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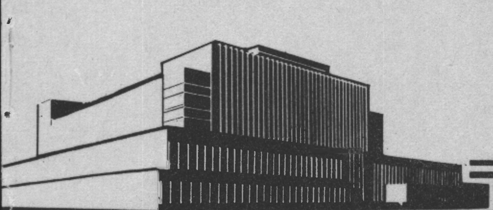
October 1959

(Report) No. 2163



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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

YIELD AND VALUE OF FINISHED LUMBER FROM WESTERN WHITE PINE TREES AND LOGS

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Introduction

This report presents data and an analysis of a cooperatively conducted survey of western white pine timber harvested from the Clearwater National Forest in northern Idaho. One part of the project was designed to determine the effect on yield and quality of lumber manufacturing methods--particularly, what effect positioning on the carriage had with respect to log defects and taper. The other part was designed to determine the effect that inherent characteristics of the logs, trees, timber stand, and logging practices had on the yield and quality of finished lumber. Data and analysis pertaining to the effect of inherent characteristics on yield and quality are presented in this report.

Procedure

Plot selection was made on a large, previously marked timber sale. Four plots with 40 marked trees on each were selected, irrespective of acreage. These plots were, in effect, a controlled random sample. The controls called for (1) all plots to be in or accessible to current harvesting operations; (2) two plots to be on topography suitable for tractors and two plots on topography too steep for tractors; and (3) timber to be as nearly representative of the entire area as possible. All exposures (north, south, east, and west) were represented among the plots. The sample trees were numbered, diameter at breast height measured, merchantable height estimated, and logs graded in the tree. These, as well as other data, were recorded.

At the time of felling, each log, long butt, or other portion of the tree was marked with the tree number and the position of the piece within the tree. They were skidded, scaled, loaded, and hauled to the mill. The practice of not squaring the ends of broken logs, as is normally done in the woods, and that of

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

transporting all sections of each tree, regardless of cull, were the only deviations from normal logging procedure.

At the sawmill landing, broken-ended logs were measured and then squared. Long logs were bucked in accordance with standard procedure. The ends were renumbered as required, and a diagram made of each log, on which were diameter, length, scale, and defect. Separate scales were made for payment and other purposes, but the scale made at this time was considered the basic study scale and included all logs.

When the logs were sawn, a diagram was made to show the position, by number, of each board in the log. Each board was then stamped to identify it by log number, and also numbered to correspond with the sawing diagram. The identity of each board was maintained throughout drying and planing until it was ready for shipment. The records kept and the data gathered form the basis for this report.

This report is divided into two main sections--the first dealing with logs, and the second with trees. Each section is further subdivided into basic data and finished lumber recovery data. For the most part, detailed basic data are summarized.

Description of Western White Pine Logs

All portions of every tree were accounted for, either as logs 4 feet in length and longer, or as broken chunks. The total number of pieces involved in the various phases of the work is shown in table 1. Recovery and value data were confined to the 943 logs sawn. Only 887 of these were considered merchantable, or 79 percent of all logs involved. The basic data used for computing curves included log diameter to the nearest 0.1 inch, log value to the nearest 10 cents, and mill tally to the nearest board foot.

Size-Class Distribution

The number of logs in each diameter class is shown in table 2. The percent in each diameter class is in accordance with the normally expected skewed distribution, with a gradual decrease in the larger diameter classes. Variations between plots are reflected in the average log diameter and average tree diameter at breast height. Even though the average log and tree size varies among plots, the ratio of diameter at breast height to average log size is fairly consistent, varying from 0.584 to 0.651. This ratio suggests the possibility of a normal variation around a mean, with a narrow range of distribution that might be quite useful in estimating the number of logs per 1,000 board feet, timber evaluation, or logging and milling costs. This ratio may warrant further investigation.

Basic data on log lengths are presented in table 3. The low percentage of 16-foot logs in plot 1 indicates the effect of breakage and rot or cull. Odd-length logs over 6 feet long, but less than 20 feet long, must be considered errors in bucking. Since the policy is to rebuck long logs over 20 feet in length, then the even lengths above 20 feet must be considered as bucking errors, and the odd-length logs as being correctly bucked. (See log bucking instructions in appendix.) Some of the errors recorded in table 8 may be attributable to breakage. These logs and those having excessive trim allowance cause additional losses in volume not included in breakage computations.

Log Scale Volume

This survey was based on a gross volume of 184,670 board feet, Scribner Decimal C log scale, established from data of the check scaler. Recovery tests are based on 943 logs sawn with a gross scale of 151,460 board feet on the same basis. In order to check the accuracy of scaling, the gross scale was determined from diameter and length data recorded on the log diagrams. A comparison of the number of logs involved and the scale of each of the three scalers is shown in table 4. Most of the logs overscaled or underscaled are those with a diameter at the half-inch mark, as one scaler may record the next larger diameter and the other the next lower. Theoretically, however, there should be about the same number of logs overscaled as underscaled.

Mill Tally Recovery

Of the 576 logs 16 feet in length, 372 were sound. These were grouped into 1-inch-diameter classes, resulting in 28 groups. The regression curve for these data is shown in figure 1. The coefficient of correlation indicates that diameter and its interrelated factors explain 96 percent of the variation between group averages.

Among the unsound logs were 22 for which cull deduction was made for sweep; these ranged in diameter from 6 to 18 inches. A regression curve for these logs, computed from individual log data, is also shown in figure 1.

There were 164 logs ranging in diameter from 6 to 33 inches on which scale deductions were made for rot. These were grouped into 20 diameter classes to compute the regression curve shown in figure 1. The volume difference between logs under 20 inches in diameter with sweep and rot was less than 3 board feet. Twenty of the logs were scaled by one or more scalers as 100 percent cull.

The variation of the volume within each group of sound logs was analyzed, and the fiducial limits at the 5 percent level were computed. The plotted values for the fiducial limits indicate a 95 percent probability that the mean volume for a group of 36-inch logs will be within plus or minus 1.76 percent, and for 6-inch logs, plus or minus 11.12 percent. Log volumes, rounded off to the nearest foot, are listed in table 5, which also shows comparison with the International 1/4 inch and the Decimal C log rule volumes. The coefficient of correlation for the fiducial limits curve is 0.7366. Considering normal variations and practical application, the International log rule volumes are so close to actual recovery volumes that this rule should be used whenever possible.

In computing a regression curve, data from 53 sound 8-foot logs were used. These logs ranged in diameter from 5.6 to 30.8 inches. The curve formula is

$$\log y = 2.116\ 188 \log b - 0.598709$$

The coefficient of correlation, r, is 0.95396. Diameter and its interrelated factors, therefore, explain 91 percent of the variations in volume of these 8-foot logs. Irregular shape, taper, trimming to upgrade, and similar factors probably account for the unexplained variation of 9 percent. Eight-foot logs will yield slightly less than half the board-foot volume of 16-foot logs because of their taper and the ratio of 2-foot lengths to total length.

A regression curve was computed for 38 sound 12-foot logs. The formula is

$$\log y = 2.103922 \log x - 0.40642$$

and the coefficient of correlation is 0.9878. Data shown in table 6, for 8-, 12-, and 16-foot logs, were computed from the curve formulas. The number and diameter distributions of logs 10 and 14 feet long were inadequate for computation of regression curves. Therefore, volumes shown for these lengths are based on volumes of the next higher and lower lengths.

Lumber Value Recovery

Dollar value regression curves for 16-foot logs were computed on the same basis as that used for volume curves. These curves are shown in figure 2. A comparison of figures 1 and 2 shows that both rot and sweep have considerably more effect on value than on volume. Sweep, however, reduces value more than rot, since the highest value portions of such logs are slabbed off before the logs are straight enough to produce full-length lumber. In addition, the relationship of the boards to the low-grade heart of a log varies from end to end. Boards may be high grade on both ends and low grade in the middle, or vice versa. On the other hand, logs with rot produce high-grade material from the outside to offset rot in the heart.

Dollar value of 8-foot sound logs was computed by individual logs (53) resulting in a formula

$$\log y = 2.39664 \log x - 1.858764$$

with a coefficient of correlation of 0.8743. Log values are less than half those of 16-foot logs. That is to be expected, since volumes for 8-foot logs are slightly less than those for 16-foot logs, due to taper and resulting shorts obtained from the longer logs. The average value per 1,000 board feet for logs less than 26 inches in diameter was, however, generally lower for logs 8 feet long than for the 16-foot logs, as shown in table 7. Since in the price schedule used there is no difference in lumber value due to length, other factors must be involved.

The most obvious factor is the difference in the size of the two samples, with perhaps the number of 8-foot logs being inadequate. Another factor may be unequal distribution of log quality. There is also the possibility that inherent unwritten grading specifications, or their application, are reflected in the grade recovery of short lumber. This raises the question as to what difference there might be if all the 16-foot lumber from a group of logs was cut in half and regraded.

