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YIELD, STAND AND VOLUME TABLES FOR DOUGLAS FIR IN CALIFORNIA

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FRANCIS X. SCHUMACHER[1]

INTRODUCTION

The United States Forest Service has reecently completed a study of the yields of Douglas fir (*Pseudotsuga taxifolia* Britt.) for even-aged stands of Oregon and Washington.[2] The work was not extended to stands south of the Willamette-Umqua divide in Oregon because from observation it is believed that this line roughly divides the Douglas fir forest into two types of decided difference in stand characteristics. But the commercial range of the species on the Pacific slope extends into California about as far south as Yosemite National Park in the Sierra and about San Francisco Bay along the coast. To report the yields of well-stocked, even-aged stands of the species in California is the object of this bulletin.

That there are significant differences in certain stand characteristics between the two general regions seems established from the work presented herein.

GROWTH OF DOUGLAS FIR STANDS IN CALIFORNIA

The growth of the species is shown by tables which state the yield of even-aged stands over a period of years. Age, timber productive quality of the area, and stand density are the most important growth-determining factors of a stand. As there is no satisfactory way of expressing stand density in absolute terms, *normal-yield tables* based on the ideal density which produces maximum volume are presented.

BASIC DATA

The normal-yield tables for Douglas fir are based on 159 sample plots scattered through the geographical range of the species in California.

[1] Assistant Professor of Forestry and Assistant Forester in the Experiment Station.

[2] McArdle, R. E. Rates of growth of Douglas fir forests. West Coast Lumberman, 54:90–95, 1928. This article summarizes the results of the study. The complete work is to be published soon as a bulletin of the United States Department of Agriculture.

Plot Selection.—Within even-aged stands plots were established so as to enclose a comparatively complete crown canopy by excluding the larger openings which follow failure of reproduction or accident and at the same time to include within boundaries the area equivalent to that which seemed to be used by the enclosed timber. Plots were surveyed with staff compass and chain.

Age Determination.—The age of each plot was determined by counting the annual rings on cores extracted (with Swedish increment borers) from near the base of several trees. By the age of the tree is understood the number of rings on the core plus the necessary correction for height growth to the point of boring. The age of the oldest tree was taken as the plot age although the difference between the ages of the youngest and oldest tree examined was seldom more than two or three years.

Field Measurements.—Diameter breast high of every tree was measured with diameter tape and tallied by species and crown class (dominant, codominant, intermediate, or suppressed).

The heights of fifteen to twenty-five trees were measured with the Forest Service hypsometer, from horizontal distances measured with the Leitz Fardi Range Finder of 20-centimeter base. Heights were plotted over diameter on cross-section paper in the field, the number of measurements necessary being judged at the time by the range of diameters present and their dispersion around the free-hand curve.

A short description of physiographic features completed the field work on each plot.

Office Computations.—The computational work necessary for each plot is evident from following paragraphs. The yield tables were constructed by correlating dependent growth variables with age and site quality by the method described by Bruce and Reineke,[3] and the stand tables are based on Charlier's[4] method of calculating theoretical frequencies.

NORMAL YIELD TABLES

Tables 1 to 11 and figures 1 to 11 indicate the growth of Douglas fir in fully-stocked stands in California, for age and site index.[5] Site index is herein defined as the height that the average dominant Douglas fir will attain, or has attained at 50 years of age. Average

[3] Bruce, D., and L. H. Reineke. Multiple curvilinear correlation in forest investigative work. Unpublished contribution of the United States Forest Service. 1927.

[4] Charlier, C. V. L. Die Grundzüge der mathematischen Statistik. p. 3–125. Lutke und Wulff, Hamburg. 1920.

[5] Before constructing these tables the sample plot data were compared to the yield tables for Douglas fir in Oregon and Washington. See p. 27.

TABLE 1

HEIGHT OF THE AVERAGE DOMINANT TREE*

Age, years	Site index—height of average dominant at 50 years				
	60	80	100	120	140
	feet	*feet*	*feet*	*feet*	*feet*
30	39	54	67	81	95
40	50	68	85	102	120
50	60	80	100	120	140
60	68	89	112	135	156
70	74	98	122	147	170
80	79	104	131	158	182
90	83	110	138	166	192
100	86	114	146	173	201
110	89	118	152	179	209
120	92	122	156	185	216
130	96	125	159	189	220
140	98	128	162	193	224
150	99	130	164	196	228
160	100	132	165	198	232

* The height from average ground level to tip of the dominant tree of average basal area for the dominant class.

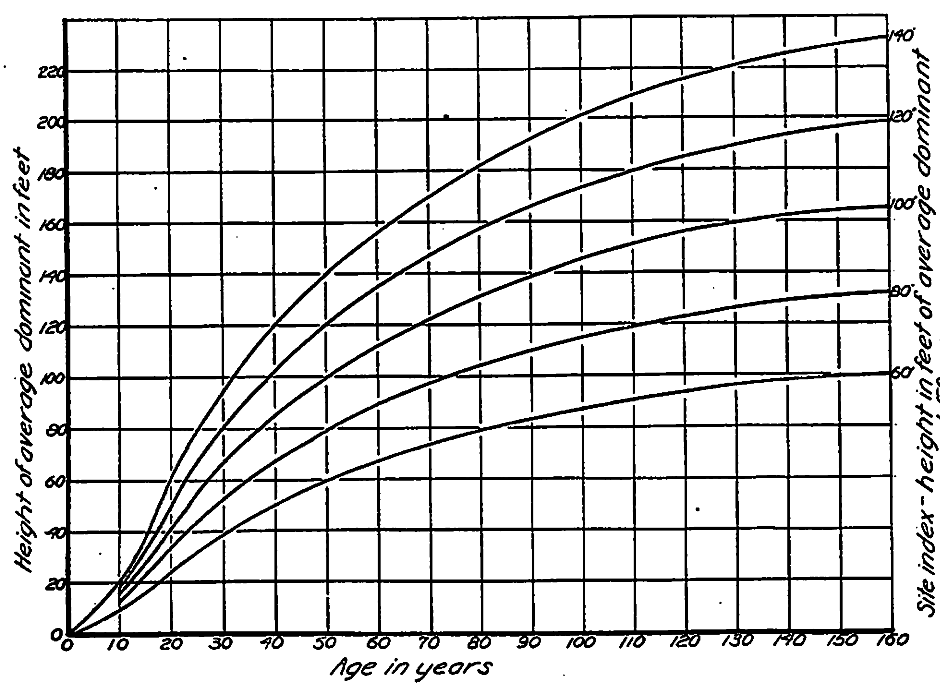

Fig. 1.—Height of the average dominant tree for age and site index. These curves were used in site classification of the plots.

TABLE 2

HEIGHT OF AVERAGE TREE*

Age, years	Site index—height of average dominant at 50 years				
	60	80	100	120	140
	feet	*feet*	*feet*	*feet*	*feet*
30	......	41	58	72	85
40	......	58	77	94	110
50	47	71	92	110	131
60	57	81	104	127	148
70	65	89	114	140	163
80	70	96	123	152	176
90	75	102	132	160	187
100	78	107	139	168	196
110	82	112	145	176	......
120	85	117	149	180	......
130	88	121	154	184	......
140	90	124	157	188	......
150	91	126	159	192	......
160	92	127	161	194	......

* The height from average ground level to tip of the tree of average basal area.

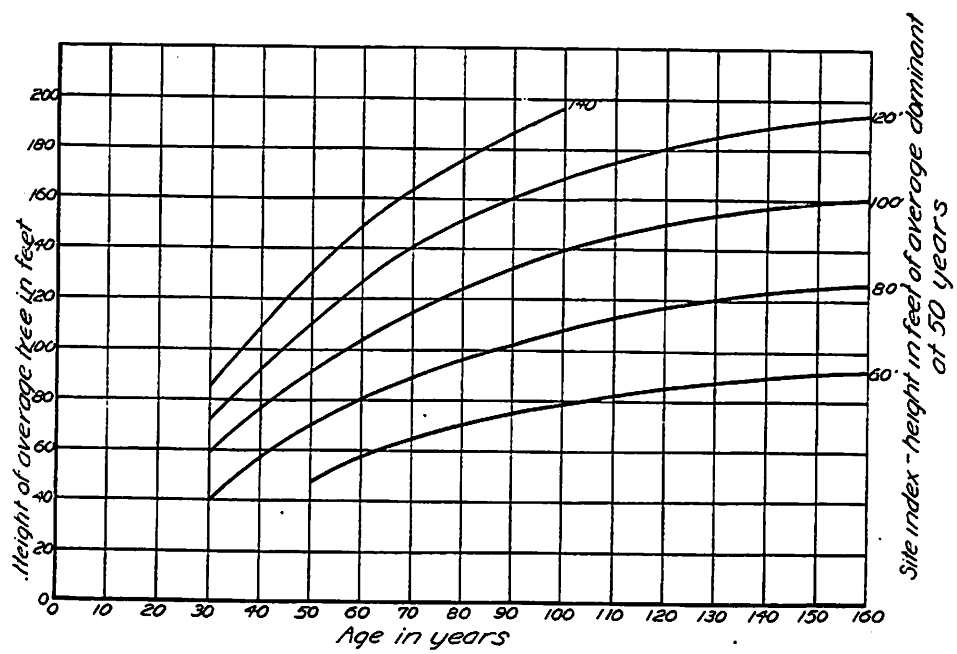

Fig. 2.—Height of the average tree for age and site index.

TABLE 3

NUMBER OF TREES TO THE ACRE*

Age, years	Site index—height of average dominant at 50 years				
	60	80	100	120	140
	Number of trees to the acre				
30	......	1060	672	485	394
40	......	780	497	364	297
50	1033	601	386	278	230
60	790	475	302	220	182
70	643	382	241	176	147
80	530	313	200	148	121
90	445	260	168	125	100
100	378	225	143	104	85
110	324	193	122	91	......
120	282	170	107	80	......
130	254	152	95	70	......
140	230	138	87	62	......
150	212	124	79	58	......
160	198	113	75	54	......

* The number of trees that have reached a height of at least 4.5 feet (breast height).

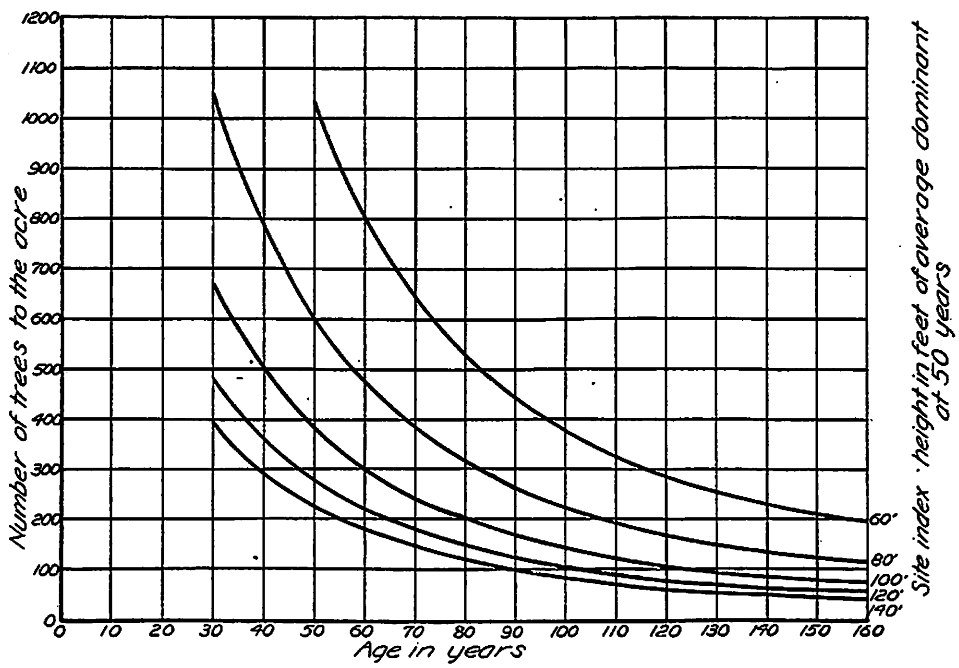

Fig. 3.—Number of trees to the acre for age and site index.

TABLE 4

BASAL AREA TO THE ACRE*

Age, years	Site index—height of average dominant at 50 years				
	60	80	100	120	140
	sq. ft.	*sq. ft.*	*sq. ft.*	*sq. ft.*	*sq. ft.*
30	......	198	217	230	243
40	......	223	243	267	285
50	205	237	264	290	305
60	214	249	281	305	319
70	222	260	295	316	328
80	228	271	305	323	334
90	233	280	313	329	339
100	238	288	318	333	342
110	242	294	322	336	......
120	245	298	326	338	......
130	248	302	328	340	......
140	250	305	330	341	......
150	251	308	331	342	......
160	252	309	332	343	......

* The sum of the cross-sectional areas at breast height, in square feet.

