Yield of EVEN-AGED STANDS OF WESTERN HEMLOCK

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Yield of Even-Aged Stands of Western Hemlock

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The early work of Dr. Walter H. Meyer and Mr. Stanton B. Hayward in collecting field data in Oregon and Washington, and in compiling the plot summaries, must be recognized as the foundation for this revision of the western hemlock yield tables.

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INTRODUCTION

In 1937 normal yield tables were compiled by Meyer (*7*) [1] for even-aged stands of Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*). The basic data for the 1937 tables were collected over the entire coastal range of the species, extending from southern Oregon through Washington and British Columbia to southeastern Alaska. Data were obtained from temporary sample plots established in even-aged stands in which species composition varied from pure hemlock to pure spruce. Common associates of the major species, found to a minor extent on the plots, are Douglas-fir (*Pseudotsuga menziesii*), western redcedar (*Thuja plicata*), Alaska-cedar (*Chamaecyparis nootkatensis*), Pacific silver fir (*Abies amabilis*) and noble fir (*A. procera*). Where Sitka spruce, Douglas-fir, and noble fir are present, these species usually occupy the higher levels of the crown canopy. Taylor (*8*) and Meyer (*7*) have described the Sitka spruce-western hemlock types and their silvical characteristics at length.

In compiling the 1937 tables, all available data were analyzed without regard to species composition or geographical location. Meyer was aware that these factors affect both site index and yields (*7, pp. 31, 42, 84*). He provided supplementary tables for correcting yields, but he considered the effect on site index to be minor. However, use of the tables since 1937 revealed additional discrepancies in yields and site index that were possibly important enough to be recognized. Finally, in 1946 the West Coast Forestry Procedures Committee of the Western Forestry and Conservation Association recommended an examination of apparent discrepancies, and a possible revision of the tables.

Site indices appeared to be too low at ages of less than 100 years, and too high at ages of more than 100 years. In Meyer's words—"A fact causing minor difficulties in site-quality determinations for Sitka spruce-western hemlock areas is that increase of height with age does not follow precisely the same course in the two species" (*7, p. 10*). J. E. Wilson, a graduate student at Oregon State University working under the author, conducted a preliminary investigation on the form of the site index curves for different geographic locations and species compositions. Wilson's results led to further analyses which suggested that different site index systems were needed for stands predominantly hemlock and for stands predominantly spruce. If true, the entire set of yield tables published in 1937 would need revision.

Further analyses indicated that many yield variables differed markedly among regions. Stands of the same age and site had much smaller average diameters in Alaska and British Columbia than in Oregon and Washington. The difference in average diameter

[1] Italic numbers in parentheses refer to Literature Cited, p. 52.

amounted to about 20 percent, and the corresponding difference in volume was even greater. These differences are attributed to denser stands at early ages in the northern latitudes, which resulted in more severe competition and earlier crown closure. Cooler and wetter summers to the north probably contribute to earlier and more complete restocking.

The average height of stands of the same age and site also differed. Average heights in Oregon, Washington, and British Columbia were about equal, but average height in Alaska was about 15 percent less. This indicates a larger number of shorter trees in the subdominant part of the Alaskan stands. Some recognition of geographical location, therefore, seemed necessary.

After these preliminary investigations a decision was made to construct a new site index system and a new set of yield tables for stands in which 40 percent or more of total basal area was in western hemlock, including separate regional tables for (1) Oregon-Washington, (2) British Columbia, and (3) Alaska when warranted by differences in yield variables.

Two types of normal yield tables were developed. One is the conventional type based upon age and site index. The other, a more recent type based upon average stand diameter, has been described by the writer (*1*), and more recently by Bruce (*3*).

The tables are based on data collected almost exclusively within the coastal fog-belt range of western hemlock, and they are strictly applicable only to stands within this range. Numerous stands of hemlock are also found on western slopes of the Cascade Range of Oregon and Washington. Although the Cascade stands have never been intensively investigated, the author believes the tables may be applied to them. This should be particularly true of the diameter yield tables, since any fundamental differences between the fog-belt and Cascade stands would be more adequately reflected in average stand diameter than in age and site index.

DEFINITION OF TERMS [2]

Breast height is the point of diameter measurement on a tree bole ordinarily located 4.5 feet above average ground level, but in this study located 4.5 feet above estimated point of germination. This qualification is necessary because hemlock frequently grows on rotten logs or stumps. All diameter and basal area statistics in these yield tables are based on measurements outside bark at breast height.

Stand age is the average age of dominant and codominant trees. Total ages of the sample trees in this study were determined by adjustment of ring counts at breast height. In Oregon and Washington, 7 years were added for all sites; in British Columbia and Alaska, 8 years were added. In Oregon and Washington, a suppressed zone of early growth was frequently found at the center of the sample trees. In such cases the suppressed zone was assigned a ring count equiva-

[2] For terms not listed, see "Forestry Terminology" (*5*).

lent to that of free-growing trees. For this reason plot ages cannot be regarded as precise.

Average diameter is the diameter corresponding to the tree of average basal area. It can be calculated by dividing number of trees into total basal area (or into the sum of the squares of tree diameters). Average diameter as defined here should be distinguished from the arithmetic mean diameter. The latter is computed by dividing the sum of the tree diameters by number of trees; it is from one-half to 2 inches smaller than the average diameter.

Average stand height is the total height corresponding to the tree of average diameter for trees over 1.5 inches as determined from a curve of total height over diameter. The curve in this case is based on trees of all crown classes.

Average height of dominant and codominant trees is the total height corresponding to the average diameter of dominant and codominant trees as determined from a curve of total height over diameter; the curve is developed from data taken only on dominant and codominant trees.

Site index is a measure of the productivity of a stand as indicated by the height attained or an estimate of the height that may be attained by dominant and codominant trees at 100 years of age. In this study, the average height of dominant and codominant trees was determined by computing the average diameter of dominant and codominant trees and then reading the height corresponding to this diameter from a curve of heights of dominant and codominant trees over their diameters.

Site quality is the relative productive capacity of a forest area determined by climatic, soil, topographic, and other factors. The better the site quality, the faster is tree growth and the greater the timber volume produced per unit of area. To simplify application of the tables, three of the 10-foot site index classes are grouped into a single site quality class. Quality classes are designated by Roman numerals I to VI. This grouping is exactly the same as employed in the Douglas-fir yield tables (*6*). The midpoints of the six site quality classes correspond to site indices of 200, 170, 140, 110, 80, and 50 in the order of I to VI. For site quality VI, however, only the upper site index class is tabulated since the basic data did not extend below this point. Stands of site quality I are rare.

