POND PINE WEIGHT EQUATIONS

Thesis for the Degree of M. S.
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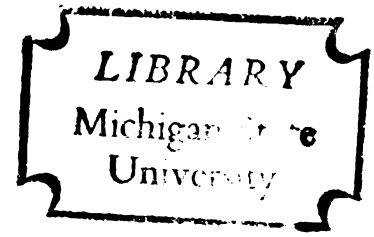

ABSTRACT

This study, conducted in North Florida, presents pond pine (Pinus serotina) tree weight prediction equations for rough green weight to 2-, 4-, and 8-inch top diameters outside bark. The data range is from 4 to 17 inches DBH. Prediction equations are also given for bark weight, peeled green tree weight and the proportion of oven dry wood in the peeled tree.

Scatter diagrams with regression lines plotted through the basic data are shown for each of the response variables. Also, the proportion of oven dry wood, at four locations in the tree stem,is shown graphically. Numerous statistics, developed by multiple regression analysis are included in the Appendix.

The prediction equations accounted for 93 to 98 percent of the variation in rough green tree weight and bark weight. The proportion of oven dry wood variable had less variation explained; at best only 54 percent of the variation in this variable could be accounted for by the dependent variables in the prediction equation.

The conclusions of this study are that pond pine tree and bark weights can be reliably predicted within the data range for the study area; that the proportion of oven dry wood decreases rapidly from the butt to the top of the stem; and that the large

amount of unexplained variation in the proportion of oven dry wood is probably caused by experimental error, natural variation and seasonal variation in moisture content of the tree.

POND PINE WEIGHT EQUATIONS

By

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INTRODUCTION

This study's purpose is to develop rough green, peeled green and oven dry weight equations for pond pine (*Pinus serotina*)[1/] located in the "Big Bend" of north Florida. The basic data were collected in Jefferson, Madison, Lafayette and Taylor Counties during the spring and summer of 1962.

Tree stem weight equations, as discussed here, are predicting equations, derived by multiple regression analysis, for estimating merchantable stem weight in pounds. They are similar to predicting equations developed for estimating tree volume in units such as cubic feet, cords or board feet.

Tree weights are of interest since considerable quantities of felled timber are bought and sold by weight, especially in the southeastern United States. While this trend toward weight purchases has been primarily with the pulp and paper industry, southern pine sawmills and treating plants are beginning to purchase timber by weight. This trend toward weight and away from volume has occurred because weight measurements are faster, simpler, more consistent and more easily checked than volume measurements. Also, working directly with tree weight eliminates the necessity of using volume-to-weight conversion factors.

1/ Scientific and common names are according to Little, (1953).

In addition, in the pulp and paper industry, many production variables such as final product yield, amount of bark, moisture percent, and by-product yield are measured by weight. Weight is also an important factor in regulating the movement of timber over railroads and public highways. Thus, it is logical for those organizations and individuals dealing in timber to be interested in tree weight.

This study presents equations for predicting the following pond pine stem weights above the stump:

y_2 = rough green weight to a 2-inch top D.O.B.

y_4 = rough green weight to a 4-inch top D.O.B.

y_8 = rough green weight to a 8-inch top D.O.B.

y_B = bark weight to a 2-inch top D.O.B.

y_P = peeled green weight to a 2-inch top D.O.B.[2/]

y_{OD} = proportion of peeled green weight, to a 2-inch top D.O.B., that is oven dry wood.

While the study is localized, the equations and statistics should be of interest in other areas.

POND PINE CHARACTERISTICS

Pond pine is one of the minor southern pines. It ranges, in the coastal plain, from the southern tip of New Jersey south-

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[2/] By subtraction, $y_P = y_2 - y_B$.

ward to central Florida and westward to southeastern Alabama. It occurs as far inland as the Piedmont Plateau through the Carolinas and Georgia (Collingwood and Brush, 1964).

Pond pine is characterized by a comparatively short trunk and a shaggy appearance caused by heavy needle clustering at branch ends. The limbs and trunk have a tendency to produce needle and twig sprouts. Pond pine, unlike most pines, sprouts readily and many stands are established after logging or fire in this manner. The cones are serotinous and consequently cones of varying ages are found on the same tree. The cones open rapidly after a fire or after the tree is felled. Apparently, fire is necessary for the establishment of well stocked natural stands (Fowells, 1965).

Pond pine inhabits the poorly drained mineral and organic soils of the lower coastal plain. On the wet organic soils it often occurs in almost pure stands, while on the poorly drained mineral soils it is found associated with species such as loblolly pine (Pinus taeda), slash pine (Pinus elliottii), cypress (Taxodium spp.), and sweetgum (Liquidambar styraciflua).

Pond pine growth is slow compared to pines such as loblolly and slash. However, the adverse site on which it occurs often accounts for the poor growth rate. Growth can be improved by the elimination of fire and providing adequate land drainage.

THE STUDY AREA

The study area is in the lower coastal plain of north Florida (Fig. 1). Elevations are generally less than 100 feet above sea level, while the topography is flat and for the most part poorly drained. Lesser vegetation includes wax myrtle (Myrica cerifera), gallberry (Ilex glabra), saw-palmetto (Serenoa repens) and titi (Cyrilla spp.). Pond pine is found primarily on organic soils and poorly drained mineral soils, such as the Leon and Portsmouth series.

The area's climate is typical of the southeastern United States; summers are hot and humid, while the winters are normally dry, with large fluctuations in daily temperature. The mean annual temperature for Perry, Florida, is 68.7°F; the January mean is 55.8°F and the August mean is 81.4°F.

Annual precipitation for the area is about 55 inches with almost half of it occurring during the months of June, July, August and September. There is an average of 245 days between dates of 32°F or below.

PROCEDURE

The study was conducted in the spring and summer of 1962 on the lands of The Buckeye Cellulose Corporation. A series of sample points was randomly located on timber type maps. These points were then located in the field and a 4-man crew moved

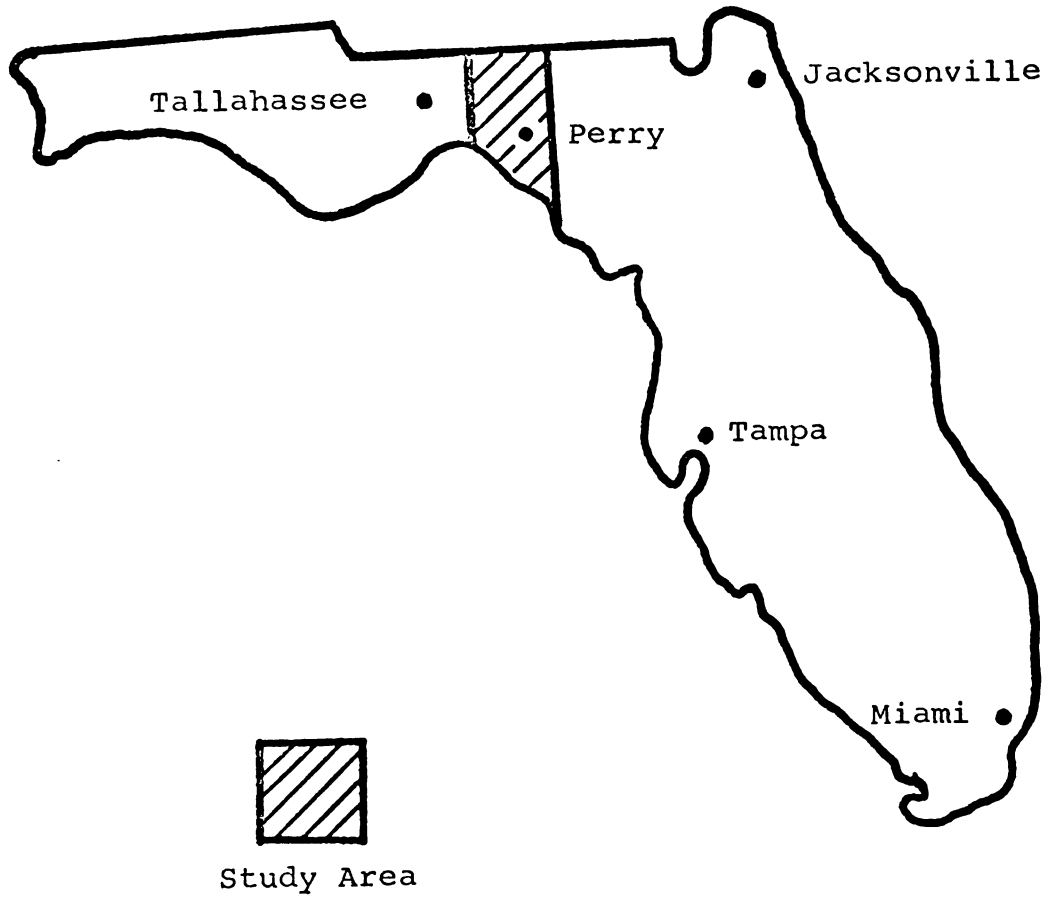

Fig. 1. Pond pine study area in north Florida.