The data just reviewed indicate a strong possibility that a previously unrecognized difference exists in the grade yield of lumber from logs of different lengths.

Log Grades

All logs sawn for this survey were graded on the sawmill deck in accordance with the Rocky Mountain system.[2]

The average mean value per 1,000 board feet and the variance of value per unit volume of each grade are presented in table 8. The value range of the logs in each grade is also shown. These results indicate that the grading system used does not perform satisfactorily in segregating the logs into quality groups. According to the objectives and standards of performance for log and tree grading systems,[3] the difference between the mean values of grades 2 and 3 is not significant. In addition, the variances of all the grades are excessively large. This overlapping is evident from the range of value encompassed by the logs in each grade. Since the log grading system, as used, is not satisfactory, additional analysis and the application of other systems are being made by the Interregional Ponderosa Pine Project.[3]

Description of Trees

Of the 160 trees used, 7 were forked. Five of these were forked near the top with negligible effect on volume, value, or length recovered. One tree was forked at 14 feet, but its volume was not significantly different from that of an unforked tree. The same was true of one tree forked just above the diameter at breast height. These were considered as one tree in all calculations, except for total length recovered in relation to height.

Size-Class Distribution

Table 9 lists the distribution of trees by height and by diameter at breast height. Data normally collected on Forest Service timber sale or forest survey

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[2] U.S. Forest Service. Field Instructions for Forest Inventory, Rocky Mountain Area. Intermountain Forest and Range Experiment Station and Rocky Mountain Forest and Range Experiment Station, U.S. Forest Service Regions 1, 2, 3, and 4. Revised April 1957.

[3] Newport, Carl A., Lockard, C. R., and Vaughan, C. L. Log and Tree Grading as a Means of Measuring Quality. Report of the Working Group of the National Log Grade Committee, U.S. Forest Service, May 1958.

cruises contain this information. The diameter and height distribution of timber in other localities, sale areas, or regions can therefore be compared with data of this report. A computed regression curve for these data is plotted in figure 3. A similar curve based on the merchantable log length recovered is also shown. The formula for determining the recovery height is

$$y = 0.57156 + 0.325006\ x - 0.0032508\ x^2$$

It is statistically significant that the coefficient of correlation of diameter and height is $r = 0.81122$. The curves indicate a tendency to overestimate the height of short timber and underestimate that of tall timber. The character of the timber and the average for each plot are shown in table 10.

Tree Scale

Since log scaling was done by several individuals at different times, data were available to check and correct errors. Regression curves for the gross volume, computed by the Scribner Decimal C log rule for each plot, are shown in figure 4. Similar curves are plotted in figure 5 for the International 1/4-inch log rule. These curves are based on 160 trees, irrespective of defect, using the formula

$$y = a + bx + cx^2$$

and individual tree data.

Before computing net scale volumes, it was necessary to eliminate cull and nonmerchantable trees. Although merchantability standards vary, the commonly applied standard that specifies a tree must have a minimum net scale of one-third the gross scale was used. The number of trees by merchantability class is listed in table 11.

Since the difference between plot curves was not significant, the data for all plots were combined and regression curves computed, as shown in figure 6.

Mill Tally Recovery

The volume of lumber planed and ready for shipment, including all grades from No. 5 Common or Industrial and better, according to Western Pine Association rules, was used in computation of recovery. Lumber-volume regression curves for all merchantable trees in the study are shown in figure 7. In addition, the regression curve is plotted for 25 trees in the survey for which no cull deduction was made other than for negligible breakage.

The two curves representing merchantable trees illustrate the similarity and variation due to choice of formula. Although the arithmetic formula is recommended for hardwoods, the logarithmic formula gave higher coefficients of correlation throughout this analysis, as illustrated in figures 8 and 9. In other statistical tests, the logarithmic formulas for other plotted data given in this report proved equal or superior to arithmetic formulas.

A composite of all the volume data curves is shown in figure 8 for comparative purposes. The coefficients of correlation are high for all curves. In the case of sound trees, 96 percent of the variations in volume are explained by diameter and its interrelated factors. The difference between this percentage and the 85 percent for merchantable trees is due to defects, primarily rot. Variations in height at any given diameter probably conform to a normal curve distribution. The addition of height as a factor in determining volume will contribute very little to the coefficient of correlation. These data indicate the possibility of using a single formula based on diameter at breast height for data processing machine calculations.

Lumber Value Recovered

The value of each of the boards produced from the western white pine logs was determined from a wholesale price list current in August 1957.

The same groups of trees were used for computing value curves that were used for computing volume. Curves for merchantable and sound trees are shown in figure 9. The logarithmic formula again gives a higher coefficient of correlation. Diameter and its interrelated factors account for 94.8 percent of the variation in value of sound trees and 81.8 percent of the variation in merchantable trees. This indicates that the reliability of any tree-grading system developed is dependent upon the extent to which it accounts for defects.

Using computed data from the curve formulas, the average values per 1,000 board feet were determined. These data are presented in table 12, which indicates the expected increase in value as the diameter increases in sound trees. The amount of defective material in the merchantable stand, however, is apparently increasing at the same rate as the value with diameter, and thus a constant or static value results. There is no doubt a relationship between the values and the ratio of sound to unsound trees. The condition of the stand, as well as the marking policy, will have a decided effect on these values and volumes. The percentage of sound trees for plots 1, 2, 3, and 4 was 13, 36, 20, and 5, respectively. Only 15.6 percent of all trees in the study were sound.

Summary of Volumes and Values Recovered

The 160 trees harvested produced 1,121 logs, 943 of which were sawn. Based on the scale record, only 132 of the trees were one-third or more merchantable. Data for these three items are listed first in table 13. Line 3 excludes all logs from nonmerchantable trees regardless of merchantability, leaving 868 logs that were sawn. Definitely cull logs sawn from the merchantable trees numbered 28, so data for the remaining 840 are shown on line 4.

Although it is difficult to predict what might have happened on a normal operation, it is reasonable to assume that certain logs barely meeting merchantability standards, which were cut from nonmerchantable long logs and scaled in the woods as cull, would probably have been left in the woods. Therefore, they have been deducted and the resulting data are shown on line 5.

In addition, there were eight logs of questionable disposition. One scaler may have considered them cull, while another scaler may have considered them worth hauling. The odds are even whether these logs would have been hauled or left in the woods. Data excluding them are compiled on line 6. The destination of nine additional logs is questionable, however, and in all probability, they would have been hauled.

Breakage

Considerable breakage was caused by a number of factors, such as topography, down timber, and rot. Top breakage is indicated in table 10. Although the merchantable top specification is 6 inches, the average recovery is 8.1 inches. This table also indicates a possible correlation of top diameter inside bark with height, in that shorter timber may be less subject to top breakage than taller timber.

The number of trees broken in felling and handling is listed in table 14. Plots 1 and 4 were on ground too steep for tractors. The effect of topography on breakage is indicated by comparing these plots with the other two. Table 14 also indicates a correlation between the number of trees broken, volume, and diameter. Diameter and height, however, are closely correlated, so the relationship is due chiefly to weight and distance of travel in falling. The high volume of breakage on plot 1 can be attributed in part to more down timber and greater prevalence of rot than existed on the other plots.

Available data do not permit an analysis detailed enough to permit attributing the correct portion of the breakage to each of the above variables. The data, however, serve to indicate the overall volume involved and the trends.

Smashed tops and top logs accounted for 294.5 lineal feet, amounting to 107.2 cubic feet. This is the equivalent of 21 logs 8.2 inches in diameter and 14 feet long, or a total of 294 feet in length, with a scale of over 735 board feet by International log rule. Although this was sound material, the quality and volume are low in relation to the number of pieces involved. Total volume is low because not all of the tops were accounted for.

Breakage in logs below the top amounted to 750.4 lineal feet, or 1,007.2 cubic feet, the equivalent of 47 logs 15 inches in diameter and 16 feet long. This does not include either cull logs that were splintered and broken up or long butts. There is no doubt, however, that some of this volume would be scaled as cull. On the other hand, these breaks contribute to losses later on. Many cracks and failures, occurring at the time of felling, are not obvious during bucking and scaling. They open up later during drying, sawing, or finishing and cause an undeterminable loss in both volume and grade.

Information on breakage and related losses obtained in this survey was incidental to the main objective and therefore not as complete and accurate as a specific study of this aspect would be. The data presented, however, are indicative of the existing situation.

APPENDIX

Log Bucking Instructions

The following cutting practices were used in bucking western white pine tree-length boles used in analyzing yield and quality of lumber as affected by inherent characteristics of the logs, timber stand, trees, and logging practices:

Trim on all logs should be 6 inches.