Site index yield table is a yield table in which site index and stand age are the independent variables used in determination of yield estimates. It is the conventional type of yield table used in the United States for species occurring in even-aged stands. The term is used in this report to distinguish this type of table from the diameter yield table.

Diameter yield table is a table in which average diameter is the principal independent variable used to determine yield estimates. The prediction of a future yield by diameter yield tables is based mainly upon projection of present average stand diameter through time.

Normal stocking is the average yield of fully stocked stands as represented by the values given in either the site index or diameter yield tables. Normal stocking can be expressed in terms of number of trees, basal area, or volume per acre.

Actual stocking is the percentage relationship of actual stand yields to normal stand yields. If actual stocking is estimated from a site index table, the normal yield is the tabular value corresponding to the age and site of the actual stand. If actual stocking is estimated from a diameter yield table, the normal yield is the tabular value corresponding to the average diameter of an actual stand.

SITE CLASSIFICATION

Preliminary analysis of the original spruce and hemlock data disclosed a considerable difference in the form of the spruce and hemlock height-over-age curves. Spruce continued to grow at a much greater rate after 100 years than hemlock, which tended to level off. For this reason, only those plots where hemlock comprised 40 percent or more of the basal area of the stand were used in developing the site and yield curves. Furthermore, only the heights of hemlock trees were used in the determination of average height of dominant and codominant trees.

Further investigation disclosed that although the level of the height-over-age curves varied widely among the three geographical regions, each regional curve maintained an almost constant percentage relationship to the others throughout the age range of the data. This indicated that one set of site index curves should be applicable over the entire geographical range of western hemlock. Hence, all plots containing 40 percent or more hemlock by basal area were pooled in developing the site classification system. The same plots were then used for all other phases of this study.

Site index or site quality of a stand can be determined readily from table 1 or figures 1 and 2. The figures, especially the alinement

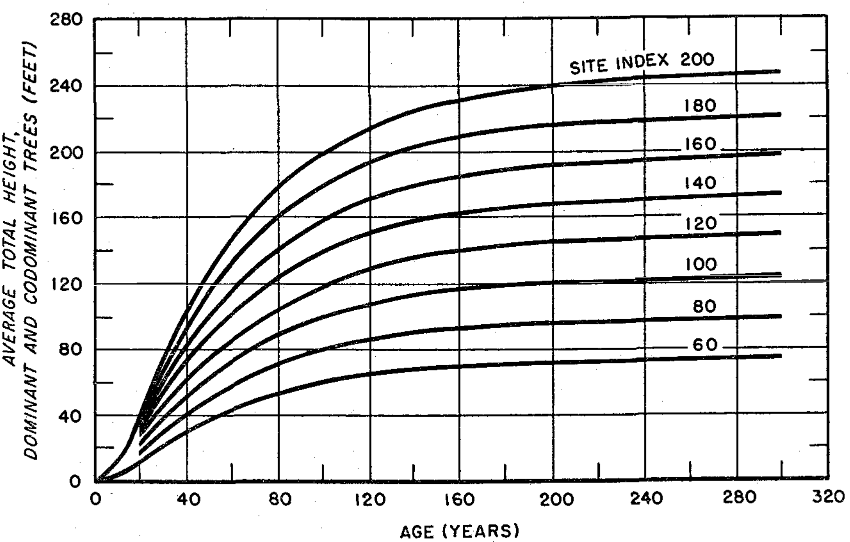

FIGURE 1.—Site index curves based on average total height of dominant and codominant western hemlock trees.

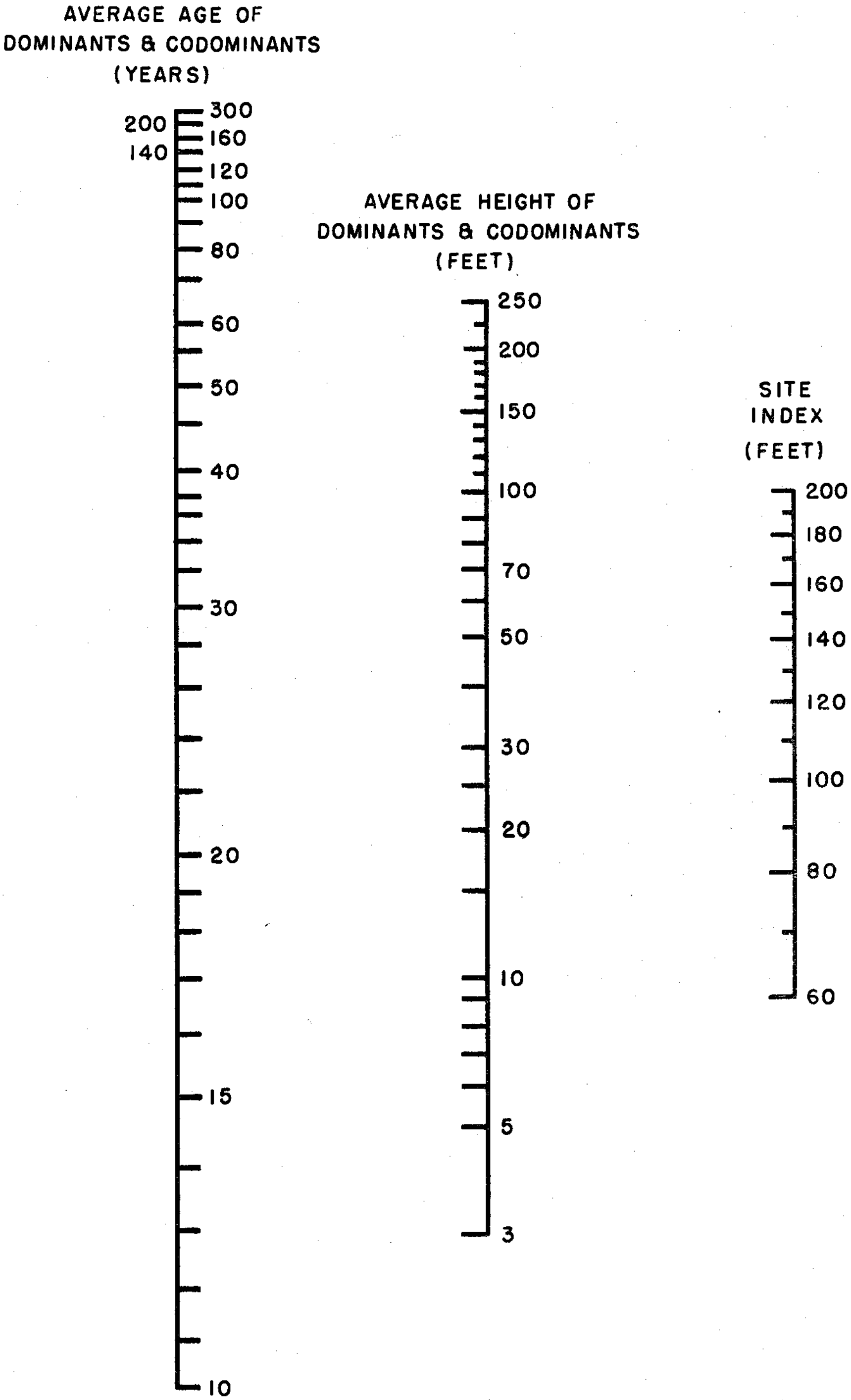

FIGURE 2.—Alinement chart for determination of site index for western hemlock.

