



# Nutrient budget for aspen forests on clay soils in west-central Alberta

by Kristin Kopra & James Fyles

## Highlights

- Nutrient inputs do not replace nutrients removed during harvesting.
- With the exception of nitrogen, tree-length harvesting more closely mimics fire disturbance in terms of nutrient losses than does full-tree harvesting.
- Removals of nitrogen, phosphorus, and potassium are larger, relative to the total nutrient pool in clay soils, than are removals of calcium and magnesium by harvesting.
- Ecological rotation times are much longer than the currently employed average of 70 year economic rotations. These numbers warrant concern and further research into nutrient inputs via weathering of minerals.

**This nutrient budget** is one of three that follow the introductory SFMN research note on nutrient budgeting entitled *Nutrient budgeting in Canadian Boreal Forests*. For general information on concepts and components of nutrient accounting, please refer to this research note.

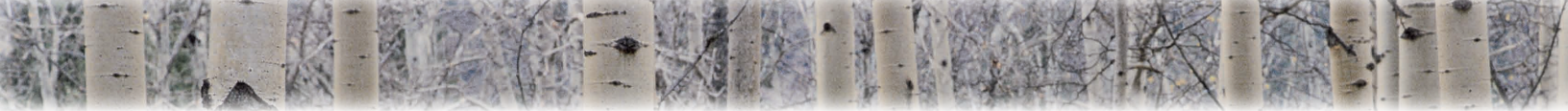
We completed a nutrient budget for an aspen forest growing on clay soils in west central Alberta. Five nutrients were accounted for: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). Nutrient

input via precipitation, existing pools in forest floor and mineral soil, and nutrient output via two different harvesting methods--full tree (FT) and tree-length (TL). For the purposes of our budgets here, full tree harvesting refers to the removal of stem, foliage, and branches off site (with no slash being returned to the site) while tree-length refers to the removal of stem only (with foliage and branches being left on site). In both cases, we have assumed that no topping has taken place.

In order to discern whether or not harvesting is currently mimicking natural disturbance patterns, we also compared the differences between nutrient loss via fire with nutrient loss via each of the harvesting methods described above. The mimicking of natural disturbance patterns—commonly referred to as emulation silviculture—has been outlined as a goal of sustainable forest management at both the provincial and federal levels. Nutrient removal comparisons between harvesting and natural disturbances are helpful in determining whether or not this management goal is being met.

## Clay soils – a special case

Clay-rich soils are common throughout the boreal zone of Canada. Many of these soils are classified as Grey Luvisols. The 'grey' refers to an often thin, light-coloured layer just below the forest floor (the A horizon) from which some of the clay has been leached lower into the soil profile (the B horizon). Clay soils have excellent water and nutrient holding capacity, due both to the ability of clay to attract nutrients and to the small pore size associated with clay soils. Luvisols are relatively nutrient-rich soils. Since many of these soils have developed from Ca carbonate rich glacial, marine, and lake deposits, they tend to be rich in Ca and to have a high pH. Clay soils also tend to be rich in organic matter, which further increases nutrient holding and storage capacity.



## Nutrient Inputs

Precipitation volume and nutrient concentration data were obtained from the Precipitation Quality Monitoring Program in Alberta (Alberta Environment) as it was contributed to the Canadian National Atmospheric Chemistry.<sup>1</sup> Two stations (Beaverlodge and High Prairie) close to the site budgeted for here were chosen and precipitation data from 1992 to 1998 were used. The data included wet deposition only.

Nutrient input via mineral weathering was not considered here due to a lack of data. Although weathering can be a valuable source of P, K, Ca, and Mg, the fact remains that to date weathering inputs are still extremely difficult to measure and data, therefore, difficult to find. Similarly, N input from N fixation by plants and microbes was not included because it is unknown in these forests. Filling these gaps in knowledge would be a useful goal of future research in order to provide a more complete picture of nutrient budgets. Nevertheless, given the data we have, this budget can serve as a useful estimation of nutrients in these aspen forests.

## Nutrient Pools

Three different nutrient pools were accounted for: (1) aspen trees, (2) forest floor, and (3) mineral soil (Table 1). Tree nutrients were estimated based on average tree and stand characteristics of aspen stands in the Edson Forest Management Area in west-central Alberta. Published equations were used to estimate the amount of each nutrient contained in the stem wood, stem bark, and foliage and branches.<sup>2</sup>

Quantities of forest floor and mineral soil total nutrients were estimated from data given in a soil survey report of the Hinton-Edson area in west-central Alberta. Six soil series, common in west-central Alberta, were chosen on the basis of soil type (Orthic Gray Luvisols) and texture. Nutrient masses (Table 1) were calculated for each horizon using nutrient concentration, horizon thickness and soil bulk density. Calculations were for a 1 m depth of soil.

