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Cost of Producing White Pine Lumber in New England

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THE PROBLEM

The lumber industry in much of the Northeast has been and is still primarily dependent upon northern white pine (*Pinus strobus*). The early colonists found large areas of pine forest, which supplied an abundance of high-quality material for building construction, cooperage, shipbuilding, and many other purposes. Because of its excellent quality, New England white pine not only was used to meet local needs but soon was in demand for extensive use in other States along the Atlantic coast, and was exported in large quantities to England and other European countries. The early commercial logging operations were extremely wasteful, as ordinarily only the choicest portions of the best trees were utilized; orders frequently specified planks free from knots, ranging from 15 to 36 inches in width and from 25 to 30 feet in length.

New England retained leadership in lumber production for more than 100 years, giving way to New York in 1840. Pennsylvania later assumed the lead, but with the introduction of railroads and the increasing demand for lumber ~~its~~ huge reservoir of white pine

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timber was soon overtaxed. By 1870 the country was drawing the bulk of its lumber supply from the Lake States, the only remaining section with virgin northern white pine forests. Early in the twentieth century, white pine ceased to be the Nation's most important lumber species.

Following the Civil War much cultivated farm land in the Northeast reverted to forest growth, and this trend has continued up to the present time. Practically pure white pine stands came in on a great part of this land, even where the species formed a relatively small proportion of the timber on adjacent lands; in fact, the gross area of the white pine second-growth forests probably exceeded that originally occupied by the white pine virgin forests. With the exhaustion of the old-growth stands and the continued demand of local consumers for the white pine to which they had become accustomed, operators naturally turned to the second-growth stands.

Although the second-growth stands did not supply such high-quality material as had come from the virgin forests, new uses and demands created by the industrial development of the Northeast and the population growth that accompanied it sustained activity in the lumber industry and brought good prices to the owners of merchantable stumpage. Second-growth white pine was extensively cut for boxboards and for specialty products, particularly products requiring clear lumber only in very short pieces, such as cooperage and matches.

Since the introduction of portable sawmills, making it possible to utilize logs of almost any size or quality, second-growth stands have very generally been clear cut almost as soon as there was opportunity to realize any profit from them. This destructive practice has been aggravated by constantly increasing taxes on standing timber as rural towns have found their sources of tax revenue shrinking rapidly because of the decline in agriculture. It has resulted in continued reduction in the quality of the timber, until most of that now available is small, knotty, and rough. It has resulted also in a substantial reduction in the area of merchantable pine timber, because the areas thus cut over are not generally restocking with white pine but in many cases are reverting to hardwoods, especially where the soils are of the heavier types, or, if burned, are being taken over by inferior species and brush.

The depletion begun by indiscriminate industrial use was brought to a climax by the hurricane of September 21, 1938, which took heavy toll through most of the pine region of New England. Pure stands of white pine suffered especially, and in some localities most of the pine timber of merchantable size was blown down. Undoubtedly, a greater volume of timber was felled by the hurricane than would otherwise have been cut in the succeeding 10 years.

In recent years southern and western woods have largely displaced local products in New England for general construction and also for the more exacting factory uses. Concurrently, fiber boxes have been encroaching steadily on the wooden-box trade on which manufacturers of second-growth white pine have been largely dependent. A glut of wind-thrown timber coming on the market when production was tending downward and when prices on the region's pine lumber products had been declining almost without interruption for about

18 years, has placed the white pine lumber industry of the Northeast in a precarious position.

The period of increased lumber-manufacturing activity incident to the salvage of the timber blown down by the 1938 hurricane is bound to be short. It is likely to be followed by a protracted period of restricted operation for the white pine lumber industry and increased pressure for utilization of immature timber. This could only bring increasing hardship to rural communities in New England. Clear cutting of relatively immature timber ordinarily destroys the owner's forest capital at a time when the stand is entering the period of most rapid production, and when the timber has not reached such size as to yield any considerable quantity of lumber in the better grades. If depletion of forest growing stock in this way continues, shrinkage in volume of lumber production will continue and consuming industries will inevitably suffer losses. Communities will lose the employment basis for business activity formerly provided by logging and wood-using industries, and landowners will be deprived of satisfactory outlets for their stumpage. On the other hand, inadequacy of forest growing stock and scarcity of wood-using industries make the practice of forestry by private owners increasingly difficult. Thus failure to manage forest lands for continued production will set up a vicious circle.

The prospect for a thriving white pine-lumber industry in the Northeast, so important to landowners and communities alike, appears to depend on abandonment of the customary short-sighted cutting practices and general adoption of a forest-management policy that will provide a continuous supply of large, high-quality timber, for which there is always good demand. The vast loss of merchantable-sized timber in the hurricane of 1938 makes it more important than ever that the remaining growing stock be managed carefully.

In order to increase the yield of high-quality material, partial cuttings should be considered as a means of building up and maintaining, at least temporarily, a growing stock containing a substantial number of trees 18 inches or more in diameter (fig. 1). With partial cutting, operations to obtain a given volume of production would have to be spread over a larger territory than with clear cutting, but it would be possible to work over the same areas at intervals of from 3 to 15 years. Under such a system trees selected for cutting include not only those that are financially mature but such others as need to be removed to ensure optimum growing conditions for the residual stand. The aim is to increase the quantity and value of annual growth by removing trees that have lost their vigor, are defective, or have poor form, and to retain a well-stocked, though irregular, residual stand composed of well-formed and thrifty immature trees and rapidly growing merchantable trees. The latter may have relatively high value for immediate liquidation, but are worth more for production of additional volumes of better grade material in the future.

The irregular and frequently modified canopy of a stand thus cut is likely to favor the establishment and growth of reproduction of white pine and other valuable species. Conditions resulting from such partial cutting are believed, also, to favor most forms of forest wildlife. Furthermore, such cutting tends to maintain and increase the forest's aesthetic and recreational values, which are always enhanced by the presence of trees of large size.

Clear cutting, however, will continue to be the logical procedure under certain economic and silvicultural conditions. For example, dense old-field stands containing a high proportion of tall, spindly, and short-crowned trees are not well adapted to partial cutting, as few of the small-crowned trees would make good growth if reserved and many would probably be destroyed or damaged by wind, snow, or sleet.

With more than half its land area better suited for forest than any other use, the pine region of New England has notable advantages for application of intensive forest management. Geographically it is well situated with respect to the major consuming centers of the East, and consequently it has a considerable advantage in competition with southern and western woods. The region is well served by a network of highways and roads, which permit ready access to almost any stand at any time and afford latitude in the choice of markets. Public organization for control of fires and provision for protection from insects and disease are of a high grade.

Furthermore, northern white pine produces wood of unsurpassed technical qualities. As the supplies of old-growth western white pine (*Pinus monticola*) and sugar pine (*P. lambertiana*) diminish, northern white pine should claim a larger part of the national market than at present for general construction purposes. When grown by methods that keep maximum knot size below 1½ inches, second-growth northern white pine is comparable in use value to second-growth western white pine and sugar pine, which are already finding their way into eastern markets. Even without forest management, it is superior to much of the second-growth southern pine. All in all, white pine provides a sound basis for profitable forest-land management and prosperous forest industries in the Northeast. Landowners and lumbermen may well give more attention to growing and manufacturing this extremely adaptable wood, and marketing it in such a manner that the public may fully appreciate its merits and utility.

Progress toward better management may be expected as timberland owners and sawmill operators come to appreciate fully the advantages of sustained yield, and to realize that operating costs and returns are largely determined by tree size and quality. Studies of production costs in other regions have shown without exception that the costs of handling small trees, which normally make up a considerable part of the total number of trees removed in the clear cutting of a second-growth stand, are relatively high, frequently exceeding the value of the low-grade product obtained from the trees. In selective cutting the proportion of less valuable trees is ordinarily smaller, and hence the average profit per thousand board feet is frequently greater than could be obtained by clear cutting.

Determination of operating costs in relation to size of timber and study of the effect upon such costs of substituting partial cutting for clear cutting are, therefore, of fundamental importance in preparing for better forest management. On the one hand, sawmill operators should be interested in knowing what classes of timber yield best returns. On the other hand, landowners will hesitate to sacrifice immature timber or allow their woodlands to be stripped if cost analyses indicate that the intrinsic value of stumpage is greater than what a purchaser can afford to pay if operating on a clear-cutting basis.

FIGURE 1.—Many-aged growing stock resulting from selective cutting of white pine.

STUDY OF SIX REPRESENTATIVE OPERATIONS

In order to analyze the situation with regard to cost of producing white pine lumber in New England and to provide a basis on which timberland owners and sawmill operators may better appraise timber values, a study of six typical white pine lumbering operations has been made by the Northeastern Forest Experiment Station and the Forest Products Laboratory of the United States Forest Service. The study included representative portable and permanent sawmills (fig. 2), a variety of logging conditions and methods, and examples of partial and clear cutting. On each job detailed observations were made, covering all activities from the time the trees were cut until the lumber was stacked in the yard. These observations included accurate measurements of labor and material, and careful division of indirect costs among all the trees included in the study and also among all the logs produced. Labor required for such operations as falling was prorated over the several logs in the tree. Items of indirect or overhead cost were ascertained with a degree of care consistent with their magnitude. Records were made of the kind and value of the product.

Together with footage of round-edged lumber, the lumber inspector tallied estimated footage, by grade, of the square-edged lumber that might have been obtained from such pieces as in his judgment could economically be edged. Estimates were made, also, as to how much the lumber sold on a mill-run basis would have been worth if graded. The standard of grading was Rules for the Inspection of Eastern White Pine and Norway Pine, published by the Northeastern Lumber Manufacturers Association on December 5, 1933. Prices used were those established in Lumber Code Authority Bulletin, v. 2, No. 9, dated July 16, 1934.

In order to follow satisfactorily the development of the areas after logging, permanent sample plots were established on each of the six areas. Prior to cutting on each series of plots a complete tally was made of the trees to be removed and of those to be reserved. These stand tallies, together with general descriptive notes, photographs, and reproduction counts provide a sound basis for interpreting subsequent developments in the light of conditions prior to logging. After logging, the plots were reexamined to determine how well the cutting had conformed to the marking, what damage had been done to the residual stand, and how much of the reproduction had been destroyed incidental to logging. Unfortunately, the value of these sample areas, which might have been expected to increase over a period of several decades, has been largely lost through premature cutting in one case and hurricane damage in others.

Two examples of each of the three common sawmill types were included in the six logging operations that were studied intensively. There were portable mills at Marlboro and Gilmanton, N. H., small permanent plants at Waterboro, Maine, and Montague, Mass., and larger mills at Townsend, Mass., and Laconia, N. H. Since the several jobs varied not only as to type of manufacturing plant but also in many other respects, it was not possible to use average figures or to make direct comparisons between operations for all phases of the study. The following is a brief description of the six logging and manufacturing operations, and of conditions on the sample plots before and after cutting.

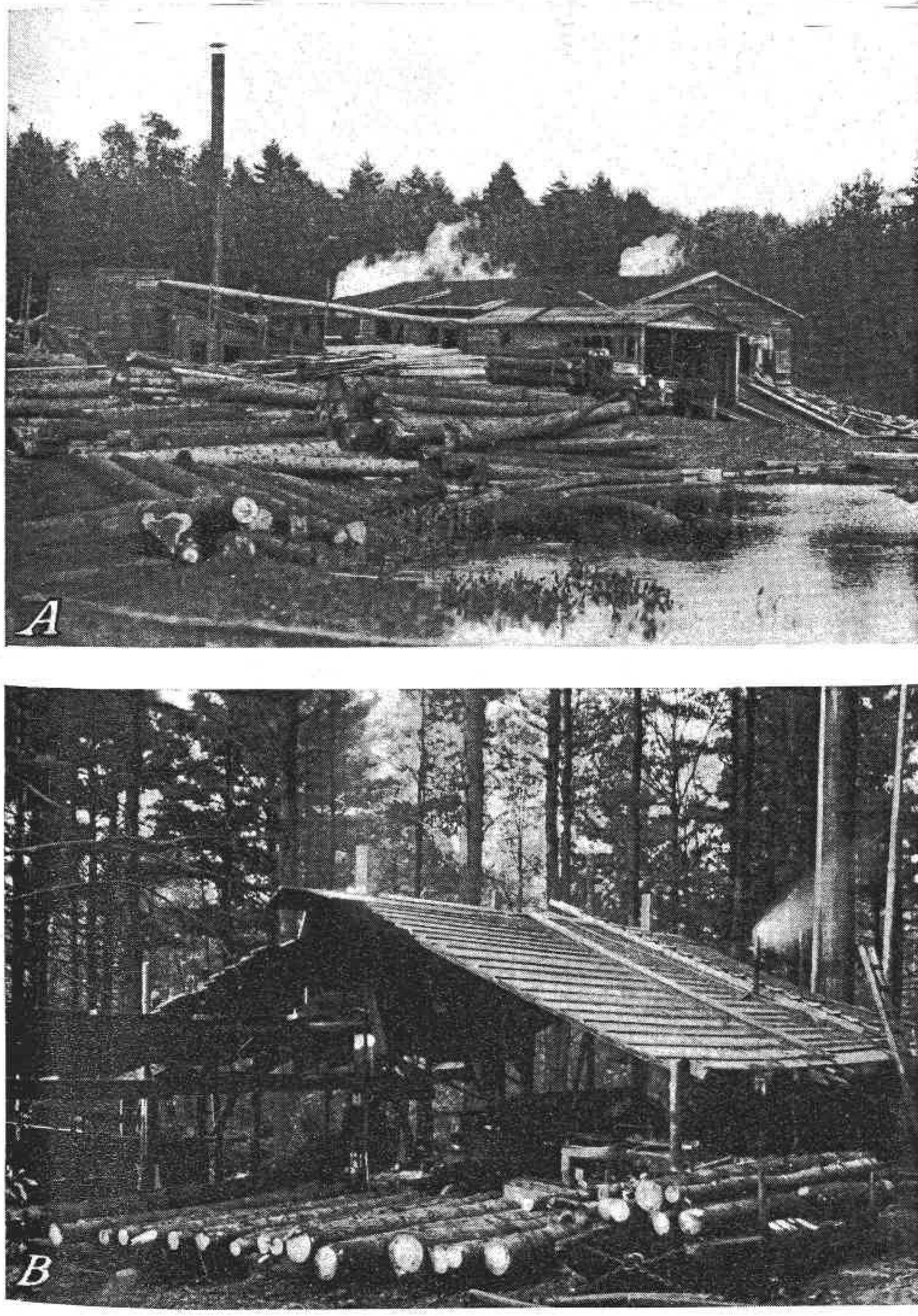

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FIGURE 2.—Typical New England white pine mills: *A*, Permanent mill, with relatively large logs from selective cuttings, Waterboro, Maine; *B*, portable steam mill, with extremely small logs from clear cutting of immature timber, Gilmanton, N. H.

