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UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

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FOREWORD

Selective logging is fundamental to industrial forestry in the northern hardwood forests of the Lake States and accordingly an intensive study of this subject merits the attention of all timberland owners not only in that region, but in other hardwood regions as well.

[1] The authors acknowledge their great indebtedness to their coworkers, A. M. Koroleff, R. M. Brown, and S. R. Gevorkiantz, of the Lake States Forest Experiment Station, and to Ray Miller, W. E. Griffee, and A. C. Wollin, of the Forest Products Laboratory, for their valuable assistance in planning the work and in collecting, computing, and analyzing the field data which form the basis for this report. Thanks are also due to J. D. Mylrea, of the Thunder Lake Lumber Co., Rhinelander, Wis.; to J. M. Bush and F. W. Hyde, of the Cleveland-Cliffs Iron Co., Marquette, Mich.; to E. A. Hamar, of the Worcester Lumber Co., Chassell, Mich.; to B. D. Stone, of the Bissell Lumber Co., Tripoli, Wis.; and to Henry Schmitz, of the College of Forestry, University of Minnesota, for their generous cooperation and assistance in the conduct of this investigation. O. T. Swan, secretary of the Northern Hemlock and Hardwood Manufacturers' Association, gave valuable suggestions in planning the investigation and was instrumental in disseminating the preliminary results among millmen and landowners in the Lake States.

[2] Maintained by U. S. Department of Agriculture at St. Paul, Minn., in cooperation with the University of Minnesota.

[3] Maintained by U. S. Department of Agriculture at Madison, Wis., in cooperation with the University of Wisconsin.

Selective logging as contrasted with the usual clear cutting of northern hardwoods, or to the "creaming" or "high grading" of the choicest timber, is a distinctly constructive, perpetuating measure which leaves the forest in a healthy, thrifty, and vigorous growing condition. While selection by species and also by sizes is not new to loggers of northern hardwoods, selective logging as referred to in this bulletin involves something of a new point of view and procedure. Thus, the term as used by the authors denotes a partial cutting practice which, by a judicious selection of the trees to be removed, meets both the silvicultural and present economic requirements, in such a way as to perpetuate and improve the forest and at the same time maintain or increase the profits to the owner.

Selective logging is a cutting method particularly suited to saw-timber operations in mixed uneven-aged forests, such as the northern hardwoods. Moreover it conforms closely with the general economic requirements of the Lake States in that it offers a method of keeping forested areas in crop production and prevents further increase in the deforested area.

Viewed broadly, the facts brought out in this publication should serve in establishing a forest plan which not only results in successive crops of valuable saw timber but establishes a system of stable land ownership and land use that contributes substantially to the economic welfare of the region.

R. Y. STUART, *Forester.*

THE PROBLEM

The Lakes States lumber industry was developed on the assumptions that the greater part of the cut-over land would be cleared for agriculture and that the rest, apparently unfit for farming or for the profitable growing of a new crop of trees, would be worthless. Lumbermen therefore clear cut the forest, taking all trees about 9 inches or larger in diameter, of which it now seems probable the smaller sizes were handled at a loss. Selective logging, which may be defined as a partial cutting practice involving a judicious selection of the trees to be removed so as to perpetuate and improve the forest and at the same time maintain or increase the profit to the owner, was not consciously practiced or seriously considered. But neither of the original assumptions turned out to be wholly correct. Only a very small percentage of the cut-over land has been actually cleared and farmed, and practically all of the cut-over land can be made to grow a new crop of trees.

The lumbermen in the Lake States can no longer move on to virgin hardwoods after having cut out their holdings. They have a choice of two lines of action—to sell their equipment in a short time and go out of business, or to perpetuate their timber supply by practicing forestry on their holdings. Quite naturally many lumbermen want to stay in the business and these lumbermen realize the need of information on the following major problems: (1) How to restock the cut-over areas, and (2) how to manage the remaining stands in order to make them go as far as possible in providing a continuous supply of timber. This bulletin deals with the second problem.

PURPOSE OF INVESTIGATION

The specific aim of this bulletin is to present the comparative results of selective and clear cutting on typical lumber operations in the northern hardwood type of timber in the Lake States. The investigation described here involved ascertaining (1) the cost of logging and milling trees of different sizes and species; (2) the quantity, grade, and value of lumber produced from them; and (3) the net returns when different proportions of the total stand were removed for lumber under selective cutting. The Lake States Forest Experiment Station and the Forest Products Laboratory have long recognized that the forest owner in the Lake States who wishes to provide a permanent supply of timber by a more conservative handling of his remaining stands requires information of this character.

WHERE THE INVESTIGATION WAS MADE

The investigation was made at four lumber operations, two of which were located in northern Wisconsin and two in the Upper Peninsula of Michigan. These operations were generally representative of the region as regards daily output, methods of logging and milling, and character of the stand.

The field work was carried on cooperatively by the Lake States Forest Experiment Station, St. Paul, Minn.; the Forest Products Laboratory, Madison, Wis.; and individual members of the Northern Hemlock and Hardwood Manufacturers' Association, during the summers of 1925 and 1926.

HOW THE WORK WAS DONE

The investigation was carried on by a crew consisting of from four to eight men who went into the woods and mills and determined the output per unit of time and the cost per thousand board feet for each step of lumber manufacture from logs and trees of different sizes. In addition the lumber from each log was graded and tallied separately, and a cruise of the trees on several sample plots was made before logging began so that it was possible to determine how the logging and milling costs and lumber values would be affected if certain sizes of trees were not cut.

The ideal way to conduct an investigation of this kind would be to study the same logs in the woods as are studied in the mill so that logging and milling information for trees could be built up by simply adding together the data for the individual logs which made up each tree. Such a plan, however, was impracticable at the operations where the investigation was made. Consequently, the logs studied in the woods were similar but not identical with those at the mill. For this reason the information on logs had to be converted into terms of trees, and the trees into terms of the stand by an indirect method which is described later. The mills during the investigation, however, were getting their logs from the same areas on which the woods studies were made. That the logs were comparable in size is shown by the fact that the average diameter of the logs studied at the mill was 12.2 inches and in the woods 12.3 inches.

In developing the technic for this study the work of Ashe (*1, 4, 5, 6, 7, 8*)[4], Bradner[5] (*10, 11, 12, 13*), Bruce (*14, 15*), Bryant (*16, 17*), Chapman (*18, 19*), White (*22, 23*), and other investigators (*9* and *21*)[6 7] has been referred to freely.

DETAILED DESCRIPTION OF METHODS FOLLOWED

A more detailed explanation of the manner in which the investigation was made is given below.

The investigation was confined to sugar maple (*Acer saccharum*), yellow birch (*Betula lutea*), and eastern hemlock (*Tsuga canadensis*).

Sample plots of 5 acres each were laid out on three of the operations studied. All timber on these plots 4 inches and larger in diameter was tallied before and after logging. The total volume of the stand was then computed from volume tables. The results were segregated by diameter classes and species, so that the volume removed and left and its distribution could be determined by diameter classes and species. This information was also used in computing weighted average costs and lumber values, and in determining the production costs and lumber values where only a certain proportion of the stand is cut under selective logging.

The scale of each log was obtained by using the Scribner Decimal C log rule, which is the official rule of the Forest Service and the legal rule in Wisconsin, although not in Michigan.

The tree diameters were measured to the nearest tenth of an inch and the log lengths to nearest tenth of a foot; log diameters were determined to the nearest inch.

Members of the crew accompanied the loggers in the woods and by means of stop watches determined the time required for felling and bucking each log and tree just as it was handled in the regular logging operation. In addition they calculated the board-foot contents of each log with a scale rule and obtained measurements for each tree. They also timed the skidders, scaled the log or logs in each skid load, and measured the distance covered by the teams on each trip. Figures on loading were obtained by timing and scaling the logs as they were loaded on the cars. A similar method was used for unloading. Where stop-watch methods could be followed, production costs were computed as illustrated in the following example: The stop-watch records showed that 176 minutes were required to buck 1,000 board feet of 13-inch logs. Based on the wages paid at the time of the study, a sawyer received $0.0113 a minute. Therefore, the cost of sawing for logs of this size was $0.0113×176 or $1.99 a thousand board feet log scale.

In railroad operation and maintenance the direct time method of calculating costs could not be used, so that the cost for this item for different diameter classes of logs was based on the cost of a car trip and the comparative capacity of a standard car loaded with logs of different sizes.

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[4] Italic numbers in parenthesis refer to Literature Cited on page 45.

[5] BRADNER, M. SAWMILL STUDIES IN THE INLAND EMPIRE. U. S. Dept. Agr., Forest Serv. Dist. 1. Proj. RSL-1. 1923. [Mimeographed.]

[6] CLAPP, E. H. STANDARD SERVICE METHODS AND PROCEDURE FOR MILL SCALE STUDIES. U. S. Dept. Agr., Forest Serv. Proj. RSL-1, 11 pp., illus. 1916. [Typewritten.]

[7] KLOBUCHER, F., and GIRARD, J. W. INLAND EMPIRE LOGGING OUTPUT HANDBOOK. U. S. Dept. Agr., Forest Serv. Dist. 1, 52 p., illus. 1925. [Mimeographed.]

The work at the mill was carried on by a crew of six men, stationed in such a way that complete records were obtained for each log from the time it came on the log deck to the time it passed out of the mill on the green chain in the form of lumber. One man scaled and numbered the logs as they entered the mill and recorded their diameters and lengths. One man noted the time required at the head saw to saw logs of different diameters. One or two men, according to the layout of the mill, placed the log number on each board or cant as it came from the head saw so that the lumber from each log could be identified on the green chain. Another man numbered similarly the lumber as it was sawed from cants, slabs, and flitches at the resaw. Finally a lumber inspector and a tallyman graded and tallied the lumber on the green chain for each log. Sugar maple and yellow birch were graded in accordance with the official rules of the National Hardwood Lumber Association, and hemlock was graded according to the Northern Hemlock and Hardwood Manufacturers' Association rules.

The comparative cost of sawing lumber from logs of different sizes was computed from the actual time required by the mill to produce a thousand board feet of lumber from logs of different diameters and the cost of running the mill for a corresponding period.

Production costs, such as selling lumber, insurance, and taxes, were considered constant for each thousand board feet regardless of the size of log, and therefore could be added without change to the direct-production cost for each diameter class.

Items of cost, such as railroad, road, and camp construction, were considered fixed charges per acre, and for this reason their cost per thousand board feet varied directly with the amount of timber removed per acre. If all the merchantable timber is removed, for example, the average cost per thousand board feet may be added to other log-run costs without change; if, however, only part of the timber is cut the cost of permanent improvements, such as railroad construction, must be proportionately higher.

The lumber prices used in this bulletin were the market quotations prevailing in the Lake States in 1925 and 1926 at the time the investigation was made. The average value of the lumber was computed on the basis of market prices and the grades obtained from the logs of different sizes.

In the woods the direct costs were changed from a log to a tree basis by determining the diameter of the average log in each diameter class of trees. This was done by dividing the merchantable height of each tree by 16 (the log length); then, by dividing the total merchantable volume of the tree by this quotient to obtain the volume of the average log. From this volume figure the corresponding diameter was read directly from the Scribner log rule. The cost of logging trees per thousand board feet gross log scale was then obtained by reading directly from the data on logs the cost of handling a log corresponding to the size of the average log in each tree class. For example, the log of average volume in a tree 20 inches in diameter is about 13.8 inches in diameter; therefore, the cost on the average, of sawing a thousand board feet was considered to be the same for trees 20 inches in diameter breast high as for logs 13.8 inches in diameter inside the bark.

In milling, instead of using the average log method just described, the diameter and volume of each of the logs that made up a tree of a given diameter class were determined from tree form curves made during the investigation. Average figures for grades, volume, and the cost of sawing for each size of log that made up a tree of a given diameter and height were read directly from the log tables and added together to give results for the entire tree. This same procedure was followed for each species and diameter class, thus giving figures for the stand as a whole.

The direct logging and milling costs and lumber values for individual trees were translated into the terms of the forest as a whole by applying figures from the sample plot data, showing the proportion of each species in the stand and the percentage of the total volume in each diameter class.

The log-run production costs and lumber values for the stand, when trees below certain diameters are omitted from the cut, were determined by applying the volume distribution figures for the stand, obtained from the tally made on the sample plots to the production costs and lumber values for trees of different diameters. An example of this computation is given on page 30.

The investigation covered time records and measurements of 900 trees for sawing timber; 1,200 trips for skidding; 2,400 logs for loading, unloading, and railroad operation and maintenance; 3,647 logs for milling; and the tally of all trees 4 inches and larger on sample plots of 5 acres each at three operations.

THE DEGREE OF GUIDANCE THAT THE RESULTS AFFORD THE LUMBERMEN

The figures on production costs, lumber values, profits, and cutting limits, which are given later in a series of tables, apply directly only to the conditions encountered and described, and are not applicable in their entirety to individual hardwood-hemlock lumber operations. This is to be expected because the production costs and the value of lumber vary with the amount of timber cut per acre, the proportion of trees of different diameters in the stand, the prevalence of eastern hemlock or any other species, and the prevailing lumber prices and wage scales. The trends established by these figures, however, may be expected to hold true generally throughout the Lake States region.

The results apply only where the logs are cut into lumber. The investigation was confined purposely to lumber because it is the main product of most of the mills of the Lake States. Furthermore, the lumbermen know how to manufacture and market it expertly, and for this reason they may be expected to develop future plans with the production of lumber in view. Where methods of manufacture and markets are such that small trees and tops of large trees are not cut into lumber but utilized for fuel, pulp wood, mine props, dimension stock, and similar purposes the financial aspects would change. This bulletin makes no attempt to forecast the results under such conditions.

The degree of guidance offered by this bulletin to the individual operator will depend on how closely the operations studied parallel his own. If his costs and species of wood correspond closely, he can use the results as a guide without further computation. If they do not, it will be necessary for him to take the basic figures given here and work out the results for his own operation.

In any event the guiding principles as to the comparative production costs and lumber values for trees of different sizes and species should apply generally within the Lake States region. Nevertheless, it is recommended that each lumberman work out specific figures for his own operation. Suggestions for computing diameter cutting limits are therefore given in the "Supplementary information" at the end of this bulletin.

PRODUCTION COSTS

LOG-RUN PRODUCTION COSTS

The following log-run costs of lumber production were used in the investigation as a basis for computations. They are an average of the costs supplied by the cooperating companies.