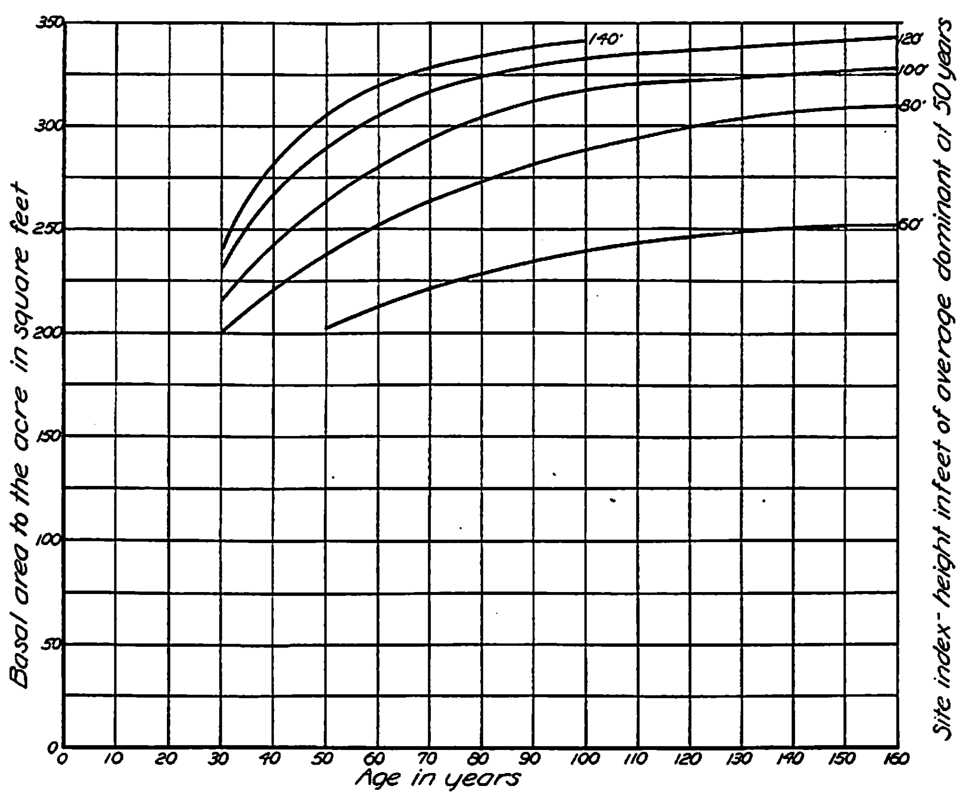

Fig. 4.—Growth in basal area to the acre for age and site index.

TABLE 5

AVERAGE DIAMETER, BREAST HIGH*

Age, years	Site index—height of average dominant at 50 years				
	60	80	100	120	140
	inches	*inches*	*inches*	*inches*	*inches*
30	....	5.9	7.7	9.3	10.6
40	....	7.2	9.5	11.6	13.3
50	6.0	8.5	11.2	13.8	15.6
60	7.1	9.8	13.1	15.9	17.9
70	8.0	11.2	15.0	18.1	20.3
80	8.9	12.6	16.7	20.0	22.5
90	9.8	14.0	18.5	22.0	25.0
100	10.7	15.3	20.2	24.2	27.0
110	11.7	16.7	22.0	26.0	....
120	12.6	17.9	23.6	27.2	....
130	13.4	19.1	25.2	29.8	....
140	14.1	20.2	26.3	31.8	....
150	14.7	21.3	27.7	32.9	....
160	15.3	22.4	28.5	34.1	....

* The diameter in inches of the tree of average basal area.

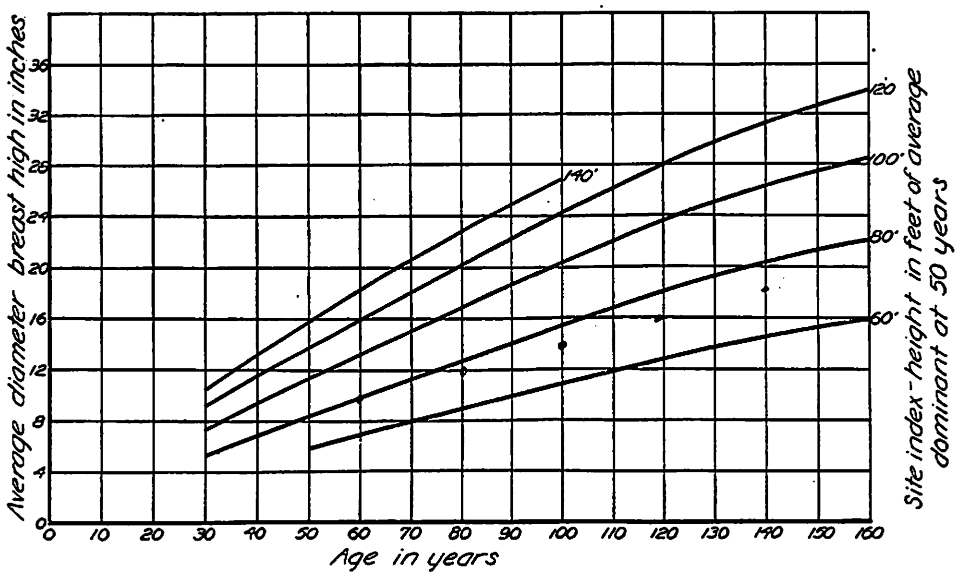

Fig. 5.—Average diameter breast high for age and site index—the diameter of the circle of average basal area.

TABLE 6

MEAN DIAMETER, BREAST HIGH*

Age, years	Site index—height of average dominant at 50 years				
	60	80	100	120	140
	inches	*inches*	*inches*	*inches*	*inches*
30	....	5.0	6.7	8.4	9.6
40	....	6.3	8.5	10.7	12.2
50	5.1	7.6	10.2	12.8	14.5
60	6.1	8.9	12.0	14.8	16.7
70	7.0	10.3	13.8	16.9	19.0
80	8.0	11.6	15.7	18.9	21.3
90	8.9	12.9	17.3	20.9	23.7
100	9.8	14.2	18.0	22.9	25.6
110	10.7	15.6	20.6	24.8	....
120	11.6	16.8	22.0	26.6	....
130	12.4	17.9	23.4	28.4	....
140	13.0	19.0	24.8	30.2	....
150	13.6	20.1	26.2	31.9	....
160	14.2	21.2	27.6	33.5	....

* The mean of all diameters on an average acre.

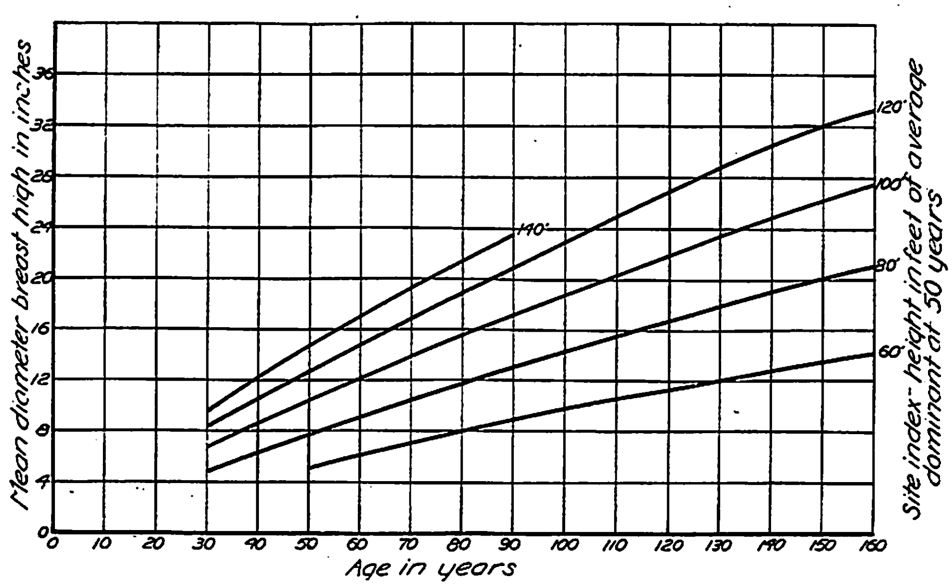

Fig. 6.—Mean diameter breast high for age and site index—the average of all diameters in the stand.

TABLE 7

Cubic Volume to the Acre*

Age, years	Site index—height of average dominant at 50 years				
	60	80	100	120	140
	cu. ft.	*cu. ft.*	*cu. ft.*	*cu. ft.*	*cu. ft.*
30	....	3,300	4,900	6,500	7,700
40	2,300	5,000	7,200	9,350	10,900
50	3,650	6,400	9,000	11,700	13,100
60	4,800	7,600	10,500	13,200	14,800
70	5,700	8,550	11,750	14,500	16,200
80	6,400	9,350	12,750	15,500	17,400
90	6,950	10,000	13,550	16,400	18,400
100	7,400	10,500	14,300	17,200	19,200
110	7,700	11,000	14,900	17,950	....
120	7,950	11,400	15,400	18,600	....
130	8,150	11,700	15,950	19,200	....
140	8,350	12,000	16,400	19,800	....
150	8,500	12,300	16,800	20,300	....
160	8,600	12,500	17,200	20,800	....

* The cubic volume of the entire stem of all trees from ground to tip but without limbs or bark. The volume table used is given following p. 22.

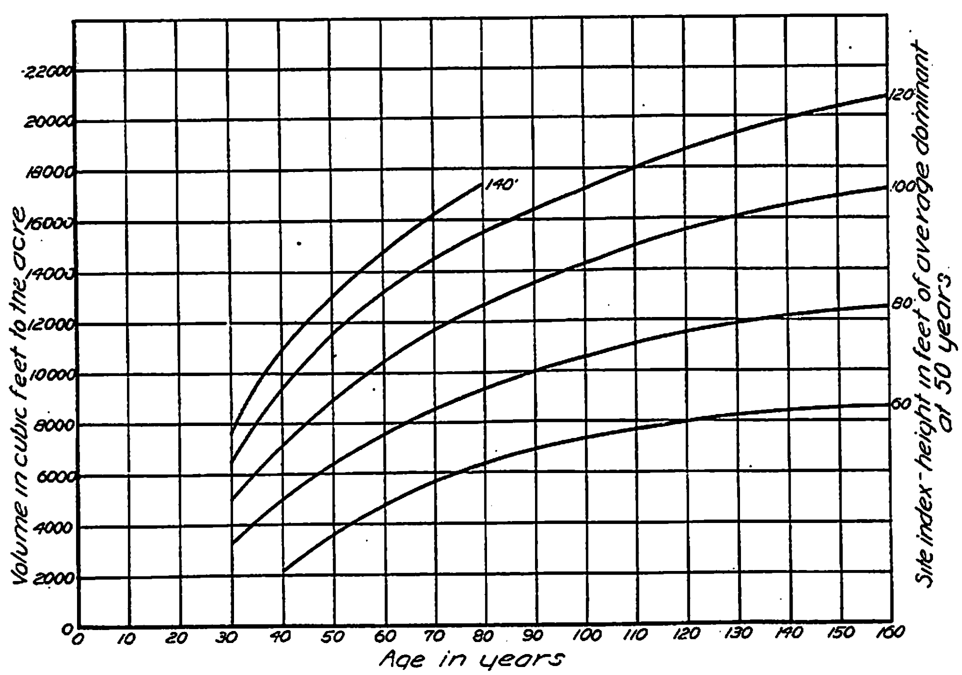

Fig. 7.—Growth in cubic volume to the acre for age and site index.

TABLE 8

MEAN ANNUAL GROWTH IN CUBIC VOLUME TO THE ACRE*

Age, years	Site index—height of average dominant at 50 years				
	60	80	100	120	140
	cu. ft.	*cu. ft.*	*cu. ft.*	*cu. ft.*	*cu. ft.*
30	....	110	163	217	257
40	58	125	180	234	270
50	73	128	180	234	262
60	80	127	175	220	247
70	82	122	168	207	232
80	80	117	159	194	218
90	77	110	151	182	205
100	74	105	143	172	192
110	70	100	135	163	......
120	66	95	128	155	......
130	63	90	123	148	......
140	60	86	117	141	......
150	57	82	112	135	......
160	54	78	107	130	......

* The cubic volume on the acre divided by the age

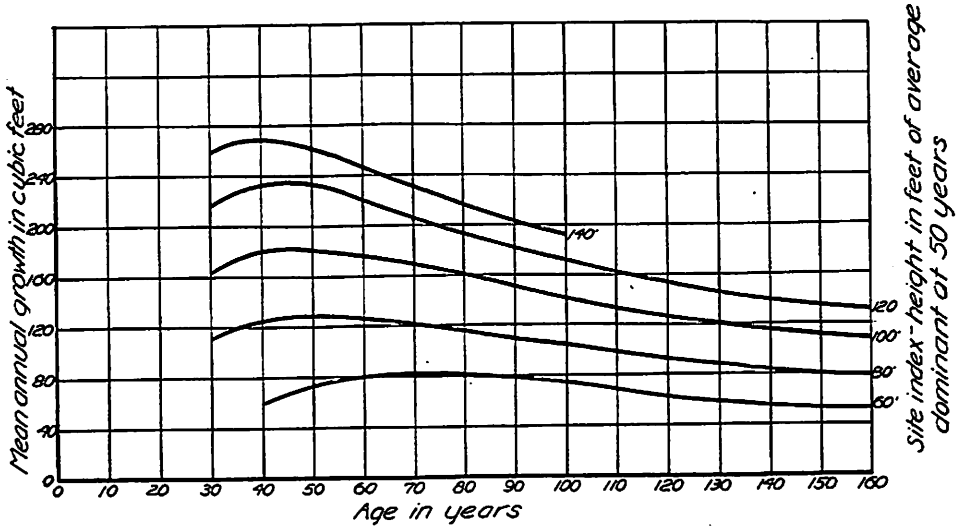

Fig. 8.—Mean annual growth in cubic volume to the acre for age and site index.

TABLE 9

NUMBER OF TREES EIGHT INCHES AND OVER, TO THE ACRE

Age, years	Site index—height of average dominant at 50 years				
	60	80	100	120	140
	Number of trees eight inches and over				
30	......	185	265	258	252
40	......	252	278	251	230
50	191	279	258	221	198
60	250	277	230	190	170
70	266	260	203	165	143
80	269	234	179	144	118
90	260	210	158	124	98
100	243	190	139	195	85
110	225	174	122	91	......
120	210	159	106	80	......
130	199	146	94	70	......
140	187	135	85	63	......
150	178	124	79	58	......
160	167	114	75	54	......

