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Nutrient Accounting for Black Spruce Plantations in Northern Ontario

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Highlights

- **Nutrient replacement times for all nutrients except nitrogen are much longer than commonly employed rotation lengths, warranting concern for nutrient sustainability.**
- **The forest floor contains a large pool of nutrients--much of which should be readily available to trees. Forest floor management should focus on maintaining this valuable nutrient source.**
- **Tree length harvesting removes less nutrients than does full tree harvesting and, thus, should be given consideration when determining management plans.**

Sustainable management of Canadian forests has been identified as a primary goal at both the provincial and national levels. Sustainable forest management is concerned with harvesting forests in a way that does not impede the ecosystem's ability to maintain diversity and complexity while providing for human desires. In order to provide timber over the long-term, a forest must have an adequate supply of nutrients that are available in a timely manner to allow for adequate regeneration growth. So how can managers be ensured that their forests will continue to have enough nutrients to maintain productivity over more than one rotation length? Surely this question must be answered if forests are to be managed sustainably.

Nutrient budgeting can be a useful tool in determining long-term sustainability of harvesting practices. Nutrient budgets entail an accounting of sorts, estimating the amount of existing nutrients in various pools within the forest (i.e. vegetation, forest floor, mineral soil), determining the amount of nutrients entering the ecosystem (via precipitation deposition and soil mineral weathering), and comparing these with the amount of nutrients leaving the ecosystem (via harvesting, fire or leaching). If the amount of incoming nutrients equals or surpasses the amount of nutrients leaving the system, nutrient sustainability can be ascertained. If more nutrients are being removed than are coming in, nutrient deficiencies--resulting in ecosystem degradation and reduced productivity--can be expected.

While nutrient budgets have been completed for some natural (i.e. unmanaged) boreal forests,[2,3] to date, very little attention has been given to nutrient cycling in intensively managed plantations.[†] Increasingly intensive management of the boreal forest in the past several decades has resulted in large tracts of forest being converted to plantations--a trend which will most likely continue well into the foreseeable future. If these plantations are to produce timber consistently over the long-term, it is necessary that we have an understanding of their nutrient budgets.

Clearcutting remains the most common method of harvesting in the boreal forest. While full tree harvesting remains the dominant logging method, in recent years tree length harvesting has been implemented in some areas. Several differences between the two methods can affect nutrient abundance and availability. For starters, full tree harvesting results in branches and foliage being removed off-site, resulting in an on-site loss of the nutrients found in these tree parts. Secondly, full tree harvesting results in more forest floor disturbance due to logs being dragged along the forest floor, resulting in a loss (and/or relocation) of essential nutrients. Some specific aspects to each system vary between

[†]One exception being Gordon et al.[4]

regional and other jurisdictional definitions of full tree and tree length harvesting (e.g. whether or not slash is returned to the site with full tree or how much--if any--of the tree is topped with tree length harvesting). For the purposes of this note, full tree harvesting (FT) refers to the removal of all above ground tree parts and assumes no slash is returned to the site. Tree length (TL) harvesting, on the other hand, refers to the removal of the stem (or bole) only, with slash in the form of leaves and branches being left on site. We assume here that no topping takes place on site for either method.

Following is a nutrient budget completed for an immature (38 years old) black spruce plantation located on silty sands in northern Ontario. Five nutrients were accounted for: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). Nutrient input via precipitation, forest floor nutrient pools, and nutrient output via two different harvesting methods (FT and TL) were calculated. In addition, we determined the amount of years it would take to replace nutrients under each harvesting regime. This note provides a case study that adds to our understanding of nutrient cycling in managed black spruce plantations.

Nutrient Inputs

Precipitation & Weathering

Precipitation is the primary avenue by which N enters a forested ecosystem. It can also be a source of other essential nutrients (P, K, Ca, and Mg). For our nutrient budget, precipitation nutrient concentration data were taken from Gordon.[3]

The weathering of parent material results in nutrient input to forest soils and is thought to represent the primary input for P, K, Ca, and Mg. The difficulty associated with measuring weathering input, the variability inherent in measuring methods, and the extremely slow process of weathering makes estimating this nutrient input challenging at best. We did not include weathering input in this analysis. Given the long term nature of weathering processes, input from weathering is not likely to have a noticeable effect on these forests within any sort of useful time frame.

Nutrient Pools

Two different nutrient pools were accounted for: black spruce trees and forest floor (Table 1). The data used was from a project near Beardmore, Ontario that was funded by the Sustainable Forest Management Network. Details of methods used can be found in Hunt.[5] Mineral soil pools were not determined for two reasons: (1) we only had soil data for the top 15 cm in these plantations, a depth that was seen as insufficient for measuring nutrient amounts in mineral soil, and (2) we figured that the amounts available in the mineral soil were, in effect, always going to be present as long as inputs (via precipitation) were greater than outputs (harvested trees).

	N	P	K	Ca	Mg
Precipitation	190.0	7.6	19.0	41.8	3.8
Needles	59.23	9.29	26.9	55.85	3.78
Branches	13.68	4.81	11.81	27.93	2.16
Stem Wood	61.37	20.82	30.53	103.71	7.48
Stem Bark	43.64	10.34	32.04	118.17	5.59
Whole Tree	177.92	45.26	101.28	305.66	19.01
Forest Floor	918.48	107.81	142.12	460.17	52.03

Table 1. Quantities (kg/ha) of five nutrients input via precipitation and those residing in various tree parts and in the forest floor pool over a 38 year period in black spruce plantations on silty sands in northern Ontario.