TABLE 1.—*Log-run production costs per thousand board feet*

[Based on companies' figures]

Woods operation	Cost, gross log scale, all species	Mill operation	Cost, lumber tally, for— Hardwoods	Cost, lumber tally, for— Hemlock
Sawing (felling, bucking, and limbing)	$2.08	Milling	$5.02	$3.21
Skidding	2.56	Depreciation	.44	.32
Loading	.69	General expense	2.11	1.79
Railroad transportation	2.90	Sorting and piling	1.56	1.12
Unloading	.15	Yard maintenance	.36	.16
Railroad construction	2.44	Taxes on yard stock	.51	.28
Logging road construction	.41	Insurance on stock	.32	.13
Camp construction	.44	Shipping lumber	1.65	1.21
Woods supervision	.54	Selling lumber	1.04	.72
Woods general expense	.64			
Taxes on logs	.10	Total	13.01	8.94
Insurance on logs	.10			
Total	13.05			
Total woods cost, lumber tally (with 18.1 per cent overrun as determined by this investigation)	11.05			

With the above figures as a basis and by means of time studies the production costs for each diameter class and for different cutting limits were determined and are given later.

CLASSIFICATION OF PRODUCTION COSTS

In determining the production cost per thousand board feet for trees and logs of different sizes and when cutting to different diameter limits it was necessary to recognize that some items of cost vary with the size of the log or tree, others with the amount cut per acre, and still others remain constant.

The classification of costs used in this analysis is as follows:

Costs that vary per thousand board feet with the size of log or tree: Woods—Sawing, skidding, loading, railroad operation and maintenance (hauling), and unloading. Mill—Sawing logs into lumber, depreciation of mill and equipment, and general expense at mill.

Costs that vary per thousand board feet with the amount cut per acre: Woods—Railroad construction, logging roads, camp construction, woods supervision, and woods general expense.

Costs that are constant per thousand board feet: Woods—Taxes, and insurance on logs. Mill—Sorting and piling, yard maintenance, insurance on stock, taxes on yard stock, and shipping and selling lumber.

LUMBER PRICES USED

The lumber prices listed in Table 2 and used in this report were the current prices f. o. b. mills where the investigations were made and are representative of 1925 and 1926 quotations.

TABLE 2.—*Current lumber prices f. o. b. mills, 1926 and 1927*

Grade	Sugar maple	Yellow birch	Grade	Eastern hemlock
FAS	$80	$110	Merchantable	$27.00
Selects	70	85	No. 3 Common	18.00
No. 1 Common	57	55	No. 4 Common	11.50
No. 2 Common	33	33		
No. 3 Common	17	19		

PRESENTATION OF RESULTS

Most of the cost figures given later in the report for logs and trees of different diameters are based on ratios established by time observations. To clarify and shorten the main discussion the results are discussed in terms of dollars and cents alone, instead of using a combination of costs, output, and time figures. The cost figures for different diameter classes bear the same relation to each other as the time figures and may be used by an operator in working out cutting limits for his own operation to a much better advantage than the time ratios. Some additional information, not necessary in developing the principal points of the investigation, is given under "Supplementary information."

THE HARDWOOD-HEMLOCK FOREST OF THE LAKE STATES

LOCATION, AREA, AND STAND

The hardwood-hemlock forest considered in this bulletin occupies the fresh, well-drained, fertile soils of the northern pine region, located for the most part in northern Michigan and Wisconsin on the rolling glaciated land about the Great Lakes. It is roughly estimated that this forest still occupies 7,000,000 acres of land and supports a merchantable stand of hardwoods and hemlock totaling 56,000,000,000 feet, 11,000,000,000 feet of which is in Wisconsin and 29,000,000,000 feet in Michigan (*20*). Of the stands in Wisconsin and Michigan probably one-third is eastern hemlock and the rest hardwoods. Although there is a large quantity of hardwood timber in Minnesota, most of it is of a different quality and character than the stand in Michigan and Wisconsin.

COMPOSITION

This forest is made up of three main species: namely, sugar maple, yellow birch, and eastern hemlock. (Fig. 1.) Several other species, including basswood (*Tilia glabra*), beech (*Fagus grandifolia*), elm (*Ulmus americana*), and northern white pine (*Pinus strobus*) occur in small amounts in mixture with the above species, but taking the region as a whole these species are of considerable less importance than the sugar maple, yellow birch, and eastern hemlock, and are not considered in this bulletin. Originally, individual trees of northern white pine were found growing among the hardwoods, but most of them were cut prior to the present century. Many of the old stands have been logged lightly for hemlock, elm, or basswood, when the market was especially good for these species. The removal of the northern white pine and occasionally of other species gave predominance to sugar maple and yellow birch, but otherwise left the forest intact. The hardwood-hemlock forest may therefore still be classed as virgin forest supporting a stand varying from 5,000 to 15,000 board feet an acre.

The character of the forest in which this investigation was made can best be judged by the distribution of the volume of the different species in the stand by size classes.

TABLE 3.—*Number of trees of different sizes in the stand and their proportionate volume by diameter classes*

[Average of 15 acres]

Diameter breast high (inches)	Trees per acre	Proportion of stand by number	Proportion of stand by volume	
			Log scale	Board measure
	Number	*Per cent*	*Per cent* [1]	*Per cent* [1]
4	16	10.4	(2)	(2)
5	16	10.4	(2)	(2)
6	12	7.8	(2)	(2)
7	12	7.8	(2)	(2)
8	9	5.8	(2)	(2)
9	9	5.8	0.6	0.7
10	9	5.8	1.7	2.0
11	8	5.2	2.8	3.2
12	10	6.5	3.7	4.2
13	6	3.9	4.6	5.0
14	6	3.9	5.3	5.7
15	6	3.9	6.0	6.3
16	6	3.9	6.6	6.8
17	6	3.9	7.0	7.1
18	3	1.9	6.9	6.9
19	2	1.3	6.6	6.5
20	2	1.3	6.2	6.1
21	2	1.3	5.8	5.6
22	2	1.3	5.4	5.2
23	2	1.3	5.0	4.7
24	3	1.9	4.5	4.2
25 and up	7	4.5	21.3	19.8
Total	154	100±	100.0	100.0

[1] For the trees with diameters of 18 inches or larger, the decreasing volumes with increasing diameters is due to defect in the large overmature trees.
[2] Negligible.

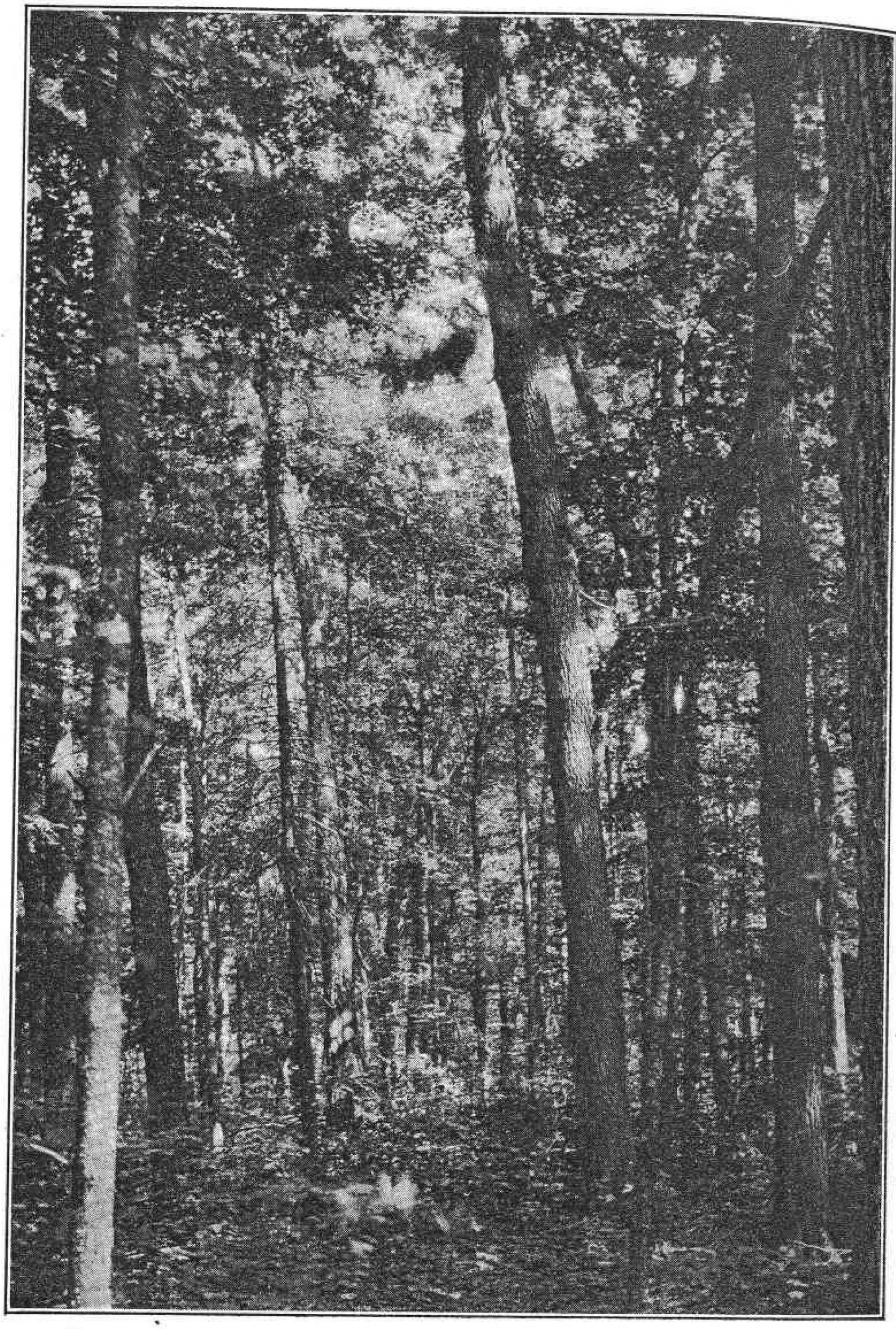

FIGURE 1.—Typical hardwood-hemlock stand of timber in the Lake States

TABLE 4.—*Volume distribution in the stand of the predominant species by diameter classes*

Diameter breast high (inches)	Sugar maple		Yellow birch		Eastern hemlock	
	Gross scale basis	Lumber tally basis	Gross scale basis	Lumber tally basis	Gross scale basis	Lumber tally basis
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
9	68	67	16	15	16	18
10	74	73	14	13	12	14
11	77	77	13	12	10	11
12	79	78	13	12	8	10
13	80	80	13	12	7	8
14	80	80	14	13	6	7
15	81	81	14	13	5	6
16	80	80	15	14	5	6
17	79	80	16	15	5	5
18	78	79	17	16	5	5
19	77	77	18	17	5	6
20	76	77	18	17	6	6
21	75	76	19	18	6	6
22	73	74	20	19	7	7
23	71	72	21	20	8	8
24	70	71	21	20	9	9
25 and up	61	62	19	18	20	20
Log run	74	74	17	16	9	10

The figures in Table 3 show that the hardwood-hemlock forest is made up of trees of all sizes and that although the small trees are large in number their aggregate volume is small. Such a forest is well suited to selective logging.

Since sugar maple, yellow birch, and eastern hemlock are not of equal value, it was necessary to know the proportion of each in the stand before the log-run value of the timber could be computed. (Table 4.)

The log-run costs and lumber values for different cutting limits in this bulletin are based on the distribution of volume and species among the different diameter classes as shown in Tables 3 and 4.

ANNUAL CUT AND FUTURE OF THE INDUSTRY

According to census figures for 1925 the total cut of hardwoods and hemlock in Michigan and Wisconsin is about two billion feet annually. At this rate of production the supply of old timber will last until about 1945.

Figures compiled in 1924 by the Northern Hemlock and Hardwood Manufacturers' Association (*3*) show the future cut of the mills in the Lake States to be as follows: 17 per cent expected to be cut out in 6 years; 25 per cent in 10 years; 29 per cent in 15 years; 17 per cent in 20 years; and 12 per cent to last more than 27 years.

The figures, of course, are based on clear cutting, such as has been practiced in the past. If, on the other hand, some form of forestry is practiced, many of the mills can extend their life for several years, if not indefinitely. The hardwood-hemlock forest in which most of the mills are cutting is an uneven-aged stand containing trees of different sizes and according to the figures in this bulletin does not yield the highest returns when clear cut and manufactured into lumber, but it is ideally adapted to selective cutting. This is fortunate because by selective logging the forest offers to those who still have several years' future cut an opportunity to extend the life of their operations and to produce a high-grade product while they are doing it.

SIZE OF LOGS AND TREES AS A FACTOR IN LUMBER PRODUCTION

WOODS OPERATIONS

DIRECT COST OF LOGGING FOR LOGS OF DIFFERENT DIAMETERS

Lumbermen usually know fairly accurately their logging and milling costs as well as their profit or loss on the basis of log run, which comprises all log sizes. However, when a logger needs data on the cost of producing logs of a certain size he seldom has more than a vague guess to rely upon. The cost of logging, the value of the product, and the profit to the operator depend to a large extent on the size of the timber. It is, therefore, of great economic importance to the operator to know the relation of the size of timber to the cost and value of the lumber produced.

The results of the investigation regarding the effect of the size of the log upon the direct cost of logging are presented in Table 5. The figures in this table are the direct costs for each step of logging per thousand board feet, gross log scale, and exclude supervision, general expense, and investment in railroad, logging road, and camp construction; all of which do not vary with the size of the log or tree.

TABLE 5.—*Direct woods cost per thousand board feet, gross log scale of producing and handling logs of different sizes of all species studied*

[Includes only cost items that vary with the size of the log]

Top diameter inside bark (inches)	Sawing [1]	Skidding	Loading	Railroad operation and maintenance	Unloading	Total
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
6	4.60	8.42	2.14	4.21	0.55	19.92
7	3.87	6.96	1.73	3.95	.43	16.94
8	3.35	5.79	1.42	3.68	.35	14.59
9	2.91	4.74	1.17	3.46	.29	12.57
10	2.60	3.87	.97	3.27	.24	10.95
11	2.34	3.15	.82	3.12	.19	9.62
12	2.16	2.59	.70	2.98	.16	8.59
13	1.99	2.18	.62	2.89	.14	7.82
14	1.88	1.92	.55	2.79	.12	7.26
15	1.77	1.71	.49	2.72	.10	6.79
16	1.69	1.56	.45	2.65	.10	6.45
17	1.62	1.45	.42	2.58	.09	6.16
18	1.57	1.40	.40	2.51	.08	5.96
19	1.52	1.37	.38	2.45	.07	5.79
20	1.47	1.36	.37	2.40	.07	5.67
21	1.43	1.36	.36	2.35	.06	5.56
22	1.40	1.37	.35	2.30	.06	5.48
23	1.37	1.40	.34	2.26	.05	5.42
24	1.35	1.43	.33	2.23	.05	5.39
Log run [2]	2.08	2.56	.69	2.90	.15	8.38

[1] Sawing includes felling, limbing, and bucking.
[2] From companies' figures.