When looking at nutrient quantities in mineral soil, it is important that we differentiate between total nutrients and available nutrients. While both quantities give us valuable information about the nutritional status of a

	N	P	K	Ca	Mg
<b>Precipitation</b>	104.8	*	11.0	34.4	5.01
Stem Wood	144.7	8.8	294.6	382.8	74.1
Stem Bark	169.3	19.4	164.1	846.7	79.4
Foliage & Branches	201.0	21.2	141.2	409.3	67
<b>Whole Tree</b>	<b>515.2</b>	<b>49.4</b>	<b>599.8</b>	<b>1638.8</b>	<b>220.5</b>
<b>Forest Floor</b>	<b>359.0</b>	<b>1.0</b>	<b>32.0</b>	<b>222.0</b>	<b>13.0</b>
<b>Mineral Soil</b>	<b>3091.0</b>	<b>90.0</b>	<b>5182.0</b>	<b>37062.0</b>	<b>4575.0</b>

**Table 1.** Quantities (kg/ha) of five nutrients found in various components of aspen stands in west-central Alberta, and nutrient input in precipitation over a 70 year rotation.  
\*indicates no data available.

site, in terms of rotation-length nutrient budgeting, available nutrients are probably of more importance. For instance, while it is likely than much of the Ca, Mg and K in mineral soils are available for plant uptake, the same is not true for P and N. Large amounts of N can be held in organic material and P in minerals that are only very slowly available to plants. This limits the amount of N and P in the mineral soil that is accessible and useful for forest production.

## 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 as outputs. The main difference between the two harvesting methods is that tree-length harvesting leaves foliage and branches on site where they decompose and their nutrients are recycled. Full-tree harvesting, on the other hand, removes foliage and branches from the site, and deposits them roadside, where they are often burned.

Nutrients can also be removed from harvested sites by water percolating through the soil. While such leaching can be a substantial contributor to nutrient output, we did not analyze it here due to two factors. First, there is little data quantifying leaching losses in these forests. Secondly, leaching is probably not substantial in these forests as the clay soils have high water and nutrient retention capacity. As can be seen in Table 2, FT harvesting removes 39% more N; 43% more P; 24% more Ca; 25% more K; and 30% more Mg than TL harvesting.

Harvesting Method	N	P	K	Ca	Mg
Tree-length	314.0	28.2	458.6	1229.5	153.5
Full-tree	515.0	49.4	599.8	1638.8	220.5

**Table 2.** Comparison of the quantities (kg/ha) of nutrients removed with two different harvesting methods over a 70 year rotation in an aspen stand on clay soils in western Alberta.

## Fire vs. Harvesting

General differences between fire and harvesting in terms of stand nutrition have been discussed in the SFMN Research Note entitled *Fire and Stand Nutrition in Boreal Forests of Canada*. For the purposes of this budget calculation, we compared nutrients lost during fires with those lost during tree-length and full-tree harvesting.

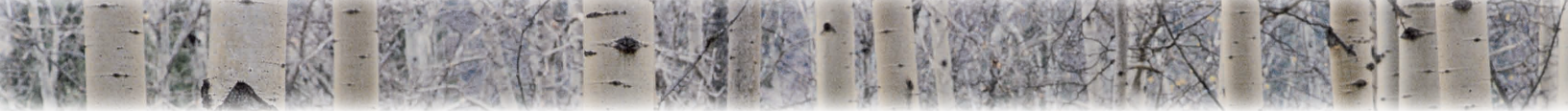
A hypothetical fire situation was imagined whereby the fire consumed all foliage and branches and half of the forest floor. Burned

tree stems were left on site, but loss of some stems was accounted for by assuming that half the nutrient amount present before fire still remained as stem after fire. It is important to note that fire severity, as generally described by depth of burn, will affect post-fire nutrient pools and/or post-fire productivity. Simply put, the amount of nutrients removed calculated here could be increased or decreased depending on severity of a given fire. We have simply provided one scenario, deemed to be a reasonable fire scenario for these forests.

