HARVARD FOREST

BULLETIN No. 13

RICHARD T. FISHER, *Director*

FORM AND DEVELOPMENT OF WHITE PINE STANDS IN RELATION TO GROWING SPACE

A Preliminary Study with Form-Class Volume Tables of Natural and Planted Stands in Central New England

BY

S. R. GEVORKIANTZ AND N. W. HOSLEY

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PRINTED AT THE HARVARD UNIVERSITY PRESS
CAMBRIDGE, MASS., U. S. A.

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FORM AND DEVELOPMENT OF WHITE PINE STANDS IN RELATION TO GROWING SPACE

1. SUMMARY

THE mutual interference of trees in a stand as governed by the available growing space affects their entire development.

From early life the growing space controls their crown and root development or their chance for dominance. It aids or retards the establishment of the crown canopy and thus regulates natural pruning and the size of the lower dead branches. Ample room presents a favorable opportunity for wood production.

The distribution of wood increment over the stem is related to the external forces, such as the weight of the crown and the bending pressure exerted upon it; but if these forces are not important (suppressed trees), the nearness to the crown, the source of the building material, is the most significant.

Thence comes the variation in form. The effect which growing space has on crown development is measurable by the relative values of dead length (height to base of crown) and crown width. From this the stem form can be determined, at least in second-growth white pine.

The knowledge of the form (form class) of trees and stands is essential for accurately determining their contents, especially when one deals with a limited number of trees.

Natural stands which are strictly normal according to existing yield tables for a given site and age are not normal at other ages unless controlled by silviculture.

Understocked stands do not always fall short of the yield of fully stocked ones, due to a higher rate of growth in basal area and similarity of form. In case they are deficient in vol-

ume at present and retain the property of a closed stand, they may attain the fully stocked yield, due to concentration of growth on larger trees and low mortality.

In cases where such stands become normal, the product of the ratio of actual and normal basal areas by the ratio of actual and normal form heights equals one. Obviously many combinations may give this result.

Stands overstocked in early years contain more volume than shown by yield tables, but soon deteriorate, owing to stagnation and high mortality.

To secure an approach to normal yield and satisfactory quality, growing space must periodically be regulated. Thus, the determination of ideal forms for various ages (see Table 17) is requisite for successful thinnings.

Owing to the effect of weevil injury and of persistent dead branches on quality, white pine should be grown in dense stands in early years.

2. GROWING SPACE

A tree's chance to gain dominance is determined by its available growing space. Aside from the conditions of habitat and inheritance, the possibility of existence and development must be assured. Growing space is one of the most important factors governing the improvement of existing stands or production of trees of certain desirable form, size, and quality.

Average growing space is another term defining density of the stand, but is capable of determination in only one way as compared with the several usual criteria of density. We usually define density in terms of either basal area, number of trees, or volume, by looking at stands with the idea of their present productiveness and without much reference to similarity of life history of the particular stands compared. Frequently we see two stands of the same age and on the same site that have similar basal areas, but differ widely in number of trees per acre. The loss in number of trees is compensated by a greater growth in diameter. The same is true of the relation between number of trees and volume per acre.

In a well-stocked stand the lower branches of the trees, being the longest, begin to touch and interlace shortly after ten years from seed, and the mutual interference above ground starts. Much, of course, will depend upon the vigor of their growth and the nearness to each other. This establishment of crown canopy can be studied very advantageously in plantations. Table 1 shows the time and height above ground at which this takes place with different spacings and sites.

TABLE 1

	Site II		Site I	
Spacing (feet)	Time when crown interference begins (years from seed)	Height above ground of closing (feet)	Time when crown interference begins (years from seed)	Height above ground of closing (feet)
3 × 3	10	1½		
4 × 4	11	2	9	2½
5 × 5	12–13	2½	10	3
6 × 6	13–14	3	13	5

If spacing is wider than six feet by six feet, closing is postponed considerably. A plantation with spacing fifteen feet by fifteen feet had crowns far apart at the age of thirty years.

As a result of abrasion of the lower parts of crowns their vigor is lessened and they become worn off, while the maximum crown-diameter begins to develop somewhat higher, thus forming immediately below a region of relative shade, which in time kills the lower branches. The increase in height to the maximum crown-diameter depends very largely upon height growth, site, and age; but if these conditions are nearly similar, it is governed by spacing. This is shown in Table 2.

TABLE 2

SHOWING THE PROGRESS OF MAXIMUM CROWN-DIAMETER WITH AGE IN STANDS OF DIFFERENT AVERAGE GROWING SPACE

Age (years)	Stand average growing space: Small	Medium	Large
	Height in feet to maximum crown-diameter		
20	15	13	10
30	27	23	18
40	38	32	27
50	46	41	36
60	52	47	43

This shade causes natural pruning, which is more rapid in narrow spacings, due to greater intensity and faster upward movement of the crowns. Figure 1 and Table 3 are quite illustrative in this respect. Age, average height, site, stock, and method of planting are exactly similar in all four spacings. The figure presents characteristic cross-sections of crown canopy.

TABLE 3

Spacing (feet)	Total crown area	Double and triple crown area	Openings between crowns	Single crown area
	(All values in per cent of total ground area)			
3 × 3	145	45	0	55
4 × 4	132	32	0	68
5 × 5	111	17	6	77
6 × 6	95	10	15	75

Single crown area, or the portion of the area occupied by only one crown, allows considerable light to pass through. Openings between crowns, usually occurring in the middle of a planted square, allow branches to survive longer and increase in size.

Natural pruning is measured by dead length, or the length of stem above ground free from living branches. For the sake of convenience it is expressed in per cent of the total height of the tree. In older trees it is taken to the average crown

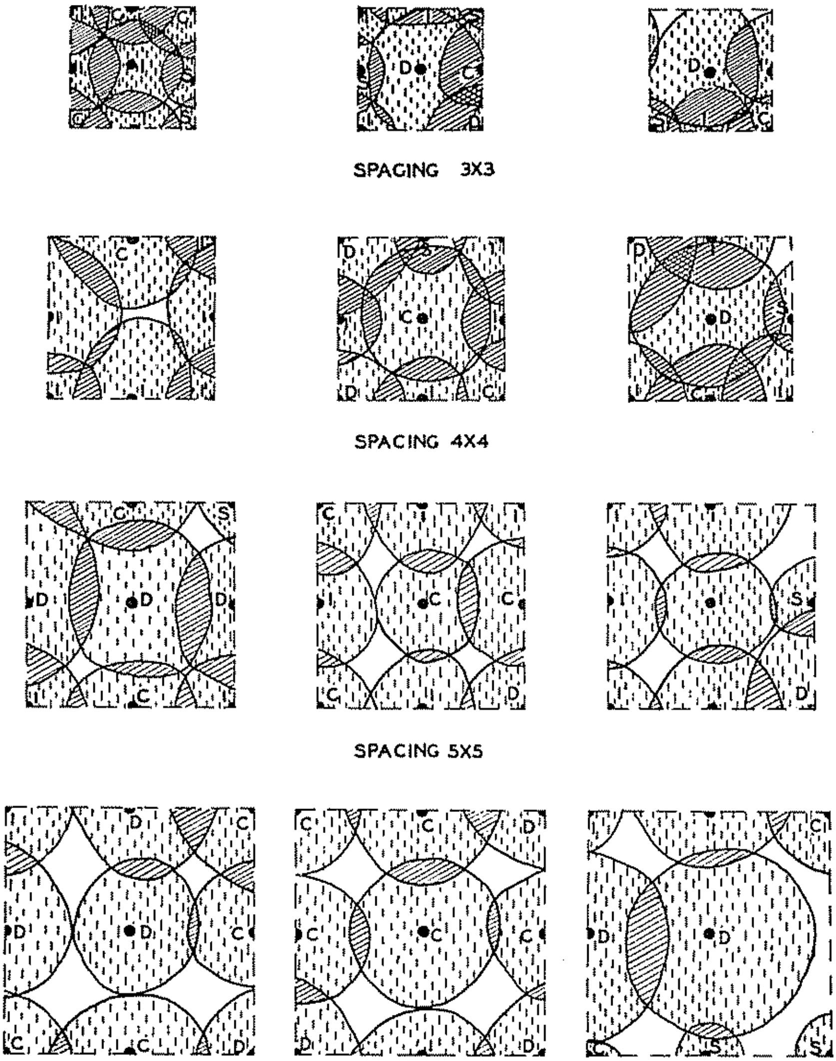

FIG. 1 TYPICAL CROSS SECTIONS OF CROWN CANOPY

AGE 16 YEARS

LEGEND:
- OPENING
- AREA OCCUPIED BY SINGLE CROWNS
- AREA OCCUPIED BY PARTS OF TWO CROWNS
- AREA OCCUPIED BY PARTS OF THREE CROWNS

CROWN CLASSES:
- D-DOMINANT
- C-CODOMINANT
- I-INTERMEDIATE
- S-SUPPRESSED

base. The influence of growing space on dead length needs no comment. Measurements, however, are rarely presented. Table 4 below shows the variation of dead length with age, space, and crown class both in planted and natural stands. It is based on 300 trees.

TABLE 4

RATE OF NATURAL PRUNING AS INFLUENCED BY GROWING SPACE

Age (years from seed)	Dominant and co-dominant trees			Intermediate and suppressed trees	
	Average growing space of stands				
	Large	Medium	Small	Medium	Small
	Dead length in per cent of total height				
10	8	12	17	17	22
15	12	20	29	26	36
20	18	28	42	36	52
25	25	37	53	46	64
30	32	46	60	54	70
35	39	52	64	59	74
40	45	56	66	63	77
45	48	59	68	66	79
50	51	61	70	68	80
55	54	63	72	70	80
60	57	66	73		

The most rapid development in dead length takes place between twenty and thirty years of age, beyond which it slows down.

Crown-diameters were long ago known (26) to be associated very definitely with crown class, stem diameters at breast height, and spacing. In fact, when we say a tree is dominant, we instantly think in terms of growing space. Dominance is a relative term. A dominant tree in a well-stocked stand, if transferred mentally into a less dense stand of the same age, may often be called an intermediate. Crown classification gives the best picture of growing space.

We may say that the higher the relative dead length of a tree at a given age and the smaller its crown width, the less growing space it has had in which to develop. It was found in this investigation that the ratio of relative dead length and crown width enables one to conveniently interpret the growing space at a given age.

$$S = \frac{l}{c} \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

where S is the measure of growing space; l, the relative dead length; and c, the crown width, or average crown-diameter in feet. Table 5 is presented below as an example of this simple relation. These plots are of the same age (fifty years) and stand, but differ in stocking.

TABLE 5

GROWING SPACE AS RELATED TO DEAD LENGTH AND CROWN WIDTH

	Plot PH-5			Plot PH-2				Plot PH-3			
Crown class	Dead length (per cent) L	Crown width (feet) C	Ratio S	Dead length (per cent) L	Crown width (feet) C	Ratio S	Crown differentiation	Dead length (per cent) L	Crown width (feet) C	Ratio S	Crown differentiation
Dominant	59	17	3.5	60	15	4.0	1.00	63	14	4.5	1.00
Co-dominant				64	11	5.8	1.45	73	8	9.1	2.02
Intermediate				69	8	8.6	2.15	73	5	14.6	3.25
Trees per acre	240			320				560			
Basal area per acre (sq. ft.)	204			286				270			
Volume per acre (cu. ft.)	5348			7976				6852			

One can see how the factor S increases with suppression. It is also interesting to note that crown-class differentiation, or the ratio of the value of S to the value for dominants in the stand, becomes larger as growing space decreases. This factor is applicable to individual trees as well as to stands. In applying it to stands, however, it is much more convenient to consider only dominant and co-dominant trees in determining the value of the factor and to use intermediate and suppressed trees if a more intensive comparison is desired. Intermediate and especially suppressed trees are usually not representative of a stand, and form together the less stable group. Furthermore, their influence on the average factor exaggerates their value in the stand.

The factor of growing space increases with age as the growing space diminishes.[1] In order to compare the growing space of stands or of trees at various ages within a given site, a certain arbitrary scheme is necessary. Such a scheme as used in classifying site (method of anamorphosis) can be very advantageously employed here. This is presented in Table 6. Ten classes of relative growing space were arbitrarily chosen, ranging from stands composed entirely of dominants to those with highly restricted conditions for development. This will allow consideration of each group of trees or stands separately according to a certain series.

TABLE 6

	Index of Growing Space									
	1	2	3	4	5	6	7	8	9	10
Age	less than			Values of factor S						more than
10	1.3	1.5	1.7	2.2	2.6	3.1	3.5	4.0	4.3	4.6
20	1.9	2.2	2.9	3.7	4.4	5.3	6.0	6.7	7.4	7.8
30	2.2	2.6	3.4	4.3	5.2	6.1	7.0	7.8	8.6	9.1
40	2.4	2.8	3.8	4.7	5.7	6.6	7.6	8.5	9.4	9.9
50	2.5	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	10.5
60	2.6	3.1	4.1	5.2	6.2	7.2	8.3	9.4	10.4	10.8
70	2.8	3.3	4.4	5.5	6.6	7.7	8.8	10.0	11.0	11.5
Index	1	2	3	4	5	6	7	8	9	10

Growing space has a tremendous influence upon diameter at breast height. A long and wide crown produces large diameters as opposed to narrow and short crowns. This is shown by Table 7 and Figure 2. This figure considers average diameters of stands obtained from basal area. For the sake of comparison the growth in average diameter of normal stands is presented.[2]

[1] In some extremely overstocked stands the reverse may be true, but these are very exceptional cases.

[2] E. H. Frothingham, White Pine under Forest Management. *U. S. Department of Agriculture Bulletin, No. 13. 1914.*

TABLE 7

RELATION OF DIAMETER GROWTH AT DIFFERENT AGES TO GROWING SPACE

	Dominant Growing Space						Co-dominant Growing Space						
	Large		Medium		Small		Large		Medium		Small		
Age (Years)	D. B. H. (inches)	Basis (trees)	D. B. H. (inches)	Basis (trees)	D. B. H. (inches)	Basis (trees)	D. B. H. (inches)	Basis (trees)	D. B. H. (inches)	Basis (trees)	D. B. H. (inches)	Basis (trees)	Total (trees)
15	3.1	5	3.1	5	2.0	..	2.7	4	2.6	..	1.7	3	17
20	5.1	..	5.0	5	3.5	5	4.2	..	4.1	5	3.0	5	20
25	6.7	..	6.4	..	4.9	..	5.6	..	5.5	..	4.2	..	..
30	8.2	4	7.7	2	6.1	5	6.9	..	6.6	1	5.2	3	15
35	9.8	..	8.9	2	7.2	..	8.2	2	7.4	3	6.1	6	13
40	11.3	8	10.0	..	8.2	4	9.5	2	8.4	..	7.0	3	17
45	12.7	..	11.0	2	9.0	8	10.8	1	9.3	2	7.7	4	17
50	14.3	5	11.9	1	9.7	..	12.1	2	10.1	..	8.4	2	10
55	15.8	..	12.8	1	10.4	4	13.5	..	10.9	2	9.1	3	10
60	17.2	2	13.7	..	11.0	..	14.8	3	11.8	..	9.6	..	5
65	18.8	..	..	..	11.5	2	16.1	..	..	..	..	..	2
70	20.3	3	..	..	12.0	..	..	..	..	..	..	..	3
Basis (trees)	..	27	..	18	..	28	..	14	..	13	..	29	129

The effect of growing space on height is very small. Moderately dense stands appear to be most favorable for height growth. Overcrowding as well as an open condition results in a somewhat deficient height growth. In the last case, however, repeated weevil injury may be solely responsible for the effect.

The influence of growing space on volume is plain. No change in form can overcome the effect of diameter growth on volume. Assume three dominant trees at the age of forty-five which have been under different restrictions of growing space and have similar form heights. The diameters are 9.0, 11.0, and 12.7 inches, breast high. The ratios of volume compared with the nine-inch tree equal

$$\left(\frac{11.0}{9.0}\right)^2 = 1.49 \text{ and } \left(\frac{12.7}{9.0}\right)^2 = 1.99$$

for the two more open-grown trees. This would imply that the efficiency of volume growth of individual trees in restricted space is only two-thirds and one-half of the efficiency in moderate and large growing spaces respectively. It seems quite possible to grow a certain volume with a wide range of number of trees per acre. A more detailed discussion of this tendency will be found on page 39.