The significant points to be kept in mind in connection with this table are (1) the increased cost of handling small logs as compared with large logs, and (2) the effect of the relative distribution of the cut among log sizes on the log-run cost of logging. With the distribution of log sizes found in these studies the log-run cost was $8.38 a thousand board feet, gross log scale. If a greater proportion of the logs had fallen in the smaller diameter classes the cost would have been higher; on the other hand, if the logs had run larger the logging cost would have been less. This point is well brought out in column 7 of Table 5 in which it is shown that the direct logging cost for 7-inch logs is $16.94 a thousand board feet, gross scale, as compared to $5.39 for 24-inch logs. The figures show, also, that the rate at which the cost of logging decreases with the increase of log diameter is much greater for small than for large logs.

RELATIVE COST OF THE DIFFERENT STEPS OF LOGGING

In every step of logging the total cost per thousand board feet is greater for small than for large logs. The rate at which the cost decreases with the increase in log size varies for the different steps in logging. This variation is illustrated by the 8-inch and 24-inch logs in Table 6, and is the largest for unloading logs and the smallest for railroad operation and maintenance.

TABLE 6.—*Approximate ratio between the direct cost of logging per thousand board feet, log scale, of 8-inch logs and of 24-inch logs*

Items	Ratio	Items	Ratio
Felling, limbing, bucking	2.5	Railroad operation and maintenance	1.6
Skidding	4.0	Unloading	7.0
Loading	4.3	All steps of logging	2.7

To make a close cost analysis of a logging operation requires a knowledge of the cost relation of each step in logging to the total cost when handling logs of different sizes. This relation between the cost of individual steps of logging and the total cost for logs of different sizes is brought out in Table 7. These figures show, for instance, that in handling 8-inch logs skidding is the largest item of expense, while for 24-inch logs railroad operation and maintenance is greatest. If an operator is handling extremely small logs, he should try to reduce the cost of skidding, while if he is handling large logs he should attempt to reduce transportation costs.

TABLE 7.—*Variation of the cost of the separate steps of logging with the size of the log*

Top diameter inside bark (inches)	Cost per thousand board feet, gross log scale, in percentage of total cost of logging for—					
	Sawing	Skidding	Loading	Railroad operation and maintenance	Unloading	Total
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
8	23.0	39.7	9.7	25.2	2.4	100
Log run	24.8	30.6	8.2	34.6	1.8	100
24	25.0	26.6	6.1	41.4	.9	100

THE DIFFERENT STEPS IN LOGGING

SAWING

The felling, limbing, and bucking of trees at the three logging operations studied were done by crews consisting of two men. Log sawyers were paid, as a general rule, on a linear-foot basis without regard to the diameter of the logs cut. Each crew of sawyers was assigned to a strip of timber which averaged about 300 feet in width and about one-fourth mile in length. The trees were usually felled in a haphazard way. Some of the sawyers tried to coordinate felling with skidding. They threw trees preferably in the direction of skidding, or in such a way that the tops of several trees came together in one pile. (Fig. 2, A.) Little care was taken in felling the trees to prevent breakage or injury to the remaining trees. Since slash disposal was not practiced, the tops and limbs were left in loose and irregular piles.

Log lengths varied from 8 feet to 20 feet. Most of the logs, however, were 12, 14, and 16 feet long, the latter predominating. The average length was close to 15 feet which included a trimming allowance of 3 inches.

The instructions to the sawyers as to the top diameter of the last log were not always definite nor strictly enforced. In small hardwood trees the top of the actually utilized bole was equal or even below the required minimum, whereas in large trees the diameter of the last log was much greater than that specified in the sawing instructions.

The smallest top diameter to which, according to company instructions, trees should be cut for lumber varied from 8 inches to 10 inches. Actually the trees were utilized to a top diameter of 6 inches to 14 inches, depending on their size. Since the sawyers were paid a flat rate per linear foot, they cut all the small trees that would pass inspection. For the same reason they cut up as much of the bole of small trees, which required little limbing, as the company would accept and cut as little of the tops of large trees, which required excessive limbing, as the company would allow. In several instances the companies accepted logs 6 inches in diameter, especially of birch, if they were straight, sound, and not knotty, although their instructions called for logs 8 inches in diameter and larger. Occasionally, a small log was rejected. The cut of each sawyer averaged 2,740 board feet, gross log scale, a day.

SKIDDING

Conditions under which skidding was done on the operations studied were typical of the hardwood-hemlock forests, namely, good bottom, fairly clear from obstructions, light underbrush, topography varying from flat to rolling and only occasionally rough. Skidding was done by horses working in single teams. Skidding tongs were used, and generally only one log was taken at a time. Small logs were sometimes skidded two or three at once with a skidding chain.

The railroad spurs were spaced on the average of about one-fourth mile apart and the logs were skidded directly to the railroad. The distance over which the logs were skidded was about 20 per

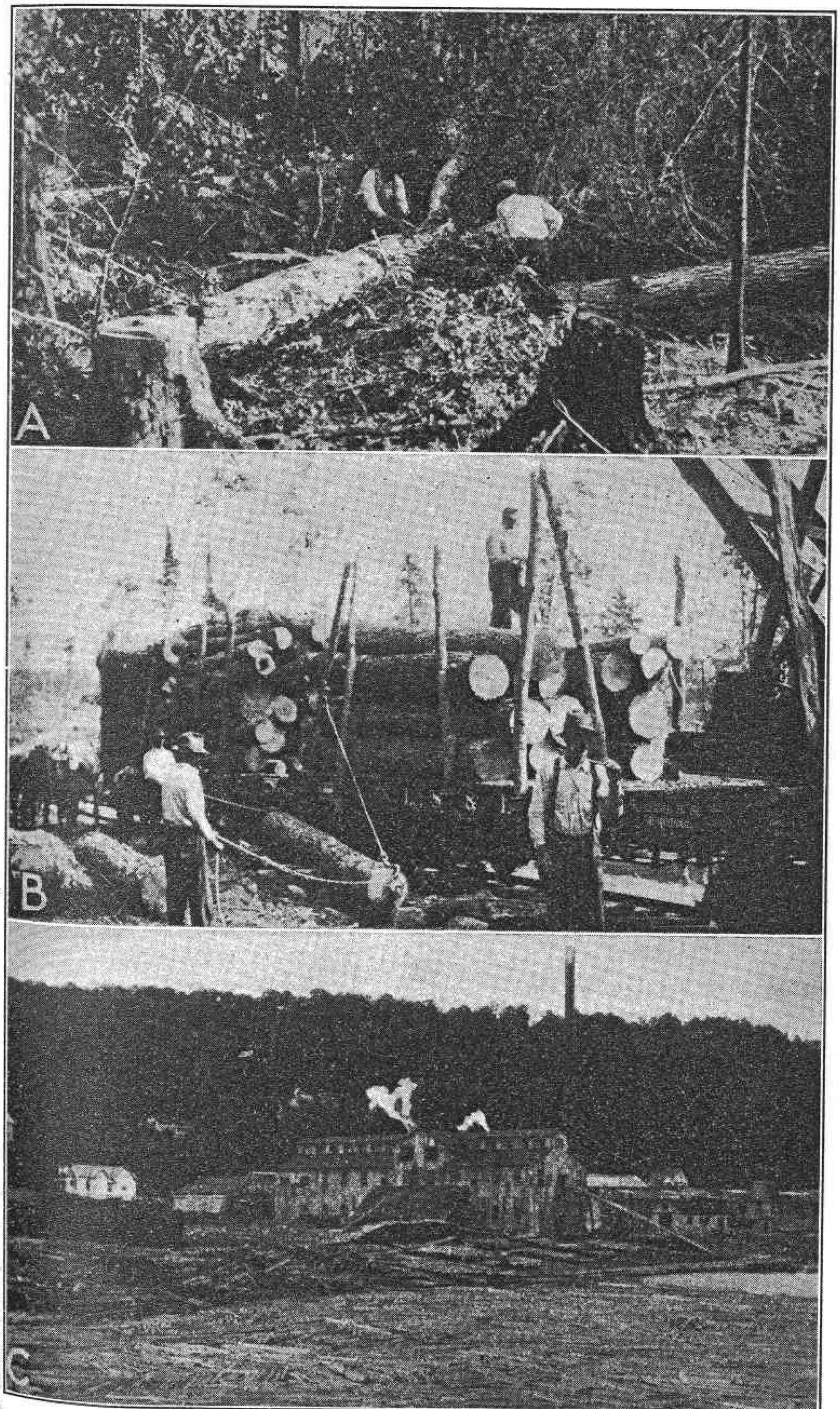

FIGURE 2.—Logging and milling operation in the Lake States: A, Cutting a sugar maple tree into log lengths; B, loading hardwood logs; C, a typical band sawmill

cent longer than the straight distance between the stump and the skidway. The average skidding distance was thus approximately 400 feet.

Skidways were made at some operations on the average of 250 feet apart and the logs piled in one or two tiers equivalent to a carload or more. In other cases no skidways were made, and logs from a given area were skidded direct to the spur tracks at some convenient point, where the cars were spotted and loaded.

LOADING

In all the operations covered by the study, logs were loaded on cars by steam loaders. (Fig. 2, B.) The average carload capacity ranged from 2,000 board feet to 6,000 board feet, gross scale. The loading crew consisted of four to six men. The average output per day varied from 31,000 to 44,000 board feet, gross scale. Large logs were loaded singly; medium and small logs were usually loaded in bundles containing two to five logs. Occasionally from six to seven logs were bundled and loaded at one time.

RAILROAD OPERATION AND MAINTENANCE

Logs were hauled from the woods to the mill at three of the operations over a standard-gage railroad and at the fourth over a narrow gage. With the exception of an 18-mile haul over a common carrier at one operation, the railroads were owned and operated by the companies covered in the study. The railroad haul varied with each operation, the maximum variation being from 18 to 36 miles. At three of the operations ordinary flat cars were used for hauling logs, and stakes made from small trees were used to hold the logs on the cars. One operator used cars equipped with iron car stakes and patent stake-releasing devices. None of the railroad grades were steep enough to require geared engines, so the ordinary type of locomotive was used.

UNLOADING

The last step of logging—that is, unloading logs from cars into the mill pond—required but little work and the cost was relatively small.

Load-holding devices on one side of the car were released which allowed a part of the logs to fall off the car onto the unloading incline where they rolled into the log pond. The rest of the load was then rolled off the car with a cant hook.

DIRECT COST OF LOGGING TREES OF DIFFERENT DIAMETERS

Direct logging costs per thousand board feet for trees of different diameters are shown in Table 8. Since these costs were computed from the costs for logs as explained under "How the work was done" they quite naturally follow similar trends; that is, small trees have a much higher logging cost per thousand board feet than large ones. For example, the total direct cost of logging per thousand board feet for trees 10 inches in diameter is 2.3 times greater than for trees 25 inches in diameter.

TABLE 8.—*Direct woods cost per thousand board feet, gross log scale, of logging trees of different sizes of all species studied*

[Includes only costs that vary with the size of the tree]

Diameter breast high (inches)	Sawing	Skidding	Loading	Railroad operation and maintenance	Unloading	Total
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
8	4.06	7.36	1.64	3.80	0.50	17.36
9	3.68	6.61	1.56	3.72	.46	16.03
10	3.38	5.94	1.46	3.63	.42	14.83
11	3.12	5.30	1.34	3.54	.36	13.66
12	2.91	4.73	1.18	3.45	.32	12.59
13	2.73	4.22	1.06	3.36	.28	11.65
14	2.57	3.76	.95	3.26	.24	10.78
15	2.42	3.36	.80	3.18	.21	9.97
16	2.29	3.00	.79	3.10	.19	9.37
17	2.18	2.67	.72	3.02	.17	8.76
18	2.08	2.41	.67	2.95	.16	8.27
19	1.99	2.19	.62	2.88	.15	7.83
20	1.91	2.00	.58	2.83	.13	7.45
21	1.85	1.88	.55	2.78	.13	7.19
22	1.79	1.76	.52	2.73	.12	6.92
23	1.74	1.66	.49	2.69	.11	6.69
24	1.69	1.57	.47	2.65	.11	6.49
25	1.64	1.51	.46	2.61	.10	6.32
26	1.60	1.46	.44	2.57	.10	6.17
27	1.57	1.43	.44	2.53	.10	6.07
28	1.53	1.39	.43	2.50	.10	5.95
29	1.50	1.38	.43	2.48	.10	5.89
30	1.48	1.31	.43	2.47	.10	5.79
Log run	2.08	2.56	.69	2.90	.15	8.38

OTHER LOGGING COSTS

In addition to the direct costs of logging shown in Tables 7 and 8, there are charges for railroad, logging road, and camp construction, also woods supervision, woods general expense, and taxes and insurance on logs; all of which are here termed other costs. These costs are listed in detail on page 7, and average $4.67 a thousand board considered as constant per acre, and are not influenced by the size of the timber except as overrun varies with trees of different sizes. These costs, however, vary directly per thousand board feet with the amount cut per acre.

TOTAL LOGGING COST

The total logging cost can be readily obtained by adding the other costs of $4.67 to the direct costs of $8.38, which are given in Table 5, making a total log-run logging cost of $13.05 a thousand board feet, gross log scale.

The log-run logging cost for each size of log or tree may be obtained by adding together the other costs and the direct logging costs of each diameter class. Such a computation, of course, assumes that the other costs are the same for individual diameters as for log run.

OVERRUN AFFECTS THE COST OF LUMBER MANUFACTURE

Before the total cost of lumber manufacture can be computed in board measure it is necessary to convert the logging costs from a log scale to a lumber-tally basis. This is done by applying an overrun figure.

Gross overrun is the amount by which the lumber tally exceeds the gross log scale. It occurs because the efficiency of the mill doing the work and the proportion of four-quarter-inch and eight-quarter-inch stock that is sawed can not be anticipated by the Scribner rule. Furthermore, the rule itself does not give consistent results for all diameters.

