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Nutrient Budgeting for Jack Pine Plantations in Northern Ontario

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Highlights

- In these jack pine plantations, replacement times for all nutrients except nitrogen exceed common rotation lengths, warranting concern for nutrient sustainability.
- In the ecosystem components looked at here, the largest quantity of nutrients by far was found in the forest floor, signaling that forest floor management should be given careful consideration and attention.
- Tree length harvesting removes less nutrients than full tree harvesting and efforts should be made to move towards harvesting in this manner.

Intensive harvesting of boreal jack pine stands has raised questions about depletion of nutrients in these forests and possible effects on long-term productivity. In recent years full tree harvesting has taken the place of conventional tree length harvesting in most forested areas across Canada. The objective of this note is to provide a case study look at what the differences between the two types of harvesting might be in terms of nutrient removal and long term sustainability.

Since differences in specifics of definitions exist across the country, it is important, from the start, to define our usage of these terms in this research note. For our purposes, full tree (FT) harvesting removes the entire aboveground portion of the tree (including foliage, branches, and stem) from the harvested site; all belowground parts of the tree (i.e. roots) but no slash remain on site. Conversely, tree length harvesting (TL) removes the merchantable stem or trunk only, leaving branches and foliage on site to decompose. Harvesting method influences the amount and type of tree material removed from the site and, thus, may affect the amount of nutrients lost from a forest during harvesting. All forest disturbances, including harvesting and fire, cause nutrients to be lost from the forest and, thus, have the potential to affect soil fertility and long-term forest productivity. Different types of disturbance have different effects on nutrient removals and the resulting stand and soil conditions.

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), 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 assumed. Harvesting can be considered unsustainable when the amount of nutrients leaving the ecosystem exceeds the amount entering. For a general primer on nutrient budgeting, please see the KETE research note entitled *Nutrient Budgeting in Canadian Boreal Forests.*

While certain components of nutrient budgets have been recorded for several unmanaged jack pine forests,[1,2] little attention has been given to nutrient budgets in 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 that is likely to 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.

This note details a nutrient budget completed for a 47 year old jack pine plantation located on fine sands in northern Ontario. Five nutrients were accounted for: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). Nutrient input via precipitation, existing pools in forest floor, and nutrient outputs via two harvesting methods (FT and TL) were calculated.

Nutrient Inputs

Precipitation & Weathering

Precipitation data were obtained from study sites in northern Ontario.[3] The weathering of soil parent material results in nutrient input to forest soils. However, the difficulty associated with measuring weathering input, the variability inherent in methodology, and the extremely slow process of weathering, makes estimating this nutrient input challenging at best. We therefore 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 operational time frame.

Nutrient Pools

Quantities of nutrients were measured in jack pine trees and forest floor (Table 1). Data were obtained from a Sustainable Forest Management Network funded project in Beardmore, Ontario.[4] Forest floor pools were included in our budget because the forest floor is the part of the soil that is most affected by management.

	N	P	K	Ca	Mg
Precipitation	235.0	9.4	23.5	51.7	4.7
Needles	42.4	5.9	20.6	32.2	3.4
Branches	13.4	4.1	9.9	10.1	2.4
Stem Wood	18.5	42.6	25.7	54.4	7.6
Stem Bark	22.8	3.5	10.6	41.6	4.5
Whole Tree	97.1	56.1	66.7	138.4	17.9
Forest Floor	605.4	104.3	105.8	165.8	37.1

Table 1. Quantities (kg/ha) of five nutrients input via precipitation and those found in the forest floor and trees on a 47 year old jack pine plantation in northern Ontario.

Mineral soil pools were not determined because 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.

For the purposes of this nutrient budget, we have assumed that all of the forest floor remains on site following harvesting and, thus, maintains its place in the nutrient cycle. FT 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 would 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.

Nutrient Outputs

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. In TL harvested stands, foliage and branches remain on site where they decompose and their nutrients are recycled; these nutrient pools are removed from FT sites. The results of our nutrient budget estimations show that full tree harvesting removes over twice as much N; 18% more P; 46% more K; 31% more Ca; and 33% more magnesium than tree length harvesting (Table 2).

Harvesting Method	N	P	K	Ca	Mg
Tree length	41.3	46.1	36.3	96.1	12.1
Full Tree	97.1	56.1	66.7	138.4	17.9

Table 2. Comparison of the quantities (kg/ha) of nutrients removed with two different harvesting methods over a 47 year rotation on a jack pine plantation in northern Ontario.

