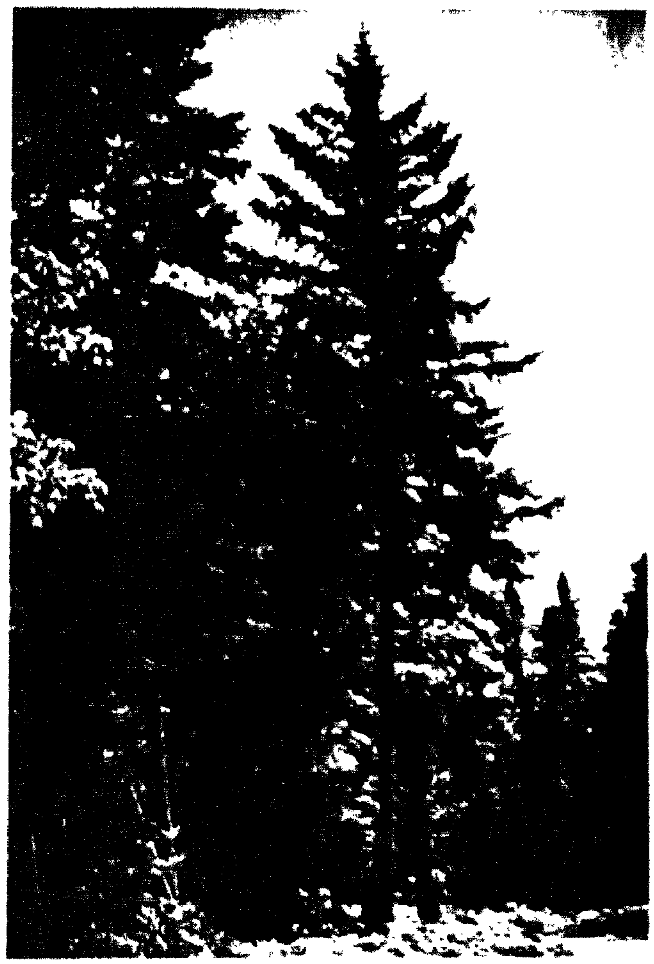
Proceedings of the SYMPOSIUM ON INTENSIVE CULTURE OF NORTHERN FOREST TYPES



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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
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.

Proceedings of the 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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Dick Kennell, USDA Forest Service, State & Private Forestry: 21 July 1976, afternoon session.

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

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INDICATIONS OF SILVICULTURAL POTENTIAL FROM LONG-TERM EXPERIMENTS IN SPRUCE-FIR TYPES

by Robert M. Frank, Research Forester,
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Abstract

Data collected since the 1950s from commercial treatments on more than 400 acres in the Penobscot Experimental Forest in Maine indicate a high mortality rate of 520 percent of net growth in the woodland preserve where timber is not harvested, a low mortality rate of 16 percent of net growth under the selection system. As the intensity of silvicultural treatment increased, periodic net annual growth increased from 10 cubic feet per acre (0.7 m^3/ha) in the woodland preserve to 56 cubic feet per acre (3.9 m^3/ha) under the selection system.

THE KEY to more productive forests is stand-improvement to replace untended and undertended stands with cultured stands containing fast-growing high-quality trees of favored species. Few are the acres that cannot be improved by ridding them of excessive trees, poor-risk trees, low-quality trees, or trees of inferior species. A rigid scheduling of intermediate cultural operations, preferably in conjunction with periodic thinnings or harvests, will accomplish this and enable the land to produce yields at capacity.

COMMERCIAL VERSUS PRECOMMERCIAL TREATMENTS

Simply stated, a cultural treatment that over time transfers at a profit the growth from undesirable trees to trees that will be removed either as crop trees or in subsequent thinnings is logically a commercial treatment. In this respect intensive culture in stands of trees is not unlike agronomy applied to other crops.

Dunfield (1974) stated that "precommercial thinning may be defined as a silvicultural method to eliminate a certain percentage of trees from a forest stand in order to increase the growing space and growth of the residual trees. The trees destroyed are usually of no commercial value, although collectively they contain a substantial volume of wood fiber."

Berg (1970) defined this in a more profound economic sense. He stated that, regardless of whether or not a thinning operation pays for itself in part or all, it must be considered a precommercial operation unless an immediate economic profit is returned. Worthington and Staebler (1961) were less restrictive. They maintained that, if an operation pays for itself, profit not withstanding, it is a commercial treatment.

