U. S. FOREST SERVICE RESEARCH PAPER NE-25
1964
NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RALPH W. MARQUIS, DIRECTOR

The Penobscot Management-Intensity Demonstration Plots

An evaluation, after 9 years, of four different treatments and their effects on growth and development of mixed softwood stands in Maine.

by Arthur C. Hart

The Author —

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Introduction

WHEN the U. S. Forest Service published its *Reappraisal of the forest situation in the United States*[1] in 1948, it described the cutting practices of the period and divided them into five broad classifications: high-order, good, fair, poor, or destructive. This concept of cutting-practice levels was further elaborated in the *1948 Annual Report* of the Northeastern Forest Experiment Station.[2]

Shortly after this, the Penobscot Experimental Forest was established near Bangor, Maine; and one of the first research activities there was to plan and install a demonstration of four of these five cutting practices (the destructive cutting practice was omitted) in a form adapted to the local spruce-fir forest type. The objectives were threefold:

- To provide examples of well-defined cutting practices as an aid to forest owners and managers in deciding upon the level of management appropriate for holdings under their control.
- To give the Northeastern Station's spruce-fir management staff some practical experience in applying their knowledge and ideas of desirable silvicultural treatments to spruce-fir stands, and to train them for subsequent research on the Experimental Forest.
- To get preliminary cost-and-return data for the different management levels.

The effects of several cuttings upon the growth and development of the reserved stands — measured 9 years after the demonstrations were established — are reported in this paper. (On one demonstration plot a cutting was made 10 years after establishment, and the stand changes that resulted are noted.)

[1] United States Forest Service. FORESTS AND NATIONAL PROSPERITY. A REAPPRAISAL OF THE FOREST SITUATION IN THE UNITED STATES. U. S. Dept. Agr. Misc. Pub. 668, pp. 46-49. 1946.

[2] Northeastern Forest Experiment Station. ANNUAL REPORT, 1948. U. S. Forest Serv. Northeast. Forest Expt. Sta., pp. 6-12. 1949.

The Demonstration Area

The demonstration area is a square 40-acre block of second-growth softwood timber located about $\frac{1}{8}$ mile north of the Experimental Forest headquarters. The area was divided into four square 10-acre plots, and one cutting practice was assigned to each plot (fig. 1). Four soil types are represented here: Plaisted stony loam, Dixmont stony loam, Dixmont-Monarda very stony loam, and Burnham-Monarda stony loam. Although the proportions vary

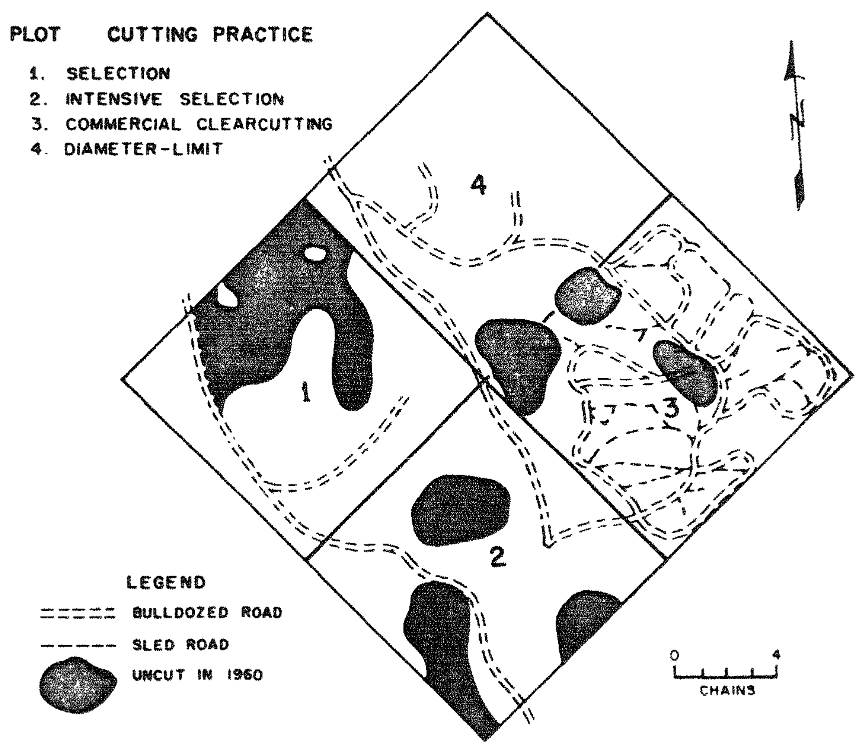


Figure 1. — The plots established on the Penobscot Experimental Forest near Bangor, Maine, to demonstrate four different management intensities.

from plot to plot, approximately half of the soils are well-drained and half are poorly to very poorly drained.[3]

The softwood stand on the area was composed primarily of spruce *(Picea rubens, P. glauca,* and *P. mariana)*, balsam fir *(Abies balsamea)*, and eastern hemlock *(Tsuga canadensis)*, with an admixture of hardwoods, northern white-cedar *(Thuja occidentalis)*, and eastern white pine *(Pinus strobus)*.

The stand was more or less uneven-aged. Hemlock ranged up to 160 years in 1950, and most of the other species ranged from 50 to 65 years. The area had not been cut over for pulpwood, but during the past 200 years it had been high-graded for sawlogs from time to time.

Methods

INVENTORY

A 100-percent inventory of all living trees in the 5-inch (d.b.h.) class and larger was made, by 1-inch diameter classes and by species on each of the four plots. Trees below the 5-inch class were tallied in a 2-percent sample comprising two strips across each plot. In this sample, trees were recorded by 1-inch diameter classes by species, starting with the 1-inch class. A reproduction tally also was made along these strips, using the stocked-quadrat method, on 40 milacres in each plot.

Four such inventories were made: one in February 1950, before cutting; one in the fall of 1951, after cutting; one in January 1955; and one in August 1959. In the 1955 and 1959 inventories, trees that had died since the previous inventory were also recorded.

TREATMENTS

The poor, fair, good, and high-order cutting-practice levels, as defined originally in 1948, may be summarized briefly as follows:

> **Poor cutting** leaves the land with limited means for natural reproduction. This practice often causes deterioration of species composition and consequent reduction in both quality and quantity of forest growth.
>
> **Fair cutting** marks the beginning of cutting practices that will maintain on the land a reasonable stock of growing timber in species that are desirable and merchantable.
>
> **Good cutting** is based on good silviculture; it leaves the land in possession of desirable species in condition for vigorous growth in the immediate future.