Inasmuch as it has been shown that the progress of dead length is related to growing space, it follows that the size at which branches die also depends on it. As seen from Table 8, knot size increases with greater growing space and with diameter breast high.

Knot size was obtained by measuring diameters of dead limbs and stubs, which at the ages studied had not been covered up.

In spite of the limited number of plots, Figure 2A clearly presents a picture of the influence of growing space on stand development. It shows how over-dense stands or stands with a high index of growing space begin to lose their superiority in volume per acre over yield table values soon after thirty-

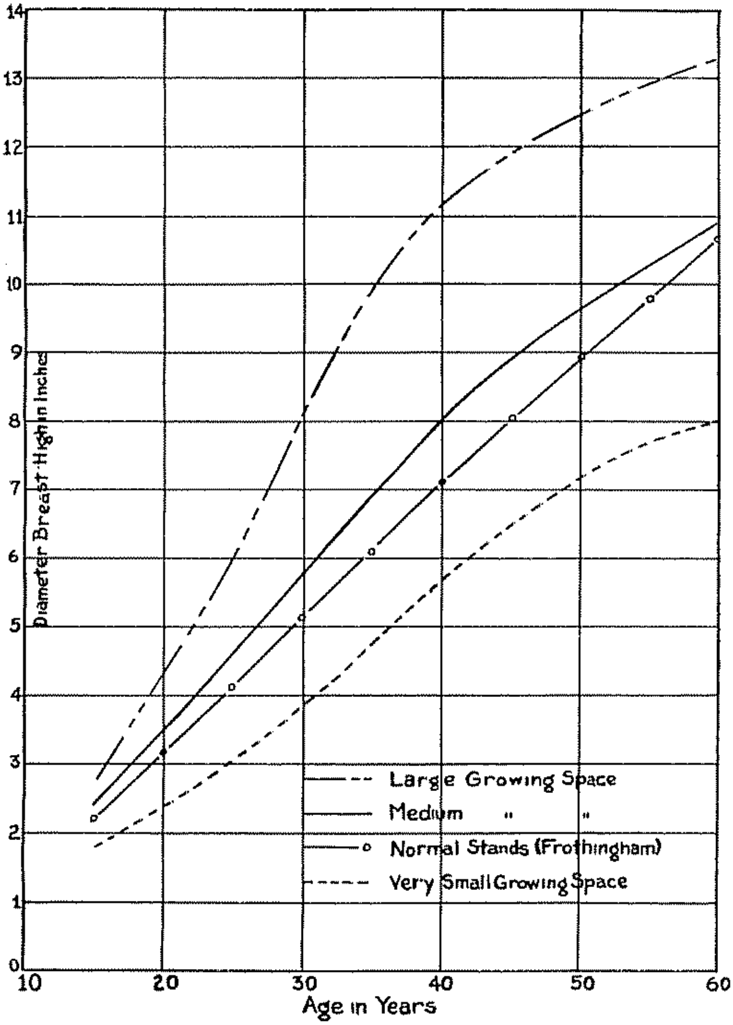

FIG. 2. RELATION OF AVERAGE DIAMETER TO AGE IN STANDS WITH DIFFERENT AVERAGE GROWING SPACE

five years of age, while moderately dense stands gain it. Stands with a low index of growing space, or understocked stands, are far from being discouraging toward the end of the rotation.

The same tendency prevails in basal area per acre. A high index of growing space at any age means more trees per acre. Cases are noted, however, where a difference of 120 trees at the age of twenty years did not change the value of the index,

TABLE 8

SHOWING THE INFLUENCE OF GROWING SPACE ON SIZE OF DEAD BRANCHES

Diameter breast high (inches)	Growing space: Restricted S = 6 and higher — Knot size: Aver. diam. (inches)	Maximum diam. (inches)	Dead length (feet)	Medium S = 4–6 — Knot size: Aver. diam. (inches)	Maximum diam. (inches)	Dead length (feet)	Large S = 4 and lower — Knot size: Aver. diam. (inches)	Maximum diam. (inches)	Dead length (feet)	Basis (trees)
1–2	.4	.6	5	.4	.6	3	.5	.8	1½	37
3–4	.5	.8	16	.6	.9	11	.7	.9	7	43
5–7	.7	1.0	28	.8	1.2	23	.9	1.2	18	51
8–10	1.0	1.6	37	1.2	1.8	32	1.5	2.0	26	38
11–14	1.2	1.7	44	1.5	2.0	39	1.7	2.5	32	14
15–18				1.6	2.5	45	2.5	3.0	36	8
Total										191

and where in stands as old as fifty years, a slightly different index may be secured with the same number of trees per acre. The explanation of this is in the proportion of intermediate and especially of suppressed trees in the stand. They raise the total number of trees per acre considerably, while their interference may be negligible. The index of growing space as it is affected by number of trees per acre or as it affects basal area and volume of stands is presented in Tables 22 and 23 of the Appendix. It thus appears that growing space is a more significant criterion of production than trees per acre, basal area, or volume.

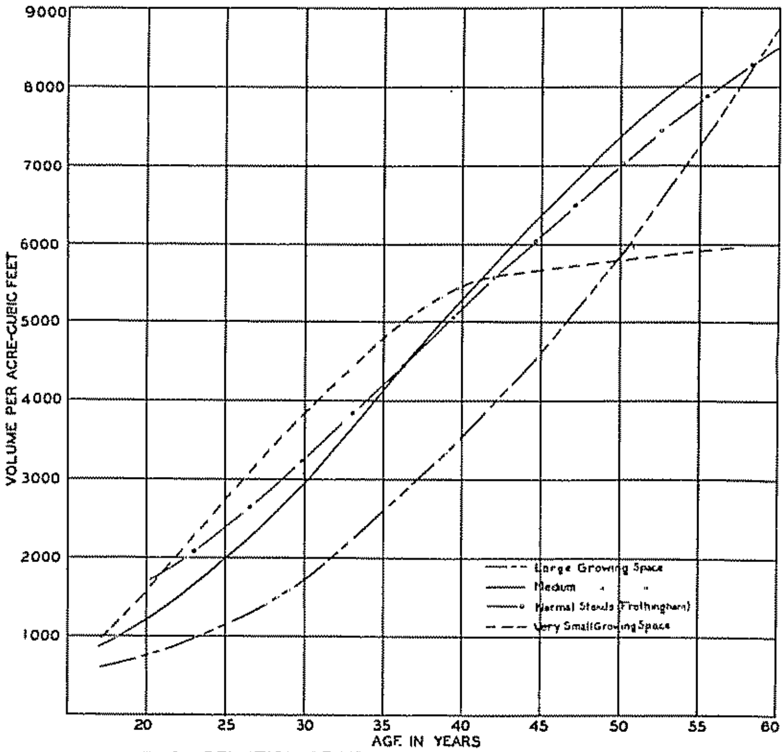

FIG. 2A. RELATION OF VOLUME PER ACRE TO AGE IN STANDS WITH DIFFERENT AVERAGE GROWING SPACE

3. FORM AND TAPER

Form. The work of the last twenty-nine years stressing the importance of determining the form of individual trees and stands for timber estimating has succeeded well in Europe. Only very recently have we begun in America to familiarize ourselves with the problem. This has been mainly through the investigations (3, 4, 5, 10, 11, 41, 47, 48) of applicability of foreign methods in determining the form of native trees. In some respects the differences found were significant enough to require modification.

Tree form is represented by a series of ratios between the diameters at given points on the stem and the diameter at breast height. Usually, however, it is expressed with sufficient accuracy by the so-called absolute form quotient, or the ratio between the diameter at half the height above breast height and the diameter at breast height. This last measure was introduced by Jonson as a modification of the old form quotient originally used by Schiffel, who took the middle diameter at one-half the total height. Form quotients expressed as percentages are separated arbitrarily into form classes.

As already mentioned, the real interest in the study of tree form dates back to 1899, when Schiffel in his "Form und Inhalt der Fichte" introduced the form quotient as a new basis for grouping the tree volume table material. Analysis of the volume table data for various conifers in Germany led Schiffel to believe that a single table could be constructed to apply to quite a number of conifers, if trees were classified by form quotient.

Maass (29) in Sweden in 1908 verified the statement made by Schiffel and went as far as to claim the universality of form-class volume-tables. The form factors of pine and spruce in Sweden compared quite closely with those of the same species in Germany for a given form class. The same tendency was observed by Tkatchenko in Russia (44).

These statements of Schiffel and Maass are as yet in the process of verification, although a large number of investigators seem to favor this view already (5, 16, 20, 44, 48).

Several attempts have been made to express taper by means of an empirical formula. The conclusion has been reached that the stem form cannot be obtained by an equation with an independent variable of less than the third order (6), or that the stem form above breast height may be represented by a hyperbola, if the effect of butt swell is neglected (3, 4, 5) or by a logarithmic curve (17, 34).

All these equations seem to fit the middle portion of the stem quite well, but in the majority of cases do not fit the extreme ends so well, i.e., tip and butt portions, which are very irregular and perhaps require separate consideration.

From this apparent irregularity of taper and also from the fact that the stem is considered as a solid of revolution about its vertical axis, thus making stem cross-sections perfectly circular in shape, Turskii (46) concludes that the analytical expression of stem form will always appear too artificial. He claims that only knowledge of basal area growth at different sections of the stem will enable one to determine tree volume accurately.

In spite of all this, however, if one considers the merchantable portion of the bole alone, there is much practical value in these approximation formulae, if their limitations and accuracy are properly presented.

So far the main status of the problem of the form of individual trees and stands can be summarized as follows:

1. Form-class volume and taper tables can be constructed for one species. They are superior to the conventional volume tables in accuracy by recognizing the differences in volume due not only to diameter and height but also, within certain limits, to form.

2. The most vital need of the method is to find some means by which the average form class of standing timber can be readily determined so that the proper form-class volume tables can be used. The form point idea advocated by Jonson in Sweden has limitations in use in this country.

One of the main purposes of this investigation has been to study these two points.

It is a common belief that absolute form factors vary very little, if at all, within the same form class in trees of given dimensions. In fact this was shown by Schiffel, Tkatchenko (44), and other investigators.

Schiffel's famous formulae expressing form factors in terms of form quotients for pine, spruce, and fir were used by many foresters abroad. Some felt the need for their modification (45). In general the interest in these formulae has considerably decreased since the introduction of the absolute form quotient.

Theoretically the form quotient does not characterize stem form completely, but for practical purposes it is the simple and convenient expression to be used in that sense.

The relationship of form factor and form quotient for white pine can be expressed by the empirical equation

$$f = 0.528q^2 + 0.217 \qquad (2)$$ [1]

where f and q are absolute form factor and absolute form-quotient respectively.

The coefficient of correlation, or the indicator of usefulness of the equation to predict the value of the form factor, was found to be approximately + 0.94 ($n = 274$), with the standard error of estimate of approximately ± 0.03 (0.0271) form-factor units. An average error in volume of individual trees in common form classes will not often exceed plus or minus six per cent.

This indicates that the knowledge of the form quotient alone (not corrected for "normal" diameter) is not sufficient to determine the absolute form factor, if greater accuracy of estimate is desired. If, however, the diameter at breast

[1] *Example:* A tree whose absolute form quotient inside bark was determined to be 0.70 will have an absolute form factor of $0.528 \times (.70)^2 + 0.217 = 0.476$.

height (d) and the total height of the tree (h) are introduced as factors, the equation changes its form to

$$f = 0.580q^2 - 0.005d + 0.0001h + 0.225 \quad \quad (3)$$ [1]

The coefficient of multiple correlation becomes approximately 0.96, and the standard error of estimate diminishes to ± 0.02 (0.01985) form factor units. The average error in volume of individual trees will not usually exceed plus or minus four and one-half per cent.

The absolute form factors were computed from the formula

$$f = \frac{1}{n}\left(\frac{1}{2} + \frac{\Sigma g}{gn}\right) \quad \quad (4)$$

where n represents the number of stem sections; gn the basal area at breast height; and Σg the sum of basal areas at each succeeding section of the stem above breast height. The portion of the stem above breast height was measured in ten sections.

Equation 3 disagrees with prevailing opinion that taper of trees of a given form class is independent of height as well as diameter. This may be unique to white pine, since the same tendency was noted in Canada by Wright (48), whose conclusion is that "in the larger trees taper is more rapid in the lower part of the tree." The differences in taper due to diameter breast high are shown in Table 12.

The same tendency can be deduced from the coefficients of partial correlation.

$$r_{13} = +0.216; \quad r_{13.4} = +0.116; \quad r_{13.24} = -0.782$$
$$r_{14} = +0.301; \quad r_{14.3} = +0.243; \quad r_{14.23} = +0.297$$

where variables 1, 2, 3, and 4 are form factor, form quotient squared, diameter breast high, and total height respectively.

The last column is of considerable interest, showing that

[1] *Example:* A tree of form class 70, sixty feet tall and eight inches at breast height has an absolute form factor of 0.580 × 0.49 − 0.005 × 8 + 0.0001 × 60 + 0.225 = 0.475.

with the same form class and total height the form factors decrease in a majority of cases with increase in diameter breast high. The influence of height on the absolute form-factor, when diameter and form class are kept constant, is positive, but not as definite as that of diameter. Taper does not vary directly with diameter breast high. In trees over four inches in diameter this may be partly due to butt swell, since butt swell extends quite well above diameter breast high and exaggerates it considerably. This is the reason why Behre developed his idea of "normal" diameter. (See also Appendix, page 42.)

Dead length seems to be associated with butt swell. Table 15 shows this relation. Trees with long dead length (short crowns) seem to have small butt swell and vice versa.

Trees with pronounced butt swell have not only long but wide crowns as well. This is especially true when trees of the same form class are compared (see page 22). Two trees differing in dead length may belong to the same form class, due to their compensating crown widths.

Trees belonging to the same crown index (see page 23) and having the same dead length do not show, as a rule, any difference in butt swell.

A generalized equation, considering absolute form factor, absolute form quotient, and dead length (L), follows:

$$f = 0.453q^2 + 0.065L + 0.214 \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$ [1]

The coefficient of multiple correlation is 0.97 +, with the standard error of estimate ± 0.014. The average error in volume of individual trees will rarely exceed three per cent.

There are various theories explaining the development of stem form.

[1] *Example*: Diameter breast high, 8 inches
Total height, 60 feet
Absolute form quotient, .70
Dead length, 40 feet ($L = \frac{40}{60} = .67$)
$f = 0.453 \times 0.49 + 0.065 \times 0.67 + 0.214 = 0.479.$

Metzger, in his theory of wind pressure (31), claims that a tree stem will assume such a form as to be able to evenly distribute the bending force caused by wind. Thus diameters will increase from the top down, and the rate of this increase will be greater if greater pressure is exerted above. On the other hand, if the wind pressure is lessened (dense stands), the increment on the lower part of the stem will become smaller and the form quotient naturally higher.

Hohenadl (17, 18) approached the subject differently and explained diameter growth at any point of the stem by the necessity to support the weight of the portion above, rather than to withstand the bending force.

Robert Hartig (14) found that volume increment is distributed differently along the stem, according to density of the stand and crown class. In dominant trees the increment is greater in the lower part of the stem, while in suppressed ones it is mostly in the upper part. Normally the volume increment increases from the base of the crown down to breast height. In trees with suppressed crowns the reverse is the case.

Schiffel observed the relation of form quotient to crown length, and used it in determining form class (36).

The form point method (Jonson) used in Sweden was applied successfully to Western yellow pine by Behre (5). The work of Wright (48) and also that done on the Harvard Forest in 1925 show that the relation between form class and form point, especially in the case of white pine, is not well defined.