Fully realizing that the terms precommercial treatment, noncommercial treatment, and commercial treatment are rapidly becoming archaic because of the more complete utilization of forest biomass, I shall make perhaps one of the last attempts to define the latter--commercial treatment, the subject under discussion. I define this intermediate cultural practice as follows:

> An operation involving the removal from a forest stand of trees primarily of merchantable size and of marketable species in a quantity sufficient to at least equal the cost of the operation and having one or more of the following purposes:

- To reduce stand density in order to increase the growing space and growth of residual trees and new regeneration.
- To reduce trees in diameter classes with excessive numbers of trees.
- To reduce the number of poor-risk trees.
- To reduce the number of trees of low species priority.

The treatment may also include the removal of both nonmerchantable-size trees and merchantable-size trees nonmarketable because of quantity, quality, or species. I have chosen to exclude from my definition pruning, the application of fertilizer, and land-drainage techniques.

CONSTRAINTS AND SILVICULTURAL CONSIDERATIONS

The minimum amount of marketable material necessary for an economic or profitable operation depends on many variables. It probably ranges between 250 cubic feet per acre and 750 cubic feet per acre (17.5 m^3/ha and 52.5 m^3/ha) in spruce-fir types. Among the important variables are species, quality, product, logging conditions including spatial distribution of trees to be harvested, skidding distance, and proximity to mill.

A commercial treatment in a developing even-age stand begins as soon as the treatment is financially self-sustaining. Both in even-age stands and in uneven-age stands, the interval between operations is such that wood losses due to mortality are minimized. This is best accomplished with relatively short periods of time between stand entries. Operating intervals of 10 to 15 years are well suited for this objective.

The amount of growing stock removed during a commercial treatment should not exceed 50 percent, and it can be as low as 10 percent on sites where the danger of excessive wind damage is apparent (Frank and Bjorkbom 1973). A second constraint on the amount of growing stock to remove involves stands not adequately stocked. These stands should be replenished promptly by adding to the growing stock an amount equivalent to a portion of each periodic increment until an acceptable stocking level is reached.

COMMERCIAL TREATMENTS IN SPRUCE-FIR TYPES --SOME EARLY EXPERIMENTAL RESULTS

Extremely varied site and stand conditions in spruce-fir types, coupled with existing market conditions, strongly suggest that silvicultural practices are never uniformly applicable (Westveld 1930). Or, there is not a "best" silvicultural system for all lands all of the time.

History and Scope

An example of various silvicultural systems and management methods applied to formerly unmanaged stands is available. Work was initiated during the 1950s and trends are developing after less than 20 years of treatment. Treatments include three intensities of the selection system, two intensities of the shelterwood system, two intensities of the diameter-limit method, one example of unregulated harvesting by the commercial clearcutting method, and a woodland preserve where harvesting is not allowed. All treatments with the exception of the woodland preserve are replicated twice. Treatment descriptions are outlined in the Appendix.

Data are reported according to availability. For instance, no data are being reported for the two-stage shelterwood treatment because the final harvest in one replication occurred less than 2 years ago. Original regeneration data were not recorded for any treatment, and second-measurement data are not yet available for the diameter-limit treatments.

The Study Area

Data are being collected in the Penobscot Experimental Forest, just 2 miles southeast of Orono, on more than 400 acres (162 ha) of spruce-fir types. Before being placed under management, these stands supported substantial amounts of hemlock and associated hardwoods. Some stands still do. The reason for these admixtures is that the Forest is located in the transition belt between the transition/hardwoods white pine/hemlock and the spruce-fir/northern hardwoods forest types as described by Westveld et al. (1956).

Sites within the study vary from areas of impeded drainage where red spruce (*Picea rubens* Sarg.), white spruce (*P. glauca* (Moench) Voss) and balsam fir (*Abies balsamea* (L.) Mill.) predominate, with northern white cedar (*Thuja occidentalis* L.) and red maple (*Acer rubrum* L.) as associates. On moderately well-drained locations, eastern hemlock (*Tsuga canadensis* (L.) Carr.) is a strong contender for site occupancy, along with occasional paper birch (*Betula papyrifera* Marsh.), eastern white pine (*Pinus strobus* L.), and red maple. A scattering of several other species is also present.

Commercial treatments being applied vary in intensity. Volumes removed in separate operations range between 300 and 1,250 cubic feet per acre (21.0 m^3/ha and 87.5 m^3/ha).

