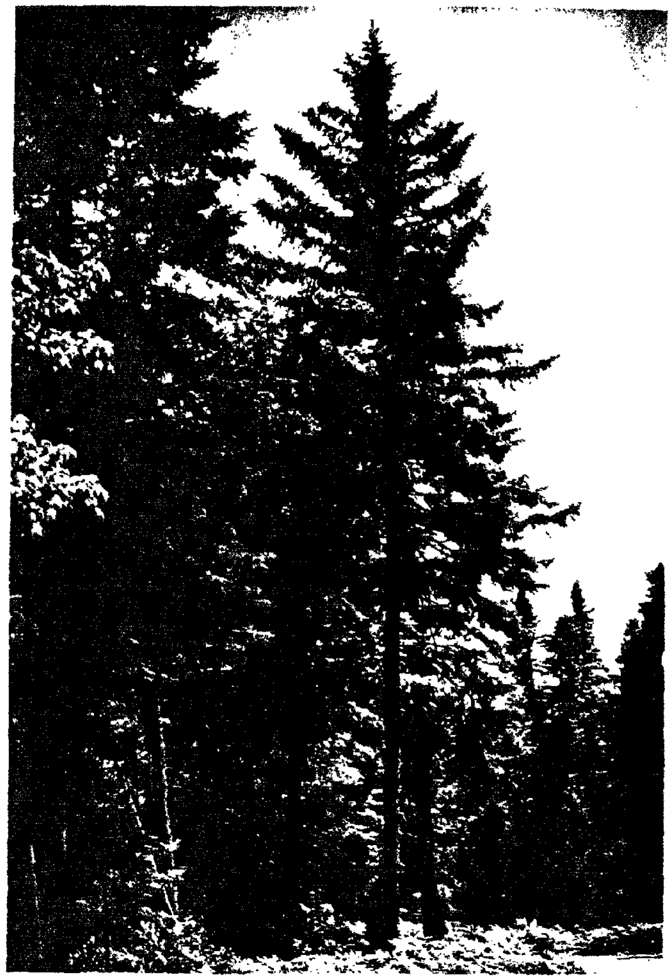
Proceedings of the SYMPOSIUM ON INTENSIVE CULTURE OF NORTHERN FOREST TYPES



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6816 MARKET STREET, UPPER DARBY, PA. 19082

FOREWORD

THE NORTHERN FOREST TYPES constitute a vast natural resource for the United States and Canada. For instance, in the eastern United States there are more than 10 million acres of commercial forest land supporting spruce and fir types alone. The magnitude and variety of this resource is such that treating it in any detail at a 3-day meeting was impossible. Rather, the idea that germinated and developed into this symposium was to present a broad picture of the extent of our knowledge of intensive cultural techniques, the status and trends of our research in the northern forest types, and some actual experiences in managing this resource; and to explore those factors that affect our use of the intensive cultural techniques we have at hand.

There is no doubt that we face a new era in the management of northern forests. The production of wood products is no longer the primary objective of many owners, and increased pressure for the social values of our forests is being felt by all landowners. We must recognize these other forest values, which in turn dictates intensification of all aspects of forest management if we are to meet the future demands of a wood-hungry society.

The enthusiastic efforts of the symposium sponsors—the School of Forest Resources, University of Maine; the Maine Bureau of Forestry; the Maine Forest Products Council; and the U.S.D.A. Forest Service—and the individuals behind those efforts, should be commended. Special thanks are due to Great Northern Nekoosa, Inc., and Brooks B. Mills for their help in providing interesting field trips, and to the Casco Bank and Trust Co. for sponsoring the symposium brochure. Also, without the enthusiastic participation of the experts invited to present papers, and the moderators of each session, the Symposium could not have taken place.

—BARTON M. BLUM
Symposium Chairman

PUBLISHER'S NOTE

This report is published by the Northeastern Forest Experiment Station as a public service. The papers it contains are published as received from the authors. Any questions or comments about these papers should be directed to the authors.

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SYMPOSIUM ON INTENSIVE CULTURE OF NORTHERN FOREST TYPES

held 20-22 July 1976 at Nutting Hall, University of Maine, at Orono.

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C. D. Hartley, Valley Forest Products Ltd., Canada: 22 July 1976, morning session.

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NUTRIENTS : A MAJOR CONSIDERATION IN INTENSIVE FOREST MANAGEMENT

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Abstract

Estimates of nutrient losses are compared for a stem-only harvest versus a whole-tree harvest of a clearcut northern hardwood stand. Combined nutrient losses due to increased leaching and removal of vegetation after stem-only harvesting are estimated to be 334 kg/ha for calcium and 265 kg/ha for nitrogen. For a whole-tree harvest, combined losses are estimated at 537 kg/ha for calcium and 486 kg/ha for nitrogen. Replenishment of available calcium and nitrogen could be a problem, depending upon the rate of soil mineralization and natural replacement.