Form point, or as it is sometimes called, form point height, is the distance, expressed in per cent of total height, either from tip or base of the tree to a point in the crown considered the center of wind pressure. The position of this point depends to a great extent on the length of the crown, since it varies only vertically. In a roundish crown it will be in its middle and in a conical crown somewhat closer to the base. Wright (48) found that the height to the center of the crown length is even a better measure to estimate form class in white pine. No one can deny the influence of wind upon stem form. It is very logical, at the same time, that crown weight should produce a similar result. It certainly is not a contradiction, because one theory helps the other.

Growing space determines whether a tree will become dominant, intermediate, or suppressed. Simultaneously with this crown development the stem is built in such a way as to withstand any lateral bending force (Metzger) or its own weight as well (Hohenadl) and hence the distribution of building material will be in accordance with the need (R. Hartig). The longer the crown, the more wind pressure it will get, and if the length of the crown is kept constant, any increase in its width means an increase in weight.

The growth in height is at the expense of the crown width (Metzger), while growing space, if ample, will allow the crown to spread. This, with the growth tendency of the branches, will give the crown a certain shape, size, weight, and surface for wind pressure. It is obvious, therefore, that one must consider crown in at least two dimensions.

In the present study a very strong relation was found between form quotient, dead length, and crown width. Dead length was taken in per cent of total height, while crown width was expressed in terms of an index as presented in Table 9. This table separates average crown diameters of each diameter group into arbitrary classes. The standard of crown index is placed at ten inches diameter breast high so that a tree seven inches at breast height and with a nine-foot crown diameter would be given crown index 12. This figure 12 was used as a term in the correlation table.

Data were separated into three broad groups:

1. Trees with dead length forty-five per cent and higher.
2. Trees with dead length lower than forty-five per cent.
3. Trees from stands representing extreme overstocking.

These groups are discussed separately.

Group 1 showed remarkable consistency in the standard error of estimate, computed to be ± 1.846 units.

The normal equation from which the value of the form quotient can be determined, with the knowledge of dead length and crown index is as follows:

$$Q = 0.4868\ L + 1.5697\ I + 18.2591$$ [1]

Where Q, L, and I are absolute form quotient outside of bark, dead length in per cent of total height, and crown index respectively.

The value of the coefficient of multiple correlation is 0.88, which, considered together with the value of the standard error given above, makes this equation very useful.

The relationship of form quotient, dead length, and crown index is not strictly linear, especially with small values of dead length. The substitution of slight curvilinearity improved the value of the coefficient of multiple correlation and reduced the value of the standard error to 1.64 units. The distribution of the error is as follows:

Difference between actual and computed form quotient ±	Number of cases (trees)
0	59
.01	50
.02	33
.03	10
.04	5
.05	3
Total	160

[1] Example: A tree eight inches in diameter and sixty feet tall has a dead length of forty-two feet and an average crown diameter of ten feet.

$$L = \frac{42}{60} = 70 \text{ per cent.} \quad I = 12. \quad \text{(See Table 9.)}$$

$$Q = .487 \times 70 + 1.570 \times 12 + 18.259 = 71.$$

The same value can be obtained from Table 10.

This corrected trend is presented in Table 10.

The coefficients of partial correlation are

$$r_{12.3} = +.87$$
$$r_{13.2} = +.87$$
$$r_{23.1} = -.89$$

where variables 1, 2, and 3 are form quotient, dead length, and crown index respectively. The importance of considering dead length and crown index simultaneously is evident and is brought forth more strongly by the fact that the coefficient of correlation between form quotient and dead length when crown index is not considered at all is only + 0.42. It is apparent, as seen from Table 10, that, when dead length is kept constant, the form quotient will increase with crown index, or that form quotient will increase with dead length within the same crown index group. The negative sign of the third coefficient of partial correlation means only that the same form quotient can be obtained with different values of dead length and crown index, i. e., trees with short dead length may retain high form quotients if their crowns are wide. This is very important to notice, since dominant trees in the stand are usually those with short dead lengths and wide crowns as compared to other crown classes. This can be seen from Table 10 by looking diagonally across.

Group 2, trees having a dead length lower than forty-five per cent, was considered separately, due to the well-known fact that the stem in the region of the crown is very irregular, both in young and old trees. The upper diameters in this case are taken well above the base of the crown. The influence of this irregularity can be seen from the distribution of error.

The standard error is ± 3.52 units with an ill-pronounced average tendency.

This group will include either young or extremely open-

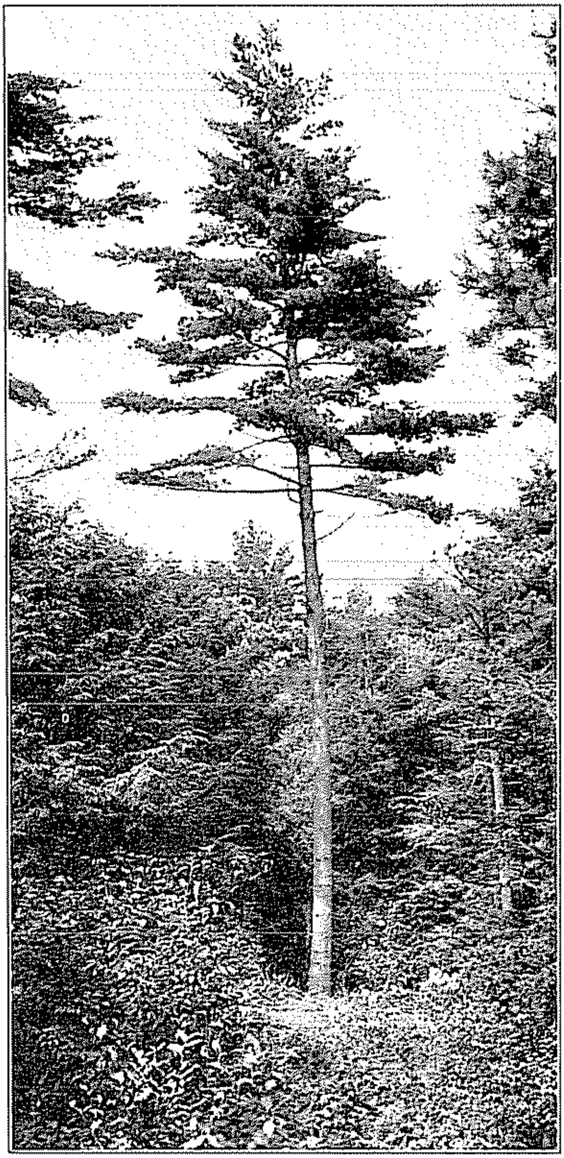

FIG 3. ILLUSTRATING THE COMPENSATION OF DEAD LENGTH AND CROWN WIDTH WITHIN A GIVEN FORM CLASS

The tree belongs in form class .70

Photograph by N. W. Hosley

FIG. 3a ILLUSTRATING THE COMPENSATION OF DEAD LENGTH AND CROWN WIDTH WITHIN A GIVEN FORM CLASS

Center tree also in form class .70

Photograph by N. W. Hosley

grown trees, and thus will present exceptional cases in timber estimating.

Difference between actual and computed form quotient ±	Number of cases (trees)
0	9
.01	10
.02	12
.03	7
.04	7
.05	9
.06	7
.07	3
Total	64

Group 3 is considered separately because it was anticipated that very dense stands would show some irregularity in form quotient. This proved to be the case, as seen from the distribution of error.

Difference between actual and computed form quotient	Number of cases (trees)	
−0.03	2	
−0.02	1	
−0.01	3	
0	4	
+0.01		2
+0.02		5
+0.03		3
+0.04		6
+0.05		4
+0.06		1
+0.07		1
+0.08		2
Totals	10	24

There is some tendency in overstocked stands toward form quotients higher than can be predicted from Table 10, but it takes stands where stagnation is evident. Stands that showed consistently higher form quotients were all of this type. The reason is most probably in the disproportionately slow growth in diameter breast high as compared to that of the upper portion of the stem (14). Extremely overstocked stands are confined to small areas.

Trees of the last two groups are subject to considerable irregularities in regard to butt swell. The data consider more or less average butt swell. When stump quotients outside of bark vary approximately within the limits given below, then the relationships in Table 10 hold. Only very abnormal trees are thus excluded.

Diameter breast high (inches)	Range of stump quotients
4	1.07–1.16
6	1.10–1.19
8	1.13–1.21
10	1.14–1.23
12	1.16–1.24
14	1.17–1.26
16	1.18–1.27
18	1.19–1.28

It appears from this discussion that, with minor exceptions, Table 10 is very useful for timber estimating. For Group 1 twenty-five trees ($3^2 \times 1.64^2$) seem to be sufficient to limit the error to form-class units which would amount to approximately one and one-half per cent of the error in cubic foot volume. The estimation of form class of the stand can be done simultaneously with height measurements. A small rule graduated in tenths (48) from 0 to 100 may be used in estimating per cent of dead length. This scale is held vertically like a Christen hypsometer so as to include the total height of the tree between 0 and 100 divisions. Dead length in per cent of total height is read where the average crown-base cuts the scale. For accurate work a Klaussner hypsometer was found to be the best.

Crown width is estimated by eye. The experience of the

Fig. 4 A STAND WITH AN AVERAGE FORM CLASS OF .60

Photograph by N. W. Hosley

Fig 4a A STAND WITH AN AVERAGE FORM CLASS OF .72

Photograph by N W Hosley

writers is that with a little practice the average crown diameter to the nearest foot can be easily determined.[1]

After the determination of form quotients of individual trees the variability of the quotient and especially the association of this variability with diameter classes should be noted. If the differences are not too large, the quotients can be averaged; if the differences are related to diameter classes, the volume line or volume curve methods of Speidel or Kopezky (25) can be used. The average height on diameter curve is drawn. Then the curve of volume over breast high diameter is gotten from sample tree volumes determined from the form-class volume tables. This curve is used for determining the volume of the stand.

It has been previously shown (5, 30) that an average form quotient can be determined and used for the entire stand. The association of dead length and crown index with form class suggests that this average tendency usually exists, since generally the lower relative dead length of dominant and co-dominant trees is balanced by wider crowns. When suppressed trees were eliminated and some abnormal trees were rejected, the standard error in estimating the form quotient of individual sample trees from their average was found to be ± 4.1 form-class units. The error is distributed as follows:

Deviation from average form quotients	Per cent of cases
0–.02	33
.021–.04	31
.041–.06	20
.061–.08	12
.081–.10	4

The consideration of form adds much accuracy to timber estimating. Conventional volume tables assume that differences in volume due to form tend to compensate, and there-

[1] Crown widths of four hundred trees (Jack pine, permanent sample plot near Cass Lake, Minnesota) were estimated in six hours.

fore a considerable number of trees is required for their proper use. With a limited sample the compensation of error becomes a matter of chance. It should be remembered that in conventional volume tables the value for a nine-inch tree, for example, may correspond to form class 70, and a fifteen-inch tree to form class 60, etc., according to the material used. The chance for a cumulative error is easily seen. Even in the case of abnormalities the use of dead length and crown index as a basis for determining form quotient is both practical and accurate.

TABLE 9

ESTIMATION OF CROWN INDEX

Diameter breast high (inches)	Crown index in Feet								
	6	8	10	12	14	16	18	20	22
1	1	1½	2¼	2¾	3½	4	4¾	5½	6
2	1½	2	2¾	3½	4¼	5	5¾	6½	7¼
3	2	2¾	3¾	4½	5½	6½	7½	8¼	9
4	2½	3½	4¾	5¾	7	8	9	10	11¼
5	3¼	4½	5¾	7	8¼	9½	10¾	12	13¼
6	4	5¼	6¾	8	9½	11	12½	14	15¼
7	4½	6	7½	9	10¾	12¼	14	15½	17
8	5	6¾	8½	10¼	12	13¾	15½	17¼	19
9	5½	7½	9¼	11¼	13	14¾	16¾	18¾	20½
10	6	8	10	12	14	16	18	20	22
11	6½	8½	10½	12¾	14¾	17	19	21¼	23¼
12	6¾	9	11¼	13¼	15½	17¾	20	22¼	24¼
13	7¼	9½	11¾	14	16¼	18½	21	23¼	25½
14	7½	9¾	12¼	14½	16¾	19¼	21¾	24	26½
15	7½	10	12½	14¾	17¼	19¾	22¼	24¾	27
16	. .	10¼	12¾	15¼	17½	20	22½	25	. .
17	. .	. .	13	15½	18	20¼	23	. .	. .
18	.	. .		15½	18¼	20½	.	.	. .
19	.	. .	.	15¾	18¼	20¾	.	.	. .
20		.		16	18½	21	.	. .	. .

Example: A tree with a diameter of 7 inches at breast height and a 9-foot crown diameter belongs to crown index 12, as does a tree 13 inches at breast height with a 14-foot crown.

TABLE 10

ESTIMATION OF FORM CLASS

Dead length per cent of total height of tree	Crown Index[1]								
	6	8	10	12	14	16	18	20	Basis trees
	Form class outside bark								
20						44	45	46	27
25						48	49	50	7
30					52	53	54		17
35				53	55	56	58		6
40				56	58	60	62		6
45				58	61	64	66		12
50			59	61	64	68	70		18
55			61	64	67	71			28
60		61	63	66	70	74			40
65		63	65	68	72	76			32
70		66	68	71	74	78			22
75		68	70	74	77				15
80	68	70	73	76					6
Basis trees	2	7	22	40	65	43	35	13	236

Taper. Table 11 shows the taper of white pine fifteen to sixty years old for each form class. These are average figures computed for the total material. An analysis showed that within the region under consideration and during a short rotation, one may consider taper for trees of a given form class to be independent of height and diameter, since no serious error will be introduced in estimating board-foot contents of trees below fifteen inches at breast height.

Young trees, as a rule, tend to be more conical in shape than the older ones, and their stems are subject to irregularities due to nodal swells. Large-sized trees, on the other hand, may have pronounced butt swell. Small trees, too, even below four inches at breast height, are noticed to have butt-swell, especially if they possess comparatively large crowns.

The problem of determining the effect on taper of any one

[1] See Table 9.

factor at a time is one of the manifold classification type. It requires a considerable amount of data in order not to overlook some other influencing factor on one hand, and, on the other hand, to have enough cases in each group so that the value of the standard error, so important in judging the significance of any effect, can be correctly interpreted.

For a given form and height class there is an evident tendency for trees with larger diameters at breast height to have smaller percentage taper values than shown by Table 11, especially in the lower part of the stem.

