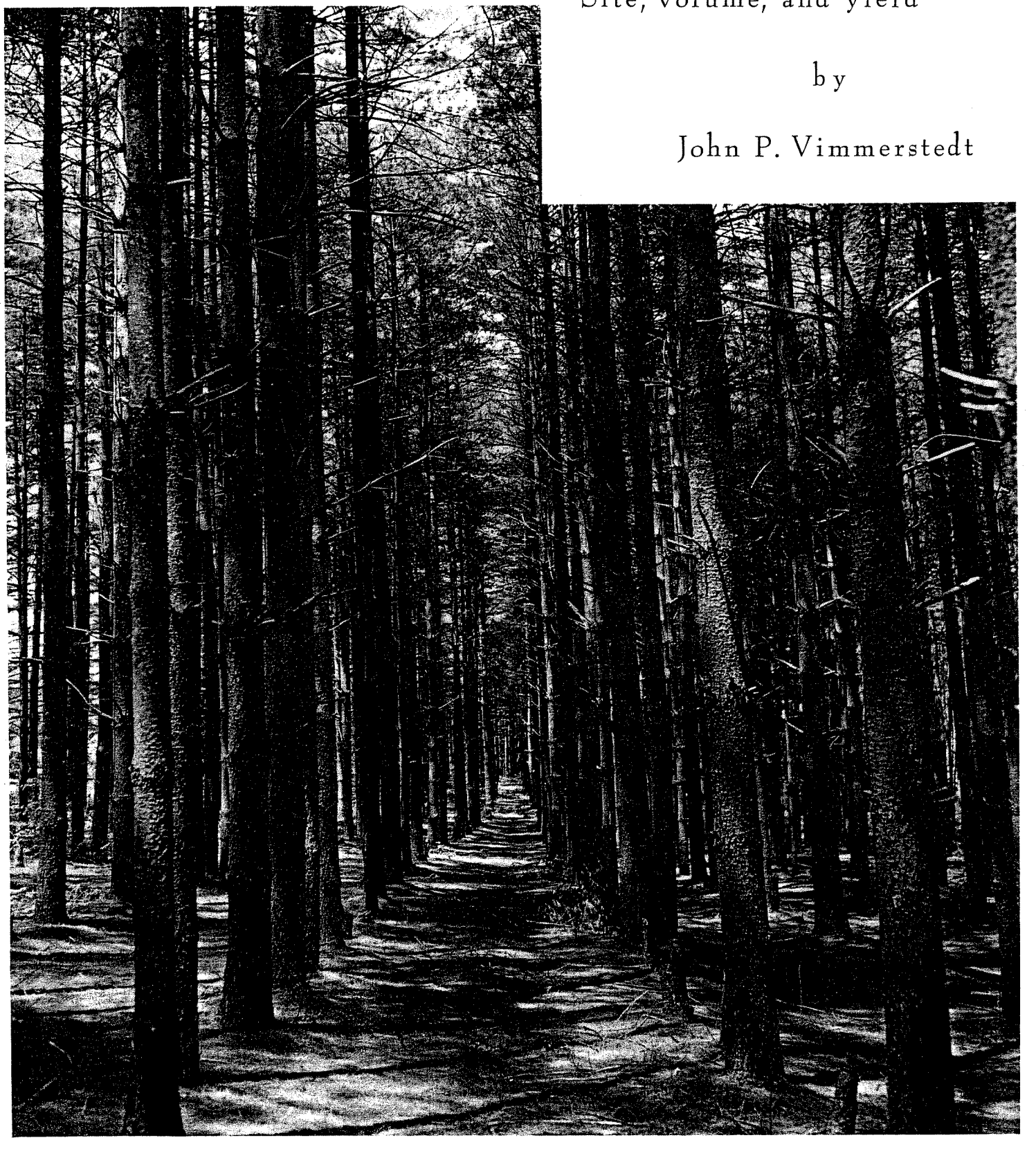
Southern Appalachian White Pine Plantations

Site, volume, and yield

by

John P. Vimmerstedt



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Cover photo:

Biltmore white pine plantation established in 1908 near Asheville, North Carolina. Picture taken 1946.

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INTRODUCTION

In the early 1930's several publications focused attention on the desirable characteristics of eastern white pine (Pinus strobus L.) growing in the Southern Appalachians. In 1932 Cope [2/] reported on the excellent growth of natural and planted stands and their relative freedom from blister rust and white pine weevil. After an extensive survey he concluded: "In North Carolina, Tennessee, and north Georgia, where white pine has shown such excellent growth rates, the amount of ribes (R. cynosbati) present in the altitudinal zones in which white pine thrives is so small that eradication costs will be almost negligible." The following year Barrett [3/] published a chart comparing the diameter growth of white pine and its associates. At all ages from 20 to 120 years the growth of white pine was more rapid than that of the other species, the nearest competitor being yellow-poplar. In the same year Kimberly [4/] published results of a study of white pine growth rates in New England and the Southern Appalachians. He found that both diameter and height growth were more rapid in the South.

With these favorable reports in the literature, and with the Biltmore plantations in North Carolina as living proof that planted white pine could succeed in the region, it is not surprising that white pine became a major species for the Civilian Conservation Corps reforestation program. Today white pine remains the preferred species for planting; from 1952 through 1960 about 20 million seedlings were planted in the 15 western counties of North Carolina.

1/ The author wishes to express thanks to Professor George M. Furnival, of Yale University, for advice on statistical matters, and to the many forest landowners in North Carolina, Tennessee, and Georgia who cooperated in the study.