Leaching

Leaching occurs when water percolates down through soil horizons, taking nutrients with it. These water-soluble nutrients can end up lower in the soil profile or can move out of the soil and into surrounding waters (e.g. groundwater, rivers, and lakes). Sufficient rainfall, coupled with porous soils (i.e. sands) can result in large amounts of calcium and other cations being leached from the soil.

Data from other studies have suggested that leaching is of relatively small importance in respect to nutrient budgeting.[2,5,6,7] Others have suggested that leaching rates are equivalent to weathering input rates and, thus, the two cancel one another out in a nutrient budget. Although leaching may affect these jack pine plantations within the first few years following harvesting, it is likely that by the age of next harvest (i.e. the rotation length—here, 47 years), leaching will not represent an important output of nutrients. For this reason, we have not included leaching in our nutrient budget.

Nutrient Replacement Times

We calculated the amount of time it will take for nutrients lost during harvesting to be replaced (i.e. "ecological rotation") by determining the number of years it will take for nutrients to be replenished via precipitation inputs.

As can be seen from Table 3, N will be replaced within one rotation length. However, the replacement times for all other nutrients is much longer than the 47 year rotation length we have employed here, as well as commonly employed rotation lengths of 65-80 years in managed jack pine forests. These replacement times warrant our attention, as it seems apparent that for these plantations, outputs via harvesting will exceed inputs via precipitation by a significant amount. In looking for nutrients, new growth will go first to the forest floor. Table 1 indicates that the forest floor contains the largest proportion of nutrients of any ecosystem component we considered. While we expect that mineral soil will hold more total nutrients, this does not diminish the importance of the large pool found in the forest floor and, in fact, may highlight it. Nutrients that are left on site in the forest floor will be in forms that are usable to new growth and, thus, stand productivity. It is important, then, to pay careful attention to forest floor management in order to maintain this valuable nutrient pool on site.

	N	P	K	Ca	Mg
To be replaced (TL)	41.3	46.1	36.3	96.1	12.1
To be replaced (FT)	97.1	56.1	66.7	138.4	17.9
Input/yr.	5.0	0.2	0.5	1.1	0.1
Years to replace (TL)	8.3	**230.4**	**72.5**	**87.3**	**121.1**
Years to replace (FT)	19.4	**280.5**	**133.4**	**125.8**	**178.7**

Table 3. Time needed to replace nutrients (kg/ha) under tree length (TL) and full tree (FT) harvesting regimes.

In all cases, as was expected, TL harvesting resulted in shorter replacement times for all nutrients, supporting the increasingly popular notion that this type of harvesting should be preferred over FT harvesting, especially insofar as nutrient cycling is concerned.

Summary

In these 47 year-old jack pine plantations, N supplies will be replenished within 1 rotation length using either harvesting method. However, the length of time needed to replace all other nutrients removed via FT harvesting is much longer than the rotation time of either our scenario (47 years) or commonly employed rotation lengths (65-85 years). TL harvesting presents a somewhat better scenario, with values for K and Ca being replaced within one rotation length but P and Mg requiring closer to 2 (Mg) or 3 (P) rotation lengths.

The long replacement times found in our analysis emphasis the importance of maintaining as much of the forest floor as possible in these forests. The forest floor represents an essential nutrient pool from which new regeneration can draw when first becoming established, as well as throughout its entire rotation. Given that nutrient amounts will not be replaced within any reasonable rotation length based solely on precipitation inputs, the amount of nutrients remaining onsite in the forest floor and mineral soil will be essential pools from which new vegetation can draw. Many of the nutrients in the mineral soil may remain unusable for long periods of time, but those in the forest floor should become available much sooner.

Implementation & Future Research

- **TL harvesting, whereby leaves and branches are left on site, will be beneficial to the ecosystem because it results in less nutrients overall leaving the system. Replacement times are much shorter for TL than for FT harvesting, indicating that, whenever possible, this type of harvesting method should be employed.**
- **Forest floor removal and/or disturbance associated with FT harvesting should be avoided in order to minimize the depletion of the important forest floor nutrient pool.**
- **Future research into mineral soil weathering and leaching rates would aid in determining the relative importance of these processes as nutrient inputs (weathering) and outputs (leaching).**
- **Future research that estimates replacement times for nutrients in naturally disturbed (i.e. fire dominated) forests would aid in determining how closely current management practices are mimicking natural disturbance patterns.**

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