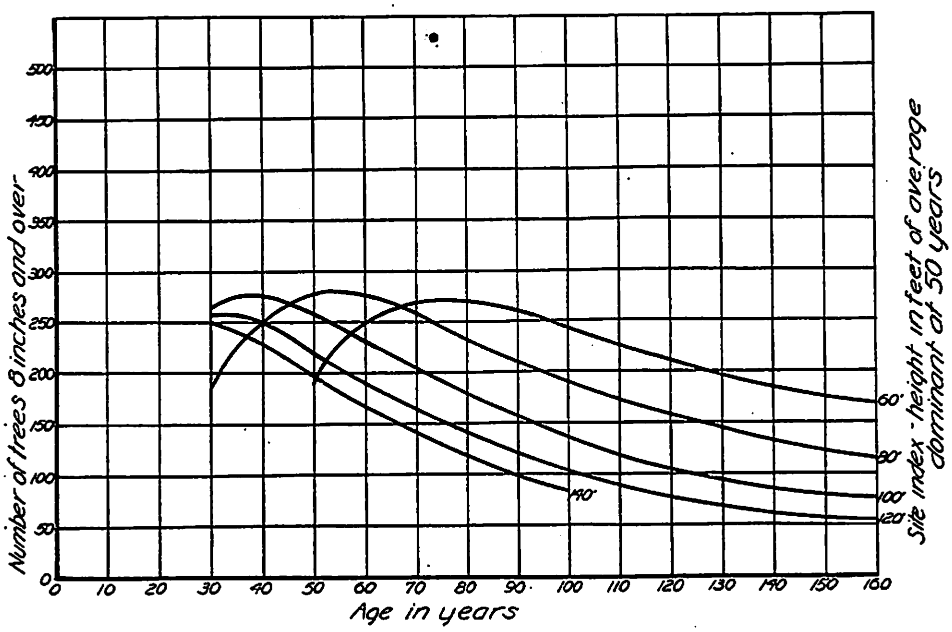

Fig. 9.—Number of merchantable trees to the acre for age and site index.

TABLE 10

VOLUME BOARD MEASURE TO THE ACRE*

Age, years	Site index—height of average dominant at 50 years				
	60	80	100	120	140
	bd. ft.	*bd. ft.*	*bd. ft.*	*bd. ft.*	*bd. ft.*
30	....	7,760	17,050	27,900	37,000
40	....	16,000	31,700	47,700	59,400
50	8,940	25,200	45,000	64,800	76,200
60	15,060	34,300	56,900	77,400	90,600
70	21,000	42,700	67,300	89,000	103,500
80	26,500	49,650	76,200	98,400	114,800
90	31,400	55,700	83,800	107,400	124,100
100	35,900	60,600	91,000	115,300	131,500
110	39,400	65,650	97,600	122,200	....
120	42,200	68,200	102,700	127,600	....
130	44,600	73,200	107,800	133,700	....
140	46,750	76,400	111,800	139,000	....
150	48,300	79,700	115,700	142,900	....
160	49,600	82,400	119,000	146,600	....

* The board foot contents of the trees by the International log rule of ⅛-inch kerf between a stump of one foot and a top diameter inside bark of 5 inches scaled in 16-foot logs with 0.3-foot trimming allotment to each. Gross volumes are presented, no account being taken of cull factors. The volume table used is given following p. 22.

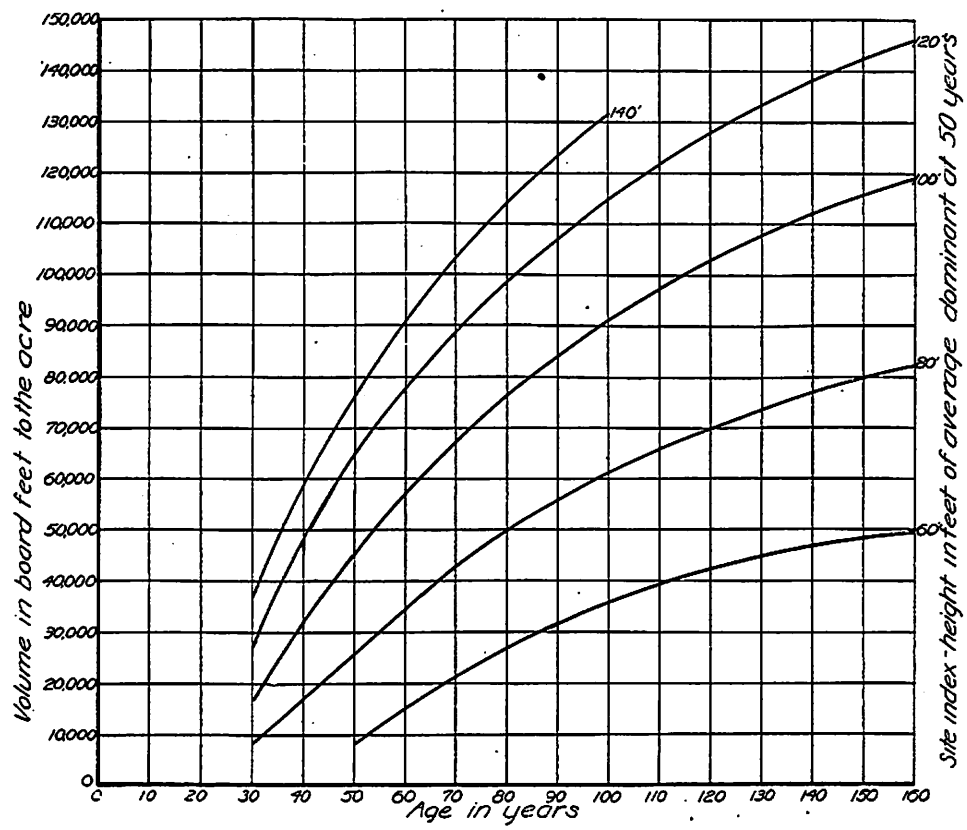

Fig. 10.—Growth in volume board measure to the acre for age and site index.

[CDF-65]

TABLE 11

MEAN ANNUAL GROWTH IN BOARD FEET TO THE ACRE*

Age, years	Site index—height of average dominant at 50 years				
	60	80	100	120	140
	bd. ft.	*bd. ft.*	*bd. ft.*	*bd. ft.*	*bd. ft.*
30	......	259	568	930	1,234
40	......	400	793	1,193	1,485
50	179	504	900	1,296	1,525
60	251	565	948	1,290	1,510
70	297	610	962	1,270	1,480
80	331	620	952	1,230	1,436
90	349	619	931	1,193	1,380
100	359	606	910	1,153	1,315
110	359	597	888	1,112	....
120	352	568	859	1,065	....
130	343	553	830	1,028	....
140	334	546	799	993	....
150	325	531	771	953	....
160	310	515	744	916	....

* The board foot volume on the acre divided by the age.

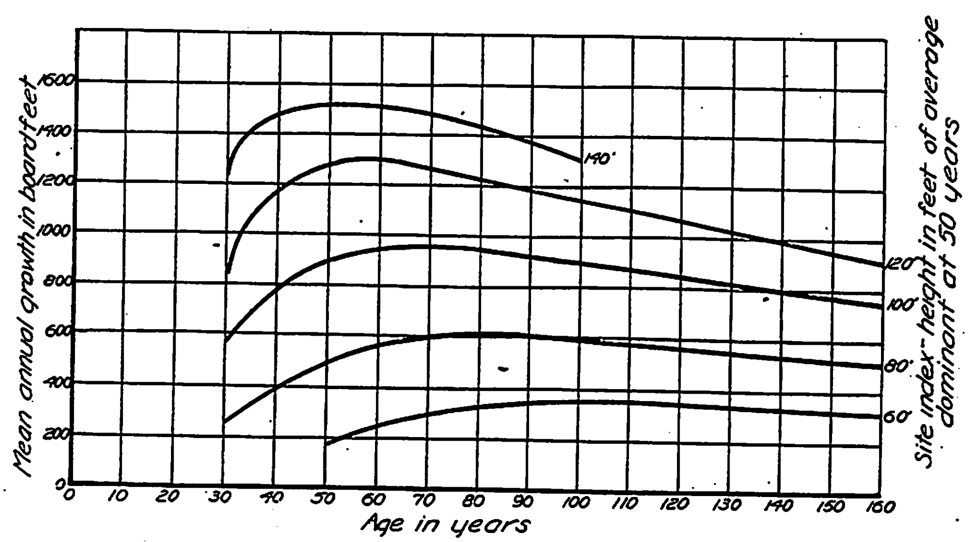

Fig. 11.—Mean annual growth in volume board measure to the acre for age and site index.

height of the dominant, or of the dominant and codominant stand is generally accepted as the most accurate and readily measurable factor of timber-productive quality of an area, because it bears a very close relationship to volume production within the limits of normal stocking.

Although the yield tables for Douglas fir in Oregon and Washington define site index as the height of the average dominant and codominant at 100 years, the height of the average dominant at 50 years is used here in order to conform with site index as defined in other California yield studies.[6,7] Height curves used in determining the site-index of each plot are shown in figure 1.

CHECK OF BASIC DATA AGAINST THE YIELD TABLES

Table 12 shows the check of the values of the 159 sample plots against the yield tables interpolated to nearest year of age and nearest foot of site index.

TABLE 12

CHECK OF BASIC DATA AGAINST YIELD TABLES

	Aggregate difference, per cent*	Mean difference, per cent**	Standard error of estimate, per cent†	Standard error of yield table value, per cent‡
Basal area	−0.0	+0.6	16.4	±1.30
All trees per acre	−0.2	+1.9	27.0	±2.14
Average d. b. h.	+0.9	+1.5	15.7	±1.24
Volume in cubic feet	−0.0	+0.3	16.3	±1.29
Volume in board measure	+0.8	+2.4	20.4	±1.67

* The aggregate difference is the sum of the plot values expressed as a percentage difference from the sum of corresponding tabular values.

** The mean difference is the mean of the per cent deviations of the plot values from corresponding tabular values.

† Standard error of estimate $(\sigma_{est}) = \frac{\Sigma(fx^2)}{N}$ in which x=deviation of each plot from its tabular value in per cent, Σ=the sum, and N=number of plots.

‡ Standard error of yield table value is the same as that ordinarily understood as standard error of the mean, the mean here being tabular value for age and site index. It is expressed thus: $\sigma_M = \frac{\sigma_{est}}{\sqrt{N}}$.

STAND TABLES

Although yield tables are basic to the solution of many forest management problems, they are not complete without stand tables as problems of valuation and utilization require knowledge of such stem distribution.

Stand tables for Douglas fir are given in table 13.[8]

6 Schumacher, Francis X. Yield, stand and volume tables for white fir in the California pine region. California Agr. Exp. Sta. Bul. 407:1–26. 1926.

7 Schumacher, Francis X. Yield, stand and volume tables for red fir in California. California Agr. Exp. Sta. Bul. 456:1–32. 1928.

8 The analysis of stem distribution and construction of stand tables is explained on pp. 32.

TABLE 13

NORMAL STAND TABLE FOR DOUGLAS FIR INCLUDING ALL TREES

D. b. h. class, inches	Age of stand in years													
	30	40	50	60	70	80	90	100	110	120	130	140	150	160
	Number of trees by diameter classes													
Site index 60 feet at 50 years														
0.0– 2.0			173	97	58	28	15	13	8	7	2	2	2	
2.0– 4.0			233	135	90	60	36	22	14	9	7	5	4	3
4.0– 6.0			251	177	127	89	62	44	31	21	16	12	9	8
6.0– 8.0			184	159	132	102	79	59	43	33	26	21	17	15
8.0–10.0			107	110	105	91	80	65	52	41	33	27	23	21
10.0–12.0			52	65	72	70	67	60	51	43	37	32	28	25
12.0–14.0			22	32	36	46	49	45	45	40	36	33	29	27
14.0–16.0			8	11	16	27	31	33	36	34	32	30	27	26
16.0–20.0				2	6	16	24	32	36	40	42	44	43	42
20.0–24.0						1	2	5	9	12	16	19	21	23
24.0–28.0										2	4	5	6	7
28.0–32.0													1	1
Total			1030	788	642	530	445	378	325	282	251	230	210	198
Site index 80 feet at 50 years														
0.0– 2.0	189	72	42	19	10	6	4	4						
2.0– 4.0	240	134	71	39	21	13	6	5	3	2	1	1		
4.0– 6.0	259	175	104	67	40	26	15	9	6	4	3	2	1	1
6.0– 8.0	183	157	119	85	55	37	25	16	11	7	5	4	3	2
8.0–10.0	105	122	101	85	65	46	32	23	17	13	9	6	5	4
10.0–12.0	53	69	77	70	60	48	36	28	21	16	12	10	7	6
12.0–14.0	21	36	48	52	50	43	37	31	24	19	15	12	9	8
14.0–16.0	5	14	26	33	37	37	32	29	25	21	17	14	11	9
16.0–20.0		4	12	23	37	43	47	46	43	39	35	30	26	23
20.0–24.0				2	7	13	22	25	28	29	28	27	25	23
24.0–28.0						2	5	8	13	15	18	19	19	19
28.0–32.0								1	3	6	8	10	12	12
32.0–36.0										1	1	3	5	6
36.0–40.0														1
Total	1055	783	600	475	382	314	261	225	194	172	152	138	123	114
Site index 100 feet at 50 years														
0.0– 2.0	65	18	10	3	2	1								
2.0– 4.0	101	47	20	10	5	3	1	1	1					
4.0– 6.0	139	73	41	22	11	6	3	2	1	1				
6.0– 8.0	136	92	56	33	20	11	6	4	2	2	1	1		
8.0–10.0	106	88	64	41	27	17	11	7	4	3	2	2	1	1
10.0–12.0	65	75	61	45	32	21	14	10	7	4	3	2	2	2
12.0–14.0	36	51	51	43	34	25	18	12	9	6	5	3	3	2
14.0–16.0	17	30	37	37	31	26	20	14	10	8	6	5	4	3
16.0–20.0	5	19	37	49	49	45	39	32	26	19	15	12	10	9
20.0–24.0		2	7	16	26	30	31	28	25	20	18	15	13	11
24.0–28.0				3	7	14	18	20	20	19	17	15	14	12
28.0–32.0					1	3	6	10	12	14	13	13	12	12
32.0–36.0							1	3	5	8	9	10	9	10
36.0–40.0									1	3	5	5	7	7
40.0–44.0											1	3	3	4
44.0–48.0													1	2
48.0–52.0														
Total	670	495	384	302	245	202	168	143	123	107	95	86	79	75