2/ Cope, J. A. Northern white pine in the southern Appalachians. Jour. Forestry 30: 821-828. 1932.

3/ Barrett, L. I. Growth rate of white pine in the southern Appalachians. Jour. Forestry 31: 570-572. 1933.

4/ Kimberly, J. T. Growth rate of white pine in the southern Appalachians and in New England. Jour. Forestry 31: 946-947. 1933.

Landowners who have invested in old-field white pine plantations are asking such questions as:

"I planted these trees 10 years ago. How long before they are big enough to cut?"

"In 20 years, what will be the volume per acre in my plantation?"

This paper should help to answer these and related questions. It contains the following information:

1. Site index curves.
2. Cubic-volume and board-foot volume tables.
3. Cubic-foot yield tables.
4. A table for predicting average stand diameter.
5. Board-foot yield tables.
6. Factors for converting cubic feet to board feet.

FIELD METHODS

A total of 78 plantations were examined during 1957-1958 in North Carolina, Tennessee, and Georgia. Sampling was limited to unburned, unthinned plantations without large openings or numerous trees of other species in the main canopy. A great variety of spacings and site qualities were encountered in the plantations (figures 1, 2, and 3). It was not possible

Figure 1.--A plantation having very close spacing of 3 x 4 feet. Plantation age is 15 years, average d.b.h. 3.3 inches.

to obtain a good distribution of plots by age, however. Distribution of yield plots by age and site index is shown in table 1. In the plantations sampled, the following observations were made:

1. Total height and age measurements on 5 or 6 dominant and codominant trees for construction of site index curves.
2. Stem taper, total height, and bark thickness measurements on 241 trees for making volume tables.
3. A complete plot tally by 1-inch diameter classes for preparation of yield tables.
4. D.b.h. and total height of 2 trees in each diameter class for construction of height/d.b.h. curves.

A total of 130 plots were established. Of these, 111 were used for preparing site index curves, and 112 for preparation of yield tables.

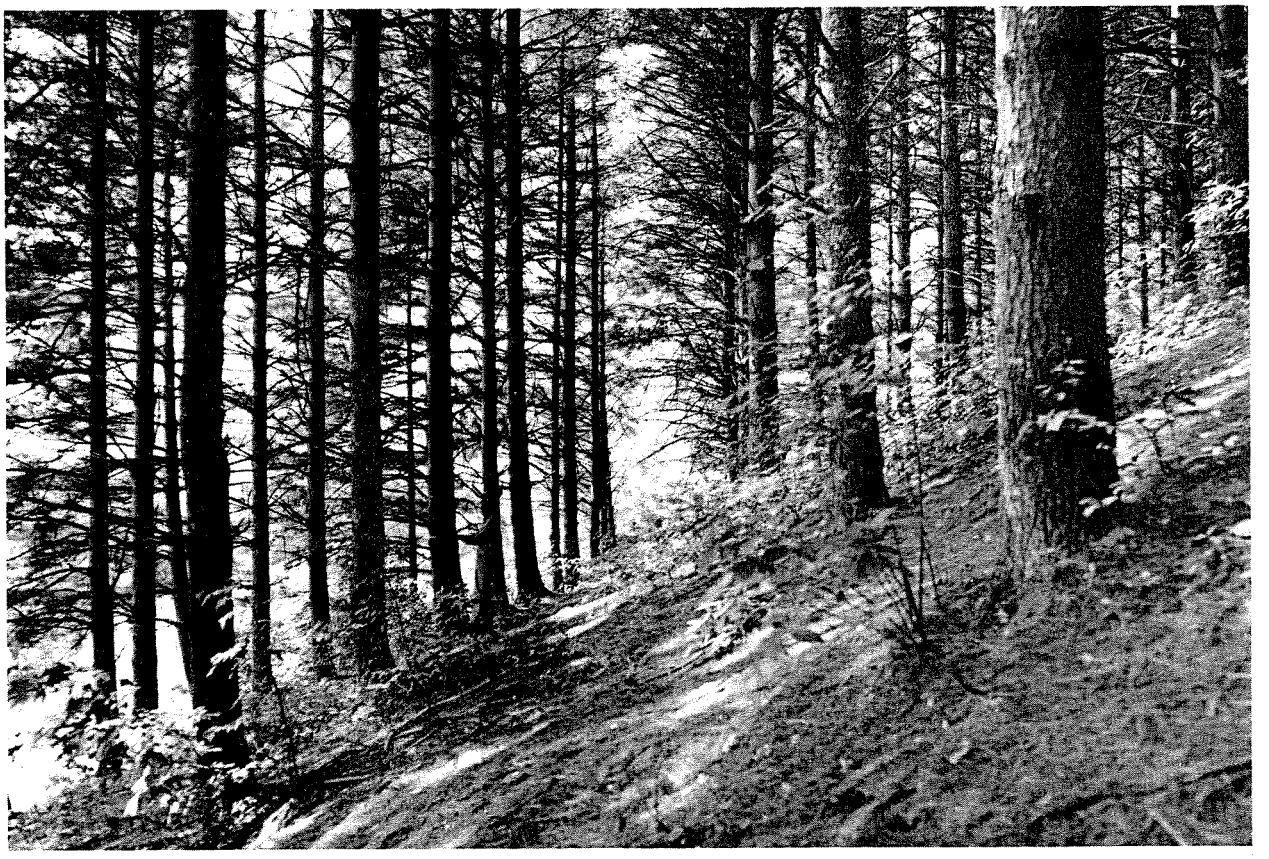

Figure 2.--Unusually wide spacing of 16 x 16 feet. Plantation age is 36 years, average d.b.h. 13.8 inches.