TABLE 1.—*Average total height of dominant and codominant trees, by age and site index*

Age (years)	Site class VI; site index 60	Site class V; site index—			Site class IV; site index—			Site class III; site index—			Site class II; site index—			Site class I; site index—		
		70	80	90	100	110	120	130	140	150	160	170	180	190	200	210
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
10	4	4	5	5	6	6	7	8	8	9	9	10	11	11	12	13
20	13	15	17	19	21	23	25	27	29	31	33	36	38	40	42	44
30	23	26	30	34	38	42	45	49	53	57	61	64	68	72	76	80
40	31	36	42	47	52	57	63	68	73	78	84	89	94	99	105	110
50	38	45	51	58	64	70	77	83	90	96	102	109	115	121	128	135
60	45	52	60	67	75	82	89	97	104	112	119	127	134	141	149	157
70	49	57	66	74	82	90	99	107	115	123	132	140	148	156	165	174
80	53	62	71	80	89	98	106	115	124	133	142	152	160	169	178	187
90	57	66	76	85	95	104	113	123	133	142	151	161	170	180	190	199
100	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210
110	63	73	84	94	104	115	125	136	146	157	167	178	188	199	209	220
120	65	75	86	97	108	118	129	140	151	161	172	183	194	205	215	226
130	66	77	88	99	110	121	132	143	155	165	177	188	199	210	221	232
140	68	79	90	101	112	123	135	146	157	168	180	191	202	214	225	236
150	69	80	91	103	114	125	137	148	160	171	183	194	206	217	229	241
160	70	81	93	104	115	127	139	150	162	173	185	197	208	220	232	244
180	71	83	95	106	117	130	142	153	165	177	189	201	213	224	236	248
200	72	84	96	107	119	132	144	155	167	180	191	204	215	227	239	251
220	72	84	97	108	121	133	145	157	169	181	193	205	218	229	241	253
240	73	85	97	109	121	133	146	158	170	182	194	206	219	231	243	255
260	73	85	98	110	122	134	146	158	170	182	194	207	219	232	244	256
280	74	86	98	110	122	134	147	159	171	183	195	208	220	233	245	257
300	74	86	98	111	123	135	147	160	172	184	196	209	221	234	246	258

chart (fig. 2), facilitate interpolations when necessary. Height measurements on 15 or 20 dominant and codominant trees in a stand, and age counts on about 10 trees, should be sufficient for most site determinations. When age counts are made at breast height, an addition of 7 years in Oregon and Washington and an addition of 8 years in British Columbia and Alaska will give a close approximation of total age. As an example, if the average height of measured dominant and codominant trees is 95 feet and average total age of sample trees is 50 years, site index is 150 or site quality is III.

The Oregon and Washington sample stands ranged in site quality from I to IV, with an average site index of 153 feet. Site quality ranged from II to VI in British Columbia and from III to VI in Alaska. Corresponding site indexes averaged 127 and 105 feet respectively. None of the sample stands in British Columbia or Alaska were site I quality, and in Oregon-Washington, only 4 out of 252 were site I. This indicates that land of site quality I is rarely found even in Oregon and Washington. The complete distribution of sample plots by age, site quality, and geographical region is presented in table 2. All plots are assumed to be representative of fully stocked stands which have at least 40 percent of total basal area in hemlock with spruce and fir as the other principal components.

SITE INDEX YIELD TABLES

Yields based on site index and age are presented for nine essential stand characteristics (tables 3 through 26):

Number of trees per acre (trees over 1.5 inches d.b.h.).
Average diameter (trees over 1.5 inches d.b.h.).
Basal area per acre (trees over 1.5 inches d.b.h.).
Average height (trees over 1.5 inches d.b.h.).
Volume, cubic feet per acre (trees over 1.5 inches d.b.h.).
Volume, cubic feet per acre (trees over 6.5 inches d.b.h.).
Volume, board feet—International ¼-inch rule (trees over 6.5 inches d.b.h.).
Volume, board feet—International ¼-inch rule (trees over 11.5 inches d.b.h.).
Volume, board feet—Scribner rule (trees over 11.5 inches d.b.h.).

Although a single set of site index curves was sufficient for all regions, two regional tables were needed for number of trees, average diameter, and basal area. One is for Oregon-Washington and the second for British Columbia and Alaska combined. For average height and all volume yields, three regional tables were needed—one each for Oregon-Washington, British Columbia, and Alaska.

TABLE 2.—*Distribution of sample plots by age, region, and site quality*

Age (years)	Oregon-Washington, site class—						British Columbia, site class—						Alaska, site class						
	VI	V	IV	III	II	I	VI	V	IV	III	II	I	VI	V	IV	III	II	I	Total
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
10	----	----	2	3	----	2	----	----	----	----	----	----	----	----	----	----	----	----	7
20	----	----	1	3	3	1	----	----	----	----	1	----	----	----	1	----	----	----	10
30	----	----	----	4	9	----	1	1	4	7	4	----	----	6	3	----	----	----	39
40	----	----	----	21	19	----	----	----	0	5	----	----	----	6	14	1	----	----	66
50	----	----	----	9	12	----	----	----	1	0	----	----	----	14	43	----	----	----	79
60	----	----	----	8	17	----	----	1	4	1	----	----	4	1	26	1	----	----	63
70	----	----	4	14	6	----	----	----	4	1	----	----	1	13	17	2	----	----	62
80	----	----	2	30	32	----	----	----	7	7	----	----	----	5	3	----	----	----	86
90	----	----	----	14	18	----	----	----	1	8	----	----	----	2	0	----	----	----	43
100	----	----	----	3	----	----	----	----	1	1	----	----	3	7	25	----	----	----	40
110	----	----	1	0	----	----	----	----	0	1	----	----	----	----	0	----	----	----	2
120	----	----	----	1	----	----	1	----	1	4	----	----	----	----	16	5	----	----	28
140	----	----	----	1	----	----	----	----	2	1	----	----	----	----	4	----	----	----	8
160	----	----	----	2	----	----	----	----	----	1	----	----	----	2	0	----	----	----	5
180	----	----	----	2	----	----	----	----	----	----	----	----	----	----	1	----	----	----	3
190–250	----	----	----	1	----	1	----	----	----	----	----	----	----	----	----	----	----	----	2
250+	----	----	----	1	5	----	----	----	----	----	----	----	----	----	----	----	----	----	6
Total	0	0	10	117	121	4	2	2	25	37	5	0	8	56	153	9	0	0	549