Table 9 gives the gross overrun for logs and trees of different diameters for all the species investigated. Overrun varies among species, but this fact has been taken into account and need not be considered here. For those interested in this phase, tables of net (gross scale minus deduction for defect) and gross overrun by species are given under "Supplementary information."

TABLE 9.—*Variation in gross overrun for logs and trees of different diameters for all species studied*

Logs				Trees			
Top diameter inside bark (inches)	Gross overrun (all species together)	Top diameter inside bark (inches)	Gross overrun (all species together)	Diameter breast high (inches)	Gross overrun (all species together)	Diameter breast high (inches)	Gross overrun (all species together)
	Per cent		*Per cent*		*Per cent*		*Per cent*
7	49.4	15	13.1	9	42.0	18	18.2
8	39.2	16	11.4	10	38.5	19	16.6
9	33.1	17	9.6	11	35.3	20	15.3
10	27.7	18	7.9	12	32.4	21	13.8
11	23.0	19	6.2	13	29.7	22	12.6
12	19.5	20	4.8	14	27.1	23	11.2
13	16.7	Log run	18.1	15	24.5	24	10.1
14	14.8			16	22.2	25	9.5
				17	20.3	Log run	18.1

Table 9 shows that overrun is greater in small logs and small trees than in large ones. Small logs and small trees yield more lumber per thousand board feet, log scale, than large ones, and in this way compensate to a considerable extent the normally greater cost of logging them; but even after this credit they are more costly to handle than large logs or trees. The following example illustrates this point:

The direct logging cost for 8-inch logs (Table 5) is $14.59 a thousand board feet, gross scale, or 2.6 times greater for 20-inch logs which cost only $5.67. The gross overrun for 8-inch logs is 39.2 per cent (Table 9) and for 20-inch logs 4.8 per cent. Reducing the above direct logging costs to a lumber tally basis by dividing them by 1 plus the overrun, they become $10.48 and $5.41, respectively. In terms of lumber tally the logging cost per thousand board feet for 8-inch logs is therefore only 1.9 times greater for 20-inch logs, as compared to the ratio of 2.6 on a gross log-scale basis.

The logging costs reduced to a lumber-tally basis given later in this bulletin were computed as illustrated by the following example:

Total log-run logging cost per thousand board feet, gross log scale	$13.05
Gross overrun for the log run in per cent	18.1
Total log-run logging cost per thousand board feet, lumber tally ($13.05 ÷ 1.181)	11.05

MILLING OPERATIONS

MILLING PRACTICE

The four sawmills at which the milling study was made were typical of the region. (Fig. 2, C.) They were equipped with one or more 6-foot to 8-foot band head saws and one 4-foot to 6-foot band resaw of either the vertical or the horizontal type, each cutting approximately 1/8-inch kerf.

With the large logs the general practice at the mills studied was to turn them on the carriage and saw either into standard lumber or into cants or flitches in a manner caluculated to produce lumber of the highest grade. Since most small logs yield little or none of the higher grades of lumber they were usually not turned on the carriage but were sawed through and through into flitches or lumber without particular regard to resultant grades. Sometimes small logs and the hearts of large logs were cut into ties. In such cases the lumber in them was graded as No. 3 Common. The logs varied in size from 7 to 20 inches in diameter and averaged about 12 inches.

Hardwoods were cut from four-quarter inch to twelve-quarter inch in thickness according to the anticipated or current market demand. Rough green dimensions of hardwoods for four-quarter-inch material were on the average one-eighth of an inch in excess of standard thickness, and widths were random. Eastern hemlock was largely sawed into thicknesses greater than four-quarter inch for dimension purposes. Six thirty-seconds of an inch in excess of yard standard thicknesses and from one-quarter inch to one-half inch in excess of the yard standard width were normally allowed in manufacturing eastern hemlock to compensate for shrinkage, sawing variation, and surfacing.

All lumber companies graded and tallied their lumber on the green chain. Sorting was done on the basis of green-chain grades, which did not necessarily correspond to standard grades, but in some cases were a combination, for example, No. 1 Common and Selects were often put in the same grade.

Lumber was piled separately by thicknesses, grades, and species. It was either kiln dried or air seasoned.

TOTAL MILLING COST FOR LOGS AND TREES OF DIFFERENT DIAMETERS

Sawmills in the Lake States are ordinarily manned and equipped in accordance with the output of the head saw. There must be sufficient men and machines behind it to take care of the lumber. When output at the head saw is at the maximum, all the machines and men are extremely busy; when output drops, the crew and equipment work at lower speed, but their hourly cost remains the same and hence the cost per thousand board feet of lumber increases. Such a variation in output occurs when sawing logs of different sizes because the output is heavy when sawing large logs and light when sawing small logs. The cost of sawing was therefore based on the comparative time required to saw 1,000 board feet of lumber at the head saw from logs of different diameters.

TABLE 12.—*Grades of lumber and average value by diameter classes for sugar maple logs*

Top diameter inside bark (inches)	Percentage of lumber in green condition of grade—					Value per thousand feet, board measure	
	FAS	Select	No. 1 Common	No. 2 Common	No. 3 Common	Green [1]	Dry [2]
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Dollars*	*Dollars*
7			4.3	14.9	80.8	21.10	20.04
8		0.1	7.6	15.9	76.4	22.64	21.51
9	0.2	1.3	10.7	16.6	71.2	24.75	23.51
10	1.1	2.5	13.5	16.8	66.1	27.11	25.75
11	2.5	3.5	16.1	17.0	60.9	29.59	28.11
12	4.1	4.6	18.5	16.8	56.0	32.11	30.50
13	5.9	5.6	20.8	16.6	51.1	34.66	32.93
14	7.6	6.6	23.0	15.9	46.9	37.03	35.18
15	9.2	7.5	25.3	15.3	42.7	39.34	37.37
16	10.7	8.5	27.6	14.2	39.0	41.56	39.48
17	12.3	9.4	29.6	13.1	35.6	43.67	41.49
18	13.9	10.1	31.4	12.2	32.4	45.62	43.34
19	15.3	10.9	32.7	11.4	29.7	47.32	44.95
20	16.7	11.6	33.5	10.7	27.5	48.78	46.34
Log run	7.0	6.1	22.6	15.0	49.3	36.08	34.28

[1] Dry values based on volume when green and on the following prices f. o. b. shipping point: FAS, $80; Select, $70; No. 1 Common, $57; No. 2 Common, $33; No. 3 Common, $17.
[2] Dry value was obtained by reducing the green value 5 per cent to cover the loss caused by degrade and shrinkage during drying.

TABLE 13.—*Grades of lumber and average value by diameter classes for sugar maple trees*

Diameter breast high (inches)	Percentage of lumber in green condition of grade—					Value per thousand feet, board measure	
	FAS	Select	No. 1 Common	No. 2 Common	No. 3 Common	Green [1]	Dry [2]
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Dollars*	*Dollars*
9		0.6	8.2	12.3	78.9	22.57	21.44
10		1.2	9.6	13.5	75.7	23.64	22.46
11	0.4	1.7	10.9	14.5	72.5	24.83	23.59
12	.9	2.1	12.3	15.3	69.4	26.05	24.75
13	1.4	2.8	13.7	15.8	66.3	27.37	26.00
14	2.3	3.2	15.1	16.0	63.4	28.74	27.30
15	3.2	3.6	16.4	16.2	60.6	30.08	28.58
16	4.1	4.2	17.7	16.1	57.9	31.46	29.89
17	5.0	4.7	18.8	16.1	55.4	32.74	31.10
18	5.8	5.2	20.3	15.9	52.8	34.07	32.37
19	6.6	5.6	21.8	15.8	50.2	35.37	33.60
20	7.5	6.0	23.1	15.7	47.7	36.66	34.83
21	8.3	6.6	24.3	15.5	45.3	37.93	36.03
22	9.1	7.1	25.5	15.3	43.0	39.14	37.18
23	10.0	7.6	26.6	15.0	40.8	40.37	38.35
24	10.9	8.1	27.6	14.6	38.8	41.54	39.46
25	11.8	8.6	28.7	14.1	36.8	42.73	40.59

[1] Dry values based on volume when green and on the following prices f. o. b. shipping point: FAS, $80; Select, $70; No. 1 Common, $57; No. 2 Common, $33; No. 3 Common, $17.
[2] Dry value was obtained by reducing the green value 5 per cent to cover the loss caused by degrade and shrinkage during drying.

TABLE 14.—*Grades of lumber and average value by diameter classes for yellow birch logs*

Top diameter inside bark (inches)	Percentage of lumber in green condition of grade—					Value per thousand feet, board measure	
	FAS	Select	No. 1 Common	No. 2 Common	No. 3 Common	Green [1]	Dry
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Dollars*	*Dollars*
7	------	------	5. 8	20. 3	73. 9	23. 93	22. 73
8	0. 7	1. 0	8. 7	20. 0	69. 6	26. 23	24. 92
9	1. 6	2. 1	11. 6	19. 6	65. 1	28. 76	27. 32
10	2. 7	3. 2	14. 2	19. 2	60. 7	31. 37	29. 80
11	3. 9	4. 2	16. 7	18. 8	56. 4	33. 96	32. 26
12	5. 6	5. 4	19. 0	18. 4	51. 6	37. 08	35. 23
13	7. 5	6. 4	20. 7	18. 0	47. 4	40. 02	38. 02
14	9. 8	7. 5	22. 2	17. 6	42. 9	43. 32	41. 15
15	12. 2	8. 6	23. 4	17. 2	38. 6	46. 61	44. 28
16	14. 6	9. 6	24. 7	16. 8	34. 3	49. 87	47. 38
17	17. 2	10. 6	26. 1	16. 4	29. 7	53. 34	50. 67
18	20. 0	11. 7	27. 5	16. 0	24. 8	57. 06	54. 21
19	23. 3	12. 8	28. 8	15. 6	19. 5	61. 20	58. 14
20	27. 3	14. 0	30. 1	15. 2	13. 4	66. 05	62. 75
Log run	12. 1	7. 6	22. 2	16. 7	41. 4	45. 36	43. 09

[1] Dry values based on volume when green and on the following prices f. o. b. shipping point: FAS, $110; Select, $85; No. 1 Common, $55; No. 2 Common, $33; No. 3 Common, $19.
[2] Dry value was obtained by reducing the green value 5 per cent to cover the loss caused by degrade and shrinkage during drying.

TABLE 15.—*Grades of lumber and average value by diameter classes for yellow birch trees*

Diameter breast high (inches)	Percentage of lumber in green condition of grade—					Value per thousand feet, board measure	
	FAS	Select	No. 1 Common	No. 2 Common	No. 3 Common	Green [1]	Dry [2]
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Dollars*	*Dollars*
9	0. 5	0. 5	6. 9	24. 4	67. 7	25. 68	24. 40
10	1. 3	1. 2	9. 0	22. 5	66. 0	27. 36	25. 99
11	2. 2	1. 8	11. 1	20. 7	64. 2	29. 08	27. 63
12	3. 1	2. 6	13. 0	19. 4	61. 9	30. 93	29. 38
13	4. 0	3. 2	14. 6	18. 3	59. 9	32. 57	30. 94
14	4. 8	3. 8	15. 9	17. 5	58. 0	34. 05	32. 35
15	5. 7	4. 5	16. 9	17. 1	55. 8	35. 64	33. 86
16	6. 6	4. 9	18. 0	16. 8	53. 7	37. 07	35. 22
17	7. 4	5. 3	18. 8	16. 6	51. 9	38. 32	36. 40
18	8. 3	5. 8	19. 5	16. 7	49. 7	39. 74	37. 75
19	9. 2	6. 2	20. 1	16. 7	47. 8	41. 04	38. 99
20	10. 0	6. 7	20. 8	16. 8	45. 7	42. 36	40. 24
21	11. 0	7. 2	21. 5	16. 9	43. 4	43. 87	41. 68
22	12. 1	7. 7	22. 4	16. 9	40. 9	45. 52	43. 24
23	13. 3	8. 2	23. 4	16. 9	38. 2	47. 30	44. 94
24	14. 5	8. 9	24. 3	16. 9	35. 4	49. 18	46. 72
25	16. 2	9. 6	25. 4	16. 9	31. 9	51. 59	49. 01

[1] Dry values based on volume when green and on the following prices f. o. b. shipping point: FAS, $110; Select, $85; No. 1 Common, $55; No. 2 Common, $33; No. 3 Common, $19.
[2] Dry value was obtained by reducing the green value 5 per cent to cover the loss caused by degrade and shrinkage during drying.

TABLE 16.—*Grades of lumber and average value by diameter classes for eastern hemlock logs*

Top diameter inside bark (inches)	Percentage of lumber in green condition of grade—			Value per thousand feet, board measure	
	Merchantable	No. 3 Common	No. 4 Common	Green [1]	Dry [2]
	Per cent	*Per cent*	*Per cent*	*Dollars*	*Dollars*
7	60.8	35.4	3.8	23.22	22.52
8	60.8	34.7	4.5	23.18	22.48
9	60.8	34.0	5.2	23.13	22.44
10	61.0	33.3	5.7	23.12	22.43
11	61.3	32.6	6.1	23.12	22.43
12	61.8	31.9	6.3	23.15	22.46
13	62.3	31.2	6.5	23.18	22.48
14	62.8	30.5	6.7	23.22	22.52
15	63.3	29.8	6.9	23.25	22.55
16	63.8	29.1	7.1	23.28	22.58
17	64.3	28.4	7.3	23.31	22.61
18	64.9	27.7	7.5	23.34	22.64
19	65.3	27.0	7.7	23.38	22.68
20	65.8	26.3	7.9	23.41	22.71
Log run	61.7	31.9	6.4	23.14	22.45

[1] Dry value based on volume when green and on the following prices f. o. b. shipping point: Merchantable, $27; No. 3 Common, $18; No. 4 Common, $11.50.

[2] Dry value was obtained by reducing the green value 3 per cent to cover the loss caused by degrade and shrinkage during drying.