Table 1.--Distribution of yield plots by age and site index

Total age (years)	Site index (height in feet at 25 years)								
	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	Total
10-14	--	1	1	2	2	2	2	--	10
15-19	1	6	17	17	10	3	6	1	61
20-24	--	1	14	5	--	--	--	--	20
25-29	--	--	--	1	1	1	--	--	3
30-34	--	--	--	--	--	--	--	--	0
35-39	--	--	--	--	--	--	1	--	1
40-44	--	--	--	--	--	--	--	--	0
45-49	--	--	2	--	1	2	--	--	5
50-54	--	--	1	4	1	--	--	--	6
55-59	--	--	2	3	--	1	--	--	6
Total	1	8	37	32	15	9	9	1	112

Figure 3.--A plantation having an unusually good site index of 78 feet at 25 years of age. Plantation age is 18 years. Average height of dominant and codominant trees is 59 feet.

SITE INDEX CURVES

Site index curves were constructed from height and age data collected on 111 sample plots. The linear regression expressed in terms of site index at age 25 was:

$$\text{logarithm of site index} = \text{logarithm of total height} - 7.819225\left(\frac{1}{25} - \frac{1}{\text{age}}\right)$$

The set of site index curves derived from this equation is shown in figure 4. The dashed line of figure 4 shows that the average plantation encountered in the study had a site index of 56. In the yield tables which follow, the quantities given for site index 55 are close to average, while site indexes above 70 are fairly rare.

The site index curves were prepared with age 25 as the index age to emphasize the fact that most of the sampled plantations were less than 30 years old. To convert to site index at age 50, multiply the site index at age 25 by 1.4335. For site indexes of 40, 50, 60, 70, and 80 at age 25 the site indexes at age 50 are 57.3, 71.7, 86.0, 100.3, and 114.7. This conversion changes the index age; it does not change the slope of the height-age relationship.

CUBIC-FOOT VOLUME TABLES

Cubic-foot volume tables were prepared from measurements on 241 trees. Volume was determined graphically and weighted regression equations of the form $\frac{\text{volume}}{(\text{DBH})^2\ (\text{total height})} = b_o + \frac{b_1}{(\text{DBH})^2\ (\text{total height})}$ were fitted to the data by least squares. The resulting equations for volume inside and outside bark to various top diameter limits are listed below:

1. cu.-ft. volume outside bark to 4.0-inch top o.b. =
$$-0.581077 + 0.0026136\,(\text{DBH})^2\,(\text{total height})$$

2. cu.-ft. volume outside bark to 3.0-inch top o.b. =
$$-0.184542 + 0.00258896\,(\text{DBH})^2\,(\text{total height})$$

3. cu.-ft. volume inside bark to 4.0-inch top o.b. =
$$-0.535206 + 0.00228831\,(\text{DBH})^2\,(\text{total height})$$

4. cu.-ft. volume inside bark to 3.0-inch top o.b. =
$$-0.254526 + 0.00228620\,(\text{DBH})^2\,(\text{total height})$$

Tables 2 and 3, computed from the above equations, may be used to estimate cubic-foot volume of white pine planted in old fields in the Southern Appalachian region.

Table 2.--Cubic-foot volumes (outside bark) for white pine plantations

TOP DIAMETER 4.0 INCHES OUTSIDE BARK

D. b. h. (Inches)	Total tree height (feet)															
	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
	Cubic-feet															
5	.73	1.05	1.38	1.71	2.03	2.36	2.69	3.01	3.34	--	--	--	--	--	--	--
6	1.30	1.77	2.24	2.71	3.18	3.65	4.12	4.59	5.07	5.54	6.01	--	--	--	--	--
7	1.98	2.62	3.26	3.90	4.54	5.18	5.82	6.46	7.10	7.74	8.38	9.02	9.66	--	--	--
8	--	--	4.44	5.27	6.11	6.95	7.78	8.62	9.46	10.29	11.13	11.96	12.80	--	--	--
9	--	--	--	6.83	7.89	8.95	10.00	11.06	12.12	13.18	14.24	15.30	16.35	17.41	--	--
10	--	--	--	--	9.87	11.18	12.49	13.79	15.10	16.41	17.71	19.02	20.33	21.63	22.94	24.25
11	--	--	--	--	--	13.65	15.23	16.81	18.39	19.97	21.56	23.14	24.72	26.30	27.88	29.46
12	--	--	--	--	--	--	--	--	22.00	23.88	25.76	27.65	29.53	31.41	33.29	35.17
13	--	--	--	--	--	--	--	--	--	--	30.34	32.55	34.75	36.96	39.17	41.38
14	--	--	--	--	--	--	--	--	--	--	--	--	40.40	42.96	45.52	48.08
TOP DIAMETER 3.0 INCHES OUTSIDE BARK																
4	.64	.85	1.06	1.27	1.48	1.68	1.89	2.10	--	--	--	--	--	--	--	--
5	1.11	1.44	1.76	2.09	2.41	2.73	3.06	3.38	3.70	--	--	--	--	--	--	--
6	1.68	2.15	2.61	3.08	3.54	4.01	4.48	4.94	5.41	5.87	6.34	--	--	--	--	--
7	2.36	2.99	3.62	4.26	4.89	5.52	6.16	6.79	7.43	8.06	8.70	9.33	9.96	--	--	--
8	--	--	4.79	5.61	6.44	7.27	8.10	8.93	9.76	10.59	11.41	12.24	13.07	--	--	--
9	--	--	--	7.15	8.20	9.25	10.30	11.35	12.40	13.45	14.49	15.54	16.59	17.64	--	--
10	--	--	--	--	10.17	11.47	12.76	14.05	15.35	16.64	17.94	19.23	20.53	21.82	23.12	24.41
11	--	--	--	--	--	13.91	15.48	17.04	18.61	20.18	21.74	23.31	24.88	26.44	28.01	29.58
12	--	--	--	--	--	--	--	20.31	22.18	24.05	25.91	27.78	29.64	31.50	33.37	35.23
13	--	--	--	--	--	--	--	--	--	--	30.44	32.63	34.82	37.01	39.19	41.38
14	--	--	--	--	--	--	--	--	--	--	--	--	40.41	42.96	45.52	48.08