[3] Proportions of well-drained soils by plots are: Plot 1 — 75 percent, Plot 2 — 25 percent, Plot 3 — 40 percent, and Plot 4 — 56 percent.

High-order cutting is the type of harvest cutting that, in the forester's judgment, will best maintain quality and quantity yields consistent with the full productive capacity of the land.

In both good and high-order cutting practices, cultural measures of an investment nature are used where needed. High-order practices imply use of more intensive cultural measures than good practices.

Because the original terms carried connotations of prejudgment, the former cutting-practice levels are now referred to as *management intensities;* and poor, fair, good, and high-order cuttings are now more objectively and descriptively designated as *commercial clearcutting, diameter-limit cutting, selection cutting,* and *intensive selection cutting,* respectively. These four management intensities, as applied in the Penobscot demonstration plots, are described as follows:

Commercial clearcutting removes all the merchantable trees in one operation, leaving scattered unmerchantable trees of poor vigor, low quality, and undesirable species. No stand-improvement measures are applied, and the area is cut again when it becomes operable for pulpwood.

Diameter-limit cutting removes all merchantable trees above specified diameter limits and retains all trees below those limits. It also retains all trees of species that currently are non-commercial, and all culls regardless of size. No stand-improvement measures are applied. The area is cut again when it becomes operable for pulpwood under the same cutting rules. In our demonstration plot, all merchantable trees were cut, down to and including the following d.b.h. limits: spruce and hemlock — 10 inches; white birch and beech — 8 inches; and balsam fir and red maple — 6 inches.

Selection cutting is based on marking and removing mature trees and trees in all size classes that are defective, slow-growing, or otherwise unpromising for future timber production. The cutting cycle is 15 years. A limited amount of stand-improvement work is done.

Intensive selection cutting is based on the same principles as selection cutting, but it includes more intensive stand-improvement measures, and the cutting cycle is 5 years. Hence, stands are up-graded more rapidly and to a higher degree.

LOGGING OPERATIONS

First Cutting 1950 (All Plots)

A crew of four to six men, using hand tools, and with occasional help from one-man chainsaws, felled and sap-peeled the trees during the summer. On three plots (all except the clearcutting), where the cutting method specified skidding in tree-lengths to bucking yards, the skidding was done in the fall, with horses. Chainsaws were used for most of the bucking. A D-4 tractor with bulldozer was used to prepare winter haul roads. On the clearcut plot, the bulldozer was also used to clear pathways for truck access to about 80 percent of the piled wood so that a minimum of sledding would be required.

Table 1. — Per cord costs and returns for four methods of cutting, 1950

Item	Intensive-selection	Selection	Diameter-limit	Commercial clearcutting
		Man-hours		
Fell-limb-peel	5.60	5.18	7.09	([1])
Skid-buck-pile	4.90	5.23	5.90	([1])
Total	10.50	10.41	12.99	10.91
		Dollars[2]		
Fell-limb-peel	5.16	5.01	6.58	([1])
Skid-buck-pile	4.69	5.01	5.65	([1])
Total	9.85	10.02	12.23	10.83
Horse	.18	.16	.17	—
Reyarding	—	—	—	.80
Tools	.31	.31	.31	.31
Roads	.70	.55	.49	.77
Total cost, roadside	11.04	11.04	13.20	12.71
Value, roadside[3]	14.71	14.36	14.78	15.25
Earned stumpage	3.67	3.32	1.58	2.54
		Peeled cords		
Volume produced	27.22	44.83	66.55	116.10

[1]Production time for the commercial clearcut plot could not be broken down because all jobs were combined in one operation.
[2]Rates: laborers at $.90 per hour, foreman at $1.27 per hour, and horse at $1.00 per day.
[3]Roadside values varied because of varying proportions of the different species.

Labor to produce a cord of wood from tree to pile ranged from 10.41 to 12.99 man-hours. The costs per cord at roadside ranged from $11.04 to $13.20. Production costs were highest for the diameter-limit method, followed by the commercial clearcutting and the two selection cuttings. We cannot explain the higher costs for the lower management intensities: we can only speculate that they are related to the higher proportions of small trees in those cuttings. In terms of earned stumpage (the difference between value and total cost of wood per cord at roadside), the plots ranked in decreasing order as follows: intensive-selection, selection, commercial clearcutting, and diameter-limit cutting (table 1). Volumes produced per acre were 2.72, 4.48, 11.61, and 6.66 cords respectively of peeled pulpwood.

After the logging job, in the fall of 1951, stand-improvement work was done in the selection and intensive-selection plots. This involved weeding, thinning, and release cutting in the intensive-selection plot, but only release cutting in the selection plot. In the intensive-selection plot 67 trees per acre were cut, including 50 that were less than 5 inches in diameter. In the selection plot only three trees per acre were removed.

A market for rough hardwood pulpwood during the winter of 1951-52 made it possible to sell about 16 cords of wood from the stand-improvement work. Total costs were $212.80, and receipts were $202.80 on the 20 acres in the 2 plots. Thus the out-of-pocket investment was 50 cents an acre.

An average of only 4.6 trees per acre on the intensive-selection plot and 3.5 trees per acre on the selection plot were considered in 1951 to warrant pruning as potential sawlog crop trees. All but one were red spruce. These trees were pruned in a special study carried out by several University of Maine silviculture students.

Second Cutting 1955 (Intensive-Selection Plot)

Felling, limbing, and peeling for the second harvest cut on the intensive-selection plot took a 4-man crew 3 days near the end of May; and 2.39 cords of wood per acre were removed. Skidding was done by a 3-man crew during 3 days in August, using a horse and small crawler tractor. Bucking and piling were done at the same time by a 3-man crew. Power saws were used for felling and bucking; axes and bark spuds were used for limbing and peeling. Labor expenditures were 11.43 man-hours per cord. Costs of production were $14.00 per cord, and roadside value $16.73 per cord, leaving a residual of $2.73 per cord as earned stumpage.

The men were paid by the hour, as in the first cutting; but both the labor rate per hour and the roadside value per cord of wood were about 12 percent higher in 1955 than in 1950.

Stand improvement on the 10 acres after this cutting consisted of killing 64 cull trees ranging from 5 to 17 inches in diameter, and 45 undesirable sound trees from 5 to 8 inches in diameter. This was done in 4 man-hours by frilling with a hatchet and treating with sodium arsenite.