Except for the earliest timber-stand-improvement operations, the removal of undesirable nonmerchantable trees has been an integral part of each periodic harvest. The selection, three-stage shelterwood, and flexible diameter-limit treatments receive varying degrees of timber-stand-improvement: the 5-year and the 10-year interval selection treatments are the most intensive. In the latter two treatments, the TSI effort is extended to include trees down to the 1-inch diameter class. The fixed-diameter-limit and unregulated harvesting treatments receive no timber-stand-improvement work. And, in the woodland preserve, no cutting or harvesting of any kind is allowed.

Growth Response and Mortality

Net annual growth of natural softwood stands that have had a minimum of past silvicultural treatment is reported by Safford (1968) to be just under 51 cubic feet per acre (3.6 m^3/ha).

With less than 20 years of intensive culture, our selection treatments average 56 cubic feet per acre (3.9 m^3/ha) per year and range from 51 to 59 cubic feet per acre (3.6 m^3/ha to 4.1 m^3/ha).

There is virtually no difference between the two diameter-limit treatments where net annual growth averages 53 cubic feet per acre (3.7 m^3/ha).

A pronounced reduction in growth is noted for the unregulated harvesting treatment when compared with both the selection and diameter-limit treatments. In this treatment, commercial clearcutting left the stand with only 58 square feet per acre (13.3 m^3/ha) of basal area in merchantable-size trees. As stocking becomes reestablished, growth increases and averages 36 cubic feet per acre (2.5 m^3/ha) per year for the treatment period. Growth during the initial measurement period was only 29 cubic feet per acre (2.0 m^3/ha) per year; during the most recent measurement period, 43 cubic feet per acre (3.0 m^3/ha) per year.

Periodic net annual growth is only 10 cubic feet per acre (0.7 m^3/ha) in the woodland preserve area. With no timber harvesting by man, natural mortality is averaging 52 cubic feet per acre (3.6 m^3/ha) per year. Expressed as a percentage of net growth, mortality is 520 percent in this treatment compared to 42 percent or 15 cubic feet per acre (1.0 m^3/ha) per year in the unregulated harvest treatment.

Annual mortality ranged from 10 cubic feet per acre to 13 cubic feet per acre (0.7 m^3/ha to 0.9 m^3/h in the diameter-limit treatments. This is 22 percent of net growth.

Corresponding figures for the more intensive selection-system treatments range from 6 cubic feet per acre to 13 cubic feet per acre (0.4 to 0.9 m^3/ha) or 16 percent of net growth.

These results are similar to the results reported by Snow (1938). He reported that over a 29-year period average annual mortality for an unthinned stand was 49 cubic feet per acre (3.4 m^3/ha). In a thinned stand losses averaged 11 cubic feet per acre (0.8 m^3/ha).

Stand Quality

The reduction in number of cull trees in a stand is a major goal in intensive forest management operations. And the more frequent a stand entry is made, the more rapid and enduring is the reduction.

Intervals of 20 years and longer allow for the continual development of undesirable growing stock. Short intervals--about 10 years--are most efficient in eliminating cull trees and other poor-risk trees that are likely to develop into cull trees (fig. 1).

Cull trees have been practically eliminated from stands being managed under intensive selection silviculture. Cull-tree volume is only 0.2 percent in the 5-year-interval treatment where four combined harvests and timber-stand-improvement operations have already been made. The 10-year-interval treatment shows a corresponding reduction in cull trees to 2.4 percent of total volume after two combined operations.

The only obvious increases in cull-tree representation occurred in the two treatments not subject to stand improvement work--the fixed-diameter-limit and unregulated harvesting treatments.

The reduction in cull-tree representation in the woodland preserve is attributed to the high mortality rate.

Species Composition Changes

An attempt to alter species composition is best described by the cliché, "It is easier said than done!" The only exception is artificial regeneration. Even with this method, invasion of the planting site by formerly undesirable species or by successional species usually requires cultural measures to insure the ultimate dominance of the planted stock.