All 32-foot logs cut to 16 feet.

All 30-foot logs cut to 16 and 14 feet.

All 28-foot logs cut to 16 and 12 feet.

All 26-foot logs cut to 16 and 10 feet.

All 24-foot logs cut to 16 and 8 feet.

All 22-foot logs cut to 12 and 10 feet.

All 20-foot logs left as is.

All 18-foot logs left as is.

All 16-foot logs left as is.

All chunks squared to nearest merchantable length.

All logs with excessive crook cut to best merchantable length.

Table 1.--Pieces of western white pine used in evaluating yield and quality

Item	Number	Proportion of total logs
		Percent
Trees	160	....
Logs bucked	721	100
Logs hauled	716	99.3
Pieces broken:		
1 end	177	24.7
2 ends	152	21.2
Pieces rebucked	1,116	99.6
Total pieces	1,121	100
Pieces sawn	943	84.5

Table 2.--Diameter of western white pine logs evaluated

Log diameter	Number of logs: Plot 1	Plot 2	Plot 3	Plot 4	All plots	Number of merchantable logs	Percentage of merchantable logs
Inches							
5	...	...	...	2	2	0	0.00
6	7	11	8	6	32	26	2.93
7	9	15	15	11	50	45	5.07
8	12	23	14	13	62	58	6.54
9	8	21	19	16	64	58	6.54
10	15	24	18	14	71	61	6.88
11	15	23	20	19	77	67	7.55
12	11	14	22	13	60	49	5.52
13	19	15	18	19	71	59	6.65
14	18	12	19	21	70	55	6.20
15	21	11	14	19	65	53	5.98
16	21	9	12	17	59	43	4.85
17	14	6	13	18	51	39	4.40
18	18	7	17	19	61	48	5.41
19	12	5	14	12	43	24	2.71
20	18	7	13	16	54	40	4.51
21	15	2	5	16	38	35	3.95
22	18	3	10	12	43	32	3.61
23	17	1	3	10	31	24	2.71
24	11	0	1	7	19	10	1.13
25	9	2	5	12	28	21	2.37
26	5	1	2	3	11	5	.56
27	12	1	2	5	20	14	1.58
28	6	0	2	6	14	8	.90
29	4	0	0	1	5	2	.23
30	2	...	1	0	3	2	.22
31	4	...	2	0	6	4	.45
32	1	...	1	1	3	1	.11
33	3	...	1	1	5	3	.34
34	1	...	0	...	1	0	...
35	0	...	1	...	1	1	.11
36	0	...	0	...	0	0	...
37	0	...	0	...	0	0	...
38	0	...	0	...	0	0	...
39	1	...	...	...	1	0	...
Total	327	213	272	309	1,121	887	100
Average diameter	17.6	12.1	14.6	16.0	15.4	...	...
Average d.b.h.	28.3	18.6	23.4	27.5	24.4	...	...
Ratio	0.622	0.651	0.624	0.584	0.631	...	...

Table 3.--Length of western white pine logs evaluated

Log length	Plot 1		Plot 2		Plot 3		Plot 4		All plots		Bucking errors	Number of merchantable logs	Percentage of merchantable logs
	Number of logs	Part of plot total	Number of logs	Part of plot total	Number of logs	Part of plot total	Number of logs	Part of plot total	Number of logs	Part of plot total			
Feet		Percent		Percent		Percent		Percent		Percent			
4	4	1.22	1	0.47	...	0.00	1	0.32	6	0.54	...	0	0
5	2	.61	...	.00	...	.00	1	.32	3	.27	...	0	0
6	9	2.75	1	.47	...	.00	1	.32	11	.98	...	3	.34
7	2	.61	...	.00	2	.74	1	.32	5	.44	0.44	2	.22
8	38	11.62	11	5.16	15	5.51	25	8.09	89	7.94	...	65	7.33
9	6	1.83	2	.94	3	1.10	5	1.62	16	1.43	1.43	6	.68
10	23	7.03	16	7.51	23	8.46	25	8.09	87	7.76	...	70	7.89
11	4	1.23	2	.94	1	.37	1	.33	8	.71	.71	4	.45
12	33	10.09	10	4.69	17	6.25	19	6.15	79	7.05	...	56	6.31
13	4	1.22	1	.47	2	.73	3	.97	10	.89	.89	2	.23
14	18	5.50	17	7.98	13	4.78	18	5.83	66	5.89	...	50	5.64
15	4	1.23	1	.47	2	.74	2	.65	9	.80	.80	6	.68
16	149	45.57	134	62.91	179	65.81	191	61.81	653	58.25	...	576	64.94
17	...	.00	4	1.88	6	2.21	1	.32	11	.98	.98	6	.68
18	11	3.36	4	1.88	6	2.20	8	2.59	29	2.59	...	23	2.59
19	4	1.22	1	.47	2	.73	...	...	7	.62	.62	2	.23
20	7	2.14	4	1.88	1	.37	7	2.27	19	1.69	...	12	1.35
21	4	1.23	2	.94	...	.00	...	...	6	.54	...	2	.22
22	1	.31	2	.94	...	...	...	...	3	.27	.27	1	.11
23	2	.61	...	...	...	...	...	...	2	.18	...	1	.11
24	...	...	...	...	...	...	...	...	...	.00	.00	0	...
30	1	.31	...	...	...	...	...	...	1	.09	.09	0	...
33	1	.31	...	...	...	...	...	...	1	.09	...	0	...
Total	327	100	213	100	272	100	309	100	1,121	100	6.23	887	100
Av. length	13.76	...	14.80	...	14.23	...	14.35	...	14.23	...	...	14.59	...

Table 4.--Comparison of scale results for western white pine logs

Scale source	Number of logs			Volume			Difference in scale	Cull
	Same scale	Overscaled	Underscaled	Overscaled	Underscaled	Gross scale		
				Bd. ft.	Bd. ft.	Bd. ft.	Percent	Bd. ft.
Diagram	943	......	......	....	....	150,090	0	....
Check scaler	668	175	100	4,020	2,650	151,460	+0.91	27,020
Deck scaler	544	62	337	1,230	8,920	142,400	-5.12	24,120
Company scaler	622	121	200	2,910	5,530	147,470	-1.75	26,980

Table 5.--Volume variations of sound western white pine logs

Log diameter inside bark	Volumes: Mill tally[1]	Volumes: Fiducial limits: 5 percent level: Lower[1]	Volumes: Fiducial limits: 5 percent level: Upper[1]	Fiducial limits	International 1/4 log rule: Volume	International 1/4 log rule: Overrun	Scribner Decimal C log rule: Volume	Scribner Decimal C log rule: Overrun
In.	Bd. ft.	Bd. ft.	Bd. ft.	±Percent	Bd. ft.	Percent	Bd. ft.	Percent
6	24	21	26	11.12	20	20.0	20	20.0
7	33	30	36	9.48	30	10.0	30	10.0
8	43	40	47	8.47	40	7.5	30	43.3
9	55	49	57	7.22	50	10.0	40	37.5
10	69	64	73	6.57	65	6.1	60	15.0
11	84	79	89	5.83	80	5.0	70	20.0
12	100	95	106	5.44	95	5.2	80	25.0
13	118	112	124	5.02	115	2.6	100	18.0
14	138	132	144	4.58	135	2.2	110	25.0
15	159	152	166	4.33	160	-.6	140	13.6
16	182	175	190	4.05	180	1.1	160	13.7
17	206	199	214	3.81	205	.5	180	14.4
18	233	224	241	3.56	230	1.3	210	10.9
19	260	251	269	3.39	260	.0	240	8.3
20	289	280	299	3.22	290	-.3	280	3.1
21	320	310	330	3.06	320	.0	300	6.7
22	353	342	363	2.92	355	-.6	330	7.0
23	387	376	397	2.79	390	-.8	380	1.8
24	422	411	434	2.67	425	-.7	400	5.5
25	460	448	472	2.56	460	-.0	460	.0
26	499	486	511	2.46	500	-.2	500	-.1
27	539	523	552	2.36	540	-.2	550	-.2
28	582	568	595	2.28	585	-.7	580	.3
29	626	612	639	2.19	630	-.6	610	2.6
30	671	657	685	2.12	675	-.6	660	1.7
31	718	704	733	2.05	720	-.3	710	1.1
32	767	752	783	1.98	770	-.4	740	3.6
33	818	802	834	1.92	820	-.2	780	4.9
34	870	854	886	1.86	875	-.6	800	8.7
35	924	907	941	1.81	925	-.1	880	5.0
36	980	962	997	1.76	980	.0	920	6.5

[1]Plotted values.

