TECHNICAL BULLETIN No. 630

OCTOBER 1938
Slightly revised April 1961

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

YIELD OF EVEN-AGED STANDS OF PONDEROSA PINE [1]

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CONTENTS

INTRODUCTION

Ponderosa pine (*Pinus ponderosa* Dougl.) is one of the most important and most interesting tree species in the western United States, because of its wide geographic range, its excellent timber qualities, and its adaptive silvical characteristics. Its range is an area about 1,000 by 1,400 miles, extending from the western border of the Great Plains to the Coast Mountains and from Mexico north into British Columbia (fig. 1). The ponderosa pine type in all its forms covers more than 50 million acres. The species is commercially valuable throughout its range, and is widely sought. The wood of old-growth trees is whitish yellow, soft, and easily worked; that of young trees is much coarser and more resinous, and therefore under present market conditions less desirable. Like other pines, ponderosa pine is adaptable to different methods of management and regeneration. Under natural conditions it most commonly grows in uneven-aged stands, but in general it thrives equally well in even-aged stands.

[1] Submitted for publication November 29, 1937.

[2] Grateful acknowledgment is made to directors and staff members of the western forest and range experiment stations for advice and for assistance in collecting data in connection with this study. Particularly valuable help was received from R. H. Weidman, of the Northern Rocky Mountain station; C. E. Behre, of the Northeastern station; D. Dunning and V. A. Clements, of the California station; and C. A. Connaughton and E. L. Mowat, of the Intermountain station. Other contributors are J. L. Alexander, of the University of Washington, formerly of the British Columbia Forest Branch, who took the measurements in the ponderosa pine of British Columbia, and W. H. Gallaher, E. N. Munns, S. B. Show, and L. H. Reineke, who conducted studies in ponderosa pine in California. For most of the computations involved in compiling and analyzing the data, credit is due S. B. Hayward, of the Pacific Northwest Forest Experiment Station.

Findings of the national-forest survey now being made by the Forest Service show that the extent of the even-aged second-growth stands is much greater than has been estimated in the past. Some extensive stands commonly thought to be uneven-aged are composites of even-aged groups. In the 10 counties of eastern Oregon and eastern Washington for which survey statistics were available at the time of writing, ponderosa pine stands classified as second growth cover more than 1,340,000 acres. Young, even-aged stands occupy 639,000 acres of this total; on the remaining 701,000 acres, the stands are even-aged and of advanced development or else have been subjected

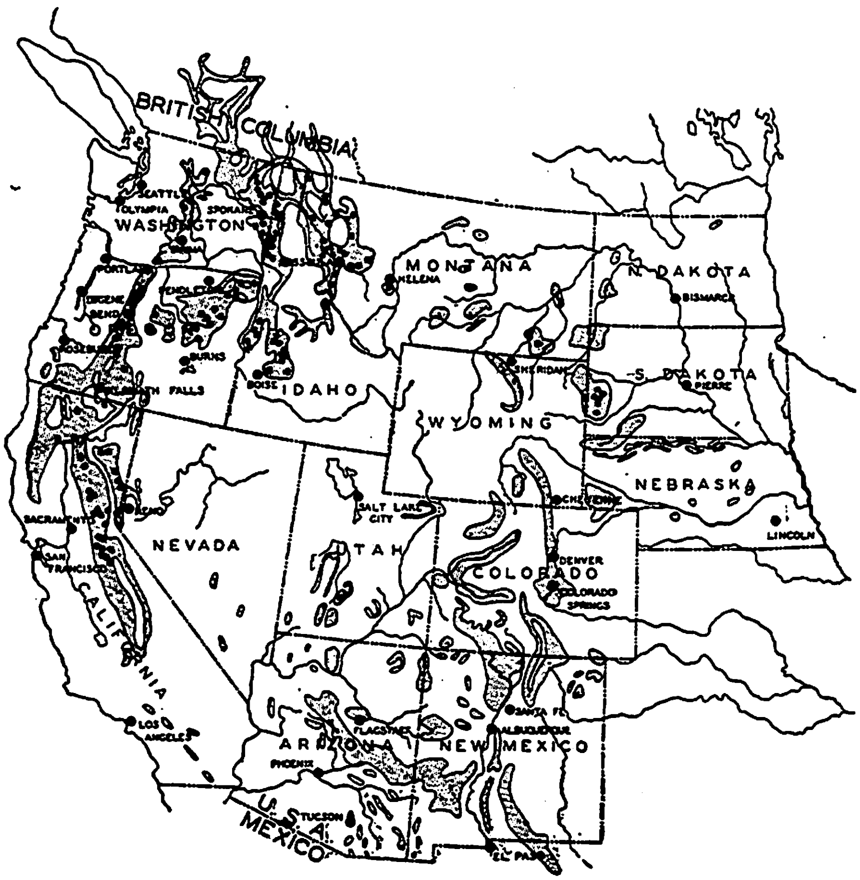

FIGURE 1.—Approximate distribution of forests in which ponderosa pine is the dominant species, and location of plots or groups of plots used in this study.

to heavy selection cutting and now have even-aged understories of pine reproduction. In California, and also in parts of Oregon, Washington, Idaho, and Montana, the even-aged stand is characteristic of old mining cuttings. In the Black Hills even-aged stands have become established on areas that have not been cut over, originating probably after extensive fires occurring in the infrequent years when seed production and the conditions governing germination and survival were favorable. The area of even-aged ponderosa pine forests is constantly increasing, primarily as a result of human activity.

The value of growth and yield studies has been stressed time and time again in forestry literature and probably is fully appreciated by most foresters. A yield study of even-aged ponderosa pine forests was necessary as a complement to the yield study of selectively cut stands of this species (*14*),[3] partly because that study indicated that the reproduction in selectively cut stands is practically even-aged.

Several studies of the yield capacities of even-aged ponderosa pine forests have previously been made, notably in California (*11*, *22*), Idaho (*3*, *4*), and British Columbia (*5*). The results of these studies were limited as to region of application, and were widely divergent. In this study an effort has been made to coordinate the best of the older data and new supplementary data and to derive a set of yield tables applying throughout the range of the species. Some of the older data used were taken as far back as 1910. The new study got under way in 1928; by 1934 the essential cooperation had been obtained in all the regions involved, and thereafter new data were accumulated rapidly. All the new data were gathered under one general work plan and under the direct initial supervision of the project leader. Sample plots were taken in California, Oregon, Washington, Idaho, Montana, South Dakota, and in a single locality in Wyoming. The pine forests of the Southwest were left unsampled, because the Southwestern Forest and Range Experiment Station after a survey of its field concluded that stands of the condition desired were not available. In the field work emphasis was laid on obtaining data on true second-growth stands, as distinct from small groups of second growth. The study was confined to fully stocked stands, which furnish the best basis of comparison for stands of all degrees of density.

The old and new data together comprised the records of 848 plots. The major computations of the study were based on data for 450 plots only, 398 plots being rejected because of nonrepresentative plot conditions or of incompleteness of data. Most of these rejected plots were taken for studies in which plot selection was not based on stand normality. Data from many of the rejected plots were used in studying the effect of stocking upon yield.

In this report some mensurational data other than growth and yield statistics are given that will assist in dealing with problems relating to stand development.

Because of the extensive area covered, the number of cooperators involved, and the variation among the stands investigated, the combination of the data into a single coordinated series of tables was not without difficulties. The accepted methods of normal-yield-table construction (*6*, *7*, *8*, *20*) had to be modified in a number of instances before acceptable results were obtained.

Detailed descriptions of the data and the methods of analysis are given in the appendix.

REGION AND TYPE

The ponderosa pine type has been intensively studied for many years, and several noteworthy publications have been issued dealing specifically with the factors affecting its distribution and describing its silvical characteristics (*1*, *2*, *9*, *16*, *17*, *18*, *19*, *23*, *24*). The previous findings, which pertain chiefly to the more common form of ponderosa pine stand, the uneven-aged, will not be reviewed.

The general characteristics of the even-aged ponderosa pine stand are its high density, its relatively deep litter and humus, and its high

[3] Italic numbers in parentheses refer to Literature Cited, p. 53.

yield per acre at maturity. All these characteristics are distinctly preferable from the silvicultural standpoint to those existing in uneven-aged stands. Even-aged pine culture is not advocated, however, except for areas where annual rainfall is about 25 inches or more, considerably above the minimum for the type's existence. If moisture is inadequate, stagnation results and no progress is made in volume production without expensive thinning operations.

Ponderosa pine endures a great range of climatic conditions, which accounts in part for the differences in development discussed in this report. Discussion of the climatic conditions under which it grows is hampered somewhat by the relative sparseness of data. In Oregon and Washington, at least, weather stations are too few and in too many instances remote from timber stands to afford data representative for the type. Baker and Korstian (*1*) recognized five divisions of the general range of the species, as follows: (1) Eastern Rocky Mountain, including central and eastern Montana, parts of North Dakota and South Dakota, most of Wyoming, a part of Nebraska, eastern Colorado, and northeastern New Mexico; (2) south plateau, including Arizona, most of New Mexico, southeastern Utah, and southwestern Colorado; (3) central plateau, including most of Nevada, most of Utah, southwestern Wyoming, and southeastern Idaho; (4) north plateau, including Washington, most of Oregon, most of Idaho, and western Montana; and (5) south Pacific, including California and southwestern Oregon. According to available meteorological records as charted by these authors, annual precipitation averages for the different subregions are as follows: Central plateau and eastern Rocky Mountain, about 18 inches; north and south plateaus, 22 inches; south Pacific, 44 inches. The variation about each of these averages is of course wide; in the north plateau, for instance, precipitation varies from 15 inches on the borders between desert and forest to more than 50 inches on the west slopes of the Cascade Range in Washington.

More significant than the amount of annual precipitation is its distribution through the seasons of the year. A summarization of the data tabulated by Baker and Korstian indicates that the portion of total precipitation occurring within the chief growing season, namely, May, June, July, and August, ranges from 48.8 percent in the eastern Rocky Mountain subregion to 7.0 percent in the south Pacific subregion. On the north, central, and south plateaus 22.1, 25, and 31.8 percent, respectively, of the annual precipitation occurs in the 4 months mentioned. The north plateau has a gradual decrease of precipitation from January to April, a sudden increase in May, further decrease through to August, and then a rapid rise to the end of the year. The curve for the central plateau is similar. The precipitation of the south plateau decreases irregularly through June and has a striking increase in July and August and a mild decrease through to November; thus its curve has two pronounced peaks.

Annual mean temperatures for the first four subregions were found to range only between 42° and 45° F. The south Pacific, however, has an annual mean of 51°. The temperature averages for the 4-month growing season are about 58° to 59° for the first four subregions and 63° for the last.

Conditions for pine growth are far better in the south Pacific subregion than in any of the others, although good sites can be found almost throughout the range of the species. The prevailing excellence of site conditions in California is partly explained by comparatively heavy precipitation, even though most of this occurs in off-season months, and by moderately high temperatures.

Although confined to approximately pure stands, this study gives indications as to the associates in even-aged ponderosa pine stands in the different subregions. In California incense cedar (*Libocedrus decurrens* Torrey) is a common associate, usually as an understory species. Other conifers associated with ponderosa pine in California, in descending order of frequency of occurrence, are Douglas fir (*Pseudotsuga taxifolia* (Lamb.) Britt.), white fir (*Abies concolor* Lindley), and sugar pine (*Pinus lambertiana* Dougl.). In Oregon the species most commonly found in mixture are lodgepole pine (*P. contorta* Dougl.), white fir, and Douglas fir; western larch (*Larix occidentalis* Nuttall) and Engelmann spruce (*Picea engelmanni* (Parry) Engelm.) are found occasionally. In Washington and Idaho Douglas fir and white fir are sometimes found. In Montana Douglas fir is the chief associate, with western larch a poor second.

As a part of the present study the composition of the minor vegetation has been observed by several investigators in different subregions. The grasses are the most common constituents of the ground cover, but identification of grasses as to species or even genera was seldom recorded. The following tabulation, based on observations made on 350 plots, shows the genera (with species, when known) of the herbs, shrubs, and small trees most commonly found, in five different subregions. The plants are listed for each subregion in descending order of number of plots on which observed. The list is by no means complete; the observations cover at least 75 different genera of herbs and 38 genera of shrubs and small trees. A number of distinctions are apparent, especially between California and the other subregions.

CALIFORNIA

Herbs	Shrubs and small trees
Trifolium sp.	*Chamaebatiaria foliolosa.*
Pentstemon spp.	*Toxicodendron diversilobum.*
Pteridium aquilinum pubescens.	*Arbutus menziesii.*
Apocynum androsaemifolium.	*Rhamnus purshiana.*
Vicia sp.	*Alnus rubra.*
Trientalis europaea latifolia.	*Prunus demissa.*
Fragaria sp.	*Philadelphus lewisii.*
Iris hartwegi.	*Arctostaphylos viscida* and other spp.
Galium sp.	*Ceanothus velutinus.*
Sidalcea sp.	*Rubus* spp.
Lupinus spp.	*Castanopsis sempervirens.*
Lathyrus sp.	*Lonicera involucrata.*
Potentilla sp.	*Rosa* spp.
	Ribes spp.

OREGON AND WASHINGTON

Fragaria spp.
Achillea lanulosa.
Lupinus spp.
Chamaenerion angustifolium.
Hieracium spp.
Geranium spp.
Chimaphila umbellata.
Lilium parvum.
Lathyrus spp.
Pentstemon spp.
Pyrola spp.
Vicia spp.
Vagnera liliacea.
Ceanothus velutinus.
Rosa gymnocarpa; R. nutkana.
Purshia tridentata.
Symphoricarpos racemosus.
Arctostaphylos uva-ursi.
Odostemon repens.
Prunus melanocarpa; P. emarginata.
Salix spp.
Spiraea corymbosa.
Vaccinium spp.

SOUTHERN IDAHO

Apocynum ambigens.
Fragaria spp.
Aster spp.
Arnica cordifolia.
Balsamorhiza sagittata.
Lupinus spp.
Frasera montana.
Geranium viscosissimum.
Silene menziesii.
Pentstemon spp.
Chimaphila umbellata.
Spiraea lucida.
Symphoricarpos oreophilus; S. racemosus.
Amelanchier alnifolia.
Prunus melanocarpa.
Odostemon repens.
Rosa spp.
Opulaster malvaceus.
Vaccinium sp.
Ceanothus velutinus.
Rubus parviflorus.
Arctostaphylos uva-ursi.

NORTHERN IDAHO AND MONTANA

Fragaria glauca; F. vesca.
Achillea lanulosa.
Balsamorhiza sagittata.
Lupinus sericeus; L. burkei; L. wyethii.
Geranium viscosissimum.
Arnica cordifolia.
Apocynum androsaemifolium.
Leontodon autumnale.
Potentilla gracilis.
Galium boreale.
Clarkia pulchella.
Antennaria anaphaloides; A. rosea.
Chamaenerion angustifolium.
Erigeron sp.
Aster spp.
Rosa spp.
Symphoricarpos racemosus.
Odostemon aquifolium.
Amelanchier alnifolia.
Prunus melanocarpa.
Arctostaphylos uva-ursi.
Spiraea lucida.
Opulaster malvaceus.
Crataegus douglasii.

BLACK HILLS

Apocynum androsaemifolium.
Achillea lanulosa.
Solidago spp.
Galium boreale.
Vicia americana.
Geranium viscosissimum; G. richardsoni.
Fragaria vesca americana.
Monarda mollis.
Antennaria dioica.
Thalictrum sp.
Mertensia sp.
Arctostaphylos uva-ursi.
Rosa spp.
Symphoricarpos pauciflorus.
Prunus virginiana melanocarpa.
Spiraea lucida.
Odostemon aquifolium.
Juniperus communis.
Lepargyrea canadensis.
Amelanchier alnifolia.
Rubus spp.
Ribes spp.

An effort to relate growth capacity of ponderosa pine stands to soils failed to reveal much of significance. The soils recognized in the field included silt loams, sandy loams, clay loams, gravel loams, loamy sands, clays, sandy clays, pumice soils, gravels, and others. All the loams, silt loams, clay loams, and clays were associated with site indexes ranging from 30 to 140 or more. For gravel, loamy sand, growing season are about 58° to 59° for the first four subregions and 63° for the last.

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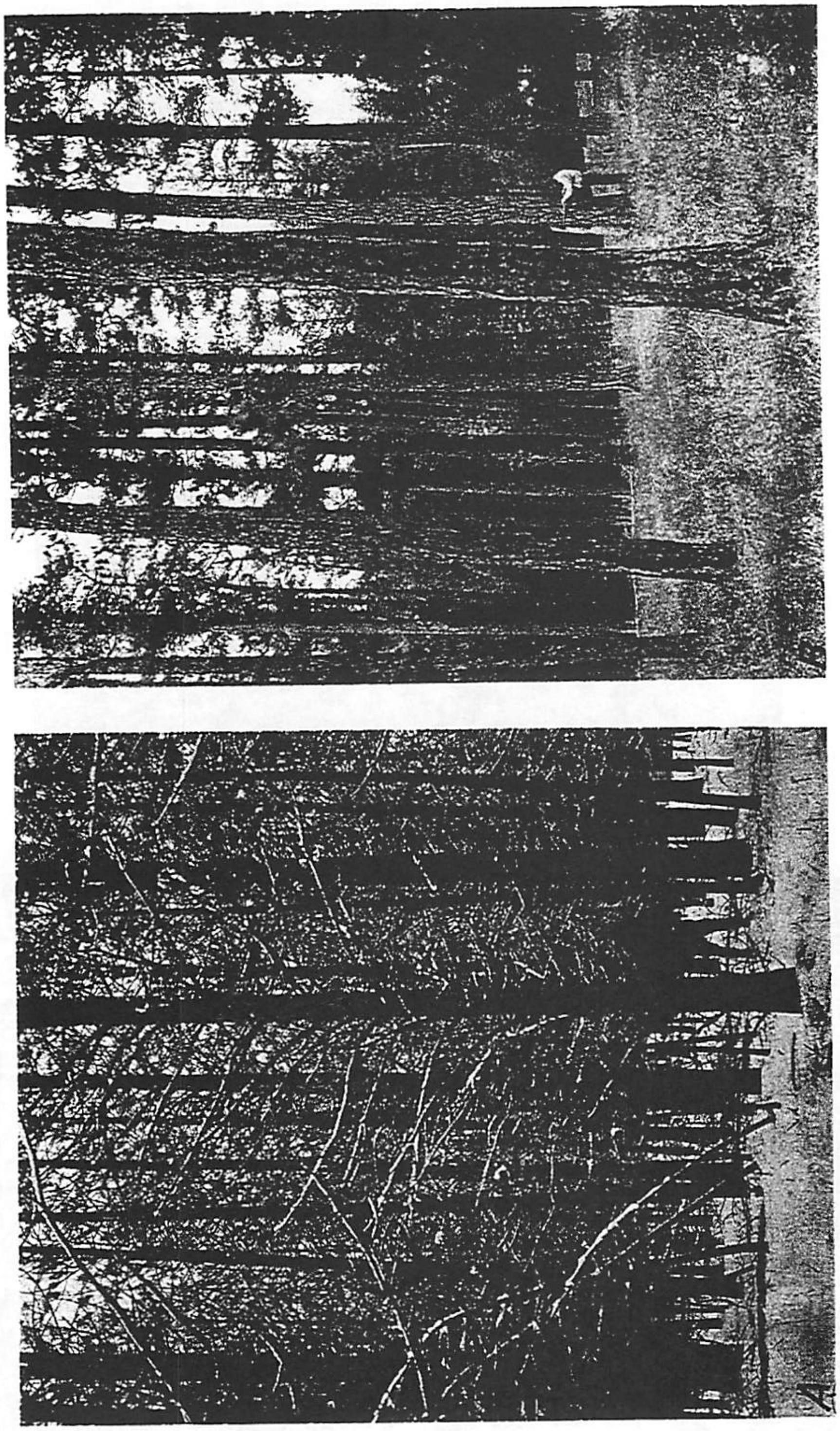

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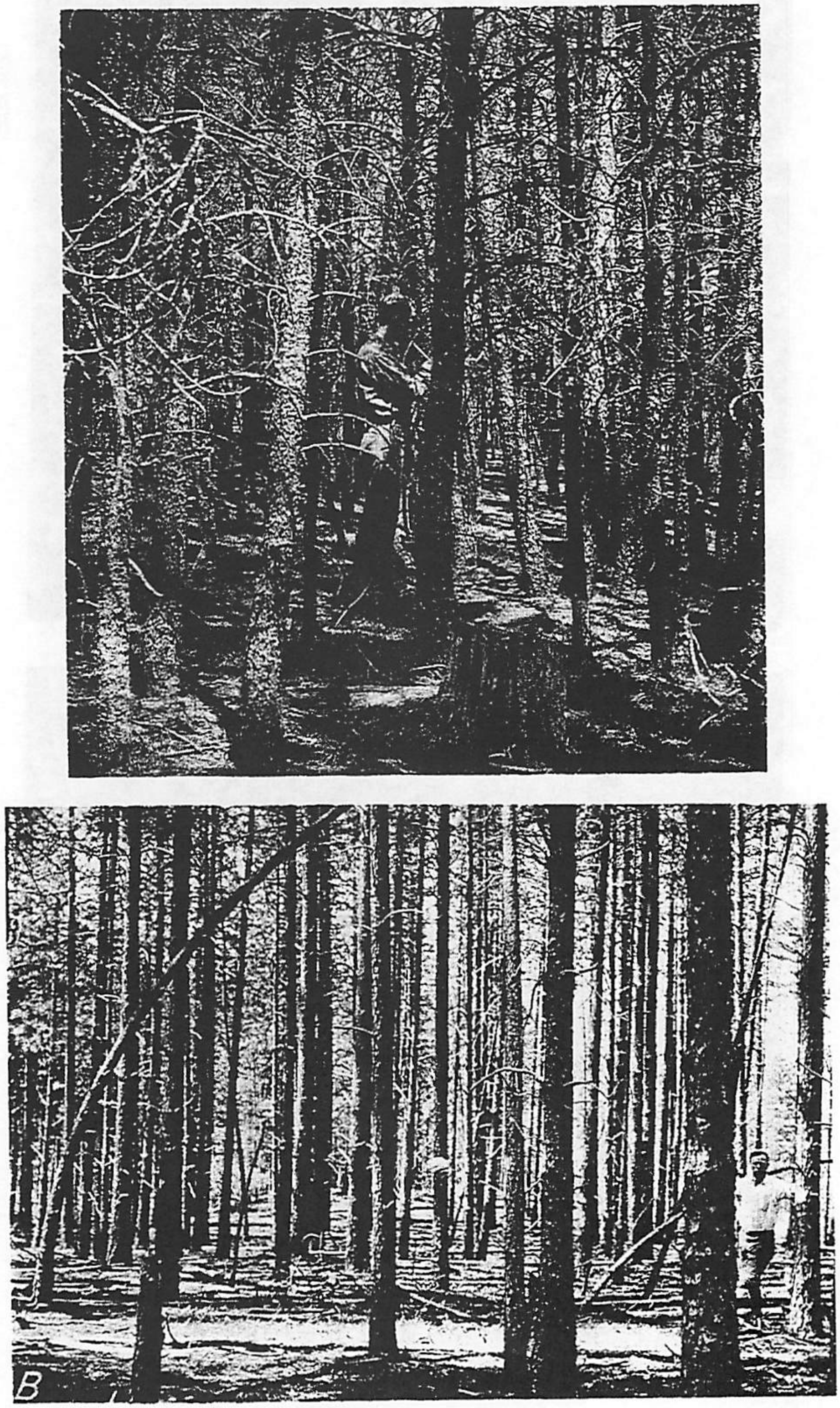
Even-aged ponderosa pine forests on land of average site quality: *A*, Stand 50 years old on area of site index 74 near Ovando, Mont.; *B*, stand 215 years old on area of site index 77 near Thompson River, Mont.



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Even-age ponderosa pine forests of 70-year age class on lands differing in site quality: *A*, Stand on area of site index 41 near Brownsville, S. Dak.; *B*, stand on area of site index 132 near Nevada City, Calif.

and pumice areas the site indexes ranged approximately from 50 to 90. For sandy areas they ranged from 30 to 70. Within any single group of soils, the darker soils seemed to be associated with higher site indexes. Most of the relations observed, however, were general only. An intensive study of the correlation between site quality and character of soil would include much more than the soil's quality, texture, color, and depth. Pearson (*17*) pointed out that in the Southwest ponderosa pine made its best growth on the more sandy or gravelly soils and reproduced more successfully on clay soils where there was a mixture of rock in the soil to facilitate root penetration. In the present study, also, it was noted repeatedly that plots where a substantial mixture of gravel was present in the soil were of higher site quality.

Plate 1 shows even-aged ponderosa pine stands on areas of average site quality in youth and maturity. Plate 2 shows stands of the 70-year age class on areas of very poor and very good site indexes.

DEFINITIONS

Acre.—In this study, as in other normal-yield studies, 43,560 square feet measured on a horizontal projection of the ground surface.

Age of stand.—Average age, in years, of sample dominant and codominant trees. If the trees are bored at breast height, to obtain total age in years it is necessary to add to the ring count a number varying from 6 for lands of the best site quality to 16 for lands of the poorest site quality.

Average diameter.—Average diameter at breast height, in inches, of an entire stand or of part of a stand, computed by dividing the total basal area of the trees by their number and converting the quotient to diameter.

Basal area.—Cross-sectional area, in square feet, at breast height.