TABLE 17.—*Grades of lumber and average value by diameter classes for eastern hemlock trees*

Diameter breast high (inches)	Percentage of lumber in green condition of grade—			Value per thousand feet, board measure	
	Merchantable	No. 3 Common	No. 4 Common	Green [1]	Dry [2]
	Per cent	*Per cent*	*Per cent*	*Dollars*	*Dollars*
9	60.8	35.8	3.4	23.25	22.55
10	60.8	35.4	3.8	23.22	22.52
11	60.8	35.0	4.2	23.20	22.50
12	60.9	34.6	4.5	23.19	22.49
13	60.9	34.2	4.9	23.16	22.47
14	61.0	33.8	5.2	23.15	22.46
15	61.2	33.2	5.6	23.14	22.45
16	61.3	32.9	5.8	23.14	22.45
17	61.7	32.4	5.9	23.17	22.47
18	61.8	32.1	6.1	23.17	22.47
19	62.1	31.6	6.3	23.18	22.48
20	62.5	31.0	6.5	23.20	22.50
21	62.7	30.8	6.5	23.22	22.52
22	63.1	30.2	6.7	23.24	22.54
23	63.4	29.8	6.8	23.26	22.56
24	63.6	29.4	7.0	23.27	22.57
25	64.0	29.0	7.0	23.30	22.60

[1] Dry value based on volume when green and on the following prices f. o. b. shipping point: Merchantable, $27; No. 3 Common, $18; No. 4 Common, $11.50.

[2] Dry value was obtained by reducing the green value 3 per cent to cover the loss caused by degrade and shrinkage during drying.

In all comparisons of lumber values the value of the lumber when in a dry condition has been used although the lumber was graded when in a green condition. The percentage of upper grades in lumber in a green condition is higher than in seasoned lumber because any defects due to drying have not appeared. Therefore, a reduction of 5 per cent in value for sugar maple and yellow birch and 3 per cent for eastern hemlock from the average value of the lumber in a green condition has been made. This reduction is not based on comprehensive tests, because they are not available, but is based on judgment and merely represents the best estimate obtainable.

SUGAR MAPLE

In sugar maple, for example (Table 12), logs 8 inches in diameter saw out no FAS.[8] They have, however, a large percentage of No. 3 Common with the result that the lumber from these logs at the 1925–26 prices was worth only $21.51 a thousand board feet. On the other hand, logs 20 inches in diameter yield over 28 per cent FAS and Selects, and in consequence the lumber was worth $46.34 a thousand board feet. Similarly, lumber produced from sugar maple trees 9 inches in diameter (Table 13) was worth only $21.44 per thousand board feet, while that from trees 25 inches in diameter was worth $40.59 per thousand board feet, because of the higher grades of lumber obtainable from the larger trees.

YELLOW BIRCH

The grades and value of lumber from yellow birch logs and trees show the same relative trend as in sugar maple. (Tables 14 and 15.)

GRADES OF SUGAR MAPLE AND YELLOW BIRCH COMPARED

There is, however, considerable difference both in quality and value of the lumber obtainable from yellow birch and sugar maple logs of the same size. In yellow birch high-grade lumber can be obtained from smaller logs and trees and in greater quantities than from sugar maple. Table 18 is a direct comparison of the average grades and value of lumber from 14-inch logs of the two species and clearly brings out this point.

TABLE 18.—*Comparison of the average grades and value of lumber from 14-inch logs of yellow birch and sugar maple*

Species	Percentage of lumber of grade—					Value per thousand feet, board measure, dry lumber
	FAS	Select	No. 1 Common	No. 2 Common	No. 3 Common	
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Dollars*
Sugar maple	7.6	6.6	23.0	15.9	46.9	35.18
Yellow birch	9.8	7.5	22.2	17.6	42.9	41.15

EASTERN HEMLOCK

The grades of lumber from eastern hemlock logs and trees of different diameters (Tables 16 and 17) follow a different trend than

[8] Firsts and Seconds—a combined grade of the two upper grades of hardwoods.

that indicated in the hardwoods. The size of the eastern hemlock logs only moderately affects the amount of lumber that falls in the upper grades. An eastern hemlock log 8 inches in diameter contains about 61 per cent merchantable lumber (50 per cent No. 1 Common and 50 per cent No. 2 Common), whereas a log 20 inches in diameter contains 66 per cent merchantable lumber, or an increase of only 5 per cent. The increase in the high grades of lumber for the same diameter classes of either sugar maple or yellow birch is from two to three times as great as that from eastern hemlock. The grades in the hardwoods and eastern hemlock are, of course, not closely comparable, yet this comparison shows that the advantage of milling large logs over small logs is not so apparent in hemlock as in the hardwoods. Moreover, this comparison indicates that small eastern hemlock logs, on the basis of the value of the final product, can be handled to a better advantage than small hardwood logs.

LUMBER VALUE AND PRODUCTION COST COMPARED

LOG-RUN LUMBER VALUE AND PRODUCTION COST

The average value of the lumber, weighted according to the volume in each diameter class and the proportion of each species in the stand (Table 4), is $33.08 per thousand feet, board measure.

The average production cost was $23.87 a thousand feet, board measure (p. 21). Subtracting the cost of production, when all trees 9 inches and larger in diameter are cut, from the lumber value leaves $9.21 per thousand board feet to cover the cost of stumpage and to provide a margin for profit and risk.

LUMBER VALUE AND PRODUCTION COST FOR LOGS AND TREES OF DIFFERENT DIAMETERS

Frequently it is desirable to know the spread between the production cost and the lumber value for trees and logs of different diameters. For this reason the cost of producing lumber (exclusive of permanent improvements, woods supervision, general expense, taxes, and insurance on logs) and its value by diameter classes for logs and trees, all species together, is given in Tables 19 and 20.

These tables show that logs must be somewhat greater than 9 inches in diameter inside the bark and trees must be about 11½ inches in diameter breast high before the lumber obtained from them is worth more than the cost of producing it, not including the charges for permanent improvements, general expense, supervision, taxes, and insurance on logs.

TABLE 19.—*Lumber production cost*[1] *per thousand board feet, lumber tally, and value of lumber for logs of different diameters of all species studied*

[Includes items that vary with the size of log or are constant per thousand board feet]

Top diameter inside bark (inches)	Logging cost[1]	Milling cost	Total lumber production cost	Value of dry lumber	Difference between total lumber production cost and value of dry lumber
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*
7	11.55	15.12	26.67	21.09	−5.58
8	10.50	15.57	26.07	22.04	−4.03
9	9.46	14.94	24.40	23.90	−.50
10	8.57	14.20	22.77	26.22	+3.45
11	7.83	13.48	21.31	28.76	7.45
12	7.21	13.02	20.23	31.27	11.04
13	6.70	12.74	19.44	33.64	14.20
14	6.33	12.49	18.82	35.58	16.76
15	5.99	12.29	18.28	37.63	19.35
16	5.79	12.06	17.85	39.50	21.65
17	5.62	11.80	17.42	41.16	23.74
18	5.53	11.50	17.03	42.40	25.37
19	5.45	11.24	16.69	43.41	26.72
20	5.40	10.12	15.52	38.98	23.46
Log run	7.10	12.82	19.92	33.08	13.16

[1] Excluding permanent improvements, supervision, general expense, taxes, and insurance on logs.

TABLE 20.—*Lumber production cost*[1] *per thousand board feet, lumber tally, and value of lumber for trees of different diameters of all species studied*

[Includes items that vary with the size of tree or are constant per thousand board feet]

Diameter breast high (inches)	Logging cost[1]	Milling cost	Total lumber production cost	Value of dry lumber	Difference between total lumber production cost and value of dry lumber
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*
9	11.29	15.45	26.74	22.08	−4.66
10	10.71	15.15	25.86	22.93	−2.93
11	10.10	14.90	25.00	23.95	−1.05
12	9.51	14.57	24.08	25.08	+1.00
13	8.98	14.27	23.25	26.31	3.06
14	8.48	13.92	22.40	27.62	5.22
15	8.01	13.58	21.59	28.90	7.31
16	7.67	13.31	20.98	30.19	9.21
17	7.28	13.09	20.37	31.46	11.09
18	7.00	12.87	19.87	32.74	12.87
19	6.72	12.66	19.38	33.85	14.47
20	6.46	12.52	18.98	35.01	16.03
21	6.32	12.38	18.70	36.24	17.54
22	6.15	12.21	18.36	37.31	18.95
23	6.02	12.04	18.06	38.40	20.34
24	5.89	11.91	17.80	39.39	21.59
25 and up	5.51	11.41	16.92	38.51	21.59
Log run	7.10	12.82	19.92	33.08	13.16

[1] Excluding permanent improvements, supervision, general expense, taxes, and insurance on logs.

In actual practice it is impossible to distribute the cost of permanent improvements by tree-diameter classes, as was done with the direct charges, since such expenditures, although constant per acre, vary per thousand board feet in accordance with diameter cutting limits; that is, with the total amount of timber removed from the land. Often, however, it is desirable to know the minimum size of tree that will pay its way. One method of arriving at an answer to this question is to allot arbitrarily to each diameter class the average cost per thousand board feet of permanent improvements, supervision, taxes, insurance, and general expense for the stand as a whole. When these costs amounting to $3.95 per thousand board feet, lumber tally, are taken into account the differences for individual diameter classes, which are given in the last column of Tables 19 and 20, show that in order to pay its way a log must be about 10¼ inches in diameter and a tree about 13½ inches in diameter breast high.

APPLICATION OF RESULTS TO SELECTIVE LOGGING

CUTTING TO A DIAMETER LIMIT

With a knowledge of the volume, value, and cost of producing lumber by diameter classes, it is possible to compute the results when only a certain proportion of the trees in a stand are cut. Removing only a part of the stand is exactly what takes place under selective logging, the chief aim of which is to remove at the lowest cost the greatest value with the least volume and at the same time keep the stand in a healthy growing condition.

EFFECT OF DIFFERENT DIAMETER CUTTING LIMITS ON THE VARIOUS COST FACTORS OF LUMBER PRODUCTION

Before considering cutting limits, it is worth while to note how the various factors in lumber production are affected when the smaller trees are not cut. (Table 21.) It has been shown that, when all trees 9 inches in diameter and larger are cut, the direct logging cost is $7.10, the milling $12.82, and the permanent improvements $3.95, making a total of $23.87 per thousand feet, board measure. Under like conditions the lumber is worth $33.08 per thousand board feet. Supposing, however, that only trees 13 inches and larger in diameter, instead of all trees 9 inches and larger, are cut, then the direct woods costs decrease 36 cents per thousand board feet, the milling cost declines 22 cents, while the value of the lumber increases $1.01, making a total gain of $1.59 per thousand board feet. Owing to a decrease in the amount of timber cut per acre, however, the permanent improvement costs have increased 51 cents per thousand board feet so that the net gain due to leaving all trees of 12-inch and smaller diameters on the ground is $1.59 minus 51 cents or $1.08 a thousand board feet. Similar calculations apply to all the items in the last column of Table 21.

TABLE 21.—*Effect of cutting to different diameter limits upon various cost factors per thousand feet, board measure, of lumber production*

Cutting to a diameter limit, breast high (inches)	Decrease in production costs		Increase in lumber value	Total increase in returns	Increase in cost of permanent improvements	Net increase in profits
	Woods (excluding permanent improvements)	Mill				
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
9 and up	0.00	0.00	0.00	0.00	0.00	0.00
10 and up	.03	.01	.08	.12	.04	.08
11 and up	.10	.06	.29	.45	.13	.32
12 and up	.21	.13	.61	.95	.28	.67
13 and up	.36	.22	1.01	1.59	.51	1.08
14 and up	.46	.32	1.47	2.25	.77	1.48
15 and up	.60	.42	1.97	2.99	1.13	1.86
16 and up	.72	.52	2.50	3.74	1.60	2.14
17 and up	.85	.63	3.05	4.53	2.19	2.34
18 and up	.97	.74	3.61	5.32	2.94	2.38
19 and up	1.09	.84	4.13	6.06	3.89	2.17
20 and up	1.20	.94	4.62	6.76	5.04	1.72

Since the hardwood-hemlock forest is ideally adapted to selective logging the question arises, what diameter limit of cutting yields the highest profit per thousand board feet and per acre?

CUTTING TREES 18 INCHES IN DIAMETER AND LARGER GIVES THE HIGHEST RETURN PER THOUSAND BOARD FEET

For the conditions studied, the highest profit per thousand board feet occurs when only trees 18 inches in diameter and larger are cut. (Table 22.) This means that the lumberman who plans on a second cut makes the most money from what he cuts when he leaves uncut all trees below 18 inches in diameter.

TABLE 22.—*Total cost of production and returns per thousand feet, board measure, by cutting to different diameter limits*

Cutting to a diameter limit, breast high (inches)	Production cost			Value of lumber	Difference between total production cost and value of lumber [1]
	Woods	Mill	Total		
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*
9 and up	11.05	12.82	23.87	33.08	9.21
10 and up	11.06	12.81	23.87	33.16	9.29
11 and up	11.08	12.76	23.84	33.37	9.53
12 and up	11.12	12.69	23.81	33.69	9.88
13 and up	11.20	12.60	23.80	34.09	10.29
14 and up	11.36	12.50	23.86	34.55	10.69
15 and up	11.58	12.40	23.98	35.05	11.07
16 and up	11.93	12.30	24.23	35.58	11.35
17 and up	12.39	12.19	24.58	36.13	11.55
18 and up	13.02	12.08	25.10	36.69	11.59
19 and up	13.85	11.98	25.83	37.21	11.38
20 and up	14.89	11.88	26.77	37.70	10.93

[1] Available for stumpage and profit.

The following example illustrates the manner in which the results in this table were calculated:

It is desired to compute the woods cost when only trees 12 inches in diameter and larger are cut. When 100 per cent of the stand (trees 9 inches and larger in diameter) is cut, the logging cost is $11.05 (p. 7). Table 3 shows that the 9-inch diameter class contains 0.7 per cent, the 10-inch class 2.0 per cent, and the 11-inch class 3.2 per cent of the entire stand cut, thus making a total of 5.9 per cent. Therefore, if only the trees 12 inches in diameter and larger are cut, only 94.1 per cent of the total volume is removed. The direct log-run cost of logging under this diameter limit is determined by subtracting from the total direct cost of $7.10 (Table 20) the cost of cutting these smaller diameters and dividing the result by 94.1, the percentage of the total volume removed. The computation follows:

0.7 per cent×11.29 (Table 20)	=$0.079
2.0 per cent×10.71 (Table 20)	= .214
3.2 per cent×10.10 (Table 20)	= .323
Total	= .616

$\frac{\$7.10-\$0.616}{94.1}$=$6.89 per thousand board feet, lumber tally. To this must be added taxes and insurance on logs, which amount to 20 cents, gross log scale (p. 7), or 17 cents lumber tally, making a total of $7.06. There remains the cost of permanent improvements, general expense, and supervision. The log-run cost, when all timber 9 inches in diameter and larger is cut, is $3.78 lumber tally. If only trees 12 inches and larger are cut the overrun declines to 17.1 per cent, with the result that the other costs become $3.82 instead of $3.78. But only 94.1 per cent of the stand was cut, so these costs will increase ($3.82—94.1) to $4.06 per thousand feet, board measure. By adding to this figure the direct costs of $7.06, the total logging cost becomes $11.12 per thousand board feet when all trees below 12 inches in diameter are left uncut. The other figures in Table 22 were computed similarly.