Results for each of the five nutrients differed (Table 3). In general, TL harvesting nutrient losses more closely resembled fire losses than did FT harvesting losses. The one exception to this generalization was N, which was lost in larger quantities with both FT harvesting and fire than with TL harvesting.

	Pre-disturbance	FT Harvest	TL Harvest	Fire
<b>N</b>	3965 (0)	3450 (-13)	3651 (-8)	3427.5 (-14)
<b>P</b>	140 (0)	91 (-35)	112.2 (-20)	104.6 (-26)
<b>K</b>	5814 (0)	5214 (-10)	5355 (-8)	5427 (-7)
<b>Ca</b>	38923 (0)	37284 (-4)	37693 (-3)	37788 (-3)
<b>Mg</b>	4809 (0)	4588 (-5)	4655 (-3)	4658 (-3)

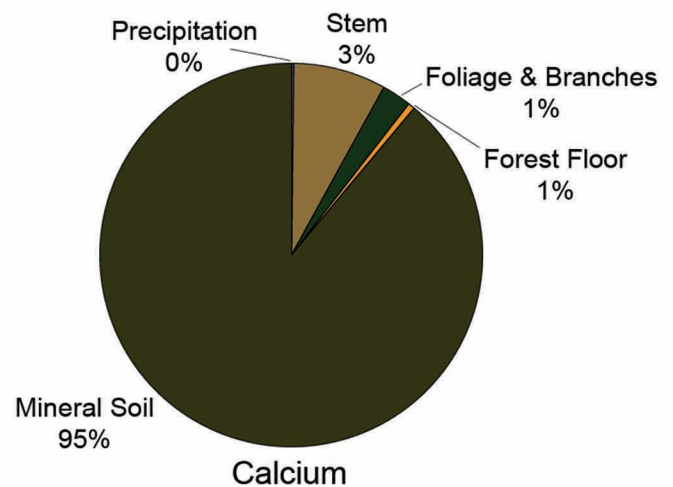
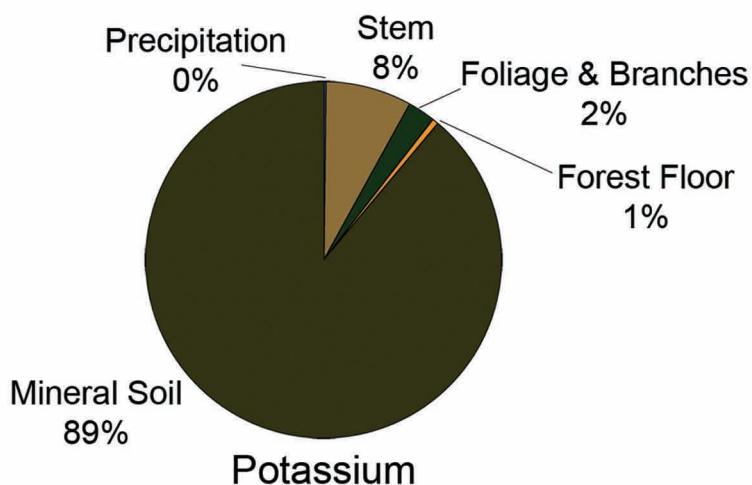
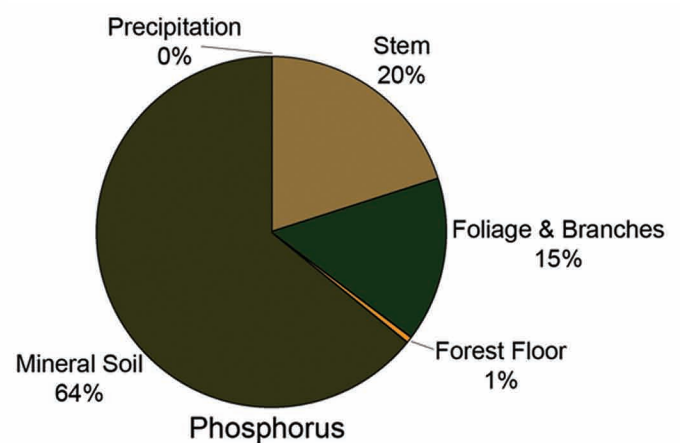
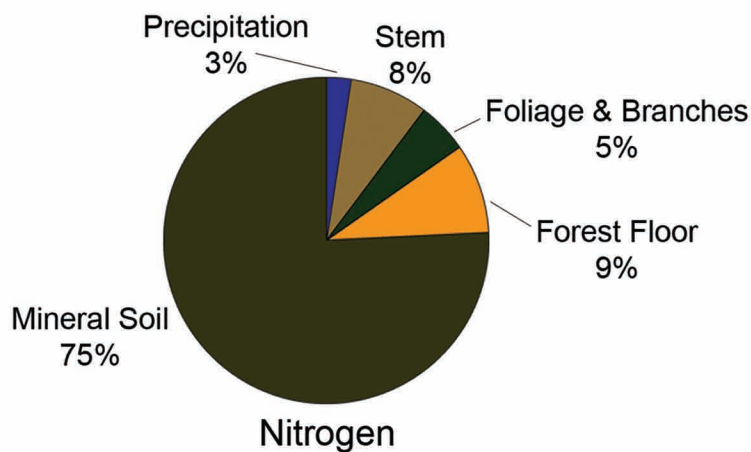
**Table 3.** Quantities of nutrients (kg/ha) left in aspen ecosystems after FT and TL harvesting and after fire. Numbers in parentheses indicate the percentage change (negative indicates a loss) between and pre- and post-disturbance levels.