Breast height.—A point of measurement on a tree bole located 4.5 feet above average ground level.

Dominance classes.—In this study, trees are classified on the basis of position in stand and of vigor into five dominance classes. Dominance class can usually be determined from diameter class and diameter growth alone. The classes are as follows:

Dominant.—The largest, tallest, and most vigorous trees in the stand. Crowns dense and comparatively wide and long. Growth rates the fastest in the stand.

Codominant.—Well-developed trees that reach into the main canopy but are subject to some side pressure from neighboring trees. Crowns less wide and dense than those of dominants. Growth rates good, but somewhat less than those of dominants.

Intermediate.—Trees of inferior development barely reaching into the main canopy, receiving little top light. Crowns usually narrow and of poor vigor. Growth rates low in comparison with those of dominants and codominants.

Suppressed.—Trees of inferior development, slow growth, and poor vigor below the main canopy, of the same age as those in the main canopy, receiving little direct light either from the top or from the side. Crowns narrow and short, with scant foliage. Growth practically at a standstill.

Understory.—Trees below the main canopy, younger or of different species than the trees of the main canopy, or both. The trees are not necessarily inferior as to development, growth, or vigor; often they are in excellent condition for their species.

Height curve.—Chart showing average heights of trees of various diameters for selected ages and site indexes.

Mean annual increment.—Average annual volume growth of the stand from year of origin to age under consideration.

Normal stand, or fully stocked stand.—A stand that, so far as any practical consideration is involved, utilizes its site completely. For ponderosa pine the canopy of a normal stand is less dense than it is for species of more humid climates and is not necessarily complete or continuous, especially if the stand is advanced in age. Maximum stocking is not implied; it practically never exists over a continuous area of more than a few acres.

Normal-yield tables.—Tables showing numbers and sizes of trees, total basal areas, and volumes for normal stands at different ages and on sites of different qualities.

Normality percentage.—Percentage ratio between a basal-area, volume, or other value for a given stand and the value shown by the yield tables for normal stands of corresponding age and site-quality class. This ratio is used to express stocking.

Number of trees.—Total number of living trees per acre that are above a specified diameter.

Partial stand.—Portion of total stand that is above a specified diameter. In this study two partial stands are dealt with, those of which the minimum breast-height diameters are 6.6 and 11.6 inches, respectively. The standard of utilization represented by values for the trees 6.6 inches and more in diameter is much more intensive than that followed in the ponderosa pine forests at the present time, but is comparable to that represented in many other yield studies made in the United States. Values for the trees 11.6 inches and more in diameter represent a practical standard approximating that now followed in most parts of the ponderosa pine region.

Periodic annual increment.—Average annual volume growth within a given age interval—in this study, 10 years.

Quadrat.—Portion of acre used to estimate stocking. For even-aged ponderosa pine forests, the size recommended is 9.33 feet on a side, or 0.002 acre.

Rotation age.—In this study, age at which mean annual increment culminates; that is, age at which the periodic and the mean annual increment become equal.

Site index.—Height, in feet, of average-diameter dominant and codominant trees at the age of 100 years, used as an indicator of site quality. "Site index 80," for instance, means that the dominant and codominant trees on the area referred to, average, have averaged, or will average 80 feet in height at 100 years.

Site quality.—The site quality of a forest area is its relative productive capacity, determined by climatic, soil, topographic, and other factors; the higher the site quality, the faster is tree growth and the greater is the timber volume produced per acre. Seven site-quality classes, each covering a series of 14 site indexes, are recommended for approximate rating. These classes are indicated by roman numerals.

Stand table.—Table showing distribution of number of trees throughout the range of diameter classes. The distribution is expressed either in percentage for stated average diameters of stand or in number for stated site-quality and age classes.

Stock table.—Table showing distribution of basal area or volume of trees throughout the range of diameter classes.

Stocking.—Degree to which an area's productivity is utilized by the existent forest stand.

Stand-density index.—Number of trees per acre contained in a stand when its average diameter is 10 inches. "Stand-density index 400," for instance, means that the stand referred to has, had, or will have a density of 400 trees to the acre when averaging 10 inches in diameter.

Volume table.—Table showing the estimated volumes of trees of various diameter and height classes, expressed in total cubic feet or in board feet, log scale, by the International rule or the Scribner rule.

YIELD

Practically all site conditions existing in the ponderosa pine region are represented by the site indexes 30 to 160. The indexes above 140 are represented practically nowhere in the region except in the vicinity of Nevada City, Calif. Table 1 and figure 2 show the heights for ages less and greater than 100 years that correspond to site indexes ranging from 40 to 160 at intervals of 10 in the table and 20 in the figure. By use of this table or this figure, the site index of any even-aged ponderosa pine stand can be estimated on the basis of the age of the stand and the height of its average-diameter dominant and codominant trees.

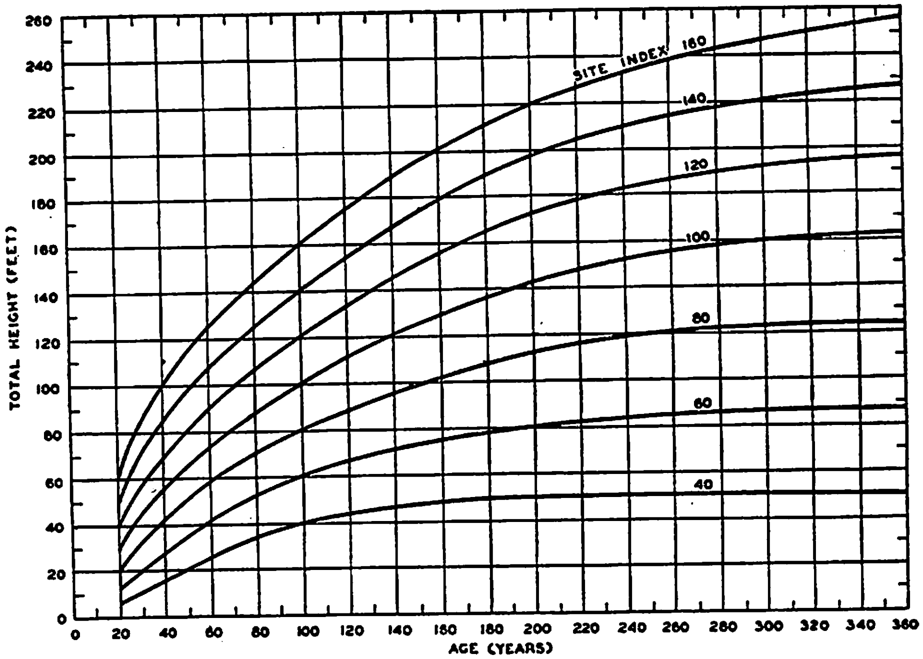

FIGURE 2.—Height of dominant and codominant trees of average breast-high diameter.

TABLE 1.—*Height of dominant and codominant trees of average breast-height diameter*

Age (years)	Height, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
20	6	9	12	16	20	25	30	35	40	45	50	55	60
30	11	15	20	26	32	38	44	51	57	64	70	77	84
40	16	22	28	35	42	49	55	63	70	77	85	93	100
50	21	28	35	43	51	58	65	73	80	89	97	105	113
60	26	34	42	50	58	66	73	81	90	99	107	115	124
70	30	39	47	56	64	73	80	89	98	108	116	125	134
80	34	43	52	61	70	79	88	97	106	116	124	133	143
90	37	47	57	66	75	85	94	104	113	123	132	142	152
100	40	50	60	70	80	90	100	110	120	130	140	150	160
110	42	53	63	74	84	95	106	116	127	137	147	158	168
120	44	55	66	77	88	100	111	122	133	144	154	165	175
130	45	57	69	80	92	104	116	128	139	151	161	172	182
140	46	59	71	83	96	108	121	133	145	157	167	179	189
150	47	60	73	86	99	112	125	138	151	163	173	185	195
160	48	61	75	89	102	116	129	143	156	169	179	191	201
170	48	62	77	91	105	119	133	147	161	174	184	196	206
180	49	63	78	93	108	122	136	151	165	179	189	201	211
190	49	63	79	95	110	125	139	154	169	183	194	205	216
200	50	64	80	97	112	128	143	157	172	187	198	209	220

Seven broad site-quality classes representing the site indexes up to 140 have been in general use in many parts of the ponderosa pine region for some years and were used in this study with only slight change (table 2). These classes can easily be distinguished in the field by the forester well versed in ponderosa pine silviculture.

A problem often encountered in evaluating site quality by tree height and age is the stagnated condition in over-dense stands of ponderosa pine on poor sites. To meet this problem in the Inland Empire region Lynch developed adjusted site curves for various levels of stocking. Curves for average-stocked stands which proved to be

TABLE 2.—*Site-quality classification for ponderosa pine,*[1] *with corresponding heights at maturity in terms of logs*

Site quality class	Site index		Logs in dominant trees at maturity [2] (number)
	Central value	Range	
I	120	+113	10 or more.
II	106	99–112	8 to 9.
III	92	85–98	7.
IV	78	71–84	5 to 6.
V	64	57–70	3 to 4.
VI	50	43–56	2.
VII	36	43—	2—.

[1] The values given for ponderosa pine in a previous publication (*14*) have here been changed slightly to make the intervals equal.
[2] Estimated in terms of 16-foot logs to 8-inch top. Maturity is assumed to begin at the age of 250 years.

better suited to the Inland Empire conditions than the present inter-regional curves were also constructed. These Inland Empire site curves* adjusted for stocking may prove useful in other parts of the ponderosa pine region upon careful checking.

STAND 0.6 INCH AND MORE IN DIAMETER

Tables 3 to 6 and figures 3 to 6 give the yield values for all trees in the stand that are 0.6 inch and more in breast-height diameter. Values are given for number of trees, basal area, average diameter, and cubic-foot volume. These tables and figures are valuable as indicating a site's productive capacity, and the yield trends in stands not yet of merchantable size. They are the standard tables from which all other yield tables of this bulletin were derived and from which still other tables, representing other standards of utilization, may be drawn.

TABLE 3.—*Number of trees per acre* [1] *0.6 inch and more in diameter*

Age (years)	Trees per acre, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
20	------	7,600	4,600	3,000	2,250	1,700	1,280	970	779	650	561	470	394
30	9,440	5,710	3,678	2,328	1,750	1,318	1,000	800	649	556	476	409	353
40	6,960	4,020	2,700	1,712	1,270	994	785	642	539	462	405	358	316
50	4,400	2,660	1,732	1,188	905	725	574	498	425	373	332	298	266
60	2,800	1,780	1,145	850	662	540	445	389	340	301	269	244	224
70	1,840	1,235	831	632	502	415	352	310	272	244	220	204	189
80	1,300	875	634	490	393	329	286	252	225	204	185	174	162
90	955	674	495	390	316	272	236	210	189	173	159	149	140
100	744	532	400	318	266	228	199	179	162	150	139	130	123
110	612	433	329	269	225	197	172	154	141	131	-----	-----	-----
120	512	368	281	230	196	171	152	136	125	115	-----	-----	-----
130	435	314	247	203	173	151	134	121	110	102	-----	-----	-----
140	375	280	219	182	153	134	120	108	99	91	-----	-----	-----
150	334	248	198	165	138	120	108	98	89	83	-----	-----	-----
160	302	227	181	150	126	109	98	88	81	75	-----	-----	-----
170	274	208	165	137	115	100	89	81	74	69	-----	-----	-----
180	254	191	152	125	106	92	82	74	68	63	-----	-----	-----
190	234	176	140	115	99	85	76	69	63	58	-----	-----	-----
200	218	167	130	108	92	79	70	64	58	54	-----	-----	-----

[1] To nearest whole number.

* LYNCH, DONALD W. EFFECT OF STOCKING ON SITE MEASUREMENT AND YIELD OF SECOND-GROWTH PONDEROSA PINE IN THE INLAND EMPIRE. Intermountain Forest and Range Expt. Sta. Res. Paper No. 56. 36 pp., illus. 1958. [Processed.]

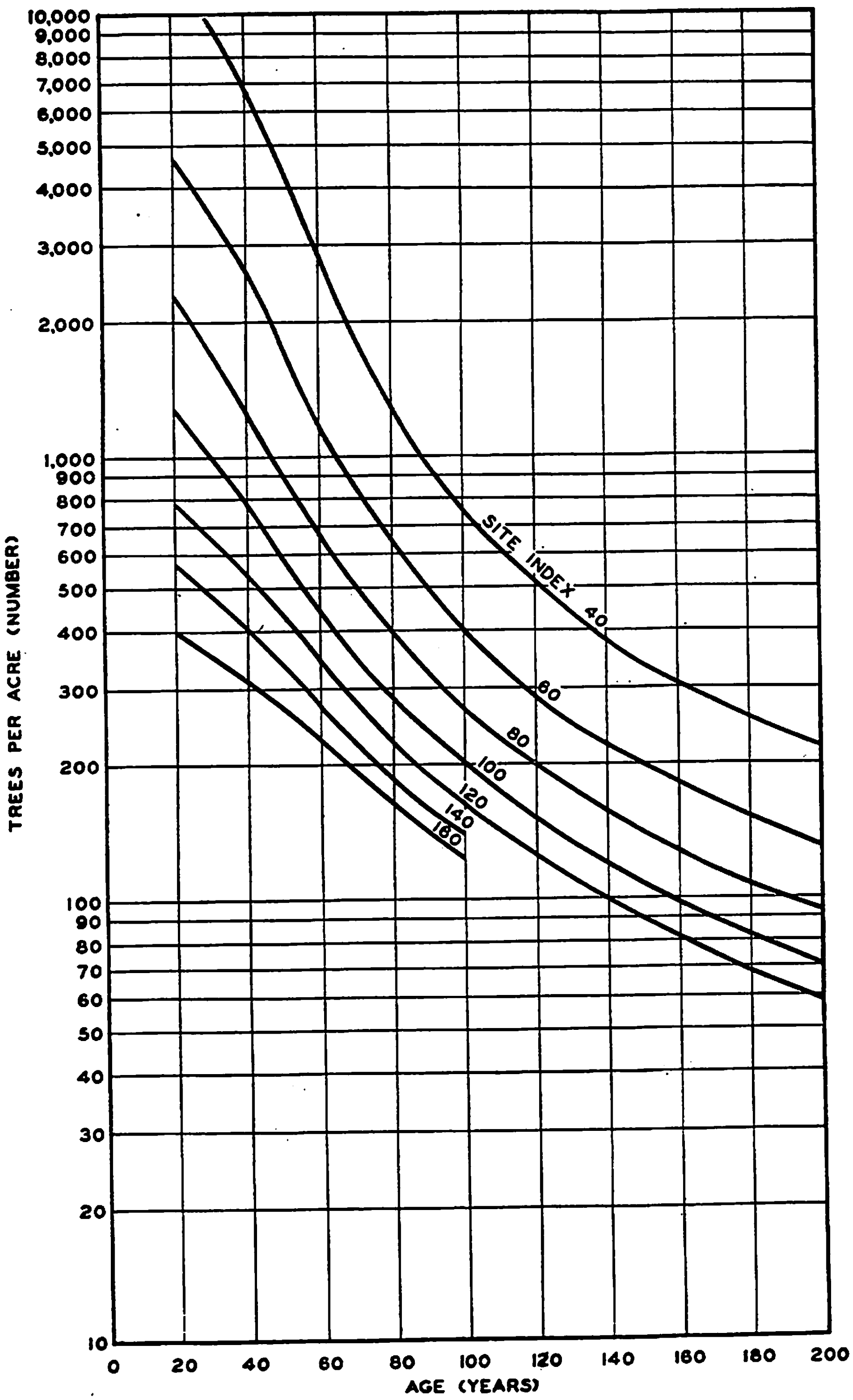

FIGURE 3.—Number of trees per acre 0.6 inch and more in breast-height diameter.

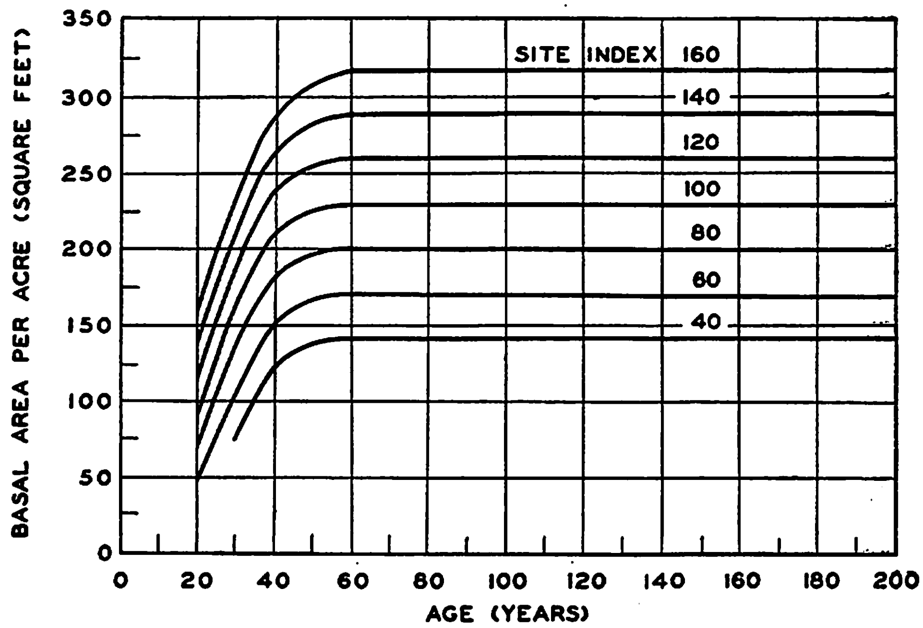

FIGURE 4.—Basal area per acre of trees 0.6 inch and more in breast-height diameter.

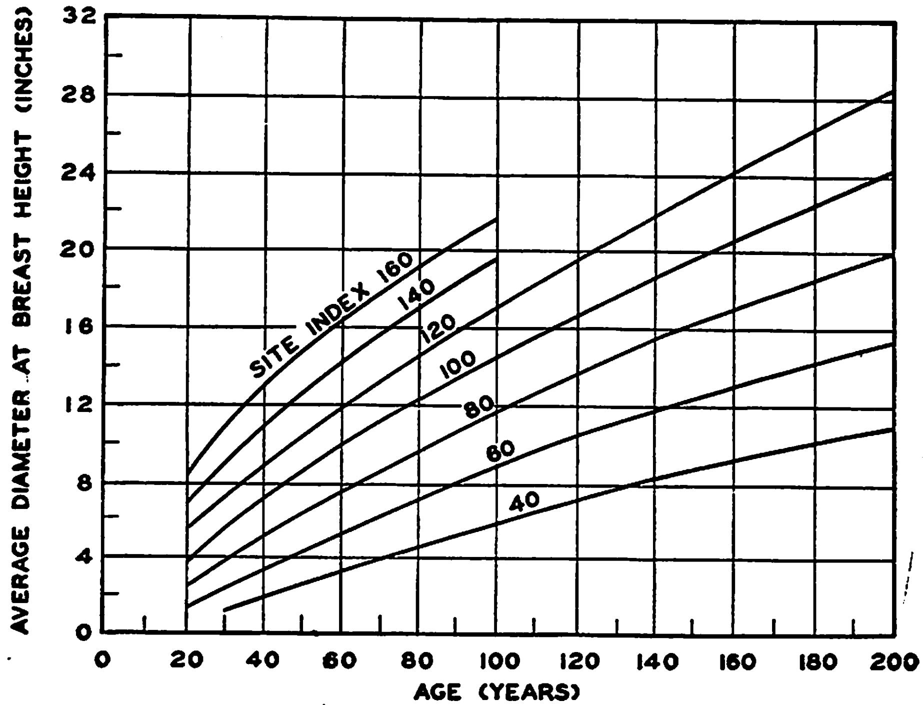

FIGURE 5.—Average diameter of trees 0.6 inch and more in breast-height diameter.

[CDF-132]

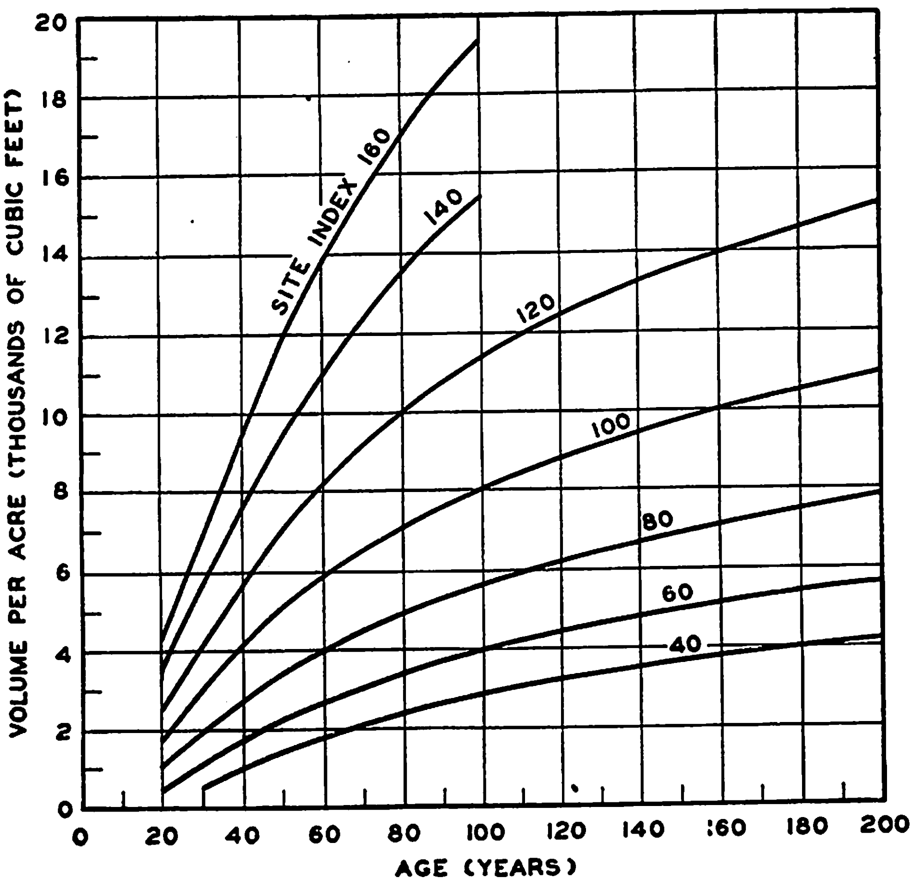

FIGURE 6.—Cubic-foot volume per acre of trees 0.6 inch and more in breast-height diameter.

TABLE 4.—*Basal area per acre*[1] *of trees 0.6 inch and more in diameter*

Age (years)	Basal area per acre, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Sq. ft.	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*
20	------	32	46	58	70	82	93	104	115	126	137	148	159
30	74	90	106	122	138	152	165	177	189	201	213	225	237
40	123	137	151	165	180	195	210	224	238	252	264	276	287
50	138	153	167	182	196	211	226	240	255	269	283	296	308
60	141	155	169	184	198	213	228	243	258	273	288	303	317
70	141	155	169	184	198	213	228	243	258	273	288	303	318
80	141	155	169	184	198	213	228	243	258	273	288	303	318
90	141	155	169	184	198	213	228	243	258	273	288	303	318
100	141	155	169	184	198	213	228	243	258	273	288	303	318
110	141	155	169	184	198	213	228	243	258	273	------	------	------
120	141	155	169	184	198	213	228	243	258	273	------	------	------
130	141	155	169	184	198	213	228	243	258	273	------	------	------
140	141	155	169	184	198	213	228	243	258	273	------	------	------
150	141	155	169	184	198	213	228	243	258	273	------		------
160	141	155	169	184	198	213	228	243	258	273	------	------	------
170	141	155	169	184	198	213	228	243	258	273	------	------	------
180	141	155	169	184	198	213	228	243	258	273	------	------	------
190	141	155	169	184	198	213	228	243	258	273	------	------	------
200	141	155	169	184	198	213	228	243	258	273	------	------	------

[1] To nearest whole number.

The tables do not list values for ages 110 and more for site indexes 140, 150, and 160, because no data were available for these ranges. Curve extensions or extrapolations would be unreliable in these extremes.

TABLE 5.—*Average diameter*[1] *of trees 0.6 inch and more in diameter*

Age (years)	Average breast-height diameter, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
20	------	0.9	1.3	1.9	2.4	3.0	3.6	4.4	5.2	6.0	6.7	7.6	8.6
30	1.2	1.7	2.3	3.1	3.8	4.6	5.5	6.4	7.3	8.2	9.1	10.1	11.1
40	1.8	2.5	3.2	4.2	5.1	6.0	7.0	8.0	9.0	10.0	10.9	11.9	12.9
50	2.4	3.2	4.2	5.3	6.3	7.3	8.5	9.4	10.5	11.5	12.5	13.5	14.6
60	3.0	4.0	5.1	6.3	7.4	8.5	9.7	10.7	11.8	12.9	14.0	15.1	16.1
70	3.7	4.8	6.0	7.3	8.5	9.7	10.9	12.0	13.2	14.3	15.5	16.5	17.6
80	4.5	5.7	7.0	8.3	9.6	10.9	12.1	13.3	14.5	15.7	16.9	17.9	19.0
90	5.2	6.5	7.9	9.3	10.7	12.0	13.3	14.6	15.8	17.0	18.2	19.3	20.4
100	5.9	7.3	8.8	10.3	11.7	13.1	14.5	15.8	17.1	18.3	19.5	20.7	21.8
110	6.5	8.1	9.7	11.2	12.7	14.1	15.6	17.0	18.3	19.6	------	------	------
120	7.1	8.8	10.5	12.1	13.6	15.1	16.6	18.1	19.5	20.9	------	------	------
130	7.7	9.5	11.2	12.9	14.5	16.1	17.7	19.2	20.7	22.2	------	------	------
140	8.3	10.1	11.9	13.6	15.4	17.1	18.7	20.3	21.9	23.4	------	------	------
150	8.8	10.7	12.5	14.3	16.2	18.0	19.7	21.4	23.1	24.6	------	------	------
160	9.3	11.2	13.1	15.0	17.0	18.9	20.7	22.5	24.2	25.8	------	------	------
170	9.7	11.7	13.7	15.7	17.8	19.8	21.7	23.5	25.3	27.0	------	------	------
180	10.1	12.2	14.3	16.4	18.5	20.6	22.6	24.5	26.4	28.2	------	------	------
190	10.5	12.7	14.9	17.1	19.2	21.4	23.5	25.5	27.5	29.4	------	------	------
200	10.9	13.1	15.4	17.7	19.9	22.2	24.4	26.5	28.6	30.6	------	------	------

[1] To nearest 0.1 inch.