MARLBORO, N. H.

The Marlboro operation was located on a well-drained hillside that had been cultivated and later pastured. The area supported a 50-year even-aged stand of white pine and red spruce (*Picea rubra*) (table 1), with occasional veterans of those species, and a few scattered white ash (*Fraxinus americana*) and paper birch (*Betula papyrifera*) trees in the smaller size classes. The area was well, although somewhat irregularly, stocked. Pine made up the bulk of the overstory but was outnumbered by the more tolerant spruce in the size classes below 9 inches. The trees were typical of old-field second-growth pine stands, being limby and containing only a small proportion of high-grade lumber. With the exception of small openings in the stand, the area supported practically no undergrowth or advance reproduction (fig. 3).

TABLE 1.—*Data on selection cutting of old-field softwood stand 50 years of age at Marlboro, N. H.*

Diameter group (inches)	Trees per acre			Basal area per acre			Volume [1] per acre			
	Original stand	Residual stand	Cut	Original stand	Residual stand	Cut	Original stand		Residual stand	Cut
	No.	*No.*	*No.*	*Sq. ft.*	*Sq. ft.*	*Pct.*	*M bd. ft.*	*Pct.*	*M bd. ft.*	*M bd. ft.*
4–10	218	174	44	69.396	50.295	27.5	[2] 7.4	22.7	[2] 5.0	2.4
11–18	125	45	80	127.326	42.090	66.9	21.5	66.0	7.0	14.5
19+	8	0	8	20.222	0	100.0	3.7	11.3	0	3.7
Total	351	219	132	216.944	92.385	57.4	32.6	100.0	12.0	20.6

[1] In round-edged lumber, as determined by mill tally.
[2] Exclusive of volume of 18 4-inch and 18 5-inch trees.

The windrow logging method employed on this job, which involved clear cutting along the skid roads, resulted in a heavier cut and more irregular residual stand than were contemplated by the forest manager. Only the larger pine and the less desirable trees in the smaller size classes were cut; however, these included 63 percent of the total volume and more than 75 percent of the pine volume.

The logs, ranging from 8 to 16 feet in length, were hauled on scoots an average distance of 549 feet to a portable mill equipped with a 48-inch circular saw and driven by a 50-horsepower Diesel engine. Log making and the hauling of logs to the mill were contracted at $4 per thousand board feet, lumber tally. Workmen at the mill received $3 for an 8-hour day. Production costs, exclusive of stumpage, interest on the operator's investment, and Federal taxes, ranged from $17.46 per thousand for 6-inch trees to $7.74 per thousand for trees 17 and 18 inches in diameter. As is typical of portable mills, the equipment, particularly the engine, was not well adapted to handling large logs; optimum mill efficiency was obtained for 15- and 16-inch trees. Production costs mounted steadily for trees more than 18 inches in diameter, reaching $10.39 for 29-inch trees. Considering the operation as a whole, the cost per thousand, exclusive of stumpage, interest on investment in equipment, and Federal taxes, averaged $8.35, and the value of the lumber per thousand averaged $16 on a mill-run basis, $18.38 on a grade basis.

The residual stand consisted of fairly well stocked patches of thrifty pine and spruce separated by fingerlike openings resulting from the

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FIGURE 3.—Old-field stand of white pine and red spruce, Marlboro, N. H.: *A*, Before cutting. Note persistent limbs and knotty character of timber. Blazes indicate trees selected for cutting. *B*, After partial cutting. Well-stocked groups separated by strips heavily cut in windrow logging.

windrow logging. Logging had done only negligible damage to the larger trees in the residual stand but had destroyed most of the scattered reproduction more than a foot high. Establishment of reproduction was an important consideration because the relatively heavy cut and the windrow logging had created large openings in the stand. Establishment of a new stand of pine in the openings was favored by the disturbance of the ground by logging and by a fair seed crop, but was impeded on about 20 percent of the area by a heavy layer of slash (fig. 3).

Three growing seasons after logging, the residual stand had suffered some loss from wind throw, especially among the spruce, but the trees that remained were thrifty, crown widths were increasing, and height growth was excellent. At that time there appeared to have been little, if any, increase in diameter growth rate. A fair stand of spruce and pine reproduction was found over most of the cut-over area, but hardwoods, particularly paper birch, together with ferns, grasses, and raspberries (*Rubus idaeus*), had taken over some of the larger openings in the stand. The supply of pine seed appeared to be a more important factor in the establishment of this species than seedbed conditions or light.

The residual trees on this area were practically all uprooted or broken by the hurricane in September 1938.

GILMANTON, N. H.

At Gilmanton the logging operation was located on a comparatively flat, well-drained area that supported a typical even-aged old-field stand of white pine. Apparently part of the tract had been cultivated after the remainder was abandoned, as two distinct age classes were represented—45 and 65 years (fig. 4). Although white pine made up most of the timber of both ages, red pine (*Pinus resinosa*) was well represented in the 65-year stand and there were a few scattered hardwoods in both stands. The area was well stocked. The 45-year stand contained 445 trees per acre with a volume of about 17,000 board feet, and the older stand contained 177 trees per acre with a volume of about 39,000 board feet (table 2). The trees in the younger stand, although retaining their limbs to the ground, were smoother than the others because the density of the stand had prevented branches from attaining diameters of much more than an inch.

TABLE 2.—*Stand and volume data on old-field stands clear-cut at Gilmanton, N. H.*

Diameter group (inches)	65-year-old stand				45-year-old stand			
	Trees per acre	Basal area per acre	Volume per acre, lumber tally		Trees per acre	Basal area per acre	Volume per acre lumber tally	
	No.	*Sq. ft.*	*M bd. ft.*	*Pct.*	*No.*	*Sq. ft.*	*M bd. ft.*	*Pct.*
4–10	60	23.322	4.3	11.0	410	97.762	12.3	72.8
11–18	103	110.798	27.2	69.6	[1] 35	28.181	4.6	27.2
19+	14	30.154	7.6	19.4				
Total	177	164.274	39.1	100.0	445	125.943	16.9	100.0

[1] None of these were more than 15 inches d. b. h.

In the older stand, branches 2 inches or more in diameter were not uncommon on the largest dominant trees. Because of the roughness of the larger trees in the older stand, the product graded only slightly better than in the younger stand. Only about 5 percent of the total yield was classed as No. 1 Common or Better.

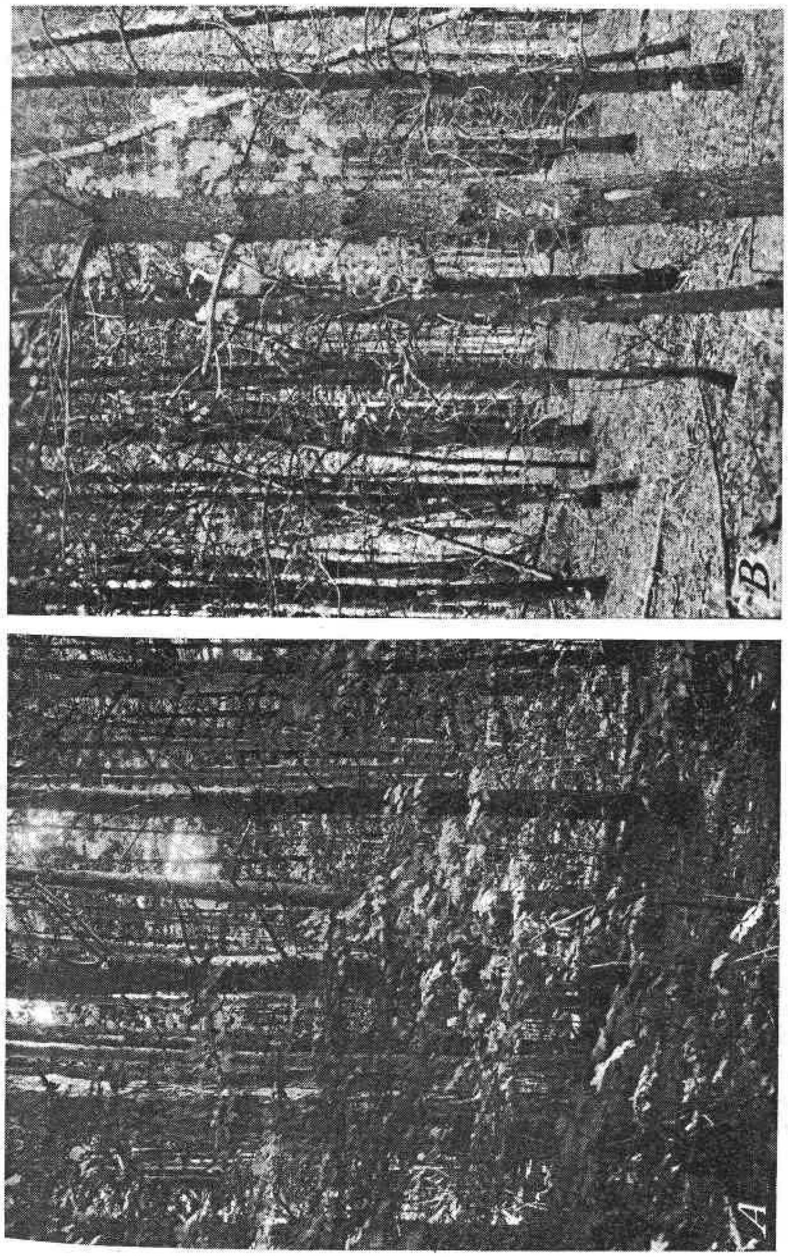

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FIGURE 4.—Old-field pine area, Gilmanton, N. H.: *A*, Stand 65 years old, with 89 percent of volume in trees more than 10 inches in diameter. Cost of operation $5.51 per thousand board feet. *B*, Stand 45 years old. More than half the trees were less than 7 inches in diameter; these were handled at a loss. Cost of operation $10.93 per thousand board feet.

Clear-cutting was the only method used in this operation, and all trees having breast-height diameters of 4 inches or more were utilized for lumber. In the 45-year stand (fig. 4) the proportion of small trees was particularly high, 229 of the 410 trees in the 4- to 10-inch class having diameters of 6 inches or less.

The logs, which ranged in length from 6 to 16 feet, were hauled on a scoot an average distance of 415 feet to the portable mill. This mill was equipped with a 54-inch, 8-gage, inserted-tooth saw and powered with a 40-horsepower steam engine that, although rated lower, delivered more power and operated more efficiently with large logs than the 50-horsepower Diesel engine at Marlboro. On this particular operation all the pine was manufactured into round-edged box lumber. The woods and mill crews were excellent workmen, industrious, experienced, and efficient. The sawyer received $4 for an 8-hour day and the marker, who acted as off-bearer, and kept a tally of the lumber sawed, received $3; all the other men received $2.75.

Production costs per thousand, exclusive of stumpage, interest on the operator's investment, and Federal taxes, ranged in the 65-year stand from $17.07 for 4-inch trees to $4.26 for the largest size—trees 24 inches in diameter. Production costs in the 45-year stand followed the same trend, ranging from $22.37 for 4-inch trees to $6.25 for 15-inch trees. The costs of producing lumber were consistently lower for 65-year trees than for 45-year trees of the same diameter because the older trees were taller, had less taper, contained greater merchantable volumes than younger trees of the same size, and consequently could be handled more efficiently. The costs of the entire operation averaged $10.03 per thousand board feet for the 45-year stand and $5.51 per thousand for the 65-year stand. The value of the graded product averaged $16.42 and $17.59 for the 45- and 65-year stands, respectively.

After clear-cutting, conditions were fairly uniform over the entire area. A few isolated or worthless trees remained, and about 40 percent of the total area was covered with a heavy layer of slash (fig. 5). It seemed improbable that a new crop of white pine would come in, as the small quantity of advance reproduction had been largely destroyed, logging had been preceded by a poor seed crop, and the trees left standing were inadequate to provide the additional seed needed.

