Temporal Changes in Soil N, P, K Reserves Resulting From Various Levels of Biomass Removal, and Their Impact on Black Spruce Foliar Nutrition

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Study Objectives

With a renewed and fast growing interest in using forest woody biomass for energy production, concerns regarding nutrient loss and impacts to soil quality have also been heightened. In this context, the objectives of the current study were: 1) to document temporal changes (out to 20-yrs post treatment) occurring to soil N, P, K pools resulting from different biomass harvest intensities conducted in upland, black spruce-dominated site types, and 2) to determine if any of the detected soil changes are correlated to patterns in planted black spruce seedling foliar nutrition or growth.

Materials and Methods

Study Site Descriptions:

Three study sites are located approximately 60 km northwest of Thunder Bay, Ontario (latitude: 49°04′ N ; longitude: 89°15′ W) and two sites are located near Nakina, Ontario (latitude: 50°15′ N ; longitude: 86°40′ W) (Fig.1). The five study sites selected for this study represent replicate conditions for two soil types commonly considered to be sensitive to increased nutrient depletions:

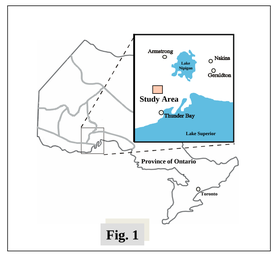

Fig. 1

Site Type 1 (coarse sandy outwash) represents a spruce-pine/feathermoss site type occupying upland, rapidly-drained, dry sites (Spodsols) dominated by black spruce (60%) and a lesser amount (40%) jack pine (Fig. 2).

Site Type 2 (coarse-loamy morainal till) represents a spruce-pine/feathermoss site type occupying upland, well-drained, moderately dry sites (Inceptisols) dominated by black spruce (80%) and jack pine (20%) with a scattered occurrence of trembling aspen (Fig. 3).

All stands were natural (post-wildfire) stands over 100 years of age at the time of harvest.

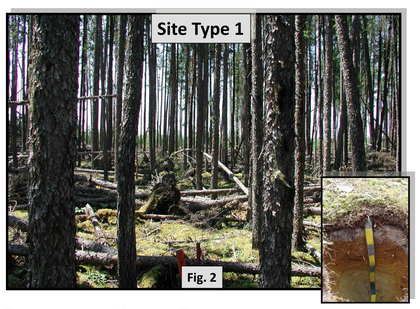

Fig. 2

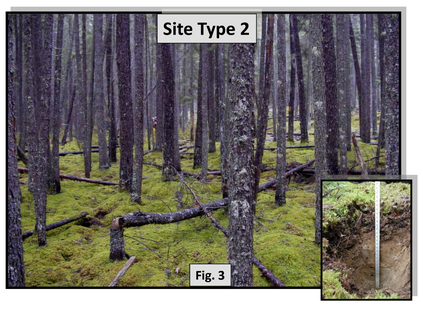

Fig. 3

Experimental Harvest Treatments:

In 1994/5, experimental harvests (30m x 30m plots with 20m buffers) were conducted consisting of 4 replicated treatments: uncut reference state condition, Stem only (SO) - coarse and fine slash left on the plots, full-tree (FT) - fine slash removed to roadside, full-tree + blade (FT+B) - complete removal of logging debris/stumps and forest floor layer (Fig. 4).

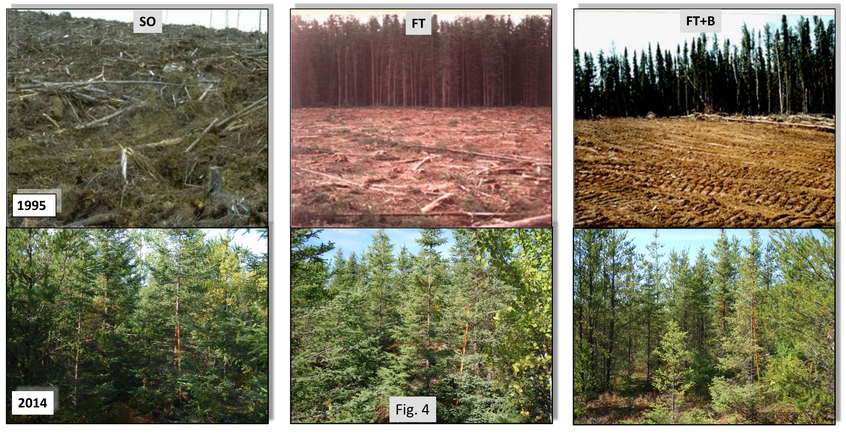

Fig. 4

Sampling Design and Procedures:

Periodic soil sampling (pre harvest, 4, 8, 10, 15, 20 years) was conducted to track changes in soil nutrient (N, P, K) reserves following the applied harvest treatments. O horizon depth and weight per unit area, mineral soil fine fraction bulk density, TKN (semimicroKjeldahl digestion), available P (Brays and Kartz No. 1 extractant), exchangeable K (NH_4 acetate solution) were determine for the O horizon and upper 20 cm of mineral soil (4 sampling locations per plot – centre of each quadrant). Uncut, mature plots were also sampled each time.