Reference to Table 22 shows that the total production cost per thousand feet, board measure, varies but little with the change in cutting limits until a diameter of 16 inches is reached. Up to this diameter the decreased cost of felling, bucking, milling, and the like, is just about offset by the increased costs of permanent improvements, general expense, and woods supervision. Above this diameter for the next 2 inches the total production increases moderately. However, the quality of the lumber is steadily improved, so that the increasing production cost is more than offset by the greater value of the lumber until a diameter limit of 18 inches is reached. This is shown by the steady increase in the difference between production cost and the value of the lumber from $9.21, corresponding to a diameter cutting limit of 9 inches, to $11.59 at 18 inches. Above this point the difference decreases, because in cutting to the larger diameter limits the volume per acre is so reduced as to greatly increase the cost per thousand board feet of permanent improvements, general expense, and woods supervision.

CUTTING TREES 12 INCHES IN DIAMETER AND LARGER GIVES THE HIGHEST RETURN PER ACRE

The greatest profit per acre was found to occur on the standard lumber operations when only trees 12 inches in diameter and larger were cut. (Table 23.) This means that the lumberman who does not plan on a second cut makes the most money from his operation when he leaves uncut all trees below 12 inches in diameter. In addition, the cut-over land has a higher potential value, because the nucleus for a future cut remains on the ground and the presence of even small trees adds to its value for recreational purposes. (Fig. 3.)

TABLE 23.—*Effect of different cutting limits on the returns per acre*

Cutting to a diameter limit, breast high (inches)	Amount cut per acre	Difference between total production cost and value of lumber per thousand feet, board measure	Total returns per acre [1]	Cutting to a diameter limit, breast high (inches)	Amount cut per acre	Difference between total production cost and value of lumber per thousand feet, board measure	Total returns per acre [1]
	Board feet	*Dollars*	*Dollars*		*Board feet*	*Dollars*	*Dollars*
9 and up	15,851	9.21	145.99	15 and up	12,554	11.07	138.97
10 and up	15,740	9.29	146.22	16 and up	11,555	11.35	131.15
11 and up	15,423	9.53	146.98	17 and up	10,478	11.55	121.02
12 and up	14,916	9.88	147.37	18 and up	9,352	11.59	108.39
13 and up	14,250	10.29	146.63	19 and up	8,258	11.38	93.98
14 and up	13,457	10.69	143.86	20 and up	7,228	10.93	79.00

[1] Cost of stumpage and margin for profit and risk must be paid out of these returns.

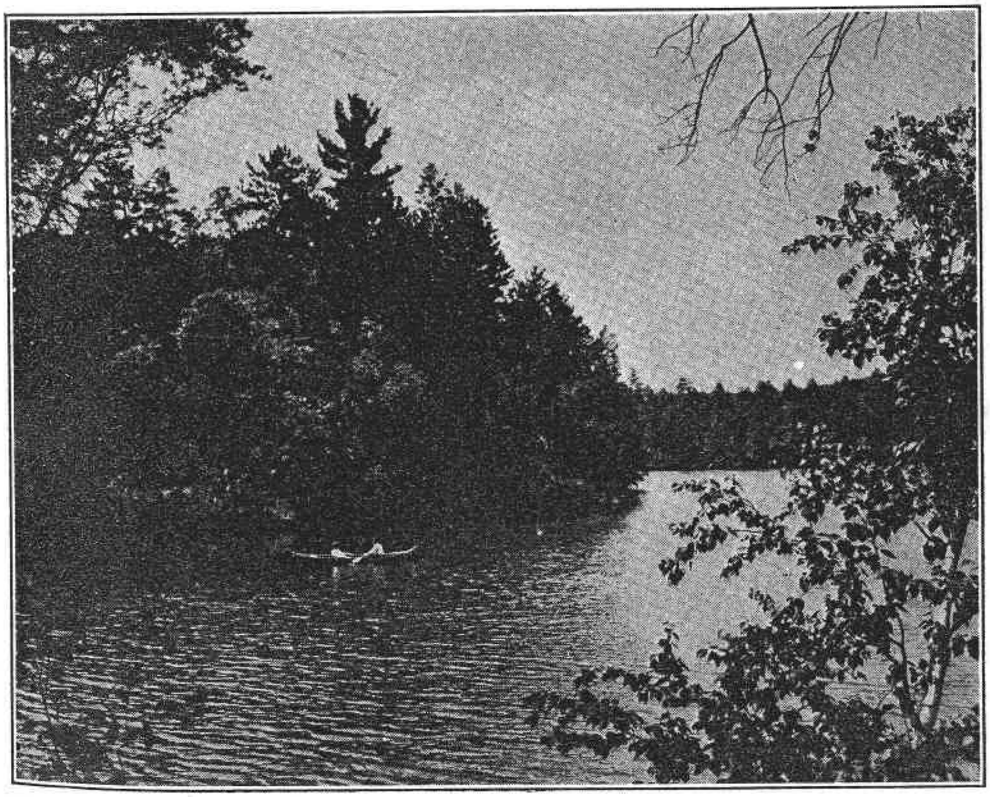

FIGURE 3.—Selective logging leaves the land covered with trees, which adds to the value of the land for recreational purposes

These results are conservative, since they are based on the assumption that woods supervision and general expense increase under selective logging. If, instead, these costs were considered as varying with the output of the woods crews, they would decrease as the diameter cutting limit increased. In such an event the difference between the returns per acre when cutting all merchantable trees and when cutting only trees 12 inches in diameter and larger would be about twice as large as shown. Furthermore, the total cost of permanent improvements has been charged to the first cut. Under selective logging the established railroad grades could be used, in part at least, for each successive cut, and in this way cheapen the production cost.

Under different conditions, diameter cutting limits other than 12 inches, which give the greatest return per acre, or 18 inches, which give the greatest return per thousand board feet, may be more satisfactory. Such limits can be set up by the operator with the aid of the information in this bulletin. It is not the purpose, however, to convey the idea that these are the only two cutting limits that need to be taken into account when setting up a cutting plan for a stand of timber.

AN ACTUAL EXAMPLE OF SELECTIVE LOGGING

An example of selective logging, in the Upper Peninsula of Michigan, near Marquette, may be cited (*24*). In a stand of timber which averaged 6,350 board feet net log scale per acre, 2,250 board feet, or about 35 per cent, was removed in selective logging. In all, 45,000 board feet was removed from 20 acres, and in addition 160 cords of chemical wood was cut from the defective portions of the trees, from the tops, and from the small cull trees which were considered not worth retaining in the stand. The stand averaged 190 trees per acre between 3 and 38 inches in diameter. On an average about eight trees were cut to the acre, and the diameter of the trees cut corresponded roughly to a diameter limit of 22 inches breast high.

The logging was done by a contractor at a cost, including felling, hauling, and loading on the cars, of $10.50 per thousand board feet. The cost of cutting, hauling, and loading chemical wood, which was disposed of at a stumpage price of 50 cents a cord, was $4 a cord.

On the entire tract only 89 trees were knocked down by felling, and only 3 of these were 12 inches or over in diameter. The cutting demonstrated that selective logging can be carried on under practical logging conditions without appreciable damage to the trees which are to be left for the next cutting. It has shown further that the cost of the method is not prohibitive; that the cost per thousand board feet compares very favorably with the usual large-scale operation where the forest is clear cut. Since the tops and the large limbs were cut into chemical wood down to 3 inches, there was no expense for slash disposal.

A most striking result of selective logging in this instance is that, because of the high quality of the product (fig. 4, C), more than half of the value of the stand was removed and yet only one-third of the volume. The average value of hardwood logs cut in ordinary logging operations during the winter of 1926–27 was about $19 a thousand feet on the cars and in some localities even less. Of these logs cut under selective logging the maple logs were worth $27.30 a thousand feet and the birch $39.31. Since there were cut 6,000 feet of birch logs and 39,000 feet of maple, the average value of the logs cut on the 20 acres was $28.93 a thousand feet. Had the entire stand been cut the value of the logs at $19 a thousand feet would have been $120.65 an acre. The value of only 35 per cent of the volume in logs taken from the largest trees was about $65 an acre.

The chemical wood, produced from the tops and defective portions of the trees and from smaller defective trees, aggregated 160 cords and brought in an additional $80, or $4 an acre.

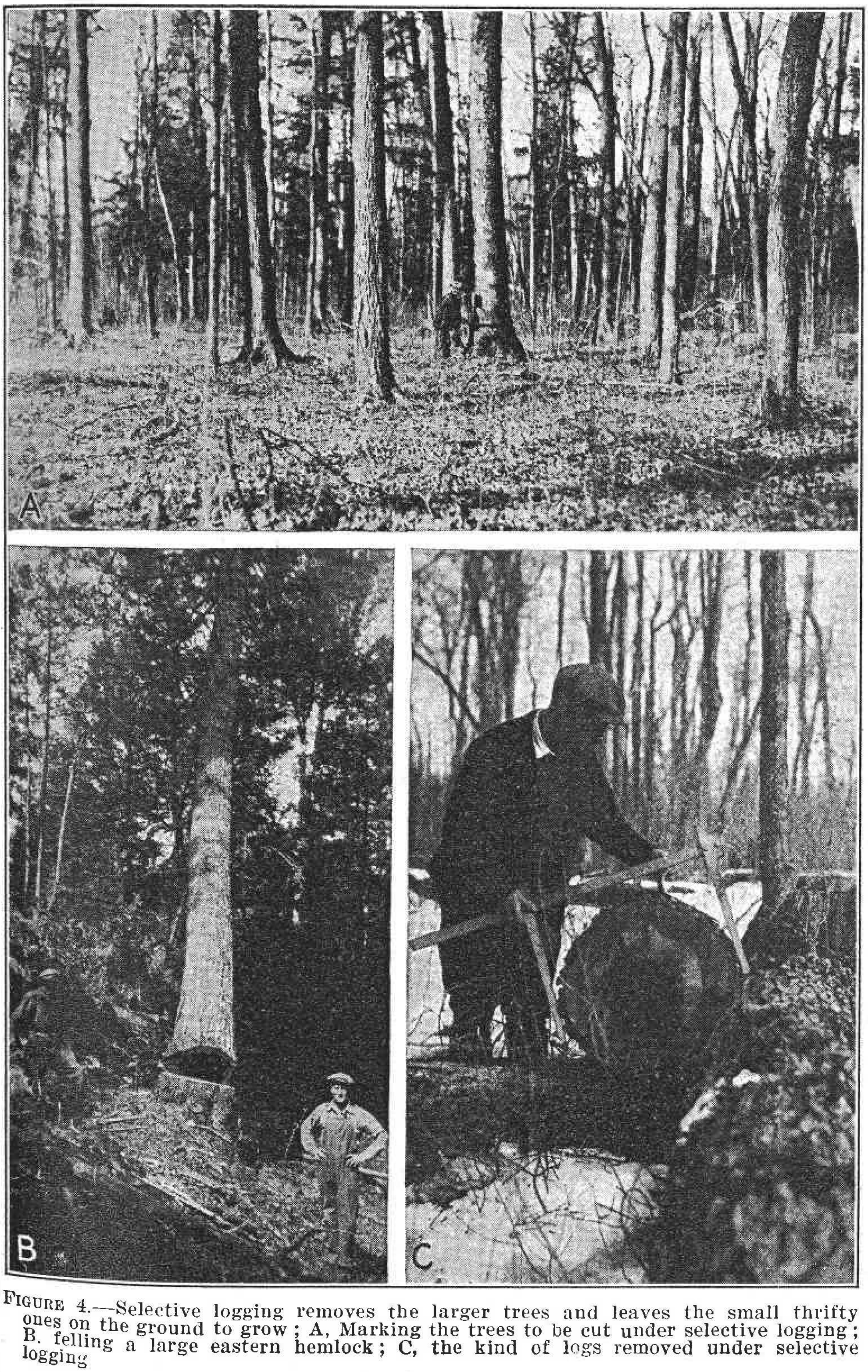

FIGURE 4.—Selective logging removes the larger trees and leaves the small thrifty ones on the ground to grow; A, Marking the trees to be cut under selective logging; B, felling a large eastern hemlock; C, the kind of logs removed under selective logging

The proceeds and the logging cost on the 20 acres, not including charges on the investment or any other carrying charges, were as follows:

Receipts from selective logging

45,000 feet of logs, at $28.93	$1,301.85
Cost of logging, at $10.50	472.50
Receipts from logs after deducting logging cost	829.35
Receipts from 160 cords chemical wood, at 50 cents stumpage	80.00
Total receipts from 20 acres	909.35
Receipts per acre	45.47

In another 20 years the 41 trees per acre between 12 and 22 inches in diameter left under selective logging will increase 2 to 4 inches in diameter. This will more than make up for the 2,250 feet removed in the selective logging. In 20 years the growth of the trees now left will bring the stand back to its original volume, and it should be possible to make another selective cut at that time of as high-quality timber and to get for it at least a similar return. With selective logging, then, the forest will be continuously productive, bringing in, according to this example, approximately $50 an acre every 20 years, or an average of $2.50 an acre a year, excluding carrying charges.

This selective cutting, although only one year's cut and by no means conclusive, opens up perspectives and possibilities worth considering.

ADVANTAGES OF SELECTIVE LOGGING

REMOVAL OF THE MOST VALUE WITH THE LEAST VOLUME

One of the most practical aspects of selective logging is that under such practice it becomes possible to take out a large part of the value of the stand in the form of larger trees and yet remove a smaller proportion of the total volume. This point is brought out in the actual example of selective logging just given and is substantiated by figures obtained in this investigation, where cutting 34 per cent of the volume (trees 22 inches in diameter and larger) removed over 39 per cent of the total value of the stand for lumber; cutting 66 per cent of the total volume (trees 17 inches and larger) removed 72 per cent of the total value.

Because the higher values in the forest are taken under selective logging, one of the chief financial obstacles to the practice of forestry is greatly reduced; namely, the carrying of large investments in virgin timber.