Third Cutting 1959-60 (Intensive-Selection Plot)

Stumpage was sold to a local contractor for the third harvest cutting on the intensive-selection plot; 3.47 cords per acre were removed. The contractor used a crew varying from one to three men during the fall and winter. A horse was used for the skidding. Total labor expenditures were 6.89 man-hours per cord. Total costs at roadside were $9.97 per cord; the value was $14.16, leaving an earned stumpage of $4.19 per cord. Sixteen cull trees marked for removal were cut by the operator. No other stand-improvement work was necessary.

A significant point noted here is that production costs under contract cutting were appreciably lower than in the previous cuttings when labor was paid by the hour.

Results

IMMEDIATE STAND CHANGES

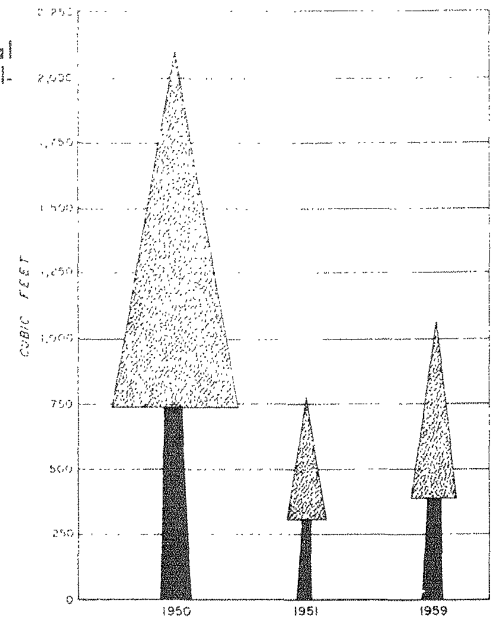
The immediate results of cutting on a stand can be expressed in two ways: (1) by the reductions in volume per acre, and (2) by changes in proportions of the different species or species groups.

The reductions in volume after the first cut, in terms of both cubic feet and rough cords[4] per acre, are shown in the following tabulation:

Cutting method	*Before cutting, 1950*		*After cutting, 1951*	
	(cu. ft.)	*(cords)*	*(cu. ft.)*	*(cords)*
Commercial clearcutting	2,092	24.61	761	8.95
Diameter-limit	1,970	23.18	1,291	15.18
Selection	1,779	20.93	1,378	16.21
Intensive selection	2,055	24.18	1,759	20.70

[4]A rough cord contains 85 cubic feet of wood.

Figure 2. — Commercial clearcut plot: cubic-foot volume per acre, by years.



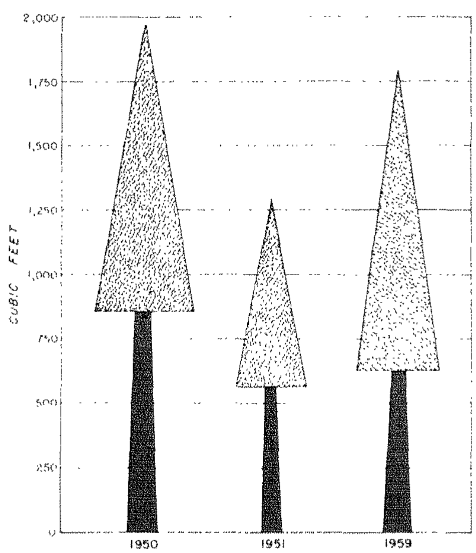


Figure 3.—Diameter-limit plot: cubic-foot volume per acre, by years.

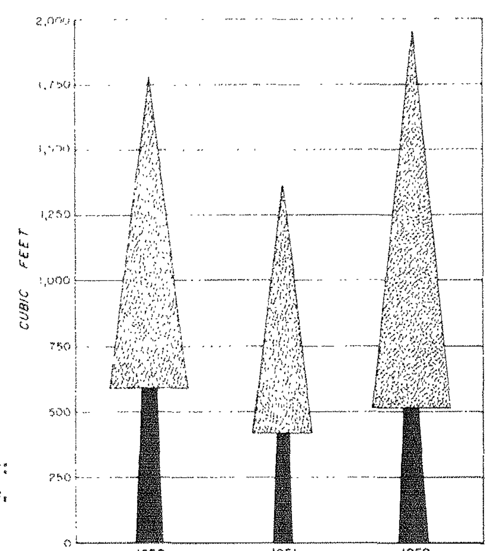


Figure 4. — Selection plot: cubic-foot volume per acre, by years.

Figures 2 to 5 depict these cubic-foot changes graphically, and also the volumes as of 1959. Changes in proportions of species and species groups on a cubic-foot volume basis are shown in figure 6. This figure also presents the situations in 1959, as well as those before and after cutting in 1950 and 1951.

Many of the changes in 1951 were comparatively small, except in the clearcutting. On that plot, spruce and fir together were reduced from 72 percent to 34 percent, and the proportions of other species increased accordingly. Other softwoods (cedar, pine, and larch) went from 12 percent to 32 percent, and hardwoods from 12 percent to 28 percent.

Of particular interest in both selection cuttings were the modest increases in the proportion of spruce and the associated decreases in the hardwood component. These changes reflected progress toward improving species composition — one of the basic goals in selection management.

For the intensive-selection plot — the only one cut since the initial treatment — the ups and downs in volume that are associated with the second and third cuttings in 1955 and 1960 are depicted in figure 5. The volume after the 1960 cut was 1,822 cubic feet per acre, as compared to 1,759 cubic feet in 1951. As of 1959, the proportion of spruce had risen from an original 26 percent to 35 percent, and hardwoods had dropped from an original 18 percent to 10 percent (fig. 6).

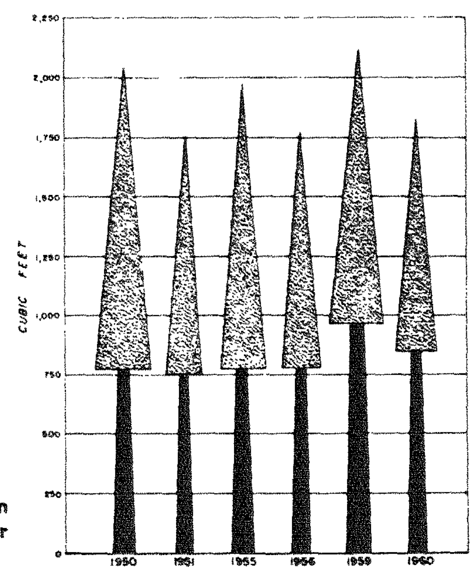


Figure 5.—Intensive-selection plot: cubic-foot volume per acre, by years.

