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HARVESTING AND SITE PREPARATION TO MINIMIZE NUTRIENT LOSSES ON UPLAND BLACK SPRUCE SITES

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INTRODUCTION

Full-tree harvesting and disturbance of the forest floor during intensive site preparation are common forestry practices in Ontario. During the forum Class Environmental Assessments on Timber Management Practices in Ontario, held from 1988 to 1992, critical concern was expressed over these activities. The potential impacts of full-tree harvesting have been discussed at other environmental forums as well. These concerns were directed to long-term site productivity and to the sustainability of forest ecosystems on sites with limited nutrient reserves. Low nutrient reserves are commonly found in soils of coarse texture, high stone content, or with near-surface bedrock. The challenge in the managed forest is to meet operational needs without sacrificing future productivity by depleting on-site organic matter and nutrient reserves. This note highlights the results of two previously published studies (Foster and Morrison 1987, 1989) on the possible effects of full-tree logging of black spruce (*Picea mariana* [Mill.] B.S.P.) and intensive site preparation on nutrient reserves on a shallow upland till.

METHODS

Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) reserves in vegetation and soils were determined for a 110-year-old black spruce stand on a shallow (30 cm) podzolized, medium-textured till near Lake Nipigon in northern Ontario. Measured reserve levels were compared to published information. Nutrient removals by conventional (stems only) and full-tree (crowns and stems) harvesting were determined.

For this investigation it was assumed that 50% of the total N content of the slash and forest floor (L and F layers), and 20% of the N in the H layer and surface 2 cm of mineral soil, would be eliminated by burning at a medium fire intensity. It was also assumed that all the nutrients in the slash, and within 5 cm of the organic layer, would be removed by blading surface materials into windrows.

RESULTS

Nutrient Removals Associated with Harvesting

The largest nutrient pools within the forest vegetation component of the Nipigon upland black spruce stand were for N and K (not shown) in the crown and Ca in the stem (Fig. 1).

Figure 1. Measurement of biomass in a black spruce stand near Lake Nipigon, Ontario.

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Conventional short wood or tree-length harvesting would result in considerable Ca removal from the site because of the amount of Ca within the bark and wood. Conventional nutrient removals were estimated to be 137, 19, 44, 352, and 22 kg/ha for N, P, K, Ca, and Mg, respectively. However, the removal of nutrient-rich foliage and branches through full-tree harvesting contributes to a much greater loss of all nutrients than do conventional harvesting practices. Full-tree harvesting nutrient removals were estimated to be 333, 42, 121, 604, and 47 kg/ha for N, P, K, Ca, and Mg, respectively. Black spruce stands were quite variable in their nutrient content (Table 1); hence, variable in the potential for nutrient removal by harvesting.

Nutrient Removals Associated with Site Preparation

For all black spruce sites examined, more N was contained in the forest floor than in the mineral soil (Table 1). While it is generally considered necessary to expose mineral soil to favor natural regeneration of black spruce on upland sites, site preparation greatly affects the soil's nutrient capital. Nutrient losses from boreal sites, as a result of windrowing, were estimated to be as large as 750 to 835 kg N per ha. These are equal to 6 times those removed in the conventional harvest of black spruce. Site preparation by prescribed burning removed quantities of N similar to windrowing (Fig. 2). In comparison to published black spruce ecosystem N contents, the Nipigon black spruce site contained greater than average N accumulations in the forest floor and mineral soil but below average N in the very productive but understocked stand (Table 1).

DISCUSSION

Harvesting

Nutrients removed by forest harvesting can be replaced if atmospheric and weathering inputs exceed the nutrient loss associated with harvesting and leaching from the soil. Rough

Figure 2. Appearance of the forest floor following a prescribed burn.

estimates of annual nutrient inputs from weathering of primary minerals and precipitation at the Nipigon location (6.5–7.0 kg/ha per yr) were greater than annual projected nutrient losses (0.4–5.5 kg/ha per yr) from full-tree harvesting (Foster and Morrison 1987).