Table 6.--Board-foot volumes of western white pine logs based on mill tally of finished lumber

Log diameter inside bark	Log length				
	8 feet	10 feet	12 feet	14 feet	16 feet
In.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.
6	11	14	17	21	24
7	15	20	24	29	33
8	21	26	31	37	43
9	26	33	40	48	55
10	33	42	50	60	69
11	40	51	61	73	84
12	48	61	73	87	100
13	57	72	87	103	118
14	67	84	101	120	138
15	78	98	117	138	159
16	89	112	134	158	182
17	101	127	152	179	206
18	114	143	172	203	233
19	128	161	192	226	260
20	143	179	214	252	289
21	158	203	237	279	320
22	175	219	[1]262	308	353
23	192	240	287	337	387
24	210	263	314	368	422
25	229	286	343	401	460
26	249	311	372	435	499
27	269	336	403	471	539
28	291	363	435	509	582
29	313	391	468	547	626
30	[1]337	420	503	587	671
31	361	450	539	629	718
32	386	481	576	671	767
33	412	513	614	716	[1]818
34	439	546	654	762	870
35	466	580	695	810	924
36	495	616	738	859	980

[1]Limits of basic data.

Table 7.--Dollar value of finished lumber from western white pine sound logs

Diameter inside bark	Value per log		Value per MBM	
	8-foot logs	16-foot logs	8-foot logs	16-foot logs
Inches	Dollars	Dollars	Dollars	Dollars
6	1.00	2.68	89.21	112.56
7	1.47	4.00	95.16	122.03
8	2.02	5.34	98.39	123.47
9	2.68	6.89	101.75	124.80
10	3.45	8.66	104.80	126.06
11	4.34	10.64	107.75	127.08
12	5.34	12.85	110.28	128.12
13	6.47	15.28	112.80	129.05
14	7.73	17.94	115.20	129.91
15	9.12	20.84	117.45	130.82
16	10.64	23.96	119.54	131.50
17	12.30	27.33	121.54	132.35
18	14.11	30.93	123.56	132.96
19	16.07	34.78	125.55	133.67
20	18.17	38.86	127.33	134.28
21	20.42	43.20	129.08	134.92
22	22.83	47.78	130.70	135.47
23	25.40	52.61	132.43	136.05
24	28.10	57.69	133.87	136.58
25	31.12	63.03	136.01	137.08
26	34.07	68.62	136.99	137.60
27	37.30	74.46	138.46	138.04
28	40.70	80.57	139.91	138.53
29	44.27	86.89	141.26	138.89
30	48.01	93.56	[1]142.63	139.41
31	51.94	100.45	143.96	139.84
32	56.04	107.60	145.22	140.10
33	60.33	115.02	146.50	[1]140.65
34	64.81	122.71	147.73	141.03
35	69.47	130.66	148.92	141.39
36	74.32	138.88	150.11	141.77

[1]Limits of basic data.

Table 8.--Grading results of western white pine logs

Log grade	Average value per MBF (lumber tally)	Basis[1]	Variance σ^2	Value range
	Dollars			Dollars
1	146	49	1,608	50-225
2	126	147	564	70-200
3	121	469	502	50-215
4	107	219	401	50-160

[1] Number of logs per grade.

Table 9.--Size-class distribution of trees yielding 160 western white pine 16-foot logs

Diameter at breast height	Number of 16-foot logs							Total
	3	4	5	6	7	8	9	
Inches								Percent
11.6 - 12.5	2	2	1					3.13
12.6 - 13.5	3	3	2					5.00
13.6 - 14.5	1	5	3					5.63
14.6 - 15.5		1	2					1.88
15.6 - 16.5		6	2	1	1			6.25
16.6 - 17.5		3		1				2.50
17.6 - 18.5		1	1	4				3.75
18.6 - 19.5			1	4	1			3.75
19.6 - 20.5				1	1			1.25
20.6 - 21.5			2	3	2			4.38
21.6 - 22.5			1	2	4	1		5.00
22.6 - 23.5				3	2	1		3.75
23.6 - 24.5			1	2	6			5.63
24.6 - 25.5				4	6	1		6.88
25.6 - 26.5					7	1		5.00
26.6 - 27.5				2	1	2		3.12
27.6 - 28.5					2	3		3.12
28.6 - 29.5					2	1		1.88
29.6 - 30.5					2	3		3.12
30.6 - 31.5			1		4	4		5.63
31.6 - 32.5					2	2		2.50
32.6 - 33.5						2		1.25
33.6 - 34.5					1	2	1	2.50
34.6 - 35.5						4		2.50
35.6 - 36.5						7		4.38
36.6 - 37.5					1			.62
37.6 - 38.5					1	1		1.25
38.6 - 39.5						1		.62
39.6 - 40.5					1		1	1.25
40.6 - 41.5						1		.62
41.6 - 42.5							1	.62
42.6 - 43.5						1		.62
43.6 - 44.5							1	.62
Total	6	21	17	27	47	38	4	
Percent	3.75	13.12	10.62	16.88	29.38	23.75	2.50	100.00

Table 10.--Average tree size of western white pine

Plot No.	Diameter at breast height	Merchantable height	Top diameter inside bark
	Inches	Feet	Inches
1	28.5	112.5	8.4
2	18.6	79.0	7.5
3	23.4	97.0	8.1
4	27.5	110.8	8.2
Av.	24.5	100.4	8.1

Table 11.--Number of trees in each of four merchantability classes

Plot No.	Number of trees cut	Number of cull trees	Merchantability class				Proportion of sound trees
			0 to 1/3	1/3 to 1/2	Over 1/2	Total over 1/3	
							Percent
1	40	5	13	4	18	22	3
2	40	0	4	4	32	36	13
3	40	1	4	7	28	35	7
4	40	0	1	4	35	39	2
Total	160	6	22	19	113	132	25
Percent	100	3.7	13.8	11.9	70.6	82.5	15.6

Table 12.--Volume and value of finished lumber from western white pine trees

Diameter at breast height	Sound trees (25)			All merchantable trees (133)		
	Volume per tree	Value per tree	Value per MBM	Volume per tree	Value per tree	Value per MBM
In.	Bd. ft.	Dol.	Dol.	Bd. ft.	Dol.	Dol.
10	96	10.77	112.19	96	11.68	121.67
15	301	37.32	123.65	258	31.26	121.16
20	679	90.13	132.74	519	62.85	121.10
25	1,278	178.60	139.75	892	108.05	121.13
30	2,141	312.30	145.87	1,389	168.21	121.10
35	3,312	500.90	151.24	2,019	244.57	121.13
40	4,832	745.20	154.22	2,792	338.22	121.14
45	6,745	1,082.00	160.41	3,716	450.17	121.14

Table 13.--Lumber and value recovery from western white pine trees and logs

Number of trees or logs	Gross scale Decimal C[1]	Net scale Decimal C[1]	No. 5 and better merchantable lumber	Relation to net scale	Total lumber value recovered	Average value per tree or log	No. 4 and better merchantable lumber	Relation to net scale
	Bd. ft.	Bd. ft.	Bd. ft.	Percent	Dol.	Dol.	Bd. ft.	Percent
160 trees	184,670	124,530	154,959	124.43	18,762.30	117.27	147,985	118.83
943 logs sawn	151,460	124,440	154,959	124.52	18,762.30	19.90	147,985	118.92
132 merchantable trees	158,580	120,650	148,602	123.17	18,155.50	137.54	142,372	118.00
840 logs sawn	151,210	120,080	144,412	119.56	17,814.20	21.21	139,216	115.94
833 logs sawn	150,300	119,850	143,565	119.79	17,731.50	21.29	138,425	115.50
825 logs sawn	148,450	118,430	141,737	119.68	17,558.10	21.28	136,755	115.47

[1] Check scale. Diagram gross scale was 183,680.

Table 14.--Tree breakage for western white pines

Plot No.	Number of trees broken	Breakage		Average diameter at breast height
		Lineal feet	Cubic feet	Inches
1	37	446.734	312.168	28.5
2	20	117.178	162.265	18.6
3	26	163.094	249.992	23.4
4	37	317.857	389.999	27.5
Total	120	1,044.863	1,114.424	....