Table 3.--Cubic-foot volumes (inside bark) for white pine plantations

TOP DIAMETER 4.0 INCHES OUTSIDE BARK

D. b. h. (Inches)	Total tree height (feet)															
	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
	Cubic-feet															
5	.60	.89	1.18	1.47	1.75	2.04	2.33	2.61	2.90	--	--	--	--	--	--	--
6	1.11	1.52	1.94	2.35	2.76	3.17	3.58	4.00	4.41	4.82	5.23	--	--	--	--	--
7	1.70	2.27	2.83	3.39	3.95	4.51	5.07	5.63	6.19	6.75	7.31	7.87	8.43	--	--	--
8	--	--	3.86	4.59	5.32	6.06	6.79	7.52	8.25	8.98	9.72	10.45	11.18	--	--	--
9	--	--	--	5.95	6.88	7.81	8.73	9.66	10.59	11.51	12.44	13.37	14.29	15.22	--	--
10	--	--	--	--	8.62	9.76	10.91	12.05	13.19	14.34	15.48	16.63	17.77	18.92	20.06	21.20
11	--	--	--	--	--	11.92	13.31	14.69	16.08	17.46	18.85	20.23	21.62	23.00	24.38	25.77
12	--	--	--	--	--	--	--	--	19.24	20.88	22.53	24.18	25.83	27.47	29.12	30.77
13	--	--	--	--	--	--	--	--	--	--	26.54	28.47	30.40	32.34	34.27	36.20
14	--	--	--	--	--	--	--	--	--	--	--	--	35.35	37.59	39.83	42.07
TOP DIAMETER 3.0 INCHES OUTSIDE BARK																
4	.48	.66	.84	1.03	1.21	1.39	1.57	1.75	--	--	--	--	--	--	--	--
5	.89	1.17	1.46	1.75	2.03	2.32	2.60	2.89	3.17	--	--	--	--	--	--	--
6	1.39	1.80	2.21	2.63	3.04	3.45	3.86	4.27	4.68	5.10	5.51	--	--	--	--	--
7	1.99	2.55	3.11	3.67	4.23	4.79	5.35	5.91	6.47	7.03	7.59	8.15	8.71	--	--	--
8	--	--	4.13	4.87	5.60	6.33	7.06	7.79	8.52	9.26	9.99	10.72	11.45	--	--	--
9	--	--	--	6.23	7.15	8.08	9.00	9.93	10.86	11.78	12.71	13.63	14.56	15.49	--	--
10	--	--	--	--	8.89	10.03	11.18	12.32	13.46	14.61	15.75	16.89	18.04	19.18	20.32	21.46
11	--	--	--	--	--	12.19	13.58	14.96	16.34	17.73	19.11	20.49	21.88	23.26	24.64	26.03
12	--	--	--	--	--	--	--	--	19.50	21.14	22.79	24.44	26.08	27.73	29.37	31.02
13	--	--	--	--	--	--	--	--	--	--	26.79	28.72	30.65	32.59	34.52	36.45
14	--	--	--	--	--	--	--	--	--	--	--	--	35.59	37.83	40.07	42.31