In each sampling year, current foliage was collected from the upper one-third of the crown from 9 permanently tagged "intensive" planted black spruce trees, located in close proximity to each of the soil sampling pits (405 seedlings in total), and foliar N, P, K was determined.

Sampling Design and Procedures (cont.):

The experiment was treated as a 2-factor RCBD, with site type and harvest treatment as main factors (site replicates as blocks). The 4 sampling points within each plot were treated as sampling units, and plot averages treated as experimental units. Analysis of Variance was performed using PROC GLM on SAS/STAT. The Student-Newman-Keuls (SNK) multiple range test was used as the means separation test for the main (qualitative) factors.

Results:

Prior to harvest the soil nutrient reserves in these mature, natural origin northern boreal sites represented 90, 43 and 54% of the total site N, P, K pools, respectively (Table 1).

Table 1. Nutrient stores partitioned by ecosystem component

Soil Type	Nitrogen (kg ha^{-1})					Phosphorus (kg ha^{-1})					Potassium (kg ha^{-1})				
	Tree Bole	Tree Crown	Organic	Mineral	Total	Tree Bole	Tree Crown	Organic	Mineral	Total	Tree Bole	Tree Crown	Organic	Mineral	Total
Sand	107	103	1169	635	**2014** (*89.6*)	9	10	5	19	**43** (*55.8*)	62	35	71	30	**198** (*51.0*)
Coarse Loam	90	93	1196	788	**2167** (*91.6*)	7	9	4	3	**23** (*30.4*)	53	33	57	53	**196** (*56.1*)

Treatment induced nutrient retention gradients were largely observed with P and K on the sandy sites. As would be expected, the FT+B (O horizon removed) treatment had significantly lower nutrient pools compared to the SO and FT treatments (Fig. 5).

20 years following harvest, P and K soil nutrient reserves in the harvest treatments on the sandy sites remain substantially reduced (~ 50% of pre-harvest levels) with N and K continuing to express the treatment-induced gradients observed at the time of harvest (Fig. 6).

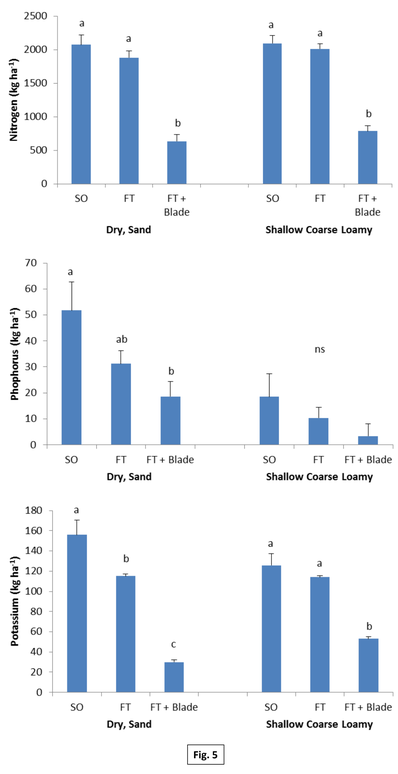

Fig. 5

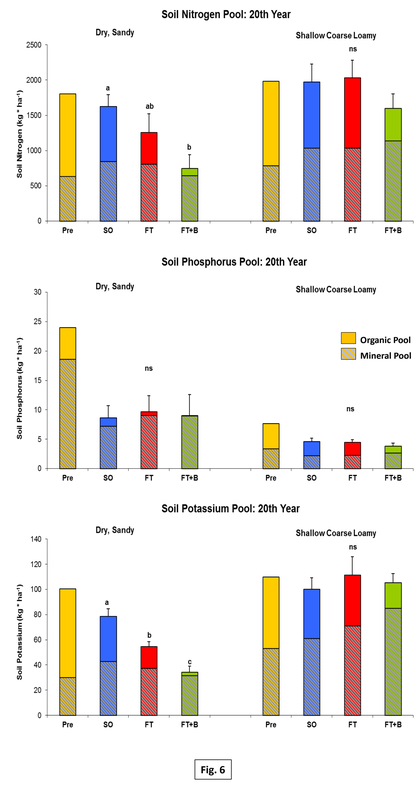

Fig. 6

Take Home Messages:

- Coarse sandy outwash sites were more susceptible to soil nutrient declines compared to the richer, loamy sites.
- Generally, there were minimal differences in soil nutrient reserves or foliar chemistry between SO and FT treatments.
- Even though soil nutrient reserves (P, K) in the harvest treatments remained below pre-harvest levels after 20 years, in almost all cases foliar nutrient contents have converged.
- Although clearcut harvesting results in long-term (20 year) declines in soil nutrient reserves, increased tree biomass removals associated with full-tree harvesting did not result in additional declines that influenced foliar nutrition or tree growth (not shown; Morris et al 2013, Can J For Res 44: 313-325).