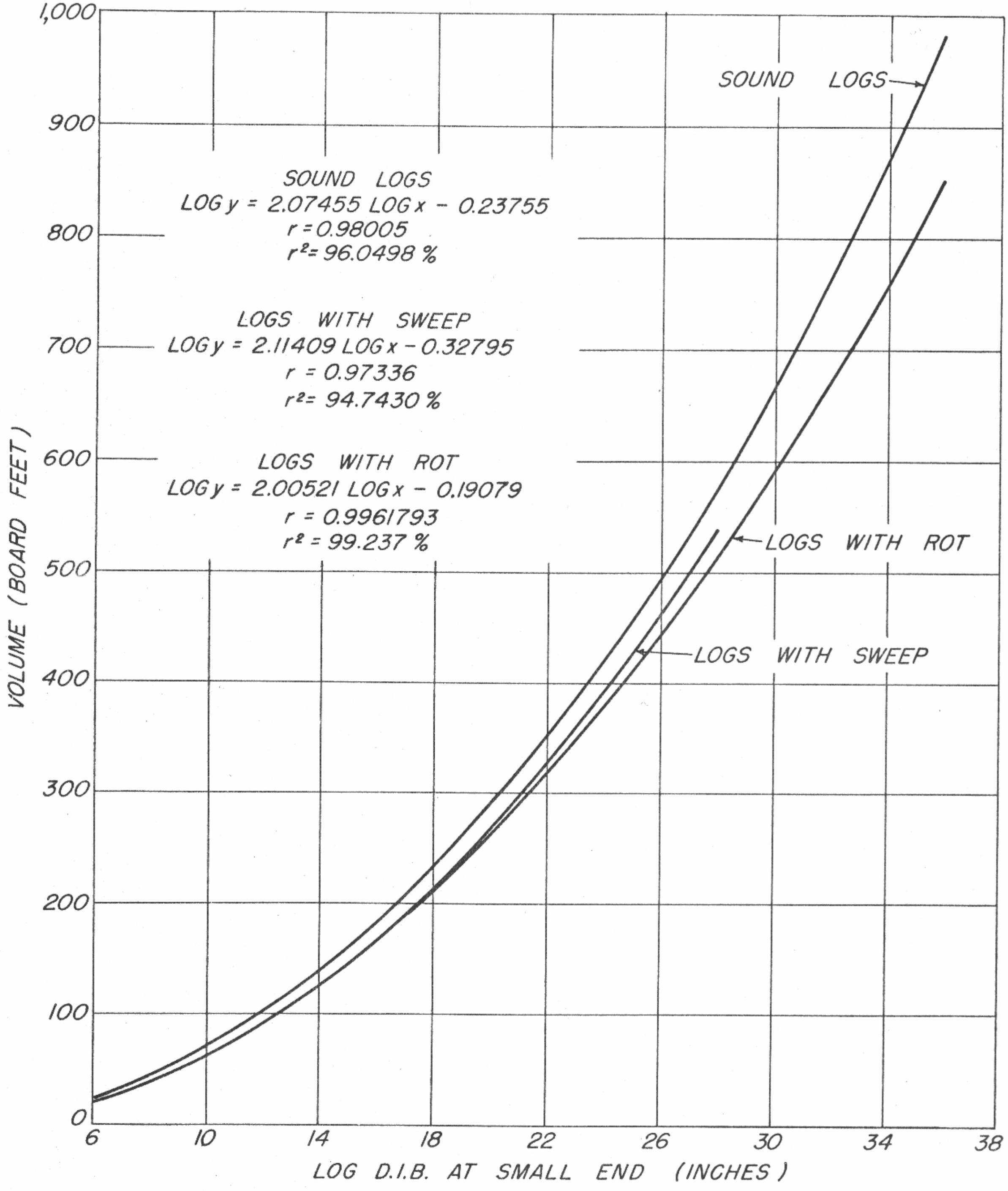

Figure 1. --Board-foot volume of 16-foot western white pine logs based on mill tally.

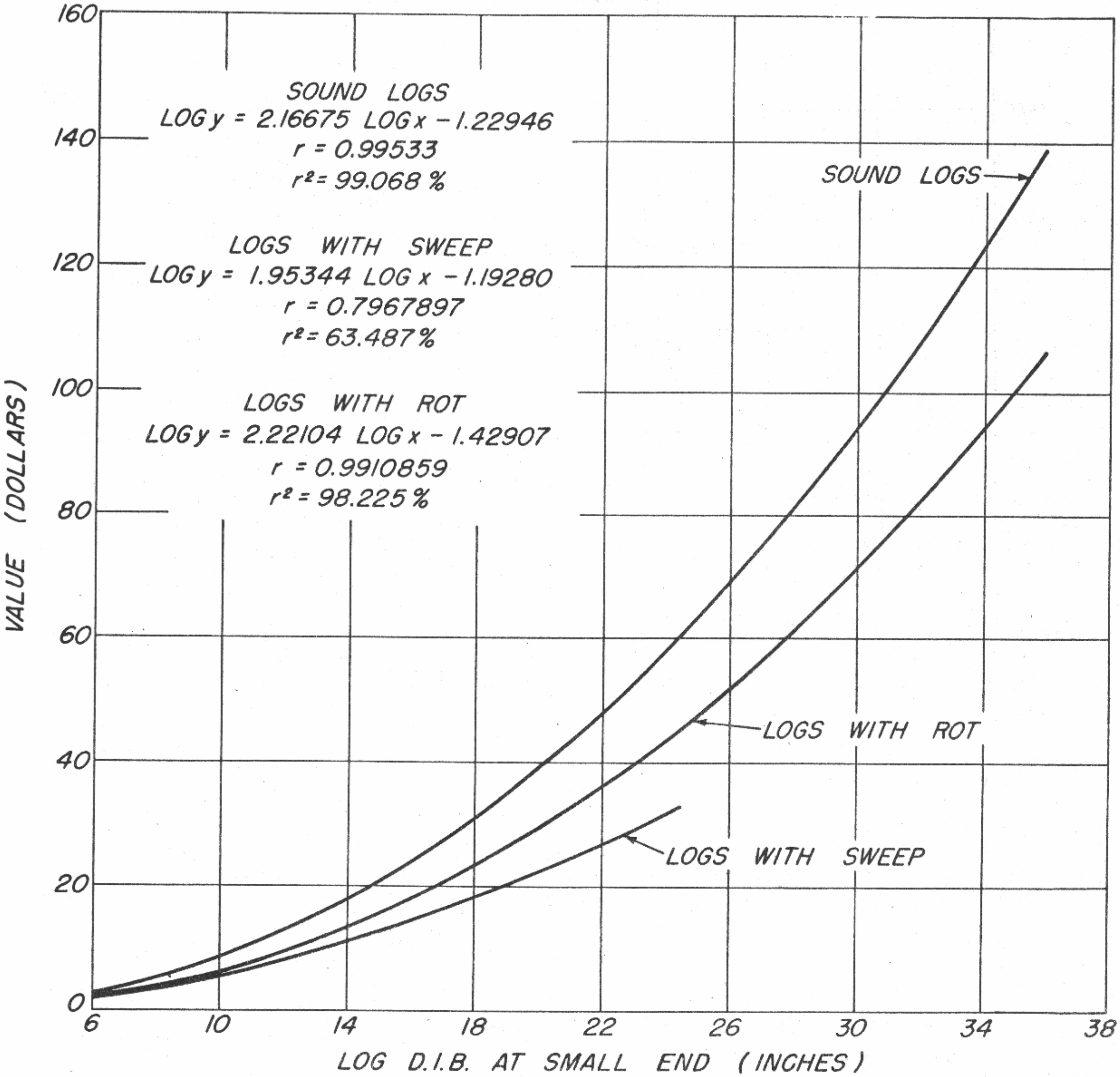

Figure 2. --Dollar value for 16-foot western white pine logs based on mill tally.