TABLE 3.—*Total trees per acre over 1.5 inches in diameter, by age and site index*

OREGON-WASHINGTON

Age (years)	Site class IV, site index—			Site class III, site index—			Site class II, site index—			Site class I, site index—		
	100	110	120	130	140	150	160	170	180	190	200	210
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
20	3, 400	3, 280	3, 160	3, 050	2, 950	2, 860	2, 780	2, 720	2, 660	2, 600	2, 550	2, 500
30	2, 070	1, 910	1, 780	1, 680	1, 590	1, 520	1, 460	1, 400	1, 360	1, 310	1, 270	1, 230
40	1, 150	990	885	810	750	710	670	640	610	585	565	545
50	640	570	510	465	430	400	380	365	350	335	325	315
60	465	420	375	340	315	295	280	265	255	245	235	228
70	375	335	305	275	255	240	225	215	205	195	187	183
80	315	280	255	235	215	200	188	180	172	165	158	153
90	275	240	220	203	188	172	165	157	150	145	139	132
100	245	213	192	177	162	150	143	137	131	125	121	117
110	220	190	173	160	148	138	130	125	120	115	110	106
120	200	175	158	145	134	125	120	114	109	104	100	97
140	173	150	137	125	118	108	102	97	93	90	86	83
160	153	135	120	110	103	95	91	86	82	79	77	75
180	140	122	110	100	94	87	82	79	75	72	69	67
200	123	114	102	94	87	81	77	74	70	67	65	63
250	112	98	90	81	76	70	67	64	61	59	57	55
300	105	93	83	77	72	66	63	60	58	56	54	52

TABLE 4.—*Total trees per acre over 1.5 inches in diameter, by age and site index*

BRITISH COLUMBIA AND ALASKA

Age (years)	Site class VI, site index 60	Site class V, site index—			Site class IV, site index—			Site class III, site index—			Site class II, site index—		
		70	80	90	100	110	120	130	140	150	160	170	180
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
20	------	------	1, 500	1, 500	2, 150	2, 950	3, 200	3, 300	3, 300	3, 300	3, 200	3, 200	3, 100
30	2, 950	3, 300	3, 300	3, 300	3, 200	2, 600	2, 550	2, 200	2, 000	1, 900	1, 800	1, 760	1, 720
40	2, 950	2, 550	2, 160	1, 970	1, 670	1, 500	1, 330	1, 200	1, 080	1, 000	950	890	840
50	2, 100	1, 750	1, 530	1, 250	1, 080	870	767	680	610	580	535	510	485
60	1, 780	1, 430	1, 170	960	790	660	570	510	450	410	390	370	350
70	1, 540	1, 200	950	780	630	520	455	410	360	340	310	295	285
80	1, 330	1, 040	750	660	530	450	380	345	300	285	265	230	240
90	1, 200	910	700	570	465	395	335	300	265	250	232	220	208
100	1, 050	810	620	510	415	350	295	265	232	220	205	195	185
110	950	730	560	450	370	315	270	240	212	200	185	175	168
120	890	670	510	420	345	290	245	220	195	180	170	160	153
140	750	570	440	360	295	250	214	190	170	155	145	135	130
160	670	510	390	320	262	225	188	170	150	140	128	120	115
180	610	470	355	290	238	200	170	150	135	125	116	110	104
200	575	440	335	270	220	185	157	140	124	115	108	103	97

TABLE 5.—*Average diameter for trees over 1.5 inches in diameter, by age and site index*

OREGON-WASHINGTON

Age (years)	Site class IV, site index—			Site class III, site index—			Site class II, site index—			Site class I, site index—		
	100	110	120	130	140	150	160	170	180	190	200	210
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
20	2. 7	2. 9	3. 0	3. 1	3. 1	3. 2	3. 3	3. 3	3. 3	3. 4	3. 4	3. 5
30	4. 0	4. 3	4. 5	4. 7	4. 9	5. 1	5. 2	5. 4	5. 5	5. 6	5. 8	5. 9
40	6. 2	6. 6	7. 0	7. 4	7. 8	8. 1	8. 4	8. 6	8. 9	9. 1	9. 3	9. 5
50	8. 6	9. 3	9. 9	10. 5	10. 9	11. 4	11. 7	12. 1	12. 4	12. 7	13. 0	13. 2
60	10. 4	11. 2	11. 9	12. 7	13. 3	13. 8	14. 2	14. 6	15. 0	15. 4	15. 7	16. 0
70	12. 0	12. 9	13. 7	14. 5	15. 0	15. 7	16. 2	16. 7	17. 2	17. 6	17. 9	18. 3
80	13. 2	14. 2	15. 1	15. 9	16. 6	17. 3	17. 9	18. 5	19. 0	19. 5	19. 9	20. 2
90	14. 3	15. 4	16. 4	17. 3	18. 1	18. 9	19. 5	20. 1	20. 6	21. 1	21. 6	22. 0
100	15. 4	16. 6	17. 6	18. 5	19. 4	20. 2	20. 9	21. 6	22. 1	22. 7	23. 2	23. 7
110	16. 3	17. 6	18. 7	19. 8	20. 6	21. 5	22. 2	22. 9	23. 6	24. 1	24. 6	25. 1
120	17. 2	18. 6	19. 8	20. 9	21. 8	22. 7	23. 4	24. 1	24. 8	25. 4	26. 0	26. 5
140	18. 8	20. 3	21. 6	22. 8	23. 7	24. 8	25. 6	26. 4	27. 1	27. 8	28. 4	28. 9
160	20. 2	21. 8	23. 2	24. 5	25. 6	26. 7	27. 5	28. 4	29. 2	29. 9	30. 5	31. 1
180	21. 4	23. 2	24. 6	26. 0	27. 0	28. 3	29. 2	30. 0	30. 9	31. 6	32. 3	32. 9
200	22. 4	24. 2	25. 8	27. 1	28. 3	29. 6	30. 6	31. 4	32. 2	33. 0	33. 8	34. 3
250	24. 3	26. 2	27. 7	29. 2	30. 6	32. 1	33. 0	34. 0	35. 0	35. 8	36. 6	37. 2
300	25. 2	27. 2	28. 7	30. 2	31. 7	33. 2	34. 3	35. 3	36. 3	37. 2	38. 0	38. 8