THE NUTRIENT CAPITAL of the forest ecosystem is a main concern in intensive management. In some cases the concern is that nutrients are lacking and additions are needed to promote additional growth and more rapid growth. In other cases concern is about the nutrients lost from a site through physical removal by harvesting and by basic changes in the nutrient cycle after harvesting.

Conceptual models for fluxes of major nutrients in forest ecosystems are now commonplace. In some cases these models are detailed; J. Melillo at Yale University (personal communication) defines 25 different compartments and numerous interrelated pathways for nitrogen flow into, within, and out of a northern hardwood forest. Less commonplace are quantitative values for the many compartments of forest nutrient cycles.

There are obvious reasons why we need quantification of the nutrient cycle. Intensive management can mean shorter rotations and more complete utilization and thus a greater drain of nutrients in harvested products. We need to know what this means in relation to overall nutrient capital and productivity of the managed site.

Harvesting the forest can also increase nutrient losses by leaching. The magnitude and importance of leaching losses will be greater for the more complete and more frequent harvests likely to accompany intensive management. Nutrients lost through leaching represent a drain on nutrient capital as well as a source for increasing the nutrient concentrations of streams and groundwater. With implementation of the Federal Water Pollution Control Act Amendments of 1972, nutrient leaching from silvicultural activities has gained recognition as a potential source of water pollution, furthering the need for quantifying leaching losses.

Information about nutrient leaching and removal by harvesting is limited. To my knowledge, only four studies have been made in the eastern United States and eastern Canada on the problem of nutrient removal in harvested trees (Jorgensen et al. 1975; White 1974; Boyle et al. 1973; Weetman and Webber 1972). More information is available about leaching of nutrients to streams (Corbett et al. 1975; Hornbeck et al. 1975a, 1975b; Aubertin and Patric 1974; Pierce et al. 1972, 1970; Verry 1972; Johnson and Swank 1973; and Stone 1973). But the research on nutrient leaching is still at a stage where it is generating more questions than answers.

In this paper I will apply information from the above and other studies to demonstrate some potential impacts of forest harvesting on nutrients and the nutrient cycle. This demonstration requires considerable extrapolation of various types of data, but serves to show the extent of our knowledge about relationships between intensive management and nutrients in northern types.

METHODS

For this demonstration I will consider two nutrients, calcium and nitrogen. Both are important ecologically in forest ecosystems, and both may undergo increased leaching after forest harvesting.

For a forest type I have chosen northern hardwoods (beech, birch, and maple mixture) because of the available information and data, and because large areas of the Northeast are covered by this type. Species composition and size classes are taken from a

90-year-old stand at the Bartlett Experimental Forest in central New Hampshire. On this area of 2.5 hectares, all trees over 2.5 cm dbh were measured (data provided by S. M. Filip, Northeastern Forest Experiment Station, Durham, N. H.).

To estimate nutrient removal by various intensities of forest harvesting, both biomass values and nutrient content of plant tissues are needed for individual components of the forest stand. Biomass values were obtained by using a dimensional analysis of a northern hardwood stand at the Hubbard Brook Experimental Forest in central New Hampshire (Whittaker et al. 1974). Diameter at breast height is used as an independent variable in a series of linear regression equations. The equations provide estimates of biomass for stem wood, stem bark, branch wood, and current leaves and twigs by individual species.

Nutrient content of these components was determined by using chemical analyses of plant tissues made at Hubbard Brook by Likens and Bormann (1970). These analyses provide nitrogen and calcium values as a percentage of biomass. Weight of nutrients in each component is estimated simply by multiplying biomass by the percentage of calcium or nitrogen.

RESULTS

Using data from the northern hardwood stand at Bartlett Experimental Forest and applying the equations from Whittaker et al. (1970), I found that total biomass in trees >2.5 cm dbh is 203 metric tons/ha (table 1). Of this total, stem wood comprises 64 percent, stem bark 7 percent, branches 27 percent, and current leaves and twigs 2 percent. By species, 34 percent of the biomass is maple, 32 percent birch, and 24 percent beech. White ash, red spruce, and eastern hemlock make up the remaining 10 percent.