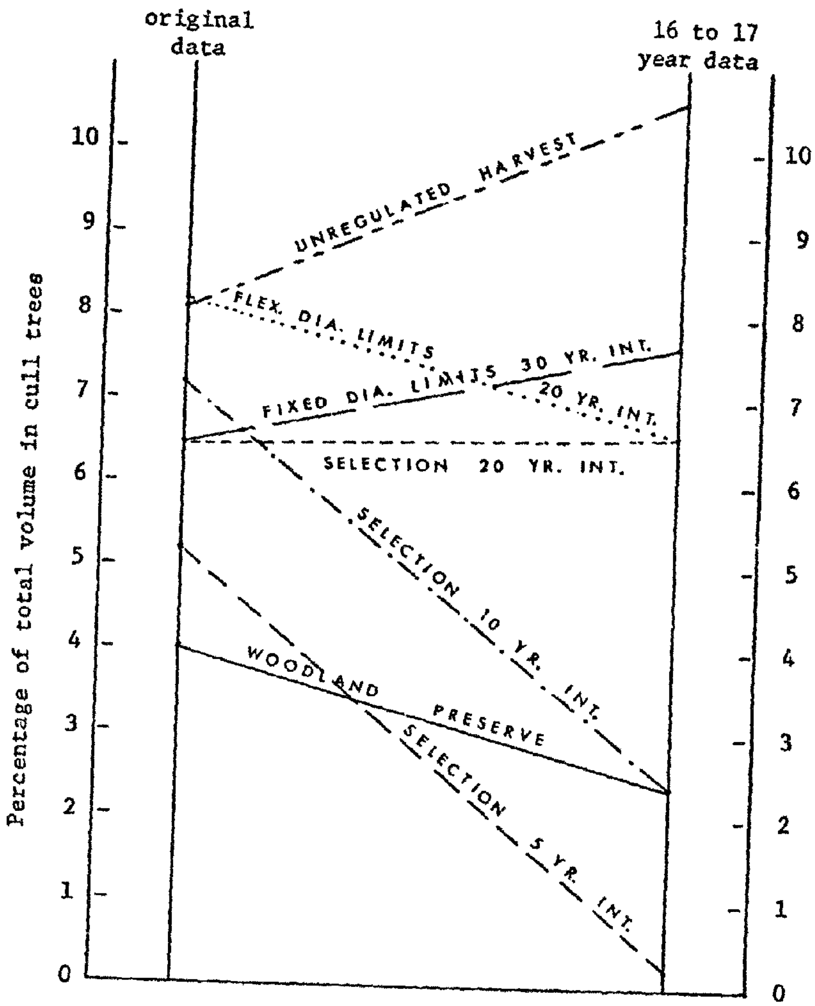

Figure 1.--Changes in stand quality by treatment, all species combined.

When natural regeneration methods are relied upon, compositional changes take place more rapidly under even-age management than under uneven-age management. An example is the shelterwood system.

Composition changes in regeneration.--All treatments show increases in numbers of balsam fir seedlings except for the selection-system treatment managed on a 5-year operating interval, where there is a slight decrease (fig. 2). The reason for this is not clear, although the frequency of stand entry with resultant logging damage may be a factor.

Fir seedlings currently range in number from fewer than 3,000 per acre (7,400/ha) in two of the three selection treatments to just over 12,000 per acre (29,600/ha) in the woodland preserve. Continuous dense overstory cover in the woodland preserve, gradually tempered here and there by mortality, plus an almost complete lack of site disturbance, has maintained site conditions suitable for fir germination and establishment but less hospitable to most other species.

Initial counts of spruce were all below 1,000 seedlings per acre (2,500/ha). However, the shelterwood-system treatment, where spruce was favored during the regeneration period, registered a 24-fold increase in spruce seedlings--from 100 to 2,400 per acre (250/ha to 5,900/ha). All other treatments registered gains, but the magnitude of the increases is much less.

The responds to the various treatments by hemlock seedlings is not unlike the response noted for spruce, particularly red spruce. This is because the environmental conditions necessary for their establishment, shade, and adequate moisture are very similar (Fowells 1965).

The reaction of the intolerant species to treatment is more predictable. Hardwoods and white pine show dramatic gains in the shelterwood treatment. In the unregulated harvesting treatment, the initial increases of these same species (original data not available) apparently peaked before regeneration counts were made. Therefore, a decline is noted between the 9th-year measurement and the 19th-year measurement. The selection treatments all show a slight decline in the numbers of intolerant species.