TABLE 11

PERCENTILE TAPERS

Form class	Stem Sections from Breast Height to Tip, Inside Bark — Diameters in per cent of D B H								
	1/10	2/10	3/10	4/10	5/10	6/10	7/10	8/10	9/10
35	87.2	71.0	54.8	43.6	35.0	28.9	21.1	14.1	7.9
37½	88.1	73.2	58.4	46.7	37.5	30.3	22.1	14.7	8.0
40	89.1	75.4	61.8	49.8	40.0	32.0	23.3	15.2	8.1
42½	89.7	77.6	64.6	52.7	42.5	33.7	24.5	15.7	8.3
45	90.4	79.7	67.5	55.8	45.0	35.6	25.9	16.3	8.5
47½	91.0	81.4	70.2	58.8	47.5	37.4	27.0	17.0	8.7
50	91.6	82.9	72.6	61.2	50.0	39.3	28.5	17.8	8.9
52½	92.2	84.2	74.8	63.8	52.5	41.4	30.0	18.7	9.2
55	92.8	85.2	76.7	66.3	55.0	43.8	31.7	19.6	9.4
57½	93.3	86.2	78.2	68.5	57.5	46.1	33.4	20.7	9.7
60	93.8	87.2	79.7	70.6	60.0	48.6	35.6	21.8	10.0
62½	94.2	88.0	81.1	72.8	62.5	51.1	37.8	23.1	10.5
65	94.8	89.0	82.5	74.7	65.0	53.7	40.0	24.6	11.1
67½	95.2	89.8	83.8	76.6	67.5	56.4	42.3	26.2	12.0
70	95.7	90.7	84.9	78.4	70.0	59.2	44.7	28.0	13.0
72½	96.2	91.5	86.2	80.0	72.5	61.5	47.2	30.1	14.1
75	96.7	92.4	87.5	81.7	75.0	64.2	49.6	32.2	15.4
77½	97.1	93.2	88.8	83.5	77.5	66.5	52.1	34.9	16.9
80	97.6	94.1	90.0	85.5	80.0	69.3	54.5	37.3	18.5
82½	98.1	95.0	91.2	87.4	82.5	72.2	57.4	39.9	20.4
85	98.6	95.8	92.6	89.3	85.0	75.5	60.3	42.5	23.0
Standard deviation	±2.8	±2.9	±2.9	±2.5	..	±2.2	±3.2	±3.3	±3.0

TABLE 12

TENDENCY OF TAPER TO VARY WITH DIAMETER AT BREAST HEIGHT

Actual Taper compared with the Average Taper Curve of Table 11 for a Given Form Class

Difference in percentage at specified tenths of the stem above breast height

Diameter breast high (inches)	1/10			2/10			8/10			9/10			Basis no. of trees
	Height class in feet												
	50	60	70	50	60	70	50	60	70	50	60	70	
7–9	+0.2	+0.2	0	+0.5	0	−0.8	+0.4	−0.3	+6.5	−1.7	+1.6	+6.0	44
10–12	+0.4	+0.8	−1.2	0	−1.0	−2.4	+1.4	+0.4	+4.5	−1.2	−0.4	+2.5	40
13–15	−2.0	−2.2	−2.2	−0.5	−1.8	−0.5	−0.5	+1.5	+3.0	−1.5	+0.5	+1.0	26
16–18	−1.0	−2.0	−2.8	0	−0.5	−3.0	0	−1.0	+1.0	+0.5	+0.5	0	10
Total													120

The first tenth-section of the stem above breast height shows the largest variation. Taper measurements for groups of trees ranging from thirteen to eighteen inches at breast height and from fifty to seventy feet in total height are on an average consistently below the trend of the total material. The difference is 2.1 ± .5 per cent, which is rather significant, since the value of the difference is four times its standard error. No similar statement, however, could be made in regard to other parts of the stem or to the groups of smaller diameters. This somewhat agrees with the investigation recently made in Canada (48), which leads one to expect the variation of taper with diameter to become more pronounced with age. See Table 13 below.

In Table 12 is shown the variation of taper with height. It appears generally that in the same diameter and form class the increase in height tends to be associated with smaller taper values in the lower part of the tree, and larger values in the upper part.

The influence of these variations in taper on board-foot volumes is slight, provided no trees older than sixty years and larger than sixteen inches breast high are considered. It was found that the variation in bark thickness frequently counterbalances the effect of taper differences, and, in general, is of greater importance.

TABLE 13

VARIATION OF TAPER WITH AGE

Stem sections from breast height to tip	Form Class 65: Second growth Central New England	Form Class 65: Old growth Canada	Form Class 65: Difference	Form Class 70: Second growth Central New England	Form Class 70: Old growth Canada	Form Class 70: Difference	Form Class 75: Second growth Central New England	Form Class 75: Old growth Canada	Form Class 75: Difference
	Diameters I. B. in per cent of D B H I B								
1	94.8	90.5	+ 4.3	95.7	93.2	+2.5	96.7	94.6	+2.1
2	89.0	83.8	+ 5.2	90.7	88.0	+2.7	92.4	90.2	+2.2
3	82.5	78.3	+ 4.2	84.9	82.8	+2.1	87.5	86.0	+1.5
4	74.7	72.2	+ 2.5	78.4	77.0	+1.4	81.7	81.1	+0.6
5	65.0	65.0	0	70.0	70.0	0	75.0	75.0	0
6	53.7	57.5	− 3.8	59.2	61.3	−2.1	64.2	66.4	−2.2
7	40.0	48.2	− 8.2	44.7	50.6	−5.9	49.6	55.0	−5.4
8	24.6	35.4	−10.8	28.0	37.0	−9.0	32.2	40.5	−8.3
9	11.1	18.9	− 7.8	13.0	20.0	−7.0	15.4	22.3	−6.9

Note: The second-growth white pine studied in central New England is from fifteen to sixty years old; old white pine in Canada is one hundred twenty years and older (After W. G. Wright. See 48.)

4. BARK THICKNESS

Second-growth white pine below sixty years of age seems to vary very little in regard to bark thickness for trees of the same size. This statement should not be extended, however, to trees older than sixty years or be interpreted as applicable to other localities, unless sufficient information in that respect is available.

Bark thickness was obtained from the relationship between diameters outside and inside of bark at tenth sections. These diameters are in direct proportion. The constants of proportionality, being nearly similar in the middle part of the stem, change toward the base and tip. This can be readily seen from Table 14.

It is very likely that young second-growth white pine in central New England keeps well within limits of one bark thickness class. At least, trees of different sizes in the same stand show as much variation in bark thickness as trees of the same size belonging to different stands. It can also be very safely assumed that density of the stand influences very little, if at all, the relative bark thickness, since no evidence of such influence was found.

The point of practical importance that this study of bark thickness brings out is that form quotients outside and inside of bark are very nearly the same. As an average one may consider the absolute form quotient inside of bark to be 1.019 times the form quotient outside of bark. This appears from the comparison of the ratios between diameters inside and outside of bark.

Since inside the bark the standard deviation of actual absolute form quotients from the predicted trend (factor 1.019) is ± 0.01 of form class units, the deviation in ninety-five per cent of cases will hardly exceed ± 0.03 units.

TABLE 14

RELATIVE DOUBLE BARK THICKNESS AT VARIOUS POINTS ALONG THE STEM

Point of measurement	Ratios of diameters inside and outside of bark	Bark factor [1]	Standard deviation of error	Basis no. of trees
Stump (1 ft. height)	.905	.095	.014	81
D. B. H.	.942	.058	.011	160
1/10 [2]	.954	.046	.010	95
2/10	.957	.043	.011	95
3/10	.958	.042		curve
4/10	.960	.040		curve
5/10	.960	.040	.010	130
6/10	.960	.040		curve
7/10	.958	.042	.011	95
8/10	.954	.046		curve
9/10	.945	.055	.012	60

[1] This factor multiplied by the diameter outside bark gives double bark thickness.

[2] Fraction of distance from D. B. H. to tip.

5. STUMP QUOTIENTS

It was found that the relation between stump diameters and the diameters breast high for a given diameter varies inversely with dead length. (See Table 15 below.)

Stump diameters were taken one foot above ground. The relationship between stump diameters inside and outside of bark has already been shown to be 0.905 as an average. This table would imply that butt swell is associated with crown development, since trees with long and wide crowns were found to have considerably greater butt swell.

TABLE 15

STUMP QUOTIENTS OUTSIDE OF BARK

Diameter breast high (inches)	Dead Length in Per cent of Total Height				Basis trees
	10–30	30–50	50–70	70 and over	
	Ratio of stump diameter to diameter breast high				
1	2.00	1.80	1.60	1.40	17
2	1.50	1.35	1.20	1.10	32
3	1.30	1.21	1.13	1.06	37
4	1.25	1.18	1.13	1.08	32
5	1.22	1.16	1.13	1.09	24
6	1.20	1.16	1.13	1.10	13
7	1.20	1.16	1.13	1.11	18
8	1.20	1.17	1.14	1.12	12
9	1.21	1.18	1.15	1.13	17
10	1.22	1.19	1.16	1.14	5
11	1.23	1.20	1.17	1.15	7
12	1.24	1.21	1.18	1.16	1
Basis trees	52	38	88	37	215

6. VARIATION OF VOLUME WITH DEGREE OF STOCKING

There are many factors that enter into the measurement of timber yield. These factors are not in direct proportion to each other. That is to say, if two stands differ only in number of trees per acre or in basal area by a certain value, we cannot say that they differ in volume in the same proportion, unless all other factors are essentially similar. Basal area per acre is one of the most influential factors of yield, but its complete significance in comparing stands is attained only when the stands are similar in form height. Furthermore, all the factors of yield change with age.

The difference in form height between two stands of the same age, site, and basal area is especially important in white pine stands on account of the effect of weevil injury on height growth and because of the effect of growing space on form. The comparison between the stands should, therefore, be extended to all the different factors upon which the yield is based. The comparison in well stocked stands is done by basal area per acre on the assumption that form height within a given site and age remains constant. If it is found that stands other than fully stocked ones have the same form heights with a given age and site, then the whole matter will simply be reduced to the measurement of basal area per acre.

However, this is not the case even in fully stocked stands. In preparing yield tables one readily sees that plots giving zero deviations from tabular basal area values do not necessarily give zero deviations from volume trends. The difference, of course, is due to inequalities of form height. Basal areas themselves do vary considerably.[1] A similar variation can be expected in volume per acre. This considerable variation inherent in normal yield tables even after certain plots are rejected shows some vagueness in the concept of normality. If one continues to reject plots on the basis of basal area so as to reduce the standard deviation to five per cent, he will seriously disturb the trends in number of trees and volume by rejecting plots that were just right in respect to these two factors.

Existing yield tables, therefore, deal with average conditions of full stocking which is not necessarily maximum yield.

[1] The standard deviation of plot basal-area deviations from tabular values is in the neighborhood of plus or minus seventeen per cent in the latest yield tables prepared (42).

The red and white fir yield tables (42) include as basic material stands ranging from forty-five to one hundred eighty-five per cent of yield table values in number of trees per acre.

The definition, "a normal stand is that producing the maximum possible volume in cubic feet for a given age and site," [1] is incomplete, because normality at any age does not mean normality at all ages. The definition requires, in other words, that we consider all stands normal whose cubic volumes come within the range of normal volumes without regard to the growth series to which the stands may belong. It will also hardly be possible to reconcile the other factors, such as number of trees per acre and basal area.

To prove these points we must consider stands not normal, i. e., understocked and overstocked stands.

The yield tables for fully stocked second-growth white pine presented in *U. S. Department of Agriculture Bulletin 13*, by E. H. Frothingham, may be used as a standard of comparison of normality.[2] The part under twenty-five years of age was disregarded, however, for fear of the obvious lack of balance between basal area and volume.

The comparison of understocked and overstocked stands with fully stocked stands on Site II is presented in Table 16.

This table clearly indicates that there is not the assumed parallelism in growth trends and that the application of the yield table to present stands or to predict the future yield is confronted with difficulties. The influence of form is ordinarily not noticed, since conventional volume tables do not take the form of individual stands into consideration.

Understocking by number of trees is not always detrimental when wood production and not quality is considered. This is especially true within the limits of a closed stand. The idea of thinning originated from the greater vigor of understocked stands. Nearly all fully stocked stands require thin-

[1] Committee on Growth and Yield. Standardization of Methods of Preparing Volume and Yield Tables. 1926.

[2] In these tables plots deviating more than ten per cent from average basal area were rejected.

ning. Plantations with usual spacings are nearly always understocked at early ages.

TABLE 16

COMPARISON OF UNDER- AND OVERSTOCKED STANDS WITH YIELD TABLE VALUES

	Understocked Stands Per cent of full stocking per acre				Overstocked Stands Per cent of full stocking per acre		
Age (years)	Number of trees	Total basal area (sq ft)	Total volume (cu ft)	Age (years)	Number of trees	Total basal area (sq ft)	Total volume (cu ft)
27	66	104	90	28	137	149	151
27	81	92	79	32	248	104	87
27	99	101	94	36	102	108	117
30	17	41	30	36	133	116	124
30	47	88	72	40	121	131	129
31	28	63	51	43	149	98	93
34	78	60	45	55	104	96	88
34	33	106	75	55	115	108	120
36	71	105	102	55	200	84	73
37	60	71	73	59	160	87	75
37	74	118	119				
38	38	100	88				
41	38	97	86				
42	40	95	57				
44	43	89	73				
45	63	83	73				
45	71	92	84				
45	95	95	97				
50	33	91	76				
50	43	108	95				
50	43	122	114				
50	52	98	104				
50	76	127	98				
60	36	111	113				
65	85	86	84				
65	43	130	120				

If understocking is understood in terms of basal area, then, as seen from the table, the stands older than forty years have basal areas over seventy per cent of basal areas of fully stocked stands. With stands under forty years basal areas below seventy per cent are frequent. Therefore, understocked stands growing at a higher rate, at least in basal area, may or may not reach fully stocked volumes, depending on how their form heights compare with those of fully stocked stands. Discussions of the approach of understocked stands to normality do not consider the question of form. In understocked stands the form improves with age, but this is not seen when the conventional volume tables are used. The heights of understocked stands are frequently lower than those of fully stocked stands, mostly due to the effect of weevil injury.

The approach of understocked stands to normality is due to ample growing space. The basal area per acre begins to increase at a higher rate than normal. The form height also increases at a higher rate, or at least remains in constant proportion with the form height of a normal stand for a given age and site.

Young overstocked stands, in turn, have more volume than fully stocked stands, but rapidly deteriorate at older ages. The effect of stagnation and of high mortality on the rate of growth in basal area counterbalances all the advantages of high form.

In the light of the interpretation of growing space and assuming the normal yield table as a standard of comparison, it appears that in order to approximate maximum volume per unit area, stands should be overstocked at early ages (see also 12, 42) and somewhat understocked toward old age. This volume will be possible with several combinations and life histories. Different natural stands reach normality of volume at different periods, but never maintain it throughout their life history. They are thus disconnected series unless controlled by man.

7. DESIRABLE STAND DEVELOPMENT

It is only with sufficient stocking and by control of growing space that pine of satisfactory quality can be grown in pure stands. Pine weevil injury in this region is not an occasional thing, but is almost the rule as far as pure stands are concerned. Repeated weeviling in widely spaced stands results in such misshapen trees that the commonly used name of "cabbage pine" was suggested.

Close spacing helps the stand to recover sooner and successfully, i. e., crooks in the stem are less pronounced than in wide spacings and the tree is not so apt to fork. Furthermore it has been noted that in dense stands there is a smaller percentage of weeviled trees than in more open stands.[1]

Old plantations were commonly spaced six feet by six or wider. Now they look very poor as a result of repeated weeviling and absence of clear length. Perhaps the initial cost of planting was low, but it is quite evident now that the final value of lumber will also be low, making a final profit questionable.

Close by a widely spaced plantation one very occasionally sees a plantation spaced three by three or four by four. Although the average diameter is small as compared to widely spaced plantings, the trees are straighter, with well-developed dead-length and good form. The dead branches are short and slender. The recovery from weevil injury is strikingly faster and more complete. The stand suggests far greater possibilities. This was noted in all closely spaced plantations studied.

Weevil injury after the stand is thirty feet tall or about thirty years old is not very common or important.

Closely spaced young plantations cannot be left too long without thinning because the growth will be considerably retarded.

[1] H. J. MacAloney. Unpublished manuscript.

TABLE 17

DESIRABLE STAND DEVELOPMENT

Diameter breast high (inches)	Age in years					
	15	30	30	45	45	60
		Stem distribution		Number of trees per acre		
1	200	10	first		second	
2	1,100	30	thinning		thinning	
3	650	100				
4	200	250				
5	50	500		30	30	
6		220		40	40	
7		80		70	70	
8		10		100	70	
9				140	60	
10				80		20
11				30		50
12				10		70
13						60
14						25
15						5
a	2,200	1,200	700	500	270	230
b	81	163		199	80	187
c	2.6	5.0		8.6		12.1
d	18	35		57		72
e				4,900	1,900	5,400
f				30,000	11,000	35,000
g	7	9		12		15
h	30	50		60		66
i	4.3	5.5		5.0		4.4
j	54	64		66		72

a Total number of trees per acre.
b Total basal area per acre.
c Average diameter of the stand.
d Average height of dominant trees.
e Total volume (cu ft.).
f Volume in Feet. Board measure.
g Desired crown diameter of dominant and co-dominant trees
h Desired dead-length in per cent of total height (dom and co-dom)
i Growing space factor (dom. and co-dom).
j Form class of dominants and co-dominants.