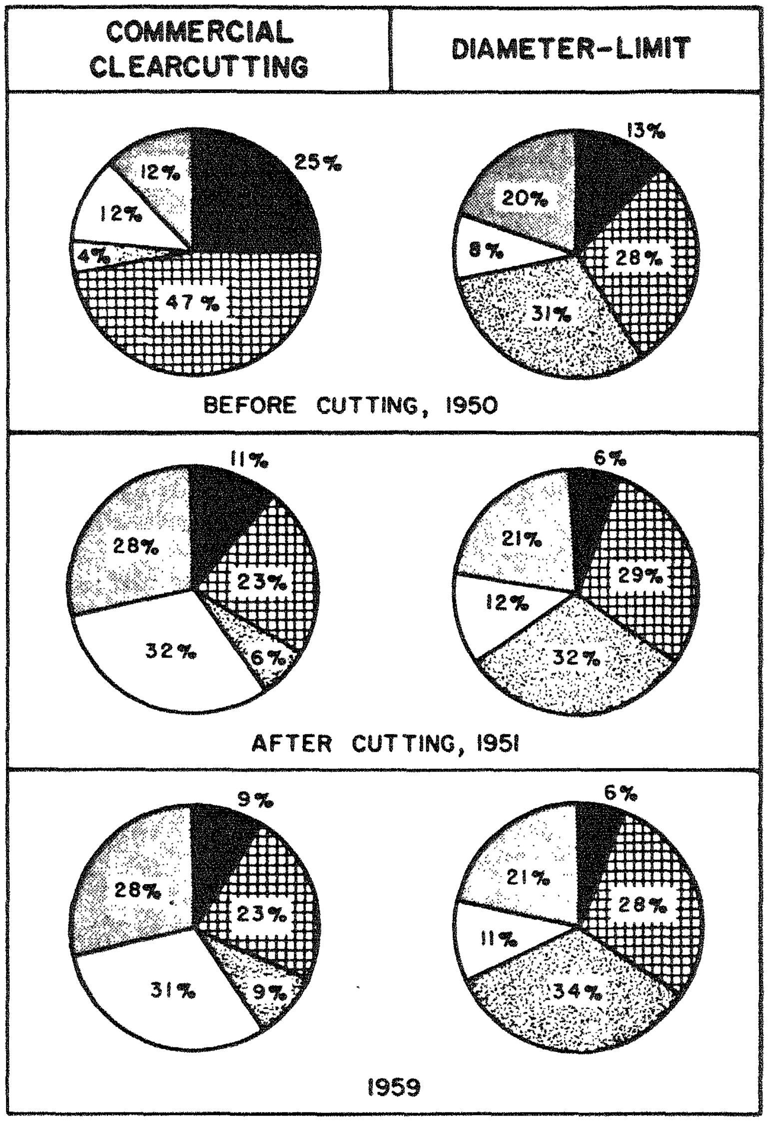
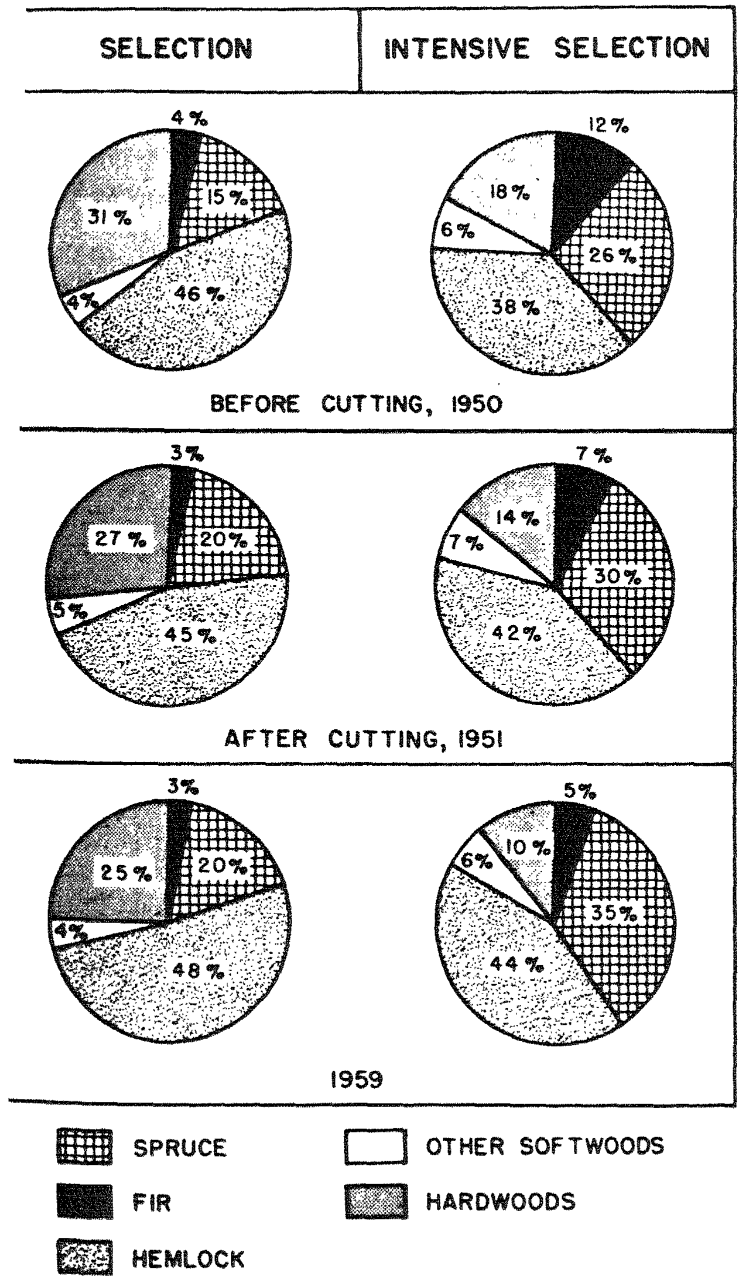


Figure 6.—Species composition, expressed in volume percentages by management intensity, before and after the first cuttings and 9 years later. In the intensive-selection plot a second cutting was made in 1955 and the diagram for 1959 depicts the situation just before the third cutting.