On reexamination three growing seasons after logging, a light stand of slow-growing white pine reproduction was found scattered irregularly over the area. Some of the reproduction was advance growth, and the remainder had come up the spring following the logging. Regardless of origin, the pine was suffering in competition with grass, blueberries (*Vaccinium* spp.), raspberries and blackberries (*Rubus* spp.), eastern bracken (*Pteridium latiusculum*), and the more rapidly growing hardwoods. As a result of clear-cutting the area is being taken over by red maple (*Acer rubrum*), pin cherry (*Prunus pennsylvanica*), striped maple (*Acer pennsylvanicum*), red oak (*Quercus borealis*), and gray birch (*Betula populifolia*) in about the order named.

Waterboro, Maine

At Waterboro the study was conducted in an old-field stand about 70 years of age on well-drained and gently sloping ground. Although thrifty in earlier years, the stand had begun to decline in vigor of growth. An even-aged group about 50 years of age occupied a small portion of the area. Scattered through the stand were a few veteran pines, hemlocks (*Tsuga canadensis*), and beeches (*Fagus grandifolia*) and some hemlock, red pine, and hardwoods of younger age classes. The area supported very little undergrowth or reproduction prior to cutting.

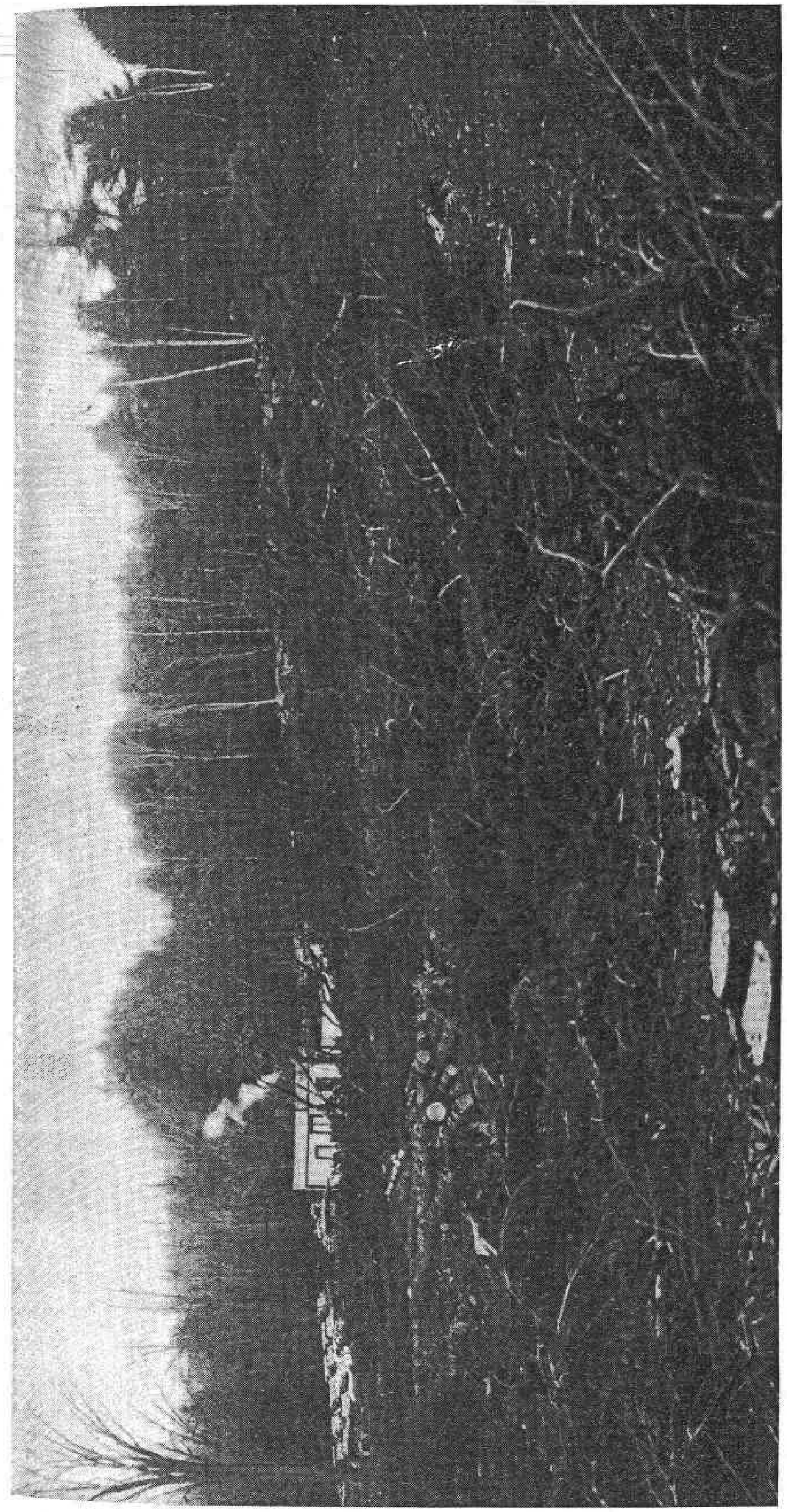

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FIGURE 5.—Gilmanton tract after clear-cutting. Fire hazard high; 40 percent of ground covered with heavy slash. Reproduction almost entirely lacking.

A selective cutting was made in the stand 70 years of age, including all the trees more than 18 inches in diameter, two-thirds of those in the 11- to 18-inch class, and about one-fifth of the smallest-sized group (table 3). Concentration of the cut in the larger size classes resulted in removal of almost 60 percent of the total volume, although only one-third of all the pines were cut (fig. 6). Trees in the smaller size classes were marked along with the larger and more profitable trees if their survival for many years seemed doubtful or if their growing space was needed to maintain the thrift of the residual stand. The residual stand was fairly well stocked, except for a few rather large openings. A clear-cutting was made in the stand 50 years of age, taking all trees except a small number of pines in the 4- to 10-inch-diameter class, which had no value either for logs or for future growth (table 4).

TABLE 3.—*Data on selection cutting of old-field softwood stand 70 years of age at Waterboro, Maine*

Diameter group (inches)	Trees per acre			Basal area per acre			Volume[1] per acre			
	Original stand	Residual stand	Cut	Original stand	Residual stand	Cut	Original stand		Residual stand	Cut
	No.	*No.*	*No.*	*Sq. ft.*	*Sq. ft.*	*Pct.*	*M bd. ft.*	*Pct.*	*M bd. ft.*	*M bd. ft.*
4-10	268	213	55	86.566	67.961	21.5	9.4	34.8	[2] 7.4	[3] 2.0
11-18	107	36	71	95.938	26.372	72.5	15.1	55.9	3.9	11.2
19+	6	0	6	14.901	.0	100.0	2.5	9.3	0	2.5
Total	381	249	132	197.405	94.333	52.2	27.0	100.0	11.3	15.7

[1] In round-edged and square-edged lumber, as determined by mill tally.
[2] Exclusive of volume of 10 4-inch trees.
[3] Exclusive of volume of 1 4-inch tree.

TABLE 4.—*Stand and volume data on 50-year old-field softwood stand clear-cut at Waterboro, Maine*

Diameter group (inches)	Trees per acre	Basal area per acre	Volume[1] per acre, lumber tally	
	Number	*Square feet*	*Thousand board feet*	*Percent*
4-10	500	133.677	[2] 13.5	53.2
11-18	64	65.167	10.6	41.7
19+	4	7.876	1.3	5.1
Total	568	206.720	25.4	100.0

[1] In round-edged and square-edged lumber, as determined by mill tally.
[2] Exclusive of volume of 40 4-inch trees.

The logs, which ranged from 8 to 16 feet in length, were either skidded on the ground or hauled on scoots to truck landings. Trucking logs from the woods to the mill, a distance of 8.4 miles, was a contract job for which the operator paid $1.76 per thousand board feet. The small permanent mill was equipped with a circular head saw and an edger; about 10 percent of the output was square-edged. Aside from trucking, all work was done on a daily wage basis. The prevailing rate was 30 cents per hour for all except the sawyer and the marker, who received $5 and $3, respectively, for an 8-hour day.

On the Waterboro operation the 16-, 17-, and 18-inch trees were handled most efficiently, the production costs for these sizes, exclusive

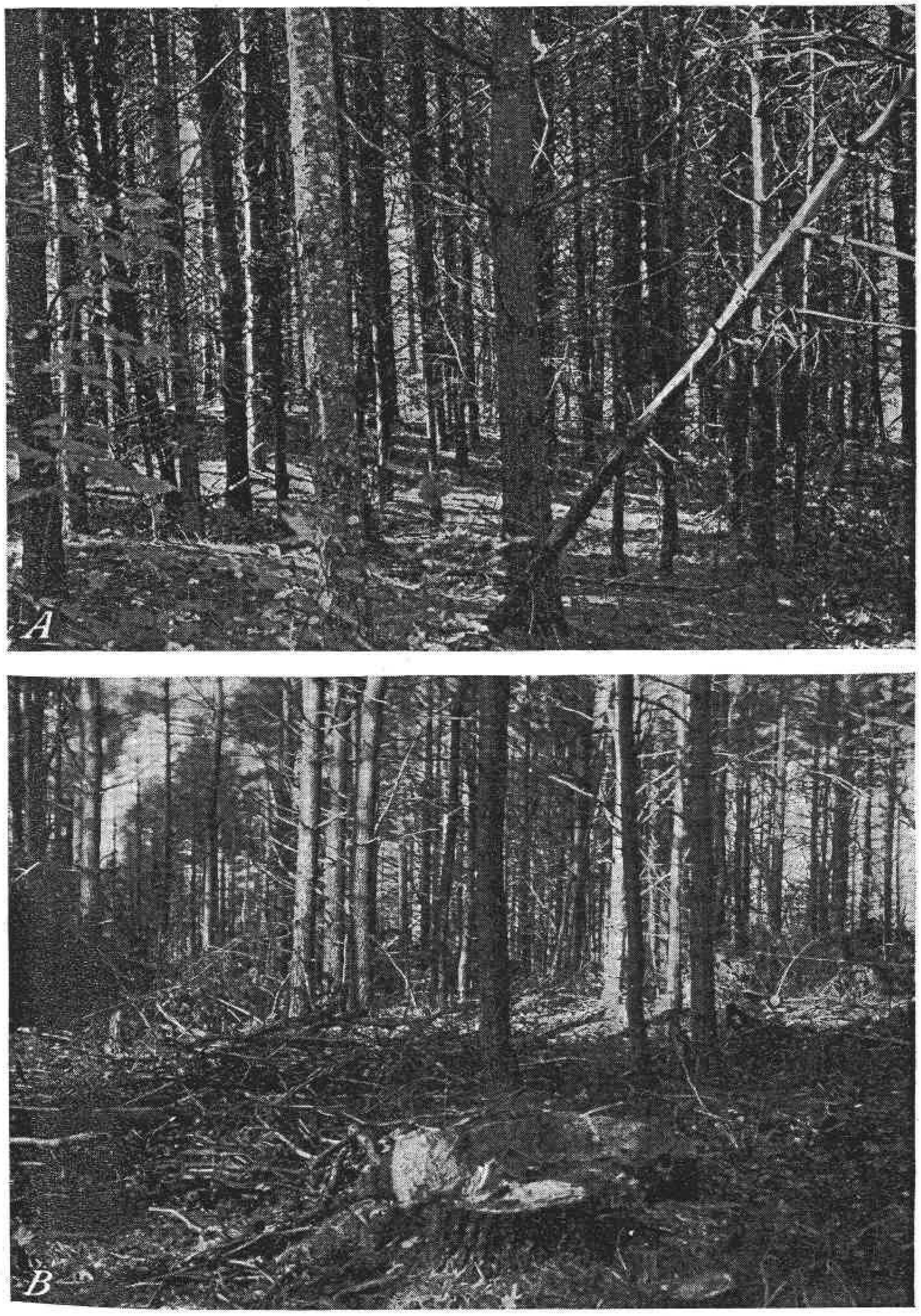

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FIGURE 6.—Old-field stand of white pine, Waterboro, Maine: *A*, Before cutting. Stand 70 years old. Two-thirds of volume in trees more than 10 inches in diameter. *B*, After selective cutting removed about 60 percent of volume. Residual stand well distributed.

of stumpage, interest, and Federal taxes, being $8 per thousand board feet lumber tally. With decrease in size there was a corresponding increase in costs, to a maximum of $15.98 for 5-inch trees. Costs for trees more than 18 inches in diameter showed a slight upward trend, reaching $8.76 per thousand for 24-inch trees. Production costs per thousand averaged $8.66 on the plot cut selectively, and $9.88 on the clear-cut plot. The margin of $1.22 in favor of selective cutting is due to the fact that more than half the volume on the area clear cut was in trees 10 inches or less in diameter, which were relatively expensive to handle, while only 13 percent of the volume taken from the area selectively cut was in trees of this class. The graded value of the product from the entire operation averaged $21.29 per thousand.

The clear-cut plot was left in very poor condition after logging, as practically all the reproduction had been destroyed and about 40 percent of the area was covered with slash heavy enough to interfere with the establishment of a new crop of pine. In making the selective cutting very few of the residual trees were damaged, although about one-third of the advance reproduction was destroyed. About 25 percent of the selectively cut area was covered with a heavy layer of slash. On this area reproduction was a secondary consideration, as the residual trees will fully utilize all except the larger openings for several decades.