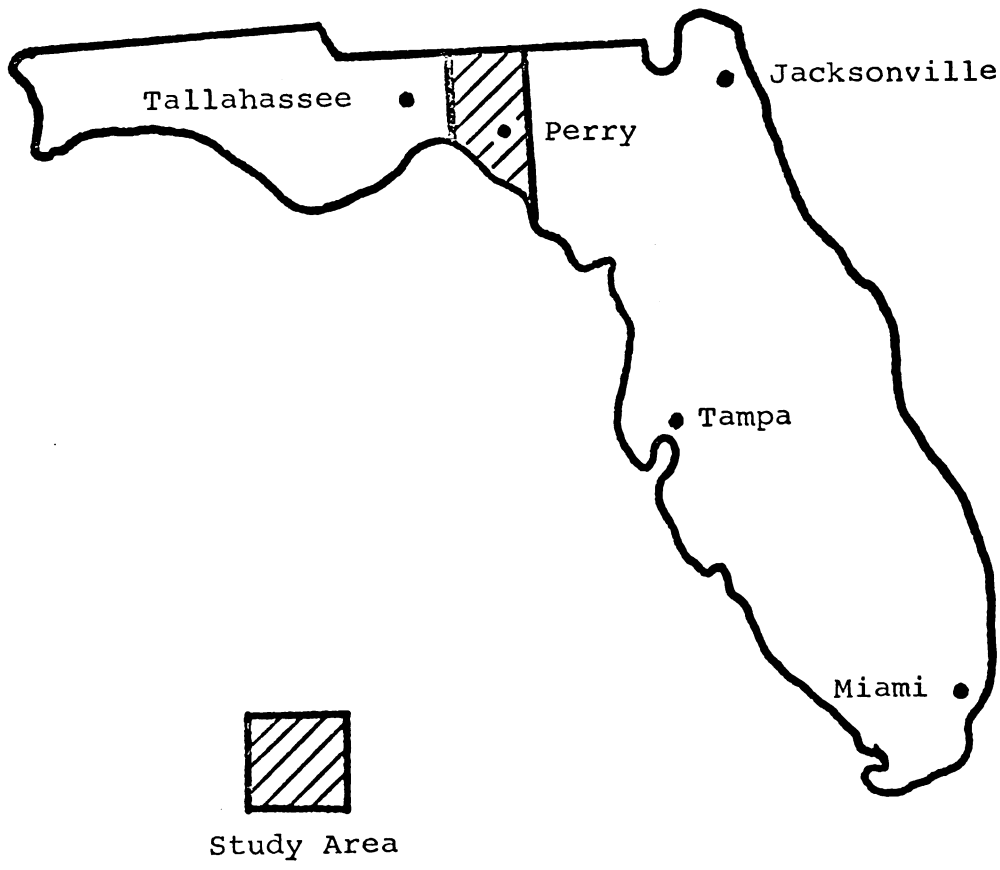

Fig. 1. Pond pine study area in north Florida.

equipment to the point. The equipment consisted of a small winch equipped crawler tractor, a specially designed skidding and hoisting arch, hydraulic scales with a 3,600-pound capacity, a chain saw, peeling spuds, diameter tapes, numerous small hand tools and miscellaneous materials. Sample trees were selected by making a clockwise sweep with a 10-factor prism and marked by numbering those trees occurring within the sample. Each sample tree had an increment core, reaching to the pith, extracted at breast height (4.5 feet above ground). The increment core was given the same number as the tree, placed in an air-tight bottle, and taken to the laboratory for specific gravity determinations.

The sample trees were then felled, keeping stump height as low as possible, limbed and topped at 2 inches D.O.B., or where the main stem was no longer identifiable and larger than 2 inches. The following measurements and weighings were then made:

1. Diameter outside bark, at breast height, to the nearest .1-inch.
2. Total tree height to the nearest foot.
3. Bark thickness, at breast height, to the nearest .05-inch.
4. Diameter inside bark, at 16.5 feet above stump, at the butt, at a point one-third of the way up the stem from the butt, at a point two-thirds up the stem from

the butt, and at the top of the used stem, all to the nearest .1-inch.

5. Tree age.
6. Rough green tree weight, to a 2-, 4-, and 8-inch top D.O.B., all to the nearest 5 pounds.
7. Peeled green weight of every fifth tree to a 2-inch top D.O.B.

The tree stem was weighed on the hydraulic scales by attaching the scales to the tree with two tongs separated by a spreader bar and hoisting the load with the tractor winch line which ran on a fixed roller at the top of the skidding arch. The tree weight was read directly off the scales which had been tared for the log tongs. Every fifth tree was peeled by hand and reweighed.

Four 2-inch thick disks were cut from each sample tree at the butt, at a point one-third of the way up the stem from the butt, at a point two-thirds up the stem from the butt, and the top of the used stem. These disks were given the same number as the tree, placed in plastic bags and taken to the laboratory for oven dry weight determinations.

The disks cut from each sample tree were brought into the laboratory, loose material was brushed from their surfaces, and they were weighed and recorded fresh green to the nearest .2-gram.

Next, they were placed in drying ovens at 100°C. The disk weights were checked periodically until a constant weight was reached, indicating cessation of moisture loss. Most samples reached a constant weight within 32 hours. The proportion of fresh green weight that was oven dry wood was calculated by dividing oven dry weight by fresh green weight.

The increment borer used to extract the increment core has a bore diameter of .170 inches which makes the end area of the core .1464 square centimeters. The fresh green volume of the increment core was calculated by multiplying the core length by the core end area. This gave increment core volume in cubic centimeters.

The increment cores were placed in drying ovens at a temperature of 100°C. The cores were removed periodically, put in drying chambers and weighed to the nearest .001-gram. Weighing had to be accomplished rapidly as the cores quickly picked up moisture from the air. Oven dry weight was reached when increment core weight remained constant. Increment core specific gravity was calculated by dividing the oven dry weight in grams by the fresh green volume in cubic centimeters. The average increment core specific gravity for 61 samples is .585 with a standard deviation of .059.

DATA ANALYSIS AND RESULTS

The purpose of this study was to provide pond pine pre-

diction equations for the following dependent variables: y_2, y_4, y_8, y_B, y_P and y_{OD}. There were 57 sample trees used for y_2, 54 for y_4, 29 for y_8, 11 for y_B, and 61 for y_{OD}.

The reasons for using differing numbers of trees is that 61 trees were sampled and used for y_{OD}; some of these trees had data missing and were not useable for y_2; 3 trees used in y_2 did not have a 4-inch top and thus could not be used for y_4; only 29 trees had an 8-inch top useable for y_8; and only 11 trees were peeled for y_B. Table 1 shows the number of trees by DBH class used for each dependent variable.

After checking the field and laboratory work for errors, the data were punched into cards for multiple regression analysis using a stepwise program on an IBM 7080 computer.

Rough Green Tree Weight: The three rough green tree weight response variables, y_2, y_4 and y_8 had eight independent variables used in the program. They were:

X_1 = DBH, diameter breast height in inches.

X_2 = Total tree height in feet.

X_3 = Tree age in years.

X_4 = Form class or $\frac{\text{d.i.b. at 16.5 feet above stump}}{\text{DBH o.b.}}$.

$X_5 = (\text{DBH})^2$

X_6 = Logarithm of total tree height.

X_7 = Logarithm of DBH.

Table 1. Number of trees in multiple regression program by DBH class.

DBH Class	Variable				
	Y_2	Y_4	Y_8	Y_B	Y_{OD}
Inches					
4	7	4			9
5	4	4		2	5
6	6	6			6
7	5	5		1	5
8	6	6		1	6
9	6	6	6	2	7
10	4	4	4	1	4
11	3	3	3	1	4
12	5	5	5	2	5
13	6	6	6		6
14	1	1	1		0
15	2	2	2		2
16	1	1	1		1
17	1	1	1	1	1
Totals	57	54	29	11	61

$X_8 = (DBH)^2$ (total tree height) = $(X_5)(X_2)$

The mean values of the variables in the rough green weight programs are shown in Table 2.

The program produced predicting equations for those variables with a partial F larger than 1.00. However, for y_2 and y_4, practically all of the variation was accounted for by the combined variable X_8, $(DBH)^2$(total tree height). For y_8, independent variable X_5, $(DBH)^2$ accounted for most of the variation. The rough green weight predicting equations and the amount of variation accounted for by the independent variables are as follows:

Response	Equation	R^2 Percent	N	SyX Pounds	$\bar{y}$ Pounds	$\bar{x}$
$\hat{y}_2$	$= .148(X_8) - 21$	97	57	112	663	$4,631 = \bar{x}_8$
$\hat{y}_4$	$= .149(X_8) - 54$	97	54	117	685	$4,956 = \bar{x}_8$
$\hat{y}_8$	$= 11.38(X_5) - 757$	93	29	173	878	$143.7 = \bar{x}_5$

Appendices 2, 3 and 4 show the multiple regression program output respectively for y_2, y_4 and y_8.

These equations are practical in that the transformed values of DBH and height, easily measured characteristics, are used to estimate weight---a value difficult to measure. The inclusion of additional variables only increased the percent of variation accounted for by 1.0, 1.3, and 3 percent, respectively, for y_2,

Table 2. Mean values of variables in multiple regression program.