SELECTION
INTENSIVE SELECTION
4%
15%
31%
4%
46%
12%
18%
6%
26%
38%
BEFORE CUTTING, 1950
3%
27%
20%
5%
45%
7%
14%
7%
30%
42%
AFTER CUTTING, 1951
3%
25%
20%
4%
48%
5%
10%
6%
35%
44%
1959
SPRUCE
FIR
HEMLOCK
OTHER SOFTWOODS
HARDWOODS

RESPONSE TO TREATMENTS

Mean annual gross growth per acre from 1951 through 1959 ranged from 56 cubic feet on the clearcut plot to 86 cubic feet on the selection plot; net growth ranged from 40 cubic feet for the clearcutting to 71 cubic feet for the intensive-selection cutting (table 2). Although considerably more growing stock was retained in 1951 on the intensive-selection plot than on the selection plot, gross growth and net growth were each almost identical on the two plots. Thus the net growth rate for the intensive-selection plot, when expressed in percent of the 1951 growing stock, was appreciably lower — 4.0 percent versus 5.1 percent. In figure 7, mean annual gross growth is broken down graphically into its basic components — net accretion, ingrowth, and mortality.

Ingrowth for the 9-year period accounted for 27 percent of the gross growth on the clearcut plot, 20 percent on both the diameter-limit and selection plots, and 17 percent on the intensive-selection plot. Mean annual ingrowth as a percent of 1951 cubic-foot volume is shown graphically in figure 8, by species groups. For all

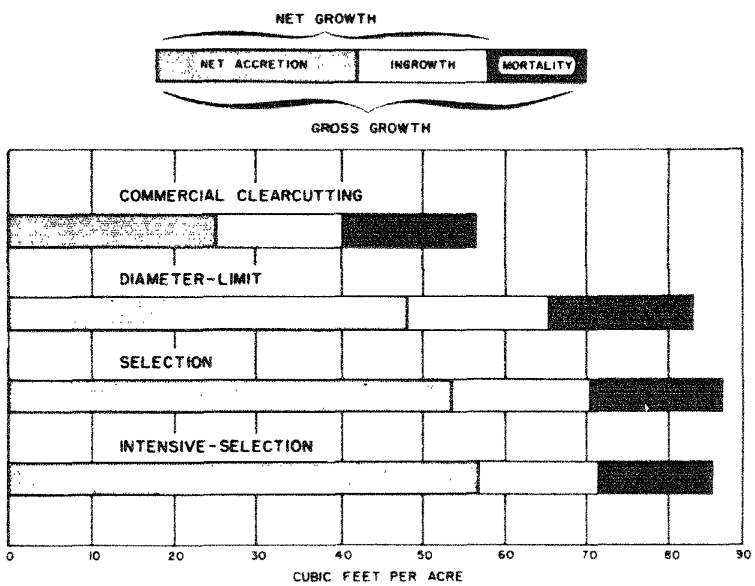


Figure 7. — Mean annual volume growth per acre, by management intensity and growth components — 1951-1959.

Table 2. — Mean annual growth and mortality, 1951-59, by management intensities

Treatment	Residual stand, 1951	Gross increment	Mortality	Net increment	Net growth rate
	Cu. ft.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Percent*
Commercial clearcutting	761	56	16	40	5.3
Diameter-limit	1,291	83	18	65	5.0
Selection	1,378	86	16	70	5.1
Intensive-selection	1,759	85	14	71	4.0

Table 3. — Percentage of milacres stocked with seedlings in 1951 and 1959, by management intensities and species

Species	Commercial clearcut		Diameter-limit		Selection		Intensive-selection	
	1951	1959	1951	1959	1951	1959	1951	1959
Fir	57	78	32	78	45	62	58	68
Spruce	12	38	5	30	38	32	2	10
Hemlock	2	22	22	68	20	52	18	42
Pine	2	15	12	12	2	5	2	8
Cedar	0	20	2	2	0	0	0	8
Larch	0	2	0	0	0	0	0	0
Maple	5	10	5	10	8	22	15	12
White birch	32	28	30	40	2	10	15	8
Beech	0	0	0	2	15	15	5	10
Other hardwoods	0	35	0	8	0	0	0	2
Not stocked	22	10	37	10	12	8	28	20

Table 4. — Numbers of trees 4.5 feet tall to 0.5 inches d.b.h. per acre in 1959

Species	Commercial clearcut	Diameter-limit	Selection	Intensive-selection
Fir	145	25	110	75
Spruce	5	0	40	5
Hemlock	0	5	30	5
Pine	0	0	0	0
Cedar	0	0	5	0
Larch	5	0	0	0
Maple	130	95	5	5
White birch	0	0	0	0
Beech	0	5	5	0
Other hardwoods	50	5	0	0

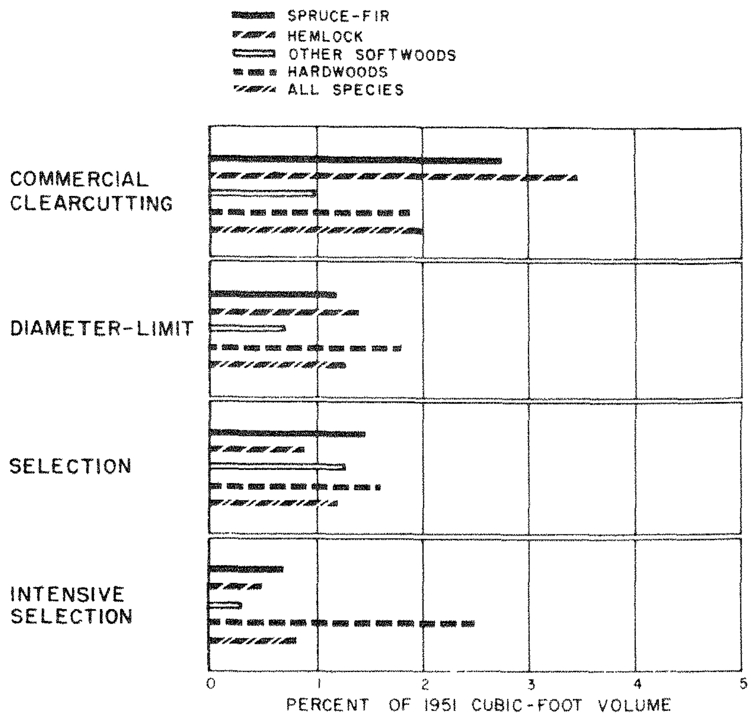


Figure 8.—Mean annual ingrowth per acre, as percent of 1951 volume, by management intensity and species group.

species collectively, annual ingrowth ranged from 2 percent of the 1951 volume on the clearcut plot down to 0.8 percent on the intensive-selection plot.