With conifers in the Canadian boreal forest, the most growth-limiting nutrient is nitrogen (Foster and Morrison 1983). In mature forests of this type, cycling of N from litter through the soil to vegetation is commonly interrupted by N accumulation in humus. After harvesting, the mineralization of forest floor N reserves generally increases, at least temporarily, because of more favorable temperature conditions in the humus. Removal of N during harvesting operations (Fig. 3), even full-tree harvesting, may not result in severe consequences since removals are modest in relation to total N reserves and their potential turnover on the cutover site.

Site Preparation

From a nutritional point of view, the nutrient content of the humus and surface mineral horizons is critical for black

Table 1. The dry-matter and nitrogen content of black spruce in Ontario and Quebec (*from* Foster and Morrison 1989).

Age (yr)	Basal area (m^2/ha)	Site[a]	Aboveground Phytomass (t/ha)	Aboveground N (kg/ha)	Forest floor N (kg/ha)	Mineral soil N (kg/ha)	Ecosystem N content (kg/ha)	N ratio[b]	Reference/Region
48	33	sand	141	482	1050	695	2227	0.69	Gordon 1983, Ontario
65	42	SL till	107	167	1200	300	1667	0.82	Weetman and Webber 1972, Quebec
110	23	L till	142	234	1790	1240	3264	0.62	Foster and Morrison 1987, Ontario
126	32	SL till	138	536	1302	982	2820	0.65	Timmer et al. 1983, Ontario
126	49	SL till	225	897	1849	1827	4573	0.60	Timmer et al. 1983, Ontario
200	–	humus/ bedrock	116	140	860	470	1470	0.68	Weetman and Algar 1983, Quebec
112	36		145	409	1342	919	2670	0.68	(averages)

[a] L = loam, SL = sandy loam.

[b] Ratio of N accumulation in phytomass plus forest floor to that in the ecosystem.

Source: Foster and Morrison (1989).

Figure 3. Biomass removal from a forest site during harvesting operations.

spruce because fine roots are commonly most abundant there. On some sites they are restricted to these horizons. Moreover, organic horizons protect the mineral soil from the impact of rainfall, thus reducing surface runoff and soil erosion.

The methods most commonly used to expose mineral soil to favor natural regeneration of upland black spruce are prescribed fire or scarification. A light fire may eliminate slash and logging debris without consuming a large portion of the forest floor and the N contained therein. Furthermore, seedling nutrition may actually benefit if short-term increases in N availability occur after burning. However, a severe burn may have serious consequences. Much of the N reserve in the slash and humus could be volatilized into the atmosphere and other plant nutrients could be subject to erosion by wind and water (*see* Nicolson 1994).

During scarification by shearblading and piling, angled or v-shaped tractor-mounted blades are sometimes used to pile surface debris. This action may also remove large portions of the biologically active, nutrient-rich organic layers and surface mineral horizons, together with stumps and branches. This can significantly reduce the nutrient reserves on a cutover site. A light scarification, i.e., one in which organic materials are mixed with the surface mineral soil, is preferable to treatments that remove slash and humus. Incorporation of organic matter into the soil also increases cation exchange capacity and hence the ability of the soil to retain nutrients.

CONCLUSIONS AND RECOMMENDATIONS

Potential nutrient removals associated with full-tree harvesting of an upland black spruce site near Lake Nipigon, Ontario, were much greater than those associated with conventional (stems only) logging. Nutrient reserves and replenishment after full-tree logging appear to be sufficient to sustain the next generation of spruce through the early growth period. Thereafter, nutrient drain on the soil reserves will be reduced to the extent that these needs are met by nutrient cycling within the tree and the stand.

Nutrients contained in slash and in forest floor horizons should be conserved by using the least destructive site preparation treatments available. Disk trenchers and patch scarifiers are recommended over shearblading, piling, or prescribed fire. The Ontario Ministry of Natural Resources and the Canadian Forest Service – Ontario have established a cooperative *Sustainable Productivity Technical Working Group* to facilitate federal and provincial research and development programs aimed at improving forest ecosystem management practices.

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