Variable	Units	Item	Response Variable Program				
			y_2	y_4	y_8	y_B	y_{OD}
y_2	Pounds	Rough green weight 2-inch top	663	711	1111	771	-
y_4	Pounds	Rough green weight 4-inch top	-	684	1090	-	-
y_8	Pounds	Rough green weight 8-inch top	-	-	878	-	-
y_B	Pounds	Peeled green weight 2-inch top	-	-	-	97	-
y_{OD}	Ratio	Proportion OD wood 2-inch top	-	-	-	-	.526
X_1	Inches	Tree DBH	9.0	9.4	11.8	-	8.7
X_2	Feet	Total tree height	43	44	52	-	42
X_3	Years	Tree age	44	46	55	45	42
X_4	Ratio	Form class	.65	.66	.73	-	-
X_5	Sq. In.	$(DBH)^2$	92.45	98.84	143.66	-	-
X_6	Logarithm	Logarithm of tree height	1.6170	1.6315	1.7063	-	-
X_7	Logarithm	Logarithm of DBH	.9193	.9515	1.0638	-	-
X_8	$(X_5)(X_2)$	$(DBH)^2$(Height)	4631	4956	7698	5156	4124
X_9	Inches	Double bark thickness	-	-	-	1.75	-
X_{10}	Ratio	Inc. core specific gravity	-	-	-	-	.585
X_{11}	$\frac{1}{X_3}$	Reciprocal of age	-	-	-	-	.029
X_{12}	$(X_1)(X_3)$	(DBH)(Age)	-	-	-	-	408
X_{13}	$\frac{1}{X_{10}}$	Reciprocal of Inc.sp.gr.	-	-	-	-	1.73
X_{14}	$\frac{1}{X_3}(X_1)$	$\frac{1}{\text{Age}}$ (DBH)	-	-	-	-	.225
Number of observations			57	54	29	11	61

y_4 and y_8. Figures 2, 3, and 4 are scatter diagrams showing the regression lines plotted through the basic data for y_2, y_4 and y_8 respectively.

Tree Bark Weight: As only every fifth tree used in the rough green weight analysis was peeled, there are only eleven bark weight sample trees. The independent variables used in the y_B program are:

X_3 = Tree age.

X_8 = $(DBH)^2$(total tree height) or $(X_5)(X_2)$.

X_9 = Double bark thickness in inches.

The mean values of these variables are shown in Table 2.

As was the case with rough green tree weight, X_8 accounted for most of the variation in bark weight. The equation and some statistics are as follows:

Response	Equation	R^2	N	SyX	$\bar{y}_B$	$\bar{x}_8$
		Percent		Pounds	Pounds	
$\hat{y}_B$	= $.017(X_8) + 9$	98	11	12	97	5,156

Appendix 5 shows the multiple regression program output for y_B. Figure 5 shows the regression line plotted through the basic data.

By subtracting the equation for y_B from the equation for y_2, a peeled green weight equation y_P is obtained. Thus, y_P = $[.148(X_8) - 21] - [.017(X_8) + 9] = .131(X_8) - 30$. Figure 6 shows

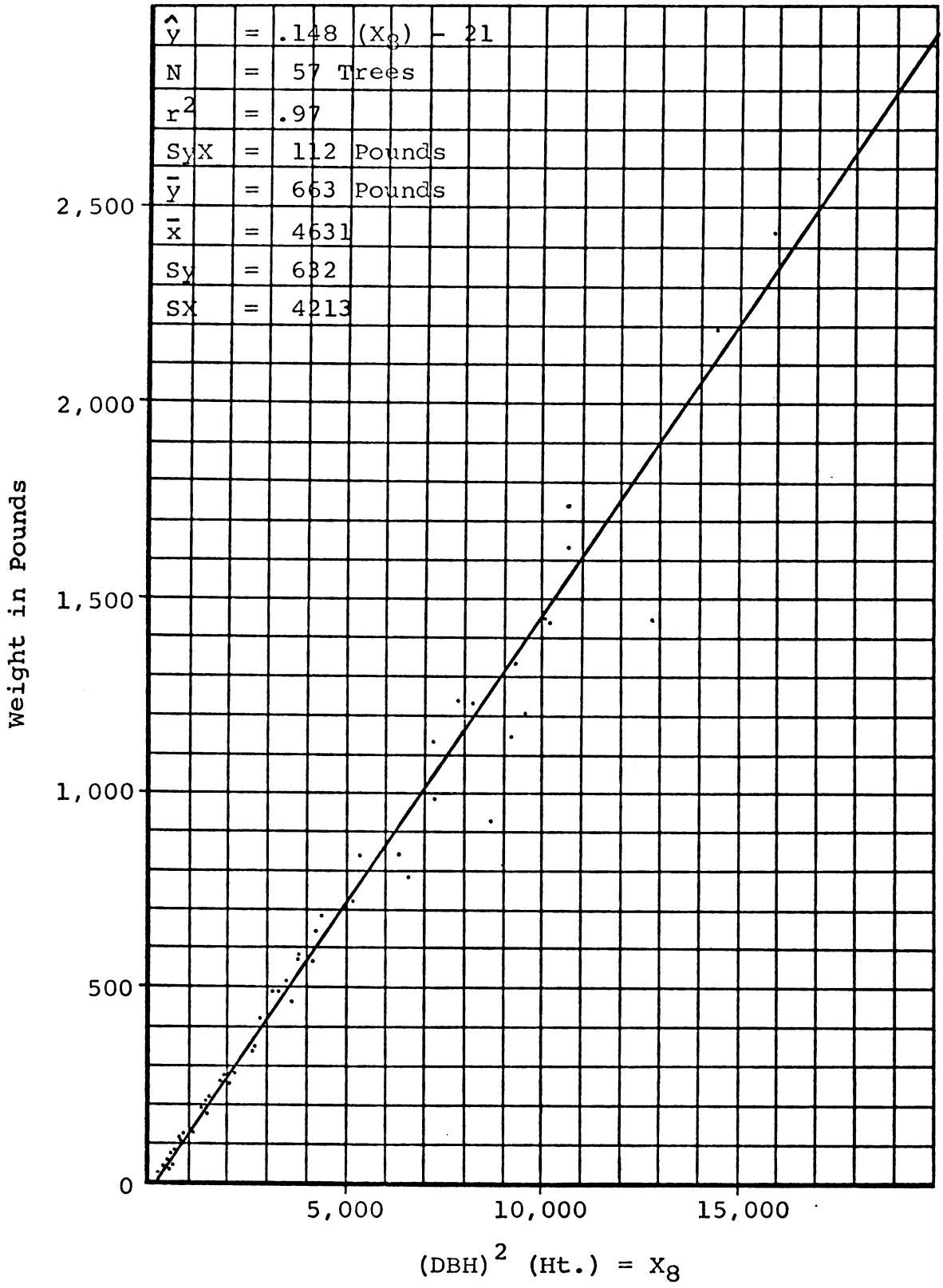

Fig. 2. Data and regression line for pond pine rough green tree weight to a 2-inch top D.O.B.

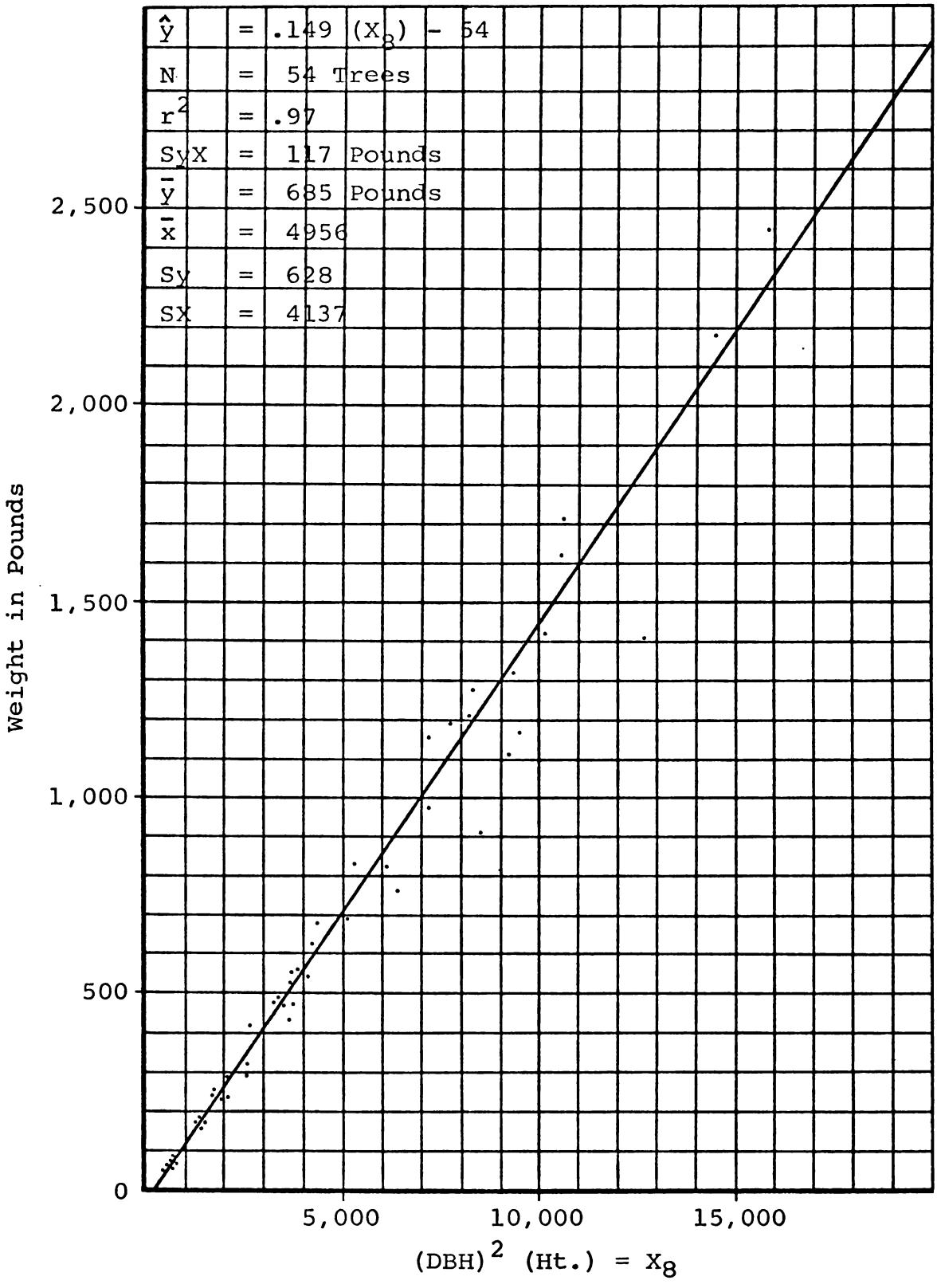

Fig. 3. Data and regression line for pond pine rough green tree weight to a 4-inch top D.O.B.