TABLE 6.—*Cubic-foot volume per acre,*[1] *including stump and tip but not bark, of trees 0.6 inch and more in diameter*

Age (years)	Volume per acre, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Cu. ft.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
20	------	200	400	700	1,000	1,350	1,700	2,100	2,400	2,750	3,350	3,750	4,350
30	500	800	1,100	1,450	1,950	2,450	3,000	3,600	4,200	4,850	5,500	6,150	6,850
40	1,050	1,350	1,750	2,150	2,750	3,400	4,100	4,900	5,650	6,650	7,500	8,400	9,350
50	1,450	1,850	2,300	2,750	3,400	4,200	5,050	6,050	7,000	8,200	9,300	10,500	11,700
60	1,800	2,250	2,750	3,250	3,950	4,850	5,850	7,000	8,150	9,500	10,900	12,300	13,700
70	2,100	2,600	3,100	3,700	4,450	5,400	6,500	7,800	9,100	10,650	12,300	13,850	15,450
80	2,400	2,900	3,400	4,100	4,900	5,900	7,100	8,500	9,950	11,650	13,500	15,150	16,950
90	2,650	3,150	3,650	4,450	5,300	6,350	7,650	9,100	10,700	12,550	14,550	16,250	18,250
100	2,900	3,400	3,900	4,750	5,650	6,750	8,100	9,650	11,350	13,350	15,450	17,200	19,350
110	3,100	3,600	4,150	5,000	5,950	7,100	8,500	10,100	11,900	14,050	------	------	------
120	3,300	3,800	4,400	5,250	6,200	7,400	8,850	10,500	12,400	14,650	------	------	------
130	3,450	4,000	4,600	5,500	6,450	7,700	9,150	10,850	12,850	15,150	------	------	------
140	3,600	4,150	4,800	5,700	6,650	7,950	9,450	11,200	13,250	15,550	------	------	------
150	3,700	4,300	4,950	5,900	6,850	8,200	9,750	11,500	13,600	15,900	------	------	------
160	3,800	4,450	5,100	6,050	7,050	8,450	10,000	11,800	13,950	16,250	------	------	------
170	3,900	4,550	5,250	6,200	7,250	8,650	10,250	12,100	14,250	16,600	------	------	------
180	4,000	4,650	5,400	6,350	7,450	8,850	10,500	12,350	14,550	16,950	------	------	------
190	4,100	4,750	5,500	6,500	7,650	9,050	10,750	12,600	14,850	17,300	------	------	------
200	4,200	4,850	5,600	6,650	7,800	9,250	10,950	12,800	15,100	17,650	------	------	------

[1] To nearest 50 cubic feet.

The maximum number of trees 0.6 inch and more in diameter per acre in young ponderosa pine stands has not been determined. It must be well over 10,000, and is probably close to 20,000. At a certain age it is greater for each successively lower site-quality class. For all site qualities the number of trees decreases with advance in age, rapidly at first and then more slowly. The number per acre at maturity is never more than a few hundred, sometimes less than 100. On land of site index 80, for instance, a fully stocked stand has 1,750

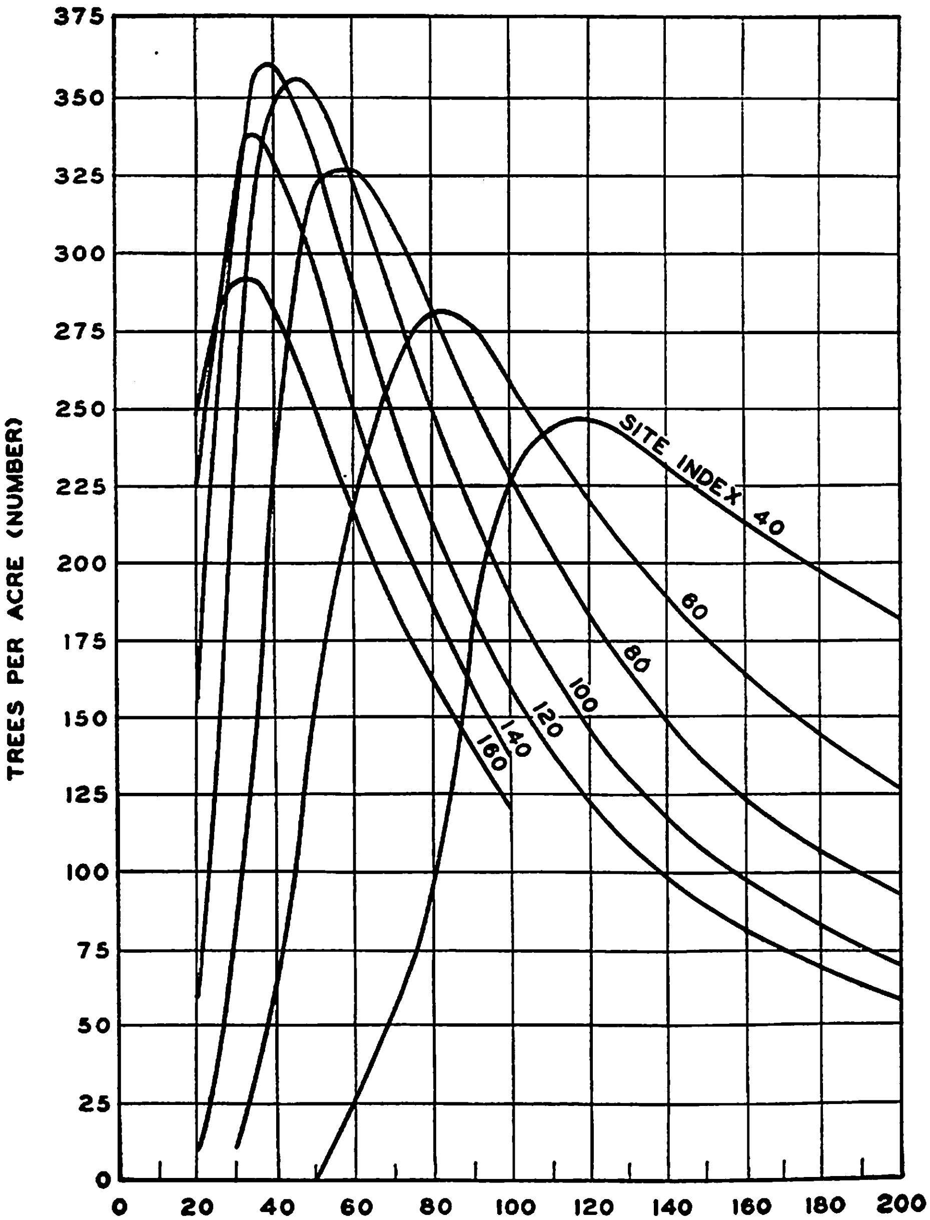

FIGURE 7.—Number of trees per acre 6.6 inches and more in breast-height diameter.

trees per acre at 30 years, but only 266 at 100 years and only 92 at 200 years.

The form of the basal-area curves in figure 4 is unusual in that the maximum value is reached at an early age and then maintained. This trend corresponds directly, however, with that shown by Behre's study of ponderosa pine in Idaho and eastern Washington (*3*, *4*).

STAND 6.6 INCHES AND MORE IN DIAMETER

Tables 7 to 11 give the yield values for all trees 6.6 inches and more in diameter. They show number of trees, basal area, average diameter, cubic-foot volume, and board-foot volume estimated by Inter-

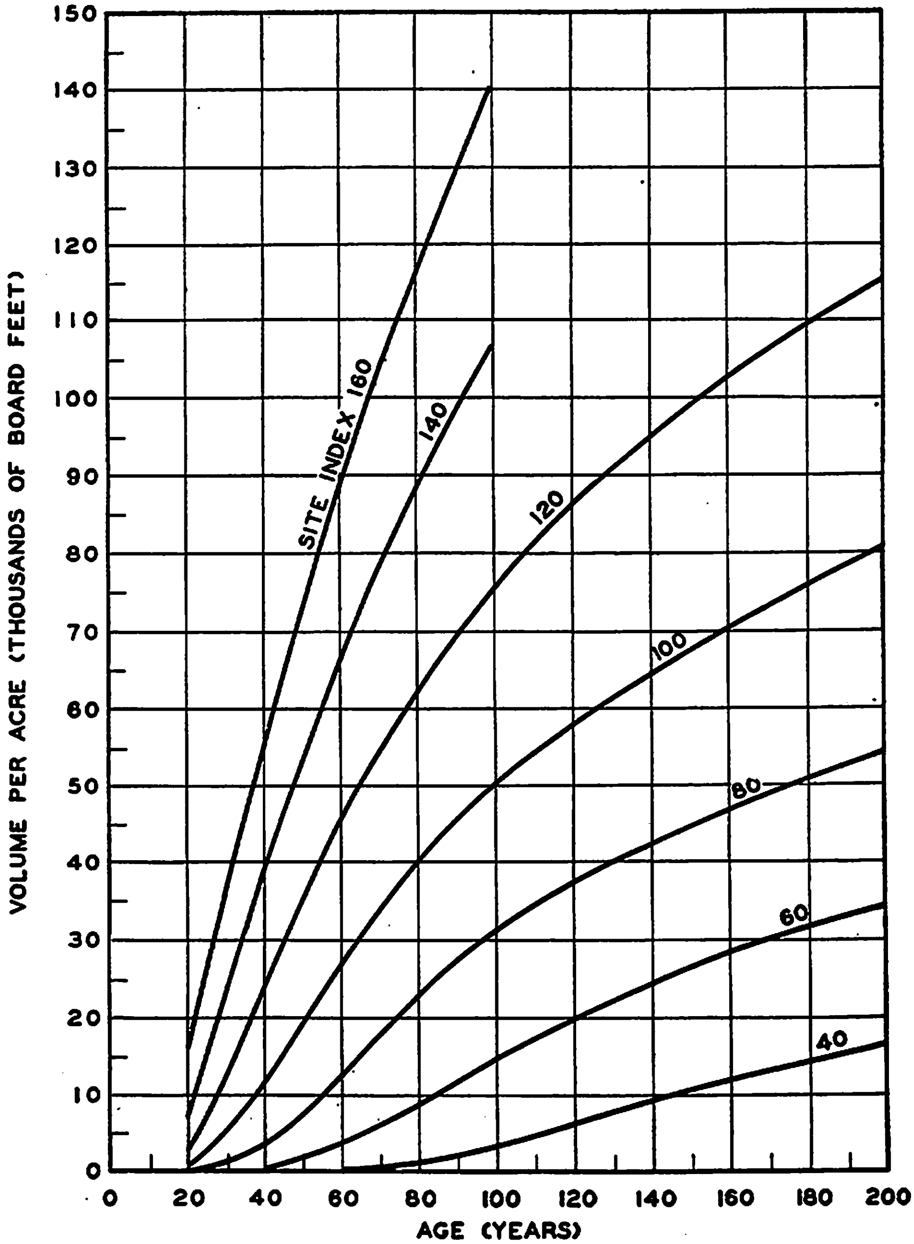

FIGURE 8.—Board-foot volume (International rule, ⅛-inch kerf) per acre of trees 6.6 inches and more in breast-height diameter.

national rule for ⅛-inch kerf to a top diameter of 6 inches inside bark. Charts showing number of trees and board-foot volume for this partial stand appear as figures 7 and 8. Other charts can be plotted from the tabulated data as needed.

The number of trees per acre in this partial stand reaches its maximum at a relatively early age for each site-quality class, but at a later age for each successively lower class. The maxima vary from 247 to 362, roughly corresponding to average spacings of 13 to 11 feet.

The board-foot values by International rule are much larger than the log scale obtained under present utilization practice, but are believed to approximate the mill scale that will be realized when the logging is conducted according to the highest standard of woods utilization and the lumber is cut with band saws. It is reasonable to assume that this standard of utilization will be attained as soon in the ponderosa pine forests as in most other forests of the far West, particularly of the Pacific Northwest. At present this table will be useful in making comparisons with yields of other timber species of the United States, since in most of the yield studies thus far made in the West these standards of estimate have been followed.

TABLE 7.—*Number of trees per acre*[1] *6.6 inches and more in diameter*

Age (years)	Trees per acre, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
20					8	28	61	104	156	202	226	242	248
30			11	47	100	166	242	290	313	322	320	308	290
40		21	66	151	238	309	348	362	360	346	329	310	284
50	11	72	154	254	318	349	354	350	334	315	295	274	253
60	28	126	218	296	326	333	324	310	291	274	252	232	218
70	55	190	260	303	310	301	286	270	249	232	213	199	186
80	96	236	280	292	282	266	249	232	215	197	182	171	160
90	175	252	274	272	253	236	216	200	184	168	157	148	139
100	226	256	259	246	227	208	190	174	159	147	138	129	122
110	244	250	240	224	203	185	166	151	139	129			
120	247	237	222	202	182	164	146	135	123	114			
130	241	224	205	185	165	146	131	120	109	101			
140	232	212	188	170	148	131	118	107	98	91			
150	222	200	175	157	134	118	107	97	89	83			
160	213	188	163	144	122	108	97	88	81	75			
170	204	178	154	132	113	99	89	81	74	69			
180	196	168	144	122	105	91	82	74	68	63			
190	188	159	134	113	98	85	76	69	63	58			
200	180	152	126	106	91	79	70	64	58	54			

[1] To nearest whole number.

TABLE 8.—*Basal area per acre*[1] *of trees 6.6 inches and more in diameter*

Age (years)	Basal area per acre, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Sq.ft.	*Sq.ft.*	*Sq.ft.*	*Sq.ft.*	*Sq.ft.*	*Sq.ft.*	*Sq.ft.*	*Sq.ft.*	*Sq.ft.*	*Sq.ft.*	*Sq.ft.*	*Sq.ft.*	*Sq.ft.*
20					2	9	20	36	59	82	100	119	138
30			3	15	32	58	94	124	148	172	192	210	227
40		6	20	51	88	126	161	188	212	235	252	268	282
50	3	22	52	96	134	165	195	219	241	260	277	292	306
60	8	42	81	125	157	185	210	231	252	268	285	301	315
70	16	69	106	144	172	195	217	237	255	271	286	302	317
80	30	93	128	157	181	202	222	240	256	272	287	302	318
90	58	109	140	167	187	207	224	242	257	272	287	303	318
100	80	121	149	173	192	210	226	242	257	272	288	303	318
110	93	131	156	177	194	211	227	242	257	273			
120	101	137	160	179	196	212	227	243	258	273			
130	106	141	163	181	197	212	228	243	258	273			
140	110	145	164	182	197	212	228	243	258	273			
150	113	148	165	183	197	212	228	243	258	273			
160	115	149	166	183	197	213	228	243	258	273			
170	118	150	167	183	197	213	228	243	258	273			
180	121	151	168	183	198	213	228	243	258	273			
190	124	152	168	183	198	213	228	243	258	273			
200	126	153	168	184	198	213	228	243	258	273			

[1] To nearest whole number.

TABLE 9.—*Average diameter* [1] *of trees 6.6 inches and more in diameter*

Age (years)	Average breast-height diameter, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
20	------	------	------	------	7.2	7.4	7.6	8.0	8.3	8.6	9.0	9.5	10.1
30	------	------	7.2	7.5	7.7	8.0	8.4	8.8	9.3	9.9	10.5	11.2	12.0
40	------	7.3	7.5	7.9	8.2	8.6	9.2	9.7	10.4	11.2	11.8	12.6	13.5
50	7.2	7.5	7.8	8.3	8.8	9.3	10.0	10.7	11.5	12.3	13.1	14.0	14.9
60	7.3	7.8	8.2	8.8	9.4	10.1	10.9	11.7	12.6	13.4	14.4	15.4	16.3
70	7.4	8.2	8.6	9.4	10.1	10.9	11.8	12.7	13.7	14.6	15.7	16.7	17.7
80	7.6	8.5	9.1	10.0	10.8	11.8	12.8	13.8	14.8	15.9	17.0	18.0	19.1
90	7.8	8.9	9.7	10.6	11.6	12.7	13.8	14.9	16.0	17.2	18.3	19.4	20.5
100	8.0	9.3	10.3	11.3	12.4	13.6	14.8	16.0	17.2	18.4	19.6	20.8	21.9
110	8.3	9.8	10.9	12.0	13.2	14.5	15.8	17.1	18.4	19.7	------	------	------
120	8.6	10.3	11.5	12.7	14.0	15.4	16.8	18.2	19.6	21.0	------	------	------
130	9.0	10.8	12.1	13.4	14.8	16.3	17.8	19.3	20.8	22.2	------	------	------
140	9.3	11.2	12.7	14.0	15.6	17.2	18.8	20.4	22.0	23.4	------	------	------
150	9.6	11.6	13.2	14.6	16.4	18.1	19.8	21.5	23.1	24.6	------	------	------
160	10.0	12.0	13.7	15.3	17.2	19.0	20.8	22.5	24.2	25.8	------	------	------
170	10.3	12.4	14.2	16.0	17.9	19.8	21.7	23.5	25.3	27.0	------	------	------
180	10.6	12.8	14.7	16.6	18.6	20.6	22.6	24.5	26.4	28.2	------	------	------
190	11.0	13.2	15.2	17.2	19.3	21.4	23.5	25.5	27.5	29.4	------	------	------
200	11.4	13.6	15.7	17.8	20.0	22.2	24.4	26.5	28.6	30.6	------	------	------

[1] To nearest 0.1 inch.

TABLE 10.—*Cubic-foot volume per acre,*[1] *including stump and tip but not bark, of trees 6.6 inches and more in diameter*

Age (years)	Volume per acre, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Cu. ft.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
20	------	------	------	------	20	140	350	830	1,300	1,840	2,520	3,150	3,970
30	------	------	50	210	420	1,060	1,770	2,630	3,420	4,320	5,150	5,950	7,040
40	------	80	310	720	1,290	2,280	3,260	4,290	5,260	6,380	7,370	8,320	9,610
50	60	280	820	1,480	2,240	3,390	4,540	5,710	6,790	8,050	9,240	10,420	11,830
60	160	640	1,450	2,220	3,100	4,340	5,560	6,820	8,000	9,420	10,860	12,260	13,760
70	360	1,130	2,080	2,920	3,820	5,090	6,350	7,710	9,040	10,600	12,260	13,850	15,450
80	690	1,640	2,650	3,530	4,440	5,720	7,020	8,460	9,940	11,640	13,460	15,150	16,950
90	1,090	2,100	3,150	4,050	4,970	6,250	7,600	9,090	10,700	12,550	14,550	16,250	18,250
100	1,480	2,500	3,570	4,480	5,410	6,700	8,090	9,620	11,350	13,350	15,450	17,200	19,350
110	1,820	2,850	3,930	4,850	5,790	7,080	8,500	10,100	11,900	14,050	------	------	------
120	2,110	3,150	4,240	5,170	6,120	7,410	8,850	10,500	12,400	14,650	------	------	------
130	2,350	3,400	4,500	5,440	6,400	7,690	9,150	10,850	12,850	15,150	------	------	------
140	2,540	3,600	4,710	5,670	6,640	7,950	9,450	11,200	13,250	15,550	------	------	------
150	2,700	3,770	4,890	5,870	6,850	8,200	9,750	11,500	13,600	15,900	------	------	------
160	2,840	3,920	5,050	6,040	7,050	8,450	10,000	11,800	13,950	16,250	------	------	------
170	2,970	4,060	5,200	6,190	7,250	8,650	10,250	12,100	14,250	16,600	------	------	------
180	3,090	4,190	5,340	6,340	7,450	8,850	10,500	12,350	14,550	16,950	------	------	------
190	3,200	4,310	5,470	6,490	7,650	9,050	10,750	12,600	14,850	17,300	------	------	------
200	3,300	4,420	5,590	6,640	7,800	9,250	10,950	12,800	15,100	17,650	------	------	------

[1] To nearest 10 cubic feet.

TABLE 11.—*Board-foot volume per acre,*[1] *International rule (⅛-inch kerf), of trees 6.6 inches and more in diameter*

Age (years)	Volume per acre, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
20	------	------	------	------	------	200	600	1,400	2,800	4,500	7,300	10,800	16,500
30	------	------	------	400	1,100	2,800	5,400	8,200	12,500	17,400	23,200	28,800	36,200
40	------	------	500	1,900	3,700	7,100	11,900	17,000	23,900	31,400	39,000	46,400	55,200
50	------	500	1,800	4,500	7,700	12,700	19,300	26,400	35,200	44,400	53,400	62,500	72,500
60	100	1,500	3,700	7,600	12,600	19,000	27,000	35,300	45,400	56,000	66,400	77,000	88,300
70	400	3,000	6,100	11,200	17,900	25,400	34,000	43,200	54,300	66,300	78,100	90,200	102,900
80	1,000	4,900	8,800	15,000	23,100	31,100	40,200	50,100	62,200	75,400	88,700	102,300	116,400
90	1,900	7,000	11,700	18,600	27,500	36,100	45,600	56,300	69,300	83,500	98,300	113,300	128,800
100	3,200	9,200	14,600	22,000	31,200	40,300	50,300	61,800	75,600	90,800	107,000	123,300	140,200
110	4,600	11,300	17,400	25,000	34,400	43,900	54,500	66,600	81,300	97,500	-------	-------	-------
120	6,200	13,300	20,000	27,700	37,300	47,200	58,200	71,000	86,400	103,600	-------	-------	-------
130	7,800	15,200	22,300	30,200	40,000	50,200	61,600	75,000	91,000	108,900	-------	-------	-------
140	9,300	17,000	24,400	32,500	42,500	53,000	64,800	78,700	95,200	113,800	-------	-------	-------
150	10,700	18,700	26,400	34,600	44,800	55,600	67,800	82,200	99,100	118,200	-------	-------	-------
160	12,000	20,300	28,300	36,600	46,900	58,100	70,600	85,500	102,800	122,200	-------	-------	-------
170	13,200	21,800	30,000	38,500	48,900	60,500	73,300	88,500	106,300	126,000	-------	-------	-------
180	14,400	23,200	31,600	40,300	50,900	62,800	75,900	91,300	109,600	129,600	-------	-------	-------
190	15,600	24,600	33,100	42,000	52,800	65,000	78,400	94,000	112,700	133,000	-------	-------	-------
200	16,700	26,000	34,600	43,700	54,700	67,100	80,800	96,700	115,600	136,300	-------	-------	-------

[1] To 6-inch top inside bark, exclusive of 2-foot stump, measured to nearest 100 board feet.

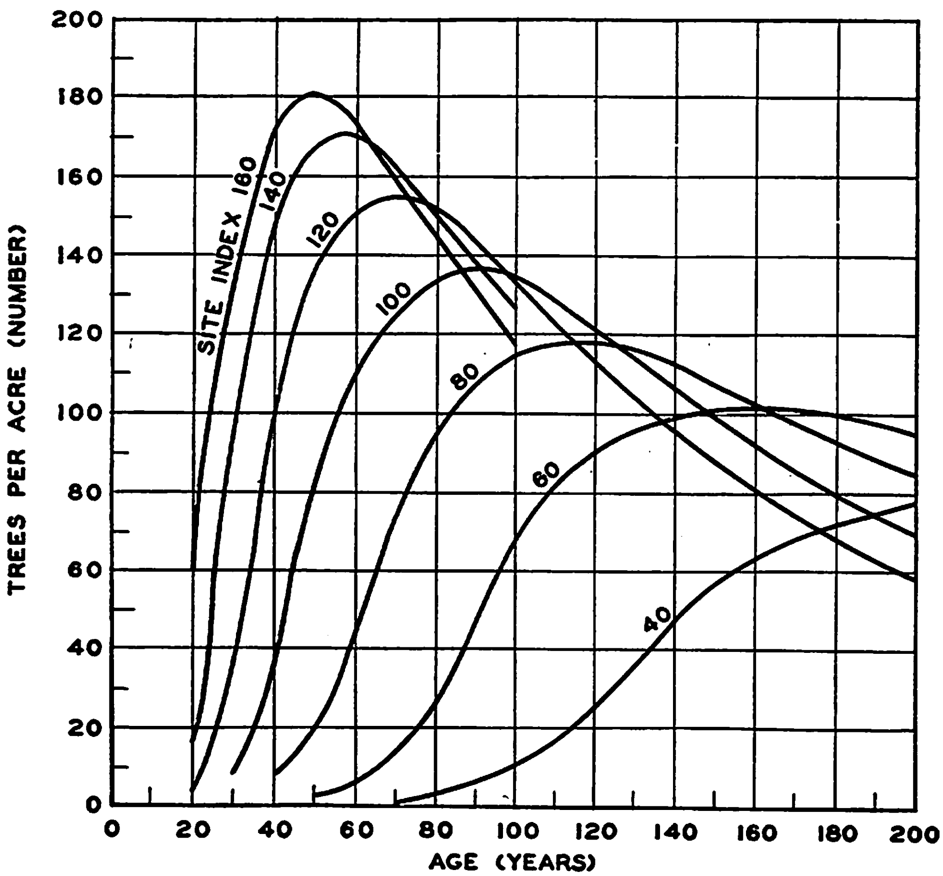

FIGURE 9.—Number of trees per acre 11.6 inches and more in breast-height diameter.