It appears that in order to insure the recovery from weevil injury and to produce at least two logs of good quality, white pine must start dense, say with a four by four or four by five spacing, and remain dense until the stand is thinned at twenty-seven to thirty years of age. During this time there will be enough trees from which to develop tentative crop trees with high dead-lengths and small knots. Thinning at this age includes cleaning and improvement cutting. It should not be made too heavy on account of exposure and as an insurance of sufficient crop trees. Also the dead length will be increased more than if the trees had more room.

At the age of forty-five years the second thinning should take place. This should be heavy and will probably pay considerably more than the cost of the thinning.[1] This leaves the final crop trees comparatively few in number, but the best in form and size. The so-called "light increment" will follow.

[1] The reader may consult the figures given in Table 17 to interpret them in terms of dollars and cents according to costs and prices involved in his particular case.

APPENDICES

APPENDIX I

FIELD DATA

In the course of this study fifty temporary plots containing 1,309 trees in both natural and planted stands were studied. Forty-six of these plots were taken in northern Massachusetts and four in southeastern Vermont. Forty-seven plots were on site II, two on site I, and one on site III. Only closed stands of pure, even-aged white pine younger than sixty-five years were considered. In order to get uniform conditions the plots were necessarily small in area, ranging from one-fortieth (most common) to one-tenth acre. Great care was taken to include just the crown area of the trees within the plot. If an error occurred in basal area and volume, it is perhaps too small to be significant, since the stands represented differ so widely that this effect is not felt. Furthermore, the question of average yield does not enter this study.

The more intensive measurements on individual stems were based on 377 sample trees. With the exception of ninety-two trees,[1] these were all on the plots described above. Diameters half way above breast height were measured in all cases, 182 by climbing, ninety-two after the trees were felled, and five with a transit reading to ten seconds. These trees grouped themselves as follows according to diameter, height, form class and age:

TABLE 18 SUMMARY OF TREES MEASURED

Diam breast high (ins)	Number of trees	Total height	Number of trees	Form class	Number of trees	Age in years	Number of plots
2	38	10	55	30	1	10	2
4	48	20	30	35	3	15	6
6	45	30	32	40	9	20	5
8	81	40	78	45	23	25	3
10	78	50	94	50	32	30	5
12	41	60	56	55	28	35	7
14	31	70	32	60	18	40	4
16	10	.	.	65	61	45	6
18	4	.	.	70	70	50	5
20	1	.	. .	75	23	55	3
. .	. .	.	.	80	9	60	2
. .	. .		.	85	2	65	2
Totals	377	.	377	.	279	.	50

[1] Trees measured in tenth-sections by W. A. Albright and N. W. Hosley on the Harvard Forest in 1925.

APPENDIX II

VOLUME FORMULA FOR SECOND-GROWTH WHITE PINE

(*a*) Volume of the stem above breast height.

Volume of a solid of revolution characterized by curve $y^2 = px^r$ may be represented [1] by

$$V = \frac{2^r}{r+1} b_m L \text{ or } V = \frac{f}{q^2} b_m L \text{ since}$$

$$f = \frac{1}{1+r} \text{ and } q^2 = \frac{1}{2^r}$$

This assumes, of course, a perfectly symmetrical stem whose shape is governed by the form exponent r.

The majority of investigators consider the function $\frac{f}{q^2}$ independent of diameter breast high and of height or of any other factor of tree growth. This assumes that $f = cq_2$, where c is a certain constant whose value is governed by the form exponent r. The following table shows each factor as it is related to the type of the solid of revolution.

Type of the solid	r	f	q	$\frac{f}{q^2}$
Cylinder	0	1.000	1.000	1.000
Paraboloid	1	0.500	0.707	1.000
Cone	2	0.333	0.499	1.333
Neiloid	3	0.250	0.354	2.000

One may clearly see the reason and limitations of Schiffel's approximation formula $f = q^2$, since a paraboloid was taken to represent the shape of the tree stem.

[1] V = volume of the stem above breast-height.
b_m = diameter at one half the stem length, L.
f and q are absolute form factor and form quotient respectively.
y is the diameter at the point on the stem x units from the tip.
p = a constant; and r, the form exponent.

The table also shows that Behre's principle of "normal" diameter and the elimination of root swell is to restore the ratio $\frac{f}{q^2}$ as given in this table for each value of q, since this table and the table for f and q presented by him (page 702, ref. 5) agree very closely.

We have found that actually [1] the relationship between absolute form factor and the absolute form quotient is

$$f = 0.453q^2 + 0.065l + 0.214$$

or that

$$\frac{f}{q^2} = 0.453 + 0.065\frac{l}{q^2} + \frac{0.214}{q^2} \text{ and hence the volume}$$

$$V_1 = \left(0.453 + 0.065\frac{l}{q^2} + \frac{0.214}{q^2}\right) b_m \text{ L; but since}$$

$b_m = \text{B}\, q^2$, where B is the basal area at breast height

$$V_1 = (0.453q^2 + 0.065\, l + 0.214) \text{ BL.}$$

(*b*) Volume of the stem below breast height.

For simplicity the stem is cubed by Smalian's formula and the stump is considered a cylinder.

$$V_2 = \frac{b_o + \text{B}}{2} 3.5 + b_o = 2.75b_o + 1.75 \text{ B}$$

where b_o and B are basal areas of the stump (one foot above ground) and at breast height respectively.

Since $b_o = q_o^2$ B, $V_2 = 2.75\, q_o^2 \text{ B} + 1.75 \text{ B} = \text{B}\, (2.75q_o^2 + 1.75)$. The factor q_o is, of course, the stump quotient.

(*c*) Volume of the total stem thus becomes

$$V = \text{B}\, [(2.750q_o^2 + 1.750) + \text{L}\, (0.453q^2 + 0.065\, l + 0.214)]$$

$$\text{or } V = \text{B}\, (\alpha + \text{L}\beta)$$

where α and β (the values of both parentheses) could be readily determined graphically.

The value of q_o if not measured directly can be obtained from Table 15.

To get the stump quotients inside of bark Table 14 can be used

For the determination of q or the absolute form quotient with a fair degree of accuracy without actual measurement, the reader is referred to the discussion on Form.

[1] No attempt was made to eliminate butt swell.

APPENDIX III

VOLUME TABLES

THE application of ordinary volume tables assumes that at any place in the region to which they apply, measurements on a large number of trees tend to compensate for the differences between actual and table volumes of individual trees. When the sample is small, these differences are very largely due to not allowing for compensation in form. The use of form-class volume tables greatly reduces this error.

The distribution of deviations of individual tree volumes from interpolated tabular volumes, as given in the form-class tables following, is presented below.

Difference (per cent) ±	Cubic Foot Table	Board Foot Table
	Number of trees used [1]	
0–2	70	67
2.1–4	90	45
4.1–6	76	28
6.1–8	33	19
8.1–10	10	9
10.1–12	2	5
12.1–14	2	2
14.1–16	..	2
Total	283	177
Standard deviation of the differences (per cent)	±4.0	±4.9

The volume tables make no allowance for defect. Before the volume tables are applied, local information of bark thickness should be secured. The tables consider that the ratio between diameters inside and outside of bark at breast height is 0.942. If the local study of bark thickness shows a different factor, a correction should be applied as shown in the table below.

[1] No trees were rejected from the data.

Actual diameters, breast high		Volume-table diameters inside bark (inches)	Difference (inches)	Corrected diameters, volume-table outside bark (inches)
Outside bark (inches)	Inside bark (inches)			
10.0	9.0	9.4	0.4	9.6
10.0	9.6	9.4	0.2	10.2

No attempt should be made to apply the tables to trees older than sixty years without the knowledge of the difference in regard to bark thickness and taper.

If the form quotient is not determined directly, it can be estimated from Table 10. Much attention in this respect should be given to butt swell. (See discussion on Form).

TABLE 19

A. TOTAL CUBIC-FOOT FORM-CLASS VOLUME TABLE

Note: Volume includes total stem inside bark. Stump height, one foot. The stem volumes above breast height were computed from the corrected normal equation 3. Bold face type indicates extent of original data.

FORM CLASS 32.5

Diameter breast high (inches)	Total height of tree (feet)							Basis (trees)
	10	15	20	25	30	35	40	
			Total volume (cubic feet)					
1	.07	.07	.08	..	..	.	..	..
2	.20	**.23**	.26	.28	.31	..	..	1
3	.	.48	.54	.60	.67	..	.	..
4	..	.81	.91	1.01	1.12	.	.	..
5	..	..	1.37	1.54	1.70	.	..	.
6	..	.	.	2.14	2.27	2.60	..	..
Basis (trees)		1	..	..	..	..	.	1

FORM CLASS 35

Diameter breast high (inches)	Total height of tree (feet)							Basis (trees)
	10	15	20	25	30	35	40	
			Total volume (cubic feet)					
1	.07	.08	.08	..	.	..	.	..
2	**.20**	.23	.26	.29	.32	..	..	1
3	..	**.48**	.54	.61	.68	.	..	1
4	..	.82	.92	1.03	1.14	..	..	..
5	..	.	1.40	1.57	1.73	..	..	..
6	..	..	.	2.18	2.42	2.66	..	..
Basis (trees)	1	1	..	.	..	..	.	2

FORM CLASS 37.5

Diameter breast high (inches)	Total height of tree (feet) 10	15	20	25	30	35	40	Basis (trees)
	Total volume (cubic feet)							
1	.07	.08	.09					
2	.21	.24	.27	.30	.32			
3		.49	.55	.62	.69			
4		.82	.93	1.05	1.16			
5			**1.42**	1.59	1.76			1
6				2.22	2.47	2.72	2.97	
7				2.95	3.30	3.63	3.97	
8					4.10	4.50	4.90	
Basis (trees)			1					1

FORM CLASS 40.0

Diameter breast high (inches)	Total height of tree (feet) 10	15	20	25	30	35	40	45	50	Basis (trees)
	Total volume (cubic feet)									
1	.07	.08	.09							
2	.21	**.24**	.27	.30	.33					1
3		.49	.56	.63	.70					
4		.83	.94	1.06	1.18					
5			1.43	1.62	1.80	1.99	2.18			
6				2.26	2.52	2.78	3.04			
7				3.05	3.38	3.72	4.07			
8					4.22	4.65	5.07	5.50	5.94	
9					5.50	6.05	6.60	7.15	7.69	
10						7.36	8.02	8.68	9.36	
Basis (trees)		1								1

FORM CLASS 42.5

Diameter breast high (inches)	Total height of tree (feet)											Basis (trees)
	10	15	20	25	30	35	40	45	50	55	60	
	Total volume (cubic feet)											
1	**07**	.08	.09									1
2	**.21**	**.24**	.27	.31	.34							2
3		**.50**	**.56**	.63	.71							3
4		.84	**.96**	1.08	1.20							2
5			1.45	1.64	1.84	2.02	2.22					
6				2.30	2.56	2.84	3.12					
7				3.09	3.44	3.80	4.17	4.54				
8					4.35	4.80	5.22	5.69	6.18			
9					5.61	6.20	6.76	7.35	7.91			
10						7.50	8.22	8.94	9.66	10.4		
11							9.85	10.7	11.6	12.4	13.2	
12							11.8	12.7	13.7	14.6	15.6	
Basis (trees)	2	3	3									8

FORM CLASS 45

Diameter breast high (inches)	Total height of tree (feet)													Basis (trees)
	10	15	20	25	30	35	40	45	50	55	60	65	70	
	Total volume (cubic feet)													
1	.07	.08	.09											
2	.21	**.25**	.28	.31	.34									3
3		**.50**	**.57**	.64	.72									5
4		**.85**	**.97**	1.09	1.22									3
5			1.47	1.67	1.87	2.06	2.26							
6				2.35	2.62	2.90	3.18							
7				3.14	3.52	3.88	4.27	4.64						
8					4.49	4.95	5.40	5.86	6.40	6.94				
9					**5.72**	6.32	6.95	7.55	8.15	8.70				1
10						7.70	8.45	9.20	9.95	10.7				
11							10.2	11.0	11.9	12.8				
12							12.1	13.1	14.1	15.1	16.1			
13								15.3	16.5	17.7	18.9			
14								17.6	18.9	20.3	21.6	22.9		
15									21.6	23.2	24.8	26.3		
16									24.4	26.1	27.8	29.5	31.2	
Basis (trees)		7	4		1									12

FORM CLASS 47.5

Diameter breast high (inches)	Total height of tree (feet): 10	15	20	25	30	35	40	45	50	55	60	65	70	Basis (trees)
	Total volume (cubic feet)													
1	**.07**	.08	.09											1
2	**.21**	**.25**	.28	.32	.35									3
3		**.50**	**.57**	.65	.73									6
4		.86	**.98**	1.11	1.24									1
5			1.49	1.70	1.90	2.11	2.32							
6				2.40	2.68	2.96	3.26							
7				3.21	3.60	4.00	4.38	4.78						
8					4.60	5.10	5.57	6.10	6.61	7.16				
9					5.85	6.50	7.12	7.77	8.39	9.00				
10						7.92	8.70	9.48	10.3	11.0				
11							10.6	11.4	12.3	13.2				
12							12.4	13.5	14.5	15.6	16.6			
13								15.8	16.9	18.2	19.4			
14								18.2	19.5	20.9	22.3	23.7		
15									22.3	24.0	25.6	27.1		
16									25.2	27.0	28.8	30.6	32.3	
Basis (trees)	2	5	4											11

FORM CLASS 50.0

Diameter breast high (inches)	Total height of tree (feet): 10	15	20	25	30	35	40	45	50	55	60	65	70	Basis (trees)
	Total volume (cubic feet)													
1	**.07**	.08	.09											1
2	.22	**.25**	.29	.32	.35									7
3		**.51**	**.58**	.66	.74									6
4		.87	**1.00**	1.14	1.27									3
5			1.51	1.72	1.93	2.15	2.37							
6				2.45	2.72	3.03	3.34							
7				3.28	3.67	4.09	4.49	4.92						
8					4.76	5.23	5.76	6.30	6.85	7.40				
9						6.65	7.30	7.99	8.60	9.30	9.95			
10							8.95	9.75	10.6	11.4	12.2			
11							10.8	11.8	12.7	13.6	14.6			
12							12.8	13.9	15.0	16.1	17.2	18.3		
13								**16.2**	17.5	18.8	20.1	21.4		1
14								**18.7**	20.1	21.6	23.1	24.6	26.1	1
15									23.0	24.6	26.3	28.0	29.6	
16									26.1	28.0	29.8	31.6	33.5	
17									29.1	31.2	33.2	35.2	37.3	
18									32.4	34.7	37.0	39.3	41.6	
19									35.9	38.4	40.9	43.4	45.9	
20									39.6	42.3	45.0	47.7	50.4	
Basis (trees)	1	10	6					2						19

FORM CLASS 52.5

Diameter breast high (inches)	Total height of tree (feet): 10	15	20	25	30	35	40	45	50	55	60	65	70	Basis (trees)
	Total volume (cubic feet)													
1	**.07**	**.08**	.09	..	..	..	..	..	..	..	..	..	..	3
2	.22	**.26**	**.29**	.33	.36	..	..	.	..	..	..	..	..	5
3	..	**.51**	.59	.67	.75	..	..	..	..	..	..	..	..	2
4	..	.87	**1.01**	1.16	1.30	.	..	..	..	..	..	..	..	2
5	..	..	1.54	1.76	1.97	2.20	2.43	..	..	..	..	..	..	..
6	..	..	..	2.49	2.80	3.12	3.44	..	..	..	..	..	..	..
7	..	.	..	3.32	3.74	4.18	4.62	5.05	..	..	..	..	..	..
8	..	..	..	.	**4.90**	5.40	5.95	6.51	7.08	7.65	..	..	..	1
9	.	..	..	..	..	6.83	7.52	8.20	8.90	9.60	10.3	..	..	..
10	.	..	..	..	..	..	9.22	10.1	10.9	11.8	12.6	..	..	..
11	..	..	..	..	..	..	11.2	12.1	13.0	14.0	15.1	16.1	..	..
12	..	..	..	..	..	..	13.2	14.4	15.5	16.6	17.8	19.0	..	..
13	..	..	..	.	.	.	.	16.6	18.0	19.4	20.8	22.2	..	..
14	.	..	..	..	..	..	..	19.3	20.8	22.3	23.9	25.4	27.0	..
15	..	..	.	..	..	.	..	..	23.9	25.6	27.4	29.1	30.8	..
16	.	..	..	..	..	..	..	..	27.0	28.9	30.8	32.7	34.7	..
17	.	..	..	..	..	..	..	..	30.1	32.3	34.6	36.8	39.1	..
18	.	..	.	..	.	..	.	..	33.5	35.9	38.3	40.7	43.2	..
19	..	..	.	..	..	..	..	...	37.2	39.8	42.5	45.1	47.7	..
20	..	..	..	.	..	.	..	.	40.9	43.7	46.5	49.4	52.2	..
Basis (trees)	2	7	3	..	1	..	..	..	..	..	..	..	..	13