Multiplying biomass by the nutrient contents of individual components of biomass (Likens and Bormann 1970), I find that total calcium and nitrogen in trees >2.5 cm dbh is 547 kg/ha and 483 kg/ha, respectively (table 2). For calcium, 229 kg/ha or 42 percent of the total in trees is bound in branches and 193 kg/ha or 35 percent of total is bound in stem bark. Stem wood contains 99 kg/ha or 18 percent, and current twigs and leaves contain only 25 kg/ha or 5 percent of the total. By species, 36 percent of the calcium total in trees

Table 1.--Dry weight of biomass, in metric tons per hectare

Species	Stem wood	Stem bark	Branches	Current leaves and twigs	Total	
	------Metric tons per hectare-------					Pct.
Beech	31.82	2.18	13.19	1.08	48.27	24
Yellow birch	26.76	3.24	14.36	.80	45.16	22
Paper birch	11.25	1.29	6.79	.31	19.64	10
Sugar maple	2.41	.31	.59	.08	3.39	2
Red maple	43.80	5.33	13.85	1.13	64.11	32
White ash	3.10	.20	1.37	.07	4.74	2
Red spruce	.45	.07	.12	.01	.65	0
Eastern hemlock	11.46	1.42	3.66	.14	16.68	8
Total	131.05	14.04	53.93	3.62	202.64	
Percent	64	7	27	2	--	--

is in maples, 30 percent in birches, and 26 percent in beech.

For nitrogen, 195 kg/ha or 40 percent of the total is in branches and 81 kg/ha or 17 percent is in stem bark (table 2). Stem wood contains 126 kg/ha or 26 percent and leaves and twigs contain 80 kg/ha or 17 percent of the nitrogen total. By species, 38 percent of the nitrogen total in trees is in birches, 32 percent in maples, and 24 percent in beech.

Only minor portions of biomass and nutrients are in trees that might be considered too small to harvest. For the Bartlett stand, trees less than 10 cm dbh contain only 3 percent of the total biomass, 2 percent of the total calcium in vegetation, and about 3 percent of the total nitrogen in vegetation.

DISCUSSION

The above data can be used to compare nutrient removal for differing harvests. An illustration is clearcutting to harvest stems only versus clearcutting for whole-tree harvest. For the Bartlett stand,

Table 2.--Calcium and nitrogen in biomass

Species	Stem wood	Stem bark	Branches	Current leaves and twigs	Total	
	----------kg per hectare-----------					Pct.
			CALCIUM			
Beech	19.2	55.2	62.0	6.4	142.8	26
Yellow birch	16.5	31.1	60.3	7.1	115.0	21
Paper birch	7.0	12.4	28.5	2.8	50.7	9
Sugar maple	2.5	4.4	2.6	0.5	10.0	2
Red maple	45.0	75.2	59.6	7.2	187.0	34
White ash	1.9	5.0	6.5	0.4	13.8	3
Red spruce	0.3	0.5	0.3	0.1	1.2	0
Eastern hemlock	6.9	9.6	9.2	0.4	26.1	5
Total	99.3	193.4	229.0	24.9	546.6	
Percent	18	35	42	5	--	--
			NITROGEN			
Beech	35.1	16.4	39.6	22.7	113.8	24
Yellow birch	24.7	19.4	63.2	21.0	128.3	26
Paper birch	10.4	7.8	29.9	8.1	56.2	12
Sugar maple	2.4	1.7	2.2	1.8	8.1	2
Red maple	42.9	29.3	51.3	23.7	147.2	30
White ash	3.4	1.5	4.1	1.5	10.5	2
Red spruce	0.3	0.2	0.1	0.1	0.7	0
Eastern hemlock	6.3	5.0	5.0	1.6	17.9	4
Total	125.5	81.3	195.4	80.5	482.7	
Percent	26	17	40	17	--	--

combined stem wood and bark contain a total of 293 kg/ha of calcium and 207 kg/ha of nitrogen (table 2). All components, including stems, branches, leaves, and twigs, contain 547 kg/ha of calcium and 483 kg/ha of nitrogen. Thus a whole-tree harvest has potential for removing about 1.9 times as much calcium and about 2.3 times as much nitrogen as a stem-only harvest.

For any harvest, some residual materials and their incorporated nutrients will be left on the site. For the comparison of the two clearcuttings mentioned above, both harvests were assumed to be about 80 percent efficient--or that 20 percent of the harvestable materials were left on the site. Thus for the Bartlett stand, harvesting stems only would remove an estimated 234 kg/ha of calcium and 165 kg/ha of nitrogen (table 3). A whole-tree harvest is estimated to remove about 437 kg/ha of calcium and 386 kg/ha of nitrogen.