STAND 11.6 INCHES AND MORE IN DIAMETER

Tables 12 to 16 and figures 9 and 10 give values for all trees in the stand that are 11.6 inches or more in breast-height diameter. The tables show number of trees, basal area, average diameter, cubic-foot volume, and board-foot volume estimated by Scribner rule to an 8-inch top diameter inside bark. The figures show number of trees

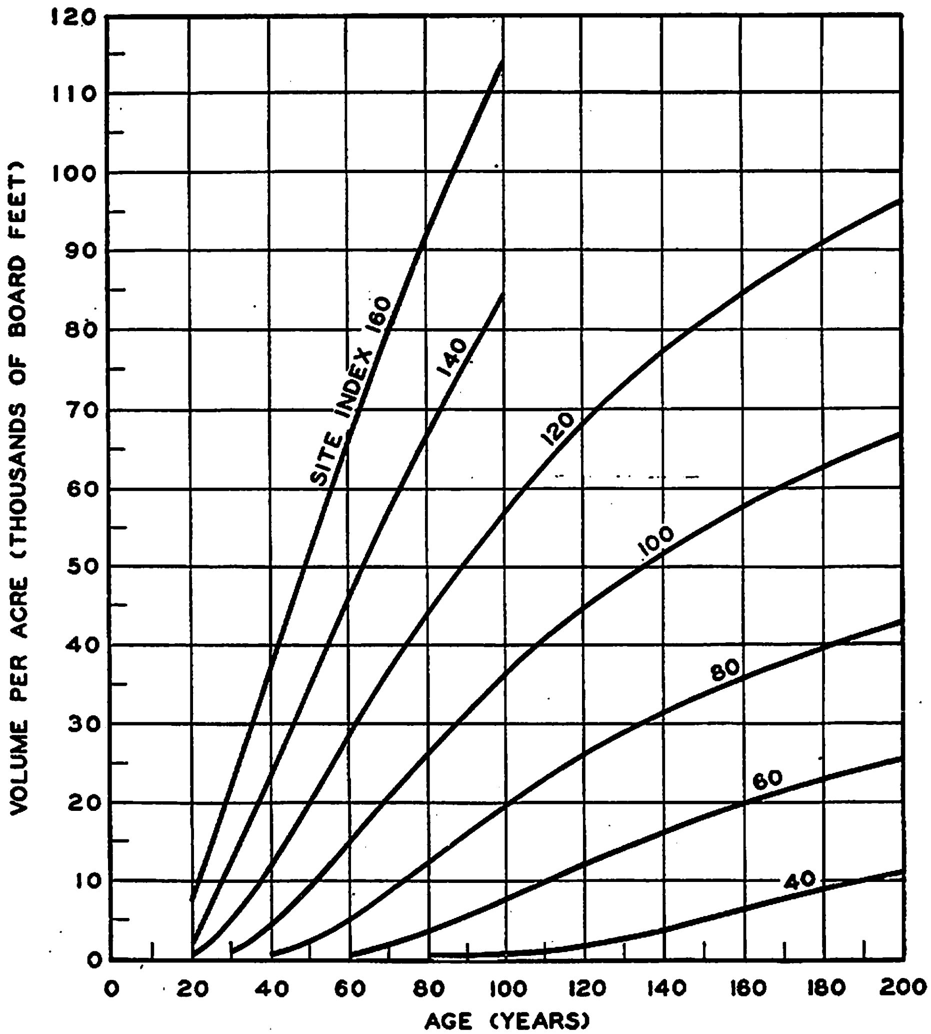

FIGURE 10.—Board-foot volume (Scribner rule) per acre of trees 11.6 inches and more in breast-height diameter.

and board-foot volume. The other values can be plotted and curved as needed.

The maximum number of trees per acre for this portion of the stand varies from 78 to 181 according to site quality. These values represent an average spacing of roughly 24 to 16 feet. The better the site quality, the larger the maximum number of trees. The spacing increases rapidly with advancing age of the stand, because of the reduction in total number of trees of this size range.

The yield values in board feet, Scribner rule, for this part of the stand approximate closely those already realized under current logging practice in well-stocked stands in many parts of the ponderosa pine region. With careful practice substantial overruns will be obtained in the mill.

TABLE 12.—*Number of trees per acre* [1] *11.6 inches and more in diameter*

Age (years)	Trees per acre, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
20	------	------	------	------	------	------	------	2	4	10	17	35	60
30	------	------	------	------	------	3	9	20	37	66	92	116	133
40	------	------	------	3	8	17	36	65	100	127	146	162	172
50	------	------	3	9	21	41	84	110	136	155	168	178	181
60	------	2	6	18	42	79	109	132	151	164	171	174	174
70	1	6	14	36	73	103	126	143	155	161	163	162	160
80	3	11	27	63	94	117	134	146	152	154	151	149	145
90	7	18	47	85	107	125	137	143	145	143	138	135	131
100	11	31	68	96	115	128	135	136	134	131	127	122	118
110	16	47	81	104	118	126	129	127	123	120	------	------	------
120	25	62	90	109	118	123	122	118	113	109	------	------	------
130	35	73	95	110	117	118	114	109	104	100	------	------	------
140	48	79	99	110	113	111	107	101	96	91	------	------	------
150	57	84	101	109	108	104	100	93	88	83	------	------	------
160	64	88	102	107	103	98	93	86	81	75	------	------	------
170	68	90	101	104	98	92	86	80	74	69	------	------	------
180	72	92	100	100	93	87	80	74	68	63	------	------	------
190	76	93	98	96	89	82	75	69	63	58	------	------	------
200	78	93	96	92	85	78	70	64	58	54	------	------	------

[1] To nearest whole number.

TABLE 13.—*Basal area per acre* [1] *of trees 11.6 inches and more in diameter*

Age (years)	Basal area per acre, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Sq. ft.	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*
20	------	------	------	------	------	------	------	2	4	9	16	33	60
30	------	------	------	------	------	3	8	18	35	64	95	126	154
40	------	------	------	3	7	15	34	63	102	138	168	199	228
50	------	------	3	8	19	39	83	115	153	186	217	246	272
60	------	2	5	16	40	78	117	150	185	217	248	273	295
70	1	5	13	34	73	110	145	178	209	236	263	284	305
80	3	10	25	62	100	135	169	199	226	251	273	292	310
90	6	17	45	88	122	155	188	215	239	259	278	297	314
100	10	29	69	106	140	172	200	225	245	264	282	300	317
110	15	46	87	122	154	183	209	231	249	268	------	------	------
120	23	62	101	136	165	192	215	235	252	270	------	------	------
130	34	77	112	146	174	198	219	238	255	272	------	------	------
140	47	87	122	154	180	202	222	240	257	273	------	------	------
150	57	96	130	160	185	205	224	242	258	273	------	------	------
160	66	103	137	165	188	207	226	243	258	273	------	------	------
170	73	110	142	169	190	209	227	243	258	273	------	------	------
180	79	116	146	172	192	211	228	243	258	273	------	------	------
190	85	121	150	175	194	212	228	243	258	273	------	------	------
200	90	125	154	177	195	213	228	243	258	273	------	------	------

[1] To nearest whole number.

TABLE 14.—*Average diameter* [1] *of trees 11.6 inches and more in diameter*

Age (years)	Average breast-height diameter, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
20	------	------	------	------	------	------	------	12.7	12.8	12.9	13.0	13.2	13.5
30	------	------	------	------	------	12.7	12.8	12.9	13.2	13.4	13.7	14.1	14.6
40	------	------	------	12.7	12.8	12.9	13.1	13.3	13.7	14.1	14.5	15.0	15.6
50	------	------	12.6	12.8	12.9	13.2	13.5	13.8	14.3	14.8	15.4	15.9	16.6
60	------	12.6	12.7	12.9	13.2	13.5	14.0	14.4	15.0	15.6	16.3	16.9	17.6
70	12.6	12.7	12.9	13.1	13.5	14.0	14.6	15.1	15.7	16.4	17.2	17.9	18.7
80	12.7	12.8	13.1	13.4	13.9	14.5	15.2	15.8	16.5	17.3	18.2	18.9	19.8
90	12.8	13.0	13.3	13.8	14.4	15.1	15.8	16.6	17.4	18.2	19.2	20.0	21.0
100	12.9	13.2	13.6	14.2	14.9	15.7	16.5	17.4	18.3	19.2	20.2	21.2	22.2
110	13.0	13.4	14.0	14.6	15.5	16.3	17.2	18.3	19.2	20.2	------	------	------
120	13.1	13.6	14.4	15.1	16.0	16.9	18.0	19.1	20.2	21.3	------	------	------
130	13.2	13.9	14.7	15.6	16.5	17.6	18.8	20.0	21.2	22.4	------	------	------
140	13.4	14.2	15.0	16.0	17.1	18.3	19.5	20.9	22.2	23.5	------	------	------
150	13.6	14.4	15.4	16.4	17.7	19.0	20.3	21.8	23.2	24.6	------	------	------
160	13.8	14.6	15.7	16.8	18.3	19.7	21.1	22.7	24.2	25.8	------	------	------
170	14.0	14.9	16.0	17.3	18.9	20.4	22.0	23.6	25.3	27.0	------	------	------
180	14.2	15.2	16.4	17.8	19.5	21.1	22.8	24.5	26.4	28.2	------	------	------
190	14.4	15.5	16.8	18.3	20.0	21.7	23.6	25.5	27.5	29.4	------	------	------
200	14.6	15.7	17.1	18.8	20.5	22.4	24.4	26.5	28.6	30.6	------	------	------

[1] To nearest 0.1 inch.

TABLE 15.—*Cubic-foot volume per acre,*[1] *including stump and tip but not bark, of trees 11.6 inches and more in diameter*

Age (years)	Volume per acre, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Cu. ft.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
20	------	------	------	------	------	------	------	40	120	280	530	1,060	1,880
30	------	------	------	------	------	60	200	470	970	1,860	2,750	3,760	4,910
40	------	------	------	30	120	340	820	1,740	2,770	3,990	5,230	6,580	7,950
50	------	------	30	150	410	970	2,060	3,230	4,600	6,170	7,670	9,260	10,780
60	------	30	120	400	990	2,040	3,280	4,710	6,320	8,080	9,830	11,520	13,140
70	------	90	310	870	1,870	3,090	4,440	6,110	7,910	9,730	11,590	13,380	15,080
80	50	220	710	1,650	2,720	4,110	5,540	7,310	9,210	11,100	13,030	14,880	16,640
90	110	470	1,310	2,400	3,520	5,010	6,520	8,310	10,280	12,230	14,200	16,110	17,940
100	240	870	1,960	3,100	4,270	5,790	7,310	9,130	11,140	13,140	15,160	17,430	19,020
110	460	1,370	2,560	3,710	4,890	6,420	7,950	9,780	11,800	13,900	------	------	------
120	780	1,820	3,060	4,220	5,410	6,950	8,490	10,330	12,360	14,540	------	------	------
130	1,140	2,210	3,460	4,640	5,850	7,400	8,950	10,800	12,840	15,070	------	------	------
140	1,450	2,550	3,810	5,000	6,230	7,780	9,340	11,200	13,250	15,500	------	------	------
150	1,720	2,840	4,110	5,320	6,560	8,120	9,680	11,550	13,600	15,850	------	------	------
160	1,950	3,080	4,360	5,600	6,840	8,420	9,990	11,850	13,950	16,200	------	------	------
170	2,160	3,300	4,590	5,840	7,090	8,680	10,270	12,150	14,250	16,550	------	------	------
180	2,360	3,510	4,810	6,060	7,320	8,920	10,500	12,400	14,550	16,900	------	------	------
190	2,550	3,710	5,020	6,270	7,530	9,140	10,750	12,650	14,850	17,250	------	------	------
200	2,730	3,900	5,220	6,470	7,730	9,340	10,950	12,850	15,100	17,600	------	------	------

[1] To nearest 10 cubic feet.

TABLE 16.—*Board-foot volume* [1] *per acre, Scribner rule, of trees 11.6 inches and more in diameter*

Age (years)	Volume per acre, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
20								100	400	900	1, 900	3, 800	7, 300
30						200	1, 000	2, 500	5, 100	8, 400	11, 800	16, 000	21, 400
40				100	600	1, 900	4, 300	7, 500	12, 100	17, 600	23, 100	29, 200	36, 500
50			100	700	2, 300	5, 000	9, 200	14, 000	20, 300	27, 400	34, 600	42, 500	51, 300
60			600	2, 200	5, 100	9, 100	14, 800	21, 000	28, 400	37, 000	45, 800	55, 300	65, 400
70		300	1, 800	4, 300	8, 500	13, 800	20, 500	27, 800	36, 400	46, 200	56, 500	67, 300	78, 800
80	100	900	3, 500	7, 000	12, 200	18, 500	26, 000	34, 200	43, 900	54, 800	66, 500	78, 600	91, 300
90	200	2, 000	5, 500	10, 000	16, 000	23, 000	31, 200	40, 200	50, 800	62, 700	75, 800	89, 200	103, 000
100	400	3, 400	7, 800	13, 100	19, 700	27, 200	36, 100	45, 800	57, 100	70, 000	84, 400	99, 100	113, 900
110	800	5, 000	10, 200	16, 200	23, 100	31, 100	40, 600	50, 800	62, 900	76, 700			
120	1, 500	7, 000	12, 500	19, 000	26, 200	34, 700	44, 600	55, 400	68, 200	82, 800			
130	2, 500	8, 900	14, 700	21, 500	29, 000	38, 000	48, 300	59, 600	73, 000	88, 300			
140	3, 800	10, 700	16, 700	23, 700	31, 500	40, 900	51, 700	63, 400	77, 400	93, 200			
150	5, 200	12, 400	18, 500	25, 700	33, 800	43, 600	54, 800	66, 900	81, 400	97, 600			
160	6, 600	13, 900	20, 100	27, 500	35, 900	46, 100	57, 600	70, 100	84, 900	101, 500			
170	7, 900	15, 300	21, 600	29, 200	37, 800	48, 400	60, 100	73, 000	88, 000	105, 000			
180	9, 000	16, 600	23, 100	30, 900	39, 600	50, 500	62, 400	75, 600	90, 900	108, 200			
190	10, 000	17, 800	24, 500	32, 500	41, 300	52, 400	64, 600	78, 000	93, 600	111, 200			
200	11, 000	19, 000	25, 800	34, 000	43, 000	54, 200	66, 700	80, 200	96, 100	114, 100			

[1] In 16-foot logs to 8-inch top, exclusive of 2-foot stump, measured to nearest 100 board feet.

COMPARISON WITH PREVIOUS FINDINGS

As has been mentioned, studies have previously been made of the yield of even-aged stands of ponderosa pine in several different portions of the range of the species. Reports on studies of this kind have been written by Gallaher,[4] Show (*22*), Alexander (*5*), Behre (*3*, *4*), Dunning and Reineke (*11*), and Reineke.[5]

Of the six studies listed, Gallaher's showed the highest volumes for given site indexes and ages, Alexander's the lowest. The small part of California to which Gallaher's data refer is unsurpassed for pine production throughout the ponderosa pine region. The even-aged stands near Nevada City and Grass Valley greatly excel any other stands, even on comparable sites, in volume production. However, the reasons for the high values obtained by Gallaher are not fully evident. His measurements were taken more than 25 years ago, and it is possible that some of the best stands represented by them have since been destroyed. Repeated surface fires have been set since that time to improve range conditions, and have reduced the stocking of the stands. Alexander's yield values, for British Columbia, are extremely low owing to the fact that stocking has been greatly reduced by repeated surface fires throughout the pine region of British Columbia and that the comparatively high ratio of stocking normality exhibited by the plots measured in the United States was nowhere duplicated in that Province.

Cubic-foot yield tables were included in all the reports but Gallaher's and Alexander's. Yields indicated by these tables for site indexes 80 and 120 are shown in table 17. Some of the values shown in the table

[4] GALLAHER, W. H. SECOND-GROWTH YELLOW PINE. File memorandum. Calif. Forest and Range Expt. Sta. 1912.

[5] REINEKE, L. H. PRELIMINARY YIELD TABLES FOR SECOND-GROWTH WESTERN YELLOW PINE. File memorandum. Calif. Forest and Range Expt. Sta. 1931.

can be read directly from the original tables; the others have been interpolated as exactly as possible.

TABLE 17.—*Ponderosa pine yields per acre indicated by findings of different investigators* [1] *in the United States*

Age (years)	Site index 80				Site index 120		
	Meyer	Behre	Dunning and Reineke [2]	Show	Meyer	Behre	Dunning and Reineke [3]
	Cu. ft.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
30	1,950	1,650	1,650		4,200	3,080	2,650
60	3,950	3,590	5,300		8,150	6,720	8,500
90	5,300	4,640	7,850	5,820	10,700	8,670	12,600
120	6,200	5,610	9,900	9,970	12,400	10,450	15,900
150	6,850	6,560	11,600	12,020	13,600	12,240	18,400

[1] Sources of values shown: Meyer, present publication; Behre (3); Dunning and Reineke (11); Show (28).
[2] Values are for stands in which heights of dominants and codominants averaged 46 feet at 50 years.
[3] Values are for stands in which heights of dominants and codominants averaged 69.5 feet at 50 years.

The values given in the table vary widely, even though the upper and lower extremes of the range of yield values shown by individual studies are not included. Meyer's and Behre's values are fairly comparable. For ages 90 years and more Reineke's values and, with one exception, Show's values are far higher. Reconciliation is well-nigh impossible. The values presented by Reineke, which were based on data gathered by him and by Show and other investigators, are not supported by the newer California data. Show's values represent chiefly yields of even-aged groups in a generally uneven-aged forest, and hence may connote a long initial period of highly competitive growth conditions or of suppression.

In view of the fact that in application of yield tables the values are adjusted to existent stand conditions, by means of normality percentages, differences between two sets of yield values are not disturbing so long as they are consistent, like the differences between Reineke's values and those of the present study. After adjustment the two may be identical. The chief difficulty with high values is psychological; many practicing foresters, familiar with average stand conditions, cannot put faith in yield tables showing values greatly exceeding average actual yields.

NORMAL MORTALITY

The enormous reduction in number of trees in a stand between early youth and maturity involves elimination of much volume that is seldom utilized under the present crude forestry practice but that will probably be utilized more commonly in the future in favorable situations and times. The trees that are normally lost through mortality should be removed in thinnings before they die.

Normal mortality as computed in this study is shown in table 18. The values tabulated were not obtained through long-term studies of mortality in single stands but were computed from the statistics obtained in the study of live stands, by a method explained in the appendix. They are uncurved, and are presented as approximate only. On land of site index 80, for example, 980 trees 0.6 inch and more in diameter die out between the ages of 20 and 40 years, 608 during the next 20-year period, 269 during the third, and so forth;

table 18 shows that the volume of the first lot of trees is only 101 cubic feet, because of their small size; that of the second is 552 cubic feet; and that of the third is 605 cubic feet. The cumulative totals for the ages 20 to 100 years, for site indexes 40, 80, 120, and 160, are 1,212, 1,723, 2,695, and 4,360 cubic feet, respectively. These totals are 42, 30, 24, and 23 percent, respectively, of the live volume for these site indexes at 100 years. It is seldom appreciated that the volume lost by a forest stand through normal mortality is such a large portion of the total production.

TABLE 18.—*Normal mortality, by 20-year periods, for all trees 0.6 inch and more in breast-height diameter*

PERIODIC VOLUME LOSS PER ACRE

Age period (years)	Site index 40	Site index 60	Site index 80	Site index 100	Site index 120	Site index 140	Site index 160
	Cu. ft.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
20–40	----------	194	101	130	106	99	73
40–60	391	556	552	613	601	741	868
60–80	499	507	605	601	893	1,267	1,719
80–100	322	427	465	722	1,095	1,344	1,700
100–120	221	307	409	727	865	----------	----------
120–140	179	248	427	710	1,088	----------	----------
140–160	144	189	425	767	1,224	----------	----------
160–180	88	225	490	699	1,073	----------	----------
180–200	107	217	347	765	961	----------	----------

CUMULATIVE VOLUME LOSS PER ACRE

Age period (years)	Site index 40	Site index 60	Site index 80	Site index 100	Site index 120	Site index 140	Site index 160
20–40	----------	194	101	130	106	99	73
20–60	391	750	653	743	707	840	941
20–80	890	1,257	1,258	1,344	1,600	2,107	2,660
20–100	1,212	1,684	1,723	2,066	2,695	3,451	4,360
20–120	1,433	1,991	2,132	2,793	3,560	----------	----------
20–140	1,612	2,239	2,559	3,503	4,648	----------	----------
20–160	1,756	2,428	2,984	4,270	5,872	----------	----------
20–180	1,844	2,653	3,474	4,969	6,945	----------	----------
20–200	1,951	2,870	3,821	5,734	7,906	----------	----------

In understocked stands volume loss by mortality is less than in normal stands, absolutely and perhaps relatively.

APPLICATION OF YIELD TABLES

In applying normal-yield tables constant emphasis must be placed on the necessity of determining as accurately as time and cost will allow the true conditions of age, site, area, and stocking. For small tracts precise determination of each of these factors is feasible; for large areas, approximate or average values must often suffice.

It is especially fruitless to predict yield for nonforested land on the assumption that a satisfactory reproduction stand will be obtained without silvicultural measures. Only when a stand has been established and age, stocking, and site conditions are known should predictions of growth rate and yield be attempted.

AGE DETERMINATION

To estimate the average age of dominant and codominant trees, inexperienced fieldmen should make increment borings in at least 15 to 20 trees or should count the rings on that many stumps. With experience and practice it becomes easy to dispense with some of the borings or stump counts. To convert age determined by boring at breast height to total age, it is necessary to make an addition varying with site quality as follows: I, 6 years; II, 8 years; III, 10 years; IV, 12 years; V, 14 years; VI and poorer, 16 years. These allowances are for free-growing dominant seedlings, not for seedlings subjected to severe competition; the time required by seedlings of the latter description to grow to breast height is much greater. For a large area, often it is impracticable to classify age of stand more closely than to within 20 years.

SITE-QUALITY DETERMINATION

An area's site index, as was previously explained, is obtained by determining the age and height of representative dominant and codominant trees. Caution must be observed to get not the maximum height for these dominance classes but the average. The most accurate way is to construct a height curve for the stand (which incidentally may be used for other purposes, such as volume computation), compute the average diameter of the dominant and codominant trees from a stand tally, and read from the curve the height corresponding to this diameter. The site index can then be read from figure 2. The usual tendency in estimating site quality without following this procedure is to overestimate.

With experience and practice it is found possible to rely more and more upon direct ocular estimates of site quality—especially if use is made of the system of seven general site-quality classes defined in table 2.

STOCKING DETERMINATION

In order to adjust normal-yield-table values to conditions actually existing in an even-aged stand, it is necessary to determine the stand's stocking. The stocking classification recommended for large areas is as follows: 70 percent of normal or more, well-stocked; 40 to 69 percent, medium-stocked; 10 to 39 percent, poorly stocked; and less than 10 percent, nonstocked. Actual stocking percentages should be computed by means of the field examinations.

Many different methods of stocking determination have been developed. None of them is perfect or is in general use. Even if satisfactory for expressing present stocking, they fail to show what changes in stocking may take place in the future. Among the different methods recommended for use on some occasions and in connection with some problems are: (1) Use of a "normality percentage," the ratio between a certain value determined for an actual stand and the value shown in the normal-yield table for the appropriate age and site classes; (2) use of stand-density index; and (3) the stocked-quadrat method.

Use of normality percentages, especially that of basal area, has been recommended time and again (*13*, *15*). In this study it has been proved that these percentages are useful as means of predicting total cubic-foot volume, total board-foot volume by International rule, and other values for the complete or nearly complete stand. Some of the correlations between normality ratios of stand factors are listed in table 19, and the more valuable ones are shown in graphic

[CDF-146]

form in figure 11. The low coefficient of correlation between the normality ratio of basal area and that of board-foot volume by Scribner rule indicates that basal-area ratio is of little use in predicting Scribner volumes. The multiple correlation of the normality ratios of basal area, average diameter, and volume by Scribner rule is higher, but not sufficiently high to be useful. As in other studies, the normality percentage for board-foot volume was found to be correlated fairly closely with that for number of trees above a specified diameter.