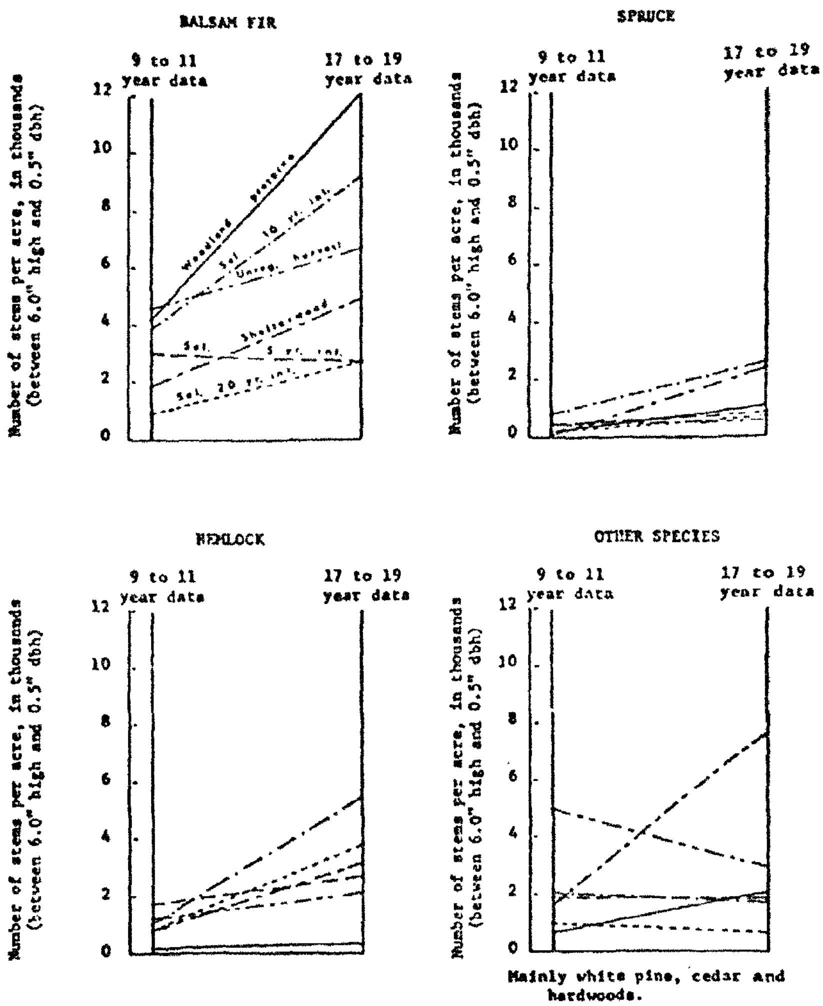

Figure 2.--Changes in regeneration, by treatment.

Ratio of balsam fir seedlings to spruce seedlings.--The slow-growing shallow root systems of spruce seedlings often are not able to reach available moisture and compete with the faster-growing balsam fir unless: (1) the organic layers of the soil profile are reduced in thickness; (2) rainfall can better penetrate the overstory following an operation; or (3) rainfall during the crucial growing season is frequent and plentiful.

Disturbance in a spruce-fir stand caused by timber harvesting usually results in a reduction of the ratio of fir seedlings to spruce seedlings. The reduction in the depth of the organic layers by scarification and the greater penetration of rainfall because of tree removals trigger a relatively greater response in establishment of spruce than in establishment of balsam fir. In the absence of logging, natural mortality can also create conditions that improve the moisture regime in the forest floor.

Immediately before the final removal of predominately spruce overstory trees in stands resulting from the shelterwood treatment, the fir-to-spruce ratio was 2:1. Eight years previously it had been 14:1. Unquestionably, this shelterwood operation was successful because a major goal was to increase spruce representation.

Since original data are not available we can only speculate about the ratio before treatment. The woodland preserve is perhaps indicative, however. The initial measurement resulted in the tabulation of a ratio of 28 fir to 1 spruce for this treatment. Currently it is 12 fir to 1 spruce. Originally, before excessive mortality, the ratio was perhaps significantly greater than 28:1.

All selection treatments display a reduction in the fir-to-spruce ratio--from about 5 to 7 fir for each spruce to a ratio of 4:1.

Composition changes in merchantable-size trees.--Changes in species representation after 16 to 17 years of observations is at best only trend-setting. And, variations based on volume in original compositional representations were pronounced (fig. 3).