TABLE 6.—*Average diameter for trees over 1.5 inches in diameter, by age and site index*

BRITISH COLUMBIA AND ALASKA

Age (years)	Site class VI, site index 60	Site class V, site index—			Site class IV, site index—			Site class III, site index—			Site class II, site index—		
		70	80	90	100	110	120	130	140	150	160	170	180
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
20	------	------	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.8	2.9	2.9	3.0
30	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.2	4.4	4.5	4.6
40	3.1	3.5	3.9	4.3	4.7	5.1	5.5	5.9	6.3	6.6	6.9	7.1	7.3
50	3.9	4.5	5.1	5.8	6.4	7.0	7.7	8.2	8.8	9.2	9.6	10.0	10.2
60	4.6	5.3	6.0	6.8	7.6	8.4	9.2	9.9	10.6	11.2	11.6	12.0	12.4
70	5.1	6.0	6.8	7.8	8.7	9.6	10.5	11.4	12.1	12.7	13.3	13.7	14.0
80	5.6	6.6	7.6	8.6	9.7	10.7	11.7	12.6	13.4	14.1	14.7	15.2	15.6
90	6.0	7.2	8.2	9.3	10.5	11.6	12.7	13.7	14.6	15.4	16.0	16.5	17.0
100	6.4	7.7	8.8	10.0	11.3	12.5	13.8	14.8	15.8	16.5	17.2	17.7	18.3
110	6.8	8.1	9.4	10.6	12.0	13.2	14.6	15.7	16.7	17.5	18.2	18.8	19.4
120	7.1	8.5	9.9	11.2	12.6	13.9	15.4	16.6	17.7	18.5	19.2	19.8	20.4
140	7.8	9.3	10.8	12.2	13.7	15.2	16.8	18.1	19.3	20.1	21.0	21.6	22.3
160	8.4	10.0	11.6	13.2	14.8	16.4	18.1	19.5	20.8	21.7	22.5	23.3	24.0
180	8.9	10.5	12.3	14.0	15.7	17.4	19.2	20.6	22.0	23.0	23.9	24.6	25.4
200	9.2	11.0	12.8	14.6	16.4	18.2	20.0	21.5	22.8	23.9	24.9	25.7	26.5

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TABLE 7.—*Basal area per acre for trees over 1.5 inches in diameter, by age and site index*

OREGON-WASHINGTON

Age (years)	Site class IV, site index—			Site class III, site index—			Site class II, site index—			Site class I, site index—		
	100	110	120	130	140	150	160	170	180	190	200	210
	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	127	138	146	151	155	158	160	162	164	166	168	172
30	187	194	200	204	208	212	215	218	220	222	225	226
40	231	237	242	246	250	254	257	259	262	264	266	268
50	259	266	272	277	281	285	288	290	293	295	297	299
60	276	283	289	295	300	304	306	309	312	315	316	319
70	290	297	303	308	312	316	320	323	325	328	330	332
80	299	306	312	319	322	327	330	333	336	339	341	342
90	307	315	321	327	331	336	339	342	345	347	349	351
100	315	323	329	334	338	343	346	349	352	355	357	359
110	320	328	334	340	344	348	352	356	358	360	363	365
120	326	334	340	346	350	355	358	361	364	366	369	372
140	335	343	349	355	359	364	367	371	374	377	380	382
160	342	350	356	363	367	372	376	379	383	386	389	392
180	348	357	363	369	373	379	383	386	390	394	397	400
200	353	361	367	374	378	384	388	392	396	401	403	406
250	361	369	376	382	388	393	398	402	406	410	414	418
300	366	374	382	389	396	402	406	410	415	419	422	426

TABLE 8.—*Basal area per acre for trees over 1.5 inches in diameter, by age and site index*

BRITISH COLUMBIA AND ALASKA

Age (years)	Site class VI, site index 60	Site class V, site index—			Site class IV, site index—			Site class III, site index—			Site class II, site index—		
		70	80	90	100	110	120	130	140	150	160	170	180
	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	--------	--------	60	80	96	109	118	126	133	138	143	146	148
30	104	124	138	150	162	170	179	184	189	194	199	201	202
40	155	171	183	194	204	213	222	227	234	237	240	243	245
50	185	199	211	222	234	241	250	255	262	266	269	272	275
60	202	215	229	239	249	257	266	272	279	283	286	290	293
70	211	226	240	250	260	269	278	284	291	296	300	303	306
80	221	235	249	259	270	278	288	294	302	306	310	313	316
90	228	242	255	267	277	287	296	302	310	314	318	322	325
100	235	249	261	274	284	294	304	310	318	322	326	329	332
110	240	254	267	279	290	300	309	316	324	328	332	335	338
120	244	259	272	284	296	305	314	321	329	333	337	340	343
140	251	266	280	292	304	314	323	330	338	342	346	350	353
160	257	273	286	299	311	320	331	338	345	350	354	357	360
180	262	278	292	304	317	326	337	343	351	356	360	363	366
200	265	282	296	309	321	331	341	348	356	360	364	368	371

TABLE 9.—*Average stand height for trees over 1.5 inches in diameter, by age and site index*

OREGON-WASHINGTON

Age (years)	Site class IV, site index—			Site class III, site index—			Site class II, site index—			Site class I, site index—		
	100	110	120	130	140	150	160	170	180	190	200	210
	Ft.	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*
20	22	24	25	27	29	30	32	34	36	38	39	41
30	36	39	42	46	49	53	56	59	63	67	71	75
40	48	52	58	63	68	73	78	83	89	94	100	104
50	59	65	72	78	84	91	97	104	110	115	122	129
60	68	77	84	91	99	107	113	121	128	135	142	150
70	77	85	94	102	109	117	126	134	142	150	158	167
80	84	93	101	110	118	127	136	146	154	162	171	180
90	90	99	108	117	127	136	145	155	163	173	183	193
100	95	104	114	124	134	144	154	163	173	183	193	204
110	99	109	119	129	140	149	160	171	181	192	202	212
120	103	112	123	134	145	154	165	176	187	198	208	219
140	107	118	129	140	151	161	173	184	195	207	218	229
160	110	122	133	144	155	166	178	190	201	213	225	237
180	112	124	136	147	158	170	182	194	206	217	229	241
200	114	126	138	149	160	173	184	197	208	220	232	244
250	116	128	140	152	163	175	187	200	212	224	236	248
300	117	129	141	153	165	177	189	202	214	227	239	251