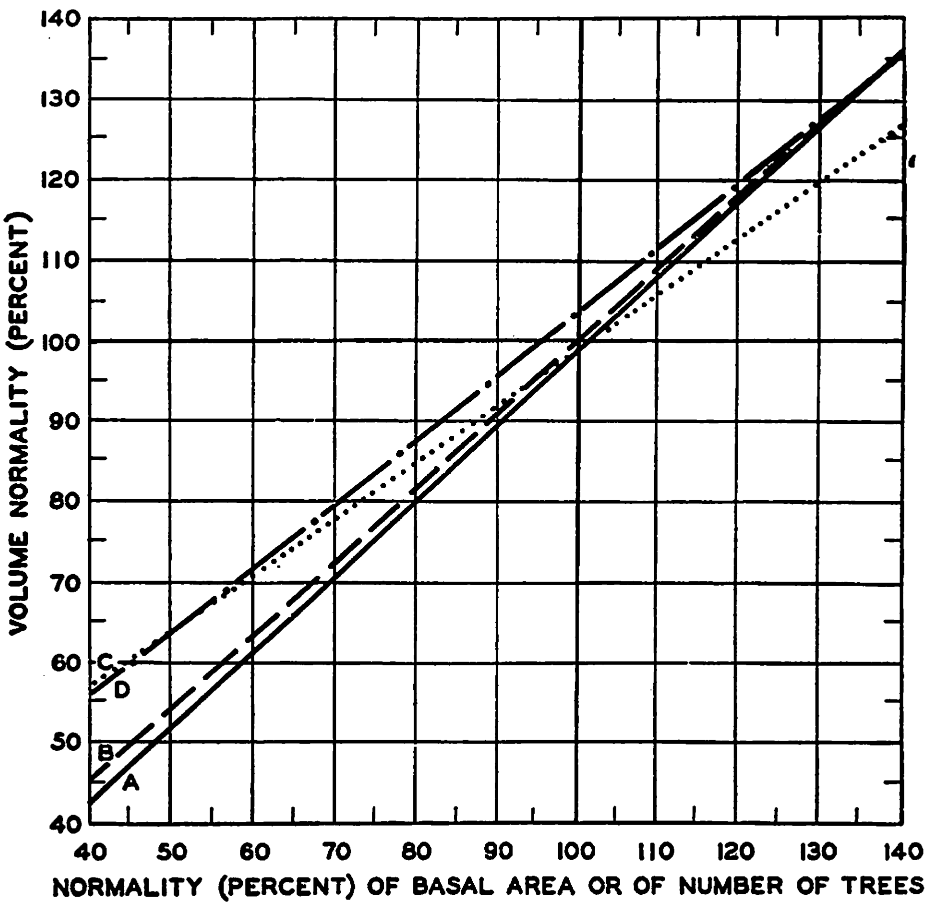

FIGURE 11.—Relations of volume normality to basal-area and number-of-trees normality: *a*, Cubic-foot volume; *b*, board-foot volume, International rule; *c* and *d*, board-foot volume, Scribner rule. The board-foot-volume relations represented are those of stands containing at least 5,000 board feet per acre. For *a*, *b*, and *c*, the independent variable is basal-area normality; for *d*, it is normality of number of trees 11.6 inches and more in diameter.

The stand-density-index method was devised rather recently by Reineke (*21*). Ordinarily it requires no knowledge of age or site. The regression line drawn by Reineke for determining stand-density index, which fitted data for a number of species very well, did not fit the data of this study; accordingly a new line was drawn for use with ponderosa pine. A system of parallel curves based on this line appears as figure 12. The relations of normality percentages for various yield values to stand-density index as determined from figure 12 are shown in table 19 and in figure 13.

TABLE 19.—*Correlation of measures of stocking with various yield values*

Relation	Plots	Correlation coefficient	Regression equation
Basal-area normality percentage with normality percentage of—	*Number*		
Cubic-foot volume	541	+0.91	CF percent=0.93 BA percent+5.42.
Board-foot volume by—			
International rule	514	+.56	BF_{Int} percent=0.85 BA percent+8.77.
	[1] 431	+.72	BF_{Int} percent=0.91 BA percent+8.61.
Scribner rule	431	+.36	BF_{Sc} percent=0.68 BA percent+26.51.
	[1] 356	+.45	BF_{Sc} percent=0.69 BA percent+29.23.
Normality percentage of number of trees 11.6 inches and more d. b. h. with normality percentage of board-foot volume by Scribner rule.	420	+.76	BF_{Sc} percent=0.74 NT percent+26.75.
	[1] 371	+.81	BF_{Sc} percent=0.80 NT percent+23.30.
Normality percentages of basal area and average diameter with normality percentage of board-foot volume by Scribner rule.	317	+.58	BF_{Sc} percent=0.82 BA percent+1.56 average D percent−148.14.
	[2] 209	+.79	BF_{Sc} percent=0.85 BA percent+1.27 average D percent−113.93.
Stand-density index with normality percentage of—			
Cubic-foot volume	450	+.79	CF percent=0.194 SDI+23.9.
Board-foot volume by—			
International rule	403	+.37	BF_{Int} percent=0.164 SDI+28.1.
	319	+.58	BF_{Int} percent=0.197 SDI+22.8.
Scribner rule	317	+.32	BF_{Sc} percent=0.192 SDI+21.4.
	[1] 248	+.39	BF_{Sc} percent=0.175 SDI+33.0.

[1] Including only plots having a volume per acre of 5,000 board feet or more.
[2] Including only plots on which the average diameter of all trees was 8.6 inches or more.

To determine stand-density index by use of figure 12 it is necessary only to know total number of trees per acre and average diameter. If, for instance, a stand has 770 trees per acre averaging 7.5 inches d. b. h., the first step in determining its stocking-normality percentage is to find in figure 12 the intersection representing this density and this diameter. The value of 450 can then be read from the guide lines by interpolation. According to figure 13 this index is associated with a cubic-volume normality ratio of 109 percent. Thus the stand is slightly above normal in volume.

Tests of the yield tables show that there is a slight relation between stand-density index and site index. The higher average stand-density indexes are associated with the lowest site indexes and the highest site indexes. For greatest accuracy, a correlation for site index should probably be introduced when stand-density index is used as a measure of stocking; but the effect is so small that it is justifiable to read indexes directly from figure 12 if they are to be used in connection with figure 13, about whose regression lines the variation is fairly wide.

The stocked-quadrat method, described by Haig (*12*) and Cowlin (*10*), is particularly useful in estimating the stocking of reproduction stands. A quadrat is classified as stocked if it contains one or more seedlings, and if it contains more than one this does not alter the classification of a neighboring nonstocked quadrat. This method gives directly an estimate of the percentage of the total area on which seedlings are present in adequate numbers. Good distribution of seedlings is the silviculturist's aim rather than large number of seedlings per acre, which does not necessarily imply satisfactory stocking. In some instances the size of the quadrat has been made to correspond with the number of trees per acre desired at the rotation age. For instance, according to table 3 a 120-year-old stand on an area of site index 80 normally contains 196 trees per acre. If these trees are

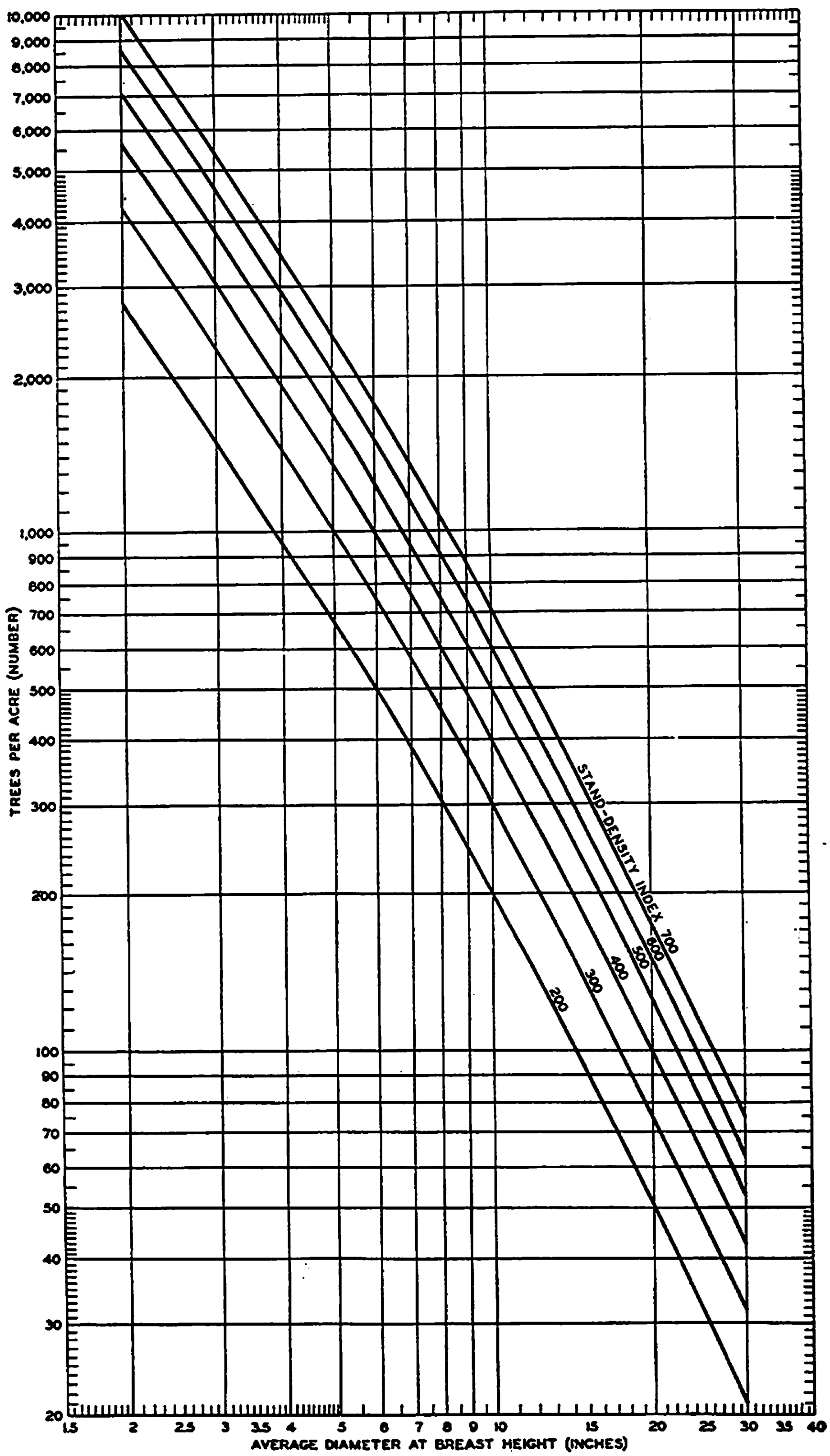

Figure 12.—Stand-density index, based on a regression line drawn for even-aged ponderosa pine.

evenly spaced, each has 222 square feet, or a 14.9-foot square, of growing space. Obviously, this spacing is much too wide for best form development of small seedlings; it will cause excessive limb development and retard shedding of limbs. In other instances quadrat size has been made to represent the growing space of each tree in a fully stocked, evenly spaced reproduction stand soon after the stand becomes established. This has led to use of a quadrat 6.6 feet on the side, corresponding to a stocking of 1,000 evenly spaced seedlings to the acre. In the greater part of the ponderosa pine range the 6.6-foot spacing is undoubtedly much too close for continued normal development. For the time being the author has compromised by dividing the acre into 500 quadrats. This corresponds to an even spacing of 9.33 feet in each direction. If ponderosa pine seedlings become estab-

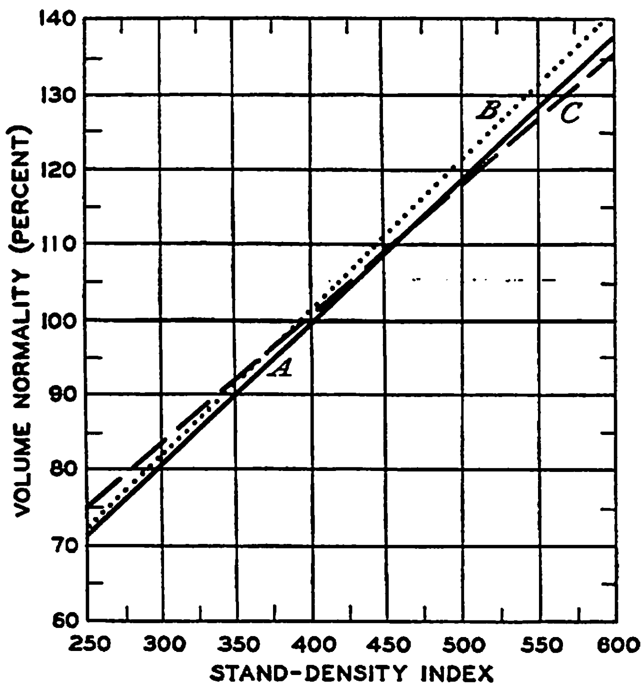

FIGURE 13.—Relations of volume normality percentages to stand-density index: *a*, Cubic-foot volume *b*, board-foot volume, International rule; *c*, board-foot volume, Scribner rule.

lished in this density they should grow well, without risk either of stagnation or of excessive limb development. This should by no means be taken to imply that an average density of 500 trees to the acre is adequate for planting, or that natural seedling reproduction averaging 500 trees per acre can be expected to develop into a satisfactorily dense stand of timber. On a ponderosa pine area where each one five-hundredth acre contains at least one established seedling, the total number of such seedlings per acre is likely to be 2,000.

Of the many ways of applying the stocked-quadrat theory, one of the more practical is to record the stocking of groups of four quadrats each at some definite interval, such as 1 chain, along survey lines evenly spaced through the area. Stopping at the end of each chain or other chosen interval, the estimator considers himself in the center of a block of four 9.33-foot quadrats. He looks in the first quadrat until he finds an established seedling or assures himself that none is present, then in the second, and so on. The number of stocked quadrats divided by the total number of quadrats examined gives directly the percentage of stocking. It is often desirable to break the total runs into definite units, such as 20 chains, in order to localize variations in stocking.

Number of seedlings per stocked quadrat increases with computed stocking. In reproduction surveys in pine stands of south-central Washington, for instance, in which groups of 4 quadrats were examined at 1-chain intervals along 20-chain strips, average total number of seedlings per stocked quadrat varied with stocking percentage as follows: 1 to 10 percent, 1; 11 to 28 percent, 2; 29 to 42 percent, 3; 43 percent and more, 4.

For second-growth ponderosa pine stands basal-area ratio or stand-density index is the most useful method for determining stocking in terms of cubic-foot volume and board-foot volume by International rule; number-of-trees normality ratio is the only valid method for determining stocking in terms of board-foot volume by Scribner rule; and the stocked-quadrat method should be used for determining stocking of reproduction.

YIELD-SURVEY PROCEDURE

A yield survey involves getting stand tallies as in a valuation survey and getting the necessary data on age of stand, site quality, and stocking for each portion of the area. The exact methods of a yield survey will not be defined in detail; they have been described in a number of previous publications, particularly the report on the study of yield of Douglas fir in the Pacific Northwest (*13*).

For greatest efficiency the field work of the survey should be done by a party of three men—one to run the line and make the map, one to estimate, and one to make increment borings, measure heights, and keep account of variations in age and site class. A forester working on a yield study of ponderosa pine soon learns to estimate heights ocularly to the nearest 10 feet with occasional checks by instrumental measurement, and eventually learns to estimate age to the nearest 20 years. For the purpose of site-index determination it is better to estimate numerous heights within 10 feet than to measure a few accurately with instruments. For extensive work it is almost imperative that the forester train himself to recognize age of stand and quality of site without much effort. Lack of such training causes undue delay in the conduct of a yield survey.

The survey maps and statistics should show divisions of area by age of stand, site quality, and stocking class. In the office the stand tallies are worked up, the map is perfected, and the areas are planimetered and tabulated. The terms in which the estimates are made, and the rotation age, vary with needs. Sometimes estimates of current growth are needed, sometimes estimates of total volume at future dates—with or without reference to rotation age; at still other times, it is necessary to calculate the best time to cut for products of specific sizes. Each of these needs and many others are met by use of the yield tables.

An instance of extensive use of yield tables is the growth calculations for the entire Douglas fir region of Oregon and Washington.[6] Similar

[6] MEYER, W. H., BRIEGLEB, P. A., and others. FOREST GROWTH IN THE DOUGLAS FIR REGION. Pacific Northwest Forest Expt. Sta., Forest Research Notes 20. 1936. [Mimeographed.]

calculations will be made for the ponderosa pine region of these States by means of the yield tables presented in this bulletin.

INCREMENT AND ROTATION

Mean annual and periodic annual increments computed from the yield tables are given in tables 20 to 25. Rotation ages for the three volume measures are summarized in table 26. For cubic-foot volume production, they range from 40 to 70 years; for board-foot volume production estimated by the International rule, from 60 to 160 years or more; for board-foot volume production estimated by the Scribner rule, from 90 to much more than 196 years. The poorer the site quality and the less complete the utilization, the greater is the rotation age.

Lands of the poorest site qualities, those for which the indexes are 40 to 60, apparently are totally unfit for lumber production because of the long rotations involved. For production of fuel wood and other small-sized material, they undoubtedly have their use.

In many respects the rotation ages stated in table 26 are unsatisfactory, since they were calculated without regard to amount invested, carrying costs, prospective returns, or other financial considerations. Calculations in which these values are taken into account are necessarily of local and temporary application only. Methods of making such calculations are described in most forest-management textbooks. Calculations of this character made in the course of this study have indicated rotation ages much lower than those shown in the table, especially when high rates of compound interest were assumed. Discounting of final net financial yield to the present time to find the present value of an immature stand further reduces rotation age.

TABLE 20.—*Periodic annual cubic-foot increment per acre of trees 0.6 inch and more in diameter*

Age (years)	Increment per acre, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Cu. ft.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
25	------	60	70	75	95	110	130	150	180	210	215	240	250
35	55	55	65	70	80	95	110	130	145	180	200	225	250
45	40	50	55	60	65	80	95	115	135	155	180	210	235
55	35	40	45	50	55	65	80	95	115	130	160	180	200
65	30	35	35	45	50	55	65	80	95	115	140	155	175
75	30	30	30	40	45	50	60	70	85	100	120	130	150
85	25	25	25	35	40	45	55	60	75	90	105	110	130
95	25	25	25	30	35	40	45	55	65	80	90	95	110
105	20	20	25	25	30	35	40	45	55	70	------	------	------
115	20	20	25	25	25	30	35	40	50	60	------	------	------
125	15	20	20	25	25	30	30	35	45	50	------	------	------
135	15	15	20	20	20	25	30	35	40	40	------	------	------
145	10	15	15	20	20	25	30	30	35	35	------	------	------
155	10	15	15	15	20	25	25	30	35	35	------	------	------
165	10	10	15	15	20	20	25	30	30	35	------	------	------
175	10	10	15	15	20	20	25	25	30	35	------	------	------
185	10	10	10	15	20	20	25	25	30	35	------	------	------
195	10	10	10	15	15	20	20	20	25	35	------	------	------

TABLE 21.—*Mean annual cubic-foot increment per acre* [1] *of trees 0.6 inch and more in diameter*

Age (years)	Increment per acre, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Cu. ft.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
20	------	10	20	35	50	68	85	105	120	138	168	188	218
30	17	27	37	48	65	82	100	120	140	162	183	205	228
40	26	34	44	54	69	85	102	122	141	166	188	210	234
50	29	37	46	55	68	84	101	121	140	164	186	210	234
60	30	38	46	54	66	81	98	117	136	158	182	205	228
70	30	37	44	53	64	77	93	111	130	152	176	198	221
80	30	36	42	51	61	74	89	106	124	146	169	189	212
90	29	35	41	49	59	71	85	101	119	139	162	181	203
100	29	34	39	48	56	68	81	96	114	134	154	172	194
110	28	33	38	45	54	65	77	92	108	128	------	------	------
120	28	32	37	44	52	62	74	88	103	122	------	------	------
130	27	31	35	42	50	59	70	83	99	117	------	------	------
140	26	30	34	41	48	57	68	80	95	111	------	------	------
150	25	29	33	39	46	55	65	77	91	106	------	------	------
160	24	28	32	38	44	53	62	74	87	102	------	------	------
170	23	27	31	36	43	51	60	71	84	98	------	------	------
180	22	26	30	35	41	49	58	69	81	94	------	------	------
190	22	25	29	34	40	48	57	66	78	91	------	------	------
200	21	24	28	33	39	46	55	64	76	88	------	------	------

[1] To nearest cubic foot.

TABLE 22.—*Periodic annual board-foot increment, International rule (⅛-inch kerf), per acre of trees 6.6 inches and more in diameter*

Age (years)	Increment per acre, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
25	------	------	------	------	------	260	480	680	970	1, 290	1, 590	1, 800	1, 970
35	------	------	------	150	260	430	650	880	1, 140	1, 400	1, 580	1, 760	1, 900
45	------	------	130	260	400	560	740	940	1, 130	1, 300	1, 440	1, 610	1, 730
55	------	100	190	310	490	630	770	890	1, 020	1, 160	1, 300	1, 450	1, 580
65	30	150	240	360	530	640	700	790	890	1, 030	1, 170	1, 320	1, 460
75	60	190	270	380	520	570	620	690	790	910	1, 060	1, 210	1, 350
85	90	210	290	360	440	500	540	620	710	810	960	1, 100	1, 240
95	130	220	290	340	370	420	470	550	630	730	870	1, 000	1, 140
105	140	210	280	300	320	360	420	480	570	670	------	------	------
115	160	200	260	270	290	330	370	440	510	610	------	------	------
125	160	190	230	250	270	300	340	400	460	540	------	------	------
135	150	180	210	230	250	280	320	370	420	490	------	------	------
145	140	170	200	210	230	260	300	350	390	440	------	------	------
155	130	160	190	200	210	250	280	330	370	400	------	------	------
165	120	150	170	190	200	240	270	300	350	380	------	------	------
175	120	140	160	180	200	230	260	280	330	360	------	------	------
185	120	140	150	170	190	220	250	270	310	340	------	------	------
195	110	140	150	170	190	210	240	270	290	330	------	------	------

TABLE 23.—*Mean annual board-foot increment,*[1] *International rule (⅛-inch kerf), per acre of trees 6.6 inches and more in diameter*

Age (years)	Increment per acre, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
20	------	------	------	------	------	10	30	70	140	225	365	540	825
30	------	------	------	13	37	93	180	273	417	580	773	960	1,207
40	------	------	12	48	92	178	298	425	598	785	975	1,160	1,380
50	------	10	36	90	154	254	386	528	704	888	1,068	1,250	1,450
60	2	25	62	127	210	317	450	588	757	933	1,107	1,283	1,472
70	6	43	87	160	256	363	486	617	776	947	1,116	1,289	1,470
80	12	61	110	188	289	389	502	626	778	942	1,109	1,279	1,455
90	21	78	130	207	306	401	507	625	770	928	1,092	1,259	1,431
100	32	92	146	220	312	403	503	618	756	908	1,070	1,233	1,402
110	42	103	158	227	313	399	495	605	739	886	------	------	------
120	52	111	167	231	311	393	485	592	720	863	------	------	------
130	60	117	172	232	308	386	474	577	700	838	------	------	------
140	66	121	174	232	304	379	463	562	680	813	------	------	------
150	71	125	176	231	299	371	452	548	661	788	------	------	------
160	75	127	177	229	293	363	441	534	642	764	------	------	------
170	78	128	176	226	288	356	431	521	625	741	------	------	------
180	80	129	176	224	283	349	422	507	609	720	------	------	------
190	82	129	174	221	278	342	413	495	593	700	------	------	------
200	84	130	173	218	274	336	404	484	578	682	------	------	------

[1] To nearest board foot.

TABLE 24.—*Periodic annual board-foot increment, Scribner rule, per acre of trees, 11.6 inches and more in diameter*

Age (years)	Increment per acre, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Bd. ft.	*Bd. ft.*	*Bd ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
25	------	------	------	------	------	------	------	240	470	750	990	1,220	1,410
35	------	------	------	------	------	170	330	500	700	920	1,130	1,320	1,510
45	------	------	------	60	170	310	490	650	820	980	1,150	1,330	1,480
55	------	------	50	150	280	410	560	700	810	960	1,120	1,280	1,410
65	------	------	120	210	340	470	570	680	800	920	1,070	1,200	1,340
75	------	60	170	270	370	470	550	640	750	860	1,000	1,130	1,250
85	10	110	200	300	380	450	520	600	690	790	930	1,060	1,170
95	20	140	230	310	370	420	490	560	630	730	860	990	1,090
105	40	160	240	310	340	390	450	500	580	670	------	------	------
115	70	200	230	280	310	360	400	460	530	610	------	------	------
125	100	190	220	250	280	330	370	420	480	550	------	------	------
135	130	180	200	220	250	290	340	380	440	490	------	------	------
145	140	170	180	200	230	270	310	350	400	440	------	------	------
155	140	150	160	180	210	250	280	320	350	390	------	------	------
165	130	140	150	170	190	230	250	290	310	350	------	------	------
175	110	130	150	170	180	210	230	260	290	320	------	------	------
185	100	120	140	160	170	190	220	240	270	300	------	------	------
195	100	120	130	150	170	180	210	220	250	290	------	------	------

TABLE 25.—*Mean annual board-foot increment,*[1] *Scribner rule, per acre of trees 11.6 inches and more in diameter*

Age (years)	Increment per acre, by site index—												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
20	------	------	------	------	------	------	------	5	20	45	95	190	365
30	------	------	------	------	------	7	33	83	170	280	393	533	713
40	------	------	------	2	15	48	108	188	302	440	578	730	912
50	------	------	2	14	46	100	184	280	406	548	692	850	1,026
60	------	------	10	37	85	152	247	350	473	617	763	922	1,090
70	------	4	26	61	121	197	293	397	520	660	807	961	1,126
80	1	11	44	88	152	231	325	428	549	685	831	982	1,141
90	2	22	61	111	178	256	347	447	564	697	842	991	1,144
100	4	34	78	131	197	272	361	458	571	700	844	991	1,139
110	7	45	93	147	210	283	369	462	572	697	------	------	------
120	12	58	104	158	218	289	372	462	568	690	------	------	------
130	19	68	113	165	223	292	372	458	562	679	------	------	------
140	27	76	119	169	225	292	369	453	553	666	------	------	------
150	35	83	123	171	225	291	365	446	543	651	------	------	------
160	41	87	126	172	224	288	360	438	531	634	------	------	------
170	46	90	127	172	222	285	354	429	518	618	------	------	------
180	50	92	128	172	220	281	347	420	505	601	------	------	------
190	53	94	129	171	217	276	340	411	493	585	------	------	------
200	55	95	129	170	215	271	334	401	480	570	------	------	------

[1] To nearest board foot.