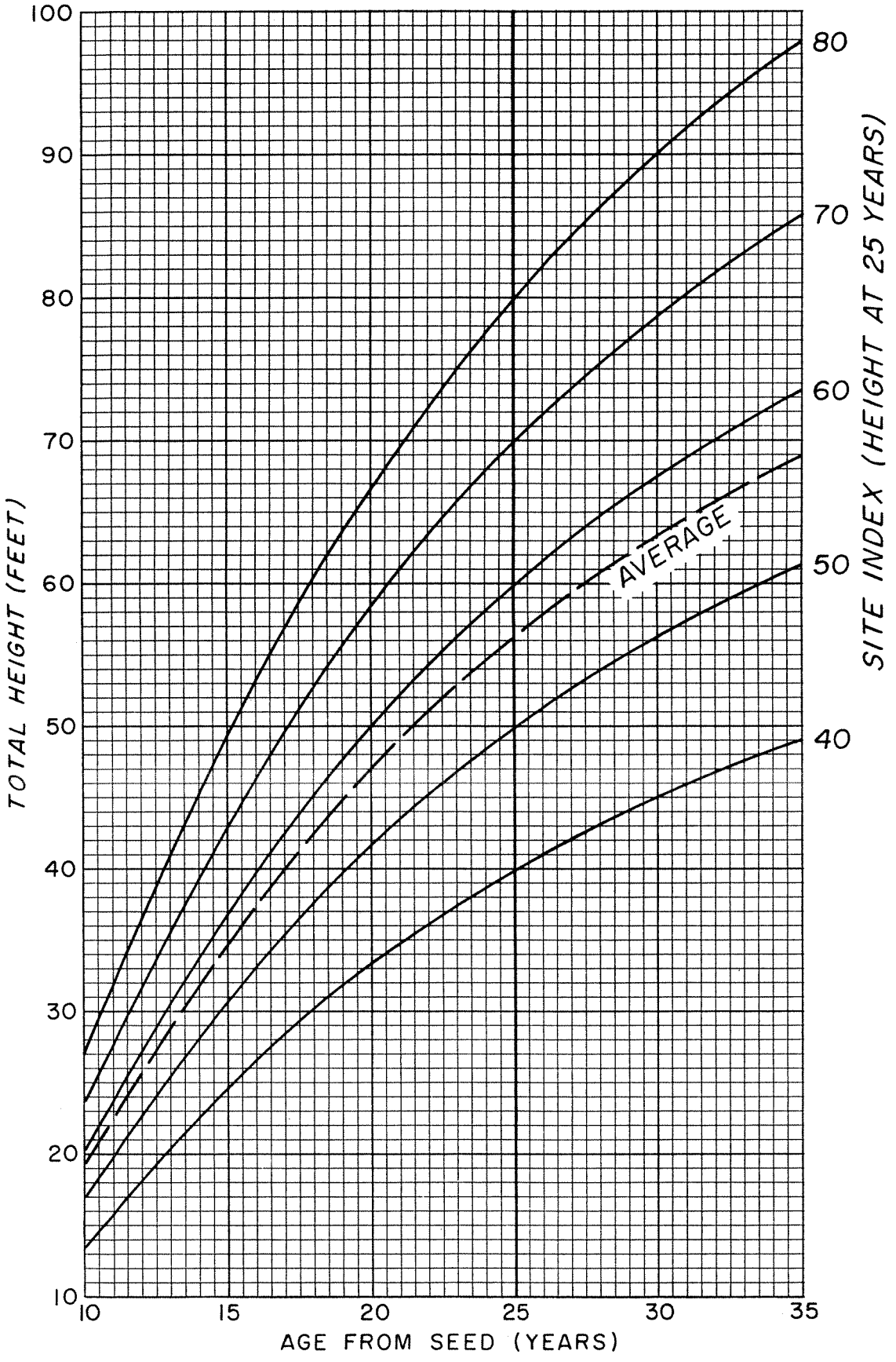

Figure 4.--Site index curves for old-field white pine plantations in the Southern Appalachians. Index age is 25 years.

BOARD-FOOT VOLUME TABLE

A board-foot volume table for small saw logs was prepared from 100 trees which contained at least one 8-foot log with a 6-inch diameter inside bark at the small end. The regression equation for the relationship between volume, D^2H, and total height is:

bd.-ft. volume to 6.0-inch top i.b. = $0.0142908(D^2H) - 0.299194H - 7.797400$.

Table 4 gives board-foot volumes (International $\frac{1}{4}$-inch rule) for trees of various heights and diameters.

Table 4.--Board-foot volume (International $\frac{1}{4}$-inch rule) for white pine, by diameter and total tree height

TOP DIAMETER 6.0 INCHES INSIDE BARK

D.b.h. (inches)	Total height (feet)										
	35	40	45	50	55	60	65	70	75	80	85
	Board feet										
7	6	8	10	12	14	16	18	20	22	24	--
8	14	17	20	23	26	29	32	35	38	41	--
9	22	26	31	35	39	44	48	52	57	61	65
10	--	37	43	49	54	60	66	71	77	83	88
11	--	--	57	64	71	78	85	92	99	107	114
12	--	--	--	80	89	98	106	115	124	133	142

In order to give some idea of the reliability of table 4, the confidence intervals shown in table 5 were calculated. This table is interpreted as follows:

1. For any <u>one</u> tree with 10-inch d.b.h. and height of 50 feet, the chances are 95 out of 100 that the actual board-foot volume will be in the interval 35 to 63, the most probable value being 49 board feet.
2. For the whole population of trees of 10-inch d.b.h. and height 50 feet, the chances are 95 out of 100 that the actual <u>average</u> board-foot volume of the group is in the interval 47.3 to 50.7, the most probable value again being 49 board feet.

Table 5.--Confidence intervals for selected board-foot volumes at 95-percent level

Tree d.b.h. (inches)	Total height (feet)									
	40		50		60		70		80	
	Individual tree	Population	Individual tree	Population	Individual tree	Population	Individual tree	Population	Individual tree	Population
8	±14.09	±2.04	±14.01	±1.55	±14.05	±1.74	±14.15	±2.52	±14.35	±3.47
10	±14.13	±2.40	±14.05	±1.74	±14.01	±1.53	±14.05	±1.84	±14.17	±2.62
12	±14.29	±3.23	±14.21	±2.85	±14.19	±2.74	±14.23	±2.93	±14.33	±3.37

CUBIC-FOOT YIELDS

By means of the data from 112 sample plots, the relation between plantation cubic-foot volume and age, site index, and spacing was investigated via regression techniques. The following predicting equation was superior to all others tested, accounting for 90 percent of the total variation:

$$\begin{aligned}\text{logarithm of cubic-foot volume per acre, outside bark to 3.0-inch top o.b.} &= 0.90555 - 24.8002\left(\frac{1}{\text{age}}\right) \\ &+ 1.40983\,[\text{logarithm (site index)}] \\ &+ 0.000789563\left(\frac{\text{original No. trees per acre}}{\text{age}}\right) \\ &+ 0.908740\left[\text{logarithm}\left(\frac{\text{site index} \times 10}{\text{age}}\right)\right]\end{aligned}$$

Cubic-foot yields predicted from this equation for plantations of various ages, site indexes, and original spacings are shown in table 6. In sampling for this study, it was not possible to find many plantations between the ages of 25 and 45 years, or with wide original spacing. Thus, although yields are given for spacings up to 12 x 12 feet and for ages up to 35 years, the volumes predicted for closer spacings and younger ages are more reliable.