TABLE 10.—*Average stand height for trees over 1.5 inches in diameter, by age and site index*

BRITISH COLUMBIA

Age (years)	Site class VI, site index 60	Site class V, site index—			Site class IV, site index—			Site class III, site index—			Site class II, site index—		
		70	80	90	100	110	120	130	140	150	160	170	180
	Ft.	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*
20	13	15	16	17	19	21	22	23	25	27	28	29	31
30	20	23	25	28	32	36	39	42	46	50	53	56	60
40	26	31	35	40	45	50	55	60	66	71	76	81	87
50	32	38	44	50	57	64	70	76	83	90	96	102	109
60	37	45	52	60	68	76	83	90	98	106	113	120	128
70	42	51	59	67	76	84	92	100	109	118	126	134	142
80	46	55	64	73	82	91	100	109	118	127	136	145	154
90	49	59	69	78	88	98	108	117	127	137	146	155	165
100	52	63	73	83	93	104	114	124	134	144	154	164	174
110	55	66	76	86	97	108	119	129	140	151	161	171	182
120	57	68	79	90	101	112	123	134	145	156	167	177	187
140	60	72	83	94	106	118	129	140	151	163	174	185	196
160	63	75	86	97	109	121	133	144	156	168	179	190	202
180	64	76	88	99	111	124	136	147	159	171	183	195	207
200	65	77	89	101	113	125	137	149	161	173	185	197	209

TABLE 11.—*Average stand height for trees over 1.5 inches in diameter, by age and site index*

ALASKA

Age (years)	Site class VI, site index 60	Site class V, site index—			Site class IV, site index—			Site class III, site index—			Site class II, site index 160
		70	80	90	100	110	120	130	140	150	
	Ft.	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*
20	12	13	14	16	17	19	20	22	23	25	26
30	18	21	23	27	30	33	36	39	43	47	50
40	24	29	33	37	42	47	52	56	61	67	72
50	30	36	41	47	54	59	65	71	78	84	90
60	35	42	49	55	63	69	76	83	91	98	105
70	40	47	55	62	70	78	85	93	102	109	118
80	43	51	60	68	77	85	93	102	110	119	128
90	46	55	64	73	82	91	100	110	119	128	137
100	49	59	68	78	87	96	106	116	126	136	145
110	52	62	71	81	91	101	111	121	131	142	151
120	54	64	74	84	94	105	115	125	136	146	157
140	57	68	78	88	99	110	121	132	142	154	164
160	59	70	81	91	102	114	125	136	147	158	169
180	60	71	82	93	104	116	128	139	150	162	173
200	60	72	84	94	105	118	130	141	152	164	175

TABLE 12.—*Volume* [1] *per acre for trees over 1.5 inches in diameter, by age and site index*

OREGON-WASHINGTON

Age (years)	Site class IV, site index—			Site class III, site index—			Site class II, site index—			Site class I, site index—		
	100	110	120	130	140	150	160	170	180	190	200	210
	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	840	1, 130	1, 270	1, 620	1, 900	2, 200	2, 380	2, 600	2, 800	3, 000	3, 200	3, 500
30	2, 740	3, 300	3, 800	4, 100	4, 500	5, 200	5, 600	6, 000	6, 400	6, 800	7, 300	7, 700
40	4, 900	5, 700	6, 300	7, 200	7, 900	8, 500	9, 200	9, 900	10, 600	11, 400	12, 100	12, 700
50	6, 900	8, 000	9, 000	10, 000	10, 900	11, 900	12, 700	13, 700	14, 600	15, 500	16, 500	17, 300
60	8, 500	9, 600	10, 600	11, 900	13, 100	14, 200	15, 100	16, 100	17, 200	18, 300	19, 300	20, 300
70	9, 500	10, 800	12, 100	13, 300	14, 500	15, 800	16, 800	17, 800	19, 000	20, 100	21, 200	22, 200
80	10, 400	11, 800	13, 100	14, 500	15, 600	17, 000	18, 000	19, 200	20, 400	21, 600	22, 800	23, 800
90	11, 200	12, 600	14, 000	15, 400	16, 500	17, 800	19, 000	20, 300	21, 500	22, 800	24, 200	25, 200
100	11, 900	13, 400	14, 800	16, 100	17, 400	18, 800	20, 000	21, 400	22, 500	23, 900	25, 300	26, 400
110	12, 400	13, 900	15, 400	16, 700	18, 100	19, 600	20, 800	22, 100	23, 400	24, 800	26, 300	27, 300
120	12, 900	14, 400	16, 000	17, 400	18, 700	20, 200	21, 400	23, 000	24, 100	25, 600	27, 100	28, 300
140	13, 700	15, 300	16, 900	18, 300	19, 800	21, 200	22, 600	24, 200	25, 500	27, 000	28, 600	29, 800
160	14, 400	16, 000	17, 600	19, 200	20, 600	22, 200	23, 600	25, 200	26, 600	28, 200	29, 800	31, 100
180	14, 900	16, 700	18, 100	19, 900	21, 400	23, 000	24, 400	26, 100	27, 600	29, 200	30, 700	32, 200
200	15, 300	17, 200	18, 600	20, 400	22, 000	23, 600	25, 200	26, 800	28, 300	30, 000	31, 500	33, 000
250	16, 200	18, 000	19, 700	21, 400	23, 100	25, 000	26, 400	28, 200	29, 800	31, 600	33, 200	34, 900
300	16, 500	18, 400	20, 100	22, 000	23, 600	25, 400	26, 900	28, 800	30, 600	32, 400	34, 200	35, 600

[1] Stumps and tips of trees included.