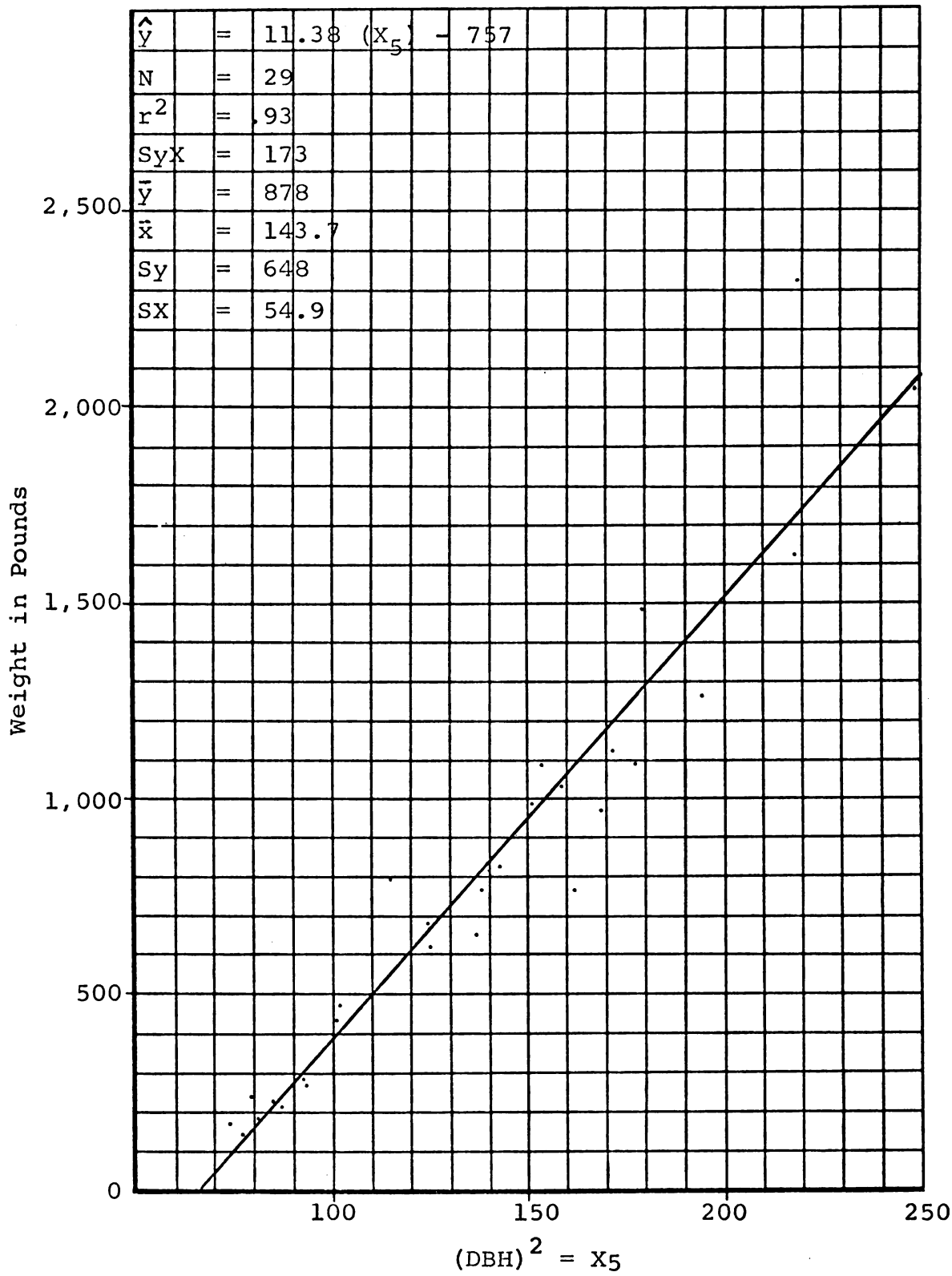

Fig. 4. Data and regression line for pond pine rough green tree weight to an 8-inch top D.O.B.

the regression line for this equation. A conservative estimate of Sy_pX is $\sqrt{S^2y_2X + S^2y_BX} = \sqrt{(112)^2 + (12)^2} = 113$.

Bark weight as a percent of rough green weight varies considerably. Figure 7 shows how this percentage varies over the range of X_8. By fitting a curve of DBH over X_8 and then superimposing DBH on X_8 in Figure 7, bark weight as a percent of rough green weight is estimated for each DBH class. Bark percent varies between 19 percent for the 6-inch DBH class and 12 percent for the 16-inch class.

Proportion Oven Dry Wood: The oven dry wood in a tree as a proportion of the peeled green weight was obtained by calculation rather than direct measurement, as was the case with rough green tree and bark weight. The calculation was made in the following manner:

Let:

A_1 = Diameter inside bark of the tree's butt disk.

A_2 = Diameter inside bark of the tree's second disk.

A_3 = Diameter inside bark of the tree's third disk.

A_4 = Diameter inside bark of the tree's top disk.

D_1 = Proportion of oven dry wood in the butt disk.

D_2 = Proportion of oven dry wood in the second disk.

D_3 = Proportion of oven dry wood in the third disk.

D_4 = Proportion of oven dry wood in the top disk.

Since the area of a circle is proportional to its diameter

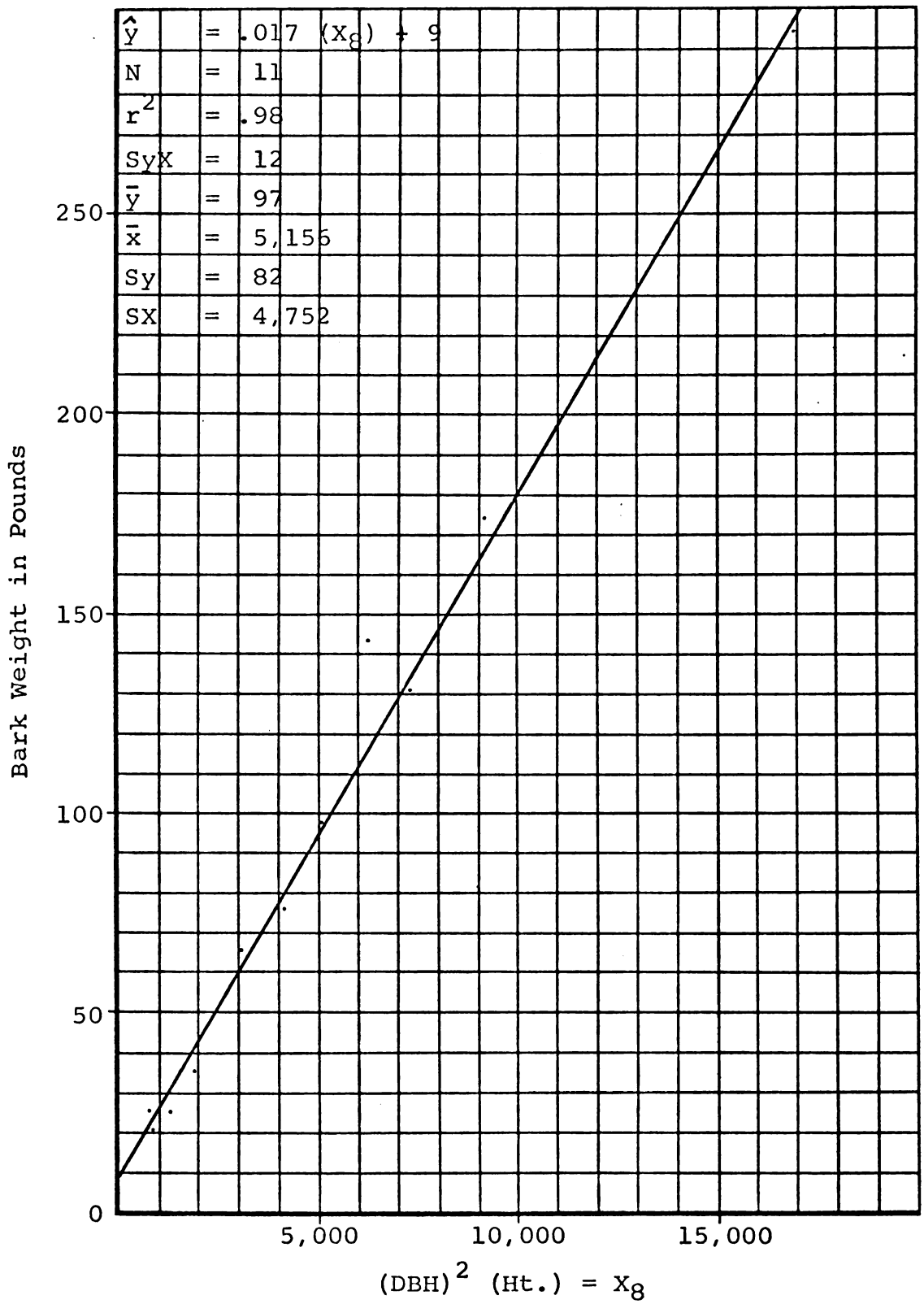

Fig. 5. Data and regression line for pond pine tree bark weight to a 2-inch D.O.B.