The stands in the study area originally were about 85 percent softwood by volume:

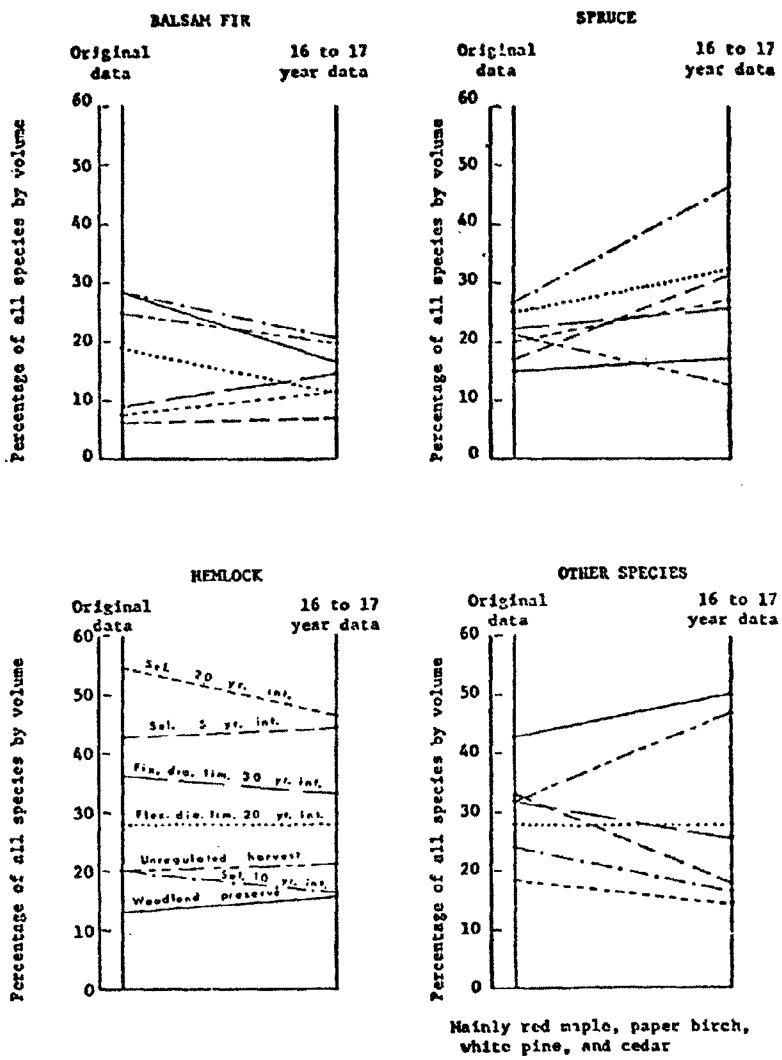

Figure 3.--Changes in species composition, by treatment.

	Percent
Spruce	22
Balsam fir	18
Hemlock	30
Cedar and White pine	15
Hardwoods	15

In general, because of risk and poor quality, balsam fir is being reduced by silvicultural treatment. Conversely, spruce representation in stands under the most intensive treatments appears to be increasing. Hemlock, with widely varied original representations, shows little change. Other species, but primarily the poor quality red maple and other hardwoods, are changing in relation to the intensity of management. Hardwoods tend to increase with little or no management and decrease in relation to other more desirable species as cultural practices intensify.

The Selection System and Diameter Distribution

The normal or classic uneven-age forest is comprised of trees of several or all ages in which no age class can be recognized. Trees of all sizes are interspersed as individuals or in small groups. Regeneration may be found either in small openings or under dense overstory trees. But in order to be assured of sustained periodic yields from an uneven-age forest, it is essential that a balanced or near-balanced diameter structure be maintained. The characteristic of gradually decreasing number of trees in successively larger diameter classes is necessary.

Plotting number of trees by diameter classes on semilogarithmic paper is one way of determining whether or not an uneven-age forest has a balanced diameter distribution. The closer the plot resembles a straight line, the better balanced is the diameter distribution.