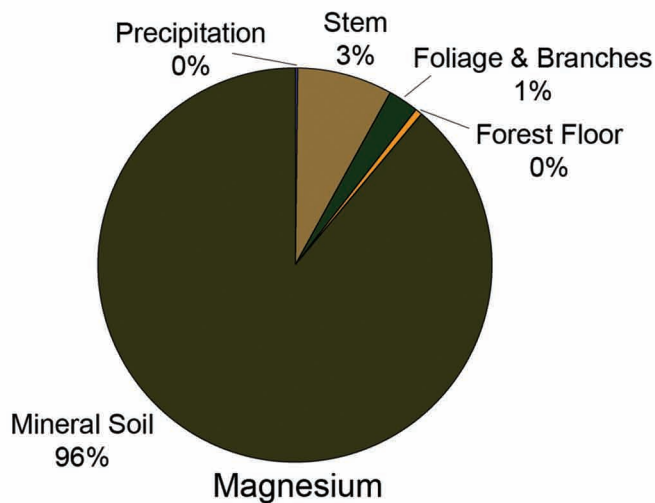
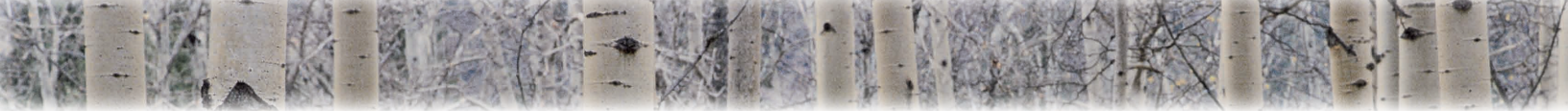


## Nutrient Budgets

The proportion of each nutrient entering, being held or leaving the aspen forest system was estimated over a 70 year rotation period to offer a view of the relative importance of all the components of these forests. The resulting nutrient budgets are shown in the pie charts below. The 70 year rotation period is considered an average rotation length for these forests. These charts suggest that removals of Ca and Mg by harvesting are small relative to the total nutrient supply in these rich forests. Relative losses of N and K are also low, particularly for TL harvesting. Current rotations of forest harvesting will leave about three-quarters or more of total nutrients in the forest.

Relative losses of P appear to be higher, but because weathering is an important source of this nutrient and has not been included in this calculation, it is difficult to discern whether P losses are higher than N or K. It is important to consider that, while current rotations will leave about three-quarters of total N and P in the forest (i.e. that found in mineral soil and forest floor), much of this is found in mineral soil, most likely in forms unavailable for plant uptake. Given that, in the case of both nutrients, the amount found in the forest floor (i.e. the amount available for plant usage) is less than the amount removed by full-tree harvesting (and, for P, by tree-length harvesting as well), careful monitoring of these nutrients is called for in order to prevent future depletion.