Temporal Trends in N, P, and K Pools:

Generally, declines in soil nutrient reserves occurred out to year 7 across harvest treatments, stabilizing thereafter (Fig. 7). As an exception, P reserves have continued to decline out to the 20 year re-sampling.

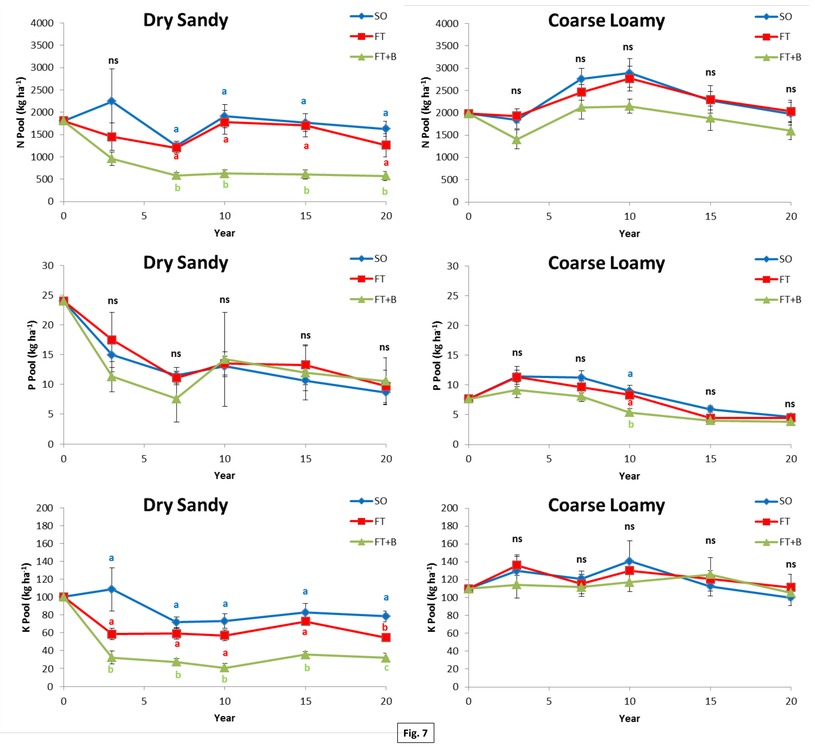

Fig. 7

Temporal Trends in Foliar N, P, and K:

Significantly lower foliar nutrient content (mg * 100needles^{-1}) were observed for the FT+B treatment from Year 4 to 15 on the sandy sites, but have converged by Year 20 (Fig. 8).

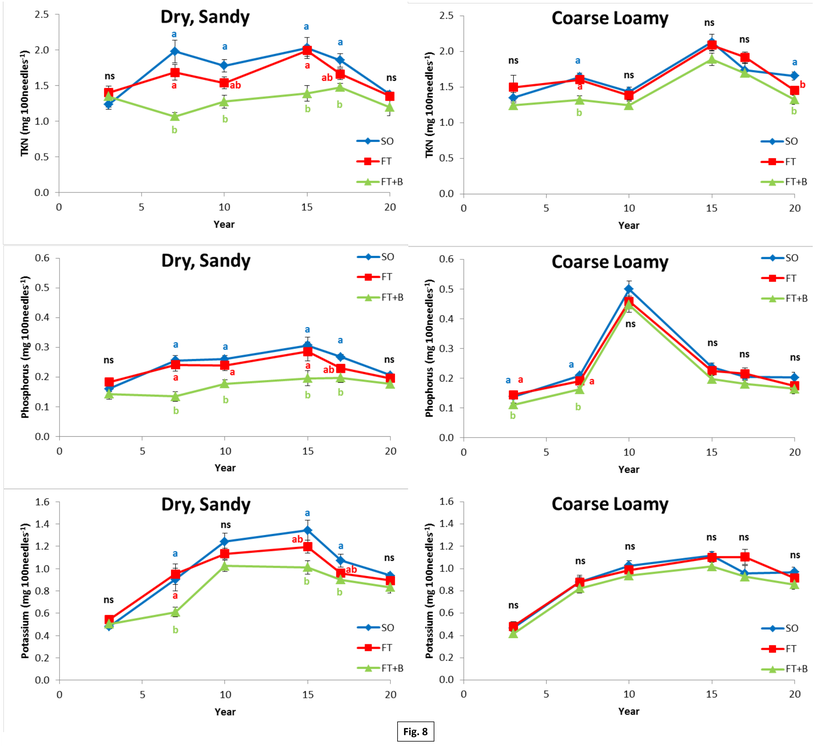

Fig. 8