Table 6.--Cubic-foot yield of white pine per acre, including bark, by site, age, and original spacing; all trees 3.0-inch d.b.h. and larger to a 3.0-inch top (o.b.) diameter

Age (years)	Average height dominants and codominants	Original spacing (feet)								
		4 x 4	5 x 5	6 x 6	6 x 7	7 x 7	8 x 8	9 x 9	10 x 10	12 x 12
	Feet	Cubic feet								
SITE INDEX 45										
10	15	298	249	226	219	213	205	200	196	192
15	28	1,171	1,040	975	955	938	914	898	888	873
20	38	2,150	1,967	1,874	1,845	1,820	1,786	1,763	1,747	1,725
25	45	2,958	2,754	2,650	2,617	2,589	2,550	2,524	2,504	2,481
30	51	3,548	3,344	3,237	3,205	3,175	3,135	3,108	3,089	3,065
35	55	3,955	3,758	3,656	3,623	3,596	3,557	3,531	3,512	3,487
SITE INDEX 50										
10	17	380	318	289	280	272	262	255	251	245
15	31	1,495	1,327	1,245	1,219	1,197	1,167	1,147	1,133	1,115
20	42	2,746	2,512	2,393	2,357	2,324	2,280	2,251	2,230	2,204
25	50	3,777	3,516	3,383	3,341	3,305	3,255	3,223	3,197	3,167
30	56	4,531	4,271	4,134	4,093	4,055	4,004	3,969	3,945	3,914
35	61	5,050	4,800	4,669	4,627	4,592	4,543	4,509	4,485	4,454
SITE INDEX 55										
10	19	474	397	360	349	340	327	319	313	305
15	34	1,865	1,656	1,553	1,521	1,493	1,456	1,431	1,414	1,391
20	46	3,425	3,133	2,985	2,940	2,899	2,844	2,808	2,782	2,749
25	55	4,711	4,386	4,220	4,168	4,123	4,061	4,019	3,988	3,951
30	62	5,652	5,327	5,157	5,105	5,058	4,995	4,951	4,920	4,882
35	68	6,298	5,986	5,822	5,770	5,727	5,665	5,623	5,594	5,554

Table 6.--Cubic-foot yield of white pine per acre, including bark, by site, age, and original spacing; all trees 3.0-inch d.b.h. and larger to a 3.0-inch top (o.b.) diameter (continued)

Age (years)	Average height dominants and codominants	Original spacing (feet)								
		4 x 4	5 x 5	6 x 6	6 x 7	7 x 7	8 x 8	9 x 9	10 x 10	12 x 12
	Feet	Cubic feet								
SITE INDEX 60										
10	20	580	485	440	427	416	400	390	383	373
15	37	2,282	2,026	1,900	1,861	1,827	1,782	1,751	1,729	1,702
20	50	4,191	3,834	3,653	3,597	3,547	3,480	3,436	3,404	3,363
25	60	5,765	5,368	5,164	5,100	5,045	4,970	4,918	4,881	4,835
30	68	6,915	6,518	6,310	6,246	6,189	6,111	6,058	6,020	5,973
35	74	7,706	7,323	7,124	7,060	7,007	6,931	6,880	6,844	6,795
SITE INDEX 65										
10	22	699	584	530	514	500	482	469	461	449
15	40	2,747	2,439	2,287	2,240	2,199	2,144	2,108	2,082	2,048
20	54	5,045	4,615	4,397	4,330	4,271	4,190	4,136	4,098	4,049
25	65	6,939	6,461	6,216	6,139	6,073	5,981	5,920	5,875	5,820
30	73	8,323	7,845	7,594	7,518	7,449	7,355	7,291	7,246	7,190
35	80	9,277	8,817	8,576	8,500	8,435	8,344	8,283	8,240	8,181
SITE INDEX 70										
10	24	830	693	630	610	594	572	557	547	534
15	43	3,261	2,896	2,715	2,660	2,612	2,546	2,503	2,472	2,432
20	58	5,991	5,480	5,222	5,142	5,071	4,975	4,911	4,866	4,807
25	70	8,241	7,674	7,382	7,291	7,213	7,104	7,031	6,978	6,912
30	79	9,883	9,315	9,018	8,927	8,845	8,734	8,658	8,604	8,537
35	86	11,015	10,469	10,181	10,093	10,016	9,908	9,836	9,784	9,714
SITE INDEX 75										
10	26	974	814	739	716	697	671	654	642	626
15	46	3,828	3,399	3,187	3,122	3,066	2,989	2,938	2,902	2,855
20	63	7,031	6,431	6,128	6,034	5,951	5,838	5,764	5,711	5,642
25	75	9,669	9,003	8,662	8,555	8,463	8,335	8,249	8,187	8,110
30	84	11,601	10,935	10,585	10,479	10,382	10,252	10,163	10,100	10,021
35	92	12,930	12,291	11,954	11,847	11,757	11,631	11,545	11,484	11,403

AVERAGE STAND DIAMETER

The same 112 sample plots used in making the cubic-foot yield tables were also used to determine the relationship between average basal area per tree and age, site index, and spacing. The regression equation for this relationship, accounting for 93 percent of the total variation, is:

$$\text{logarithm average basal area per tree} + 2 = 1.42826 - 0.463267 \left[\text{logarithm} \left(\frac{\text{original No. trees per acre}}{\text{age}}\right)\right] + 0.00717020\ (\text{site index}) + 0.0106594\ (\text{age}).$$

The diameter of the tree of average basal area in terms of age, site index, and original spacing is shown in table 7.