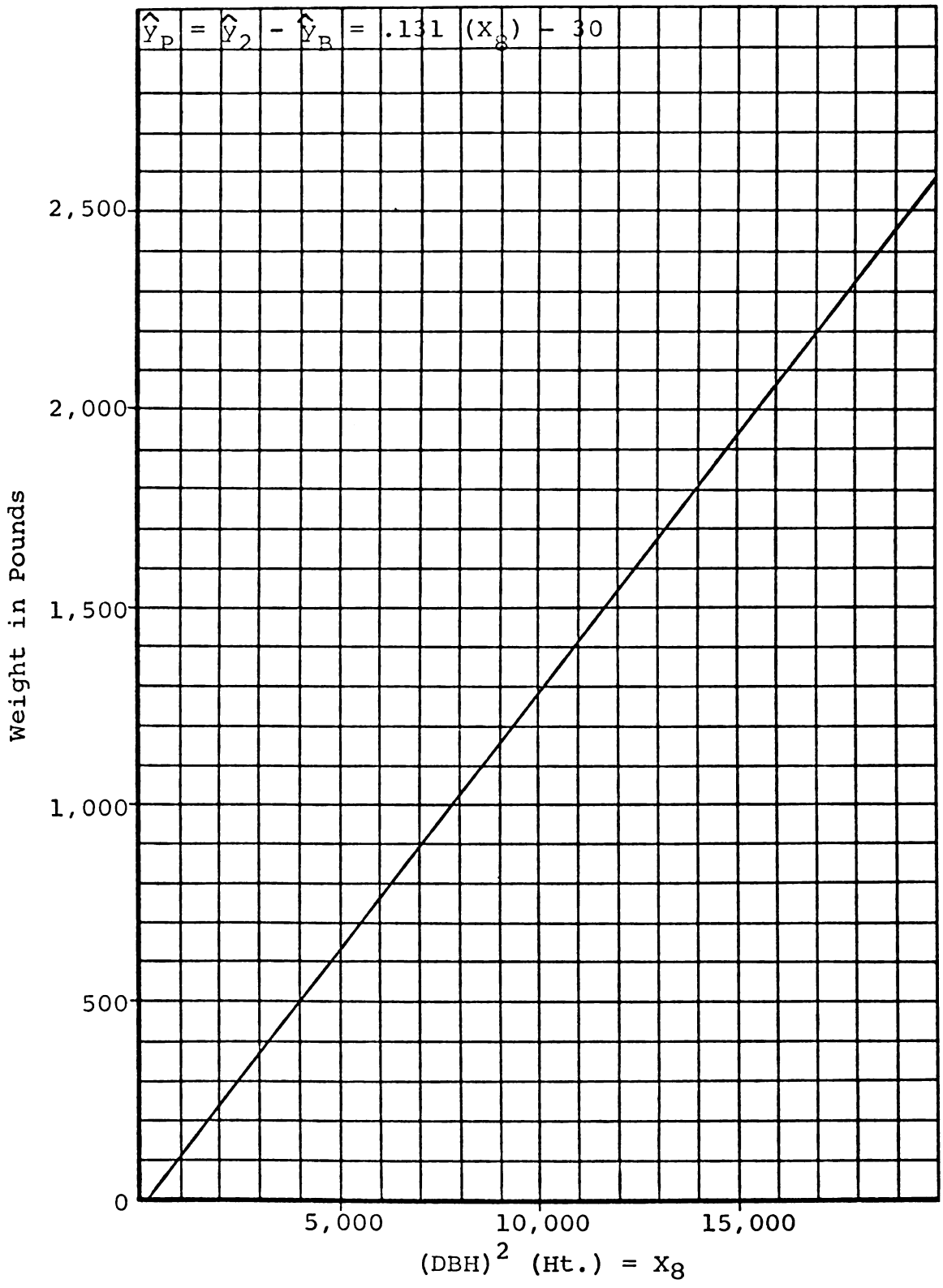

Fig. 6. Regression line for pond pine peeled green weight to a 2-inch top D.O.B.

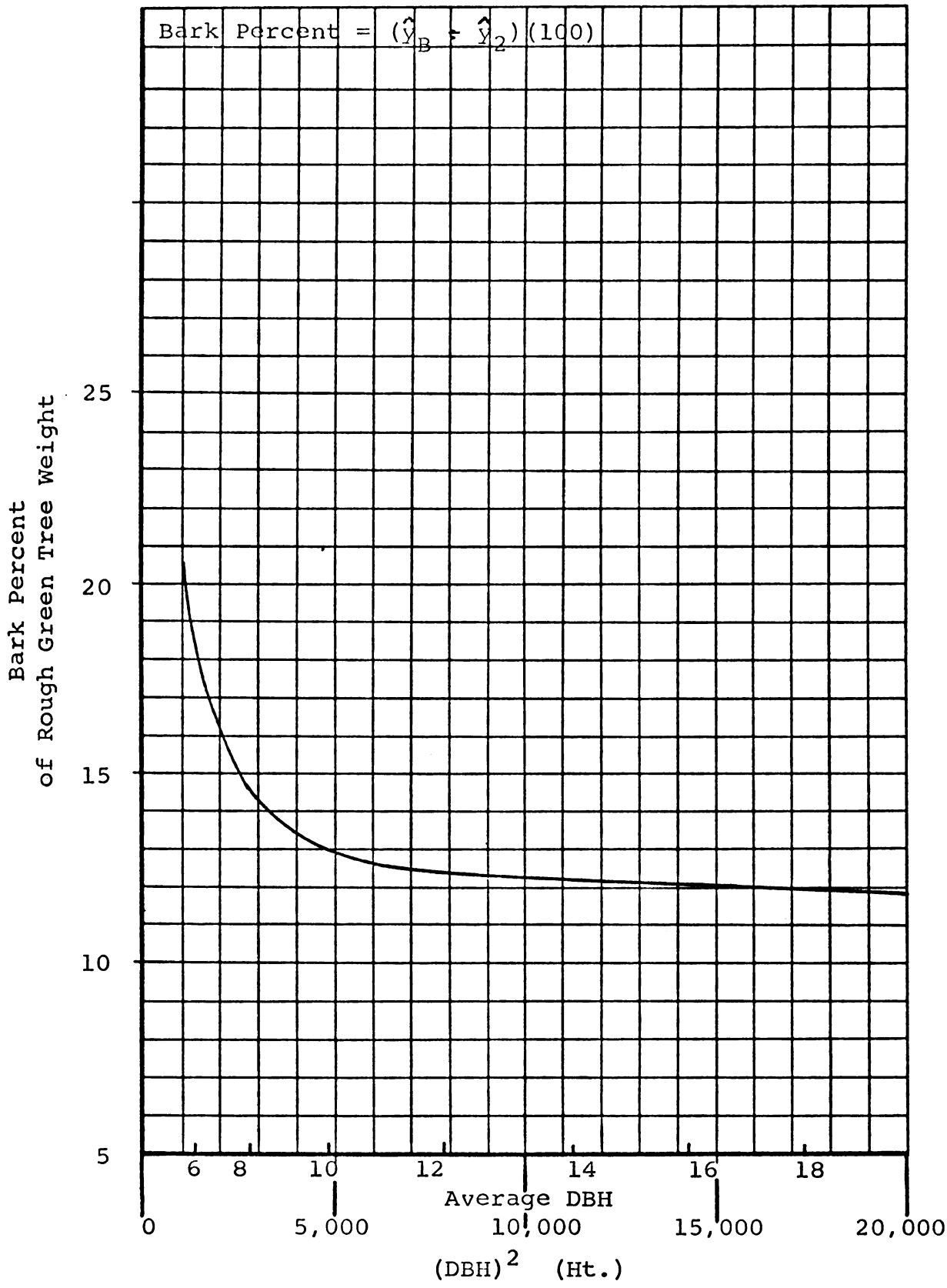

Fig. 7. Pond pine bark weight as a percent of rough green tree weight to a 2-inch top D.O.B. by $(DBH)^2$ (Ht.) and DBH class.

squared, the proportion of oven dry wood in the used tree stem, y_{OD}, is estimated by:

$$y_{OD} = \frac{A_1^2 D_1 + A_2^2 D_2 + A_3^2 D_3 + A_4^2 D_4}{A_1^2 + A_2^2 + A_3^2 + A_4^2}$$

Mean values for all sample disks are shown in Table 3.

The relationships for disk locations within the tree are shown graphically in Figure 8.

The independent variables used in the y_{OD} programs are:

X_1 = DBH in inches.

X_2 = Total tree height in feet.

X_3 = Tree age in years.