TABLE 26.—*Rotation ages for even-aged stands of ponderosa pine, by cubic-foot and board-foot measure*

Site index	Cubic-foot measure	Board-foot measure		Site index	Cubic-foot measure	Board-foot measure	
		International rule	Scribner rule			International rule	Scribner rule
	Years	*Years*	*Years*		*Years*	*Years*	*Years*
40	70	------	------	120	39	76	107
60	54	161	196	140	41	70	97
80	42	107	148	160	45	64	87
100	40	90	124				

STAND AND STOCK TABLES

Table 27 is a stand table for average ponderosa pine conditions throughout the portion of the range of the species covered by this study. Table 28 shows the results of applying the percentages shown in table 27, or interpolated values, to the number-of-trees yield table for total stand (table 4). If desired, comparable values can be computed for other ages and site conditions. Since there is a decided variation from one region to another, distributions for four representative sets of local conditions are given in table 29, namely, those of the west slopes of the Sierra Nevada, of Oregon and Washington, of Idaho and Montana, and of the Black Hills.

TABLE 27.—*Percentage distribution of total number of trees per acre by diameter class in stands of different average breast-height diameters, for range as a whole*

Diameter class (inches)	Trees per acre, by average diameter of stand													
	1 inch	2 inches	3 inches	4 inches	5 inches	6 inches	7 inches	8 inches	9 inches	10 inches	11 inches	12 inches	13 inches	14 inches
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1	80.0	48 0	19.0	12.0	8.0	4.6	3.3	2.4	1.5	0.7				
2-3	19.1	46.5	57.0	44.0	32.5	25.4	17.7	13.1	9.5	6.6	4.1	2.5	1.5	1.0
4-5	.9	5.0	20.0	30.0	31.5	28.0	25.5	20.0	16.5	13 2	10.1	6.7	4.5	3.1
6-7		.5	3.5	10.7	17 7	22.0	23.0	22.5	20.5	17.5	15.8	12.8	9.8	7.5
8-9			.5	2.7	7.4	12.0	15.5	19.0	19.0	19.0	18.5	16.5	14.2	11.9
10-11				.6	2.2	5.6	8.8	11.7	15.2	17.0	17.0	18.0	17.0	15.0
12-13					.7	1.7	3.9	6.4	9.0	12.0	13.5	15.5	16.5	16.5
14-15						.7	1.6	3.1	5.0	7.3	10.0	12.1	14.0	15.0
16-17							.7	1.3	2.4	3.9	5.8	7.6	9.8	12.0
18-19								.5	1.4	1.8	3.0	4.6	6.5	8.5
20-21										1.0	1.4	2.2	3.6	5.1
22-23											.8	1.0	1.6	2.7
24-25												.5	1.0	1.1
26-27														.6
28-29														
30-31														
32-33														
34-35														
36-37														
38-39														

Diameter class (inches)	Trees per acre, by average diameter of stand													
	15 inches	16 inches	17 inches	18 inches	19 inches	20 inches	21 inches	22 inches	23 inches	24 inches	25 inches	26 inches	27 inches	28 inches
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1														
2-3	0.6	0.5												
4-5	2.1	1.5	1.5	1.1										
6-7	5.0	3.8	3.0	2.2	2.5	2.0	1.7	1.4	1.2	1.0				
8-9	9.3	7.4	5.6	4.5	3.4	2.7	2.0	1.7	1.3	1.2	1.9	1.7	1.5	1.4
10-11	13.0	10.3	9.4	7.5	6.0	4.8	3.8	3.2	2.5	2.1	1.8	1.4	1.2	.9
12-13	15.0	14.0	11.5	10.2	8.6	7.5	6.0	4.8	4.1	3.3	2.8	2.4	1.9	1.7
14-15	16.5	15.5	14.0	13.0	11.5	10.0	8.5	7.4	6.4	5.4	4.5	3.8	3.2	2.7
16-17	13.5	14.5	15.0	15.0	13.0	11.5	11.0	9.5	8.0	7.0	6.4	5.5	4.7	3.9
18-19	10.8	12.5	13.0	13.5	14.5	13.5	13.0	12.0	10.5	9.5	8.6	7.2	6.0	5.5
20-21	7.2	9.3	11.2	12.0	13.5	13.5	13.5	13.5	13.0	11.5	10.0	9.5	8.5	7.4
22-23	3.9	5.7	7.9	9.6	10.5	12.0	12.5	12.5	13.0	13.0	12.0	11.0	10.0	9.5
24-25	2.0	3.0	4.5	6.0	8.1	10.0	10.7	11.5	12.0	12.0	13.0	12.5	12.0	11.5
26-27	1.1	1.4	2.3	3.3	4.8	6.7	8.3	9.6	10.6	11.5	11.5	12.0	12.0	12.0
28-29		.6	1.1	1.5	2.4	3.7	5.2	7.0	8.6	9.7	9.9	10.5	12.0	11.5
30-31				.6	1.2	1.6	2.6	3.9	5.3	7.0	8.6	9.7	9.7	10.0
32-33						.5	1.2	1.5	2.6	4.1	5.8	7.3	8.8	9.7
34-35								.5	.9	1.7	2.4	4.0	5.5	7.2
36-37											.8	1.5	2.4	3.9
38-39													.6	1.2

The numbers of trees shown in these stand tables for given breast-height-diameter ranges do not invariably check with the values shown in yield tables 7 and 12; vastly differing techniques were used in deriving the two kinds of tables, and little attempt was made to adjust the results.

TABLE 28.—*Distribution of total number of trees per acre by diameter class in stands of different ages and site indexes, for range as a whole*

SITE INDEX 40

Diameter class (inches)	Trees per acre, by age class									
	20 years	40 years	60 years	80 years	100 years	120 years	140 years	160 years	180 years	200 years
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
1	--	4,072	532	146	41	19	9	4	2	1
2-3	--	2,645	1,568	504	190	89	43	26	16	9
4-5	--	223	588	396	216	128	68	47	32	24
6-7	--	20	98	177	156	115	82	58	44	36
8-9	--	--	14	61	89	79	75	57	49	40
10-11	--	--	--	16	37	47	48	48	43	37
12-13	--	--	--	--	11	22	27	30	30	28
14-15	--	--	--	--	4	9	14	17	20	22
16-17	--	--	--	--	--	2	6	9	13	11
18-19	--	--	--	--	--	2	2	5	3	6
20-21	--	--	--	--	--	--	1	1	1	3
22-23	--	--	--	--	--	--	--	--	1	1
Total	--	6,960	2,800	1,300	744	512	375	302	254	218

SITE INDEX 60

Diameter class (inches)	20 years	40 years	60 years	80 years	100 years	120 years	140 years	160 years	180 years	200 years
1	3,359	486	96	23	7	2	1	--	--	--
2-3	1,168	1,457	350	110	42	15	5	3	1	1
4-5	64	608	358	159	70	33	16	8	4	2
6-7	9	130	217	149	81	49	28	17	10	6
8-9	--	19	90	98	78	53	37	24	17	11
10-11	--	--	26	56	58	45	39	31	22	16
12-13	--	--	8	25	32	37	34	31	24	20
14-15	--	--	--	10	19	24	25	25	24	19
16-17	--	--	--	4	8	13	16	18	19	18
18-19	--	--	--	--	3	6	10	12	14	15
20-21	--	--	--	--	2	3	5	7	9	11
22-23	--	--	--	--	--	1	2	3	5	6
24-25	--	--	--	--	--	--	1	1	2	3
26-27	--	--	--	--	--	--	--	1	1	1
28-29	--	--	--	--	--	--	--	--	--	1
Total	4,600	2,700	1,145	634	400	281	219	181	152	130

SITE INDEX 80

Diameter class (inches)	20 years	40 years	60 years	80 years	100 years	120 years	140 years	160 years	180 years	200 years
1	810	103	22	4	--	--	--	--	--	--
2-3	1,171	399	97	32	8	4	1	--	--	--
4-5	238	394	158	57	21	6	3	2	1	--
6-7	27	235	149	75	36	17	7	4	2	2
8-9	4	99	116	75	46	25	13	7	4	3
10-11	--	30	64	65	47	31	18	12	7	5
12-13	--	10	33	39	39	32	22	14	10	7
14-15	--	--	15	25	31	29	24	19	14	10
16-17	--	--	6	12	19	21	21	18	15	11
18-19	--	--	2	6	11	15	17	17	15	12
20-21	--	--	--	2	5	9	13	13	13	12
22-23	--	--	--	1	2	4	7	10	11	11
24-25	--	--	--	--	1	2	4	6	7	9
26-27	--	--	--	--	--	1	2	3	4	6
28-29	--	--	--	--	--	--	1	1	2	3
30-31	--	--	--	--	--	--	--	--	1	1
Total	2,250	1,270	662	393	266	196	153	126	106	92

[CDF-157]

TABLE 28.—*Distribution of total number of trees per acre by diameter class in stands of different ages and site indexes, for range as a whole*—Continued.

SITE INDEX 100

Diameter class (inches)	Trees per acre, by age class									
	20 years	40 years	60 years	80 years	100 years	120 years	140 years	160 years	180 years	200 years
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
1	211	29	4							
2–3	634	137	35	7	2					
4–5	320	196	63	19	5	2	1			
6–7	95	181	85	34	12	5	2	1		
8–9	20	121	85	49	22	9	4	2	1	1
10–11		68	71	50	27	15	8	4	2	1
12–13		35	47	44	31	20	11	7	4	2
14–15		13	32	36	32	23	14	9	6	3
16–17		5	13	23	25	22	17	11	8	5
18–19			6	13	19	20	17	13	9	6
20–21			4	7	12	16	16	13	10	8
22–23				3	7	10	13	12	11	9
24–25				1	3	6	9	10	10	9
26–27					2	3	5	8	8	8
28–29						1	2	5	6	7
30–31							1	2	4	6
32–33								1	2	3
34–35									1	1
36–37										1
Total	1,280	785	445	286	199	152	120	98	82	70

SITE INDEX 120

Diameter class (inches)	20 years	40 years	60 years	80 years	100 years	120 years	140 years	160 years	180 years	200 years
1	62	9								
2–3	234	51	10	2						
4–5	242	92	28	6	2					
6–7	148	108	44	14	4	3	1			
8–9	65	108	61	23	9	4	2	1	1	
10–11	21	75	58	32	15	7	3	2	1	1
12–13	7	48	51	37	19	10	5	3	1	1
14–15		28	39	35	23	13	7	4	2	1
16–17		13	25	28	24	16	10	6	4	2
18–19		5	14	22	22	18	12	8	5	3
20–21		2	6	14	19	17	14	9	6	4
22–23			3	7	13	14	12	11	7	5
24–25			1	3	7	11	11	10	9	6
26–27				2	4	7	9	9	8	7
28–29					1	4	7	8	7	8
30–31						1	4	6	6	7
32–33							2	3	5	6
34–35								1	4	5
36–37									2	2
Total	779	539	340	225	162	125	99	81	68	58

TABLE 28.—*Distribution of total number of trees per acre by diameter class in stands of different ages and site indexes, for range as a whole*—Continued

SITE INDEX 140

Diameter class (inches)	Trees per acre, by age class									
	20 years	40 years	60 years	80 years	100 years	120 years	140 years	160 years	180 years	200 years
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
1	24	2								
2-3	111	17	2							
4-5	146	44	8	3						
6-7	129	65	19	6	3					
8-9	81	75	32	13	4					
10-11	42	67	39	16	8					
12-13	19	55	45	22	11					
14-15	7	38	42	26	14					
16-17	2	23	32	27	17					
18-19		11	24	26	19					
20-21		5	14	18	18					
22-23		3	7	14	17					
24-25			3	8	13					
26-27			2	4	8					
28-29				1	4					
30-31				1	2					
32-33					1					
Total	561	405	269	185	139					

SITE INDEX 160

Diameter class (inches)	20 years	40 years	60 years	80 years	100 years	120 years	140 years	160 years	180 years	200 years
1	9									
2-3	42	5								
4-5	75	15	4	1						
6-7	83	32	9	3	2					
8-9	74	46	16	6	3					
10-11	53	54	23	10	4					
12-13	32	53	31	14	6					
14-15	15	43	35	19	9					
16-17	7	30	32	21	12					
18-19	3	20	28	24	15					
20-21	1	11	21	21	18					
22-23		5	13	17	15					
24-25		2	7	13	13					
26-27			3	8	11					
28-29			2	4	8					
30-31				1	4					
32-33					3					
Total	394	316	224	162	123					

TABLE 29.—*Percentage distribution of total number of trees, by diameter class, in stands of different average breast-height diameters, under representative local conditions*

WEST SLOPE OF SIERRA NEVADA, CALIFORNIA

Diameter class (inches)	Trees in class: 2 inches	3 inches	4 inches	5 inches	6 inches	7 inches	8 inches	9 inches	10 inches	11 inches	12 inches	13 inches	14 inches	15 inches	16 inches	17 inches	18 inches	19 inches	20 inches	21 inches	22 inches	23 inches	24 inches
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1	60.0	38.0	16.3	5.7	2.1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
2–3	28.0	36.0	42.7	34.3	21.4	14.0	8.0	4.5	2.6	1.7	1.1	0.8	---	---	---	---	---	---	---	---	---	---	---
4–5	11.3	19.6	24.2	32.0	33.0	29.0	23.0	16.5	11.2	7.4	5.1	3.7	3.1	2.3	1.6	1.3	0.9	---	---	---	---	---	---
6–7	.7	5.7	12.2	17.0	23.5	25.5	26.0	24.5	21.2	16.9	13.1	10.3	7.9	6.1	4.9	3.7	2.9	2.9	2.4	1.8	1.3	---	---
8–9	---	.7	3.8	7.7	12.3	16.7	19.0	21.5	22.0	21.0	18.7	16.2	14.0	11.6	10.0	8.5	7.1	5.9	4.9	4.2	3.4	---	---
10–11	---	---	.8	2.6	5.3	9.0	12.8	15.5	17.5	19.0	19.0	18.0	17.0	16.0	13.5	12.5	11.1	10.2	8.9	7.8	6.7	---	---
12–13	---	---	---	.7	1.7	3.8	6.5	9.2	11.8	14.0	15.5	16.0	16.0	16.0	14.0	14.0	13.0	12.0	10.8	10.2	9.6	---	---
14–15	---	---	---	---	.7	1.4	3.1	4.9	7.2	9.3	11.4	13.0	14.0	14.0	14.5	13.0	13.0	12.0	12.0	12.0	11.0	---	---
16–17	---	---	---	---	---	.6	1.1	2.2	3.7	5.5	7.4	9.1	10.3	11.0	12.5	12.0	12.0	12.0	12.0	11.5	11.0	---	---
18–19	---	---	---	---	---	---	.5	.8	1.7	2.9	4.5	6.0	7.1	8.0	9.6	10.5	10.0	10.0	10.0	10.5	10.5	---	---
20–21	---	---	---	---	---	---	---	.4	.7	1.4	2.3	3.4	4.8	5.8	6.6	7.5	9.0	9.5	9.5	9.0	9.0	---	---
22–23	---	---	---	---	---	---	---	---	.4	.6	1.1	2.0	2.9	4.2	5.0	5.7	6.3	7.0	7.5	7.5	8.5	---	---
24–25	---	---	---	---	---	---	---	---	---	.3	.5	.9	1.6	2.6	3.6	4.5	5.2	5.7	6.0	6.1	6.0	---	---
26–27	---	---	---	---	---	---	---	---	---	---	.3	.4	.8	1.4	2.3	3.0	3.7	4.4	4.9	5.4	5.7	---	---
28–29	---	---	---	---	---	---	---	---	---	---	---	.2	.5	.6	1.1	2.1	2.7	3.4	4.0	4.5	4.9	---	---
30–31	---	---	---	---	---	---	---	---	---	---	---	---	---	.4	.5	1.1	1.7	2.3	2.9	3.5	4.0	---	---
32–33	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.3	.4	.9	1.6	2.0	2.5	3.1	---	---
34–35	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.2	.5	.7	1.4	1.8	2.3	---	---
36–37	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.4	.5	1.0	1.5	---	---
38–39	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.3	.5	.9	---	---
40–41	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.2	.4	---	---
42–43	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.2	---	---

OREGON AND WASHINGTON

1	56.0	26.5	16.0	12.0	9.2	6.0	3.3	2.0	1.0	0.8													
2-3	38.0	51.5	43.0	31.0	22.8	18.0	14.2	10.0	6.9	4.4	3.3	2.4	1.6	1.2	0.9	0.7							
4-5	5.2	17.0	25.0	28.5	27.0	23.0	20.5	17.0	14.1	10.8	7.9	5.4	4.2	3.1	2.3	1.7	1.8	1.3	1.1	0.9			
6-7	.8	4.2	10.9	15.8	19.0	21.0	20.0	18.5	17.0	15.0	12.3	9.9	7.6	5.9	4.6	3.6	2.7	2.2	1.6	1.3	1.8	1.4	1.2
8-9		.8	3.8	7.7	11.2	14.5	16.0	17.5	17.0	16.0	15.5	13.3	11.1	9.1	7.2	6.1	4.7	3.9	3.1	2.4	2.0	1.6	1.3
10-11			1.0	3.3	6.0	8.7	11.5	14.0	15.0	16.0	16.0	16.0	14.0	11.7	11.0	8.9	7.6	6.4	5.2	4.3	3.5	2.9	2.4
12-13			.3	1.1	2.8	4.6	7.1	9.2	11.7	13.0	14.0	15.0	15.5	14.5	13.0	11.5	10.2	8.7	7.4	6.4	5.4	4.7	4.0
14-15				.6	1.2	2.4	3.9	5.8	7.8	10.1	11.8	12.5	14.0	14.5	14.0	13.0	11.5	10.5	9.6	8.7	7.8	6.7	5.9
16-17					.8	1.1	2.0	3.2	4.8	6.5	8.4	10.4	11.0	13.0	13.0	13.0	13.0	12.0	11.0	10.0	9.0	8.2	7.2
18-19						.7	.9	1.5	2.5	3.9	5.3	6.9	9.0	10.6	12.0	13.0	13.0	13.0	12.0	12.0	11.0	10.0	9.0
20-21							.6	.8	1.3	1.9	2.9	4.2	5.8	7.4	9.2	11.2	12.5	13.0	13.0	12.0	11.0	11.0	10.0
22-23								.5	.9	1.0	1.5	2.2	3.3	4.6	6.3	8.1	10.0	11.3	13.0	13.0	13.5	12.0	11.5
24-25										.6	.7	1.1	1.7	2.5	3.6	4.9	6.5	8.4	9.6	11.4	12.0	13.0	12.5
26-27											.4	.7	.7	1.2	1.8	2.6	3.7	5.0	6.7	8.4	10.2	11.2	12.0
28-29													.5	.7	.7	1.1	1.8	2.7	4.0	5.2	6.8	8.3	10.0
30-31															.4	.6	1.0	1.1	1.8	2.5	3.5	5.0	6.6
32-33																		.5	.9	1.0	1.7	2.5	3.7
34-35																				.5	.8	1.1	1.8
36-37																						.4	.9

IDAHO AND MONTANA

1	53.0	23.0	10.2	4.3	2.0																		
2-3	40.0	53.0	45.8	32.7	21.0	14.3	9.7	5.8	3.6	2.5	0.8												
4-5	6.5	19.7	30.5	34.5	32.0	25.7	20.8	15.7	11.8	8.5	6.8	5.4	3.8	2.8	1.8	1.2	0.8						
6-7	.5	3.8	10.6	19.6	25.3	27.0	23.5	20.5	17.6	15.0	12.4	9.6	7.2	5.6	4.2	2.9	1.9	1.8	1.2	0.9			
8-9		.5	2.5	6.9	13.5	19.2	22.0	22.5	20.0	17.0	15.0	13.5	11.5	9.8	8.0	6.2	4.4	3.2	2.3	1.5	1.4	1.0	
10-11			.4	1.7	4.7	9.5	14.3	18.1	19.5	19.0	17.5	15.0	14.0	11.8	11.0	9.4	7.7	6.2	4.5	3.3	2.6	1.6	1.4
12-13				.3	1.5	3.3	6.7	10.5	14.5	17.0	17.5	17.5	15.5	13.5	12.0	11.3	10.2	8.8	7.5	5.7	4.3	3.4	2.9
14-15						1.0	2.3	4.6	8.0	11.5	14.0	15.5	15.0	15.5	14.0	12.5	12.0	11.0	10.0	8.6	7.2	5.8	4.4
16-17							.7	1.7	3.4	6.0	9.0	11.3	14.0	15.0	14.0	13.5	13.5	12.0	11.5	11.0	9.5	8.2	7.0
18-19								.6	1.2	2.4	4.4	7.0	9.7	11.4	13.5	14.0	13.0	13.0	12.5	12.5	11.5	11.0	9.3
20-21									.4	1.1	1.9	3.4	5.6	8.0	10.3	12.0	13.0	13.5	13.0	13.0	12.5	12.0	11.0
22-23											.7	1.3	2.6	4.3	6.6	9.0	10.6	11.7	12.5	12.5	13.5	13.0	12.0
24-25												.5	.8	1.7	3.2	5.0	7.4	9.8	11.0	11.4	12.5	12.5	14.0
26-27													.3	.6	1.1	2.2	3.8	5.6	8.0	9.7	10.5	11.5	12.0
28-29															.3	.8	1.3	2.6	4.1	6.3	8.3	10.0	11.2
30-31																	.4	.8	1.5	2.8	4.3	6.3	8.3
32-33																			.4	.8	1.5	2.8	4.5
34-35																					.4	.9	1.7
36-37																							.3

TABLE 20.—*Percentage distribution of total number of trees, by diameter class, in stands of different average breast-height diameters, under representative local conditions*—Continued

BLACK HILLS

Diameter class (inches)	Trees in class																						
	2 inches	3 inches	4 inches	5 inches	6 inches	7 inches	8 inches	9 inches	10 inches	11 inches	12 inches	13 inches	14 inches	15 inches	16 inches	17 inches	18 inches	19 inches	20 inches	21 inches	22 inches	23 inches	24 inches
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1	60.0																						
2–3	31.0	77.0	54.5	33.0	17.0	7.0	1.6																
4–5	9.0	17.6	30.7	37.5	35.0	28.0	20.4	11.0	4.0														
6–7		5.4	12.0	20.5	28.0	31.0	29.0	25.0	19.0	13.0	5.0												
8–9			2.8	7.6	14.6	21.0	25.0	27.0	25.0	22.0	17.0												
10–11				1.4	4.6	10.0	16.0	20.5	24.0	25.0	23.0												
12–13					.8	2.7	6.5	11.9	17.5	18.5	22.5												
14–15						.3	1.3	4.1	8.3	14.7	17.5												
16–17							.2	.5	2.2	6.4	12.3												
18–19										.4	2.7												

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Table 30 is the stock table for cubic-foot volume and table 31 for board-foot volume by Scribner rule. These tables represent average conditions and also conditions in individual subregions. No attempt is made here to present stock tables for selected ages and site indexes.

Stand and stock tables have many different uses, chief among which is prediction of the sizes of trees producible in future times. For the purposes of many calculations it is essential to know exactly how many trees of certain diameter classes will be obtained or how many years will pass before certain numbers of trees attain specified diameters. These tables are especially valuable in calculation of logging costs and profits. Often it is necessary to introduce tree size into computations of net costs and to deduce from these what silvicultural treatment is preferable.

The methods by which the stand and stock tables were constructed are described in the appendix.