Mean annual mortality, as a percent of 1951 cubic-foot volume, is shown graphically in figure 9, by species groups. For all species, the losses ranged from 2.1 to 0.8 percent. It is curious that annual ingrowth and annual mortality for all species are almost identical (figs. 8 and 9); and it is equally curious that these two growth components, as expressed in cubic feet (fig. 7), are nearly equal within management intensities. This may be largely coincidence: when individual species groups are compared (figs. 8 and 9), many dissimilarities are evident.

Cutting stimulated the establishment of reproduction (stems less than 4.5 feet tall) on all plots. The percentages of milacres

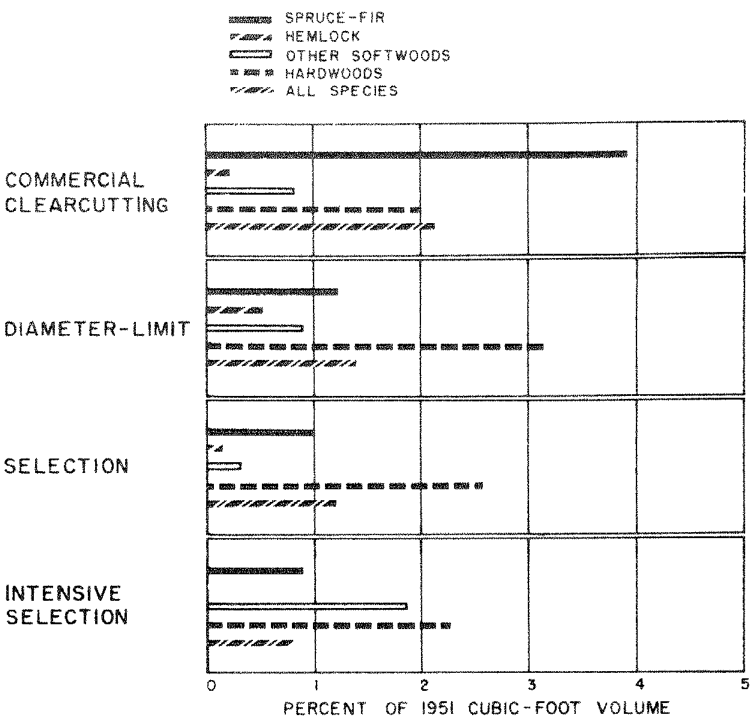


Figure 9. — Mean annual mortality per acre, as percent of 1951 volume, by management intensity and species group.

that were not stocked with established seedlings declined under each treatment between 1951 and 1959 (table 3). A seedling was considered established if it had developed one or more branches.

Fir was the most numerous species in the reproduction in 1951, and still was most numerous in 1959. Hemlock was second in 1959 on all but the commercial clearcut plot, where spruce was second. Other hardwoods — including gray birch and the aspens — were a close third.

In terms of the numbers of stems per acre in trees 4.5 feet tall to 0.5 inch d.b.h. (table 4), balsam fir was first, followed by spruce and hemlock, on the two selection plots. Fir also predominated on the clearcut plot, with red maple a close second; but it was exceeded by red maple on the diameter-limit plot.

Discussion

In cutting systems based upon individual tree selection, a forest manager can manipulate growing-stock levels and stand structure in an effort to achieve his management objectives. These objectives commonly are maximum growth and quality production for a given intensity of management. However, little research information is available for determining the best stocking and stand-structure goals to work toward in any specific forest situation. Selection of these goals is in large part a matter of judgment.

Stocking and stand-structure goals have been set up for the two selection plots in the Penobscot study as part of the overall study planning, and the cuttings on those plots have been pointed toward eventual attainment of those goals, which are described, together with some graphic information on progress toward their attainment, in an appendix (page 21).

But these silvicultural goals are secondary here. The pertinent question is: have the Penobscot demonstration plots accomplished the objectives set for them? In 9 years, the first two objectives for the cutting-practice plots have been accomplished very well. More time will be needed before the third objective can be accomplished fully.

The first objective was to provide examples of different cutting practices as an aid to forest owners and managers. More than a thousand people have examined the four plots since they were established in 1950. Among these visitors have been not only forest owners, farmers, industrial woodland managers, company officials, professional foresters, and forestry students, but also bankers, Grangers, and other interested laymen.

In the second objective — to provide experience and training to the spruce-fir management staff — the demonstration plots have been an excellent training ground for our local researchers. The plots have served as a springboard for the plunge into a compartment management study in which all the treatments used in the demonstration, plus several additional ones, are being tested and compared on a larger scale.

The third objective — to get preliminary cost and return data — has been realized only to a limited degree. Long-term comparisons of costs and returns among the four intensities of management will not be possible until the commercial clearcut plot again reaches an operable stage. Even among the other intensities, more cuttings must be made before definite data on returns will be available. However, the following generalizations do emerge rather clearly from our 9-year records and experience:

- In stands similar to those on the plots, light partial cuttings are possible with no greater expenditure per unit of volume for labor and equipment than in commercial clearcutting.
- Net growth per acre after cutting is more than twice as much where a reasonable amount of growing stock is retained than where clearcutting has reduced growing stock to a minimum.
- As long as a stand is reasonably well stocked, variations in the amount of stocking make little difference in the quantity of wood grown annually per acre.

Certain advantages and certain disadvantages are associated with each of the cutting methods represented on the demonstration area. Selection cutting favors: stand improvement, accelerated increment of merchantable volume, reduced fire hazard as compared to clearcutting, continued protection of the soil, prevention of weed-plant growth, and probably more efficient wood production. Selection cutting also permits close control of the growing stock and more salvage of the natural mortality. Usually the end products for harvesting are of higher quality than in other cutting methods. Moreover, the frequent cuts provide a continuous supply of game food.

The main disadvantages, as compared with other cutting methods, are that in selection cutting, management is more complicated, tree marking is required, the cost per unit volume for temporary logging facilities such as camps and bulldozed truck roads is increased, and the dense stocking may eventually eliminate — unless interrupted by a catastrophe — the less shade-tolerant species such as pine and birch.