The original diameter distributions of the three selection treatments were not similar (fig. 4). The major difference was in the number of saplings in the 5-year-interval treatment. The stands receiving this treatment originally supported about one-half the number of saplings compared to the 10- and 20-year intervals. In fact, the original diameter distribution was considered balanced. However, the continual removal of poor-risk trees and other unwanted trees in the initial four harvest-TSI operations resulted in

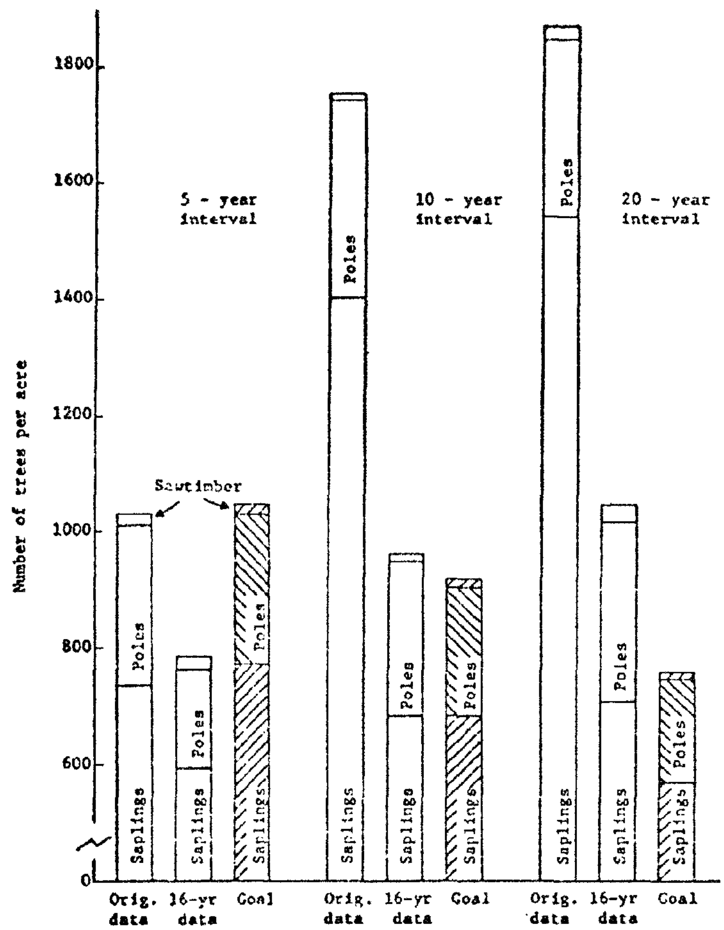

Figure 4.--Diameter-class distribution for selection-system treatments, by operating interval.

less-than-desirable stocking. Until stand density a again approaches the goal, only additional poor-risk trees will be removed in subsequent operations.

The 10-year-interval treatment area is balanced after two entries. The next combined harvest-TSI operation at 20 years will concentrate on the removal of poor-risk trees as well as excess trees in any diameter class. It is reasonable to assume that the current balanced state will be maintained.

The second stand entry for the 20-year-interval treatment at 20 years is expected to result in a reasonable state of balance.

All selection treatments displayed a reduction in the fir-to-spruce ratio between about the 10th year after treatment and the 20th year after treatment--from about 5 to 7 fir for each spruce to a ratio of 4:1.

During the same period, the ratio of fir to spruce changed slightly in the unregulated harvesting treatment--from 12 fir for each spruce to 11 fir for each spruce. In this treatment spruce is not favored; indeed, most spruce were removed during the commercial clearcutting. This reduction in spruce seed-source trees has perhaps negatively influenced the fir-to-spruce ratio.

IN CLOSING ....

Much can be done to improve the condition of spruce-fir stands. For long-term investment, the employment of commercial treatments utilizing silvicultural systems and skillful methods of harvesting are no more costly than no system at all and ill-timed harvests that fail to take into consideration the needs of the stand.

Indications of silvicultural potential from long-term experiments suggests that it is possible to increase growth, improve stand quality, change species composition, and control diameter distribution.

Immediate results from formerly mismanaged and undermanaged stands cannot be expected. But the continual application of approved commercial treatments designed to aid stands to produce near their capacity, will eventually mean larger profits to the landowner.

The measures suggested in this paper are considered sound and practical. I believe they can be undertaken at a profit.

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APPENDIX I

Cultural treatments and goals for various silvicultural systems and methods are as follows:

I. Species preference, where applicable, in order of desirability:

Red spruce/black spruce, white spruce, balsam fir, pine, paper birch, hemlock, cedar, other species.

II. Tentative optimum stand structures and goals for the selection system:

A. Species composition, in percent basal area--Spruce, 35-55 percent; balsam fir, 15-25 percent; white pine, 5-10 percent; paper birch, 5-10 percent; hemlock, 15-25 percent; cedar, 5-10 percent; other species, 5-10 percent.

B. Stand density, basal area per acre, at beginning of an operating interval for trees 0.5 inches (1.27 cm) dbh and larger:

1. 5-year operating interval--115 ft^2 (26.4 m^2/ha).