X_8 = $(DBH)^2$(total tree height).

X_{10} = Increment core specific gravity.

$X_{11} = \frac{1}{X_3}$

$X_{12} = (X_1)(X_3)$

$X_{13} = \frac{1}{X_{10}}$

$X_{14} = \frac{1}{X_3}(X_1)$

A single variable equation using X_{10}, increment core specific gravity, accounted for 45 percent of the variation in proportion of oven dry wood in peeled green pond pine. A three-variable equation increased the amount of variation ex-

Table 3. Mean values and standard deviations for sample disks from 61 trees.

Disk Location in Stem	Mean Disk Diameter Inches	Mean Oven Dry Weight Grams	Mean Fresh Green Weight Grams	Mean Proportion Oven Dry Wood	Standard Deviation
Butt	8.8	154.8	277.0	.561	±.061
One-third used length	6.4	120.8	235.9	.514	±.064
Two-thirds used length	4.8	88.7	191.2	.465	±.055
Top of used length	1.8	17.6	44.0	.407	±.052

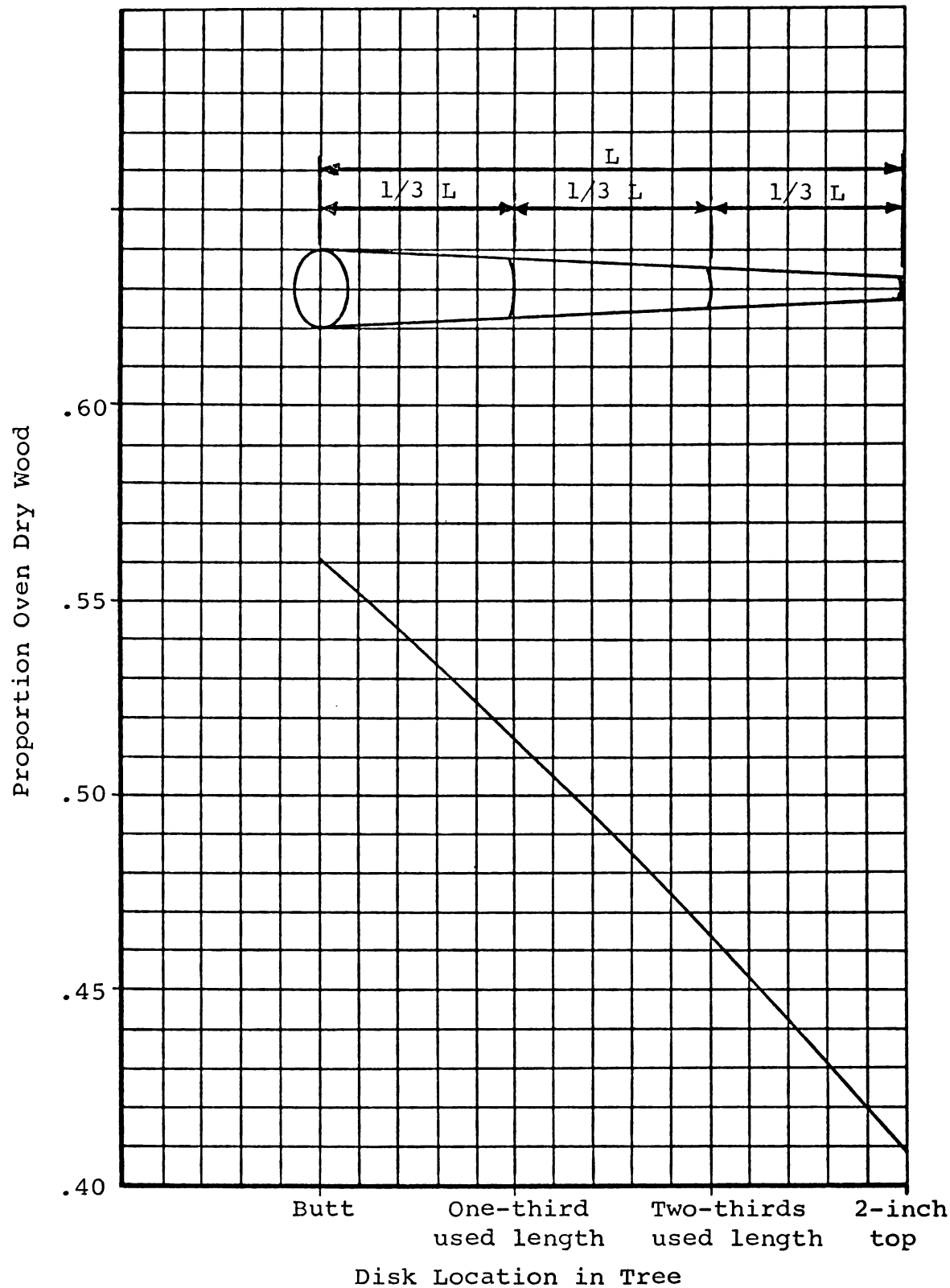

Fig. 8. Average proportion oven dry wood in fresh green pond pine disks by location in the tree.

plained to 54 percent.

The proportion oven dry wood equations are:

Response	Equation	R^2 Percent	N	SyX	$\bar{y}$	$\bar{x}$
1. y_{OD}	$.642\ (X_{10}) + .151$	45	61	.043	.526	.585
2. y_{OD}	$.489\ (X_{10}) +$	54	61	.039	.526	.585
	$.0025\ (X_2) -$					41.9
	$.006\ (X_1) +$					8.7
	.187					

Appendices 6 and 7 show the multiple regression program output, respectively, for equations 1 and 2. Figure 9 is the scatter diagram for y_{OD} with the regression line for equation No. 1, above, plotted through the data.

DISCUSSION

The objectives of the study were partially met with the development of weight equations that explain most of the variation in rough green tree weight and bark weight. Unfortunately, the best prediction equation for the proportion of oven dry wood in peeled green pond pine, could, at best, only account for 54 percent of the variation associated with this variable.

There may be several reasons for the lack of a high R^2 for y_{OD}. First, for the variables chosen, this may be as much variation as can be accounted for. Second, many detailed measurements

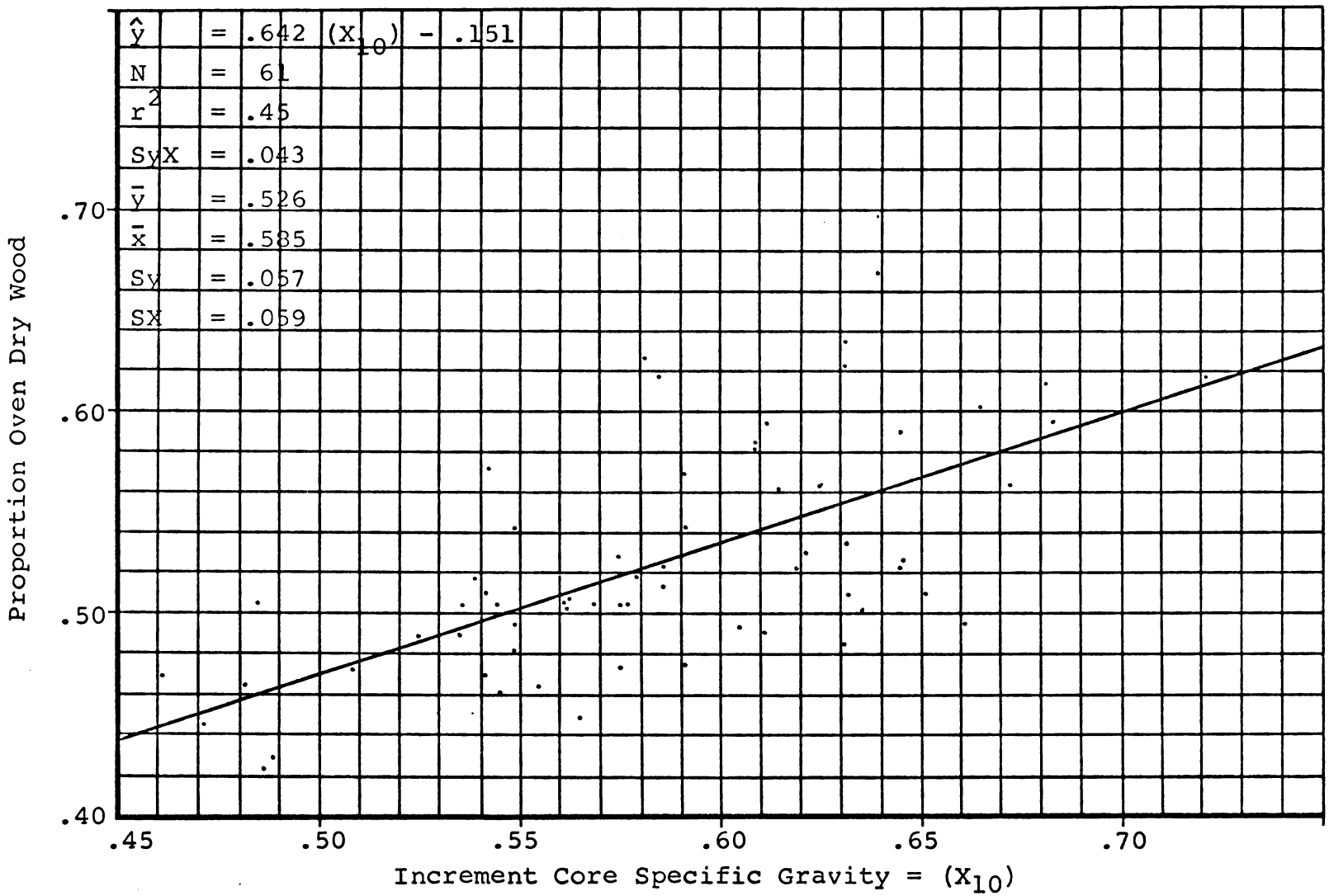

Fig. 9. Data and regression line for pond pine proportion oven dry wood in peeled green tree.

and oven drying could have induced large experimental errors. Certainly, experimental error contributed to unexplained variation. Third, y_{OD} was not a direct measurement, but calculated from four stem samples, assumed to consistently represent the entire tree. Fourth, there is variation in tree stem moisture content from season to season. Peck (1959) reported seasonal moisture variation on an oven dry basis for loblolly pine, which, when converted to a green weight basis, is as follows:

Season	Sapwood Percent	Heartwood Percent
Winter	52.3	37.1
Spring	51.7	32.4
Summer	51.7	36.3
Autumn	50.0	31.9

Bishop and Markworth (1933), also working with loblolly pine, found green weight moisture percent varied between 36.3 percent in May and 42.9 percent in November.