Clearcutting has the advantage of not requiring marking; and because of the larger volume of wood removed, clearcutting entails the lowest cost for temporary logging improvements per unit of volume. However, clearcutting has definite disadvantages: it leaves the land with limited means for natural regeneration of desirable species, unless advance reproduction is present; it removes minimum-sized merchantable trees during their period of rapid growth; 16 to 20 percent of the area is cleared for roads; dense slash smothers reproduction and prevents establishment of new seedlings for 15 years or more; fire hazard is increased for at least 10 years after cutting because of the dense slash, and for an additional 15 or 20 years because of even-aged reproduction; a long period of time elapses before another cut can be made; usually the quality of harvested products is lower; and game food, although initially produced in abundance, soon grows out of reach of the animals.

Clearcutting would be a logical method to apply in mature or overmature stands where a good crop of advance reproduction is present, and where partial cutting would result in considerable mortality of reserved trees. Stands in remote areas and on poor sites also might be cut in this manner.

Diameter-limit cutting is a compromise between selection cutting and clearcutting. It is best applied in vigorous young stands having a nearly uniform distribution of size classes. Minimum-sized merchantable trees in stages of rapid growth are retained for another harvest in the forseeable future. Usually, however, a diameter-limit cutting results in uneven stocking. And it tends to remove many vigorous trees above the limit while leaving defective and poor-vigor trees below the limit.

Under present economic conditions, intensive-selection cutting can be applied profitably only to the most accessible stands on the best sites. Many owners of small woodlots are in this enviable position and should be able to profit by adopting such management.

For the vast areas of second-growth forest, owners and managers should carefully weigh the advantages and disadvantages of each cutting method in the light of their particular situations and needs. In general, partial cutting — either to carefully picked diameter limits or by marked tree selection — is probably the most effective practical way to perpetuate these second-growth spruce-fir stands.

Summary

Four different methods of cutting merchantable spruce-fir-hemlock stands—commercial clearcutting, diameter-limit cutting, selection cutting, and intensive selection cutting — were applied on 10-acre demonstration plots on the Penobscot Experimental Forest in central Maine. Besides providing effective demonstrations of the four cutting practices, the plots have shown in their first 9 years that —

- Production costs per cord at roadside were highest for the diameter-limit method, next the clearcutting, then the two selection methods.

- Net growth per acre per year — 65 to 71 cubic feet (0.77 to 0.84 cord) — was very nearly the same for the diameter-limit, selection, and intensive-selection plots. On the clearcut plot the net growth was much less—40 cubic feet (0.47 cord) per acre.
- Mortality was greatest on the clearcut plot, and diminished with increased stocking of the reserved stand. Fir, beech, and yellow birch had the highest mortality rates.
- The commercial clearcutting reduced the proportion of spruce-fir and increased the proportion of other softwoods and hardwoods. Diameter-limit cutting reduced the proportion of fir, but had little effect on other species. Selection cutting slightly increased the proportion of spruce-fir and decreased hemlock slightly. Intensive selection reduced the proportion of fir and hardwoods but increased spruce and hemlock.
- All the cuttings stimulated the establishment of new reproduction. Balsam fir led all other species in new seedlings.

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Appendix

STAND STRUCTURE GOALS FOR SELECTION PLOTS

No one knows the optimum growing stock level that should be maintained in spruce-fir stands to produce the greatest growth values. Until such information is available, we have to make certain assumptions and set up tentative stocking and stand structure goals.

If no major catastrophes such as fire, disease, or insect attack occur, a balanced, uneven-aged structure should provide an uninterrupted periodic yield on the two plots managed on the selection principle. The fundamental characteristic of such a balanced, uneven-aged stand is a gradual decrease in numbers of trees by diameter classes as the diameters increase, with the same ratio prevailing between numbers of trees in successive diameter classes. When plotted on semilogarithmic paper, the numbers of trees by diameter classes should approximate a straight line.

The goal in both selection plots is to build stand structures that can be maintained by the selection system of management, operating in one plot on a 5-year cutting cycle and in the other plot on a 15-year cycle. Under the 5-year cycle on the intensive-selection plot, most of the poorer trees have been removed after three cuts. Future cuts at 5-year intervals will

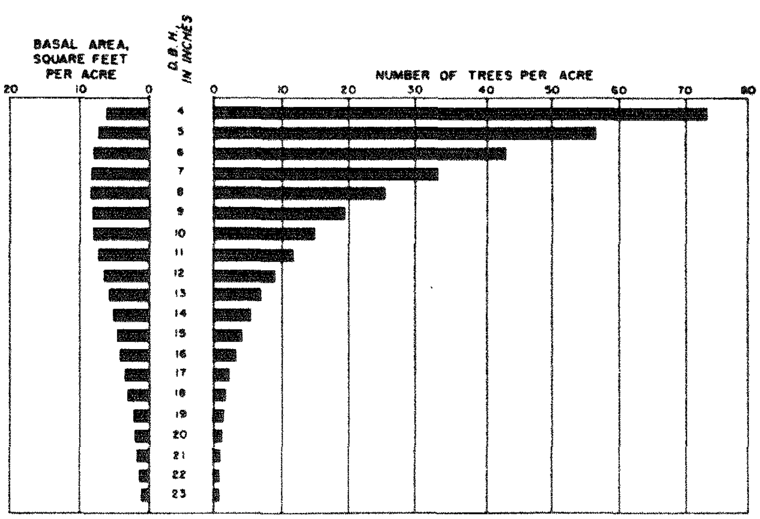

Figure 10. — Stand and stocking goals after each cutting under intensive-selection management.

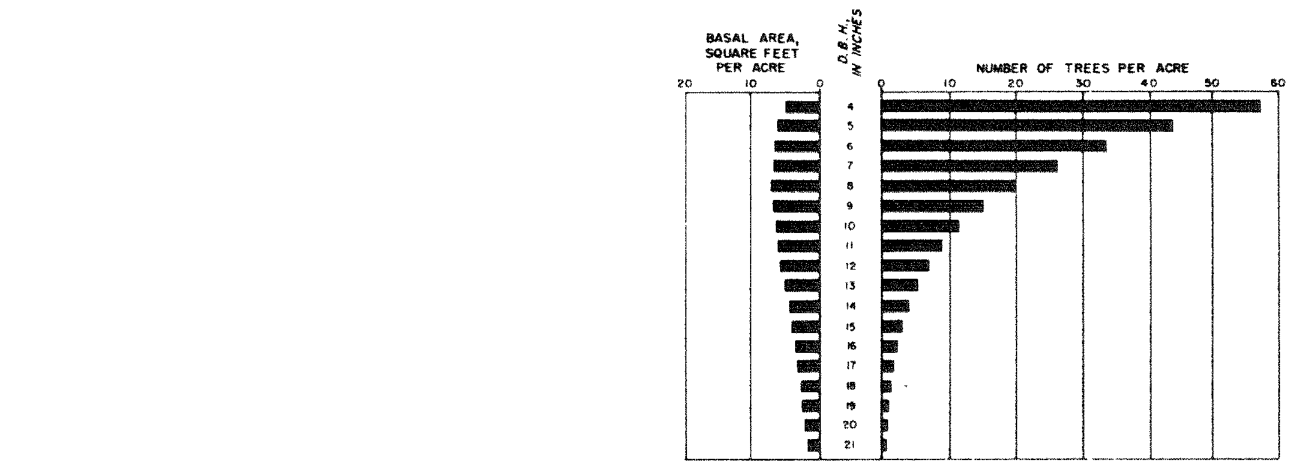

Figure 11. — Stand and stocking goals after each cutting under selection management.