Three years after the cutting, the residual stand on the selectively cut area was responding favorably to the opening up of the canopy. The trees were thrifty and were making good height growth, and their increase in crown width was gradually closing the openings in the canopy. At that time little acceleration in diameter growth rate was apparent except in the case of some of the smaller residuals, which before the cutting had been very slow-growing intermediate and suppressed trees. These small trees did not in all cases respond favorably to a change in growing conditions; there was some mortality, and it was chiefly in trees of this sort. A few residual trees were windthrown by the 1938 hurricane.

Reproduction on the selectively cut area after 3 years consisted of a scattered stand of hemlock, balsam fir (*Abies balsamea*), and white pine with a well-stocked understory of red maple, red oak, white oak (*Quercus alba*), and paper birch. The fact that new pine reproduction was sparse can probably be attributed more to the absence of seed than to the method of cutting. The catch was uniformly poor on the selectively cut area, the clear-cut area, an adjacent area burned 1 year after cutting, and on the fire lines subsequently established where the mineral soil was exposed. From the standpoint of reproduction regardless of species, the selective cutting was far more satisfactory than the clear cutting; grasses, bracken, blueberries, and maianthemum (*Maianthemum canadense*) had largely taken over the clear-cut area, but on the partially cut area they were an important factor only in some of the larger openings.

Mount Toby Forest, Mass.[1]

A typical old-field stand about 70 years of age, in which a light shelterwood cutting had been made about 12 years previously, pro-

[1] Field work on the Mount Toby operation was conducted in cooperation with R. P. Holdsworth and J. Harry Rich, of the forestry department, Massachusetts State College.

vided the basis for the study of the Mount Toby Demonstration Forest of the Massachusetts State College, Amherst, Mass. Although the canopy of this stand was fairly complete, the number of stems per acre was relatively low, only a few pines less than 10 inches in diameter persisting. The trees had very little clear length, dead limbs and branch stubs ordinarily occurring from the base of the crown to the ground. With the exception of a few groups of hemlock saplings, the area supported only a light stand of advance reproduction and undergrowth.

The logs were cut in lengths ranging from 8 to 14 feet and skidded to locations where a man with a horse could readily load them onto a truck. They were skidded an average distance of 41 feet and trucked 3.2 miles to a mill in Montague at a cost of 47 cents and $1.18 per thousand board feet, respectively. The total production costs per thousand board feet on this job, exclusive of stumpage, interest on the operator's investment, and Federal taxes, ranged from $15.80 for 5-inch trees to $9.97 for 19-inch trees. The costs of producing lumber from trees above the 19-inch class increased to $10.21 for the largest size, 27 inches. Considering the operation as a whole, the production costs per thousand were $10.28 and the value of the graded lumber averaged $31.05.

The mill was a small, permanent, water-power type, very completely equipped, including in addition to a circular head saw a planer, an edger, matcher, cut-off saws, and wood-turning machinery. Whereas 90 percent of the product of the Waterboro mill, of the same general class, was sold round-edged for boxboards, only 5 percent of the Montague mill's product was sold in this form; the remainder was sold square-edged, or manufactured and sold as trim, planed boards, and other finished products. The well-populated area adjacent to this mill afforded a very good market for slabs, shavings, and sawdust byproducts yielding more than $2 in value at the mill for each thousand feet of lumber.

As is indicated in table 5, nearly 54 percent of the total volume was cut; this included most of the trees more than 18 inches in diameter but less than half the trees in the smaller diameter classes. The reserved stand of 7,743 board feet per acre included only trees that appeared to be wind-firm and of a type that would respond favorably to this opening up of the stand (fig. 7). As the logging was done by careful and experienced men working under close supervision,

TABLE 5. *Data on selection cutting of old-field softwood stand 70 years of age at Mount Toby, Mass.*

Diameter group (inches)	Trees per acre			Basal area per acre			Volume[1] per acre			
	Original stand	Residual stand	Cut	Original stand	Residual stand	Cut	Original stand		Residual stand	Cut
	No.	*No.*	*No.*	*Sq. ft.*	*Sq. ft.*	*Pct.*	*M bd. ft.*	*Pct.*	*M bd. ft.*	*M bd. ft.*
4-10	31	18	13	8.313	4.727	43.1	0.9	5.3	[2] 0.5	[3] 0.4
11-18	51	29	22	59.334	33.281	43.9	11.2	65.5	6.2	5.0
19+	10	2	8	24.722	4.694	81.0	5.0	29.2	1.0	4.0
Total	92	49	43	92.369	42.702	53.8	17.1	100.0	7.7	9.4

[1] In round-edged and square-edged lumber, as determined by mill tally.
[2] Exclusive of volume of four 4-inch trees.
[3] Exclusive of volume of one 4-inch tree.

the damage to the residual stand was negligible. In addition to improving growing conditions for the residual trees, the manager of the tract wished to take advantage of the excellent pine seed crop in order to obtain a new stand in which this species would be well represented. Suitable seedbed conditions were assured, since in the normal course of the logging operation brush and small hardwoods were broken or cut back, large openings were made in the canopy, and the ground was torn up sufficiently to expose the mineral soil. Because the Mount Toby Forest is used intensively for recreation, part of the slash was piled and burned to reduce the fire hazard and improve the appearance of the cut-over area.

FIGURE 7.—White pine shelterwood area, Mount Toby Forest, Mass. Open stand, 70 years of age, remaining after shelterwood cutting; reproduction in first year after cutting at rate of 17,000 seedlings per acre.

Three years after logging, the residual stand was developing satisfactorily, although the diameter growth rate had not increased appreciably following the cutting. At that time there was a thrifty stand of 3-year white pine reproduction well distributed over the entire tract except on the spots where slash had been burned, these spots having received no seed since the burning. The pine seedlings were largely overtopped by hardwood sprout growth, and it appeared that unless released within the next few years much of the pine would be shaded out by the faster-growing white and red oaks, red maple, and black cherry (*Prunus serotina*). The residual stand on this tract was all blown down by the hurricane.

TOWNSEND, MASS.

Conditions on the Townsend tract represented two extreme types of old-field white pine growth. One portion of the tract (fig. 8) sup-

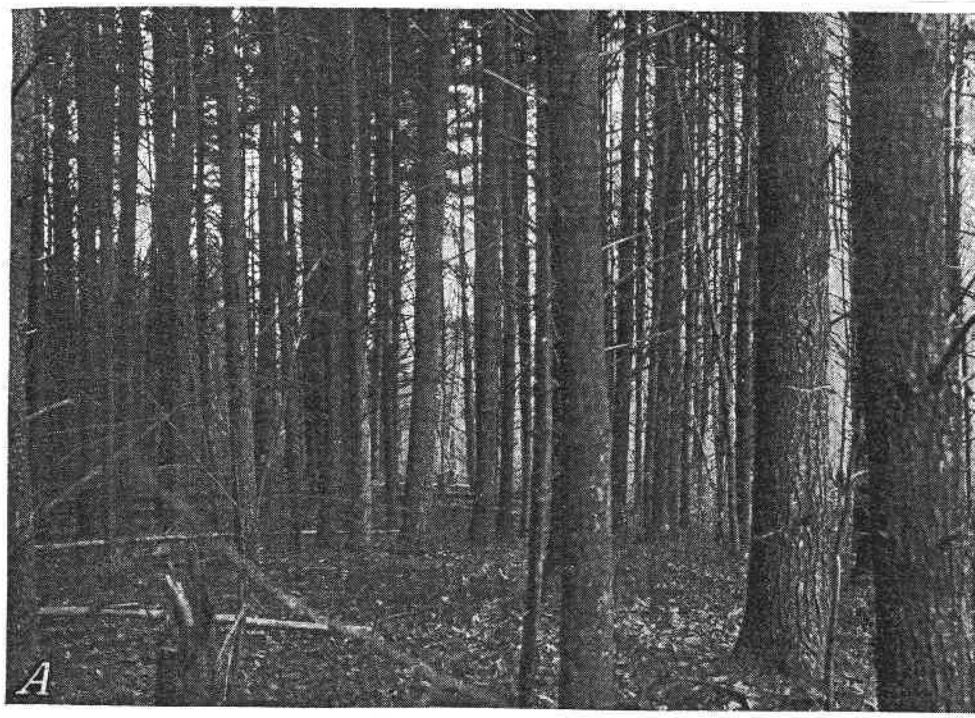

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FIGURE 8.—Dense even-aged white pine, Townsend, Mass.: *A*, Before cutting. Tall, slender stems and short crowns present a difficult problem for partial cutting. Reproduction lacking. *B*, After shelterwood cutting that removed 60 percent of the volume. Thrifty trees with good crowns, mostly 10 to 14 inches in diameter, left as source of seed, as shelter for reproduction, and for additional growth.

ported a very dense, slow-growing, practically pure stand of white pine about 70 years old, in which the trees were for the most part tall, spindly, and short-crowned, with dead branches from the base of the crown to the ground. On the remainder of the tract occurred an irregular stand of white pine trees up to 25 inches in diameter with a mixture of pitch pine (*Pinus rigida*), oak, and other hardwood species (fig. 9). Most of the larger trees in this relatively open stand were about 70 years of age. There was practically no reproduction under the heavy shade of the dense stand; the relatively open stand had a well-stocked understory of red maple, white pine, red oak, and black cherry reproduction, together with mountain-laurel (*Kalmia latifolia*) and other brush species. The larger pines in mixture with the hardwoods were in general well-formed and thrifty, had 12 to 16 feet of clear length, and were in every respect superior to the trees growing in the adjacent dense, overstocked stand, but the pine volume of this relatively open stand underran that on the heavily stocked area by 16,000 to 20,000 board feet per acre.

Portions of both the dense overstocked stand and the irregular open-grown stand were removed by clear cutting. Table 6 gives the numbers of trees, basal areas, and volumes removed in this operation. Shelterwood and selection cuttings, also, were made in the dense and open-grown stands, respectively. Data showing what proportions of the stands were cut and reserved are given in table 7.

TABLE 6.—*Stand and volume data on dense 70-year and on many-aged old-field stand clear-cut at Townsend, Mass.*

70-YEAR STAND

Diameter group (inches)	Trees per acre		Basal area per acre		Volume [1] of white pine per acre	
	White pine	Hardwoods	White pine	Hardwoods		
	Number	*Number*	*Square feet*	*Square feet*	*Thousand board feet*	*Percent*
4-10	76	15	28.428	5.120	[2] 5.6	11.7
11-18	137	4	146.981	4.487	35.9	75.1
19+	9	0	25.140	0	6.3	13.2
Total	222	19	200.549	9.607	47.8	100.0

MANY-AGED STAND

Diameter group (inches)	Trees per acre: White pine	Trees per acre: Hardwoods	Basal area per acre: White pine	Basal area per acre: Hardwoods	Volume: Thousand board feet	Volume: Percent
4-10	65	128	23.632	29.572	4.5	14.1
11-18	78	2	83.234	1.566	20.3	63.6
19+	11	0	28.216	0	7.1	22.3
Total	154	130	135.082	31.138	31.9	100.0

[1] In round-edged and square-edged lumber, as determined by mill tally.
[2] Exclusive of volume of five 4-inch trees.

In making the shelterwood cutting on the densely stocked portion of the area, establishment of a stand of white pine reproduction was the primary, but not the sole, consideration. This cutting included some trees of all the diameter classes and, so far as possible, eliminated the short-crowned, intermediate, and suppressed trees and the roughest and least desirable stems from the larger size classes. The cutting removed more than two-thirds of the pines and about 60 percent of the total volume of 47,000 board feet per acre. The trees reserved in this shelterwood cutting as a source of seed and as protection for

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FIGURE 9.—Irregular many-aged stand, Townsend, Mass.: *A*, Large, clear stems of desirable quality marked for cutting. Dense laurel underbrush. *B*, Stand left by removal of 41 percent of pine volume. Operating costs less than in clear cutting.

TABLE 7.—*Data on shelterwood cutting in dense 70-year stand and on selection cutting in many-aged old-field stand at Townsend, Mass.*

Diameter group (inches)	Trees per acre				Basal area per acre				Volume[1] of white pine per acre			
	Original stand		Cut		Original stand		Cut					
	White pine	Hardwoods	White pine	Hardwoods	White pine	Hardwoods	White pine	Hardwoods	Original stand		Residual stand	Cut
	No.	*No.*	*No.*	*No.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*M bd. ft.*	*Pct.*	*M bd. ft.*	*M bd. ft.*
DENSE 70-YEAR STAND												
4–10	149	13	133	13	57.023	4.465	49.081	4.465	11.2	23.9	1.7	9.5
11–18	136	4	65	4	127.819	3.563	59.612	3.563	30.9	66.0	16.5	14.4
19+	8	0	8	0	18.704	0	18.704	0	4.7	10.1	0	4.7
Total	293	17	206	17	203.546	8.028	127.397	8.028	46.8	100.0	18.2	28.6
MANY-AGED STAND												
4–10	86	114	13	114	28.730	26.284	3.585	26.284	5.3	19.6	4.7	0.6
11–18	70	15	19	15	74.360	11.538	28.056	11.538	18.2	67.4	11.2	7.0
19+	7	0	7	0	14.126	0	14.126	0	3.5	13.0	0	3.5
Total	163	129	39	129	117.216	37.822	45.767	37.822	27.0	100.0	15.9	11.1

[1] In round-edged and square-edged lumber, as determined by mill tally.

the resulting seedling growth were mostly between 10 and 14 inches in diameter (fig. 8). They were selected as thrifty, well-formed individuals that appeared wind-firm and capable of making accelerated growth following the opening of the stand. It was contemplated that this residual stand would be removed in one or two operations after reproduction became well established.