TIMBER HAS A HIGHER VALUE UNDER SELECTIVE LOGGING

The value of timber for the production of lumber under selective logging increases until about an 18-inch diameter limit of cutting is reached. (See last column Table 22.) Above an 18-inch diameter limit the value declines because the increased cost of permanent improvements more than offsets the reduction in production costs. Timber value as here used is the difference between the total production cost plus 15 per cent as a margin for profit and the selling price of the lumber. Table 24, which is based on the figures obtained in this investigation, shows that if all trees 9 inches in diameter and larger are cut the timber (stumpage) is worth $7.10 a thousand board feet net log scale, but if only trees 20 inches in diameter and larger are cut the timber has a value of $8.33 a thousand board feet.

TABLE 24.—*Comparative value of timber for standard lumber when cutting to different diameter limits*

Cutting limit, diameter breast high (inches)	Value of stumpage per thousand feet, board measure, lumber tally	Value of stumpage per thousand feet, board measure, net log scale	Cutting limit, diameter breast high (inches)	Value of stumpage per thousand feet, board measure, lumber tally	Value of stumpage per thousand feet, board measure, net log scale
	Dollars	*Dollars*		*Dollars*	*Dollars*
9 and up	5.63	7.10	15 and up	7.47	9.22
10 and up	5.71	7.19	16 and up	7.72	9.48
11 and up	5.95	7.47	17 and up	7.86	9.60
12 and up	6.31	7.90	18 and up	7.83	9.52
13 and up	6.72	8.37	19 and up	7.51	9.09
14 and up	7.11	8.82	20 and up	6.91	8.33

LOGS HAVE A HIGHER VALUE UNDER SELECTIVE LOGGING

Most of the cut under selective logging is made up of large trees, hence the logs from them yield higher grades of lumber and must therefore have a higher value. Information on the value of logs of different sizes is helpful in determining whether they are more profitable for lumber, veneer, or other products.

By subtracting from the value of the lumber, the milling cost plus 15 per cent, and by correcting for overrun, the value of the logs is obtained. These values are given in Table 25.

TABLE 25.—*Relative value of logs of different sizes and species, and of all species together for standard lumber*

Top diameter inside bark (inches)	Logs per thousand board feet	Value of logs per thousand board feet, net log scale, of—			
		Sugar maple	Yellow birch	Eastern hemlock	All species studied
	Number	*Dollars*	*Dollars*	*Dollars*	*Dollars*
7	42	0.73	4.37	16.19	5.70
8	31	4.43	8.72	15.89	5.99
9	24	8.36	13.01	15.62	9.35
10	19	12.38	17.24	15.39	13.27
11	16	16.26	21.24	15.22	17.26
12	13	19.58	25.25	15.34	20.70
13	10	22.54	28.66	15.53	23.62
14	9	25.14	32.44	15.72	25.91
15	7	27.72	36.05	15.81	28.41
16	6	30.16	39.70	15.87	30.58
17	5	32.46	43.50	16.05	32.64
18	5	34.54	47.56	16.24	34.26
19	4	36.25	52.09	16.41	35.54
20	4	37.65	57.43	16.58	31.93

EARLY SECOND CUT

How soon a lumberman may return for a second cut will depend on (1) the number, size, and species of trees left, and (2) on the site (soil quality and growing conditions). In a recent study (25) made in Wisconsin, the annual growth per acre in partially cut stands ranged from 102 to 240 board feet. The average annual growth for 17 plots, aggregating close to 400 acres, was in round figures 145 board feet. The detailed results of this study are contained in Table 31 (p. 44) from which an owner of timber may make a rough estimate of the rate of growth that may be obtained from mixed hardwood timber left standing after partial cutting and the number of years that must elapse before a definite amount may again be cut. To illustrate: If a light, partial cutting of 50 per cent of the volume is made from a stand averaging 13,000 board feet, it will probably require about five years to grow 1,000 board feet, or 15 years to grow 3,000 board feet. If from 75 to 85 per cent of the merchantable volume is removed, it may take 7 years to replace 1,000 board feet by growth or 21 years for 3,000 board feet. If still heavier cutting is made, the time required to produce a second merchantable cut is further extended. Being average figures, Table 31 applies more accurately to large tracts than to small ones.

IMPROVEMENT OF THE FOREST

Care must be used in designating trees to be removed under selective logging. Clinging rigidly to a diameter limit of cutting may not produce the best results since in order to obtain the maximum growth of trees left in the woods, some trees above or below the cutting limit may be taken or left, depending on the soundness, thrift, growth rate, species, and form of the timber, danger from windfall, and the needs of the young growth on the ground. Trees below the diameter limit might be cut very properly if their removal is necessary to thin out a thick patch, while trees above the cutting limit might be left if they stand in openings.

The average quality of lumber from the first cutting is often of lower quality than that from later cuttings, because the owner should remove a number of defective and poorly formed trees along with the better trees. These poor trees reduce the average quality of the lumber slightly, but by taking them out the remaining good trees have a better chance to increase their growth rate and in this way offset the loss. This point should be kept in mind when considering the results of selective cutting.

The results of two operations in the Lake States have shown that it is entirely practicable to log selectively without seriously damaging the trees left on the ground. This is important since it is necessary to save the small trees and leave the forest in good condition in order to get the best possible growth after each cutting.

Selective logging makes it possible for the owner to favor the species he desires to grow, whereas under clear cutting, even with fire protection, there is no assurance of the regrowth of the desired species. Instead of sugar maple and yellow birch there may be aspen, red maple, and other less desirable species, and quite probably the new stand will be either too thick or too thin.

Selective logging not only removes the most valuable part of the stand but at the same time improves the growth of the remaining timber and affords opportunity to encourage the growth of species that are wanted. (Fig. 4, B.)

SOLVING THE SMALL-LOG PROBLEM

Small logs are produced from small trees and from the tops of large trees. Selective logging reduces the proportion of small logs, because the small trees are not cut. Cutting small trees is avoidable and is inconsistent with good forest practice. Leaving them involves no waste in utilization, but, on the contrary, it actually contributes to the increased growth and perpetuation of the stand. The small trees (8 inches to 14 inches in diameter) are just at the period in their development where the growth is rapid, and if left they may be considered an asset. On the other hand, if the logs from these small trees are cut into lumber they become a liability and must be carried at the expense of the large logs.

The top logs from large trees, however, are unavoidable and can be viewed from different financial angles than the logs from small trees. Whether these top logs are utilized or not, the tree itself must be felled in order to get the large logs, and all improvements for effective logging and milling must be provided. Once cut down these logs are of no value to the forest, but are a liability from a fire hazard and sanitation standpoint. Under such conditions it should be permissible not to charge the top logs obtained from large trees with the costs of felling, permanent improvements, and depreciation. Under this method of cost accounting, top logs of 8 or 9 inches in diameter show a slight profit. These costs obtain where the small logs are sawed into lumber with the same machinery as that used for cutting large logs. If top logs are cut by special equipment into products other than lumber, such as dimension stock and ties, they will probably show a much better profit.

FIRE HAZARD REDUCED UNDER SELECTIVE LOGGING

A forest cut selectively is not so great a fire hazard as a clear-cut area. The comparatively small number of trees that are cut per acre, even when the tops are not utilized for chemical wood, do not make heavy slash and such slash is separated by green standing timber. Moreover, the conditions are less favorable for a fire to continue to burn because the humidity of the air is higher, the temperature of the air and soil lower, and the wind movement considerably less than in a clear-cut forest. (Fig. 5.) Actual observations conducted on the climatic factors within and without a hardwood forest in the Lake States show that the maximum air temperatures during July and August were from 4 to 5 degrees higher in an unforested area than in a forested area and the relative humidity of the air for the same months was between 6 and 7 per cent less in the unforested area than in the forested area. The wind movement in the unforested area for the summer season averaged 2.7 miles per hour and only 0.6 mile during the same period in the forest. During the warm days of the summer, the temperature of the soil in the open was from 8 to 10 degrees higher than in the forest.

It is generally known from experience that the danger from fires during the period between the middle of July to the end of October is especially great when the relative humidity of the air falls below 50 per cent. In the unforested area studied there were 14 days during this period when the relative humidity fell below 50 per cent, and only 6 days when the relative humidity of the air in the forest was below this danger point, which indicates that the relative danger from fire in a forest cut selectively is not great.

In the fall the herblike vegetation in the forest is still green, while in the open all the grass has been killed by frost and it is readily inflammable. In the early spring the dead vegetation in the open dries earlier and is readily inflammable at a time when the forest is still moist.

For the foregoing reasons the fire hazard in a forest cut selectively is much less than in a forest cut clear with heavy slashings left on the ground.

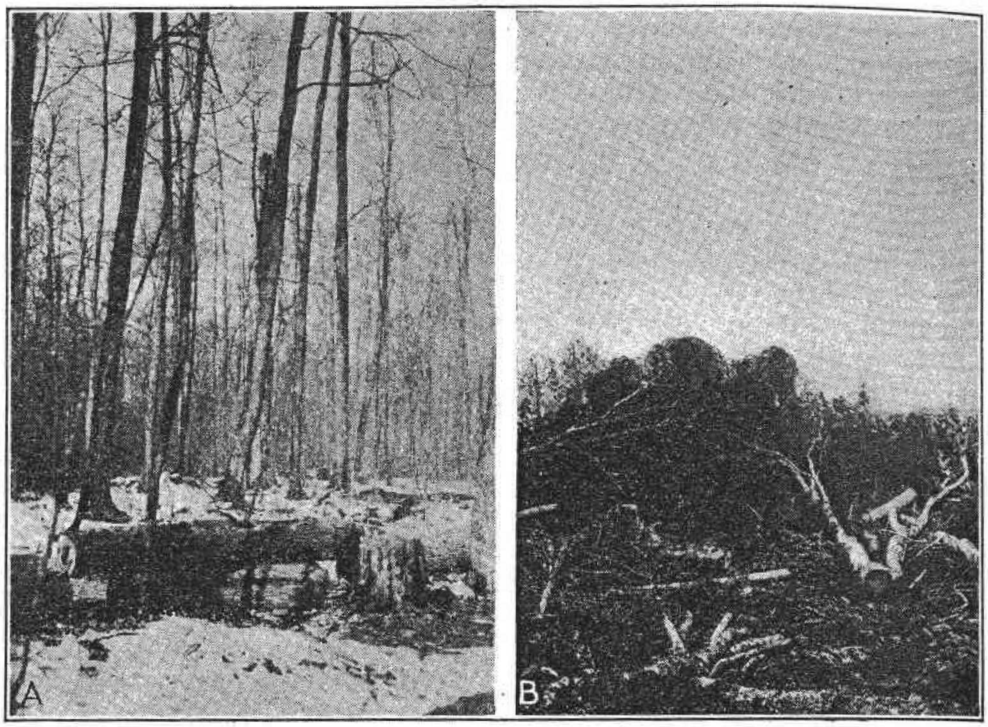

FIGURE 5.—Areas cut under selective logging and under clear cutting: A, Selectively logged area with thrifty young trees left on the ground to grow into a future cut; B, a clear-cut area with heavy slashings

BUSINESS AND COMMUNITY STABILIZED

Selective logging prolongs the life of a lumber operation and with adequate acreage will make it permanent by providing a continuous supply of timber. On the other hand, clear cutting of all merchantable timber with no provision for regrowth involves heavy depreciation charges against the plant, railroad, and other permanent improvements with a consequent increase in the cost of doing business. Moreover, it prevents the development of a permanent community. With selective logging the reverse is true. The life of the operation is prolonged or made permanent, and as a result depreciation charges are reduced. A feeling of permanency is created in the community with the result that schools, churches, and business may be safely established on a substantial basis.

Selective logging on forest areas eliminates the cut-over land problem. Further, selective logging goes far toward a satisfactory solution of the tax problem, for selectively cut lands receive favorable consideration under the forest crop laws in both Michigan and Wisconsin.

SELECTIVE LOGGING—A PROBLEM FOR EACH INDIVIDUAL OPERATOR

Immediate financial considerations as well as indirect advantages indicate the desirability of a change of logging methods in the Lake States. Selective logging seems to be the logical answer. The figures in this bulletin indicate that operators who are producing only lumber and who have no thought of making their operation permanent should refrain from cutting trees under 12 inches in diameter. By so doing they make the highest profit per acre from their operation and at the same time increase the value of their cut-over land by leaving small trees uncut.

The establishment of a diameter limit for the operator who wants to practice selective logging with a view to permanent operation is not so simple. What diameter limit of cutting he chooses will depend largely on the grade of logs and lumber he wishes to produce, the size and character of his timber holdings, the time he can allow between successive cuts, and his ability or desire to invest in future growth. No attempt is made to set down a definite cutting limit. From the facts presented here each individual owner who wishes to go into selective logging will have to make an analysis of his own operation and then decide for himself the diameter limit of cutting that best meets his needs. For example, one operator in the Lake States after analyzing his operation has decided that cutting all trees 22 inches in diameter and larger is the most profitable for him. (Fig. 4, C.) Another owner with different conditions might decide on a higher or lower cutting limit. For the operations investigated a diameter cutting limit of 18 inches gave the highest return per thousand board feet.

CONCLUSIONS

Based on this investigation, the comparative results under clear cutting and selective cutting on lumber operations in the hardwood-hemlock type in the Lake States may be summarized as follows:

For the tracts studied and with the cost distribution used here, the highest profit per thousand board feet occurs when only trees 18 inches in diameter and larger are cut. If the owner has a good supply of timber on hand and is planning on a second cut, the 18-inch diameter cutting limit will net him the highest profit for each thousand feet of lumber produced and yet leave enough timber (41 per cent of the original volume) on the ground to provide a second cut of large timber within a reasonable time.

The highest profit per acre is obtained when only trees 12 inches in diameter and larger are cut. This means that the lumber operator, even if he has no thought of a second cut but wants to remove in one logging all the merchantable timber, really loses money by cutting trees less than 12 inches in diameter.

A change from clear cutting (all trees 9 inches in diameter and up) to cutting to a diameter limit does not increase the cost of lumber production until a diameter limit of about 16 inches is reached. Above this point the production cost begins to rise because the cost of permanent improvements becomes increasingly greater and more than offsets the total effect of the cheapened direct logging and milling costs and the increased value of the lumber.

The most desirable diameter cutting limits will vary from one operation to another according to the distribution of trees by diameter classes in the stand, prevalence of a particular species, price of lumber, and management plans adopted by the operator. The cutting limits shown in this bulletin apply to the conditions studied. In so far as these operations are representative of the region, the diameter cutting limits may be considered to apply to the region as a whole.

Selective logging helps to solve the problem of the small log. By leaving uncut the small trees the number of small logs is greatly reduced.