TABLE 13—(*Concluded*)

D. b. h. class, inches	Age of stand in years													
	30	40	50	60	70	80	90	100	110	120	130	140	150	160
	Number of trees by diameter classes													
Site index 120 feet at 50 years														
0.0– 2.0	26	14	2	1										
2.0– 4.0	51	20	8	4	1	1	1							
4.0– 6.0	77	39	19	8	4	2	1	1						
6.0– 8.0	92	52	29	16	8	4	2	1	1	1				
8.0–10.0	86	60	37	21	13	7	4	2	2	1				
10.0–12.0	67	56	41	26	17	10	6	4	3	2	1	1	1	
12.0–14.0	45	47	40	29	20	13	8	6	4	3	2	1	1	1
14.0–16.0	26	35	35	28	21	15	10	7	5	3	3	2	1	1
16.0–20.0	16	33	48	48	40	32	24	17	13	9	7	6	5	4
20.0–24.0		7	18	28	31	28	24	20	16	13	10	8	6	5
24.0–28.0			3	10	16	21	20	19	16	14	12	10	8	7
28.0–32.0				1	5	10	14	14	14	13	12	10	8	8
32.0–36.0					1	3	6	9	10	11	10	10	8	8
36.0–40.0							2	4	5	7	8	8	8	7
40.0–44.0								1	3	3	5	5	6	6
44.0–48.0										1	2	3	4	4
48.0–52.0												1	2	2
52.0–56													1	1
Total	486	363	280	220	177	146	122	105	92	81	72	65	59	54

D. b. h. class, inches	30	40	50	60	70	80	90	100	110	120	130	140	150	160
Site index 140 feet at 50 years														
0.0– 2.0	12	10	2											
2.0– 4.0	26	10	3	1	1									
4.0– 6.0	48	22	8	4	2	1	1							
6.0– 8.0	63	33	16	7	4	2	1	1						
8.0–10.0	69	42	22	13	7	3	2	1						
10.0–12.0	62	45	28	17	10	6	3	2						
12.0–14.0	49	43	31	20	12	8	5	3						
14.0–16.0	34	37	30	23	14	9	6	4						
16.0–20.0	29	44	49	44	32	23	16	11						
20.0–24.0	3	13	29	31	29	24	18	14						
24.0–28.0		1	10	18	21	21	18	15						
28.0–32.0			1	6	11	14	15	13						
32.0–36.0				1	3	7	10	11						
36.0–40.0					1	3	5	7						
40.0–44.0							1	3						
44.0–48.0								1						
48.0–52.0														
Total	395	300	229	183	147	121	101	86						

VOLUME TABLES

Preliminary to the study of yields in cubic and board feet, volume tables in these units were prepared.[9] The basic tree data of the tables presented are from measurements taken by the Division of Forestry from eight, previously measured, even-aged sample plots in Mendocino and Trinity counties. The ages of the trees measured were from 33 to 111 years.

Table 14 is the volume in cubic feet, and states the entire volume of the stem, including stump and top, but without bark. It was prepared by correlating cylindrical form factor with diameter, height and site index. As no significant relationship was discovered with site index, the table may be used for any site class.

TABLE 16

CHECK OF BASIC TREE DATA AGAINST VOLUME TABLES

	Aggregate difference, per cent	Mean difference, per cent	Standard error of estimate, per cent	Standard error of volume table value, per cent
Cubic foot volume	−0.0	−0.7	11.7	±0.71
Board foot volume	−0.7	−0.4	12.1	±0.81

Table 15 is the volume in board measure. It includes the board-foot contents of the trees between a one-foot stump and top diameter inside bark of five inches. It was prepared by correlating the number of board feet to a cubic foot with the diameter and height of the trees.

Table 16 shows the check of the basic tree data with the volume tables.

DISCUSSION

The generic name of Douglas fir, *Pseudotsuga,* implies that its common name is a misnomer in that the tree is not a true fir of the *Abies* genus, such as red and white fir.

One of the outstanding differences in characteristic growth between Douglas fir and the California true firs already studied[10] is the fact that the crown of the former becomes rather widespread when not confined by neighboring trees. Now diameter breast high bears a

[9] The check of the volumes of the basic tree data against the volume tables for immature Douglas fir in Oregon and Washington is explained on pp. 35.

[10] See Bul. 407 and Bul. 456 previously referred to.

noticeably constant ratio to crown width in any one timber species; hence the net result of widespread Douglas fir crowns with their associated greater trunk diameters at breast-height—when the stand is deficient in number of trees—is the tendency to form complete crown canopies and therefore to approach normal stocking by basal area. Figure 12 indicates this within the limits of the data presented. The regression of average diameter breast high on number of tree is

$$\text{Average d.b.h. in per cent of the tabular value} = \sqrt{\frac{1{,}000{,}000}{\text{Number of trees in per cent of the tabular value}}}$$

Now basal area in square feet is .00545 times the number of trees times the *square* of average diameter breast high in inches. But

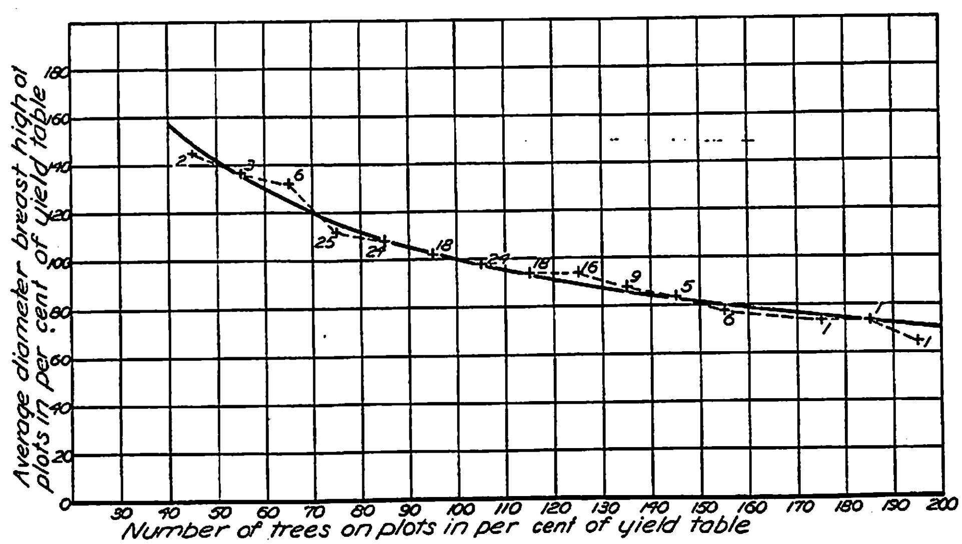

Fig. 12.—Relation between average diameter and number of trees.

within a given site-age class by the above equation, the number of trees times the square of the average diameter is constant; that is, basal area tends to be independent of the number of trees as long as there are at least sufficient trees to allow a complete crown canopy.

The true firs, on the other hand, have characteristically narrow crowns even when growing in the open; hence they have not the ability to form complete crown canopies when deficient in number of trees. Deficiency in number of trees within a site-age class results in deficiency in basal area, because of the narrower crowns and the crown diameter—diameter breast high ratio. Therefore, average diameter is proportional to the number of trees and not to the *square*

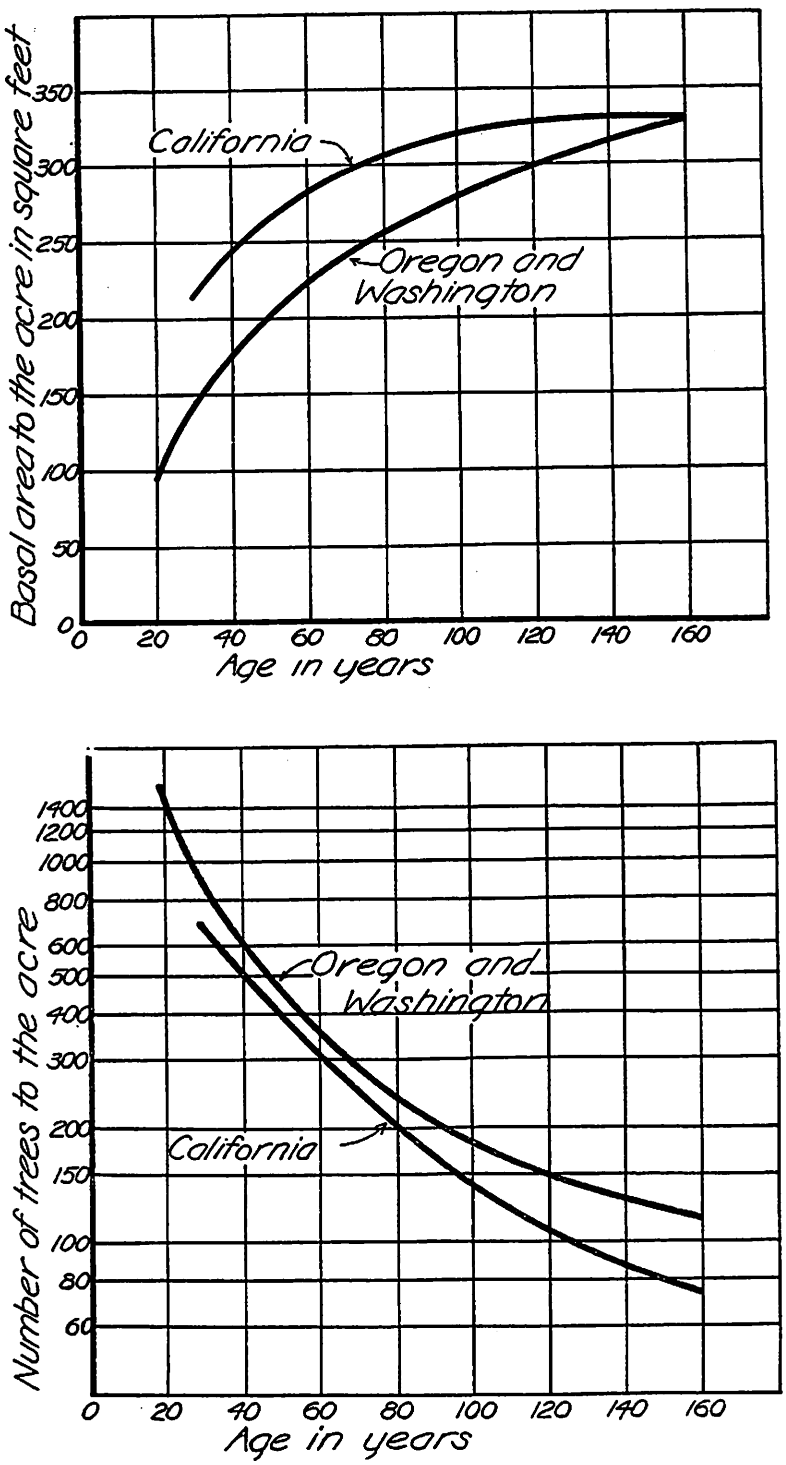

Fig. 13.—Comparison of California stands by basal area and by number of trees with those of Oregon and Washington for site index 140 feet—height of the average dominant and codominant tree at 100 years.

root of the number; while the effect on basal area of increasing the number of trees through normality to an overstocked condition is that it rises to a maximum and then falls off.[11]

The differences in growth of Douglas fir between the central and southern parts of its range are evident from figure 13 which shows the comparison of yield values in basal area and in number of trees with age for average site class. One must infer that the stand in California breaks up earlier in life than it does farther north for the following reasons:

(1) It has fewer trees to the acre throughout and these decrease at a greater rate.

(2) It grows faster in basal area when young, but after about 100 years this growth practically stops though in the north it is still vigorous.

Such differences are not unknown in other species which have a wide latitudinal range. In taking part in a recent discussion as to the relative merits of timber producing regions in the United States, Zon[12] compares the yield of two Russian species—Scotch pine and birch—in northern and southern provinces of that country and notes the same tendencies.

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11 See figures 6 and 7, Bul. 456.

12 Zon, R. Forestry versus climate. Jour. Forestry. 26:711–713. 1928.

APPENDIX

YIELD AND STAND TABLES

BASIC DATA

The sample plots on which the yield and stand tables are based were measured by the Division of Forestry in 1927. Out of the 175 plots originally measured, 16 were discarded (see table 20). The 159 actually used are from the following watersheds given in table 17.