The selection cutting in the irregular stand of pine included chiefly trees more than 13 inches in diameter. It took all the hardwoods and enough smaller undesirable pines to provide adequate growing space for the residual stand (fig. 9). This operation removed one-fourth of the pines, constituting 11,100 board feet per acre or 41 percent of the total white pine volume.

On the areas where partial cuttings were made, logging damage to the residual stands was negligible. On the shelterwood area 17 percent of the ground was covered with dense slash; on the selection area, where the cutting was lighter, only 8 percent of the ground was covered by a layer of slash heavy enough to hinder the development of reproduction. In the selection cutting more than half the advance reproduction was destroyed, as advantage was taken of openings where the bulk of the reproduction occurred in preference to destroying trees of sapling size. As a result of unusual weather conditions immediately following the logging operation, a few trees were windthrown on the very exposed portion of the shelterwood area adjacent to the clear-cut area. Clear cutting destroyed practically all advance reproduction and left about one-third of the area covered with a heavy layer of slash. In view of the excellent white pine seed crop at the time of logging, this species appeared to have an excellent chance to reestablish itself over the entire area.

In this operation the logs were loaded on wagons and hauled an average distance of 1⅔ miles to a large permanent mill. The rather high hauling costs, $3.08 per thousand board feet, would have been substantially reduced by more favorable road and weather conditions, and would have been further reduced by more efficient organization of the loading operation. About 40 percent of the output of this mill, which was equipped with a band head saw and edger, was square-edged lumber. The remaining 60 percent was remanufactured by the operator. In comparison with most of the other jobs included in this study, woods and mill utilization was very good, as short lengths and small sizes were used for cooperage, one of the principal products of this plant.

Production costs, exclusive of stumpage, interest on the operator's investment, and Federal taxes, for the Townsend operation as a whole, averaged $9.69 per thousand board feet, ranging from $18.59 for 5-inch trees to $8.17 for the largest trees handled—25 inches in diameter. In determining the production costs for any one of the three cutting methods, the diameter of the trees removed was the most important factor; for a given size class, the effect of method of cutting as such was negligible. Because of differences in sizes of trees cut by the different methods, costs differed as follows: Clear cutting in both types of stands, $9.60; shelterwood cutting, $10.43; selection cutting, $8.94. Average value per thousand board feet produced for the entire operation was $22.97. Values differed little between the clear-cut and shelterwood areas, but were somewhat better for the selectively cut area.

In the second year after the cutting the residual trees were all removed from the selective and shelterwood cutting areas. This unforeseen logging operation largely destroyed the value of the permanent sample plots, which were established to follow the development not only of the understory but also of the residual stands.

In the third year after the cutting the clear-cut portion of the densely forested area supported a well-distributed stand of pine reproduction, except where the ground was covered with a dense layer of slash. If the new stand is allowed to develop undisturbed, a considerable portion of this pine will eventually be crowded out by the red maple, gray birch, white oak, beech, pin cherry, bracken, grass, sweetfern (*Comptonia asplenifolia*), and raspberry that have invaded the area. On the shelterwood cutting area, the stocking of reproduction was lighter and the white pine seedlings averaged slightly smaller. However, as there was much less competition from hardwoods and herbaceous growth on this area, the pine probably has as good a chance of developing into a well-stocked stand as the larger-sized reproduction on the clear-cut area.

The advance reproduction that had survived in the open stand was not thrifty, and few new pine seedlings had come in on either the clear-cut or the partly cut portion. Competition with an established and faster growing understory of hardwoods and mountain-laurel, and unfavorable seedbed conditions, were probably responsible for this generally unsatisfactory condition.

HOLDERNESS, N. H.

On the Holderness area, which was formerly pastured, the rather open and irregular overstory was made up chiefly of a 70-year even-aged stand of white pine together with a few hemlocks and hardwoods.

The openings in the stand were well stocked with hemlock, red spruce, balsam fir, and hardwoods of varying size and age (fig. 10), which provided a better basis for a continuous series of selective cuttings than the other stands included in this study. The owner of this tract was one of the first landowners in New England to realize the possibilities of pruning, and about 30 years prior to this study he pruned practically all the limby pines to an average height of 17 feet in order to increase the yield of high-grade lumber. Table 8, based on a sample plot established in a typical portion of the stand, indicates the distribution of pine in the several size groups before and after cutting.

TABLE 8.—*Data on selection cutting of old-field softwood stand at Holderness, N. H.*

Diameter group (inches)	Trees per acre			Basal area per acre			Volume[1] per acre			
	Original stand	Residual stand	Cut	Original stand	Residual stand	Cut	Original stand		Residual stand	Cut
	No.	*No.*	*No.*	*Sq. ft.*	*Sq. ft.*	*Pct.*	*M bd. ft.*	*Pct.*	*M bd. ft.*	*M bd. ft.*
4-10	157	149	8	40.252	37.607	6.6	5.0	17.3	[2] 4.6	[3] 0.4
11-18	74	15	59	81.493	10.554	87.0	17.9	61.9	2.2	15.7
19+	12	0	12	26.090	0	100.0	6.0	20.8	0	6.0
Total	243	164	79	147.835	48.161	67.4	28.9	100.0	6.8	22.1

[1] In round-edged and square-edged lumber, as determined by mill tally.
[2] Exclusive of volume of twenty-four 4-inch trees, thirty-four 5-inch trees, and twenty 6-inch trees.
[3] Exclusive of volume of one 4-inch tree, one 5-inch tree, and one 6-inch tree.

The cut included less than half the trees, but about three-fourths of the volume (fig. 10). The landowner believed that the best financial results would be obtained by periodically making heavy selective cuttings that would yield a relatively high immediate return and substantially reduce the investment, but still leave the nucleus of another good stand of timber. This operation did not conform to the most desirable forest-management practice, as the cut included a considerable number of medium-sized thrifty trees that had been pruned in 1910 and might well have been reserved for further production of high-quality lumber.

In order to prevent severe damage to the residual stand, the ordinary practice was to skid the logs to woods roads rather than to attempt to load them directly on the scoots. Transportation in the woods, including skidding the logs and hauling them on scoots an average distance of 518 feet to the truck landing, cost $1.76 per thousand board feet. Trucking to a large permanent mill at Laconia, a distance of 24 miles, was contracted at $3.32 per thousand board feet lumber tally. The total costs per thousand of producing lumber, exclusive of stumpage, interest, and Federal taxes, averaged $12.10, ranging from $19.98 for 7-inch trees to $10.77 for the largest trees handled, 22 inches in diameter. The value of the product averaged $30.79 per thousand.

Because the site is more truly representative of the spruce and northern hardwood region than of the white pine region, white pine, contrary to the owner's expectations, is rapidly giving way to the more tolerant spruce, hemlock, and hardwoods (fig. 10). According to sample-plot observations 3 years after logging, it seems probable that pine will become a relatively unimportant species on this area. A considerable number of the residual pines died after the logging operation, while in

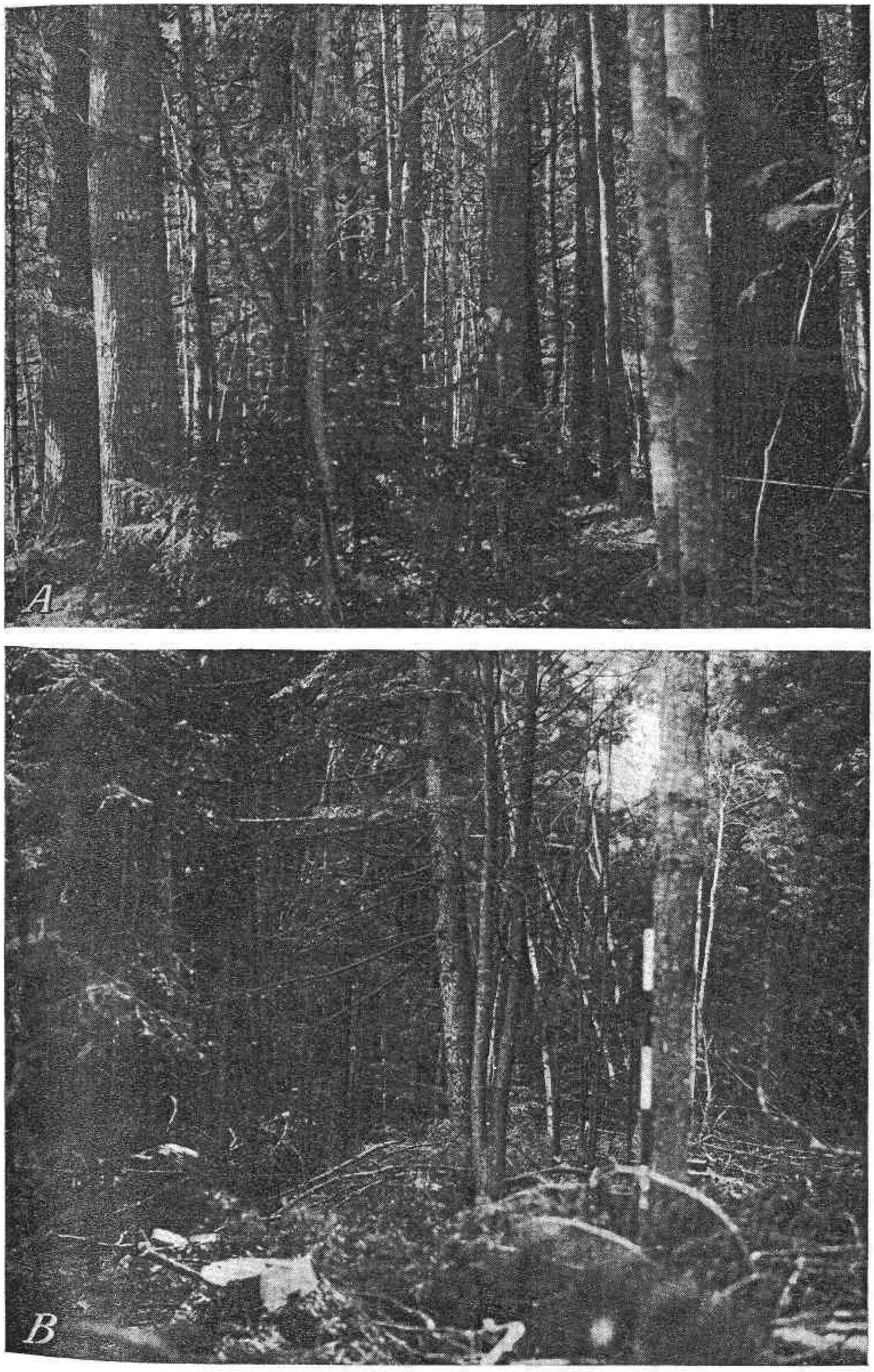

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Figure 10.—Many-aged stand, Holderness, N. H.: *A*, Before cutting. High-quality trees, about 70 years old. *B*, After removal of large trees. Thrifty young timber preserved for future growth.

general the hardwoods responded favorably to the changed growing conditions. In the understory the scattered stand of hemlock, spruce, and pine reproduction was negligible as compared with the rank growth of red maple, red oak, sugar maple (*Acer saccharum*), paper birch, and gray birch. A good white pine seed crop immediately before cutting or in the year following it would have increased the proportion of this species, as at this time seedbed conditions were favorable. On a site such as this it is not probable that pine could compete successfully with the faster-growing hardwoods, even if it were to become established at the start. The 1938 hurricane made successful regeneration of white pine still less probable by felling most of the pines in the overstory.

LUMBER-PRODUCTION RATES AND COSTS

The lumber-production rates and costs determined in this study are suggested for use both as a yardstick for a going operation and as a basis for appraising the value of standing timber and estimating probable costs on an operation before it gets under way. As a general rule operators, large and small, do not anticipate or make due allowance for indirect charges—an omission that has been responsible for many financial misfortunes in the lumber industry. Average rates of log making, based on all six jobs studied, are given in table 9, which

TABLE 9.—*Average labor required for log making in white pine timber and skidding white pine logs* [1]

Rates by tree size				Rates by log size			
Diameter at breast height (inches)	Labor per thousand board feet		Labor per 100 cubic feet	Top diameter inside bark	Labor per thousand board feet		Labor per 100 cubic feet
	Lumber tally	Net scale			Lumber tally	Net scale	
LOG MAKING							
	Man-hours	*Man-hours*	*Man-hours*	*Inches*	*Man-hours*	*Man-hours*	*Man-hours*
4	8.39	10.23	4.57	4	8.24	14.82	4.96
6	6.59	8.05	3.87	6	5.52	7.98	3.51
8	5.09	6.25	3.24	8	4.06	5.18	2.75
10	4.08	4.91	2.72	10	3.22	3.78	2.29
12	3.52	4.18	2.44	12	2.76	3.06	2.03
14	3.22	3.81	2.30	14	2.56	2.75	1.92
16	3.12	3.66	2.27	16	2.45	2.60	1.87
18	3.10	3.64	2.30	18	2.41	2.54	1.87
20	3.12	3.68	2.36	20	2.44	2.58	1.91
22	3.19	3.75	2.42	22	2.54	2.66	2.00
24	3.29	3.84	2.48	24	2.66	2.80	2.12
26	3.42	3.97	2.58	26	2.81	3.00	2.30
28	3.59	4.14	2.71				
SKIDDING—400 FEET							
6	3.68	4.62	2.18	4	4.06	7.08	2.37
8	2.79	3.53	1.80	6	2.78	4.12	1.80
10	2.31	2.90	1.57	8	2.06	2.74	1.44
12	2.01	2.50	1.42	10	1.74	2.13	1.27
14	1.82	2.25	1.33	12	1.57	1.81	1.19
16	1.69	2.07	1.26	14	1.46	1.63	1.12
18	1.59	1.95	1.20	16	1.37	1.49	1.06
20	1.50	1.84	1.15	18	1.30	1.40	1.01
22	1.43	1.75	1.11	20	1.26	1.35	.99
24	1.38	1.69	1.08	22	1.25	1.34	1.00
26	1.37	1.68	1.07	24	1.27	1.36	1.02
28	1.39	1.70	1.09	26	1.32	1.40	1.07

[1] Log-making data are combined from all 6 operations; skidding data are from operations at Marlboro and Gilmanton, N. H., and Waterboro, Maine, skidding distance, 400 feet.