FORM CLASS 55

Diameter breast high (inches)	Total height of trees (feet): 10	15	20	25	30	35	40	45	50	55	60	65	70	75	Basis (trees)
	Total volume (cubic feet)														
1	**.08**	.08	.09	..	..	..	..	..	..	..	..	..	..	..	2
2	.22	**.26**	.30	.34	.37	..	..	..	..	..	..	..	..	..	4
3	..	.51	.59	.68	**.76**	..	..	..	..	..	..	..	..	..	1
4	..	**.88**	**1.02**	1.18	1.32	..	..	..	..	..	..	..	..	..	3
5	..	..	**1.56**	1.79	2.02	2.25	2.49	..	..	..	..	..	..	..	1
6	..	..	..	2.55	2.88	3.21	3.54	..	..	..	..	..	..	..	..
7	..	..	..	**3.39**	3.84	4.30	4.76	5.22	..	..	..	..	..	..	1
8	..	..	..	..	5.02	**5.58**	6.15	6.72	7.31	7.92	..	..	..	..	1
9	..	..	..	..	..	7.05	**7.75**	8.46	9.20	9.90	10.6	..	..	..	1
10	..	..	..	..	..	..	9.50	10.4	11.3	12.2	13.0	..	..	..	..
11	..	..	..	..	..	..	11.4	12.4	13.5	14.6	15.6	..	..	..	..
12	..	..	..	..	..	..	13.6	**14.8**	16.0	17.2	18.4	19.6	..	..	1
13	..	..	..	..	..	..	..	17.3	18.7	20.1	21.5	22.9	..	..	..
14	..	..	..	..	..	..	..	19.9	21.5	23.1	24.8	26.4	28.0	..	..
15	..	..	..	..	..	..	..	..	24.7	26.4	28.2	30.0	31.9	..	..
16	..	..	..	..	..	..	..	..	27.8	29.8	31.9	33.9	36.0	..	..
17	..	..	..	..	..	..	..	..	31.1	33.4	35.8	38.2	40.5	..	..
18	..	..	..	..	..	..	..	..	34.6	37.2	39.7	42.2	44.8	47.4	..
19	..	..	..	..	..	..	..	..	38.3	41.1	43.9	46.8	49.6	52.4	..
20	..	..	..	..	..	..	..	..	42.2	45.2	48.2	51.2	54.2	**57.2**	1
Basis (trees)	2	5	3	1	1	1	1	1	..	..	..	..	..	1	16

FORM CLASS 57.5

Diameter breast high (inches)	Total height of tree (feet): 10	15	20	25	30	35	40	45	50	55	60	65	70	75	Basis (trees)
	Total volume (cubic feet)														
1	.08	.09	.09	..	..	..	..	..	..	..	..	..	..	..	..
2	.23	**.27**	.31	.35	.38	..	..	..	..	..	..	..	..	..	2
3	..	**.52**	.60	.69	.78	.	..	..	..	..	..	..	..	..	3
4	..	.89	1.04	1.20	1.35	..	..	..	..	..	..	..	..	..	..
5	..	..	**1.59**	1.82	2.07	2.31	2.56	..	..	..	..	..	..	..	1
6	..	..	**2.28**	2.63	**2.96**	3.31	3.64	..	..	..	..	..	..	..	2
7	..	..	..	3.49	3.96	4.42	4.90	5.38	..	..	..	..	..	..	..
8	..	..	.	..	**5.15**	5.75	6.33	6.96	7.55	8.16	..	..	..	..	1
9	..	..	..	..	..	7.25	8.00	8.72	9.50	10.2	11.0	..	..	..	..
10	..	..	..	..	..	..	9.85	10.8	11.7	12.6	13.5	..	..	..	..
11	..	..	..	..	..	..	..	**13.0**	14.1	15.2	16.3	..	..	..	1
12	..	..	..	..	..	..	..	15.3	16.6	17.8	19.1	20.4	..	..	..
13	..	..	..	..	..	..	..	17.8	19.3	20.8	22.2	23.6	..	..	..
14	..	..	..	..	..	..	..	20.6	22.2	23.9	25.6	27.4	29.1	..	..
15	..	..	..	..	..	..	..	..	25.4	27.3	29.2	31.1	33.0	..	..
16	..	..	..	..	..	..	..	..	**28.8**	30.9	33.0	35.2	37.4	..	1
17	..	..	..	..	..	..	..	..	32.3	34.7	37.1	39.5	41.9	..	..
18	..	..	..	..	..	..	..	..	35.9	38.6	41.2	**43.8**	46.5	49.2	1
19	..	..	..	..	..	..	..	..	39.9	42.8	45.6	48.5	51.4	54.3	..
20	.	..	..	..	..	..	..	..	43.7	46.8	49.9	53.0	56.2	59.3	..
Basis (trees)		5	2	.	2	.	..	1	1	.	.	1	..	..	12

FORM CLASS 60

Diameter breast high (inches)	Total Height of tree (feet): 10	15	20	25	30	35	40	45	50	55	60	65	70	75	Basis (trees)
	Total volume (cubic feet)														
1	.08	.09	.10	..	..	..	..	..	..	..	..	..	..	..	..
2	..	.27	.31	.36	.39	..	..	..	..	..	..	..	..	..	..
3	..	..	.61	.70	.79	.89	.98	..	..	..	..	..	..	..	..
4	..	..	1.06	**1.22**	1.38	1.54	1.71	..	..	..	..	..	..	..	1
5	..	..	1.62	1.87	2.12	2.37	2.63	2.88	..	..	..	..	..	..	..
6	.	..	.	..	3.02	3.38	3.73	4.12	4.50	..	..	..	..	..	..
7	..	..	..	..	4.07	4.54	5.04	5.52	6.00	..	..	..	..	..	..
8	..	..	..	..	..	5.90	**6.55**	7.16	7.80	8.41	9.05	..	..	..	1
9	..	..	..	..	..	7.50	**8.22**	9.00	9.80	10.6	11.4	12.2	..	..	1
10	.	..	..	..	..	..	10.1	**11.1**	12.0	**13.0**	14.0	14.9	..	..	2
11	..	..	..	..	..	..	12.2	13.3	14.4	**15.6**	16.7	17.8	..	..	1
12	..	..	..	..	..	..	14.4	15.7	17.1	18.4	19.8	21.2	22.5	..	..
13	..	..	..	..	..	..	..	18.4	19.9	21.4	23.0	24.6	26.2	..	..
14	..	..	..	..	..	..	.	21.2	23.0	24.8	26.6	28.3	30.1	..	..
15	..	..	..	..	.	..	..	..	26.2	28.2	30.3	32.3	34.3	..	..
16	..	..	..	..	..	..	..	..	29.7	32.0	34.2	36.4	38.7	..	..
17	..	..	..	..	..	..	..	..	33.3	35.8	**38.3**	40.8	43.4	..	1
18	..	..	..	..	..	..	..	..	37.1	39.8	42.6	45.4	48.2	51.0	..
19	..	..	..	..	..	..	..	..	41.1	44.2	47.2	50.3	53.4	56.5	..
20	..	..	..	..	..	..	..	..	45.2	48.6	51.9	55.2	58.6	62.0	..
Basis (trees)		..	..	1	..	..	2	1	..	2	1	..	..	..	7

FORM CLASS 62.5

Diameter breast high (inches)	Total height of tree (feet) — Total volume (cubic feet) 10	15	20	25	30	35	40	45	50	55	60	65	70	75	Basis (trees)
1	.08	.09	.10	..	..	..	..	..	..	..	..	..	..	..	..
2	..	.28	.32	.37	.40	.44	..	..	..	..	..	..	..	..	..
3	.	..	.62	.72	.81	**.91**	1.00	..	..	..	..	..	..	..	1
4	..	..	1.08	1.25	1.42	1.59	1.76	..	..	..	..	..	..	..	..
5	..	..	..	1.91	**2.17**	2.44	2.70	2.97	..	..	..	..	..	..	1
6	..	..	..	..	3.10	3.48	**3.85**	4.22	4.62	..	..	..	..	..	1
7	..	..	..	..	4.19	4.69	5.19	**5.68**	6.18	..	..	..	..	..	1
8	..	.	..	..	.	6.10	**6.75**	7.40	8.05	8.70	9.35	..	..	..	1
9	.	..	..	.	..	..	8.50	**9.30**	10.1	10.9	11.8	12.6	..	..	1
10	..	..	..	..	..	..	10.4	11.4	12.4	13.4	**14.4**	15.4	..	..	1
11	..	..	..	..	..	..	12.7	13.8	15.0	16.2	17.3	18.5	..	..	..
12	..	..	..	.	..	..	14.9	16.3	17.7	19.1	20.5	21.8	23.2	..	..
13	..	..	..	..	..	..	..	19.1	**20.7**	22.3	23.9	**25.5**	27.1	.	2
14		..	..	..	..	..	..	22.0	**23.8**	25.7	**27.6**	29.5	31.3	..	2
15	..	..	..	..	..	..	..	25.2	27.3	29.4	31.5	33.6	35.7	..	..
16	..	..	..	..	..	..	..	..	30.7	33.0	35.4	37.8	40.1	..	..
17	..	..	..	..	..	..	..	..	..	36.9	39.6	42.2	44.9	..	..
18	.	..	..	..	..	..	..	..	..	41.0	44.0	47.0	50.0	53.0	..
19	..	..	..	.	..	.	..	..	..	45.6	48.8	52.0	55.2	58.4	..
20	..	..	..	..	..	..	..	..	..	50.2	53.6	57.2	60.6	64.1	..
Basis (trees)	..	..	..	1	1	2	2	2	..	2	1	..	..	11	

FORM CLASS 65

Diameter breast high (inches)	Total height of tree (feet): 10	15	20	25	30	35	40	45	50	55	60	65	70	75	Basis (trees)
	Total volume (cubic feet)														
1	.08	.09	.10	..	..	..	..	..	..	..	..	..	..	..	..
2	..	.28	.33	.37	.41	..	..	..	..	..	..	..	..	..	..
3	..	..	.63	.73	.83	.93	1.03	..	..	..	..	..	..	..	..
4	..	..	1.10	1.28	1.46	1.63	1.81	..	..	..	..	..	..	..	..
5	..	..	..	1.96	**2.23**	**2.51**	2.78	3.05	..	..	..	..	..	..	2
6	..	..	..	..	3.20	3.58	**3.96**	4.34	4.74	5.12	..	..	..	..	1
7	..	..	..	..	4.30	4.82	5.34	5.84	6.37	6.88	7.40	..	..	..	..
8	..	..	..	..	..	6.28	**6.95**	**7.62**	8.30	9.00	9.67	10.4	..	..	4
9	..	..	..	..	..	..	**8.75**	**9.60**	**10.4**	11.3	12.2	13.0	13.9	..	6
10	..	..	..	..	..	..	10.8	**11.8**	**12.8**	13.9	**15.0**	**16.0**	**17.0**	..	5
11	..	..	..	..	..	..	..	**14.3**	**15.6**	**16.8**	**18.0**	19.3	20.6	..	6
12	..	..	..	..	..	..	..	16.8	18.2	**19.7**	**21.2**	22.6	24.1	25.6	1
13	..	..	..	..	..	..	..	..	21.4	**23.2**	**24.9**	26.6	28.3	30.0	2
14	..	..	..	..	..	..	..	..	24.7	**26.7**	**28.6**	30.6	**32.5**	34.5	3
15	..	..	..	..	..	..	..	..	..	30.4	**32.6**	34.9	37.1	39.3	1
16	..	..	..	..	..	..	..	..	..	34.2	36.7	39.2	**41.6**	44.0	1
17	..	..	..	..	..	..	..	..	..	38.4	41.2	**43.9**	46.7	49.4	1
18	..	..	..	..	..	..	..	..	..	42.7	45.7	48.8	51.8	54.8	..
19	..	..	..	..	..	..	..	..	..	..	50.6	54.0	57.4	60.8	..
20	..	..	..	..	..	..	..	..	..	..	55.6	59.3	63.0	66.7	..
Basis (trees)		..	..	..	1	1	5	8	4	4	5	2	3	..	33

FORM CLASS 67.5

Diameter breast high (inches)	Total height of trees (feet) — Total volume (cubic feet): 10	15	20	25	30	35	40	45	50	55	60	65	70	75	Basis (trees)
1	.08	.09	.10	..	..	..	..	..	..	..	..	..	..	..	..
2	..	.29	.34	.38	.42	..	..	..	..	..	..	..	..	..	..
3	..	..	.64	.75	.85	.96	1.06	..	..	..	..	..	..	..	..
4	..	..	1.12	1.31	1.49	1.68	1.86	..	..	..	..	..	..	..	..
5	..	..	..	2.01	2.29	**2.58**	2.86	3.14	3.44	..	..	..	..	..	1
6	..	..	..	..	3.28	3.68	4.08	4.49	**4.89**	5.29	5.70	..	..	..	1
7	..	..	..	..	4.42	4.98	5.52	**6.05**	6.58	**7.14**	7.08	8.22	..	..	3
8	..	..	..	..	..	6.46	**7.17**	**7.87**	8.59	9.30	**10.0**	**10.7**	11.4	..	6
9	..	..	..	..	..	..	9.03	**9.98**	**10.8**	11.7	12.6	13.5	**14.4**	..	4
10	..	..	..	..	..	..	**11.1**	**12.2**	**13.3**	14.4	**15.5**	16.6	17.7	..	5
11	..	..	..	..	..	..	..	**14.8**	16.1	17.4	18.7	**19.9**	21.2	..	2
12	..	..	..	..	..	..	..	17.4	18.9	20.5	22.0	23.4	25.0	..	..
13	..	..	..	..	..	..	..	..	22.4	**24.1**	**25.8**	**27.4**	29.0	..	4
14	..	..	..	..	..	..	..	..	25.7	**27.7**	29.7	31.7	33.6	35.6	1
15	..	..	..	..	..	..	..	..	..	31.5	33.8	**36.2**	38.4	40.7	1
16	..	..	..	..	..	..	..	..	..	35.4	38.0	40.6	43.2	45.8	..
17	..	..	..	..	..	..	..	..	..	39.8	42.6	45.4	48.3	51.3	..
18	..	..	..	..	..	..	..	..	..	44.4	47.2	50.1	53.8	56.6	..
19	..	..	..	..	..	..	..	..	..	..	52.5	56.1	59.7	63.3	..
20	..	..	..	..	..	..	..	..	..	..	57.6	61.6	65.6	69.6	..
Basis (trees)			..	..	..	1	2	8	4	3	3	6	1	..	28