2. 10-year operating interval--100 ft^2 (23.0 m^2/ha).

3. 20-year operating interval--80 ft^2 (18.4 m^2/ha).

C. Diameter-class distribution:

1. Maximum size tree at end of an operating interval is 20 inches (50.8 cm) dbh.

2. Quotient ("q") between adjacent classes is 1.4.

D. Harvest limitations:

1. Initial harvest--up to 35 percent of gross volume for both the 5-year and 10-year operating intervals; up to 45 percent of gross volume for the 20-year interval.

2. Subsequent harvests--50 percent to 100 percent of net periodic growth for both the 5-year and 10-year operating intervals; 75 percent to 100 percent of net periodic growth for the 20-year operating interval.

E. Timber stand improvements:

1. Remove all cull, wolf, and other unwanted trees to 0.5 inches (1.27 cm) dbh and prune up to 75 spruce and pine per acre (185/ha) for both the 5-year and 10-year operating intervals; to 4.5 inches (11.4 cm) dbh and prune up to 50 spruce and pine per acre (124/ha) for the 20-year operating interval.

III. Objectives and constraints of the three-stage shelterwood system:

A. First harvest--remove overmature, defective, and slow-growing trees; remove less desirable species; create conditions favorable for the establishment of regeneration; increase growth rate of residuals. Limit removal to 50 percent of gross volume.

B. Second harvest--made about 10 years after first to further improve growing stock; increase growth of regeneration; and continue to establish new regeneration. Limit removal to two-thirds of gross volume.

C. Third and final harvest--made about 5-10 years after second harvest to remove all trees down to 2.5 inches (6.4 cm) dbh when stocking of regeneration is at least 85 percent and the area supports 1,000 or more trees per acre (2,500/ha) 2 feet (0.6 in) or over in height.

D. Stand improvement work--includes the deadening of culls and trees interfering with potential spruce seed trees.

IV. Diameter-limit management constraints and guides:

A. Flexible diameter basis:

1. Diameter limits, in inches (centimeters)

Species	First Harvest		Second Harvest	
	(in)	(cm)	(in)	(cm)
Balsam fir	6.5	(16.5)	6.5	(16.5)
Spruce	9.5	(24.1)	14.5	(36.8)
Hemlock	9.5	(24.1)	12.5	(31.8)

Pine	10.5	(26.7)	14.5	(36.8)
Larch	--	--	12.5	(31.8)
Cedar	--	--	7.5	(19.0)
Paper birch	7.5	(19.0)	9.5	(24.1)
Other hardwoods	6.5	(16.5)	5.5	(14.0)

2. Stand-improvement work limited to leaving some trees above limits for seed source and wind protection and removing some trees below limits to prevent their complete loss.

3. The operating interval is 20 years and the volume removed in subsequent harvests is limited to periodic net growth.

B. Fixed diameter basis:

1. Diameter limits, in inches (centimeters)

Species	All harvests	
	(in)	(cm)
Balsam fir	All merchantable	
Spruce	9.5	(24.1)
Hemlock	9.5	(24.1)
Pine	10.5	(26.7)
Larch	All merchantable	
Cedar	7.5	(19.0)
Other hardwoods	7.5	(19.0)

2. Stand-improvement work is not scheduled.

3. Subsequent harvests are made when stand is operable for the same volume as originally removed.

V. Unregulated harvesting by the commercial clear-cutting method--a brief description:

Most merchantable trees on operable areas are removed in a single harvest. No stand-improvement work is done. Small patches of merchantable trees considered inoperable are left to grow. The next harvest is made when it is operable for the same volume as originally removed.

APPENDIX II

Before treatment, parameter averages for the entire 400-acre study area were as follows:

Basal area--146 square feet per acre (34 m^2/ha).
Volume--2,075 cubic feet per acre (145 m^3/ha).
Number of trees less than 4.5 in. dbh--1,090 per acre (2,700/ha).
Number of trees 4.5 in. dbh and larger--360 per acre (890/ha).

Percentage species representation--

Species	Parameter		
	Volume[1]	Basal area[2/]	No. trees[2/]
Spruce	22	17	8
Balsam fir	18	24	56
Hemlock	30	28	11
Other	30	31	25

1/ Trees 4.5 inches dbh and larger.

2/ Trees 0.5 inches dbh and larger.