Table 7.--Diameter at breast height of tree of average basal area

Age (years)	Original spacing (feet)								
	4 x 4	5 x 5	6 x 6	6 x 7	7 x 7	8 x 8	9 x 9	10 x 10	12 x 12
	Inches								
SITE INDEX 45									
10	3.1	3.5	3.8	3.9	4.1	4.3	4.6	4.8	5.2
15	3.7	4.1	4.4	4.6	4.7	5.1	5.3	5.6	6.1
20	4.2	4.6	5.0	5.2	5.4	5.7	6.1	6.4	6.9
25	4.7	5.2	5.6	5.8	6.0	6.4	6.8	7.1	7.8
30	5.2	5.7	6.2	6.5	6.7	7.1	7.5	7.9	8.6
35	5.7	6.3	6.7	7.1	7.4	7.8	8.3	8.7	9.5
SITE INDEX 50									
10	3.3	3.6	3.9	4.1	4.2	4.5	4.8	5.0	5.4
15	3.8	4.2	4.6	4.8	4.9	5.3	5.5	5.8	6.4
20	4.3	4.8	5.2	5.4	5.6	6.0	6.3	6.6	7.2
25	4.9	5.4	5.9	6.1	6.3	6.7	7.1	7.4	8.1
30	5.4	6.0	6.5	6.7	7.0	7.4	7.8	8.2	9.0
35	5.9	6.6	7.2	7.4	7.7	8.2	8.6	9.1	9.9
SITE INDEX 55									
10	3.4	3.8	4.1	4.3	4.4	4.7	5.0	5.2	5.7
15	4.0	4.4	4.8	5.0	5.2	5.5	5.8	6.1	6.6
20	4.5	5.0	5.5	5.6	5.9	6.2	6.6	6.9	7.5
25	5.1	5.6	6.1	6.3	6.6	7.0	7.4	7.7	8.4
30	5.6	6.2	6.8	7.0	7.3	7.7	8.2	8.6	9.3
35	6.2	6.9	7.5	7.7	8.0	8.5	9.0	9.5	10.3
SITE INDEX 60									
10	3.5	3.9	4.3	4.4	4.6	4.9	5.2	5.4	5.9
15	4.1	4.6	5.0	5.2	5.4	5.7	6.0	6.3	6.9
20	4.7	5.2	5.7	5.9	6.1	6.5	6.9	7.2	7.8
25	5.3	5.9	6.4	6.6	6.8	7.3	7.7	8.1	8.8
30	5.9	6.5	7.1	7.3	7.6	8.1	8.5	8.9	9.7
35	6.4	7.1	7.8	8.1	8.4	8.9	9.4	9.8	10.7
SITE INDEX 65									
10	3.7	4.1	4.5	4.6	4.8	5.1	5.4	5.7	6.2
15	4.3	4.8	5.2	5.4	5.6	6.0	6.3	6.6	7.2
20	4.9	5.4	5.9	6.1	6.4	6.8	7.1	7.5	8.2
25	5.5	6.1	6.6	6.9	7.1	7.6	8.0	8.4	9.1
30	6.1	6.7	7.4	7.6	7.9	8.4	8.9	9.3	10.1
35	6.7	7.5	8.1	8.4	8.7	9.3	9.8	10.3	11.2
SITE INDEX 70									
10	3.9	4.3	4.7	4.8	5.0	5.3	5.6	5.9	6.4
15	4.5	5.0	5.4	5.6	5.8	6.2	6.6	6.9	7.5
20	5.1	5.7	6.2	6.4	6.6	7.1	7.5	7.8	8.5
25	5.7	6.4	6.9	7.1	7.4	7.9	8.3	8.8	9.5
30	6.4	7.0	7.7	7.9	8.2	8.8	9.3	9.7	10.6
35	7.0	7.8	8.4	8.8	9.1	9.6	10.2	10.7	11.7
SITE INDEX 75									
10	4.0	4.5	4.8	5.0	5.2	5.5	5.8	6.1	6.7
15	4.7	5.2	5.7	5.9	6.1	6.4	6.8	7.2	7.8
20	5.3	5.9	6.4	6.7	6.9	7.4	7.8	8.2	8.9
25	6.0	6.6	7.2	7.5	7.7	8.2	8.7	9.1	9.9
30	6.6	7.3	8.0	8.3	8.6	9.1	9.6	10.1	11.0
35	7.3	8.1	8.8	9.1	9.5	10.1	10.6	11.1	12.2

BOARD-FOOT YIELDS

Since white pine is more valuable as lumber than as pulpwood, board-foot yields of plantations are of considerable interest. In order to construct board-foot yield tables, the relation between the board-foot/cubic-foot ratio of 90 sample plots and plantation height and diameter was determined. No plot of a particular diameter class was used unless all the plots in that diameter class had some board-foot volume. Plantations with an average diameter less than 4.6 inches were not used.

