspective!

And this is only part of the story. For a nutrient such as N, we also need to have an idea of how much will become available over time. Decomposition is a continuous process and nutrients can be released from soil organic matter quickly or slowly. The amount of nutrient released is a function of the amount of organic matter and the 'life' of the soil. Here, micro-organisms, namely bacteria and fungi, are the key players as is the environment in which they live, particularly soil temperature and water.

As decomposition proceeds nutrients are released (mineralized) and sometimes tied-up (immobilized) by micro-organisms in their quest for energy and growth. Whether or not nutrients are mineralized or immobilized is key to plant nutrition. For instance, as slash on a harvested site decomposes, the N, P, Ca, K and Mg it contains are mineralized by micro-organisms and enter the soil solution for plant uptake under ideal circumstances. However, nutrients are not always mineralized. Mineralization depends on the C:N ratio, which at 30 or less is most favourable for mineralization. For instance, as high C content logging residues (i.e. a high C:N ratio) decompose, otherwise available nutrients such as N are 'tied-up' by decomposers until the C:N ratio drops significantly. This could, in turn, lead to poor, initial tree seedling growth.

Nutritional information and decision-making

Harvesting practices and nutrients

If we know about the nutrition of a given forest, we can make some educated predictions about the impact of management practices and the supply of nutrients to subsequent generations. Most of the total nutrients in a 65-year-old Ontario jack pine forest, for example, reside in the lower mineral soil (the B horizon) with comparatively fewer nutrients in the vegetation and the forest floor (see table below). But of course, only a small percentage of those soil nutrients are available. While K, Ca and Mg levels are considered to be sufficient to sustain subsequent tree growth after harvest, N and P levels in the soil and forest floor are not. In this particular case, tree-length harvesting would leave a greater supply of nutrients on site compared to full-tree harvesting.[2] Studies of poor jack pine sites in Quebec support the idea that full-tree harvesting should be avoided in order to prevent site productivity problems.[4]

The same recommendations hold true for black spruce on poor sites with shallow soils where full-tree harvesting may deplete nutrients, particularly N and Ca reserves in the system although full-tree harvest is not likely to affect the early period of regenerating spruce growth.[2,5] In general, nutrient losses tend to be higher in coniferous systems compared to hardwoods yet demands by hardwoods on nutrient reserves are higher. Studies of trembling aspen in Quebec have shown that full-tree harvesting on almost any site (from shallow to deep, till to clay soils) results in higher nutrient losses compared to tree-length harvesting.[3]

Component	N	P	K	Ca	Mg
Tree – total	204	17	105	155	25
FF – available	19	1	71	60	8
FF – total	283	13	680	396	157
MS – available	15	6	539	172	37
MS – total	2,920	2,152	80,637	34,406	21,075

Distribution of elements (kg/ha) in a 65-year-old jack pine forest on a sandy site in Ontario (adapted from Morrison and Foster, 1979[1]).

Site preparation, fertilization and fire

The nutritional status of a forest should not only influence the harvesting method but also how the site is prepared. Should the area be scarified, burned or ploughed? Removal of some of the thick forest floor associated with some black spruce sites could result in greater nutrient availability to the next generation. Mixing forest floor with the upper mineral soil may have a similar effect while reducing vegetation competition and maintaining site nutrient status by enhancing decomposition.

Some studies have found that much of the N supply under coniferous stands comes from the forest floor as opposed to the mineral soil.[5] This would suggest that, at least on sites with thin forest floor (organic layers), site preparation should aim to only minimally disturb the organic layer. Removal or displacement of the forest floor on these sites will remove a key pool of nutrients for regenerating stands, especially if little harvest residue is left on the site.

Would fertilization provide a benefit? In young forests where vigorously growing 'weeds' (e.g. Kalmia or salal) monopolize nutrients, fertilization can help increase the available nutrient pool and, therefore, improve tree growth. How does fire affect nutrient cycling in forests? Prescribed fire most certainly impacts on forest nutrition through its effect on organic matter (likely reducing the amount) and more directly through an initial post-fire flush of nutrients. This practice would be most efficient where nutrients are tied-up in a thick organic layer. Clearly, different forests will respond in different ways, nutritionally speaking, to such fires as they would to wildfires (for a detailed discussion of fire and forest nutrition refer to the SFMN Research Note *Fire and Stand Nutrition in the Canadian Boreal Forest*).

Each of these practices has significant impacts on certain nutrient pools. The trick is to find out which nutrient pools are impacted by a given management practice and to then meld that information with nutritional data in order to come up with a complete picture of what is going on and what can be anticipated.

Summary

An understanding of forest nutrition is useful both in diagnosing stand growth problems and in predicting growth patterns of future generations after harvest. Each forest component – trees, understory vegetation, forest floor and mineral soil – represent nutrient pools. These pools vary in size depending on forest composition and soil type amongst other factors. Nutrient pools are dynamic too, with continual additions through litterfall and precipitation, removals through leaching and of course, harvesting. It appears that full-tree harvesting is feasible and less risky to long-term site productivity with a deep mineral soil and a thick (but not too thick) organic layer. In other cases, such as upland jack pine on coarse, shallow soils, tree-length harvesting may be a preferable option.

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