TABLE 30.—*Percentage distribution of cubic-foot volume, by diameter class, in stands of different average breast-height diameters, for range as a whole and subregions*

ENTIRE RANGE

Diameter class (inches)	Volume in average diameter class																						
	2 inches	3 inches	4 inches	5 inches	6 inches	7 inches	8 inches	9 inches	10 inches	11 inches	12 inches	13 inches	14 inches	15 inches	16 inches	17 inches	18 inches	19 inches	20 inches	21 inches	22 inches	23 inches	24 inches
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
2–3	70.0	34.0	15.0	5.5	2.5	1.4	0.7	0.2	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------
4–5	23.7	45.0	39.0	23.5	13.5	8.1	4.3	3.0	1.8	0.8	0.4	------	------	------	------	------	------	------	------	------	------	------	------
6–7	5.3	16.0	30.0	34.0	28.0	10.5	14.0	8.8	6.0	4.2	2.6	1.9	1.0	0.6	------	------	------	------	------	------	------	------	------
8–9	.9	3.9	11.5	22.5	26.0	25.0	21.0	17.0	12.2	9.0	6.2	4.8	3.4	2.2	1.9	1.3	1.0	0.7	------	------	------	------	------
10–11	.1	1.0	3.4	9.5	16.0	21.0	23.0	21.0	20.0	15.0	11.8	8.3	6.6	5.0	3.7	2.7	1.8	1.2	1.4	1.0	0.5	------	------
12–13	------	.1	1.0	3.4	7.3	12.3	16.0	19.0	18.5	19.0	17.0	13.0	10.0	8.2	6.4	5.0	3.7	2.7	1.9	1.5	1.4	1.3	1.1
14–15	------	------	.1	1.4	3.4	6.6	10.0	14.0	16.5	18.0	19.0	17.0	16.0	13.0	11.0	8.5	6.5	5.0	3.7	2.7	2.0	1.5	1.3
16–17	------	------	------	.2	1.7	3.0	5.2	8.0	11.0	14.0	16.0	19.0	18.0	17.0	15.0	12.5	11.0	8.9	7.5	5.8	3.9	3.0	2.1
18–19	------	------	------	------	.9	1.6	3.0	4.2	6.4	9.2	11.5	15.0	17.0	18.0	16.5	16.0	14.0	12.5	11.0	9.0	7.2	6.0	4.3
20–21	------	------	------	------	.2	1.0	1.6	2.6	3.9	5.1	7.3	9.0	12.0	15.0	17.5	17.5	17.0	17.0	14.5	13.0	12.0	9.7	8.2
22–23	------	------	------	------	------	.4	.9	1.5	2.3	3.1	4.3	6.0	9.0	9.4	12.0	15.5	17.0	17.0	17.0	16.0	16.0	14.5	13.0
24–25	------	------	------	------	------	.1	.2	.6	1.0	1.7	2.3	8.5	3.0	5.6	7.5	9.5	12.5	14.5	16.5	17.0	17.0	17.0	16.0
26–27	------	------	------	------	------	------	.1	.1	.3	.7	1.2	1.6	2.5	3.5	4.6	5.7	7.5	9.5	12.0	14.0	15.0	16.0	17.0
28–29	------	------	------	------	------	------	------	------	.1	.2	.3	.7	1.1	1.9	2.7	3.8	4.8	6.0	7.5	10.0	11.5	13.0	14.5
30–31	------	------	------	------	------	------	------	------	------	------	.1	.2	.3	.5	1.0	1.6	2.6	3.6	4.6	6.0	7.5	9.4	10.5
32–33	------	------	------	------	------	------	------	------	------	------	------	------	.1	.1	.2	.4	.6	1.3	2.1	3.3	4.5	5.8	7.1
34–35	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	.1	.3	.7	1.4	2.5	4.2
36–37	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	.1	.3	.7

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CALIFORNIA

2-3		28.0	15.0	7.0	3.0	1.4	0.8																
4-5		30.0	28.0	22.0	13.0	8.1	5.0	3.2	1.8	1.0	0.6												
6-7		26.0	31.0	28.0	24.0	17.5	12.7	8.8	6.2	4.2	2.6	2.0	1.3	0.7	0.5								
8-9		8.2	18.6	24.0	26.0	25.0	18.5	15.0	11.5	8.8	6.3	4.7	3.3	2.6	1.9	1.6	1.0	0.7					
10-11		1.8	5.5	12.8	19.5	22.0	23.0	19.0	16.5	14.0	10.5	8.3	6.4	4.9	3.9	3.2	2.7	2.1	2.0	1.5	1.2		
12-13			1.9	4.2	9.5	14.5	20.0	22.0	19.0	17.0	14.5	11.0	9.0	7.8	6.7	4.7	4.3	3.5	3.0	2.8	2.1		
14-15				1.4	3.0	6.9	10.5	15.0	18.0	17.0	17.0	16.0	13.0	11.0	9.0	7.5	6.5	5.3	4.5	3.7	3.2		
16-17				.6	1.4	2.7	5.5	8.8	12.0	15.0	16.5	16.0	16.0	14.0	12.0	11.0	8.5	7.9	6.5	6.0	5.0		
18-19					.6	1.9	2.3	4.6	7.8	10.5	13.0	14.0	15.0	14.0	13.0	12.0	11.0	9.5	8.5	7.0	6.0		
20-21							1.7	2.2	4.2	6.5	8.7	11.5	12.0	14.0	14.0	13.0	12.0	12.0	10.5	8.5	8.0		
22-23								1.4	1.9	3.4	5.6	8.0	10.4	11.0	12.0	13.0	14.0	13.0	12.0	10.5	9.5		
24-25									1.1	1.9	3.1	4.9	6.9	9.0	10.5	12.0	12.0	12.0	12.0	11.5	11.0		
26-27										.7	1.6	2.6	4.3	6.0	8.5	9.4	10.5	11.0	12.0	11.5	12.0		
28-29												1.0	1.9	3.8	5.2	7.2	8.7	10.0	10.5	12.0	12.0		
30-31													.5	1.2	2.3	4.2	5.8	7.7	9.3	11.0	11.0		
32-33															.5	1.2	2.4	4.3	6.9	9.0	10.5		
34-35																	.6	1.0	1.3	4.0	6.2		
36-37																			.6	.6	1.3		
38-39																			.4	.4	.6		
40-41																					.4		

OREGON AND WASHINGTON

2-3		38.0	15.5	7.0	3.8	2.1	1.2	0.8	0.5														
4-5		44.0	29.5	16.0	9.7	5.4	3.8	2.5	1.7	1.4	0.9	0.6	0.3										
6-7		14.5	32.0	26.0	17.5	13.5	9.0	6.1	4.3	2.9	2.0	1.4	1.1	1.0	0.7	0.3							
8-9		3.5	16.8	28.0	23.0	17.0	14.0	10.6	8.5	6.2	4.7	3.5	2.6	1.8	1.2	1.1	1.0	0.8	0.4	0.3			
10-11			4.8	14.5	22.0	21.0	18.0	15.0	13.0	10.5	8.4	6.5	5.0	4.0	3.0	2.1	1.5	1.1	1.0	.7	0.8	0.5	0.4
12-13			1.4	6.5	15.0	19.0	20.0	18.0	16.0	14.0	13.0	11.0	9.5	7.7	5.7	4.5	3.5	2.5	1.9	1.4	1.1	1.0	.9
14-15				2.0	6.7	13.2	17.0	19.0	19.0	18.0	16.0	15.0	13.5	11.5	9.9	8.5	7.0	5.1	3.9	3.1	2.3	1.8	1.3
16-17					1.8	6.3	10.8	15.0	17.0	18.0	19.0	18.0	17.0	17.0	14.5	12.5	10.5	8.0	7.3	5.5	4.3	3.5	2.4
18-19					.5	2.1	4.6	8.5	11.3	15.0	16.0	18.0	17.0	17.0	17.0	16.0	14.5	14.5	12.5	10.0	8.0	6.2	5.0
20-21						.4	1.3	3.3	5.9	8.5	11.0	12.5	15.0	16.0	17.0	17.0	17.0	17.0	15.0	14.5	12.5	11.0	9.0
22-23							.3	1.2	2.2	4.1	6.0	8.1	10.5	11.5	13.5	15.0	17.0	17.0	17.0	17.0	16.0	15.0	13.0
24-25									.6	1.4	2.3	3.7	5.3	7.2	9.5	11.0	12.5	14.5	17.0	17.0	17.0	17.0	17.0
26-27											.7	1.4	2.3	3.5	5.0	7.0	8.5	10.5	11.5	14.0	16.5	17.0	17.0
28-29												.3	.9	1.4	2.1	3.4	4.4	5.5	7.4	9.0	11.0	13.0	15.0
30-31														.4	.9	1.2	1.8	2.4	3.3	4.8	6.3	8.0	10.0
32-33																.4	.8	.9	1.2	1.9	2.8	4.0	5.7
34-35																		.2	.6	.7	1.0	1.4	2.3
36-37																				.1	.4	.5	.8
38-39																						.1	.2

TABLE 30.—*Percentage distribution of cubic-foot volume, by diameter class, in stands of different average breast-height diameters, for range as a whole and subregions*—Continued

IDAHO AND MONTANA

Diameter class (inches)	Volume in average diameter class																						
	2 inches	3 inches	4 inches	5 inches	6 inches	7 inches	8 inches	9 inches	10 inches	11 inches	12 inches	13 inches	14 inches	15 inches	16 inches	17 inches	18 inches	19 inches	20 inches	21 inches	22 inches	23 inches	24 inches
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
2–3	68.0	35.0	16.0	6.8	2.7	1.4	0.7	0.5															
4–5	26.5	43.0	38.0	25.2	15.3	8.1	4.7	2.6	1.8	1.2	0.6												
6–7	5.5	17.0	29.0	34.0	27.0	20.5	13.6	7.9	5.0	3.2	2.2	1.9	1.3	0.9	0.5								
8–9		5.0	12.5	22.0	29.0	28.0	23.0	18.0	12.2	8.6	5.8	3.9	2.5	1.9	1.5	1.3	0.9						
10–11			4.5	8.4	16.5	22.0	25.0	23.0	20.0	15.0	10.9	8.2	5.7	4.0	2.9	2.3	1.7	1.9	1.4	1.0	0.7	0.5	0.3
12–13				2.9	6.7	13.0	18.0	22.0	23.0	20.0	16.5	13.0	10.5	7.7	6.1	4.4	3.4	2.6	2.0	1.6	1.1	1.0	.7
14–15				.7	2.8	5.0	10.0	15.5	19.0	22.0	22.0	19.0	16.0	13.5	11.0	8.0	6.5	5.3	4.1	3.1	2.4	1.8	1.4
16–17						2.0	4.1	7.3	12.0	16.0	19.0	20.0	19.0	18.0	15.0	12.0	10.5	8.2	7.0	5.3	4.3	3.3	2.6
18–19							.9	2.5	5.0	9.2	13.5	17.5	19.0	19.0	19.0	17.0	15.0	13.0	10.5	9.0	7.0	5.9	4.5
20–21								.7	2.0	4.0	7.0	10.7	15.0	17.0	18.0	19.0	18.0	16.0	14.0	13.0	10.5	8.5	8.0
22–23										.8	2.5	4.6	7.7	11.0	14.0	17.0	18.0	18.0	18.0	16.0	15.0	13.0	11.5
24–25												1.2	2.7	5.4	8.8	11.4	14.0	17.0	17.0	18.0	18.0	16.0	14.0
26–27													.6	1.6	3.0	6.0	8.3	11.0	14.0	15.0	17.0	18.0	17.0
28–29															.7	1.6	3.1	5.6	8.6	12.0	13.0	15.0	17.0
30–31																	.6	1.4	2.9	5.0	8.0	11.0	13.0
32–33																			.5	1.0	2.6	5.0	7.8
34–35																					.4	1.0	1.8
36–37																							.4

BLACK HILLS

Diameter class (inches)	2 inches	3 inches	4 inches	5 inches	6 inches	7 inches	8 inches	9 inches	10 inches	11 inches	12 inches	13 inches	14 inches	15 inches	16 inches	17 inches	18 inches	19 inches	20 inches	21 inches	22 inches	23 inches	24 inches
2–3	50.0	20.0	11.0	6.0	2.3	1.1																	
4–5	44.5	55.0	43.0	29.0	17.7	9.9	6.0	2.8	1.1	0.3													
6–7	5.5	23.1	34.0	34.0	33.5	25.5	16.5	11.2	6.4	3.7	1.4												
8–9		1.9	11.4	25.5	29.0	28.5	24.5	21.0	15.0	11.0	6.6												
10–11			.6	5.5	15.7	24.5	28.0	26.0	23.5	17.5	14.5												
12–13					1.8	10.5	20.0	24.0	25.5	24.5	21.5												
14–15							5.0	13.6	20.8	24.0	23.0												
16–17								1.4	7.7	16.0	22.0												
18–19										3.0	11.0												

[CDF-166]

TABLE 31.—*Percentage distribution of Scribner board-foot volume by diameter class in stands of different average breast-height diameters,[1] for range as a whole and subregions*

ENTIRE RANGE

Diameter class (inches)	Volume in diameter class														
	12 inches	13 inches	14 inches	15 inches	16 inches	17 inches	18 inches	19 inches	20 inches	21 inches	22 inches	23 inches	24 inches	25 inches	26 inches
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
12-13	96.0	59.0	30.0	17.0	10.5	6.5	4.2	2.9	1.9	1.1	0.8	-----	-----	-----	-----
14-15	4.0	30.4	33.0	25.0	17.5	12.5	8.6	6.1	4.1	3.2	2.2	2.0	1.5	0.8	-----
16-17	-----	9.0	23.3	25.0	22.0	18.0	14.2	11.0	8.0	6.0	4.2	3.3	2.5	2.1	1.8
18-19	-----	1.5	10.2	18.5	21.0	20.0	18.0	14.5	12.0	9.7	7.8	5.7	4.5	3.5	2.7
20-21	-----	.1	2.8	9.7	15.4	18.0	19.0	18.0	16.0	13.0	11.5	10.0	7.5	6.6	5.0
22-23	-----	-----	.7	3.6	8.2	12.8	15.0	16.5	16.5	16.5	15.0	13.0	11.5	9.0	8.0
24-25	-----	-----	-----	1.0	3.8	7.4	11.2	14.3	16.5	16.5	16.5	16.0	13.5	13.0	11.5
26-27	-----	-----	-----	.2	1.3	3.4	6.1	9.4	12.5	14.0	15.5	16.0	16.0	14.0	13.0
28-29	-----	-----	-----	-----	.3	1.0	2.5	4.6	7.0	10.7	12.0	13.0	15.0	16.0	16.0
30-31	-----	-----	-----	-----	-----	.4	.9	2.0	3.9	5.8	8.5	11.0	12.5	13.0	14.0
32-33	-----	-----	-----	-----	-----	-----	.3	.7	1.3	2.7	4.2	6.3	8.9	11.0	12.5
34-35	-----	-----	-----	-----	-----	-----	-----	-----	.3	.8	1.6	2.9	4.6	7.3	9.0
36-37	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	.2	.8	1.8	3.0	4.5
38-39	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	.2	.7	1.8
40-41	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	.2

CALIFORNIA

Diameter class (inches)	12 inches	13 inches	14 inches	15 inches	16 inches	17 inches	18 inches	19 inches	20 inches	21 inches	22 inches	23 inches	24 inches	25 inches	26 inches
12-13	98.0	52.0	29.0	17.0	10.8	7.5	5.1	3.9	3.0	2.2	1.6	1.3	1.0	0.8	-----
14-15	2.0	35.0	30.0	21.0	15.2	11.0	7.5	5.1	4.0	2.9	2.3	1.7	1.4	1.0	-----
16-17	-----	10.7	24.0	24.0	19.0	14.5	11.4	8.5	6.8	5.6	4.1	3.5	2.5	2.0	-----
18-19	-----	2.1	12.0	18.5	19.0	15.0	13.0	10.5	9.2	8.1	6.5	5.0	4.1	3.2	-----
20-21	-----	.2	3.6	11.5	16.5	18.0	17.0	14.0	11.0	10.2	8.5	7.5	6.2	5.0	-----
22-23	-----	-----	1.2	5.2	10.5	14.5	16.0	16.0	13.0	11.0	10.0	9.0	7.8	6.5	-----
24-25	-----	-----	.2	2.2	5.3	11.3	14.0	17.0	18.0	15.0	14.0	12.0	11.0	9.5	-----
26-27	-----	-----	-----	.5	2.8	5.3	9.8	13.5	17.0	18.0	18.0	16.0	14.0	12.0	-----
28-29	-----	-----	-----	.1	.8	2.3	4.6	7.8	11.5	15.5	17.0	19.0	19.5	17.0	-----
30-31	-----	-----	-----	-----	.1	.6	1.5	3.0	5.0	8.5	12.5	16.0	18.5	21.0	-----
32-33	-----	-----	-----	-----	-----	-----	.1	.7	1.4	2.7	4.6	7.2	10.8	16.0	-----
34-35	-----	-----	-----	-----	-----	-----	-----	-----	.1	.3	.9	1.7	3.0	5.5	-----
36-37	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	.1	.2	.5	-----

OREGON AND WASHINGTON

Diameter class (inches)	12 inches	13 inches	14 inches	15 inches	16 inches	17 inches	18 inches	19 inches	20 inches	21 inches	22 inches	23 inches	24 inches	25 inches	26 inches
12-13	100.0	50.0	28.0	16.9	10.0	6.1	3.8	2.7	1.4	1.0	0.6	-----	-----	-----	-----
14-15	-----	36.0	31.5	22.1	17.0	12.9	8.4	5.6	4.5	3.0	2.4	2.2	1.4	1.0	0.7
16-17	-----	13.1	25.8	27.0	22.0	18.5	14.8	11.5	8.3	6.4	4.4	3.8	3.1	2.3	1.9
18-19	-----	.9	11.5	20.0	21.5	20.5	17.5	15.2	12.8	10.6	8.6	6.5	4.7	3.7	3.0
20-21	-----	-----	3.2	9.4	16.2	17.0	19.0	18.5	16.5	14.0	11.5	10.0	8.5	6.8	5.4
22-23	-----	-----	-----	3.5	8.6	14.0	16.5	16.5	17.5	17.0	15.0	13.5	11.8	9.7	8.2
24-25	-----	-----	-----	1.1	3.6	7.2	11.0	13.5	15.0	16.0	16.5	15.5	14.5	13.0	10.8
26-27	-----	-----	-----	-----	1.1	2.6	5.7	9.2	11.0	12.5	14.5	14.5	15.5	15.5	14.5
28-29	-----	-----	-----	-----	-----	1.2	2.6	5.0	8.0	9.5	11.5	12.5	12.5	13.5	14.0
30-31	-----	-----	-----	-----	-----	-----	.7	2.3	3.8	6.8	8.6	10.5	11.0	12.0	12.0
32-33	-----	-----	-----	-----	-----	-----	-----	-----	1.2	3.2	4.8	7.2	9.4	10.5	11.5
34-35	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1.6	3.8	6.0	8.0	10.3
36-37	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1.6	4.0	6.1
38-39	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1.6

IDAHO AND MONTANA

Diameter class (inches)	12 inches	13 inches	14 inches	15 inches	16 inches	17 inches	18 inches	19 inches	20 inches	21 inches	22 inches	23 inches	24 inches	25 inches	26 inches
12-13	99.8	62.0	31.0	16.0	10.0	6.0	4.0	2.6	1.7	1.1	0.7	0.4	0.2	-----	-----
14-15	.2	32.5	38.0	29.0	18.0	13.0	8.5	5.9	4.3	2.9	2.2	1.5	1.0	0.8	-----
16-17	-----	5.1	22.5	29.0	26.0	20.0	15.5	11.5	8.0	6.5	4.6	3.6	2.6	1.7	-----
18-19	-----	.4	6.9	17.0	23.0	22.0	19.0	15.0	13.0	10.0	8.0	6.3	4.7	3.5	-----
20-21	-----	-----	1.6	6.8	14.0	18.0	19.0	19.0	16.0	13.5	11.5	9.7	8.0	6.5	-----
22-23	-----	-----	-----	2.0	6.4	12.0	16.0	17.0	18.0	16.0	14.0	11.5	10.5	9.0	-----
24-25	-----	-----	-----	.2	2.2	6.2	11.0	14.0	16.0	17.0	17.0	15.0	13.0	12.0	-----
26-27	-----	-----	-----	-----	.4	2.4	5.0	9.5	12.0	15.0	16.0	16.0	16.0	15.5	-----
28-29	-----	-----	-----	-----	-----	.4	1.8	4.3	7.5	10.7	13.0	16.0	16.0	16.0	-----
30-31	-----	-----	-----	-----	-----	-----	.2	1.1	3.0	5.5	8.7	11.8	14.5	15.5	-----
32-33	-----	-----	-----	-----	-----	-----	-----	.1	.5	1.7	3.8	6.6	9.2	11.5	-----
34-35	-----	-----	-----	-----	-----	-----	-----	-----	-----	.1	.5	1.6	3.9	6.4	-----
36-37	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	.4	1.6	-----

[1] Trees 11.6 inches and more in diameter.

HEIGHT

Figure 14 presents seven sets of height curves illustrating for representative ages and site indexes the average heights of trees of various

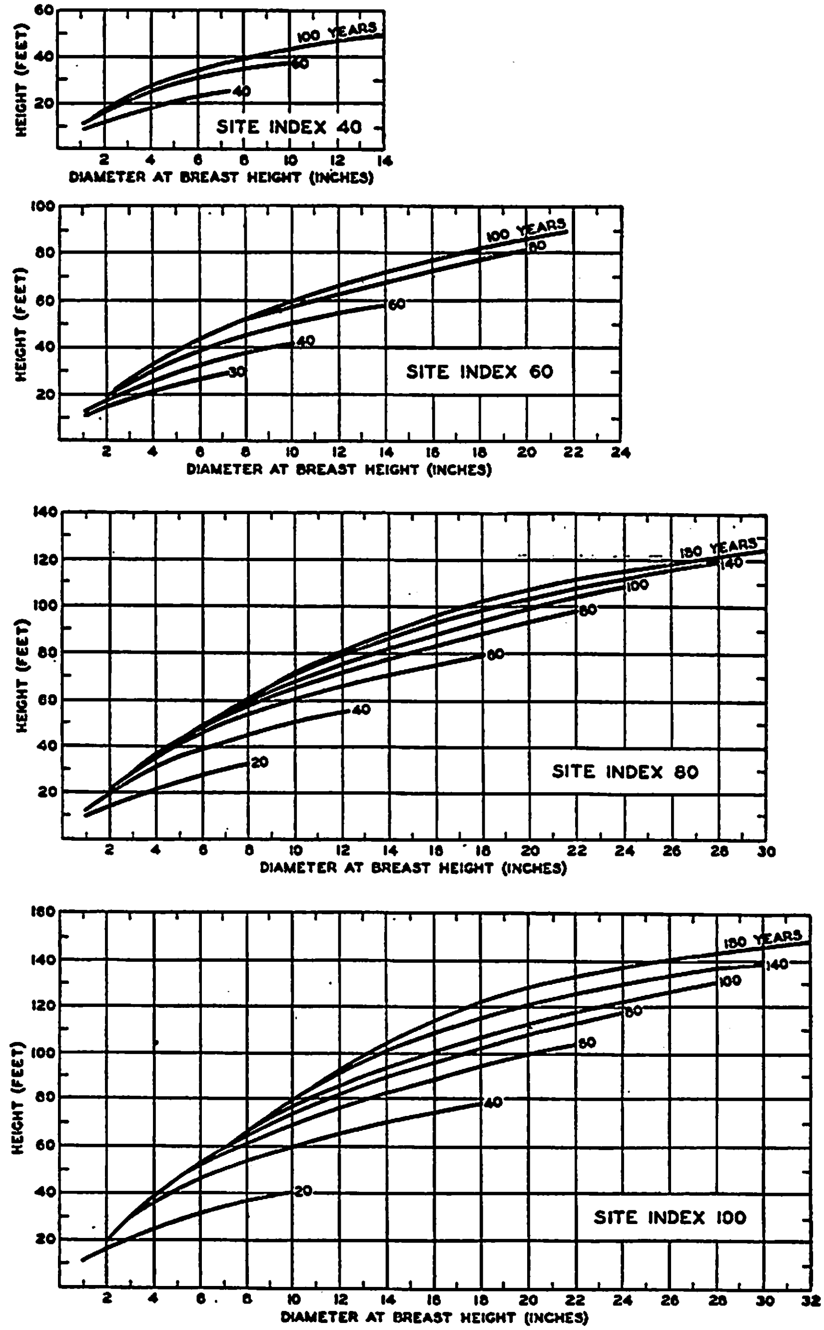

FIGURE 14a.—Total heights of trees of various diameter classes, for seven sets of representative ages and site indexes 40 to 100.

breast-height diameters. These curves are based on 10,101 height measurements. They are useful in calculating the volume, growth, and yield of second-growth ponderosa pine forests.