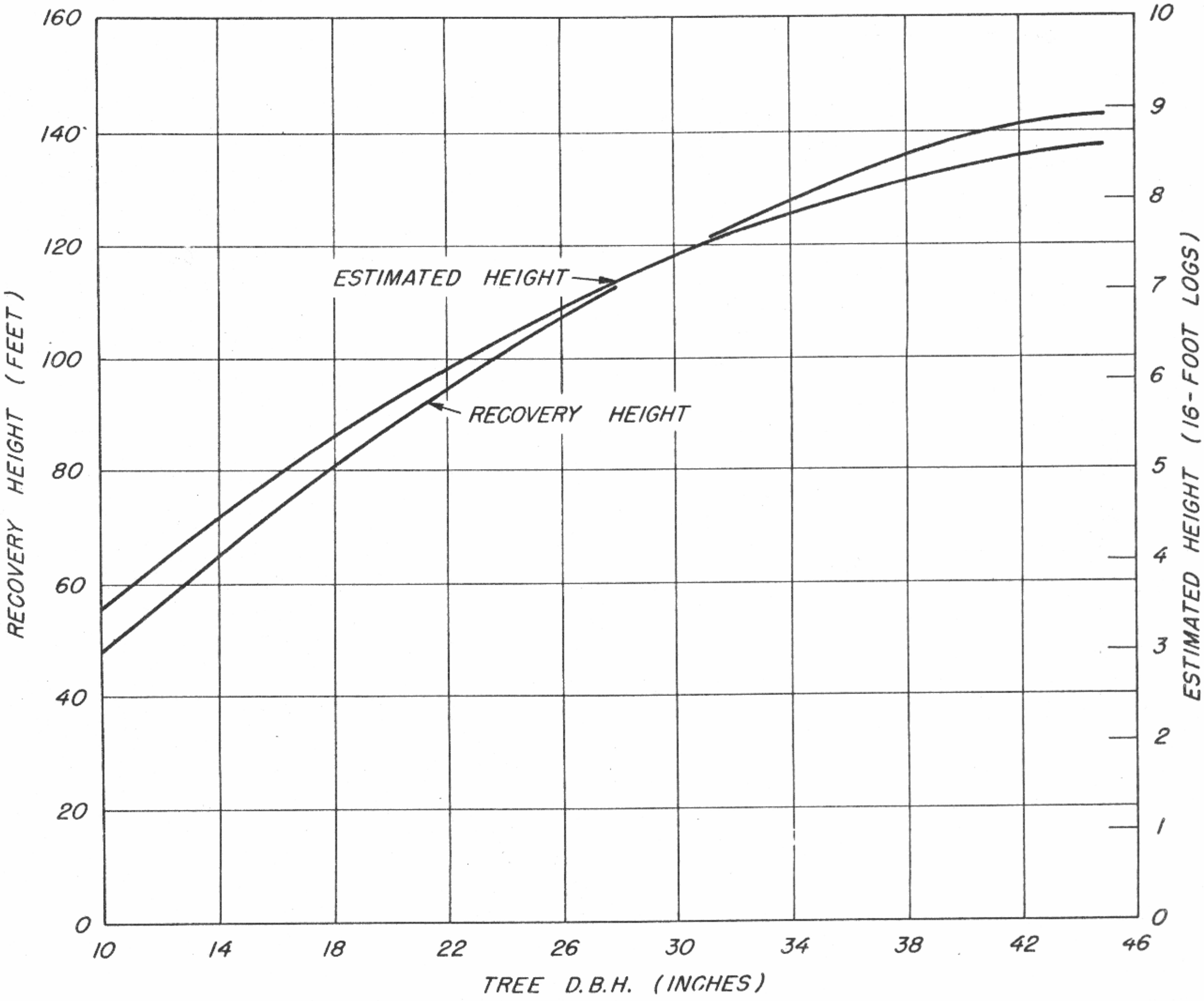

Figure 3. --Relation of log height in tree to diameter of tree at breast height.

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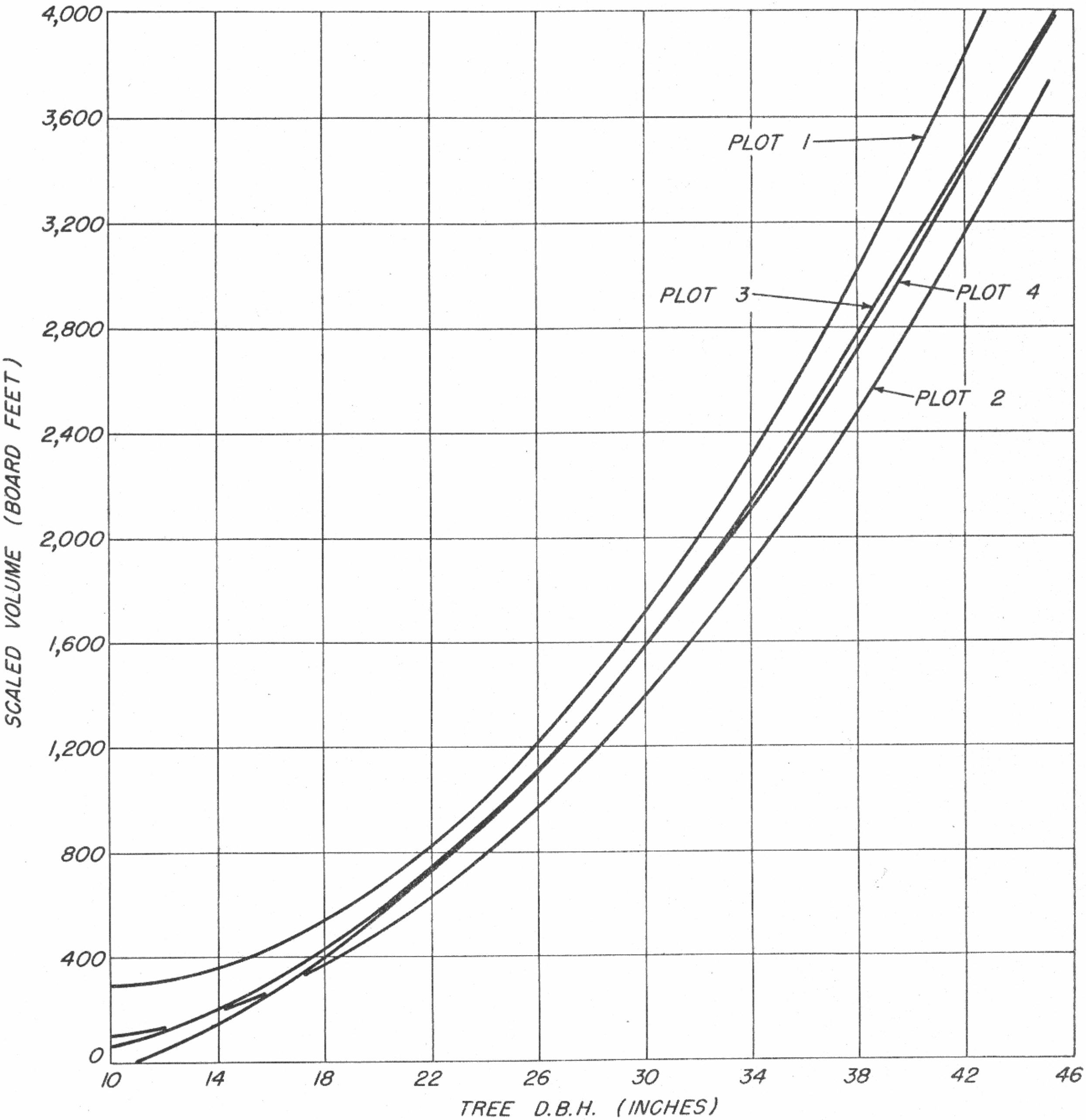

Figure 4.--Gross volume as determined by Scribner Decimal C log scale for western white pine.