TABLE 10.—*Average labor required for hauling white pine logs 10 miles by motor truck and for milling* [1]

HAULING

Rates by tree size				Rates by log size			
Diameter at breast height (inches)	Labor per thousand board feet		Labor per 100 cubic feet	Top diameter inside bark	Labor per thousand board feet		Labor per 100 cubic feet
	Lumber tally	Net scale			Lumber tally	Net scale	
	Man-hours	*Man-hours*	*Man-hours*	*Inches*	*Man-hours*	*Man-hours*	*Man-hours*
6	2.67	2.94	1.40	4	2.71	4.20	1.39
8	2.40	2.70	1.38	6	2.40	3.22	1.38
10	2.25	2.51	1.37	8	2.21	2.66	1.36
12	2.14	2.36	1.36	10	2.08	2.31	1.34
14	2.06	2.26	1.35	12	1.98	2.08	1.33
16	2.00	2.18	1.33	14	1.90	1.93	1.31
18	1.94	2.12	1.32	16	1.84	1.84	1.29
20	1.90	2.08	1.32	18	1.79	1.76	1.27
22	1.87	2.04	1.30	20	1.77	1.69	1.26
24	1.89	2.03	1.30	22	1.79	1.66	1.27
26	1.93	2.05	1.31	24	1.82	1.67	1.29

MILLING

4	14.2	17.4	7.3	4	9.3	16.6	5.6
6	8.9	11.3	5.3	6	4.9	7.1	3.3
8	5.6	7.3	3.8	8	3.1	4.0	2.3
10	4.0	5.1	2.8	10	2.5	3.0	1.9
12	3.1	4.0	2.3	12	2.2	2.6	1.8
14	2.7	3.4	2.1	14	2.0	2.4	1.7
16	2.5	3.1	2.0	16	1.9	2.2	1.6
18	2.3	2.9	1.9	18	1.9	2.1	1.5
20	2.2	2.8	1.8	20	1.9	2.1	1.5
22	2.2	2.7	1.8				
24	2.2	2.7	1.8				

[1] Hauling data from Waterboro, Maine, Mount Toby Forest, Mass., and Holderness, N. H., operations; milling data from Gilmanton, N. H., operation.

also shows average rates of skidding logs a distance of 400 feet as determined from the operations at Marlboro, Gilmanton, and Waterboro.

Logs were trucked only on the Waterboro, Holderness, and Mount Toby jobs; table 10 gives average labor required in these three operations for hauling logs a distance of 10 miles; and also the labor required for milling on the basis of data obtained in the Gilmanton mill, a plant typical of well-powered steam portable mills cutting only round-edged lumber. Milling conditions differed extremely among the six jobs studied. Manufacturing time and costs are naturally higher for square-edged than for round-edged lumber. Furthermore, inadequacy of power adversely affected milling costs at some of the plants studied.

In using these tables a job may be analyzed on the basis of either average tree or average log, but in order to make the best possible use of the data it is necessary to consider the distribution of trees or logs, preferably the latter, by size class. If the labor requirement for a particular operation is appreciably higher than the average figures obtained in this study, a careful analysis should be made to determine whether the excess can be reduced. Absolute uniformity in production rate among operations is, of course, not to be expected, because class of timber, the lay of the land, and other factors are bound to have their influence. If the logging chance is particularly difficult, labor requirement will be high, and little can be done about it. If, on the other hand, logging conditions are comparatively good and labor requirement is nevertheless high, it is apparent that at some point performance is below par. If it develops that the falling and bucking output is low, an effort should be made to effect improvement in this phase of the operation. Possibly output can be increased by better tools, better crews, piece work, or closer supervision with a view toward improving the skill or efficiency of the workmen.

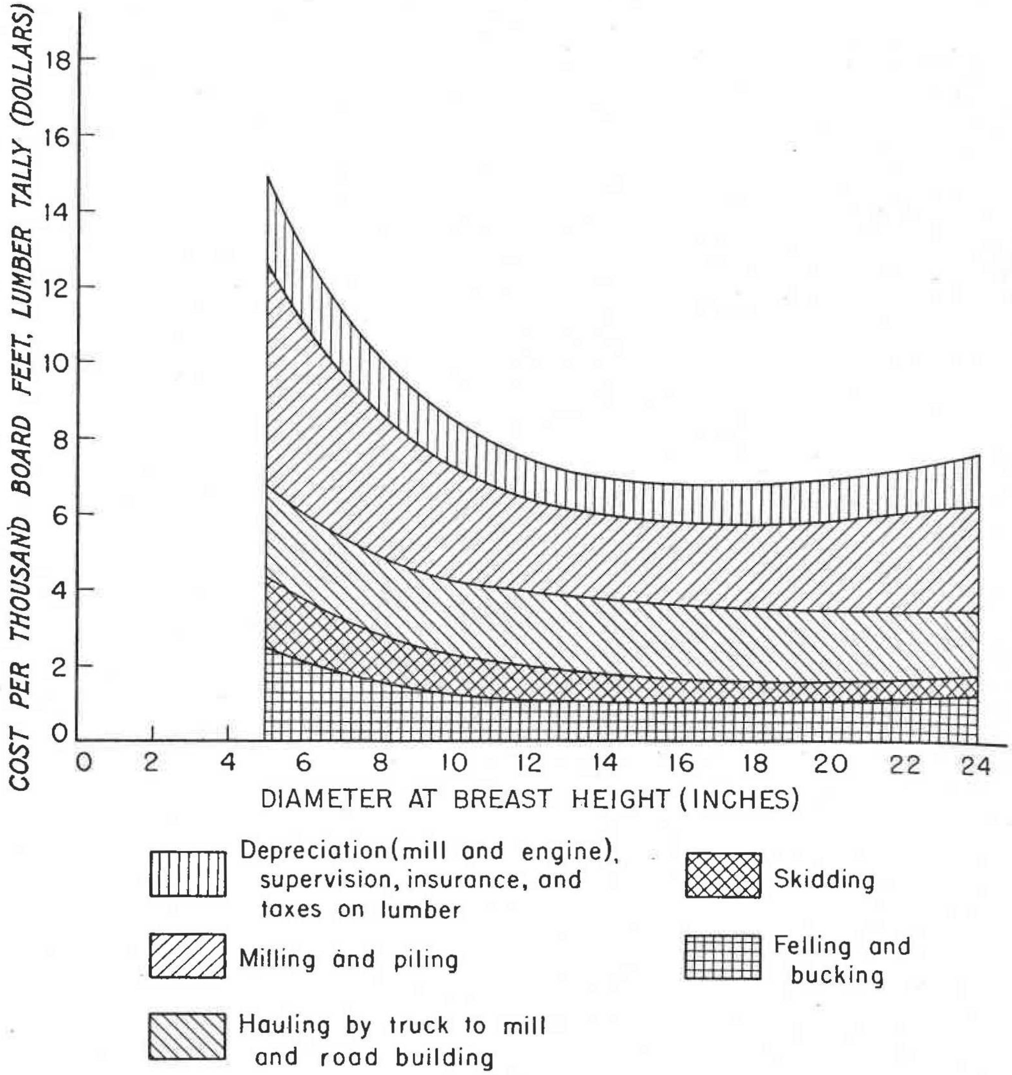

Figure 11.—Costs of producing lumber from white pine trees of different sizes. (Curved values based on 551 trees, containing 66,000 board feet, sawed in permanent mill at Waterboro, Maine.)

This study showed that on small operations the sawmill is the pace setter. If a mill is producing 8,000 to 10,000 board feet per day and logs are being milled as cut, two falling crews, two skidding crews, and one swamper-loader are required. When skidding distances are short, the two skidding crews are unoccupied almost half the time, but it is usually impossible to combine the long and short hauls satisfactorily or keep the skidding crews busy at something else when they are not needed for skidding. In this study, slack time of skidding crews was classed as delay time and eventually prorated along with other delay time over the entire volume of timber included in the job, and thus was absorbed proportionately by the large and small logs. To charge idle time to individual logs and trees would upset entirely the relation between size of timber and time required to handle the timber.

The simplest method of computing probable operating costs by use of the tables requires estimating the size of tree having average volume for the stand in question. If the average tree were estimated at 16 inches in breast-height diameter, reference to table 9 would show that on a lumber-tally basis log making would require 3.12 man-hours per thousand board feet. If the wage rate per hour for falling and bucking were 35 cents, the labor cost for this operation would be $1.09 per thousand. To this would be added overhead costs such as supervision, tools, and insurance. Costs could be computed in the same manner for other steps in production, namely, skidding, log hauling, and milling.

It is not uncommon to figure the total cost of a logging and milling job and then divide by the total footage turned out by the mill to arrive at the average lumber-production cost per thousand board feet. While this method is satisfactory for some purposes, it does not make possible a close analysis of the job, step by step; hence, it permits uneconomical practices or inefficiencies, that might well be corrected, to escape attention.

As an example of a detailed logging and milling analysis, figure 11 indicates the break-down of production costs for trees of different sizes on the Waterboro operation, in which the mill was a small permanent type producing both round- and square-edged lumber. This figure brings out the importance of size of timber in relation to all major phases of production from the time the trees are cut until the green lumber is stacked in the yard.

CONCLUSIONS

Large Timber Is Most Profitable To Handle

This study and all similar studies in other regions of the United States have demonstrated that log size, which of course depends on tree size, is the most important of the factors determining the costs of lumber production, the grade of lumber obtained, the margin for profit in operation, and the price that can be paid to the timberland owner for stumpage.

Ordinarily small logs require more time than large logs in both the logging and the milling operation for the production of an equivalent volume of lumber. In the Waterboro operation, which represents a fair average of conditions on the six jobs included in the study, it cost $15.89 to produce a thousand feet of lumber from 4-inch logs, the smallest and least profitable size class, and the product had a value of only $15.21 as graded lumber. This cost figure does not include Federal taxes, interest on the operator's investment, or stumpage. A stumpage charge of $6 per thousand would mean a loss of $6.68 to the operator for each thousand feet of lumber manufactured from 4-inch logs. The highest returns were obtained from 17-inch logs, as the graded lumber from these logs, worth $36.39 per thousand, was manufactured at a cost of only $7.48. A stumpage charge of no more than $6 for logs of this size would leave the operator a margin for profit, Federal taxes, and interest on his investment amounting to $22.91 per thousand. The 18- to 21-inch logs on this operation were obtained from extremely rough open-grown trees, which not only were too large to be handled very efficiently with the equipment at hand but contained a relatively greater proportion of low-grade lumber than the medium-sized logs. This condition was not general in the six operations; in most cases the grade yield, and consequently the margin for profit, etc., held up well for the maximum size classes. Tree size showed the same general influence as log size; for example, the graded lumber from 5-inch trees had a value $7.68 per thousand less than the costs of production, including a $6 stumpage charge, while there was a margin of $13.37 for 20-inch trees. Obviously, under these conditions an operator could afford to pay much more for stumpage if most of the small timber were to be left standing than if all the trees were to be removed.

A distinction should be made between small logs coming from the tops of large trees and small logs representing a considerable proportion of the volume of small trees. The former may be considered a byproduct, and should not bear a proportionate share of the falling, road-building, and overhead expense. Tops left in the woods, unlike small trees left standing, represent not an asset but rather a liability as an additional fire hazard. Top logs should therefore be utilized even if so small that as butt logs they could be handled only at a loss.

The fact that the larger logs and trees not only can be handled more efficiently but also produce a much greater proportion of high-quality lumber is an important consideration, as the better grades are usually very much in demand and command a good price. Small logs yield little but low-grade lumber, which is salable only for such products as boxboards and of which there is usually a surplus on the market. The Holderness operation, although not entirely comparable with the Waterboro operation because the trees were pruned, illustrates the significance of grade as it affects profit. Cost items, including $5.56 per thousand feet for transportation, which involved a truck haul of 24 miles to a mill, totaled $12.10 per thousand, the highest on any of the jobs included in this study. Yet if stumpage were charged at $7, there would still be a margin for profit on the graded product of $11.69 per thousand, exclusive of Federal taxes and interest on mill investment. On the other hand, the low-quality 65-year-old stand at Gilmanton yielded a margin for profit of only $7.08 per thousand even though the stumpage charge was $5 instead of $7, log transportation cost only $1.21 per thousand because the portable mill was located within a few hundred feet of the timber, and total production cost was only $5.51 per thousand, the lowest for any operation studied.