## Replacement Times

Lastly, we estimated the “ecological rotation”, or the amount of time it will take to replace the nutrients lost under each harvesting regime. The method we used to determine these replacement times compared the difference in precipitation inputs with nutrient exports via tree harvesting over a 70 year rotation period. As noted above, we have not accounted for weathering inputs in these systems, which could be significant for K, Ca, and Mg and would lessen the replacement times given

	N	K	Ca	Mg
Incoming/year	1.5	0.2	0.5	0.1
To be replaced (TL)	314.0	458.6	1229.5	153.5
To be replaced (FT)	515.0	599.8	1638.8	220.5
Years to replace (TL)	<b>209.6</b>	<b>2921.0</b>	<b>2499.0</b>	<b>2143.1</b>
Years to replace (FT)	<b>343.8</b>	<b>3820.4</b>	<b>3330.9</b>	<b>3078.5</b>

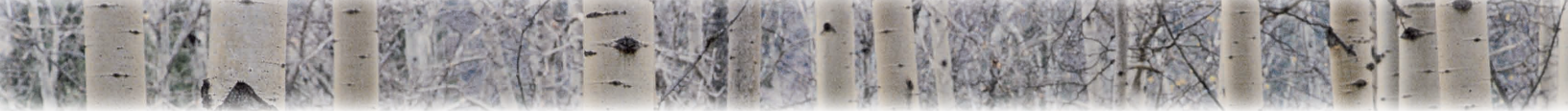
**Table 4.** Replacement times for four nutrients under two different harvesting regimes in aspen stands on clay soils in west-central Alberta.

in Table 4. Rotation times for P were not calculated due to a lack of input data. As can be seen, the amount of time required to replace all nutrients based on input via precipitation only is much longer than the current 70 year rotation. These numbers are cause for concern and highlight the need to quantify weathering inputs in order to gain a more accurate picture of what is happening in these forests.

## Summary

Atmospheric input is smaller than output for all of the nutrients. It is possible that levels present in nutrient pools within the ecosystem are high enough to outweigh losses due to harvesting using either method within a single rotation period (70 years). On a long term basis, however, if these nutrient pools are constantly called on to supply nutrients that are not wholly being replaced by atmospheric inputs, depletion will most certainly be a concern. Replacement times are high, which may be partially explained by the lack of weathering input accounted for here. However, this explanation does not hold for N which is primarily input into systems via precipitation. For this limiting nutrient, the amount of time it would take to replace losses with TL harvesting is three times longer than the average (70 year) rotation; it is nearly five times longer with FT harvesting. This warrants concern over the sustainability of either harvesting system over the long term.

This analysis suggests that both harvesting methods will remove more nutrients than would be lost under fire disturbed conditions. All types of stand destroying disturbance exceed the input rate of nutrients. Our results suggest that harvesting is not fully sustainable in terms of nutrients. Nutrient budgets should be monitored



and considered in management decisions about harvesting and silviculture. Research should be conducted to improve our knowledge of these forests. We have time to increase our understanding of nutrition in these forests, and to come up with potential solutions before we are faced with decreasing productivity due to depleted nutrient reserves.

## References

1) Canadian National Atmospheric Chemistry Precipitation Database. 2003. Environment Canada, Meteorological Service of Canada, 4905 Dufferin Street, Toronto, Ontario, Canada M3H 5T4

2) Chatarpaul, L., D.M. Burgess, and I.R. Methven. 1985. *Equations for estimating above-ground nutrient content on six eastern Canadian hardwoods*. Canadian National Forestry Institute. Inf Rept PI-X-55.

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The Forest Nutrition Group is:

James Fyles, Dave Morris, Suzanne Brais,  
David Pare, Robert Bradley, Cindy Prescott,  
Andrew Gordon, Alison Munson, Barbara Kischuk,  
and Benoit Cote

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## Implementation & Future Research

Several useful management implications come out of this nutrient budgeting. Effective sustainable forest management will be helped if forest managers implement the following ideas into their planning:

- Forest managers should recognize that nutrients are removed at a higher rate during harvesting than they are replaced through precipitation inputs.
- Forest floor management should aim to leave as much forest floor on site when harvesting, as this is where new growth will go first for available nutrients.
- TL harvesting removes less nutrients than does FT harvesting. De-limbing on site will help keep important nutrients in the forests where they are needed (especially N and P).
- Research that allows nutrient removal at time of harvest to be calculated from stand data and growth and yield projections should be supported.
- Forest managers should identify forest soil types within management areas that will have higher removal rates, and thus will warrant more careful consideration.
- Burned ecosystems should be used as a baseline for comparison with managed sites.
- Further research (and continued research at places such as the EMEND site) into the effects of fires on these systems, as well as safety guidelines that should aid in decreasing runaway fires should be a primary consideration in years to come.