TABLE 17

DISTRIBUTION OF PLOTS BY PRINCIPAL WATERSHEDS

Region and watershed	Number of plots
Coast Range:	
Clear Lake	3
Gualala River	3
Garcia River	2
Noyo River	5
Big River	3
Eel River	38
Van Duzen River	6
Mad River	12
Redwood Creek	23
Trinity River	38
Klamath River	5
Sierra Nevada Mountains:	
American River	14
Yuba River	5
Feather River	2
Total	159

The composition of the plots by basal areas of the various species included is shown in table 18.

TABLE 18

COMPOSITION OF BASAL AREA OF THE PLOTS USED

Species	Basal area in percentage of total
Douglas fir	94.99
Western yellow pine	1.48
Oak, laurel and madrone	1.04
Redwood	0.98
White fir	0.57
Sugar pine	0.45
Incense cedar	0.37
Grand fir	0.12
Total	100.00

The distribution of the plots by site and age classes is given in table 19. In this table, site index is defined as the height of the average dominant and codominant at 100 years, as the tables were first constructed on site index so defined for purposes of comparison with yields of Douglas fir in Oregon and Washington.

TABLE 19

DISTRIBUTION OF PLOTS BY SITE AND AGE CLASSES

Age in years	Site index—height in feet of the average dominant and codominant tree at 100 years														
	75-84	85-94	95-104	105-114	115-124	125-134	135-144	145-154	155-164	165-174	175-184	185-194	195-204	205-214	Total
25- 34						1	1	4	1					1	8
35- 44			1	1			2				2	2			8
45- 54		1				3	1	2	5						12
55- 64	4	1		1	5	10	8	10	6	7	5	2			59
65- 74	1	4	5	7	2	5	2	2	7	4					39
75- 84				2											2
85- 94							1								1
95-104									1		2				3
105-114					1	5	6								12
115-124							1	7	3						11
125-134										1					1
135-144							2								2
145-154															
155-164															
165-174									1						1
Total	5	6	6	11	8	24	24	25	24	12	9	4		1	159

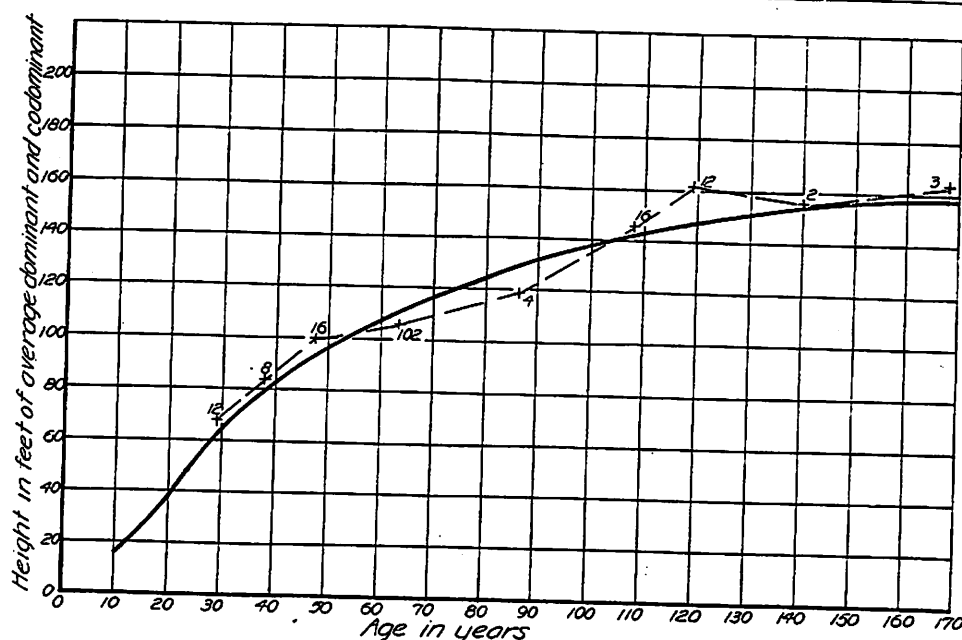

Fig. 14.—Comparison of heights of average dominant and codominant tree in the California plots with the height curve for Oregon and Washington stands of the same average site index.

Comparison of the California Sample Plots with Yield Tables for Douglas Fir in Oregon and Washington

Yield tables for Douglas fir in Oregon and Washington define site index as the height of the average dominant and codominant tree at 100 years. In order, therefore, to compare the values of the California sample plots with the Oregon-Washington tables, each California plot was assigned a site index number as defined for the tables of the northern material. That the latter's height growth curve for the average dominant and codominant, on which site index is based, fits the California data is shown in figure 14. Then the values of each California plot were compared with the Oregon-Washington yield tables and the percentages of the former to the latter were arranged

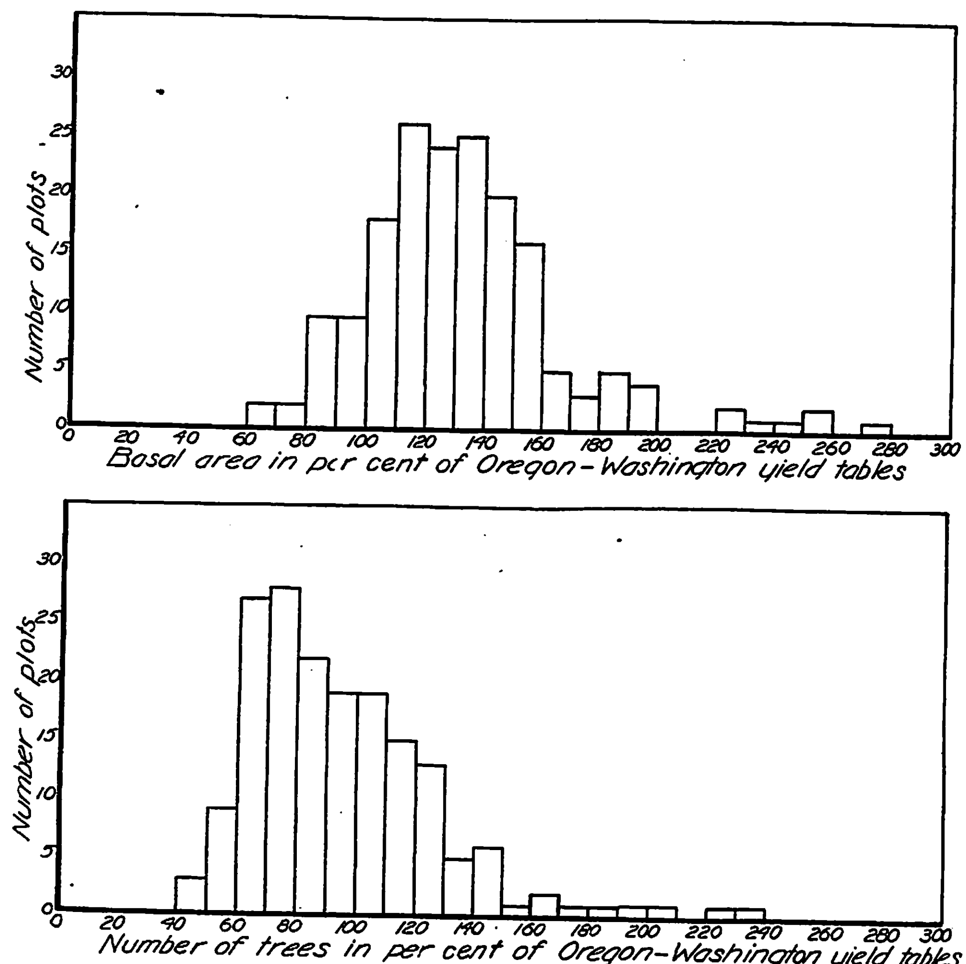

Fig. 15.—Frequency distribution of the California sample plots in per cent of the Oregon-Washington yield tables by basal area and by number of trees.

in a frequency array by basal areas and by numbers of trees. Figure 15 shows these dispersions graphically. The comparison of the means for the original 175 plots are as follows:

By basal area, + 33.2% ± 2.65%
By number of trees to the acre, — 4.3% ± 2.49%

Were the means of the California plots by both basal area and number of trees either higher or lower than the Oregon-Washington tables by about the same amount, one might doubt the validity of the comparison, as the differences might be due to different conceptions as to what constitutes normal stocking, on the part of those who originally laid out and measured the plots in the two regions. But as the basal area of the California material is 33 per cent higher, and the number of trees 4 per cent lower, this can hardly be the case.

REJECTION OF ABNORMAL PLOTS

The rejection of abnormal plots is based on the above comparison. Those which deviated by about two standard deviations from the mean difference of the California plots were checked over for explanation of their abnormal values. As the explanation was seldom evident from the measurements taken or from the plot description, nearly all were rejected. Table 20 summarizes the rejected plots.

TABLE 20

CALIFORNIA PLOTS REJECTED AS ABNORMAL

Age, years	Site index	Per cent of difference from corresponding values in Oregon-Washington yield tables		Basis for rejection
		By basal area	By number of trees	
63	71	+ 55	+ 62	Too many incense cedar trees
67	98	+ 45	+ 61	Too many incense cedar trees
72	109	+ 84	+107	Basal area and number of trees too high
67	122	+ 95	+ 80	Basal area and number of trees too high
111	125	+147	+ 76	Basal area and number of trees too high
27	130	+126	− 8	Basal area too high
27	132	+152	+ 9	Basal area too high
168	146	+ 44	− 26	Basal area too high
91	148	+ 74	+ 24	Basal area too high
27	151	+125	− 20	Basal area too high
45	158	+173	+ 53	Basal area and number trees too high
45	156	+139	+ 45	Basal area and number trees too high
168	150	+ 80	+ 11	Basal area too high
45	171	+ 83	+ 88	Too many redwood sprouts and tan oak trees
45	178	+ 53	+139	Basal area and number trees too high
33	200	+ 99	+125	Too many redwood sprouts

The means of the remaining 159 plots are as follows:

Basal area: $+25.9 \pm 1.97\%$
Number of trees: $-9.6 \pm 1.97\%$

Obviously these figures cannot be accepted as due to chance fluctuation. There must be differences in Douglas fir stand characteristics between the southern and central part of its range on the Pacific slope.

CONSTRUCTION OF THE YIELD TABLES ON THE 100-YEAR SITE INDEX

Rather than correlate the percentage deviations of basal area, number of trees, and of other growth units with age and site, the original units are correlated directly with age and site on the 100-year site index and later transferred to the 50-year site index to conform with site as defined for other California species.

Basal Area, Number of Trees, and Cubic Volume.—Plot values on the acre basis for these variables were correlated with age and site by comparing them with the multiple linear regression equation, and, by a series of successive estimates, converting the net regression lines for age and for site index as well as the relationship between actual and estimated values, to curvilinear forms where necessary. The calculation of the correlation, measured by the correlation index, is analogous to the Pearsonian correlation ratio:

$$CI=\sqrt{1-\left(\frac{\sigma_{est}}{\sigma_y}\right)^2}$$

in which CI = correlation index

σ_{est} = the standard error of estimate; the standard deviation of the dependent (y) variable measured from the regression line or curve.

σ_y = the standard deviation of the dependent variable.

The term $\frac{\sigma_{est}}{\sigma_y}$ measures the percentage dispersion of the dependent variable due to factors other than the independent variables—in this case, age and site index—considered; that is, it measures the extent of the independence of the relationship.

The numerical value of the correlation index and of the standard error of estimate give the best idea of the association of a particular dependent variable with age and site index. These are:

For basal area: $\sigma_{est} = 34.8$ sq. ft.; CI = .845
For no. of trees: $\sigma_{est} = .116$ log trees; CI = .909
For cu. volume: $\sigma_{est} = 1930$ cu. ft.; CI = .880

Average Diameter Breast High.—This is the diameter in inches of the tree of average basal area. It varies as the square root of the total basal area divided by the number of trees. If the curves for these variables are accurate, it may be calculated directly from them. This was accordingly tried, giving the average diameter breast high of the yield tables.

A check on the work is afforded by the relationship,

$$100\left(\frac{BA_a}{BA_t}\right)=100\left[\frac{T_a}{T_t}\cdot\left(\frac{D_a}{D_t}\right)^2\right]$$

in which BA = the total basal area,

T = the number of trees,
D = average diameter breast high,
and subscripts a and t refer to actual and tabular values respectively.

The basal area of each plot in per cent of its tabular basal area was subjected to this equation with the following results:

Mean = 100.38%; standard deviation = 1.72% showing a satisfactory check.

Height of Average Tree.—This was arrived at through the relationship of the ratio of height of average tree to height of average dominant and codominant with average diameter (fig. 16).

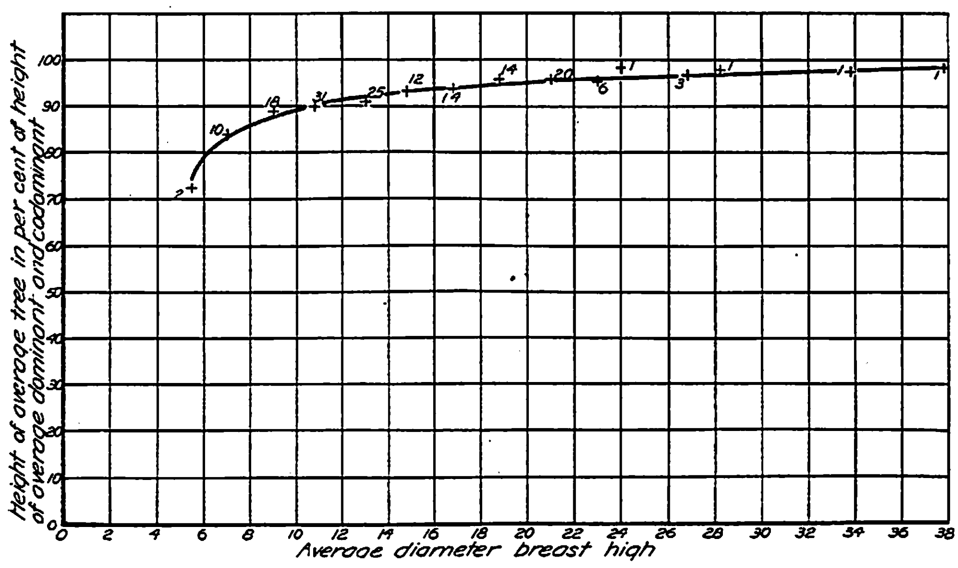

Fig. 16.—Ratio of height of average tree to height of average dominant and codominant tree for average diameter.