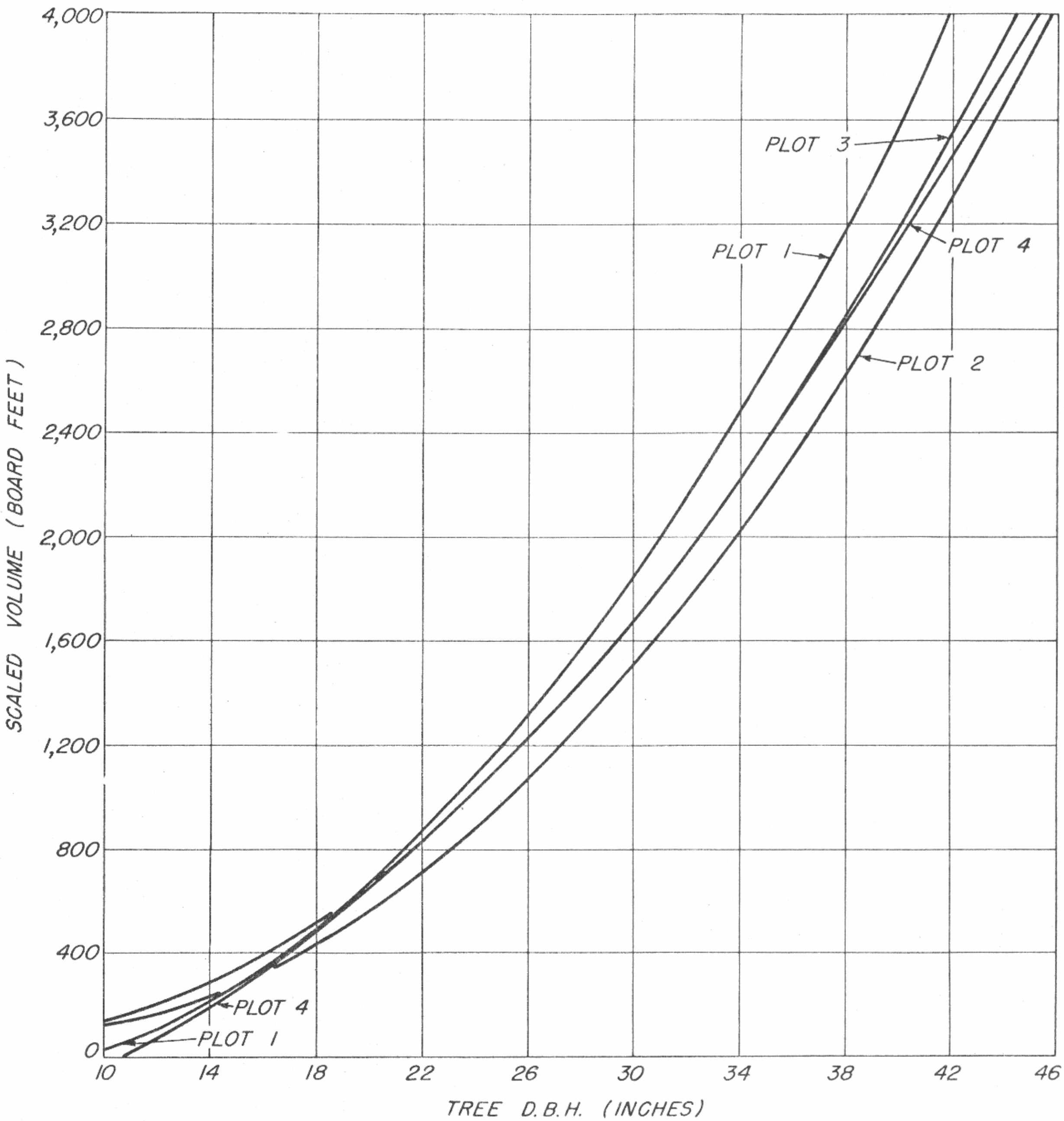

Figure 5. --Gross volume as determined by International 1/4-inch log scale for western white pine.

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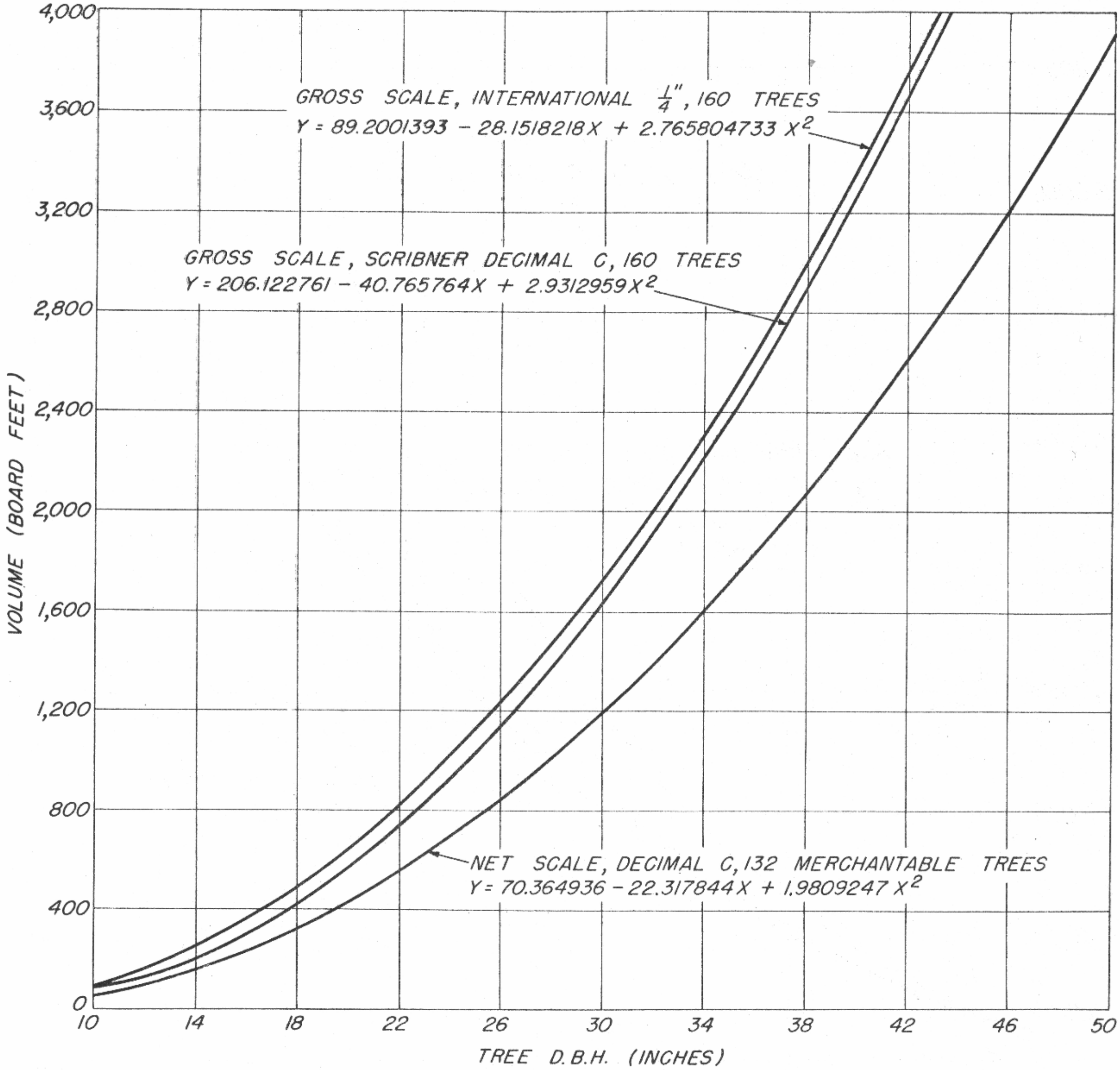

Figure 6. --Comparison of tree volume data as determined with Scribner Decimal C and International 1/4-inch scales for western white pine. All plots combined.

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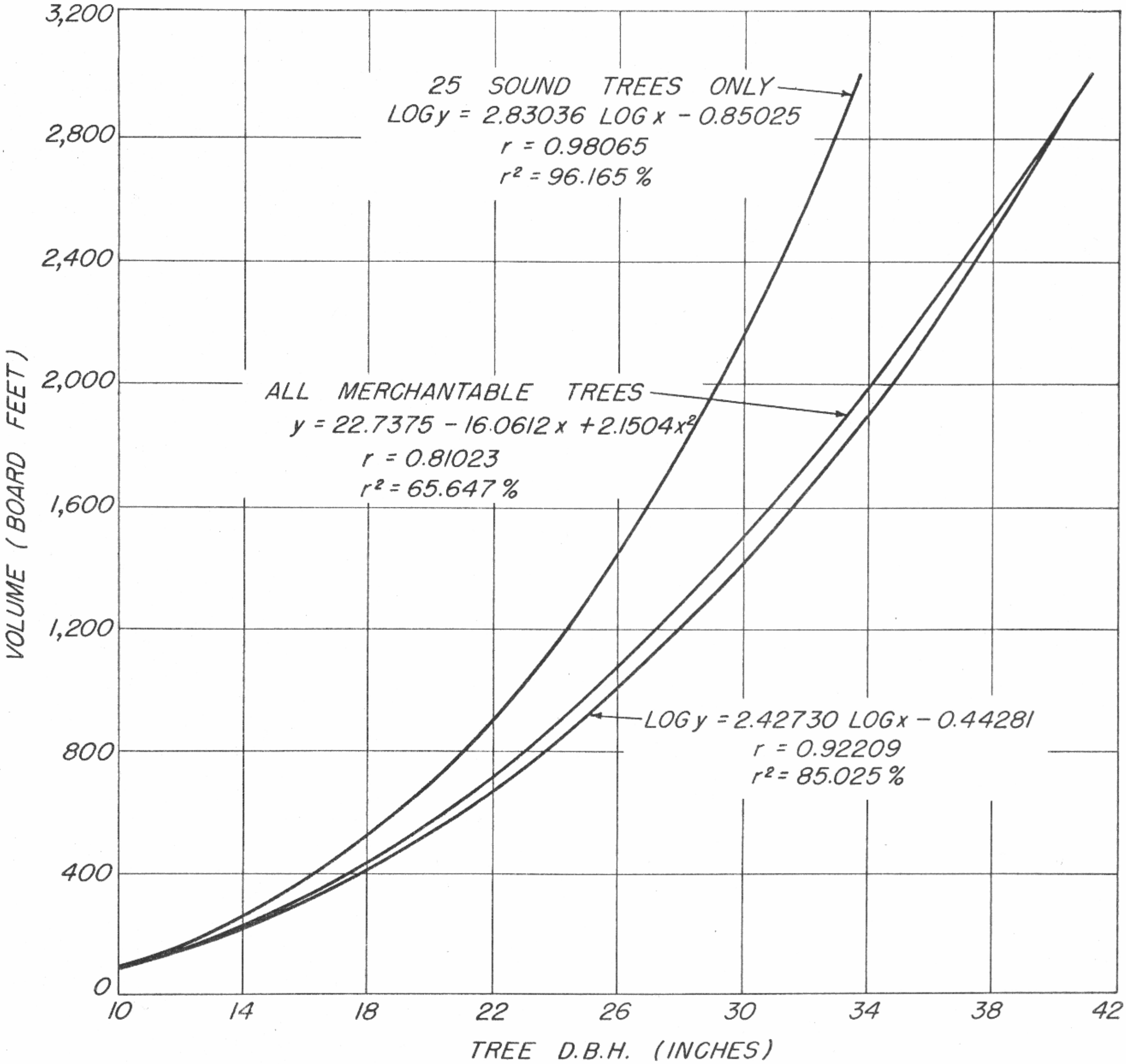

Figure 7. --Mill tally lumber volume for western white pine trees on all plots.