Under selective logging, the annual growth per acre will range from 102 to 240 board feet, depending upon (1) the number, size, and species of trees left at the time of cutting, and (2) on the site (soil quality and growing conditions).

Under selective logging, it becomes possible to take out a large part of the value of the forest in the form of larger trees, and yet remove a smaller proportion of the total volume.

Since, as a general rule, only the larger trees are cut under selective logging, the logs from them yield higher grades of lumber and consequently lumber of higher value.

Selective logging is a means of improving the forest. By marking the trees for removal, the owner can favor the species that he wants to grow, instead of leaving entirely to nature the kind of trees that may come in after logging. (Fig. 4, A.)

A forest cut selectively represents much less of a fire hazard than a forest cut clear with heavy slashings left on the ground.

Selective logging prolongs the life of a lumber operation. It does away largely with the problem of cut-over land. It helps in the solution of the tax problem and contributes to the stability of the community in which the sawmill is located.

SUPPLEMENTARY INFORMATION

The tables which follow are for reference purposes and will be helpful in establishing satisfactory wage scales and in working out cutting practices for individual operations.

BASIS OF PAYMENT

The basis on which woods felling crews are paid has a marked effect on selective logging. A number of operators pay their log cutters a flat rate per linear foot. Quite naturally the cutters skin the land of all the small trees the company will accept. Sawing 8-inch logs requires nearly three times as much work a thousand board feet as sawing 24-inch logs, yet with the payment on a linear foot basis a sawyer's earnings per thousand board feet is 12½ times as great for 8-inch as for 24-inch logs. (Table 26.) Table 25 shows that based on the actual labor involved the payment for 8-inch logs per linear foot is about $0.007 or $3.35 a thousand board feet, instead of $5.50 a thousand board feet when based on the flat rate system. For 16-inch logs based on the actual labor involved, the payment is $0.017 a linear foot instead of $0.011, and it is $1.69 a thousand board feet instead of $1.11 as is the case with the flat-rate linear-foot basis.

Table 26.—*Cost of sawing for logs and trees when payment is based on actual labor involved and when based on a definite amount per linear foot for all species studied*

Top diameter inside bark (inches)	Cost of sawing per thousand board feet, gross scale at $0.011 per linear foot	Rate of payment for sawing—			
		Logs: On basis of labor involved at average rate of $2.08 per thousand board feet and $0.011 per linear foot		Trees	
		Per linear foot	Per thousand board feet, gross scale	Diameter breast high (inches)	Per thousand board feet, gross scale
	Dollars	*Dollars*	*Dollars*		*Dollars*
6	9.78	0.0052	4.60	8	4.06
7	7.33	.0058	3.87	9	3.68
8	5.50	.0067	3.35	10	3.38
9	4.19	.0076	2.91	11	3.12
10	3.26	.0088	2.60	12	2.91
11	2.75	.0094	2.34	13	2.73
12	2.23	.0107	2.16	14	2.57
13	1.81	.0121	1.99	15	2.42
14	1.53	.0134	1.88	16	2.29
15	1.24	.0156	1.76	17	2.18
16	1.11	.0168	1.69	18	2.08
17	.95	.0187	1.62	19	1.99
18	.83	.0209	1.57	20	1.91
19	.73	.0228	1.52	21	1.85
20	.63	.0257	1.47	22	1.79
21	.58	.0272	1.43	23	1.74
22	.53	.0292	1.40	24	1.69
23	.47	.0323	1.37	25	1.64
24	.44	.0338	1.34	26	1.60
Log run	2.08	.0110	2.08	27	1.57
				28	1.53
				29	1.50
				30	1.48
				Log run	2.08

It is therefore evident that sawyers when paid at a flat rate of $0.011 a linear foot are penalized when cutting large logs and favored when cutting small logs. The sawyers are aware of this in a general way and as a result slaughter the small trees if given an opportunity.

It seems quite certain that the flat-rate system of payment has exerted more influence than is ordinarily recognized in bringing about clear cutting of the forest. The figures in Table 26 may be used to compute linear-foot payment that is fair to both the sawyer and operators. Such a method of payment is worth considering if an operator wishes to save his small trees.

DIRECT COST OF MILLING TREES OF DIFFERENT DIAMETERS AND SPECIES

Table 27 gives the cost of milling for trees of different species and diameters. The operator who does not have the same proportion of hardwoods and hemlock as found in this study can use the information in these tables to compute a weighted average cost of milling for his own operation.

VARIATION IN THE AMOUNT OF DEFECT

Defect varies both in the size of log and the species. (Table 28.) This information is valuable to the man who is buying logs.

TABLE 27.—*Cost of milling trees per thousand feet board measure, by diameter classes and species*

Diameter breast high (inches)	Sugar maple	Yellow birch	Eastern hemlock	Diameter breast high (inches)	Sugar maple	Yellow birch	Eastern hemlock
	Dollars	*Dollars*	*Dollars*		*Dollars*	*Dollars*	*Dollars*
9	16.27	16.75	11.29	18	13.05	13.05	9.51
10	15.75	16.14	11.09	19	12.87	12.83	9.31
11	15.37	15.67	10.90	20	12.75	12.66	9.12
12	14.98	15.19	10.70	21	12.62	12.53	8.96
13	14.58	14.70	10.51	22	12.48	12.40	8.76
14	14.18	14.27	10.30	23	12.36	12.27	8.62
15	13.80	13.83	10.10	24	12.27	12.18	8.52
16	13.54	13.54	9.91	25	12.18	12.10	8.43
17	13.27	13.26	9.71				

TABLE 28.—*Amount of defect by species and size of tree*

Diameter breast high (inches)	Sugar maple	Yellow birch	Eastern hemlock	Diameter breast high (inches)	Sugar maple	Yellow birch	Eastern hemlock
	Per cent	*Per cent*	*Per cent*		*Per cent*	*Per cent*	*Per cent*
7	3.6	6.2	1.0	15	5.4	10.0	8.5
8	3.8	6.4	2.9	16	5.7	10.9	9.0
9	4.0	7.0	4.4	17	6.3	11.8	9.5
10	4.3	7.5	5.4	18	7.0	12.4	9.5
11	4.8	8.1	5.4	19	8.0	12.8	9.5
12	5.1	8.4	5.8	20	8.8	12.9	9.6
13	5.3	8.9	6.7	Log run	5.5	9.5	7.9
14	5.1	9.7	7.9				

NET AND GROSS OVERRUN FOR LOGS AND TREES OF DIFFERENT DIAMETERS AND SPECIES

Tables 29 and 30 give the net and gross overrun for logs and trees of different diameters and species. This information is of interest to the lumberman who is buying logs and may be used by the operator who is computing diameter cutting limits for his own holdings.

TABLE 29.—*Gross overrun for logs and trees of different diameters and species*

Logs				Trees			
Top diameter inside bark (inches)	Gross overrun of—			Diameter breast high (inches)	Gross overrun of—		
	Sugar maple	Yellow birch	Eastern hemlock		Sugar maple	Yellow birch	Eastern hemlock
	Per cent	*Per cent*	*Per cent*		*Per cent*	*Per cent*	*Per cent*
7	46.3	29.5	64.0	9	40.0	28.7	64.0
8	40.1	26.5	52.5	10	37.3	26.8	59.2
9	34.0	23.4	42.5	11	34.7	25.0	54.5
10	28.9	20.5	34.0	12	32.1	23.3	50.0
11	24.3	17.6	28.5	13	29.6	21.5	45.5
12	20.7	15.0	24.2	14	27.2	19.7	41.2
13	17.8	12.5	20.2	15	25.0	18.0	36.0
14	15.7	10.2	16.5	16	22.8	16.3	33.0
15	14.0	8.5	13.5	17	20.8	14.7	29.5
16	12.3	6.5	11.0	18	18.9	13.1	26.0
17	10.5	4.5	10.0	19	17.3	11.7	23.0
18	8.6	3.0	9.5	20	16.0	10.3	20.5
19	6.5	2.0	9.0	21	14.6	9.0	18.5
20	4.4	1.5	8.5	22	13.4	7.8	16.5
Log run	19.1	11.4	22.4	23	12.1	6.6	14.8
				24	11.0	5.6	13.7
				25	9.8	4.6	12.8

TABLE 30.—*Net overrun for logs and trees of different diameters and species*

Logs				Trees			
Top diameter inside bark (inches)	Net overrun of—			Diameter breast high (inches)	Net overrun of—		
	Sugar maple	Yellow birch	Eastern hemlock		Sugar maple	Yellow birch	Eastern hemlock
	Per cent	*Per cent*	*Per cent*		*Per cent*	*Per cent*	*Per cent*
7	51.7	38.0	65.7	9	44.4	37.4	69.5
8	45.7	35.2	57.0	10	41.8	35.8	64.8
9	39.5	32.7	49.0	11	39.5	34.2	60.2
10	34.7	30.2	41.6	12	37.2	32.6	55.7
11	30.6	28.0	35.8	13	35.1	31.1	51.4
12	27.2	25.5	31.8	14	33.0	29.6	47.4
13	24.4	23.5	28.8	15	31.0	28.2	43.7
14	21.9	22.0	26.5	16	29.1	26.7	40.2
15	20.5	20.5	24.0	17	27.3	25.4	37.4
16	19.1	19.5	22.0	18	25.7	24.3	34.8
17	17.9	18.5	21.5	19	24.3	23.2	32.4
18	16.8	17.6	21.0	20	23.0	22.2	30.1
19	15.7	17.0	20.5	21	21.8	21.3	28.4
20	14.5	16.5	20.0	22	20.8	20.5	26.8
Log run	26.0	23.1	32.9	23	19.9	19.8	25.7
				24	19.1	19.2	24.8
				25	18.4	18.6	23.9

SUGGESTIONS FOR COMPUTING CUTTING LIMITS

The following suggestions are set down for the use of the timber owner who wishes to compute for his own operation the results to be expected if he cuts his timber to certain diameter limits. Before attempting to make any computations it is suggested that the parts of this bulletin "How the work was done" and "Classification of costs," be reviewed carefully.

The first things an operator will need in working out his own cutting limits are volume distribution tables similar to Tables 3 and 4. He will also need to go into his own woods and cruise, say 15 sample acres located at different places on his holdings. From the cruiser's figures and volume tables he can then compute the volume distribution by species and diameter classes for his stand of timber. The values from these tables should then be applied to the figures for individual diameters which are given in this bulletin for the purpose of setting up production costs and lumber values for each diameter class that will apply to his own operation. An example will best illustrate the method:

Assume that the owner's volume distribution figures when multiplied by the total direct costs of logging for each diameter class, column 7, Table 8, give a weighted average of $8.80 instead of $8.38. Then suppose his average direct logging cost is $9.68. Subtracting $8.80 from $9.68 shows that his costs are 10 per cent higher than the figures used in this publication. Direct costs for each diameter class for his own operation can now be computed by simply increasing the costs given in this publication by 10 per cent. Logging 8-inch trees would then cost $19.10 a thousand board feet instead of $17.36; logging 20-inch trees, $8.19 instead of $7.45.

By this same procedure the owner can set up costs for individual diameters and weighted log-run figures for each step of logging. Overrun figures may be computed in a similar manner.

Milling costs can be calculated as in the preceding example, but in addition a weighted average cost within each diameter class should be computed because of the difference in the cost of sawing between hardwoods and softwoods. Likewise, the value of the lumber should be weighted within each diameter class as well as for the stand as a whole because of the difference in value of the various species.

With the above computations made the operator can compute the results when cutting to different diameter limits. The method of doing this has already been explained on page 30.

PREDICTION OF GROWTH IN STANDS SELECTIVELY CUT

Table 31, which is based on the actual relationships found by the study, shows what happens to the annual volume growth in stands from which merchantable timber has been removed by partial cutting in varying amounts from 42 to 99 per cent of the original stand, that is, from light cuttings to practically clear cuttings. If one of the factors named in the table is known or is easily determined in the field, one can predict all other factors affecting the growth of the stand. The most easily determined factor is the amount of merchantable volume left on a cut-over area, and the thing that any timber owner wishes most to know is what the remaining stand will produce during the next 20 to 30 years in the form of sawmill material. If, for instance, the timberland owner finds that after selective logging there is 3,000 board feet in the form of merchantable trees left, then, according to Table 31, the stand may be expected to grow at the rate of 5.5 per cent a year. By multiplying the growth per cent by the amount of merchantable timber left, the average annual growth per acre per year for the next 25 years is obtained:

$$\frac{5.5\times3000}{100} = 165 \text{ board feet.}$$

TABLE 31.—*Relation between amount of merchantable timber left, percentage of volume growth, and average annual growth in board feet*

Rough diameter cutting limit (inches)	Volume per acre left after cutting	Volume removed from original stand; basis, 13,000 board feet [1]	Volume growth per year in percentage of total volume left after cutting	Average gross annual increment per acre	Average period required to grow 1,000 board feet gross scale [1]	Character of cutting
	Board ft.[1]	*Per cent*	*Per cent*	*Board ft.*[1]	*Years*	
	13,000	----------	1.6	210	----------	Virgin stand.
20 or 22 and up	7,500	42	2.6	195	5	Light partial cutting.
	6,000	54	3.1	185	5½	
14 or 16 and up	3,300	75	5.2	170	6	Heavy partial cutting.
	2,400	82	6.6	160	6	
	1,900	86	8.1	155	6½	
	1,550	88	9.8	150	7	
12 or 13 and up	1,200	91	12.0	145	7	Very heavy partial cutting.
	900	93	15.0	135	7½	
	700	95	19.4	135	7½	
	450	97	24.6	110	9	
11 and up	210	98	31.0	65	15	Clear cutting.
	100	99	----------	45	22	

[1] Measured by Scribner Decimal C rule.

It must be borne in mind that the volume growth figures represent growth that took place in the course of about 25 years after the first cutting and refer to definite conditions at the time of cutting. In applying these figures to present cuttings the prediction must also extend only to a period of about 25 or 30 years in the future, as the conditions for which they hold true may change within that period. Much of the unmerchantable timber may become merchantable by that time and the entire rate of growth modified. The figures as given, therefore, are not yield values, but are merely a prediction of growth for definite conditions of cut-over areas, namely, a certain amount of merchantable timber left on the ground and a certain number of small unmerchantable trees in the stand.

Furthermore, the figures of growth are gross values. Deduction should be made for decay or natural mortality in the stand, which will vary according to the condition of the trees left, the injuries they received during the first logging, and the character of the soil in which they grow. Each timber owner will have to make his own estimate as to the amount that should be allowed for this loss. It will seldom, however, exceed 10 per cent of the annual increment.

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