Volume in Board Feet.—This is based on the correlation of the ratio of board feet to a cubic foot, with the average diameter (fig. 17). The curved ratio applied to cubic volume gives board foot volume.

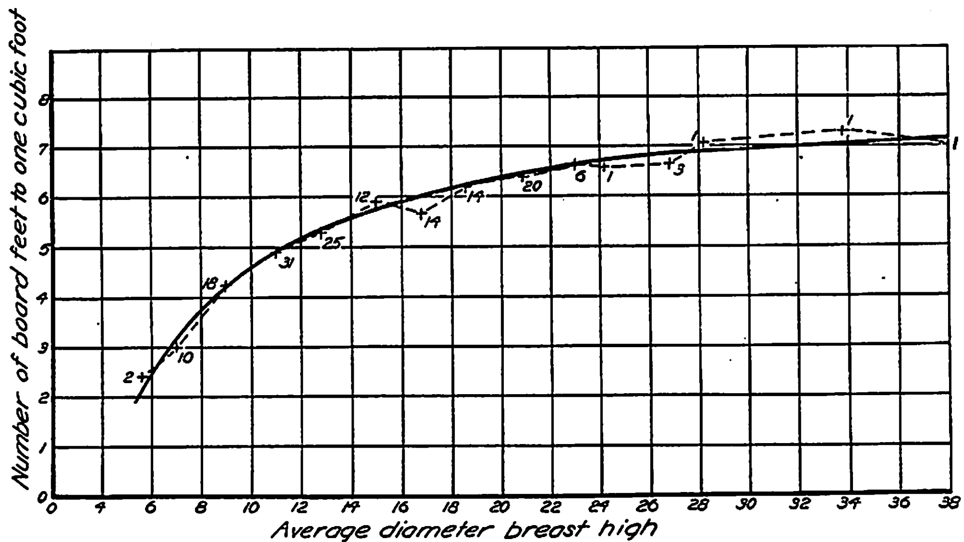

Fig. 17.—Relation of the number of board feet per cubic foot to average diameter.

Site Index Translated to Height of Average Dominant at 50 Years

In order to change the basis of the yield tables from height of average dominant and codominant at 100 years to height of average dominant at 50 years, the latter site index was plotted over the former (fig. 18) and the final tables re-read accordingly.

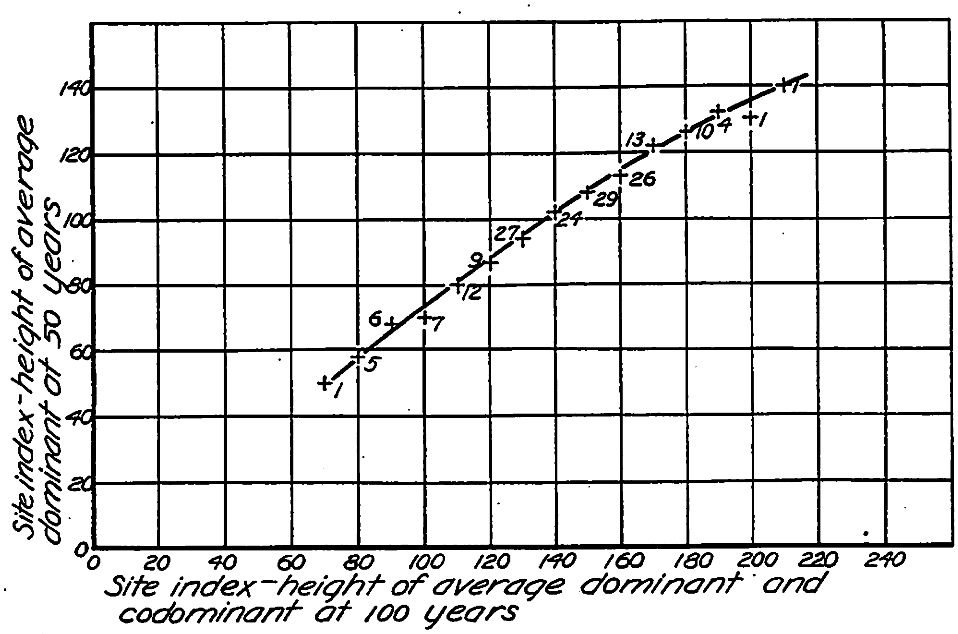

Fig. 18.—Relation of site index based on the height of the average dominant tree at 50 years to site index based on the height of the average dominant and codominant tree at 100 years.

CONSTRUCTION OF THE STAND TABLES

The distribution of trees by diameter class in a stand forms a frequency series which may be analyzed and graduated into a frequency curve when four constants are known—(1) the mean diameter, (2) the standard deviation, (3) the coefficient of asymmetry, (4) the coefficient of excess. These were computed for each of the 159 sample plots.

Average Diameter, Mean Diameter and Standard Deviation.—Average diameter, mean diameter and standard deviation are tied together in any one stand by the relationship,

$$\sigma^2 = A_{dbh}^2 - M_{dbh}^2$$

in which σ = the standard deviation of diameter distribution,
A_{dbh} = the diameter of average basal area,
M_{dbh} = the mean of the diameters breast high.

As these three constants were computed independently for each plot, their relationship was checked as follows:

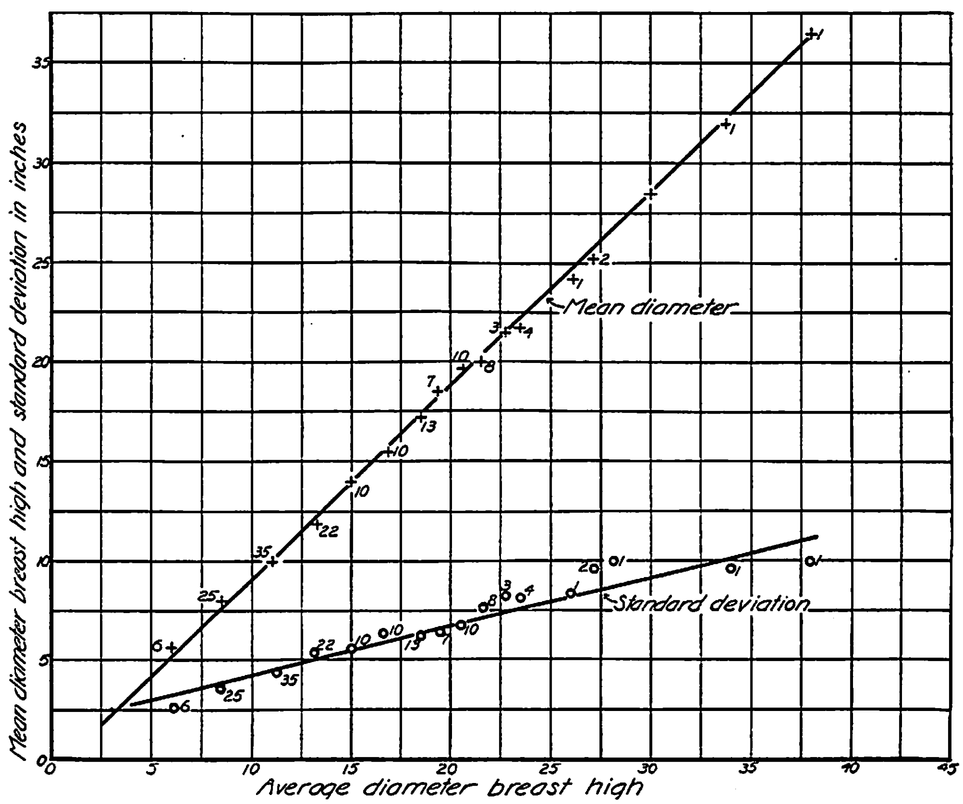

Fig. 19.—Relation of mean diameter and standard deviation to average diameter.

1. The plots were sorted into classes according to the squares of their average diameters using class intervals of 50 square inches.

2. For each plot within the respective classes, were tallied the squares of its average diameter, of its mean diameter, and of its standard deviation. Adding the sums of the squares of mean diameter and of standard deviation, and subtracting this total from the sums of squares of average diameter left an aggregate difference of 15 hundredths of one per cent.

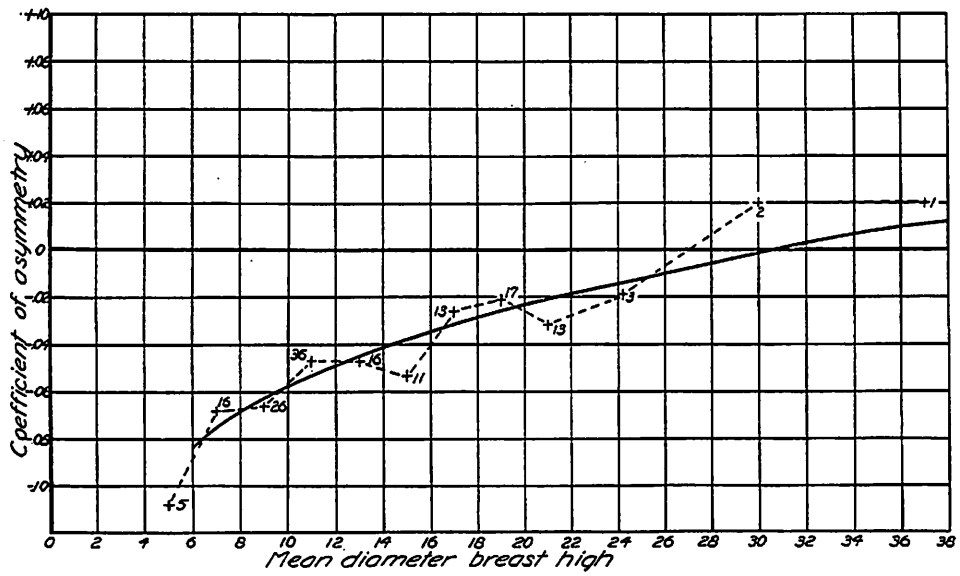

Fig. 20.—Relation of the coefficient of asymmetry to mean diameter.

3. Within each class interval were plotted the square root of the average of the mean diameters squared, and of the average of the standard deviations squared, over the square root of the average of the average diameters squared (fig. 19). Straight lines were fitted to these points so that

$$M_{dbh}^2 + \sigma^2 = A_{dbh}^2$$

Asymmetry and Excess.—The coefficient of asymmetry (β_3) and the coefficient of excess (β_4) of the plots were correlated with mean diameter (figs. 20 and 21).

Starting with average diameter of a site-age class from table 5, its mean diameter and standard deviation were read from figure 19, and, for the indicated mean diameter, its coefficient of asymmetry and

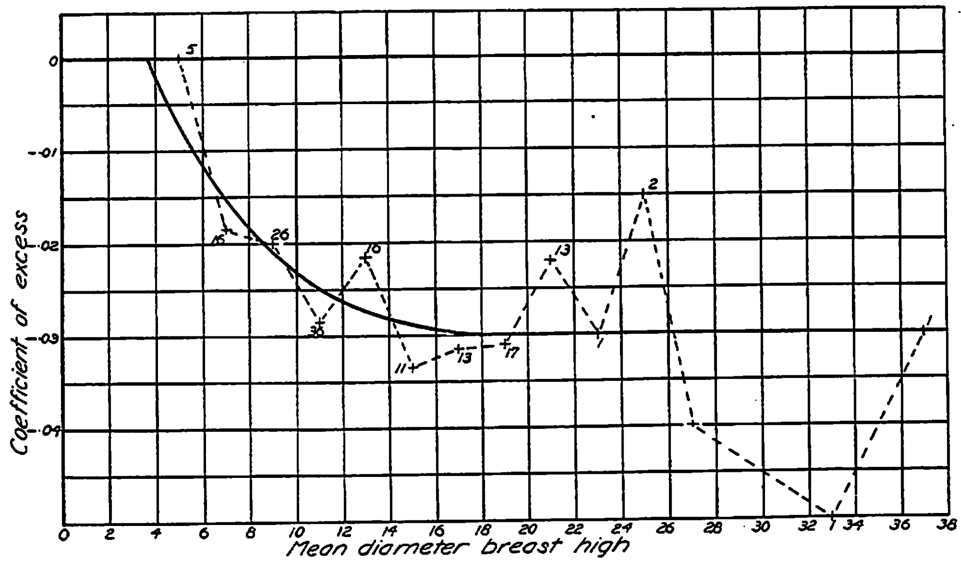

Fig. 21.—Relation of the coefficient of excess to mean diameter.

of excess taken from figures 20 and 21; from these parameters, with the aid of Charlier's Tables,[13] the theoretical frequencies were calculated.

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[13] Charlier's "Type A" frequency curve has the form

$$F(x)=\frac{N}{\sigma}\left\{\phi_0(x)+\beta_3\phi_3(x)+\beta_4\phi_4(x)\right\}$$

in which

$F(x)$ = frequency of x (in this case frequency per unit of one-half standard deviation measured from mean diameter).