The regression equation for predicting board-foot/cubic-foot ratio is:

$$\frac{\text{board feet (International } \frac{1}{4}\text{-inch rule to 6.0-inch top i.b.)}}{\text{cubic feet (outside bark to 3.0-inch top o.b.)}}$$

$$= 9.607418 - 3.538879 \left[\text{logarithm} \left(\frac{100}{\text{average plantation basal area}}\right)\right]$$

$$+ 0.0282083 \text{ (height of dominant stand).}$$

This board-foot/cubic-foot ratio is for stands, not for individual trees. The equation accounted for 95 percent of the total variation encountered. Table 8 was constructed by multiplying the cubic-foot yields of table 6 by the board-foot/cubic-foot ratio obtained from the above equation. It is interesting to note that while cubic-foot yield decreases with increasing space per tree, board-foot yield increases. This is due to the larger average diameter of plantations with wider spacings.

Table 8.--Board-foot yield of white pine per acre to 6.0-inch top diameter i.b., International $\frac{1}{4}$-inch rule

Age (years)	Original spacing (feet)								
	4 x 4	5 x 5	6 x 6	6 x 7	7 x 7	8 x 8	9 x 9	10 x 10	12 x 12
	Board feet								
SITE INDEX 45									
10	--	--	--	--	--	--	--	--	6
15	--	--	--	--	86	257	403	531	753
20	--	557	1,016	1,199	1,388	1,702	1,974	2,217	2,640
25	1,542	2,311	2,912	3,157	3,411	3,848	4,231	4,575	5,175
30	3,581	4,435	5,137	5,427	5,736	6,256	6,728	7,150	7,883
35	5,650	6,561	7,332	7,659	8,003	8,586	9,117	9,588	10,449
SITE INDEX 50									
10	--	--	--	--	--	--	--	--	50
15	--	--	107	238	366	579	761	921	1,200
20	577	1,327	1,884	2,110	2,342	2,731	3,071	3,377	3,914
25	2,980	3,892	4,623	4,925	5,239	5,783	6,266	6,697	7,454
30	5,837	6,857	7,714	8,073	8,457	9,107	9,699	10,233	11,159
35	8,723	9,815	10,758	11,164	11,592	12,323	12,989	13,585	14,678
SITE INDEX 55									
10	--	--	--	--	--	--	--	37	116
15	--	69	467	623	777	1,034	1,256	1,452	1,795
20	1,551	2,416	3,075	3,346	3,625	4,097	4,513	4,888	5,549
25	4,980	6,030	6,898	7,261	7,642	8,304	8,891	9,424	10,358
30	8,893	10,071	11,092	11,524	11,991	12,786	13,510	14,164	15,310
35	12,780	14,048	15,173	15,664	16,186	17,078	17,896	18,633	19,980

Table 8.--Board-foot yield of white pine per acre to 6.0-inch top diameter i.b., International $\frac{1}{4}$-inch rule (continued)

Age (years)	Original spacing (feet)								
	4 x 4	5 x 5	6 x 6	6 x 7	7 x 7	8 x 8	9 x 9	10 x 10	12 x 12
	Board feet								
SITE INDEX 60									
10	--	--	--	--	--	--	56	112	207
15	--	518	978	1,161	1,342	1,647	1,912	2,146	2,561
20	2,925	3,896	4,658	4,975	5,305	5,866	6,365	6,815	7,612
25	7,637	8,817	9,824	10,250	10,701	11,493	12,196	12,840	13,970
30	12,849	14,177	15,369	15,878	16,434	17,382	18,256	19,045	20,432
35	17,940	19,374	20,695	21,276	21,898	22,965	23,953	24,842	26,475
SITE INDEX 65									
10	--	--	--	--	--	73	150	216	328
15	418	1,148	1,668	1,877	2,087	2,442	2,754	3,031	3,521
20	4,760	5,823	6,687	7,052	7,437	8,092	8,677	9,211	10,159
25	11,052	12,344	13,491	13,985	14,509	15,435	16,268	17,030	18,376
30	17,860	19,322	20,682	21,276	21,924	23,037	24,071	25,010	26,666
35	24,399	25,987	27,502	28,182	28,906	30,165	31,337	32,396	34,345
SITE INDEX 70									
10	--	--	--	15	81	186	275	352	483
15	1,195	1,982	2,562	2,799	3,038	3,445	3,806	4,128	4,702
20	7,122	8,258	9,222	9,636	10,073	10,828	11,507	12,130	13,240
25	15,333	16,717	17,999	18,561	19,164	20,234	21,203	22,096	23,675
30	24,021	25,594	27,126	27,804	28,550	29,842	31,047	32,145	34,091
35	32,261	33,984	35,691	36,479	37,317	38,780	40,152	41,390	43,683
SITE INDEX 75									
10	--	--	68	143	217	336	437	525	676
15	2,224	3,056	3,691	3,955	4,223	4,686	5,097	5,468	6,133
20	10,064	11,251	12,309	12,771	13,265	14,123	14,905	15,622	16,909
25	20,582	22,026	23,441	24,072	24,753	25,975	27,088	28,118	29,952
30	31,503	33,161	34,857	35,624	36,471	37,951	39,341	40,612	42,873
35	41,736	43,577	45,483	46,362	47,321	49,003	50,581	52,017	54,689

USE OF TABLES

The tables are easy to use. As an example, consider a plantation established 8 years ago with 2-year-old seedlings planted at a spacing of 8 x 8 feet. Average total height of 6 dominant and codominant trees is presently 20 feet. Figure 4 shows that this plantation has a site index of 60. Knowledge of tree age, initial spacing, and site index permits a determination to be made of present yields, plus a forecast of the future behavior of the plantation, by entering appropriate tables. Predictions for the plantation at age 20 are as follows:

1. From table 6: volume per acre = 3,480 cubic feet.
2. From table 7: diameter of tree of average basal area = 6.5 inches.
3. From table 8: board-foot volume per acre = 5,866 board feet.

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