The weight prediction equations presented here can be used in forest inventories in the same manner as volume equations are used, or by using Tables 4 and 5, which have pond pine tree weights calculated by DBH class and 10-foot total height intervals, respectively, for a 2- and 4-inch top D.O.B.

Peeled green weights for a 2-inch top D.O.B. are shown in

Table 4. Pond pine rough green tree weight to a 2-inch top D.O.B., by DBH and height class.

DBH Class	Total Tree Height in Feet					
	30	40	50	60	70	80
Inches	----------Pounds----------					
5	89	126				
6	138	191	245	298		
7	196	268	341	413	485	
8	262	357	451	546	640	
9	338	457	577	697	817	
10	422	570	718	865	1013	
11	515	694	873	1052	1230	1409
12		830	1043	1255	1468	1681
13		978	1227	1477	1727	1977
14		1137	1427	1717	2006	2296
15		1309	1641	1974	2306	2639
16		1492	1870	2249	2627	3005
17			2114	2541	2968	3396
18			2373	2852	3331	3811

$\hat{y}_2$ = $.148\ (DBH)^2\ H - 21$

N = 57 Trees sampled

r^2 = .97

$S_{y \cdot x}$ = 112 Pounds

$\bar{y}$ = 663 Pounds

Mean DBH = 9.0 Inches

Mean Height = 43 Feet

Sy = 632 Pounds

Table 5. Pond pine rough green tree weight to a 4-inch top D.O.B., by DBH and height class.

DBH Class	Total Tree Height in Feet					
	30	40	50	60	70	80
Inches	----------Pounds----------					
5	58	95				
6	107	161	214			
7	165	238	311	384		
8	232	327	422	517	612	
9	308	429	550	671	792	
10	393	542	691	840	989	
11	487	667	847	1027	1207	
12		804	1019	1234	1449	1664
13		953	1205	1457	1709	1961
14		1114	1406	1698	1990	2282
15		1288	1623	1959	2294	2630
16		1473	1854	2236	2618	3000
17		1670	2100	2531	2962	3393
18			2361	2844	3328	3811

$\hat{y}_2$ = .149 $(DBH)^2H$ - 54

N = 54 Trees sampled

r^2 = .97

$S_{y\cdot x}$ = 117 Pounds

$\bar{y}$ = 685 Pounds

Mean DBH = 9.4 Inches

Mean Height = 44 Feet

Sy = 628 Pounds

Table 6 by DBH class and 10-foot total height intervals. Bark percent by DBH class as shown in Figure 7 may also be used to estimate peeled green weight.

To use the y_{OD} equation, an increment core specific gravity sample is necessary. From average increment core specific gravity, an estimate of the proportion of oven dry wood in the peeled green tree stem can be made.

In addition to using the equations as mentioned, considerable statistical information is included. A summary of the multiple regression program outputs are included in the Appendix. In addition, simple correlation coefficient matrices for each problem are in the Appendix, along with definitions (from Steele and Torrie, 1960) of the statistics presented. These data should be of value to anyone planning similar studies.

CONCLUSIONS

The following conclusions are drawn from the results of this study:

1. Pond pine rough green tree weight can be predicted quite reliably for 2-, 4-, and 8-inch top D.O.B. within the data range. The sample trees ranged between 4 and 17 inches DBH.
2. Bark weight can also be reliably predicted for trees to a 2-inch top D.O.B. While the sample size was small, (11 trees), the regression equation accounted

Table 6. Pond pine peeled green tree weight to a 2-inch top D.O.B. by DBH and height class.

DBH Class	Total Tree Height in Feet					
	30	40	50	60	70	80
Inches	----------Pounds----------					
5	68	101				
6	111	159	207	255		
7	163	227	291	355	419	
8	222	305	388	471	554	
9	288	394	394	500	606	
10	363	494	625	756	887	
11	446	604	762	920	1078	1236
12		725	913	1101	1289	1477
13		856	1077	1298	1519	1740
14		997	1254	1511	1768	2025
15		1149	1444	1739	2034	2329
16		1311	1647	1983	2319	2655
17			1863	2242	2621	3000
18			2092	2517	2942	3367

$$\hat{y}_P = \hat{y}_2 - \hat{y}_B = .131\ (X_8) - 30$$

for 98 percent of the bark weight variation.

3. There is a substantial difference in bark as a percent of rough green weight to a 2-inch top D.O.B. by DBH class. The 6-inch DBH class has about 19 percent of its rough green weight in bark, while the 10- and 17-inch DBH classes have 13 and 12 percent, respectively.

4. The proportion of oven dry wood weight to peeled green weight is highest in the butt of the tree and lowest in the top. There is almost a straight line relationship in the decline of oven dry wood from butt to top. The decline is from .561 in the butt to .407 in the top.

5. The variation in proportion oven dry wood was not satisfactorily explained. Possibly natural variation, experimental errors and seasonal variation in moisture content contributed to the large amount of unexplained variation.

LITERATURE CITED

Bishop, G.N. and G.D. Marckworth.
1933. Some Factors Influencing Resin Concentration in Loblolly and Slash Pines. Jour. Forestry 31(8): 953-960.

Collingwood, G.H. and W.D. Brush.
1964. Knowing your Trees. The American Forestry Association. 349 pp.

Fowells, H.A.
1965. Silvics of Forest Trees in the United States. U.S.D.A., Forest Service, Agriculture Handbook No. 271. 761 pp.

Little, E.L., Jr.
1953. Check List of Native and Naturalized Trees of the United States (Including Alaska). U.S.D.A., Agric. Handbook 41. 472 pp.

Peck, E.C.
1959. The Sap or Moisture in Wood. U.S.D.A. Forest Service, Forest Products Laboratory Publ. No. 768. 5 pp.

Steele, R.G.D. and J.H. Torrie.
1960. Principles and Procedures of Statistics. McGraw-Hill Book Company, Inc. 481 pp.

APPENDIX

Appendix 1. Simple regression statistics[1/]

$\hat{y}$ = Predicted value for dependent variable.

y = Response or dependent variable.

$\bar{y}$ = Mean of observed dependent variables.

x = Independent variable.

$\bar{x}$ = Mean of observed independent variables.

N = Number of observations.

r^2 = Proportion of variation explained by prediction equation = $\frac{\Sigma(y - \hat{y})^2}{\Sigma(y - \bar{y})^2}$

$S_{y \cdot x}$ = Standard error of estimate = $\sqrt{\frac{\Sigma y^2 - \frac{(\Sigma xy)^2}{\Sigma x^2}}{N - 2}}$ = $\sqrt{\text{Residual M Sq.}}$

S_y = Standard deviation of dependent variable = $\sqrt{\frac{\Sigma y^2 - \frac{(\Sigma y)^2}{N}}{N - 1}}$

S_x = Standard deviation of independent variable = $\sqrt{\frac{\Sigma x^2 - \frac{(\Sigma x)^2}{N}}{N - 1}}$

Confidence limits for a predicted $\hat{y} = \hat{y} \pm t \sqrt{(\text{Residual MSq})\left(\frac{1}{N} + \frac{(x_0 - \bar{x})}{\Sigma x^2 - \frac{(\Sigma x)^2}{N}}\right)}$

Where: x_0 = selected value of x

t = t for given probability level and degrees of freedom for residual mean square.

1/For several independent variables see Steele and Torrie, 1960.

$$\text{b coefficient} = \frac{\Sigma xy - \frac{(\Sigma x)(\Sigma y)}{N}}{\Sigma x^2 - \frac{(\Sigma x)^2}{N}}$$

$$\text{Standard error of b coefficient} = \sqrt{\frac{\text{Residual MS}}{\Sigma x^2 - \frac{(\Sigma x)^2}{N}}}$$

Confidence interval for $B = b \pm t\, S_b$

Where: t = t for given probability level and degrees of freedom for residual mean square.

Standardized b coefficient = Regression coefficient when each variable is in deviations from the mean of its standard deviation. Used for comparing the relative importance of the independent variable $= b \frac{S_x}{S_y}$

Appendix 2. y_2 multiple regression program statistics

Dependent variable: y_2 - rough green pond pine tree weight in pounds to a 2-inch top D.O.B.