Figure 12, based on the Townsend operation, graphically illustrates the advantages of large tree size. Production costs per thousand board feet decline rapidly with increase in tree size, leveling off only for trees more than 20 inches in diameter, and at the same time graded-lumber values steadily increase. While proceeds from utilization of 6-inch trees fail to meet the costs of production, values in the 20-inch and larger size classes exceed costs by more than $15 per thousand; this is the operator's margin for stumpage, interest, taxes, and profit.

Although the six operations differed in many respects, the study data indicate that ordinarily lumber cannot profitably be manufactured from trees less than 10 inches or logs less than 8 inches in diameter. One extreme in profitable utilization is represented by the Mount Toby job, in which the operator could meet a $6 stumpage charge and still show a profit in manufacturing lumber from 6-inch trees and 5-inch logs. At Holderness, after $7 per thousand was deducted for stumpage, trees less than 15 inches and logs less than 10 inches in diameter failed to meet the costs of lumber production. Log-transportation cost, which amounted to $1.65 on the Mount Toby job and $5.56 on the Holderness job, was a very important factor in determining the minimum tree and log classes that could profitably be handled.

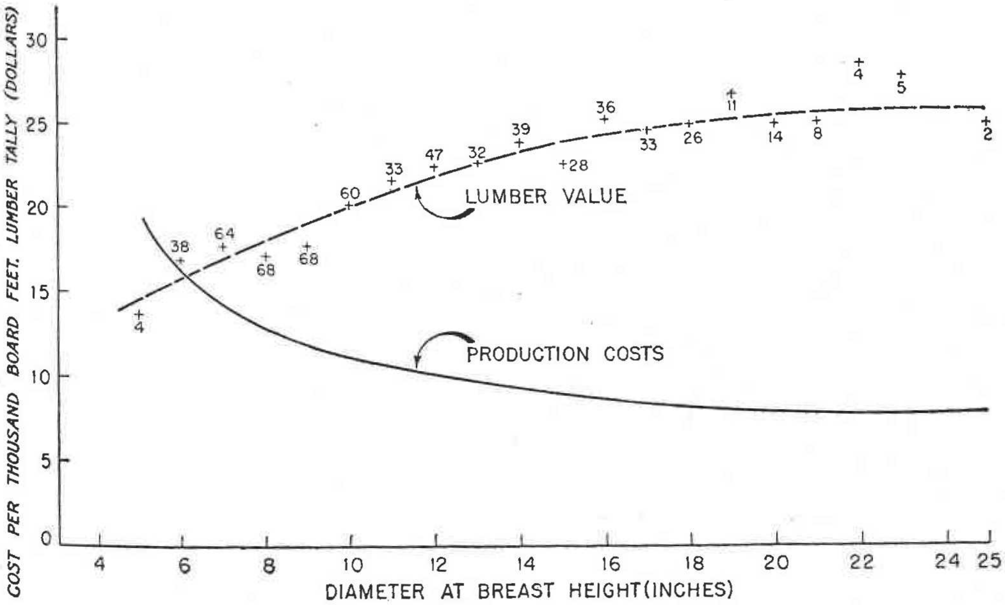

FIGURE 12.—Production costs and graded-lumber values for white pine trees of different sizes. (Basis, data for 640 trees containing 127,200 board feet of lumber sawed in permanent mill at Townsend, Mass.)

Partial Cutting Does Not Increase Operating Costs in Accessible Stands

Operators accustomed to clear cutting frequently contend that the advantage of partial cutting in yielding logs of greater average size and value will be substantially offset by increased cost of cutting the trees and removing the logs from the stand. It might be expected that the increased care required in felling trees would make this item of cost somewhat higher on selection cuttings, but that the smaller volume of slash on the ground would result in lower skidding costs. The six operations in this study included a sufficient range of cutting practices to yield convincing evidence on the comparative cost of partial cutting.

For the clear-cutting jobs included in the study, the time required to fall and buck a thousand board feet, lumber tally, ranged between 84.4 and 99.3 man-minutes, while for the partial cuttings it ranged between 87.2 and 101.3 man-minutes. Time required to scoot logs, per thousand board feet and 100 feet of distance, averaged 19 minutes on the clear-cutting operations but only 16.7 minutes on the partial cuttings. Although these figures do not take into account such variables as stand conditions, logging conditions, and labor efficiency, they are the result of an essentially random choice in regard to these factors. They thus indicate that method of cutting, as such, is a minor consideration in respect to costs of production.

As the costs of log making and transportation were not affected appreciably by the method of cutting, the average returns per thousand on the partial-cutting jobs studied were relatively high. The cut on these jobs was made up largely of trees in the upper diameter classes, which could be handled economically and which contained a large proportion of high-quality lumber. On each of the clear-cutting operations the average profit per thousand was much lower, as the cut included a considerable number of small trees that were handled either at a loss or with a very small margin of profit. Evidently, when road building or other improvement costs are not involved, landowners and operators alike may safely appraise white pine timber for selective cutting on the basis of size, without regard to proportion of stand to be removed.

When an extensive improvement program is needed to make the forest fully accessible, the owner may be forced to liquidate more of his investment in growing stock than is desirable from a silvicultural standpoint. It should be remembered, however, that the heavier the cut the longer will be the period before another operation is feasible, and that the amount of income, in the long run, depends chiefly on the amount of productive capital invested, that is, the growing stock. Furthermore, a sound investment in permanent improvements will make future selective cuttings more profitable.

Sometimes, in order to improve their immediate financial condition or reduce their investment, landowners may wish or be forced to liquidate valuable stumpage. The New England practice of annually taxing standing timber on the basis of its market value is in some cases an important consideration to an owner who might otherwise build up and maintain a large forest capital. In the event of liquidation, a careful determination would frequently indicate that the highest immediate returns could be obtained not by cutting all trees that would make lumber but rather by reserving trees in the intermediate as well as in the smaller size classes.

Desirable Silvicultural Conditions Are Generally Maintained by Partial Cutting

From the silvicultural standpoint, the relative merits of clear and partial cutting cannot be fully determined until the residual stands on the selectively cut areas have become fully adjusted to the changed growing conditions and reproduction on areas cut over by both methods is well established. According to observations immediately following and several years after cutting, areas on which a portion of the stand had been reserved were making the more satisfactory development. Losses from death and wind throw were confined chiefly to the smaller stems. Most of the residual pines were thrifty and were making good height growth, and openings in the canopy were filling in. Little increase in the diameter growth rates of the individual trees was apparent, but there was no evidence of the tendency to decline that is normal in untreated stands of uniform crown canopy.

Establishment of white pine reproduction on the areas studied appeared to depend on available seed supply more than on method of cutting. Unless done in the fall or winter following a seed crop, clear cutting, unlike partial cutting, leaves no source of seed to restock openings. Moreover, the clear-cut areas were about 40 percent covered with a dense layer of slash that will preclude establishment of a new stand of reproduction for some time, whereas even the heaviest of the partial cuttings had left not more than 25 percent of the area covered with dense slash.

The development of seedlings becoming established after any sort of cutting is greatly influenced by soil quality. On a light soil such as that at Townsend, it seems probable that white pine would maintain an important position regardless of method of cutting. On heavy soil such as that at Holderness, hardwoods are extremely aggressive, and pine can be maintained only at excessive cost for cultural work. On soils intermediate between these extremes, it may be expected that the future stand will develop as a mixture of pine and hardwoods. In any event, weeding is generally necessary to obtain satisfactory development of white pine reproduction.

Light partial cuttings are highly desirable on areas where aesthetic and recreational values are a consideration, while clear cuttings have little or no place on such areas. Ordinarily, a light cutting operation improves the appearance of a white pine stand in which no cutting has been done previously. Pure white pine stands are not well suited to most forms of wildlife; partial cutting tends to ameliorate this condition, by maintaining an irregular canopy with numerous openings and by leading to the introduction of hardwoods and a palatable ground cover.

Another important advantage of partial cutting as compared with clear cutting lies in the relatively lower fire hazard. Unless the large quantities of slash resulting from clear cutting are burned in connection with logging operations, a very high fire hazard prevails for several years. After selective cutting, not only is the quantity of slash less but the residual stand protects the ground from drying out, reduces wind movement, and maintains a generally lower temperature and higher humidity.

Timber Values Are Greatly Increased by Pruning

Pruning has received considerable attention in the Northeast in recent years, because dead branches of white pine growing in old-field stands and plantations persist as stubs for many years. Without pruning, even-aged stands produce a very small proportion of lumber in the better grades; but such stands can produce much good-quality lumber if selected well-spaced crop trees are carefully pruned before they attain a diameter of much more than 8 inches. It is not advisable to prune all the trees in a dense young stand, because only 100 to 200 trees per acre will reach maturity in any event.

The Holderness study provided an opportunity to obtain data on one of the early efforts in pruning; many of the trees cut on this job had been pruned with an ax to a height of 7 feet about 40 or 45 years prior to logging, and with a saw to a height of 17 feet about 30 years prior to logging. In many respects this pruning was not satisfactory by present-day standards. At the time when the later pruning was done the stand was about 40 years old, and some of the trees were a foot in diameter and had limbs 2 inches thick. Branch wounds of this size healed rather slowly, and several years elapsed before the trees began to produce wood free from defect. In order to obtain the maximum benefits, pruning should be undertaken early in the life of the stand, when the limbs are small and easily removed, the danger of fungus infection is less, wounds heal rapidly, bark is not likely to be overgrown, and pitch pockets are not likely to form. Trees may safely be pruned to the desired height (ordinarily 17 feet) in a single operation, unless this involves removal of a considerable proportion of the live crown. In order to reduce the diameter of the knotty core pruning may be undertaken when the trees are quite small, in which case two or three operations in a period of 6 to 10 years may be necessary to remove the side branches from 17 feet of stem.

Although the Holderness pruning job did not conform to technical standards for such work, the contrast between this stand and unpruned stands was very striking. The effects of pruning are well brought out by a comparison of the volumes of the different lumber grades obtained from 63 pruned butt logs from the Holderness area and those obtained from an equal number of butt logs from the five other operations. The logs were all more than 10 inches in diameter, and both the pruned and the unpruned group averaged 12.7 inches in diameter. Aside from selecting the unpruned logs to equal the others in average diameter, the samples were chosen at random. The percentage of C Select and Better lumber obtained from the pruned logs was 29.7, whereas the unpruned sample yielded only 1.3 percent of this quality lumber. A similar ratio existed for all the upper grades; 69.0 percent of the lumber obtained from the pruned logs was No. 1 Common or Better, but only 13.9 percent of the lumber obtained from the unpruned logs was in that category. The proportion of No. 2 Common was about the same for both types of logs, namely, 20 percent. About two-thirds of the lumber from the unpruned logs fell in the grades below No. 2 Common, while only 11 percent of the product obtained from the pruned logs was in those grades. The general appearance of unpruned trees in stands adjacent to the one studied at Holderness would indicate that if the butt logs there had not been pruned they would have been little, if any, better than the samples from the five other operations.

The value of the square-edged lumber produced from the selected samples of pruned and unpruned logs was computed by use of figures for the eight recognized grades ranging from $59 per thousand board feet for C Select and Better to $12 per thousand for No. 6 Common lumber. The value per thousand of the lumber from the pruned logs averaged $45.10 as compared with only $29.90 for the unpruned logs, a margin of $15.20 or more than 50 percent in favor of the pruned logs. Since the butt logs contained approximately half the used volume, it appears that the pruning practiced in the Holderness stand raised the average value of all the lumber cut from the pruned trees more than $7 per thousand board feet.

These figures should leave no question as to the importance of proper pruning in the management of white pine forests. Legitimate costs will ordinarily be offset by increased value. Furthermore, the larger prospective return from growth on pruned stems is an added incentive for holding trees until they have attained large size, and thus contributes substantially toward the purposes of selective cutting.

Greater Values Are Obtained in Manufacture of Square-Edged Rather Than Round-Edged Lumber

The custom of sawing second-growth white pine logs through and through without turning them, and then selling the product in the form of round-edged, ungraded lumber, grew up during a period when white pine was in great demand for boxboards at high prices. The wisdom of this practice has become questionable now that boxboard prices have declined and square-edged lumber commands a substantially higher price per thousand than the round-edged product. During the period when this study was in progress, mill-run white pine lumber was worth $16 per thousand if round-edged and $26 per thousand if square-edged. Thus, there was a margin of $10 per thousand to cover the cost of edging and the accompanying loss of scale.

Indications as to potential profit through edging were obtained in the study by means of estimates of the footage, by grade, of square-edged lumber that might have been obtained from the boards that were sold round-edged. Many boards, because of excessive crook or sweep, could not be tallied otherwise than as round-edged without building up a prohibitive waste figure. Hence the square-edged tally included only such pieces as in the judgment of the inspector could economically be edged. About three-fourths of the lumber cut in operations such as those included in this study could be edged without excessive waste.

On the Marlboro, Gilmanton, and Waterboro operations the 125,860 feet of round-edged lumber suitable for edging had a mill-run value of $2,013.76. The square-edged tally for the same material was 99,515 board feet, with a mill-run value of $2,587.39. Thus it appears that edging, although reducing the scale about 21 percent, would have increased the sale value of the product about 28 percent. The increased value, equivalent to $4.56 per thousand feet of round-edged lumber, very substantially exceeds the cost of edging.