For the purposes of this nutrient budget, we have assumed that all of the forest floor remains on site and, thus, maintains its place in the nutrient cycle. Full tree harvesting can remove some of the forest floor. If forest floor is removed during harvesting and/or subsequent silvicultural treatments, the nutrient losses associated with that removal need to be accounted for. Thus, we present the amount of nutrients found in the forest floor in order to allow for inclusion of this type of removal for specific management scenarios.

The amount of nutrients found in the trees of these black spruce plantations was lower than those recorded in other studies,[2,3,5] and we attribute this to the young age of the stand. Although 38 years is younger than rotation lengths for most managed black spruce stands, it is closer to rotation ages recorded for other black spruce plantations in eastern Canada and the northeastern U.S.[1] We offer here an analysis of what the nutritional ramifications of each harvesting method will be if the stand were to be harvested at its current age (38 years).

Nutrient Outputs

Leaching

Leaching can represent a key pathway to nutrient loss in some forested ecosystems. Particularly prone to leaching are those forests which lie on coarse textured soils. Harvesting can cause an increase in leaching if sites are not revegetated quickly enough because it leaves soils exposed to precipitation, percolation, and leaching. Again, the effects of this will be amplified with coarse textured soils where water moves easily and quickly down the soil profile and, eventually, out of the soil environment into surrounding water bodies.

We did not analyze leaching losses for this nutrient budget due to two factors: (1) there was a lack of data for leaching in these forests, and (2) leaching was not thought to be an important avenue for nutrient loss in these forests due to the high water and nutrient retention capacities of [relatively fine textured] silty sands.

Full tree vs. tree length harvesting

Nutrient budget comparisons between FT and TL harvesting were based on the removal of various parts of the tree. Recall that in our definition of TL harvesting, foliage and branches remain onsite, where as with FT harvesting, they are removed.

Table 2 suggests that full tree harvesting removes 41% more N; 31% more P; 38% more K; 27% more Ca; and 31% more Mg than tree length harvesting.

	N	P	K	Ca	Mg
Tree length	105.0	31.2	62.6	221.9	13.1
Full tree	177.9	45.3	101.3	305.7	19.0

Table 2. Comparison of the quantities (kg/ha) of nutrients removed with two different harvesting methods for a 38 year black spruce plantation on silty sands in northern Ontario.

Nutrient Replacement Times

In determining what we can expect as far as nutrient supply is concerned on these plantations, we calculated how long it will take to replenish nutrients lost through harvesting. Our calculations here (Table 3) represent the amount of years it will take for nutrients lost through harvesting to be replenished through precipitation input. (i.e. the ecological rotation).

As can be from Table 3, the replacement times for N are well within the 38 year rotation of our scenario using either harvesting method. However, none of the other nutrients examined here will be replenished within the 38 year rotation set for our scenario. In fact, the replacement times for P, K, Ca, and Mg are longer than common rotation lengths (80-100 years) for non-plantation stands for either harvesting method. Even if rotation lengths were increased some, the amount being removed via either harvesting method will increase some as well,[‡] and will result in an increase of replacement times for all nutrients.

	N	P	K	Ca	Mg
To be replaced (TL)	105.0	31.2	62.6	221.9	13.1
To be replaced (FT)	177.9	45.3	101.3	305.7	19.0
Input (precipitation)/yr.	5.0	0.2	0.5	1.1	0.1
Years to replace (TL)	21.0	**155.8**	**125.1**	**201.7**	**130.7**
Years to replace (FT)	35.6	**226.3**	**202.6**	**277.9**	**190.1**

Table 3. Time needed to replace nutrients under TL and FT harvesting regimes. All amounts are kg/ha.

These long replacement times could be cause for concern. Because nutrients will not be replaced by precipitation inputs alone over the rotation, it will be necessary for new growth to rely on nutrient pools found in the forest floor and mineral soil. In looking at the amount of nutrients found in the forest floor (Table 1), it is clear that the forest floor will most likely provide a much needed source of nutrients for these plantations, not

[‡]As is supported by work done in Gordon on similarly aged stands.[3]

only in the beginning of regeneration, but throughout the entire rotation period. Maintaining as much of the forest floor as possible should be the aim of forest floor management in these plantations.

Summary

In the 38 year old plantations we budget for here, N supplies will be replenished within one rotation length. However, the length of time needed to replace all other nutrients removed via either harvesting method, is much longer than the rotation time of either our scenario (38 years) or commonly employed rotation lengths (80-100 years). These findings run contrary to results determined in other black spruce stands[3,5] and represent an addition to our understanding of the effects of harvesting on black spruce plantations in northern Ontario. The differences between findings in at least one other study[6] and ours here reside primarily in the input amounts (not the amount in trees) and, to a lesser degree, the amount of slash that was calculated as being returned to the site after full tree harvesting. We suggest that nutrient input via precipitation is a much more important component to sustainable management than has traditionally been recognized.

Implementation & Future Research

- Forest floor management should include maintaining as much forest floor on site as possible and minimizing nutrient displacement caused by various silvicultural practices (i.e. scraping, etc..)
- TL harvesting results in shorter replacement times for all nutrients and efforts should be made to practice this type of harvesting method.
- Future research should focus on analysis of variation in precipitation amounts (and subsequent replacement times) for forest types and regions across the country.
- Research into weathering rates for these sites would be helpful in determining what sort of time line (and in what quantities) nutrients are supplied via this avenue.

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