Independent variable: X_8 $(DBH)^2$ (tree height)

Number of observations: 57

R^2, percent of variation explained: 97

Standard error of y_2: 112

Mean of y_2: 663

Standard error as a percent of mean: 17

Analysis of variance:

Source	D.F.	Sum Square	Mean Square	F
Total	56	22,397,860		
Regression	1	21,707,460	21,707,460	1,729**
Residual	55	690,402	12,553	

Tabular F .01 with 1/55 df = 7.08

B coefficients and 95 percent confidence limits:

Variable	Mean	B coeff	95 Percent Confidence Limits Upper	Lower	Standard Error	Standardized b Coefficient
X_8	4632	.148	.155	.141	.004	.984

Constant term in prediction equation = -21

Equation: $y_2 = .148\ (X_8) - 21$

Appendix 3. y_4 multiple regression program statistics

Dependent variable: y_4 - rough green pond pine tree weight in pounds to a 4-inch top D.O.B.

Independent variable: X_8 $(DBH)^2$ (tree height)

Number of observations: 54

R^2, percent of variation explained: 97

Standard error of y_4: 117

Mean of y_4: 684

Standard error as a percent of mean: 17

Analysis of variance:

Source	D.F.	Sum Square	Mean Square	F
Total	53	20,885,770		
Regression	1	20,175,480	20,175,480	1,477**
Residual	52	710,283	13,659	

Tabular F .01 with 1/52 df = 7.19

B coefficients and 95 percent confidence limits:

Variable	Mean	B coeff	95 Percent Confidence Limits Upper	Lower	Standard Error	Standardized b Coefficient
X_8	4957	.149	.157	.141	.004	.982

Constant term in prediction equation = -54

Equation: $y_4 = .149\ (X_8) - 54$

Appendix 4. y_8 multiple regression program statistics

Dependent variable: y_8 - rough green pond pine tree weight in pounds to a 8-inch top D.O.B.

Independent variable: X_5 $(DBH)^2$

Number of observations: 29

R^2, percent of variation explained 93

Standard error of y_8: 173

Mean of y_8: 879

Standard error as a percent of mean: 20

Analysis of variance:

Source	D.F.	Sum Square	Mean Square	F
Total	28	11,752,940		
Regression	1	10,941,420	10,941,420	364**
Residual	27	811,516	30,056	

Tabular F .01 with 1/27 df = 7.68

B coefficients and 95 percent confidence limits:

Variable	Mean	B coeff	95 Percent Confidence Limits Upper	Lower	Standard Error	Standardized b Coefficient
X_5	143.7	11.38	12.61	10.16	.597	.965

Constant term in prediction equation = -757

Equation: $y_8 = 11.38\ (X_5) - 757$

Appendix 5. y_B multiple regression program statistics

Dependent variable: y_B - pond pine bark weight to a 2-inch top D.O.B.

Independent variable: X_8 $(DBH)^2$(Tree Height)

Number of observations: 11

R^2, percent of variation explained: 98

Standard error of y_B: 12

Mean of y_B: 97

Standard error as a percent of mean: 13

Analysis of variance:

Source	D.F.	Sum Square	Mean Square	F
Total	10	66,551		
Regression	1	65,216	65,216	440**
Residual	9	1,335	148	

Tabular F .01 with 1/9 df = 10.56

B coefficients and 95 percent confidence limits:

Variable	Mean	B coeff	95 Percent Confidence Limits Upper	Lower	Standard Error	Standardized b Coefficient
X_8	5157	.017	.019	.015	.0008	.990

Constant term in prediction equation = 9

Equation: $y_B = .017\ (X_8) + 9$

Appendix 6. y_{OD} multiple regression program statistics

Dependent variable: y_{OD} - proportion oven dry wood in peeled green pond pine stem.

Independent variable: X_{10} - Increment core specific gravity.

Number of observations: 61

R^2, percent of variation explained: 45

Standard error of y_{OD}: .043

Mean of y_{OD}: .526

Standard error as a percent of mean: 8.1

Analysis of variance:

Source	D.F.	Sum Square	Mean Square	F
Total	60	.1947		
Regression	1	.0874	.0874	48.07**
Residual	59	.1073	.0018	

Tabular F .01 with 1/59 df = 7.08

B coefficients and 95 percent confidence limits:

Variable	Mean	B Coeff	95 Percent Confidence Limits Upper	Lower	Standard Error	Standardized B Coefficient
X_{10}	.585	.642	.824	.461	.093	.670

Constant term in prediction equation = .151

Equation: $y_{OD} = .642\ (X_{10}) + .151$

Appendix 7. y_{OD} multiple regression program statistics

Dependent variable: y_{OD} - Proportion oven dry wood in peeled green pond pine stem.

Independent variables:
X_{10} - Increment specific gravity
X_2 - Total tree height
X_1 - Tree DBH

Number of observations: 61

R^2, percent of variation explained: 54

Standard error of y_{OD}: .039

Mean of y_{OD}: .526

Standard error as a percent of mean: 7.5

Analysis of variance:

Source	D.F.	Sum Square	Mean Square	F
Total	60	.1947		
Regression	3	.1058	.0353	22.62**
Residual	57	.0889	.0015	

Tabular F .01 with 3/57 df = 4.13

B coefficients and 95 percent confidence limits:

Variable	Mean	B Coeff	95 Percent Confidence Limits Upper	Lower	Standard Error	Standardized B Coefficient
X_{10}	.585	.489	.685	.295	.010	.511
X_2	41.9	.0025	.004	.001	.001	.586
X_1	8.7	-.006	-.001	-.011	.003	.366

Constant term in prediction equation = .187

Equation: $y_{OD} = .490\ (X_{10}) + .003\ (X_2) - .006\ (X_1) + .187$

Appendix 8. Correlation coefficients for variables in pond pine rough green weight to a 2-inch top D.O.B. (y_2 program).

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	y_2
X_1	1.00								
X_2	.81	1.00							
X_3	.70	.71	1.00						
X_4	.77	.79	.67	1.00					
X_5	.98	.78	.66	.71	1.00				
X_6	.81	.99	.72	.83	.76	1.00			
X_7	.98	.81	.71	.80	.93	.82	1.00		
X_8	.95	.85	.67	.69	.98	.81	.88	1.00	
y_2	.94	.80	.66	.70	.97	.77	.86	.98	1.00
Mean	9.0	43	44	.65	92.45	1.6169	.9193	4632	663
Standard Deviation	3.5	12.4	18.3	.12	66.73	.1308	.1785	4214	632

N = 57

Appendix 9. Correlation coefficients for variables in pond pine rough green weight to a 4-inch top D.O.B. (y_4 program).

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	y_4
X_1	1.00								
X_2	.79	1.00							
X_3	.64	.67	1.00						
X_4	.72	.76	.61	1.00					
X_5	.99	.75	.61	.67	1.00				
X_6	.77	.99	.68	.81	.73	1.00			
X_7	.99	.80	.66	.76	.95	.79	1.00		
X_8	.96	.84	.63	.65	.98	.79	.91	1.00	
y_4	.95	.77	.62	.67	.97	.75	.90	.98	1.00
Mean	9.4	44	46	.66	98.84	1.6315	.9515	4957	685
Standard Deviation	3.1	11.9	17.8	.11	64.01	.1223	.1462	4138	628

N = 54

Appendix 10. Correlation coefficients for variables in pond pine rough green weight to a 8-inch top D.O.B. (y_8 program).

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	y_8
X_1	1.00								
X_2	.56	1.00							
X_3	.32	.43	1.00						
X_4	.44	.26	.14	1.00					
X_5	.99	.55	.34	.44	1.00				
X_6	.56	.99	.44	.21	.55	1.00			
X_7	.99	.57	.31	.43	.98	.57	1.00		
X_8	.95	.76	.42	.44	.95	.74	.94	1.00	
y_8	.95	.60	.38	.51	.96	.59	.93	.96	1.00
Mean	11.8	52	55	.73	143.66	1.7063	1.0638	7699	879
Standard Deviation	2.2	9.4	14.8	.05	54.91	.0808	.0819	3843	648

N = 29

Appendix 11. Correlation coefficients for variables in pond pine bark weight (y_B program).

	X_3	X_8	X_9	Y_B
X_3	1.00			
X_8	.81	1.00		
X_9	.52	.59	1.00	
Y_B	.85	.99	.60	1.00
Mean	46	5157	1.75	97
Std. Dev.	16	4752	.38	82

N = 11

Appendix 12. Correlation coefficients for variables in pond pine proportion oven dry wood (y_{OD} program).

	X_1	X_2	X_3	X_8	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	y_{OD}
X_1	1.00									
X_2	.83	1.00								
X_3	.70	.69	1.00							
X_8	.95	.85	.67	1.00						
X_{10}	.37	.50	.56	.38	1.00					
X_{11}	-.70	-.71	-.94	-.63	-.60	1.00				
X_{12}	.89	.79	.91	.90	.49	-.84	1.00			
X_{13}	-.39	-.51	-.58	-.39	-.99	.63	-.50	1.00		
X_{14}	.23	.08	-.48	.17	-.34	.44	-.19	.35	1.00	
y_{OD}	.31	.54	.50	.37	.67	-.52	.42	-.67	-.32	1.00
Mean	8.7	42	42	4338	.585	.03	408	1.73	.22	.526
Std. Dev.	3.4	13.2	18.6	4125	.059	.013	299	.18	.08	.057

N = 61