N = total frequency.

σ = standard deviation.

$$\phi_0(x)=\frac{1}{\sqrt{2\pi}}e^{\frac{-x^2}{2}}$$

$$\phi_3(x)=\frac{d^3\phi_0}{dx^3}$$

$$\phi_4(x)=\frac{d^4\phi_0}{dx^4}$$

These are tabulated for unit frequency with x in terms of standard deviation in Charlier.

Coefficient of asymmetry, $\beta_3=-\frac{\nu_3}{6\sigma^3}$ (ν_3 = the 3rd moment measured from the mean).

Coefficient of excess, $\beta_4=\frac{1}{24}\left(\frac{\nu_4}{\sigma_4}-3\right)$ (ν_4 = the 4th moment measured from the mean)

VOLUME TABLES

BASIC DATA

From 10 to 50 taper measurements were taken on each of eight of the yield study sample plots, two of the plots on cut-over lands of the Union Lumber Company, Mendocino County, two on holdings of the Casper Lumber Company, Mendocino County, and four on the Trinity National Forest in Trinity County.

Diameters were measured along the stem of each felled tree outside and inside bark at breast-height, at each tenth of length above breast-height, at each fifth of length from the lowest tenth downwards and at 1 per cent of total height from the ground.

TABLE 21

BASIC DATA OF THE VOLUME TABLES

Plot	County	Trees measured	Plot age	Site index*
Ft. Bragg No. 1	Mendocino	42	33	200
Ft. Bragg No. 2	Mendocino	10	33	210
Casper No. 2	Mendocino	25	45	178
Casper No. 3	Mendocino	42	45	171
Minersville No. 3	Trinity	25	68	93
Minersville No. 4	Trinity	25	68	90
Minersville No. 14	Trinity	48	72	109
South Fork Trinity River No. 16	Trinity	50	111	143

* Height of average dominant and codominant at 100 years.

Table 21 shows the number of trees by plots and the range in age and site of the data.

Each tree was plotted on cross-section paper and its cubic volume computed as the sum of the sectional volumes, each by the Smalian formula. The section lengths were in per cent of total height starting with the stump of 1 per cent, the second section of 3 per cent, the third of 6 per cent, and the remaining nine sections each having length of 10 per cent of tree's total height.

COMPARISON WITH DOUGLAS FIR VOLUME TABLES FOR OREGON AND WASHINGTON

It would only make for confusion to construct volume tables for a particular region when tables for the same species based on data of another region may apply. As there is no readily observable difference between the forms of Douglas fir in California as against Oregon and Washington, the volumes of the California data were checked against the cubic volume table for immature Douglas fir in Oregon and Washington.[14]

The volumes of the tree data basic to the latter table were, however, computed as of different sectional lengths than those noted above for the California trees. Stumps of 1½ feet were used and all other sections, regardless of tree's size, were cubed in 10-foot lengths.

In order to ascertain what differences in volume result from the two methods of calculation, the trees of Minersville Plot No. 14 were cubed by both methods. It was found that for constant height, both methods gave the same results independent of diameter; but for constant diameter, volume of trees less than about 50 feet in total height averaged 6 per cent higher when cubed by the method used for the California data, though the calculated volumes of taller trees were independent of the method of computation. However, only 19 out of the 267, or 7 per cent of the trees of all the plots are less than 55 feet tall; so that the difference in method should carry little weight in explaining any difference between the actual volumes and those tabulated for the species in Oregon and Washington.

Following are the results of the check of the California trees against the Oregon-Washington volume tables:

Number of trees	267
Aggregate difference	—2.4 per cent
Mean difference	—6.2 per cent
Standard error of estimate	13.4 per cent

Now if the California trees of all sizes have consistently greater or less taper than the Oregon-Washington trees, there should be no correlation between the per cent deviation and tree size. In other words, a blanket correction factor might be applied to the table to arrive at true average volume.

This, however, is not the case. The multiple correlation coefficient between per cent deviation and diameter and height was found to be

$$r_{1 \cdot 23} = .485 \pm .034$$

in which subscript $_1$ = per cent deviation of the California volumes,
$_2$ = diameter at breast-height,
$_3$ = Total height.

[14] McArdle, R. E. A set of volume tables for second-growth Douglas fir in western Oregon and Washington. Issued in mimeographed form by the Pacific Northwest Forest Experiment Station, June 10, 1926.

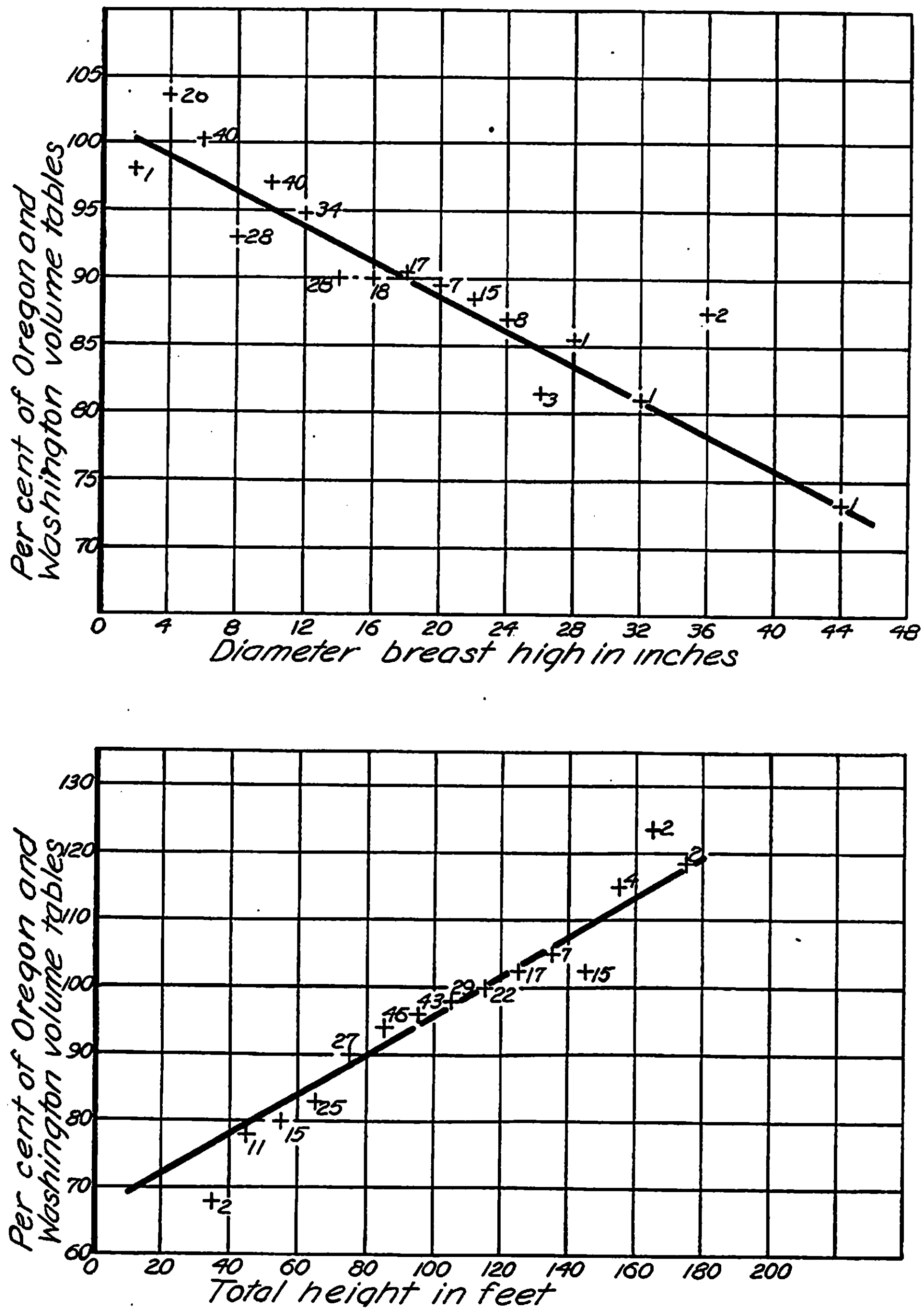

Fig. 22.—Comparison of the California tree volumes with the Oregon-Washington cubic foot volume table by diameter and by height.

Site index was also included as an independent variable in the trial correlation, but the coefficient was not materially increased thereby. It seems likely that site quality does not affect taper in comparatively young timber. Differences in taper due to site probably become significant in mature timber only, for several volume tables for mature timber in which site quality is one of the important variables are now in use.

The volumes of California immature Douglas fir compared to the cubic volume table for Oregon and Washington vary with diameter and with height, as shown in figure 22, in which the deviations of the data from the multiple regression equation are compared with the net regression lines for diameter with average height and for height with average diameter. The differences must be due to one or more of the following mensurational factors which make for systematic differences in volume when the latter is based on diameter at breast-height outside bark and on total height of tree:

a Differences in bark thickness.
b Differences in taper near the base of the tree.
c Differences in taper in the upper part of the bole.

In order to compare taper of the species between the two regions, it is necessary that the basic data be analyzed and compared. For this purpose, the original field data from Oregon and Washington were loaned by the United States Forest Service.[15]

Lower Taper and Bark Thickness.—These factors were analyzed in one operation rather than separately because their effect on volume is dependent upon their sums.

The taper of a typical timber tree is concave towards its axis from the tip downward until a point is reached, usually within the first tenth of its length from the ground, below which it becomes convex toward its axis. The importance of the lower taper from a volume-determining standpoint lies in the fact that the diameter of the tree is nearly always taken at 4½ feet from the ground (breast-height), which may or may not be above the point of taper inflection, depending partly upon the size of the tree and partly upon many other factors difficult of measurement and analysis, and too involved for ready application. It thus happens that the diameter at breast-height

[15] The writer is deeply indebted to Director T. T. Munger of the Pacific Northwest Forest Experiment Station, United States Department of Agriculture, for the use of 1600 taper measurements—over 80 per cent of the basic data of the Oregon-Washington volume tables.

is not satisfactory for accurate volume determination in conjunction with a volume table. But as it comes at such a handy point, practically all volume tables are based upon it.

If the taper inside bark of Douglas fir were the same throughout the upper nine-tenths of its length in its entire range on the Pacific slope, it is evident that trees of the same total height and diameter inside bark at one-tenth height would have the same volume. But if the lower taper and bark thickness differ with latitude, while the upper taper remains the same, their volumes may differ significantly if based on a diameter, outside bark, below the point of inflection, because in one case the diameter measured will be greater than in the other.

The following method was used to analyze the effect of bark thickness and lower taper of the California Douglas fir on cubic volume as tabulated in the Oregon-Washington volume table:

(1) Using the northern tree data, diameter breast high outside bark was correlated with total height, site index and diameter inside bark at one-tenth of total height. The effect of site index was found to be negligible, and was dropped as a variable.

(2) The regression which was found to be linear, was put up in the form of an alignment chart, and a new diameter outside bark at breast-height read for the 267 California trees according to their total height and diameters inside bark at one-tenth height, by referring these measurements to the chart.

(3) Having assigned to each California tree the diameter at breast-height outside bark which it would have had, had bark thickness and lower taper been the same as that of the northern data, its cubic volume was again checked against the volume table, on the new diameter and total height.

The multiple correlation coefficient between per cent deviation of the tree volumes from the tabular for diameter breast high and height was computed to be

$$r_{1\cdot23} = .173 \pm .060$$

a much less significant figure than the correlation based on the original check; but the mean of the per cent deviation $= +4.3\% \pm 0.8\%$, which is approximately 10 per cent higher than the original check.

This indicates that in the lowest tenth of length, the California trees have greater taper, greater bark thickness, or both, than the northern trees, for the greater the ratio of diameter at breast-height outside bark to an upper diameter inside bark, the less becomes volume for a given diameter at breast-height, other factors remaining constant.