gradually mold the stand toward a balanced, uneven-aged form. Under the 15-year cycle on the selection plot, the second cut — to be made in 1965 — will begin to convert that stand to the desired form. Eventually this should result in stands where each cut can equal the periodic growth while maintaining the basic structure of the growing stock indefinitely.

The trees on these two plots are of all sizes, and their diameter-class frequencies now resemble those of the typical all-aged structure. The resemblance will become closer with each succeeding cut until the stand-structure goals are attained.

The goals chosen for the intensive-selection plot at the beginning of a cutting cycle are: 120 square feet of basal area, 23 inches d.b.h. as the maximum tree size, 0.5 tree of this size per acre, and "q" (the ratio between tree numbers in successive diameter classes) of 1.3.

For the selection plot, the goals are: 90 square feet of basal area, 21 inches d.b.h. maximum tree size, 0.7 tree of this size per acre, and the same "q" — 1.3. On both plots, a maximum tree size of 24 inches d.b.h. is anticipated at the end of the cutting cycles.

These stand-structure goals are based on available silvicultural information and prevailing market demands and utilization practices. Integrated products are the present management objective. The goals, particularly with respect to maximum tree sizes, definitely should be viewed as flexible and subject to change as future circumstances may warrant.

With the present management objectives in mind, the stand and stocking goals — in terms of numbers of trees and square feet of basal area by diameter classes — were worked out for each of the two intensities of selection management (figs. 10 and 11). Also, for each management intensity, the theoretical distribution of basal area among diameter classes shown in figures 10 and 11 for the stocking goals is compared to actual distributions at different times during treatment of the stands on the two plots (figs. 12 and 13). And finally, actual and theoretical distributions of basal area by 4-inch d.b.h. size classes are summarized in table 5.

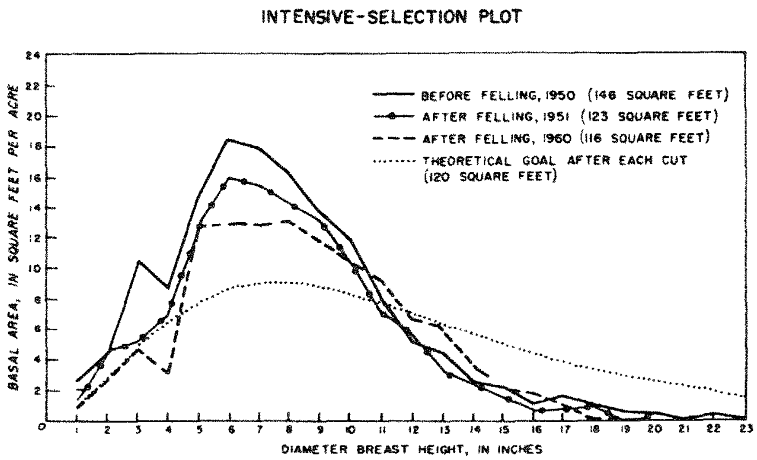

Figure 12. — Basal-area distribution per acre, all species, by 1-inch diameter classes. Intensive-selection plot.

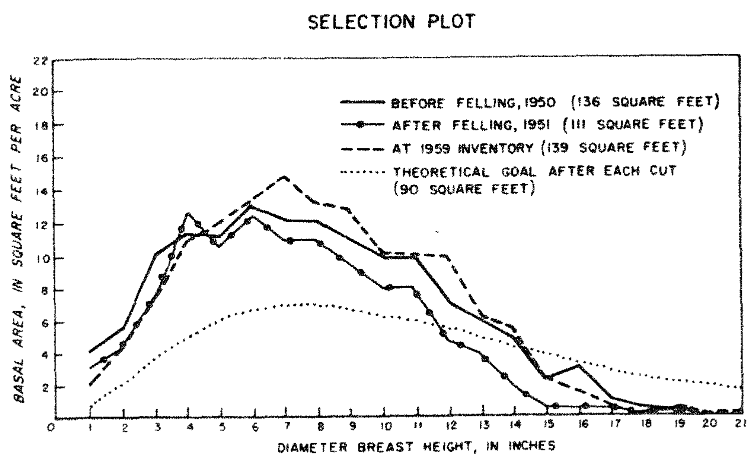

Figure 13. — Basal-area distribution per acre, all species, by 1-inch diameter classes. Selection plot.

Table 5. — Distribution of basal area, by d.b.h. size classes

Year	Total basal area	Sub-merchantable: 1-4 inches	Small: 5-9 inches	Medium: 10-14 inches	Large: over 14 inches
	Square feet	*Percent*	*Percent*	*Percent*	*Percent*
		SELECTION PLOT			
1950	136	23	44	27	6
1951[1]	111	25	49	24	2
1955	117	20	50	27	3
1959	137	18	48	30	4
Theoretical goal	90	13	37	30	20
		INTENSIVE-SELECTION PLOT			
1950	146	18	55	22	5
1951[1]	123	15	58	24	3
1955[1]	126	17	54	26	3
1959[1]	116	10	54	31	5
Theoretical goal	120	12	36	29	23

[1]After cutting.

It is obvious that the goal on the intensive selection plot will not be reached for perhaps 30 years or more because the stand contains so few trees larger than 18 inches d.b.h. The goal may be reached sooner on the selection plot, because some trees of all sizes up to and including 21 inches d.b.h. are now present. Cuts in the immediate future in both plots should be concentrated on the small and medium-sized trees. Trees larger than 14 inches d.b.h., unless in poor condition, should be retained through the next few cutting cycles so as to build up growing stock in the larger diameters.