Nutrient losses also occur as a result of increased leaching in the several years immediately after harvest. From several studies in central New Hampshire (Pierce et al. 1970; Hornbeck et al. 1975a and 1975b), I have estimated leaching losses from the Bartlett stand to be increased about 100 kg/ha for both calcium and nitrogen (table 3). Thus combined losses

Table 3.--Soil nutrient capital and losses due to clearcuttings in which 80 percent of product is removed

Nutrient losses and reserves	Calcium	Nitrogen
	-------kg per hectare---------	
Losses due to:		
Stem-only harvest	234	165
Whole-tree harvest	437	386
Leaching losses	100	100
Total losses:		
Stem-only harvest	334	265
Whole-tree harvest	537	486
Soil reserves:		
Bound	6,000-20,000	6,000-8,000
Available	500-1,000	25-250

from a stem-only harvest are 334 kg/ha for calcium and 265 kg/ha for nitrogen. For a whole-tree harvest, combined losses are estimated at 537 kg/ha for calcium and 486 kg/ha for nitrogen.

One means of evaluating the losses is to compare them with nutrient content of the forest soil (table 3). For soils similar to those at Bartlett, total bound calcium is estimated between 6,000 and 20,000 kg/ha, and available calcium is estimated between 500 and 1,000 kg/ha. Corresponding estimates for nitrogen are 6,000 to 8,000 kg/ha bound and 25 to 250 kg/ha available. When compared with the total reserves in the soil, the calcium and nitrogen losses from either stem-only or whole-tree harvests are relatively small. However, in the case of nitrogen, of which the soil reserves are smaller, combined losses from stem-only harvesting may represent 3.3 to 4.5 percent of the bound nitrogen in the soil, and losses from whole-tree harvesting may represent 6.1 to 8.1 percent.

The above evaluations are in terms of total nutrient reserves in the soil. Important concerns also include how much of the losses come from the pool of nutrients readily available for plant use, and how fast such losses are replenished. Most of the increased losses to leaching probably come from the available pool. This could mean that as much as 20 percent of the available calcium and much of the available nitrogen could be lost to leaching (table 3).

Replenishment of the available pool could be a problem for both calcium and nitrogen. Although there were large calcium reserves bound in rocks and soils, the conversion to available calcium is slow (Johnson et al. 1968). In previous studies, Boyle et al. (1973) and Weetman and Webber (1972) both projected the depletion of calcium as being potentially the first adverse consequence of whole-tree harvesting. In the case of nitrogen, there is little, if any, input from rock-weathering; so most available nitrogen must come from soil mineralization. Both nitrogen and calcium are supplied to the available pool through precipitation, but the amounts are relatively small. At Hubbard Brook, the annual additions in precipitation average 2.2 kg/ha for calcium and 6.5 kg/ha for nitrogen.

Replenishment of nutrients may become a more significant problem if rotation age is reduced. Most northern forest types are currently on 50- to 100-year or longer rotations, thus providing a good opportunity for natural replacement of nutrients. Intensive management and improved utilization could shorten rotations to 30 years or less. The possibility of shorter rotations further emphasizes the need for information about rates and methods by which nutrients are made available for plant use, both before and after harvesting.

There are options that may reduce the loss of nutrients due to harvesting. An example for whole-tree harvesting: avoid removing leaves, either by harvesting in the dormant season or by felling trees well in advance of skidding so that senescence and leaf fall occur on site. Such an action for the Bartlett stand could reduce calcium removal by 25 kg/ha and nitrogen by 80 kg/ha (table 2). Configuration of the harvest can also affect nutrient losses. After a Hubbard Brook watershed was clearcut progressively in strips, nutrient losses to leaching were one-third to one-half less than those from nearby watersheds that were cut in large blocks (Hornbeck et al. 1975b).

In addition to the gross nutrient losses discussed above, forest harvesting can have other more subtle impacts on the nutrient cycle. For example, the removal of hydrogen ions by exchange in the forest canopy (Eaton et al. 1973) may lessen the impact of acidic precipitation that occurs in the Northeast (Likens and Bormann 1974). The important chemical changes that occur as precipitation passes through the canopy raise the question of what may happen when the forest canopy is removed. In an earlier study at Hubbard Brook, in which a previously forested watershed was devegetated for a 3-year period, the stream water pH decreased from 5.1 to 4.3 (Likens et al. 1970). This change represents about a fivefold increase in hydrogen-ion content of stream water. There were many complex changes in the chemical composition of the stream as a result of devegetation. However, the absence of hydrogen-ion exchange in the canopy may have contributed to the increased acidity of stream water after vegetation was eliminated.

As another example, recent studies at Hubbard Brook indicate that nitrogen is fixed in northern hardwood stands at an estimated rate of 1 to 11 kg/ha/yr (personal communication, Joann Roskoski, Yale University). Practically all the fixation occurs in rotting wood, especially in material greater than 2 cm diameter. More intensive harvesting may leave less of this material on the site and eliminate much of the substrate for future nitrogen fixation.

Both the gross and subtle impacts on nutrients must be considered in attempts to harvest greater quantities of wood from northern forest types. Cooperation is needed between the manager and the researcher in quantifying the changes in nutrient cycles and in implementing practices that will conserve nutrients on the site.

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