TABLE 13.—*Volume*[1] *per acre for trees over 1.5 inches in diameter, by age and site index*

BRITISH COLUMBIA

Age (years)	Site class VI, site index 60	Site class V, site index—			Site class IV, site index—			Site class III, site index—			Site class II, site index—		
		70	80	90	100	110	120	130	140	150	160	170	180
	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	--------	--------	780	980	1,170	1,400	1,660	1,910	2,160	2,400	2,640	2,750	2,930
30	1,120	1,450	1,870	2,300	2,720	3,200	3,680	4,170	4,600	5,030	5,450	5,800	6,100
40	2,140	2,800	3,400	4,000	4,800	5,600	6,350	7,100	7,850	8,400	8,950	9,500	10,200
50	3,200	4,000	4,870	5,700	6,750	7,800	8,850	9,900	10,850	11,600	12,400	13,100	13,900
60	4,000	4,900	5,950	7,000	8,100	9,300	10,600	11,800	12,850	12,800	14,700	15,500	16,500
70	4,480	5,600	6,800	8,000	9,250	10,500	11,900	13,200	14,400	15,400	16,500	17,300	18,200
80	5,040	6,300	7,550	8,800	10,250	11,600	13,100	14,300	15,700	16,600	17,700	18,700	19,600
90	5,550	6,800	8,150	9,600	11,000	12,500	14,000	15,300	16,600	17,700	18,700	19,800	20,700
100	5,880	7,300	8,750	10,300	11,750	13,400	14,900	16,100	17,550	18,600	19,700	20,700	21,600
110	6,240	7,800	9,230	10,900	12,400	14,000	15,500	16,800	18,200	19,400	20,400	21,600	22,500
120	6,550	8,100	9,650	11,400	12,900	14,600	16,000	17,500	18,800	20,000	21,000	22,300	23,200
140	7,120	8,800	10,450	12,200	13,900	15,800	17,000	18,500	19,800	21,100	22,200	23,500	24,500
160	7,640	9,400	11,100	13,000	14,600	16,300	17,800	19,400	20,700	22,000	23,200	24,500	25,600
180	8,000	10,000	11,700	13,500	15,200	16,900	18,500	20,000	21,500	22,800	24,200	25,400	26,500
200	8,280	10,200	12,100	14,000	15,600	17,400	18,900	20,600	22,000	23,600	24,800	26,200	27,200

[1] Stumps and tips of trees included.

TABLE 14.—*Volume* [1] *per acre for trees over 1.5 inches in diameter, by age and site index*

ALASKA

Age (years)	Site class VI, site index 60	Site class V, site index—			Site class IV, site index—			Site class III, site index—			Site class II, site index 160
		70	80	90	100	110	120	130	140	150	
	Cu. ft.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
20	------	------	500	700	850	1, 050	1, 300	1, 500	1, 700	1, 900	2, 100
30	800	1, 200	1, 550	1, 950	2, 300	2, 650	3, 050	3, 350	3, 800	4, 200	4, 600
40	1, 850	2, 300	2, 900	3, 550	4, 200	4, 800	5, 500	6, 100	6, 900	7, 350	8, 000
50	2, 700	3, 500	4, 250	5, 050	6, 000	6, 800	7, 800	8, 550	9, 500	10, 150	10, 900
60	3, 400	4, 400	5, 300	6, 300	7, 300	8, 400	9, 500	10, 500	11, 650	12, 400	13, 300
70	4, 000	5, 050	6, 100	7, 300	8, 400	9, 600	10, 900	12, 050	13, 200	14, 100	15, 200
80	4, 500	5, 700	6, 850	8, 100	9, 350	10, 700	12, 000	13, 250	14, 500	15, 450	16, 500
90	5, 000	6, 200	7, 500	8, 900	10, 250	11, 600	13, 000	14, 300	15, 700	16, 550	17, 600
100	5, 350	6, 650	8, 000	9, 500	11, 000	12, 400	13, 800	15, 200	16, 550	17, 500	18, 500
110	5, 700	7, 100	8, 500	10, 100	11, 650	13, 100	14, 600	16, 000	17, 350	18, 300	19, 300
120	6, 000	7, 500	8, 950	10, 600	12, 200	13, 800	15, 300	16, 600	18, 000	19, 050	20, 000
140	6, 600	8, 150	9, 800	11, 400	13, 100	14, 700	16, 200	17, 700	19, 100	20, 200	21, 200
160	7, 050	8, 700	10, 450	12, 200	13, 900	15, 500	17, 100	18, 550	19, 950	21, 150	22, 300
180	7, 500	9, 200	11, 000	12, 800	14, 500	16, 200	17, 800	19, 200	20, 600	21, 900	23, 200
200	7, 850	9, 650	11, 550	13, 200	15, 000	16, 700	18, 400	19, 800	21, 200	22, 600	24, 100

[1] Stumps and tips of trees included.

TABLE 15.—*Volume*[1] *per acre for trees over 6.5 inches in diameter, by age and site index*

OREGON-WASHINGTON

Age (years)	Site class IV, site index—			Site class III, site index—			Site class II, site index—			Site class I, site index—		
	100	110	120	130	140	150	160	170	180	190	200	210
	Cu. ft.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
30	760	1,210	1,700	2,060	2,460	2,980	3,330	3,680	4,050	4,250	4,900	5,200
40	3,500	4,400	5,000	5,800	6,400	7,300	8,100	8,800	9,400	10,100	11,000	11,600
50	6,160	7,300	8,300	9,400	10,300	11,300	12,200	13,200	14,200	15,100	16,100	17,200
60	7,900	9,100	10,300	11,600	12,600	13,800	14,800	15,900	16,900	16,100	19,100	20,000
70	9,200	10,500	11,900	13,100	14,200	15,500	16,500	17,700	18,900	20,100	21,100	22,200
80	10,100	11,600	13,000	14,300	15,400	16,700	17,900	19,200	20,400	21,600	22,800	23,800
90	11,000	12,500	13,800	15,200	16,500	17,800	19,000	20,300	21,500	22,800	24,200	25,200
100	11,700	13,300	14,700	16,000	17,400	18,800	20,000	21,400	22,500	24,000	25,300	26,400
110	12,300	13,800	15,400	16,700	18,100	19,600	20,800	22,100	23,400	24,800	26,300	27,300
120	12,800	14,400	16,000	17,400	18,700	20,200	21,400	23,000	24,100	25,600	27,100	28,300
140	13,700	15,300	16,900	18,300	19,800	21,200	22,600	24,200	25,500	27,000	28,600	29,800
160	14,400	16,000	17,600	19,200	20,600	22,200	23,600	25,200	26,600	28,200	29,800	31,100
180	14,900	16,700	18,100	19,900	21,400	23,000	24,400	26,100	27,600	29,200	30,700	32,200
200	15,300	17,200	18,600	20,400	22,000	23,600	25,200	26,800	28,300	30,000	31,500	33,000
250	16,200	18,000	19,700	21,400	23,100	25,000	26,400	28,200	29,800	31,600	33,200	34,900
300	16,500	18,400	20,100	22,000	23,600	25,400	26,900	28,800	30,600	32,400	34,200	35,600

[1] Stumps and tips of trees included.