FORM CLASS 70

Diameter breast high (inches)	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	Basis (trees)
	Total height of tree (feet) — Total volume (cubic feet)																
1	.08	.09	.10	..	..	..	..	..	..	..	..	..	..	.	..	..	..
2	..	.30	.34	.39	.44	..	..	..	..	..	..	..	..	..	..	..	..
3	..	..	.65	.76	.87	.98	1.09	..	..	..	..	..	..	..	..	..	..
4	..	..	1.15	1.34	**1.54**	1.72	**1.91**	2.10	2.30	..	..	..	.	..	..	..	2
5	..	..	..	2.07	**2.36**	2.66	2.96	3.26	3.56	..	..	..	..	..	..	..	1
6	..	..	..	..	3.36	**3.80**	**4.21**	**4.62**	5.04	5.48	5.90	..	..	..	..	..	7
7	..	..	..	..	4.55	**5.12**	**5.68**	**6.24**	6.83	7.38	**7.97**	8.50	..	..	..	..	6
8	..	..	..	.	..	6.65	**7.40**	**8.13**	**8.86**	9.60	**10.4**	11.1	**11.8**	12.5	..	..	7
9	..	..	..	..	..	..	9.30	10.3	**11.1**	**12.1**	13.0	14.0	14.9	**15.8**	16.8	..	4
10	..	..	..	..	..	..	..	12.5	**13.7**	**14.8**	16.0	**17.1**	18.2	19.4	20.5	..	5
11	..	..	..	..	..	..	..	**15.0**	**16.4**	**17.8**	19.2	20.6	21.9	23.3	24.6	..	2
12	..	..	..	..	..	..	..	17.9	**19.5**	**21.1**	22.7	**24.3**	25.9	27.5	29.1	..	2
13	..	..	..	..	..	..	..	..	**22.7**	**24.6**	26.4	28.3	**30.2**	32.0	33.9	..	3
14	..	..	..	..	..	..	..	..	26.6	**28.7**	30.8	**32.8**	34.9	37.0	39.1	41.2	2
15	..	..	..	..	..	..	..	..	.	**32.4**	34.8	37.2	**39.6**	42.0	44.5	47.0	2
16	..	..	..	..	..	..	..	..	..	36.7	39.4	**42.2**	**44.9**	47.6	50.3	53.0	2
17	..	..	..	..	..	..	..	..	..	..	44.1	47.1	**50.1**	53.2	56.3	59.4	1
18	..	..	..	..	..	..	..	..	..	..	48.9	52.2	55.6	59.0	62.4	65.8	..
19	..	..	..	..	..	..	..	..	..	..	54.4	58.1	61.8	65.6	69.3	73.0	..
20	..	..	..	..	..	..	..	..	..	..	59.8	63.9	68.0	72.0	76.1	80.2	..
Basis (trees)		..	..	..	2	3	6	7	7	8	2	4	6	1	..	..	46

FORM CLASS 72.5

Diameter breast high (inches)	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	Basis (trees)
	Total height of tree (feet) — Total volume (cubic feet)																
1	.08	.09	.10	..	..	..	..	..	..	..	..	..	..	..	..	..	..
2	..	.30	.35	.40	.45	..	..	..	..	..	..	..	..	..	..	..	..
3	..	..	.66	.78	.89	1.00	1.12	..	..	..	..	..	..	..	..	..	..
4	..	..	1.18	1.38	1.58	1.78	1.97	2.18	2.38	..	..	..	..	..	..	..	..
5	..	..	..	2.12	**2.43**	**2.74**	3.06	3.36	3.68	4.00	..	..	..	..	..	..	4
6	..	..	..	..	3.48	**3.92**	4.36	**4.80**	5.24	5.69	6.13	..	..	..	..	..	3
7	..	..	..	..	4.70	5.30	**5.90**	6.48	**7.07**	7.66	8.24	**8.84**	9.44	..	..	..	3
8	..	..	..	..	..	**6.88**	7.62	**8.40**	**9.20**	9.95	10.7	**11.5**	12.2	13.0	..	..	5
9	..	..	..	..	..	..	9.65	10.7	11.6	12.6	13.5	14.5	15.5	16.4	..	..	..
10	..	..	..	..	..	..	**11.8**	**13.0**	14.2	15.4	**16.6**	**17.8**	**19.0**	**20.2**	..	..	7
11	..	..	..	..	..	..	..	15.5	17.0	18.5	20.0	22.4	22.9	25.4	..	..	..
12	..	..	..	..	..	..	..	18.6	20.2	21.8	23.5	25.2	26.9	28.5	..	..	..
13	..	..	..	..	..	..	..	21.8	23.8	25.8	27.8	29.7	**31.5**	33.4	..	..	1
14	..	..	..	..	..	..	..	..	27.5	29.7	31.9	34.1	36.3	38.5	40.8	43.0	..
15	..	..	..	..	..	..	..	..	..	34.0	36.4	39.0	**41.5**	44.0	46.5	49.1	1
16	..	..	..	..	..	..	..	..	..	..	40.9	43.8	46.7	49.6	52.4	55.3	..
17	..	..	..	..	..	..	..	..	..	..	45.8	49.0	52.2	55.4	58.6	61.8	..
18	..	..	..	..	..	..	..	..	..	..	50.9	54.4	58.0	61.5	65.0	68.5	..
19	..	..	..	..	..	..	..	..	..	..	56.6	60.5	64.4	68.2	72.2	76.0	..
20	..	..	..	..	..	..	..	..	..	..	62.2	66.5	70.8	75.0	79.3	83.6	..
Basis (trees)		..	..	..	1	5	2	4	2	..	1	4	4	1	..	..	24

FORM CLASS 75

Diameter breast high (inches)	Total height of tree (feet): 10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	Basis (trees)
	Total volume (cubic feet)																	
1	.08	.09	.11	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
2	..	.31	.36	**.41**	.46	..	..	..	..	..	..	..	..	..	..	..	..	1
3	..	..	.68	.80	.92	1.04	1.16	..	..	..	..	..	..	..	..	..	..	..
4	..	..	1.21	1.41	1.62	1.83	2.04	2.25	2.46	..	..	..	..	..	..	..	..	..
5	..	..	..	..	2.51	**2.83**	**3.16**	3.48	**3.81**	4.13	4.46	..	..	..	..	..	..	3
6	..	..	..	..	3.58	4.04	**4.50**	4.96	5.42	5.88	6.35	6.80	..	..	..	..	..	1
7	..	..	..	..	..	5.47	**6.10**	**6.70**	**7.32**	**7.92**	8.54	**9.16**	9.78	..	..	..	..	5
8	..	..	..	..	..	..	7.90	8.70	9.50	10.3	**11.1**	11.9	**12.7**	13.5	..	..	..	3
9	..	..	..	..	..	..	10.0	11.0	12.0	13.0	14.0	**15.0**	16.0	17.0	18.1	..	..	1
10	..	..	..	..	..	..	..	13.4	14.7	15.9	**17.1**	18.4	19.6	20.8	22.1	..	..	1
11	..	..	..	..	..	..	..	16.3	17.8	19.2	**20.7**	22.2	**23.6**	25.1	26.6	..	..	2
12	..	..	..	..	..	..	..	19.2	21.0	**22.7**	24.4	**26.2**	28.0	29.7	31.4	33.2	..	2
13	..	..	..	..	..	..	..	..	24.5	26.6	28.7	30.7	32.8	34.9	37.0	39.1	..	..
14	..	..	..	..	..	..	..	..	28.4	30.7	33.0	35.3	37.6	39.9	42.3	44.6	46.9	..
15	..	..	..	..	..	..	..	..	..		37.7	40.3	42.9	45.6	48.1	50.8	53.4	..
16	..	..	..	..	..	..	..	..	..	..	42.4	45.4	48.5	51.5	54.5	57.5	60.5	..
17	..	..	..	..	..	..	..	..	..	..	47.3	50.8	54.3	57.8	61.2	64.7	68.2	..
18	..	..	..	..	..	..	..	..	..	..	52.9	56.6	60.4	64.1	67.9	71.8	75.5	..
Basis (trees)		.	..	1	..	1	3	1	2	2	3	3	3	..	..	..	..	19

FORM CLASS 77.5

Diameter breast high (inches)	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	Basis (trees)
	Total height of trees (feet) — Total volume (cubic feet)																	
1	.09	.10	.11	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
2	..	.32	.37	.42	.48	..	..	.	..	..	..	..	..	..	..	.	..	..
3	..	..	.70	.83	.95	1.07	1.20	.	..	..	..	.	..	.	.	..	..	..
4	..	..	1.24	1.45	1.67	1.89	2.10	2.32	2.54	..	..	..	..	..	..	..	..	..
5	..	..	..	..	2.59	2.92	3.26	3.59	3.94	4.27	4.62	..	..	..	..	..	..	..
6	.	..	..	..	3.70	**4.18**	4.66	5.14	5.62	6.10	6.58	7.06	..	..	..	..	..	1
7	..	..	..	.	..	5.65	6.30	6.94	7.58	8.24	8.86	9.52	10.2	..	..	..	..	..
8	..	.	.	.	..	..	8.15	9.00	9.88	**10.7**	11.5	12.4	13.2	14.1	..	..	..	2
9	..	..	..	..	..	.	..	11.4	12.4	13.5	**14.5**	15.6	16.6	17.7	18.8	..	..	1
10	..	..	..	..	.	..	..	13.9	15.2	16.5	17.7	19.1	20.4	21.7	23.0	..	..	..
11	..	..	..	..	..	..	..	16.6	18.1	19.7	21.3	23.0	24.6	26.2	27.8	..	..	..
12		..	..	..	..	..	.	19.9	21.7	23.6	25.4	27.3	29.1	30.9	32.7	34.5	..	..
13	.	..	..	..	.	..	..	..	25.8	27.8	29.8	32.0	34.0	36.2	38.3	40.3	..	..
14	..	..	..	..	..	..	..	.	29.4	31.8	34.2	36.6	39.0	41.4	43.9	46.3	48.7	..
15	..	..	..	..	..	..	..	..	..	..	39.0	41.8	44.6	47.5	50.4	53.2	56.0	..
16	.	..	..	..	.	..	..	..	..	..	44.0	47.2	50.4	53.6	56.7	59.9	63.1	..
17	..	..	..	..	.	..	..	..	..	..	49.4	53.0	56.5	60.1	63.7	67.3	70.9	..
18	..	.	..	..	..	..	.	.	..	..	55.0	58.9	62.8	66.7	70.7	74.6	78.5	..
Basis (trees)		..	.	..	..	1	..	..	.	2	1	..	..	..	..	..	..	4

FORM CLASS 80

Diameter breast high (inches)	Total height of tree (feet): 10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	Basis (trees)
	Total volume (cubic feet)																	
1	.09	.10	.11	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
2	..	.32	.38	.43	.49	..	..	..	..	..	..	..	..	..	..	..	..	..
3	..	..	.72	**.85**	**.98**	1.11	1.24	..	..	..	..	..	..	..	..	..	..	2
4	..	..	1.27	1.49	**1.72**	1.95	2.18	2.40	2.63	..	..	..	..	..	..	..	..	1
5	..	..	..	..	2.67	3.02	3.37	3.72	4.07	4.42	**4.78**	5.13	..	..	..	..	..	1
6	..	..	..	..	3.81	4.31	**4.81**	5.30	5.81	**6.30**	6.81	7.30	..	..	..	..	..	2
7	..	..	..	..	..	**5.84**	6.50	7.18	7.85	8.52	9.20	9.86	10.6	..	..	..	..	1
8	..	..	..	..	..	..	8.44	9.35	10.3	**11.1**	12.0	**12.9**	13.7	14.7	..	..	..	2
9	..	..	..	..	..	..	..	11.8	12.9	14.0	15.1	**16.2**	17.3	18.4	19.5	..	..	1
10	..	..	..	..	..	..	..	14.4	15.8	**17.1**	18.5	19.8	21.2	22.6	23.9	..	..	1
11	..	..	..	..	..	..	..	17.4	19.0	20.6	22.2	23.8	25.4	27.0	28.7	..	..	..
12	..	..	..	..	..	..	..	20.6	22.5	24.4	26.3	28.2	30.1	32.0	33.9	35.8	..	..
13	..	..	..	..	..	..	..	..	26.2	28.4	30.7	32.9	35.1	37.4	39.6	41.8	..	..
14	..	..	..	..	..	..	..	..	30.3	32.8	35.4	37.9	40.5	43.1	45.6	48.2	50.7	..
15	..	..	..	..	..	..	..	..	34.6	37.5	40.4	43.3	46.2	49.1	52.0	55.0	57.9	..
16	..	..	..	..	..	..	..	..	39.1	42.4	45.7	49.0	52.2	55.5	58.8	62.1	65.4	..
17	..	..	..	..	..	..	..	..	..	..	51.3	54.9	58.5	62.2	65.8	69.5	73.2	..
18	..	..	..	..	..	..	..	..	..	..	57.2	61.3	65.3	69.6	73.5	77.6	81.7	..
Basis (trees)	..	..	..	1	2	1	1	..	..	3	1	2	..	..	..	..	..	11

TABLE 20

B. MILL TALLY VOLUME TABLE

(Board Foot Measure)

Note: Volume excludes bark. Stump height, one foot. Top diameter inside bark, four inches. Based on taper curves; scaled by twelve and two-tenths foot logs by mill-tally log rule constructed on the Harvard Forest on the basis of 2222 logs. Sawing: sixty per cent two and one-eighth inch round-edge; remainder, one inch square-edge and one inch sidings.

Boldface indicates extent of original data.

SECOND-GROWTH WHITE PINE

FORM CLASS 50

Diameter breast high (inches)	Total height of tree (feet) 25	30	35	40	45	50	55	60	65	70	75	80	85	Basis (trees)
	Volume (feet board measure)													
5						10	10	11						
6			12	14	16	18	20	21						
7			16	20	23	26	28	31						
8			23	27	30	34	38	42	46					
9				33	38	43	48	54	59					
10				40	48	55	62	68	75					
11				50	59	68	76	84	92	101				
12				61	71	81	91	100	110	120				
13					**83**	95	106	119	131	143	155			1
14						108	122	138	152	167	180			
15						124	140	157	173	189	205			
16								180	198	216	236	254	272	
17								203	222	242	264	285	308	
18								227	249	272	297	320	345	
19								256	281	307	332	358	387	
20								284	314	344	372	400	431	
Basis (trees)					1									1

FORM CLASS 52.5

Diameter breast high (inches)	Total height of tree (feet): 25	30	35	40	45	50	55	60	65	70	75	80	85	Basis (trees)
	Volume (feet board measure)													
5						10	11	12						
6			12	15	17	19	21	23						
7			18	21	24	27	30	33						
8			**24**	28	32	36	40	45	49					1
9				34	40	46	51	57	63					
10				43	50	58	65	72	79					
11				53	62	72	80	88	97	106				
12				64	74	84	95	106	116	126				
13						98	111	125	137	150	162			
14						113	129	145	159	174	188			
15						131	148	165	181	199	215			
16								189	208	227	248	267	285	
17								213	234	255	278	301	322	
18								240	263	287	313	337	361	
19								269	296	322	348	375	406	
20								297	328	350	388	410	449	
Basis (trees)			1											1

FORM CLASS 55

Diameter breast high (inches)	Total height of tree (feet): 25	30	35	40	45	50	55	60	65	70	75	80	85	Basis (trees)
	Volume (feet board measure)													
5						11	12	12						
6			13	15	17	20	22	24						
7			19	**22**	25	29	32	35						1
8			**26**	30	34	38	42	47	51					1
9				**37**	42	48	54	60	66					1
10				45	53	61	68	76	83					
11				56	66	75	84	93	102	111				
12				67	**78**	88	100	111	122	132				1
13						103	116	130	143	157	169			
14						120	135	152	167	182	197			
15						137	156	173	190	207	225			
16								199	218	238	259	278	299	
17								223	246	268	291	313	338	
18								251	277	301	327	352	378	
19								282	310	337	365	394	424	
20								311	343	375	**405**	438	469	1
Basis (trees)		1		2	1						1			5

FORM CLASS 57.5

Diameter breast high (inches)	Total height of tree (feet): 25	30	35	40	45	50	55	60	65	70	75	80	85	Basis (trees)
	Volume (feet board measure)													
5					10	11	12	13						
6			**14**	16	18	21	23	25						1
7			20	23	26	30	34	37						
8			**27**	31	35	40	44	49	54					1
9				38	45	51	58	63	70					
10				48	56	64	72	80	88					
11				59	69	78	88	98	107	116				
12				70	82	92	104	116	127	138				
13						107	122	136	149	164	176			
14						125	142	159	174	190	205			
15						**144**	163	181	199	217	235			1
16								208	229	249	270	290	312	
17								234	257	281	305	327	353	
18								263	290	315	342	368	394	
19								295	324	352	381	412	443	
20								325	358	390	423	457	488	
Basis (trees)			2			1								3