[CDF-168]

Curves of this sort are a recent addition to yield studies, in spite of the fact that many thousands of heights have been taken in stands of

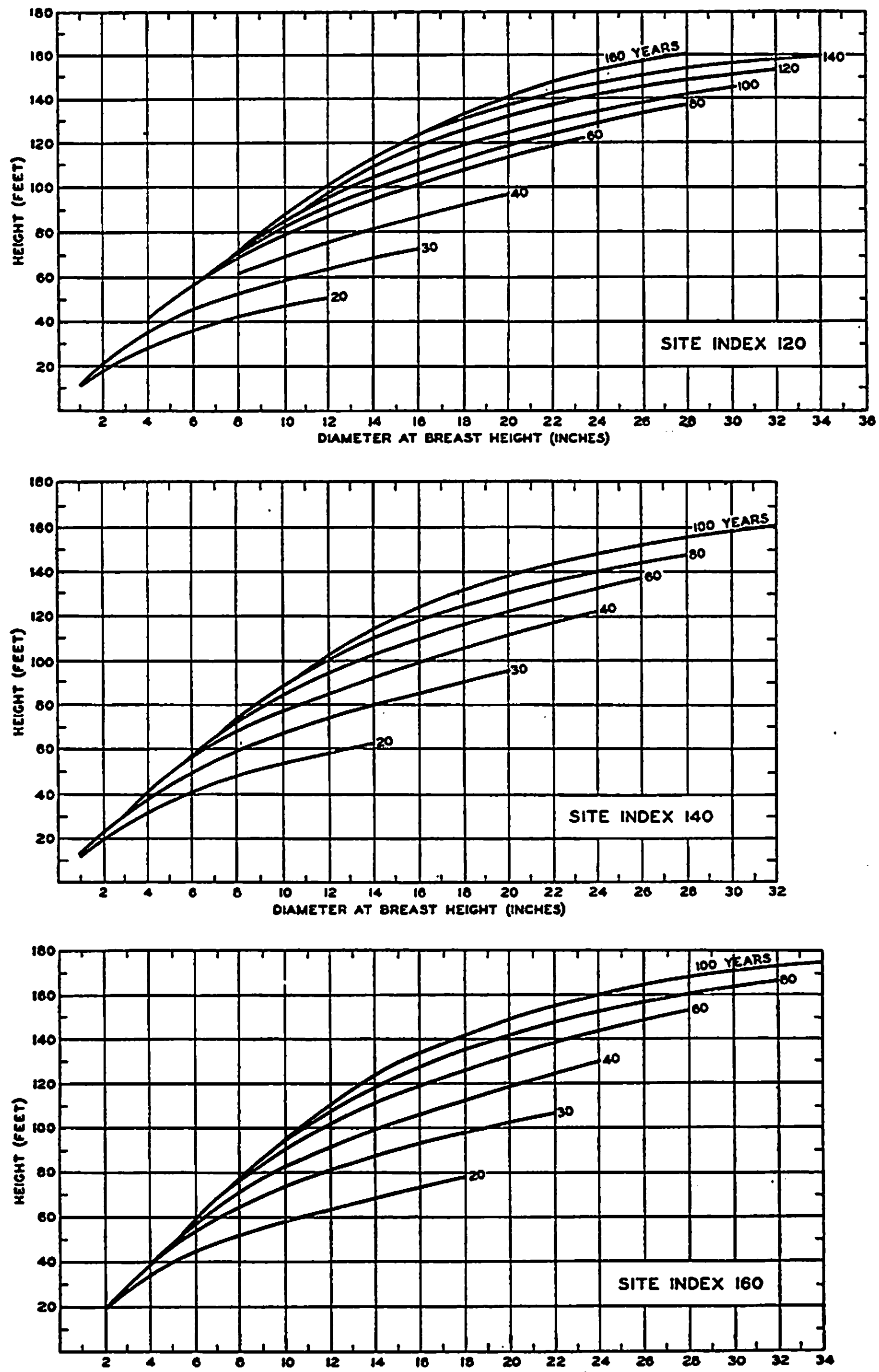

FIGURE 14*b*.—Total heights of trees of various diameter classes, for seven sets of representative ages and site indexes 120 to 160.

many age and site classes in every such study. The reason for this probably lies in the previous lack of a suitable method of analysis.

The method used in this study, which is described in the appendix, is simple and gives fairly accurate results, although it has the fault of subjectiveness. It is to be hoped that further study will lead to development of an objective technique for this purpose.

To apply these height charts, all the information required is age of stand and approximate site index. Heights for age classes not shown in the charts can be interpolated ocularly. Availability of these charts makes it unnecessary for timber cruisers to measure many tree heights. Such measurement has commonly been neglected, because of the time and inconvenience involved.

VOLUME

A volume study is prerequisite to a yield study. In this project, special effort was made to obtain all available stem and taper analyses for second-growth ponderosa pine and these data were supplemented with new material. Table 32 gives cubic-foot volume of the entire tree, including stump and tip but not bark or branches. Table 33 gives board-foot volume by International rule for ⅛-inch kerf, and table 34 gives board-foot volume by Scribner rule.

TABLE 32.—*Cubic-foot volume table for second-growth ponderosa pine, by total height of trees* [1]

Diameter at breast height (inches)	Volume by total height—													
	20 feet	30 feet	40 feet	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	110 feet	120 feet	130 feet	140 feet	150 feet
	Cu. ft.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
4	0.8	1.2	1.5	1.9	2.2									
6	1.7	2.3	2.9	3.6	4.2	4.8	5.5							
8		3.7	4.9	6.0	7.1	8.3	9.5	11	12					
10		5.8	7.7	9.5	11.5	12.5	15.5	17.5	20	22	24			
12			11	14	17	20	23	26	29	32	35	38		
14			15	19	23	28	32	36	40	44	48	52	56	
16			20	26	31	36	42	47	52	58	63	68	72	76
18			26	33	40	46	53	60	66	74	80	86	92	98
20			32	41	50	58	66	74	83	91	99	107	114	121
22				49	60	70	80	90	100	110	119	129	137	146
24				59	71	83	96	107	119	130	141	151	162	171
26				70	84	98	112	125	139	152	164	177	186	199
28					98	114	130	144	160	175	189	203	216	229
30					112	130	148	165	182	198	214	230	244	259
32					126	146	167	186	204	222	239	257	272	288
34					140	165	186	208	226	246	265	284	300	316
36						182	206	230	250	271	290	311	328	344
38						200	227	252	274	296	315	337	356	374
40						220	248	274	298	321	341	364	384	404
42							269	296	322	346	367	391	412	433
44							290	318	346	371	393	418	440	462
46								340	370	396	419	445	468	492
48								362	394	421	445	472	496	521
50								385	418	446	471	499	524	550

[1] Data collected in Oregon, California, Arizona, Colorado, New Mexico, and Montana. Basis, 2,947 trees. Volume includes peeled stump, stem, and top. Table prepared by alinement-chart method, 1935. Aggregate deviation from basic data, +0.24 percent. Standard deviation, ±11.8 percent.

TABLE 33.—*Board-foot volume table (International rule, ⅛-inch kerf) for second-growth ponderosa pine, by total height of trees* [1]

Diameter at breast height (inches)	Volume (board feet in tens) by total-height class											
	40 feet	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	110 feet	120 feet	130 feet	140 feet	150 feet
	Bd.ft.	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*
8	1	1	1	2	2	------	------	------	------	------	------	------
10	2	3	4	6	7	9	10	12	13	------	------	------
12	4	6	8	10	12	15	17	19	22	24	------	------
14	6	9	12	16	19	22	25	28	32	35	38	------
16	9	13	17	22	26	30	34	38	43	47	52	56
18	12	17	22	28	34	39	44	50	55	61	66	72
20	15	22	28	35	42	49	56	62	70	76	84	91
22	------	27	35	43	52	60	68	76	85	94	103	111
24	------	33	42	52	62	72	82	93	102	112	122	131
26	------	------	50	62	74	86	98	110	121	132	142	152
28	------	------	59	73	87	101	114	127	139	151	162	173
30	------	------	69	85	101	117	131	144	158	170	182	194
32	------	------	79	98	116	133	148	161	176	190	202	216
34	------	------	90	112	130	149	164	179	194	210	224	238
36	------	------	------	125	144	164	180	197	214	230	245	260
38	------	------	------	138	158	179	197	215	234	250	266	283
40	------	------	------	151	172	195	214	234	254	272	289	307
42	------	------	------	------	187	211	232	253	274	293	312	331
44	------	------	------	------	202	226	250	272	294	315	335	355
46	------	------	------	------	------	243	268	291	314	337	359	380
48	------	------	------	------	------	260	286	311	335	359	383	406
50	------	------	------	------	------	278	306	331	357	382	407	432

[1] Data collected in Oregon, California, Montana, Arizona, Colorado, and New Mexico. Basis, 2,865 trees. Stump height, 1 to 2 feet. Trees scaled in 16-foot log lengths with 0.3 foot trimming allowance to 6-inch top diameter inside bark. Table prepared by alinement-chart method, 1935. Aggregate deviation from basic data, −0.10 percent. Standard deviation, ±18.4 percent.

TABLE 34.—*Board-foot volume table (Scribner rule) for second-growth ponderosa pine, by total height of trees* [1]

Diameter at breast height (inches)	Volume (board feet in tens) by total-height class											
	40	50	60	70	80	90	100	110	120	130	140	150
	Bd.ft.	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*	*Bd.ft.*
10	1	1	2	2	3	3	4	4	5	------	------	------
12	2	4	5	6	8	10	11	12	14	15	------	------
14	4	6	8	11	13	15	18	20	22	24	26	------
16	6	10	12	16	18	21	24	27	30	34	36	40
18	9	13	17	21	24	29	34	37	41	46	50	54
20	12	17	22	27	32	37	44	48	53	58	64	69
22	------	21	27	34	41	47	54	60	67	74	81	89
24	------	26	33	42	50	58	66	74	83	91	100	109
26	------	------	41	51	60	69	79	90	100	109	119	129
28	------	------	48	59	70	82	94	106	117	127	138	148
30	------	------	56	69	81	96	109	122	134	145	157	167
32	------	------	64	80	95	110	124	138	151	163	175	186
34	------	------	74	91	109	124	140	154	168	181	194	206
36	------	------	------	104	123	138	156	171	185	199	213	226
38	------	------	------	117	137	152	172	188	203	218	232	247
40	------	------	------	130	150	167	188	204	221	237	252	268
42	------	------	------	------	163	182	203	221	238	256	273	289
44	------	------	------	------	176	197	218	238	257	275	293	309
46	------	------	------	------	------	211	234	255	275	294	313	329
48	------	------	------	------	------	225	249	272	293	313	333	350
50	------	------	------	------	------	240	264	289	311	332	353	371

[1] Data collected in Oregon, California, Montana, Colorado, Arizona, and New Mexico. Basis, 2,865 trees. Stump height, 1 to 2 feet. Trees scaled in 16-foot log lengths with 0.3-foot trimming allowance to 8-inch top diameter inside bark. Table prepared by alinement-chart method, 1935. Aggregate deviation from basic data, −0.25 percent. Standard deviation, ±17.8 percent.

The volumes corresponding to given diameters and heights of ponderosa pine trees are commonly considered to vary with site quality. The results of this investigation tend to support this theory; but because the data are in some respects incomplete and unsatisfactory, definite statements as to variation with site quality cannot be made. Instead, the data have been analyzed as a group for variation of volume with form. The expression for form tentatively accepted is the ratio between diameter inside bark at a height of 18 feet up the bole and breast-height diameter outside bark. Use of this quotient takes into account the two most important factors, namely the greater butt swell and the greater bark thickness usually observed on land of the better site classes.

In applying the volume tables to a specific stand these two measurements should be made on 30 or more trees, either after felling or by

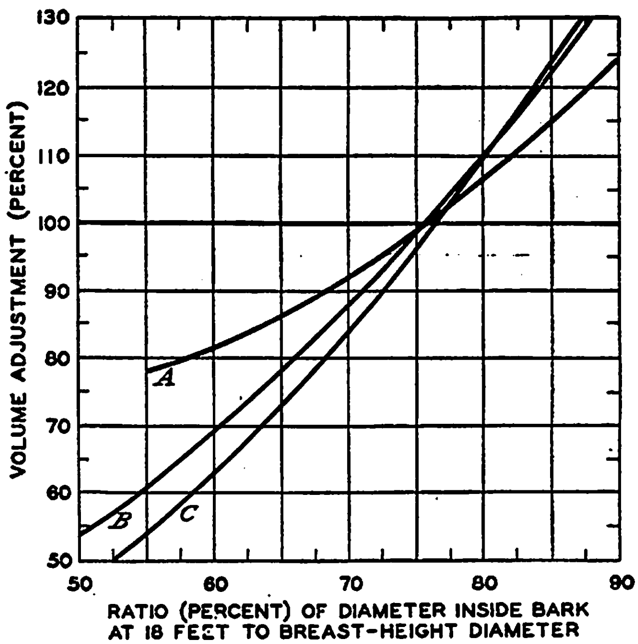

FIGURE 15.—Second-growth volume adjustment based on ratio of diameter inside bark at 18 feet to diameter outside bark at breast height: *a*, cubic-foot volume; *b*, board-foot volume, International rule; *c*, board-foot volume, Scribner rule.

climbing, the average ratio should be determined, and the corresponding adjustment factor should be sought in figure 15. The correction factors are most accurate for trees 10 inches and more d. b. h. For trees of smaller diameter, the ratio used here is not a good expression of form and use of the correction factors shown in figure 15 is not recommended.

If tables 32–34 are to be used frequently for interpolated diameter and height classes, it is advisable to convert them to graphical form, most preferably on double logarithmic paper of the largest cycle obtainable. Logarithmic paper with a cycle approximately 18 by 18 inches, for instance, has been prepared by the Pacific Northwest Forest Experiment Station for its own use and has proved entirely acceptable.

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APPENDIX

BASIC DATA

The data used in constructing the normal-yield tables in this bulletin are measurements taken on 450 temporary sample plots by seven or more investigators and their assistants in five national-forest regions. On more than 300 of these plots the measurements were made under one working plan, with general supervision by the author. Tables 35 and 36 show the distribution of the 450 plots by State, age class, and site-index class. The standard plot sizes in the normal-yield study were 1 acre for old stands and one-quarter acre for young stands. Departures from standard size were made often, to obtain uniform stand conditions. The distribution of the 450 plots by size was as follows:

Size (acre):	*Number of plots*
Less than 0.10	8
0.10 to 0.24	184
0.25 to 0.49	170
0.50 to 0.74	38
0.75 to 0.99	47
1.00 or more	3
	450

Efforts were made to sample true even-aged-forest conditions; measurement of plots in small patches of timber was not favored.

TABLE 35.—*Distribution of plots accepted in normal-yield study, and their average site indexes, by State*

State	Plots	Average site index	State	Plots	Average site index
	Number			*Number*	
Washington	10	73.6	Montana	119	65.2
Oregon	56	78.5	South Dakota	31	51.0
California	109	109.2			
Idaho	125	83.5	Total	450	

TABLE 36.—*Distribution of plots accepted in normal-yield study by age class and site-index class*

Age class (years)	30–49	50–69	70–89	90–109	110–129	130-149	150–169	Total
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
20–29		3	3		2	3		11
30–49	30	30	31	22	11	12	1	137
50–69	11	44	38	18	17	7	2	137
70–89		10	19	17	5	5		56
90–109	2	11	15	5				33
110–129	5	4	12	17	2			40
130–149		2	9	4				15
150–169		8	8	1				17
170–189		1	2					3
190–209			1					1
Total	48	113	138	84	37	27	3	450

Records were available for 398 plots in addition to the 450 accepted in the normal-yield study; some of these records were used to determine the effect of stocking upon yield. No data were available for the Southwest.[7]

Some of the new data were rejected, because they represented stands for which the density indexes were less than 250 or more than 550. Measures of rejection commonly used in yield studies, such as deviation by more than twice the standard error from the average value, were not applied in this study; therefore variation about the yield-table values as expressed by standard errors tends to be greater than usual. Wide variation had to be accepted because true normality had not been clearly defined and opinion in regard to it varied among the investigators themselves.

It may eventually be found necessary to supplement the data for a few subregions, particularly the Black Hills. Existing data for the Black Hills checked closely with those for the other subregions as to cubic volume, but differed from them considerably as to board-foot volume. It is probable that separate yield tables will be required for the Black Hills.

METHODS OF TABLE CONSTRUCTION

YIELD TABLES

In the ponderosa pine yield study it was necessary to depart somewhat from the standard methods of yield-table construction developed by Bruce (*6*), Bruce and Reineke (*7*), Reineke (*20*), and Bruce and Schumacher (*8*).

The success of yield-table construction depends primarily upon correct initial determination of the site quality of the plots. The investigator cannot proceed with the study until he has constructed dependable site curves. In the ponderosa pine study the site curves drawn up by the standard method (*6*) were obviously wrong. They were too flat in the lower range and too steep in the higher, and did not fit well any curve formed by data taken under site conditions known to be uniform. Attempts to modify the curves by a study of standard deviations and coefficients of variation (*8*) about the graduating curve led to errors of the opposite nature. A new method was therefore used.

The plots of each of 11 major subregions were treated as a separate group. The average height of average-diameter dominant and codominant trees for each plot in the subregion was plotted over age. An average curve was then fitted to the data, and an estimated site index read for the group. The next step was to set up a chart with site index as abscissa and height of average dominant and codominant trees as ordinate, to plot readings of the heights for selected age classes of each of the groups of data, and to curve these readings out by age class. The fit was made easily, the major part of each curve being rectilinear. A little forcing of the curves at the lower extremities was required to make them pass through the 0:0 coordinate. The final step was to construct a chart showing height over age for site indexes at intervals of 10. The results were not subjected to any rigid test, but were found to correspond to height-on-age curves, each representing a single site index, that were constructed from the height-on-age data available for certain localities fairly uniform in site conditions.

The success of this method depended upon the availability of groups of data for which average site quality varied widely. In this study site index ranged from 41 for the poorest group to 120 for the best. Had the territory covered by the investigation been limited as in earlier studies, probably this method would not have been feasible.

After the site-index curves were constructed, site index was determined for each plot and all the data were sorted on the basis of 20-foot site-index groups and 10-year age classes. At this stage the standard procedure is to construct graduating curves, with age as the abscissa and the stand value as the ordinate, and read the estimated plot values from the curve. The site-index curves are then drawn on both sides of the graduating curve, at intervals determined by ratio of sums of estimated plot values to sums of actual plot values for each site-index group. An alternative technique for the last step is a study of the coefficients of variation (*8*). These techniques, also, had to be modified. In the first place, for the data taken on land of good site quality the maximum age class was 70 years; whereas for those taken on average sites it was 190 years. Also, growth stagnation on a large

[7] It is possible, however, that the yield tables presented here can be applied to the even-aged groups common in the pine stands of the Kaibab Plateau, through some modification of yield-survey technique and study of the relations between values such as number of trees or volume for the Kaibab stands and corresponding values of the normal-yield tables.

[CDF-176]

number of plots in young stands and the poor site quality of many others tended to warp various sections of the graduating curves. For these reasons each graduating curve was confined to average site-index classes, namely those in the range from 60 to 100. The curve was anamorphosed, with age as abscissa, and upon the anamorphosed chart the data were plotted by site-index class. The points for each site-index class ordinarily fell in a straight line, which did not pass through the origin. Selected intercepts were then plotted over site index and curved out. Finally, the curved values of the intercepts were used directly to get the spacings of the site-index curves about the graduating curve. The customary cross checks were made among basal area, number of trees, and average diameter.

The yield tables for partial stands were constructed by the usual method (*6*) with slight modifications. The standard method calls for a single average curve of a stand value, such as percentage of total basal area included in the partial stand, over average diameter of total stand. The values for site index 40, the lowest in the scale, differed consistently from the average curve in these plottings and were therefore curved out and dealt with separately. The values for site index 50 were interpolated between the values for site index 40 and those for site index 60.

After the yield tables were completed checks were made on the fit of the data from different subregions to the yield tables. These resulted in certain minor changes in the tables. On the whole, however, the results were accepted as they stood. Aggregate deviations of subregional groups of data from the final yield tables, and the standard deviations of the entire group, are shown in table 37. The deviations for certain subregions may at first glance seem inordinately large; but they should not be construed as indicating a weakness in the tables, since rejection of plots was not severe.

TABLE 37.—*Aggregate deviations of plot data from normal-yield values, by subregion*

Subregion	Plots	Aggregate error (percent of estimated value) for—				
		Number of trees	Basal area	Cubic-foot volume	Board-foot volume	
					International rule	Scribner rule
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
California	109	+9.6	+7.6	+6.5	+7.8	+4.2
Oregon and Washington	66	−24.7	−3.9	−6.2	−.5	+5.3
Idaho [1]	65	−31.1	−5.4	−3.4	+3.7	+7.7
Southern Idaho	42	−6.4	−10.0	−9.0	−9.3	−8.7
Northern Idaho and Montana	137	+7.5	−2.2	−3.6	−8.0	−11.5
Black Hills	31	+15.8	+14.6	−2.7	−30.3	−61.0
Total	450	+.64	+.03	−1.25	+.13	−.21

[1] Data taken by Behre (*3, 4*).

For several western timber species including Sitka spruce and western hemlock (*15*), the plotting of yield values over average diameter without reference to site quality or age has resulted in compact curves in which no effect of site or age can be determined. Curves of this character have pronounced advantages, chief of which is the possibility of more reliable yield prediction on the basis of average diameter alone. In the case of ponderosa pine the curve of yield over average diameter shows a strong residual effect of site and age, which makes its utility negligible.

STAND AND STOCK TABLES

The stand and stock tables of this study were constructed by the graphical method used in a recent study of the yield of Sitka spruce and western hemlock (*15*). This method is in part a reversion to one used in early stand-table studies. It is simpler than the alinement-chart method (*7*) or any of the mathematical methods now in use. Its accuracy depends in part on availability of a large quantity of data. In the author's opinion, for use in constructing a series of tables of different kinds it is more accurate than the alinement-chart method or the mathematical methods; it may be less desirable than one or another of those methods in some instances, but it is believed to be the only method now known that can be applied to normal, skewed, and truncated curves for number of trees, basal area, or volume with equal ease and accuracy. The saving in time is enormous and was a prime factor in this study, in which literally dozens of stand and stock tables were prepared.

First the plots were sorted on the basis of 1-inch gradations in average diameter. Number of trees (or cubic-foot or board-foot volume) was listed, by diameter class, for each plot. Cumulative sums and percentages from smallest to largest diameter were then obtained for each diameter group and plotted on arithmetic frequency paper for successive limiting diameters. For instance, the percentage of total number of trees in the 1- and 2-inch classes was plotted on the 2.5-inch gradation, and that of the 1-, 2-, 3-, and 4-inch classes on the 4.5-inch gradation. The plottings were curved out only slightly or extended so that readings of diameter limits could be made at the graduations for certain percentages including 2, 5, 20, 50, 80, 95, and 98. These readings were plotted on ordinary rectangular coordinate paper with average diameter as the abscissa and diameter limit as the ordinate, and the plottings were curved out by the percentage intervals. Except for the high percentages, these fittings were made easily. This gave the basis for constructing on arithmetic frequency paper a complete set of fitted and coordinated curves, which ordinarily needed little further adjustment. To obtain table 28, the percentages applying to the successive diameter limits of a stand tally were applied to the yield table for number of trees in total stand (table 3) through the medium of the table for average diameter of total stand (table 5).

In the case of board-foot volume by Scribner rule, the basis of the initial sorting was average diameter not of total stand but of trees 11.6 inches and more in diameter. This switch resulted in much stronger curves in the subsequent steps.

HEIGHT TABLES

Figure 14, height curves for stands of representative age and site-quality class, was constructed by a method described in reports on yield studies for Sitka spruce and western hemlock (*15*) and for Douglas fir.[8] This method is largely graphical and therefore somewhat subjective, but for the present seems to be the only feasible technique available for constructing such curves. Multiple curvilinear correlation methods in their present form failed to give a satisfactory solution.

First the plots were sorted on the basis of 1-inch gradations in average diameter and the heights measured on all the plots of each group were listed by diameter. The average heights for individual diameter classes were computed and were plotted over diameter on rectangular coordinate paper. A smooth curve was drawn through the plottings and the height corresponding to the average diameter for the group of plots determined. The curved heights corresponding to diameters at 1-inch intervals were then expressed as percentages of this height. These percentages were next plotted over average stand diameter and curved out by 1-inch diameter classes.

Preparation of the site-age height charts began with reading the diameters for selected ages and site-index classes from the normal-yield table for average breast-height diameter of total stand (table 5). The heights of the average-diameter dominant and codominant trees for the same classes were read from table 4 and were converted to height of average tree of all dominance classes by means of a chart not given here. Percentage height values were read for average diameters of selected ages and site indexes, shown in table 5, and multiplied by average height in feet to get the heights for the full range of diameters.

The accuracy of this method depends upon the availability of a large quantity of data.

MORTALITY TABLES

The values for the mortality tables were computed through the medium of the number-of-trees table (table 3), the stand table (table 28), the height curves (fig. 14), and the cubic-foot volume table (table 32). The method of computation has been explained at length in a previous yield-study report (*15*) and will not be described here in full. In brief, it consists in deducing by means of the stand tables the number and size of the trees eliminated by supression from one decade to another. For instance, according to table 4 a stand of site index 80 has at 60

[8] MEYER, W. H. HEIGHT CURVES FOR EVEN-AGED STANDS OF DOUGLAS FIR. Pacific Northwest Forest Experiment Station. 1936. [Mimeographed.]

years 662 trees per acre, and at 80 years only 393 trees, or 269 trees less, per acre. From the stand tables for the two ages (table 28) the differences in number of trees for individual diameter classes, starting from the smallest, are cumulated until the total loss in number is found. In the case cited the loss per acre is eighteen 1-inch trees, sixty-five 2- and 3-inch trees, one hundred and one 4- and 5-inch trees, seventy-four 6- and 7-inch trees, and eleven 8- and 9-inch trees. The height for each diameter class, for the lower age class, is read from figure 14, and the volumes are computed. This method gives actually a minimum estimate of the volume lost during the period, since it makes no allowance for growth of the trees from the beginning of the decade to the time when they die or for death of any large trees.

VOLUME TABLES

The three volume tables were constructed by the base-alinement-chart method; separate base charts were used for each table, and the cubic-foot and board-foot tables were cross-checked by means of board-foot-cubic-foot ratios.

The deviations computed after the tables were completed indicated that volume may vary consistently with site quality, but the data were too unsatisfactory and unrepresentative for definite conclusions on this point. Many, perhaps most, of the present volume data are for young trees in uneven-aged stands; thus it is possible that the data do not fairly represent conditions in even-aged stands. In future investigations in second-growth ponderosa pine emphasis should be given to study of variation of volume with site quality or of the relation between form and volume, in order to define relations that may be more satisfactory than those stated here. When reliable volume data taken in even-aged stands of a good range of age classes on sites of all qualities are finally obtained and analyzed, if these data show variation with site quality the values of the yield tables for volume (tables 6, 11, 16) can easily be adjusted.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1961 O—586665