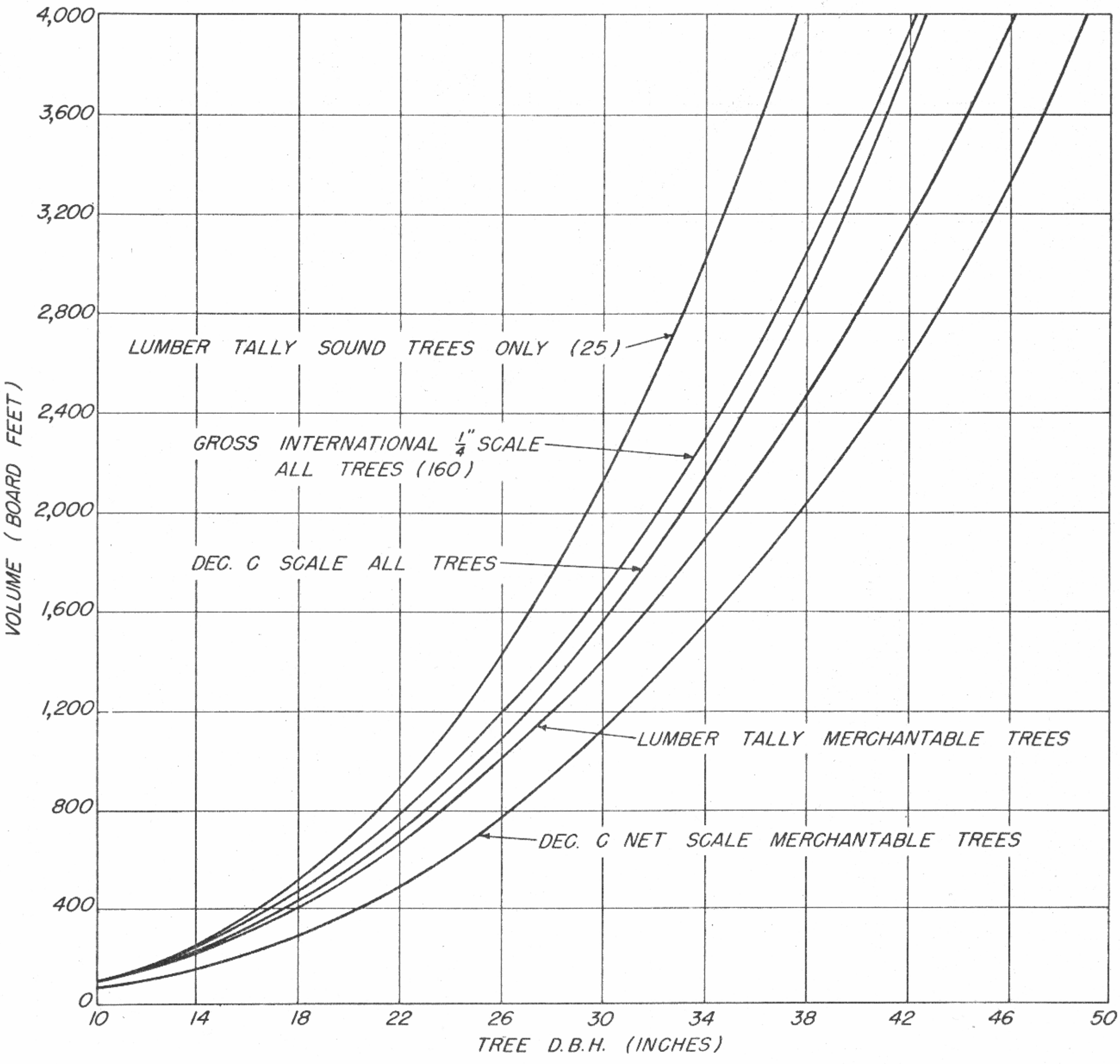

Figure 8. --Relation of board-foot volume to diameter at breast height of western white pine trees.

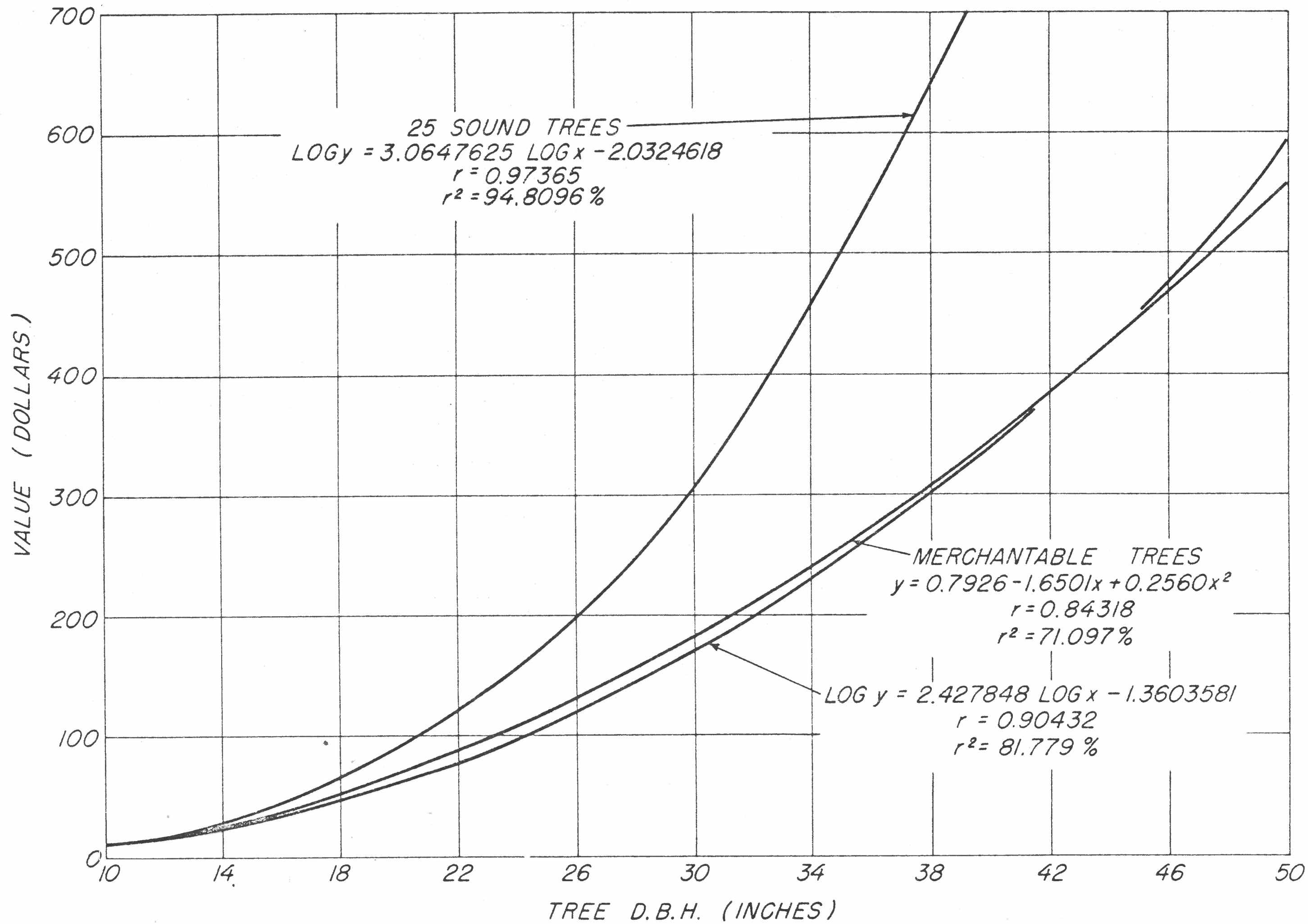

Figure 9.--Finished lumber value per tree, western white pine.