FORM CLASS 60

Diameter breast high (inches)	Total height of tree (feet): 25	30	35	40	45	50	55	60	65	70	75	80	85	Basis (trees)
	Volume (feet board measure)													
5				10	11	12	13	14						
6			14	17	19	22	24	26						
7			20	24	28	32	35	39	42					
8			28	**32**	37	42	47	52	57					1
9				**40**	47	54	61	67	73	80				1
10				50	**58**	67	**76**	84	92	100				2
11				62	72	81	**91**	102	112	122				1
12				74	85	96	109	121	133	144	156			
13						112	127	142	156	171	185			
14						131	149	165	182	198	214			
15						151	171	189	208	227	246			
16								217	239	260	282	302	326	
17								**245**	270	295	319	342	368	1
18								277	304	330	358	384	412	
19								309	338	367	398	430	463	
20								340	372	406	440	476	511	
Basis (trees)				2	1		2	1						6

FORM CLASS 62.5

Diameter breast high (inches)	Total height of tree (feet): 25	30	35	40	45	50	55	60	65	70	75	80	85	Basis (trees)
	Volume (feet board measure)													
5				**11**	12	13	14	15						1
6			16	**18**	20	23	25	27						1
7			22	26	**30**	34	37	41	45					1
8				**34**	39	44	49	54	60					1
9				42	**50**	57	64	70	77	84				1
10				53	62	70	79	**88**	96	105				1
11				65	75	85	96	107	117	128				..
12				77	89	100	114	127	139	150	163			..
13						**118**	133	148	**162**	177	191			2
14						**138**	155	**173**	189	206	222			2
15						158	179	198	217	236	256			..
16								227	249	271	293	316	339	
17								256	282	308	333	358	383	
18								289	318	345	374	401	428	..
19								322	352	382	416	449	482	..
20								352	388	423	459	496	533	..
Basis (trees)				3	2	2		2	1					10

FORM CLASS 65

Diameter breast high (inches)	Total height of tree (feet): 25	30	35	40	45	50	55	60	65	70	75	80	85	Basis (trees)
	Volume (feet board measure)													
5			**10**	**12**	13	14	15	16	18					2
6			17	**19**	22	24	26	29	32	35				1
7			23	27	31	36	39	43	47	51				..
8				**35**	**41**	47	52	57	63	68	73			4
9				**45**	**52**	**60**	67	**74**	81	88	95	101		6
10				56	**65**	**74**	83	**92**	**101**	**109**	119	127		4
11				68	**78**	**89**	**101**	**112**	123	133	145	156		6
12				81	93	105	**119**	132	145	157	170	184		1
13						124	**139**	**154**	169	184	200	215		2
14						144	**162**	180	197	**214**	232	249		3
15						166	186	**206**	226	247	266	288		1
16								236	**260**	282	306	329	354	1
17								266	**294**	321	347	373	400	1
18								301	331	360	390	418	445	..
19								334	366	398	432	467	503	..
20								369	404	440	477	515	557	..
Basis (trees)			1	6	7	4	5	4	3	2				32

FORM CLASS 67.5

Diameter breast high (inches)	25	30	35	40	45	50	55	60	65	70	75	80	85	Basis (trees)
						Volume (feet board measure)								
5			**11**	13	14	15	16	18	19					1
6			18	20	23	**26**	28	31	34	37				1
7			24	29	**33**	38	**41**	45	49	54	58			3
8				**37**	**43**	49	55	**60**	**66**	72	77	82		5
9				47	**55**	**62**	70	77	85	**92**	99	105		4
10				**59**	**68**	**77**	87	**96**	105	114	124	132		5
11				72	**83**	94	105	117	**128**	140	151	162		2
12				85	98	110	**124**	138	152	164	178	192		1
13						130	**145**	**162**	**177**	192	208	224		3
14						151	**169**	188	206	224	242	261		1
15								214	**236**	259	279	302		1
16								246	271	296	320	343	368	
17								276	305	335	362	389	416	
18										376	406	435	462	
19										415	450	486	522	
20											496	536	582	
Basis (trees)			1	2	7	4	3	3	6	1				27

Total height of tree (feet)

FORM CLASS 70

Diameter breast high (inches)	25	30	35	40	45	50	55	60	65	70	75	80	85	Basis (trees)
						Volume (feet board measure)								
5			**11**	13	15	16	18	19	20	22				1
6		16	**19**	**21**	**24**	27	30	32	35	39				7
7			25	**30**	**34**	39	43	**47**	52	56	61			4
8				**39**	**46**	**51**	57	**63**	69	**75**	80	86		7
9				50	58	**65**	**73**	81	88	96	**103**	110		4
10				62	72	**80**	**91**	100	**110**	119	128	137		5
11				76	**87**	98	**110**	122	134	146	158	169		2
12				90	103	**115**	**129**	144	**158**	171	186	200		2
13						**135**	**152**	169	185	**202**	218	234		3
14						159	**177**	**197**	**216**	235	253	273		2
15								**224**	**247**	**270**	292	315	335	2
16								256	**283**	**310**	335	359	384	2
17								289	320	**350**	378	405	433	1
18										392	423	451	480	
Basis (trees)			3	5	6	7	8	2	4	6	1			42

Total height of tree (feet)

FORM CLASS 72.5

Diameter breast high (inches)	25	30	35	40	45	50	55	60	65	70	75	80	85	Basis (trees)
	Total height of tree (feet) — Volume (feet board measure)													
5			**12**	14	16	18	19	20	22	23				3
6			**20**	22	**25**	28	31	34	37	41				2
7			27	**31**	36	**41**	45	49	**54**	59	64			4
8				**41**	**47**	**53**	60	66	**72**	78	84			6
9				52	60	68	76	84	92	100	108			
10					**74**	**84**	94	**104**	**114**	**124**	**134**	143		7
11						102	114	127	139	152	164	176		
12						120	135	150	165	179	194	208		
13							159	176	193	**211**	228	243	261	1
14							186	205	225	245	264	284	305	
15								234	258	**282**	305	328	350	1
16									295	323	350	375	401	
17										365	393	422	451	
Basis (trees)			5	2	4	2		1	5	4	1			24

FORM CLASS 75

Diameter breast high (inches)	25	30	35	40	45	50	55	60	65	70	75	80	85	Basis (trees)
	Total height of tree (feet) — Volume (feet board measure)													
5		11	**13**	**15**	17	**19**	21	22	23	25				3
6		18	21	**24**	27	30	33	36	39	43				1
7		26	29	**33**	**38**	**43**	**48**	52	57	62				4
8				43	49	56	**62**	69	75	**81**				3
9				55	63	71	79	88	**96**	104				1
10						87	98	**108**	119	129	140	149		1
11						106	119	**132**	145	**158**	171	183		2
12						126	**141**	156	**172**	187	202	216		2
13								184	201	220	237	253	271	
14								213	235	256	276	296	318	
15								245	270	295	319	342	366	
16										337	364	391	418	
17										379	410	439	470	
Basis (trees)			1	3	1	2	3	2	2	3				17

FORM CLASS 77.5

Diameter breast high (inches)	25	30	35	40	45	50	55	60	65	70	75	80	85	Basis (trees)
						Volume (feet board measure)								
5		11	14	16	18	20	22	23	25	27				
6		19	**22**	25	28	32	35	38	42	45				1
7		26	30	35	40	45	50	54	59	64				
8		- -		45	52	58	**65**	72	78	84				2
9		- -		58	66	74	**83**	92	100	108				1
10		- -				91	102	113	124	135	146	156		
11		- -				111	124	137	151	164	178	191		
12		- -				131	147	163	179	195	210	225		
13		- -						191	210	230	247	264	283	
14		- -						222	244	266	288	309	331	
15		- -							284	308	332	357	381	
16		- -								350	379	408	432	
Basis (trees)			1				3							4

FORM CLASS 80

Diameter breast high (inches)	25	30	35	40	45	50	55	60	65	70	75	80	85	Basis (trees)
						Volume (feet board measure)								
5	10	12	15	17	19	21	23	25	27	29				1
6	16	19	23	**26**	30	33	37	41	44	48				1
7		- -	**30**	36	41	46	52	57	62	67				1
8		- -		48	54	61	68	75	81	88				
9		- -		60	68	77	86	96	104	113				
10		- -				95	**106**	118	129	141	152	163		1
11		- -						143	157	171	185	199		
12		- -						169	187	204	219	234		
13		- -						199	219	239	257	275	295	
14		- -						231	254	278	300	322	345	
15		- -								321	348	372	397	
16		- -								364	394	424	449	
Basis (trees)		1	1	1			1							4

FORM CLASS 82.5

Diameter breast high (inches)	25	30	35	40	45	50	55	60	65	70	75	80	85	Basis (trees)
						Volume (feet board measure)								
5	11	13	16	18	20	23	25	27	29	31				1
6	16	20	24	28	31	35	39	43	47	51				
7			32	38	43	49	54	60	65	70				
8				50	57	63	71	78	85	92				
9				63	72	81	90	100	109	118				
10						100	112	123	135	147	159	170		
11								149	164	178	193	207		
12								177	195	212	228	244		
13								208	228	250	268	288	308	
14								241	265	290	314	337	360	
15										335	364	388	411	
Basis (trees)								1						1

FORM CLASS 85

Diameter breast high (inches)	25	30	35	40	45	50	55	60	65	70	75	80	85
						Volume (feet board measure)							
5	12	14	17	19	22	24	27	29	32	34			
6	17	21	25	29	33	37	41	45	50	54			
7			34	40	46	51	57	63	68	74			
8				53	59	66	74	82	89	96			
9				65	75	85	94	104	114	124			
10						105	117	128	141	154	166	178	
11								155	171	186	202	218	
12								186	203	221	239	257	
13								218	239	261	282	303	322
14								254	279	305	331	356	380
15										351	380	408	436

TABLE 21

C. BOARD-FOOT CUBIC-FOOT RATIOS

Diameter breast high (inches)	Form Class 50			Form Class 60			Form Class 70			Form Class 80		
	Height class (feet)											
	50	60	70	50	60	70	60	70	80	60	70	80
	Number of feet board measure per one cubic foot of wood											
8	5.0	..	..	5.4	5.8	..	6.1	6.3	..	6.2	6.4	..
10	5.2	5.6	..	5.6	6.0		6.2	6.5	6.7	6.4	6.6	6.8
12	5.4	5.8	..	5.6	6.1	6.4	6.3	6.6	6.9	6.4	6.8	6.9
14	..	5.9	6.4	5.7	6.2	6.6	6.4	6.7	7.0	6.5	6.9	7.1
16	..	6.0	6.5	..	6.3	6.7	6.5	6.9	7.1	..	7.0	7.2
18	..	6.1	6.6	..	6.5	6.8	..	7.0	7.2	..	..	..
20	..	6.3	6.8	..	6.6	6.9	..	..		..	..	..

TABLE 22

SOME SIGNIFICANT PLOTS

WHITE PINE PLANTATIONS

Plot	Age from seed (years)	Approximate spacing feet × feet	Number of trees per acre: Now	Number of trees per acre: When 10 years old	Average height (feet): Dominants	Average height (feet): Total stand	Basal area per acre (square feet)	Average D. B. H. (inches)	Total volume per acre (cubic feet)	Average dead length (per cent)	Average Absolute form quotient I.B.	Index of growing space
Ch-1	13	5 × 6	1480	1480	14	13	39.4	2.2	410	15	.43	3
A-1	16	3 × 3	3800	4640	18	16	89.7	2.1	985	31	.50	6
A-2	16	4 × 4	2520	2760	18	16	83.1	2.5	895	30	.52	5
A-3	16	5 × 5	1760	1780	18	17	79.5	2.9	870	20	.50	4
A-4	16	6 × 6	1200	1200	17	16	62.2	3.1	685	14	.49	2
H-1	16	5 × 5	1720	1740	20	18	93.9	3.2	1020	18	.46	4
H-a	19	6 × 6	1360	...	19	17	85.2	3.4	865	24	.49	4
R-1	20	6 × 6	1320	1320	21	20	109.5	3.9	1230	31	.53	4
Mt. H-1 ..	20	6 × 6	1200	1240	23	21	133.5	4.5	1570	33	.56	4
Gtn-2	27	4 × 5	1320	2240	33	32	152.0	4.6	2580	50	.63	7
Gtn-3	27	6 × 7	1080	2000	33	32	136.6	4.8	2170	48	.60	6
Wa-1	27	6 × 6	880	1120	38	36	155.6	5.7	3040	60	.70	6
D-4	30	15 × 15	208	208	28	27	70.0	7.8	980	30	.55	1
Dx-1	34	12 × 12	320	320	41	39	202.9	10.8	3050	32	.54	2
D-3	37	9 × 9	520	540	47	45	142.2	7.1	3340	60	.68	5
Gtn-1	43	4 × 5	1000	2200	52	48	214.0	6.3	5370	67	.71	6
D-1	45	10 × 10	400	400	53	50	184.2	9.2	4440	52	.65	3
D-2	45	10 × 10	448	448	53	51	203.5	9.1	5130	60	.68	4

TABLE 23

SOME SIGNIFICANT PLOTS

NATURAL STANDS

Plot	Age from seed (years)	Number of trees per acre		Average height (feet)		Basal area per acre (square feet)	Average D. B. H. (inches)	Total volume per acre (cubic feet)	Average dead length (per cent)	Average form quotient I.B.	Index of growing space
		Now	When 15 years old	Dominants	Total stand						
S. C. XI–3	19	7623	10,000	18	14	100.4	1.5	1370	51	.62	10
Ox–1	28	1760	3,760	43	37	234.6	4.9	4550	64	.65	7
Sut.–1	30	560	...	34	32	150.2	6.8	2360	35	.57	2
Ath.–1	32	2680	8,700	34	28	189.0	3.3	3220	55	.70	8
S. C.–a	34	760	1,160	34	32	116.3	5.3	1980	47	.63	3
S. C. XI–1	36	1200	2,000+	47	43	231.0	6.0	5530	70	.72	7
S. C. XI–2	36	640	840+	49	45	208.2	7.7	4570	62	.68	5
Pn–1	36	920	2,240	48	45	214.2	6.4	5230	66	.72	6
P. H.–6	37	640	900+	50	46	237.9	8.2	5470	63	.69	4
Ma–1	38	320	320	45	44	204.3	10.8	4220	43	.65	2
Ma–2	40	920	1,080	51	47	282.4	7.5	6640	58	.68	5
Wi–4	41	280	400	48	45	205.2	11.6	4680	54	.70	2
Wi–5	42	280	...	40	37	203.6	10.8	3180	28	.50	1
Wi–3	44	280	...	48	47	196.3	11.3	4400	51	.66	2
Wi–1	45	600	1,320+	58	56	210.7	8.0	5950	75	.73	7
P. H.–3	50	560	800+	52	50	269.6	9.4	6850	70	.70	5
P. H.–4	50	320	500+	56	52	254.1	12.1	6620	64	.70	3
P H.–2	50	320	500+	64	62	285.8	12.8	7980	64	.65	4
P. H.–5	50	240	400+	55	55	204.3	12.5	5350	59	.70	2
S. C. V–1	55	920	3,000+	56	50	203.2	6.4	5680	70	.74	6
S. C.–F	55	520	...	72	67	261.2	10.0	9380	77	.74	6
S. C. V–2	55	480	600+	64	61	231.2	9.4	6840	67	.69	4
Pop.–1	59	640	2,300+	64	60	214.8	7.9	6300	74	.79	8
S. C.–C	60	142	...	83	80	276.0	18.9	9650	69	.70	3
S. C. IV–1	65	298	350+	78	77	228.0	11.9	7740	66	.67	3

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