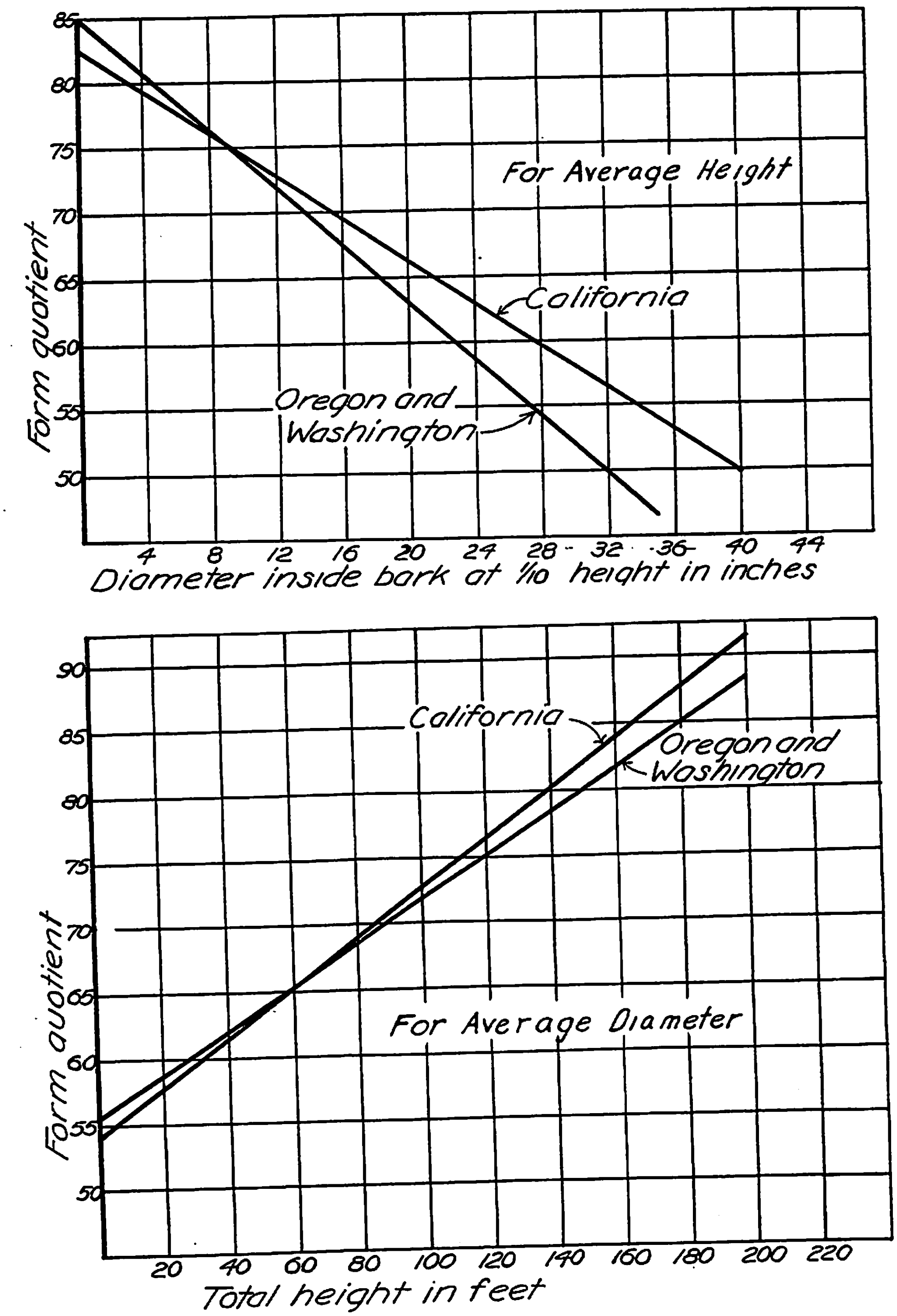

Fig. 23.—Comparison of form quotations of the California trees with the form quotients of the Oregon-Washington trees by diameter inside bark at one-tenth height and by total height.

Upper Taper.—The upper taper of the Douglas fir material was analyzed by comparing form quotients of the trees from the two regions. For this purpose form quotient is defined as the diameter inside bark at one-half total height divided by diameter inside bark at one-tenth total height. It is evident that the higher the form quotient the closer does the bole approach a cylinder in form except near the tip.

Figure 23 shows the effect of tree size on form quotient for both the northern and the California trees.

It must be concluded that the volume tables for immature Douglas fir in Oregon and Washington—in which the northern foresters have full confidence, as they are based on nearly 2000 trees—do not apply immature trees of the same species in California, because

(1) The California trees have greater basal flare, the tendency of which is less volume for a given diameter at breast-height.

(2) The California trees have higher average form quotients with consequent tendency to greater volume. This is in general, however, more than offset by the loss in volume due to basal flare.

Therefore, since the average taper of immature Douglas fir in California differs from that of the northern states, tables 14 and 15 were prepared.

TABLE 14—DOUGLAS FIR—VOLUME IN CUBIC FEET

Diameter, breast height, inches	Total height in feet: 30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	Basis, number of trees
	Volume in cubic feet																		
3	0.55	0.80	1.04	1.29	1.55	1.80													2
4	0.97	1.38	1.79	2.23	2.68	3.10													11
5	1.49	2.08	2.70	3.39	4.02	4.70													22
6	2.07	2.90	3.82	4.75	5.63	6.28	7.18	8.09	8.98	9.75	10.05	11.1	12.22	13.0	13.9	14.7	15.5	16.3	22
7	2.76	3.90	5.03	6.32	7.58	8.72	7.80	11.0	12.0	13.0	14.0	15.3	16.3	17.5	18.6	19.7	20.8	22.0	16
8	3.57	5.02	6.53	8.18	9.80	11.30	12.6	14.0	15.5	16.8	18.1	19.7	21.0	22.4	23.8	25.2	26.7	28.2	10
9	4.43	6.24	8.08	10.0	12.1	14.1	15.9	17.8	19.2	21.0	22.7	24.8	26.1	27.9	29.9	31.3	33.2	35.0	19
10	5.33	7.58	9.92	12.4	14.9	17.0	19.2	21.5	23.4	25.5	27.6	29.8	32.0	34.0	36.1	38.3	40.3	42.7	24
11	6.35	9.00	12.0	14.9	17.7	20.5	23.1	25.8	28.0	30.3	33.0	35.8	37.9	40.3	43.4	45.7	48.5	51.6	24
12	7.48	10.7	14.0	17.4	20.8	24.0	27.0	30.0	32.9	35.9	39.0	42.0	45.0	47.8	50.7	54.0	56.9	60.4	14
13	8.56	12.4	16.2	20.0	24.0	27.8	31.6	35.0	38.3	41.6	45.4	49.0	52.2	55.5	59.3	62.4	66.0	70.0	14
14	9.87	14.1	18.6	23.0	27.5	31.9	36.4	40.3	44.0	47.8	52.3	56.2	60.0	64.2	68.0	71.6	76.1	80.4	13
15	11.2	16.0	21.0	26.2	30.9	36.10	40.8	45.6	50.0	54.4	59.0	63.7	68.0	72.4	76.7	81.5	86.0	90.8	11
16	12.7	17.9	23.6	29.5	35.0	40.8	46.4	51.5	56.4	61.5	66.7	71.8	77.0	80.9	86.8	91.0	96.8	102	7
17		20.0	26.3	32.8	39.1	45.4	51.6	57.0	63.0	68.7	74.5	80.0	86.0	91.2	96.5	102	108	115	5
18		22.0	29.1	36.3	43.2	50.5	57.4	63.5	69.7	75.8	82.6	88.3	95.2	101	108	113	120	128	10
19		24.2	32.0	40.1	48.0	56.0	63.2	69.5	76.8	83.9	90.8	98.1	105	112	119	125	132	140	8
20		26.7	35.2	44.3	52.6	61.0	68.7	76.3	84.0	91.4	99.0	108	115	122	130	138	145	153	3
21		29.1	38.2	48.2	57.3	66.7	75.6	83.1	92.0	100	109	118	126	134	142	150	159	168	6
22		31.3	41.4	52.3	62.2	72.8	81.8	90.0	100	109	118	127	137	146	154	162	171	180	5
23		33.4	45.0	56.4	67.0	78.7	88.0	97.0	108	119	129	139	149	158	167	176	186	197	5
24		36.1	48.5	61.8	72.2	84.0	95.0	104	117	128	138	149	160	170	180	190	200	211	8
25			52.0	65.5	78.0	90.0	191	112	123	135	148	159	170	180	191	202	214	226	0
26			55.3	70.0	83.8	97.5	109	120	133	145	158	170	181	195	206	219	230	242	3
27			59.1	74.5	89.9	103	114	129	141	155	169	180	196	207	220	231	244	260	2
28			62.7	79.5	95.0	111	122	138	150	165	179	191	208	220	233	247	260	276	0
29			66.8	84.0	100	118	130	145	160	174	189	202	219	232	249	262	275	292	0
30			70.6	89.0	108	122	139	153	170	185	200	216	231	247	262	278	291	309	0
31			75.0	94.0	113	130	146	162	180	196	211	229	247	260	278	299	309	326	0
32			78.7	98.8	119	138	154	170	190	208	222	241	260	275	293	310	326	345	1
33			81.6	104	125	146	161	180	200	218	235	251	271	290	306	327	342	361	0
34			86.7	109	131	157	170	190	210	230	246	267	288	303	325	343	360	380	0
35			90.8	114	138	160	179	200	220	240	260	280	300	320	340	360	380	400	0
36			95.1	120	145	168	189	210	230	250	270	291	316	333	354	377	398	420	1
37			99.5	124	151	176	197	220	240	261	283	305	328	349	370	393	413	437	0
38			103	130	159	182	205	230	250	273	298	320	345	365	390	412	432	451	0
39			109	136	164	191	213	239	261	287	309	333	359	380	405	430	452	478	0
40			112	141	171	200	221	249	272	300	321	349	375	397	424	450	472	498	0
41			118	149	179	208	232	260	285	311	335	361	390	413	440	469	494	517	0
42			121	153	187	214	242	271	298	324	349	375	406	430	460	485	510	540	0
43			126	160	194	223	252	282	309	338	361	390	423	448	475	502	530	558	0
44			132	168	200	232	261	290	319	348	377	405	433	464	495	522	550	580	1
Basis, No. of trees	....	2	17	19	26	31	50	36	33	16	11	9	11	4	....	2	....	....	267

The volume is total cubic volume of the stem, including stump and top, but excluding bark.
Basis, 267 taper measurements taken by the Division of Forestry in 1927 from even-aged stands in Mendocino and Trinity Counties.
Age of trees, 30 to 110 years on stump.
Heavy lines in the tables show limits of basic data.

TABLE 15

DOUGLAS FIR—VOLUME IN BOARD FEET

Diameter breast height, inches	Total height in feet: 60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	Basis, Number of trees
	Volume in board feet															
6	4	10	15	19	25	30	34	39	45	52	58	66	73	79	87	5
7	10	20	27	33	39	47	53	62	69	77	86	96	107	117	126	16
8	20	32	42	50	60	68	79	91	100	113	124	139	150	161	175	10
9	30	44	61	73	84	95	110	125	140	152	167	185	200	216	230	19
10	40	58	81	97	112	128	143	162	181	198	215	238	254	274	295	24
11	49	73	98	120	138	155	177	200	220	240	260	286	309	332	353	24
12	59	87	115	144	165	187	212	238	261	287	312	340	368	394	421	14
13	70	107	140	170	193	220	250	279	306	338	366	400	430	454	493	14
14	84	124	162	198	223	259	290	320	354	390	427	460	500	535	570	13
15	97	142	189	225	256	294	330	367	406	448	483	526	570	602	626	11
16	111	160	214	254	291	332	370	415	460	500	543	595	642	692	735	7
17	126	182	240	285	328	373	415	463	515	564	613	665	718	778	824	5
18	140	203	268	317	365	415	461	518	575	627	680	740	798	860	915	10
19	157	226	298	350	403	458	517	572	634	695	751	817	883	950	1000	8
20	174	250	320	384	445	505	559	628	700	768	827	900	975	1040	1110	3
21	190	273	348	418	482	550	613	690	764	817	900	980	1070	1140	1210	6
22	206	299	375	452	525	600	662	750	836	907	978	1070	1150	1230	1300	5
23	224	323	420	490	573	656	718	812	900	985	1080	1150	1240	1320	1410	5
24	240	350	454	530	617	705	774	880	975	1060	1140	1240	1340	1420	1520	8
25	261	378	480	573	664	735	837	950	1060	1140	1230	1320	1450	1530	1640	0
26	277	405	523	617	705	807	890	1010	1120	1210	1310	1410	1540	1640	1750	3
27	296	334	560	656	760	867	951	1080	1200	1300	1400	1510	1630	1770	1880	2
28	316	463	598	700	815	918	1010	1150	1270	1390	1500	1620	1760	1870	2000	0
29	335	492	634	741	860	976	1070	1210	1340	1470	1600	1720	1880	2000	2100	0
30	355	526	670	792	910	1040	1140	1300	1430	1560	1700	1830	1990	2100	2200	0
31	374	553	715	833	967	1090	1200	1380	1510	1650	1800	1930	2090	2220	2380	0
32	396	583	754	880	1020	1160	1270	1440	1590	1740	1900	2030	2200	2380	2500	1
33	415	613	792	928	1080	1210	1350	1510	1690	1850	2000	2150	2300	2500	2620	0
34	437	642	830	975	1130	1280	1400	1600	1750	1920	2100	2260	2430	2610	2780	0
35	457	684	878	1020	1190	1340	1500	1690	1850	2040	2200	2380	2580	2740	2900	0
36	480	707	912	1070	1250	1400	1560	1760	1920	2130	2300	2500	2680	2890	3040	1
37	502	738	955	1110	1300	1480	1620	1830	2000	2230	2400	2600	2800	3000	3200	0
38	525	770	997	1180	1380	1530	1700	1910	2100	2320	2530	2720	2930	3160	3340	0
39	546	810	1030	1220	1420	1600	1790	2000	2200	2430	2640	2830	3060	3290	3490	0
40	570	836	1080	1280	1490	1680	1890	2090	2300	2550	2730	2920	3200	3420	3630	0
41	593	872	1120	1340	1550	1730	1920	2180	2390	2640	2880	3080	3330	3850	3760	0
42	617	910	1180	1390	1600	1800	2000	2240	2490	2720	3000	3200	3480	3700	3920	0
43	640	945	1210	1450	1680	1890	2090	2310	2580	2830	3100	3340	3600	3810	4050	0
44	680	985	1270	1500	1720	1950	2170	2440	2690	2950	3330	3480	3750	3980	4200	1
Basis, number of trees	4	20	29	50	36	33	16	11	9	11	4	0	2	0	0	215

Stump height, 1 foot.
Trees scaled in 16-foot logs with 0.3-foot trimming allowance to 5 inches d. i. b. in top by International rule (⅛-inch kerf).
Basis, 215 trees, measured by the Division of Forestry, 1927, in even-aged stands in Mendocino and Trinity Counties.
Heavy lines in the tables show limits of basic data.
Age of trees, 30 to 110 years on stump.