Obviously, an operator selling the entire output of his mill as round-edged lumber is not in position to pay as much for stumpage as one equipped to manufacture square-edged lumber. Timberland owners may well consider this factor when negotiating for the sale of their timber. Progressive operators will make provision for edging. Although edging may be done on the head saw in a portable mill, this practice is neither efficient nor satisfactory. Since an edger is practically essential for the manufacture of square-edged lumber, widespread recognition of the advantages of edging would tend toward elimination of portable mills in favor of permanent, well-powered mills equipped with auxiliary machinery capable of producing efficiently a variety of well-manufactured products.

In reducing the lumber tally by about 20 percent, edging naturally alters the ratio between log scale and lumber tally. On the Marlboro operation, where all the lumber was cut round-edged, the lumber tally overran the International ¼-inch kerf log scale by 22.9 percent, while on the Mount Toby job, where 95 percent of the timber was squared, the lumber tally underran the log scale by 2.2 percent.

Graded Lumber Values Exceed Mill-Run Prices

Another questionable practice characteristic of portable-mill operations in the white pine region is selling lumber on a mill-run basis rather than according to recognized lumber grades. Justification for this practice has been based very largely on the assumption that, with relatively small quantities of generally knotty timber being cut at each mill setting, lumber of the better grades would not accumulate in volume sufficient to make separate marketing practical, and that the relatively large proportion of low-grade lumber could not be sold at all after the better grade had been segregated. Estimates of potential profit through selling on a grade basis were obtained in this study by applying the scale of prices shown in table 11. Although only square-edged lumber is customarily sold by grade, estimates of graded value were made for round-edged lumber also, by taking sixteen twenty-sixths of the lumber-code minimum prices for 5-inch square-edged material. This ratio is based on mill-run values per thousand board feet for round-edged and square-edged lumber of $16 and $26, respectively.

Table 11.—*Prices per thousand board feet of square-edged and round-edged lumber* [1]

Thickness and width (inches)	C Select and Better	D Select	No. 1 Common	No. 2 Common	No. 3 Common	No. 4 Common	No. 5 Common	No. 6 Common
Square-edged:								
4/4:								
6	$59.00	$48.00	$43.00	$36.00	$27.00	$23.00	$19.00	$12.00
8	59.00	48.00	43.00	36.00	28.00	24.00	21.00	12.00
10	64.00	53.00	50.00	36.00	29.00	25.00	21.00	12.00
12	82.00	69.00	60.00	46.00	32.00	26.00	21.00	12.00
5/4:								
10	79.00	63.00	58.00	41.00	32.00	27.00	23.00	12.00
12	92.00	74.00	68.00	51.00	35.00	28.00	23.00	12.00
8/4:								
8	79.00	63.00	51.00	41.00	31.00	26.00	23.00	12.00
10	84.00	68.00	58.00	41.00	32.00	27.00	23.00	12.00
12	97.00	79.00	68.00	51.00	35.00	28.00	23.00	12.00
Round-edged:								
4/4	36.25	29.50	26.50	21.50	15.40	13.50	11.75	7.50
5/4 and 6/4	45.50	35.75	31.50	24.60	17.25	14.75	13.00	7.50
8/4	48.50	38.75	31.50	24.60	17.25	14.75	13.00	7.50

[1] Basis, Lumber Code Authority Bull., v. 2, No. 9, July 16, 1934.

Although untreated second-growth white pine stands seldom yield more than 10 percent of square-edged lumber in the No. 1 Common and Better grades, and are likely to yield more than 70 percent in the grades below No. 2 Common, average value per thousand on a grade basis was well above mill-run values for every operation studied. When most lumber was being cut round-edged, graded values ran from $1.44 to $4.22 above the price paid for round-edged lumber on a mill-run basis, $16 per thousand. On the Mount Toby operation, where 95 percent of the product was square-edged, the average graded value was $31.05, or more than $5 above the mill-run price for square-edged lumber. Only the low-grade lumber obtained from logs less than 6 inches in diameter was worth more on a mill-run than on a grade basis. The spread between graded and mill-run values increased with increase in log diameter except on some of the operations where the largest logs were obtained from very rough wolf trees and so contained little or no lumber of the upper grades.

In sawing logs to be sold on a mill-run basis, the chief objective is likely ~~to be obt~~aining maximum quantity yield in the least possible time. Were there a greater incentive to saw for quality, the logs would be turned on the carriage more frequently and, although the milling costs would be slightly higher, the spread between graded and mill-run values would be even more pronounced than indicated by this study.

Another feature of lumber sales made on a grade basis is pronounced influence of width and length of boards on lumber values. Table 11 shows that the premium paid for increased width mounts very rapidly as lumber grade rises. Furthermore, narrow boards are excluded from the better grades and thicker stock. The widths that command the best prices can be cut only from logs 14 inches or more in diameter. On the other hand, width ordinarily receives very little consideration in setting the price of mill-run round-edged box lumber. Similarly, standard grading rules restrict the proportion of lumber in short lengths that may be included in shipments. Thus, entirely aside from the presence or absence of knots and other defects, large timber produces higher-valued lumber than small timber. Furthermore, waste in manufacture is relatively greater for narrow boards than for wide ones because the quantity of material lost in edging is about the same regardless of board width. Since narrow stock comes mostly from small logs, it tends to cup more in drying than wide stock. Finally, narrow boards and short lengths cost more to handle after leaving the mill than wide boards and long lengths.

The high value obtainable from the better grades of lumber by selling on a grade basis is another reason for not cutting immature trees, which in addition to being expensive to handle yield only low-quality products and reduce the average value of the mill output. It is another reason, also, for adopting forest-management practices calculated to produce large trees with straight, clear stems. Unless no other outlets are available, consideration of graded values should further deter landowners from selling timber to portable-mill operators who do not produce graded lumber.

Utilization and Disposal of Mill Waste Merit Consideration

Close utilization in the woods characterized all the operations. Stumps were cut as low as practicable, tops were consistently small, and logs were commonly cut in lengths as short as 8 feet. In one operation, limbs and tops too small for saw timber were used as cooperage stock. Such material amounted to 2.6 cubic feet for each thousand board feet of saw timber. In another operation, undersized logs were used for small box stuff. Four cutting areas were worked over for fuel wood, and yielded more than one-quarter of a cord for each thousand board feet of saw timber.

The quantity and type of waste incidental to the manufacture of lumber depended on quality and form of timber, judgment and skill of mill crew, adjustment of mill equipment, form of lumber, and thickness of saws. Sawdust amounted to about 20 percent of the log volume at each of the mills equipped with a circular head saw, but to only 11 percent at the Townsend band mill. The sawdust percentages would have been lower had the mills cut any considerable quantity of dimension stock and less inch lumber. A factor of almost equal importance is whether the lumber is cut square-edged or round-edged. Where all or most of the lumber was left round-edged, slabs and edgings amounted to only about 15 percent of the log volume; but where most of it was square-edged, as at the Montague mill, serving the Mount Toby operation, volume of slabs and edgings amounted to 28 percent of log volume.

The percentage loss in edging is directly related to size of logs, being relatively greater for small logs than for large ones. Noticeable savings were effected where skillful sawyers made a special effort to hold the slab loss to a minimum.

Variations in manufacturing losses caused corresponding variations in yield in board feet of lumber per cubic foot of logs. The band mill at Townsend produced 8.1 board feet per cubic foot, with 40 percent of the product square-edged. For the three circular mills cutting round-edged lumber, the ratio was 7.27 board feet per cubic foot. At the Montague mill, where 95 percent of the product was squared, the yield was only 6.27 board feet per cubic foot.

Utilization and disposal of slabs, sawdust, and other mill waste depend largely on local circumstances. The permanent mills made better disposition of waste material than the portable mills, because permanent-mill operators not only had auxiliary manufacturing equipment in the plants but also had developed markets for material they were not prepared to remanufacture. Thus, at Townsend only a limited quantity of waste was available for fuel because small pieces of lumber could be used to advantage in the cooperage plant. At Laconia, where the logs from the Holderness operation were cut up, the sawdust was burned but dry shavings from the box shop were sold to a wood-flour mill, and slabs, trimmings, and edgings were sold locally for domestic fuel. At the Montague mill, good slabs were cut into shingles and edgings were cut up for moldings, etc. Although this was a water-power mill, it had a ready market for all its waste, which added more than $2 net profit for each thousand feet of lumber cut.

Profits from white pine operations elsewhere, even though not so well situated with respect to markets as the Montague and Laconia mills, may well be increased by giving more consideration to the utilization and marketing of mill waste.

Inadequacy of Power Reduces Margin For Profit

Sawmill and other operating equipment should be such as to permit efficient handling of the bulk of the timber likely to be encountered. It is uneconomical, of course, to provide extra power and heavy facilities for handling occasional logs of exceptional size, but the power of the mill and the power available for bringing logs to the mill should be adequate for ready handling of the usual range of sizes in second-growth timber, such as that included in this study.

It is generally recognized that mill efficiency increases with size of logs up to a certain point and from there on decreases. On the Gilmanton, Holderness, and Townsend operations there was no reversal of the decrease in cost of producing lumber as size of logs increased, which indicates that the optimum size of logs for these mills was not exceeded. In the mill at Marlboro, maximum lumber output was obtained from logs 14 inches in diameter and from 15- and 16-inch trees. In the Montague mill, 14-inch logs and 19-inch trees were handled most efficiently. Above these optimum sizes, costs on these two operations showed a decided upward trend, because the mills were not adequately powered. The Waterboro mill was slightly underpowered; consequently its costs of producing lumber from the larger log and tree sizes likewise showed an upward trend. On all these jobs, in spite of the higher milling costs beyond certain sizes, the margin for profit continued to rise with increase in log and tree diameters (although at a slackening rate), because of increase in quality and value of the product.

CHARACTERISTICS OF THE WELL-MANAGED FOREST

The operations included in this study provided an opportunity to cover satisfactorily most of the utilization factors involved in production of northern white pine lumber in New England. From the standpoint of forest-management study, the stands were less satisfactory. In any case, it is beyond the purview of this study to predict what may ultimately prove to be the optimum system of white pine management. Moreover, none of the areas included in the study represented management conditions approaching the ideal. The results indicate, however, that for conditions now generally prevalent selective cutting is superior to clear cutting.

In no case was the growing stock of the character which long-range forest management would produce under any system of cutting, but it is perhaps safe to say that in this respect the selectively cut plots were at a greater disadvantage than the others. On some of them, the stands were too young to demonstrate fully the advantages of selective timber management; on others, because treatment had not been given in earlier years, partial cutting was difficult and was useful primarily as a means of encouraging pine reproduction. In most cases, the larger trees were generally so rough as to be of little if any better quality than the smaller. In no case were the range and distribution of diameter classes fully satisfactory. Furthermore, none of the operations exemplified the application of cuttings light enough to permit working over the same ground at intervals shorter than 20 years.

Since white pine forests managed for long periods under the method suggested in this report are not in existence, the salient features of such a forest can be stated only hypothetically. The forest would be irregular. On all but the lightest soils, it would probably contain a considerable mixture of hardwoods. Groups of large clean stems would be intermingled with irregular patches of young merchantable timber. Reproduction would be generally present, increasing in size near the edges of numerous small openings. These openings would be filled with vigorous saplings or seedlings, depending upon the length of time since they were created by removal of groups of mature trees. Individual stems of exceptionally fine development up to 30 inches or more in diameter would be scattered throughout the forest.

Such a managed stand would perhaps average 20,000 board feet per acre over large areas, with size-class distribution something like that shown in table 12.

TABLE 12.—*Theoretical growing stock in well-managed white pine forest*

Diameter group (inches)	Volume per acre		Basal area per acre	Trees per acre
	Thousand board feet	*Percent*	*Square feet*	*Number*
6–10	2	10	14	38
11–18	10	50	50	40
19+	8	40	36	12
Total	20	100	100	90

Whereas the trees in each of the stands studied were mostly about the same height, in the theoretical stand the trees of smaller diameter would be substantially shorter than the larger trees. For the most part they would have well-formed crowns and be vigorous enough for continued height growth and sustained increase in diameter in response to release by successive light selective cuttings. As a result of partial suppression during early years, few of the trees would develop heavy branches on the lower portions of the trunk. Aided by judicious pruning, the trees reaching largest size would present straight, clear stems, the length of which would depend upon site quality and stand density. On average sites, clear length should amount to two or three logs.

In such a forest it should be possible to obtain a large part of the cut from trees more than 18 inches in diameter. Trees below that diameter would be cut only if damaged or if overcrowded. A growing stock of this sort might be capable of a realizable annual growth of about 600 board feet per acre, which would mean that 6,000 board feet per acre could be removed every 10 years.

Even if no greater lumber value were obtained from such trees than from similar-sized trees in the stands studied at Townsend, gross annual yield would average $15 per acre, and $16.50 per thousand board feet would be available for stumpage, interest, taxes, and profit. With values and costs similar to those in the operation at Holderness, N. H., comparable figures would be $19.50 per acre and $21 per thousand board feet. The possibilities indicated by these figures provide substantial incentive for landowners to build up forest capital as rapidly as possible. In this the landowners should have the fullest cooperation of lumbermen, who would profit along with them by a shifting of cut from small trees of low realization value to larger trees of better quality costing less to handle.

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