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TABLE 16.—*Volume*[1] *per acre for trees over 6.5 inches in diameter, by age and site index*

BRITISH COLUMBIA

Age (years)	Site class VI, site index 60	Site class V, site index—			Site class IV, site index—			Site class III, site index—			Site class II, site index—		
		70	80	90	100	110	120	130	140	150	160	170	180
	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.*
30	------	------	------	------	------	500	1,050	1,400	1,950	2,300	2,750	3,000	3,300
40	------	550	1,210	1,900	2,660	3,400	4,320	5,100	5,880	6,400	6,950	7,700	8,280
50	1,200	2,000	2,970	3,850	4,930	6,300	7,400	8,500	9,650	10,400	11,300	12,100	12,900
60	2,160	3,200	4,320	5,500	6,730	8,150	9,550	10,800	12,100	13,200	14,200	15,150	16,150
70	2,730	4,050	5,340	6,700	8,140	9,700	11,200	12,600	14,000	15,200	16,400	17,200	18,400
80	3,420	4,800	6,260	7,800	9,350	11,000	12,700	14,100	15,650	16,600	17,700	18,700	19,600
90	3,890	5,600	6,960	8,700	10,300	12,100	13,800	15,200	16,600	17,700	18,700	19,800	20,700
100	4,440	6,200	7,650	9,500	11,230	13,100	14,850	16,100	17,550	18,600	19,700	20,700	21,600
110	4,900	6,700	8,340	10,200	12,000	13,800	15,500	16,800	18,200	19,400	20,400	21,600	22,500
120	5,200	7,200	8,880	10,800	12,650	14,450	16,000	17,500	18,800	20,000	21,000	22,300	23,200
140	5,980	8,000	9,850	12,000	13,900	15,800	17,000	18,500	19,800	21,100	22,200	23,500	24,500
160	6,620	8,650	10,680	12,750	14,600	16,300	17,800	19,400	20,700	22,000	23,200	24,500	25,600
180	7,130	9,300	11,400	13,400	15,200	16,900	18,500	20,000	21,500	22,800	24,200	25,400	26,500
200	7,420	9,800	11,900	13,900	15,600	17,400	18,900	20,600	22,000	23,600	24,800	26,200	27,200

[1] Stumps and tips of trees included.

TABLE 17.—*Volume* [1] *per acre for trees over 6.5 inches in diameter, by age and site index*

ALASKA

Age (years)	Site class VI, site index 60	Site class V, site index—			Site class IV, site index—			Site class III, site index—			Site class II, site index 160
		70	80	90	100	110	120	130	140	150	
	Cu. ft.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
30	--------	--------	--------	--------	--------	--------	800	1, 200	1, 600	1, 950	2, 300
40	--------	--------	1, 100	1, 700	2, 300	3, 000	3, 700	4, 400	5, 100	5, 600	6, 200
50	1, 000	1, 850	2, 700	3, 600	4, 500	5, 300	6, 300	7, 300	8, 500	9, 300	10, 000
60	1, 850	2, 850	3, 950	5, 000	6, 050	7, 250	8, 400	9, 500	10, 900	11, 900	12, 800
70	2, 500	3, 650	4, 850	6, 100	7, 400	8, 800	10, 200	11, 400	12, 800	13, 900	14, 900
80	3, 100	4, 250	5, 700	7, 100	8, 500	10, 050	11, 600	13, 000	14, 400	15, 400	16, 500
90	3, 600	5, 000	6, 400	8, 000	9, 550	11, 150	12, 800	14, 300	15, 700	16, 550	17, 600
100	4, 050	5, 600	7, 050	8, 800	10, 450	12, 100	13, 800	15, 200	16, 550	17, 500	18, 500
110	4, 500	6, 050	7, 650	9, 550	11, 250	12, 900	14, 600	16, 000	17, 350	18, 300	19, 300
120	4, 900	6, 500	8, 200	10, 100	12, 000	13, 650	15, 300	16, 600	18, 000	19, 050	20, 000
140	5, 550	7, 400	9, 200	11, 200	13, 100	14, 700	16, 200	17, 700	19, 100	20, 200	21, 200
160	6, 150	8, 100	10, 050	12, 100	13, 900	15, 500	17, 100	18, 550	19, 950	21, 150	22, 300
180	6, 650	8, 700	10, 800	12, 800	14, 500	16, 200	17, 800	19, 200	20, 600	21, 900	23, 200
200	7, 100	9, 200	11, 300	13, 200	15, 000	16, 700	18, 400	19, 800	21, 200	22, 600	24, 100

[1] Stumps and tips of trees included.

TABLE 18.—*Volume* [1] *per acre by International rule (¼-inch kerf) for trees over 6.5 inches in diameter, by age and site index*

OREGON-WASHINGTON

Age (years)	Site class IV, site index—			Site class III, site index—			Site class II, site index—			Site class I, site index—		
	100	110	120	130	140	150	160	170	180	190	200	210
	M bd. ft.	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*
30	2	4	6	8	10	13	14	15	17	19	21	23
40	15	20	24	28	32	35	39	43	47	51	55	60
50	30	36	43	50	56	62	69	76	82	90	97	103
60	42	50	59	69	78	87	95	103	111	119	127	132
70	53	63	74	84	93	102	111	119	127	135	141	148
80	62	74	85	95	104	112	120	128	137	145	152	160
90	71	82	92	102	110	119	128	136	144	153	161	169
100	77	89	98	108	117	126	134	142	151	160	169	177
110	82	93	100	112	121	130	139	148	157	166	176	185
120	86	97	106	116	125	136	144	154	163	172	182	192
140	91	102	112	123	133	144	153	164	173	184	194	204
160	97	108	119	129	139	151	160	171	181	193	203	214
180	100	112	123	134	145	157	166	178	189	200	212	221
200	102	115	126	138	149	161	172	184	195	207	217	228
250	109	121	134	147	158	171	184	196	206	219	231	243
300	111	125	138	150	163	176	187	201	213	226	239	250

[1] Scaling length for logs, 16 feet; stump, 2 feet; top diameter inside bark, 6 inches; trim allowance per log, 0.3 foot.

TABLE 19.—*Volume*[1] *per acre by International rule (¼-inch kerf) for trees over 6.5 inches in diameter, by age and site index*

BRITISH COLUMBIA

Age (years)	Site class VI, site index 60	Site class V, site index—			Site class IV, site index—			Site class III, site index—			Site class II, site index—		
		70	80	90	100	110	120	130	140	150	160	170	180
	M bd. ft.	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*
30	--------	--------	--------	--------	--------	--------	3	5	5	7	9	10	11
40	--------	--------	4	7	12	16	21	24	27	31	34	39	43
50	4	7	11	18	24	31	39	45	53	58	63	67	74
60	7	13	19	27	35	44	53	62	70	76	82	89	95
70	11	18	26	36	44	54	64	74	83	90	98	106	112
80	14	24	33	43	52	63	74	84	95	103	110	119	125
90	17	28	38	49	59	71	82	93	105	114	119	128	135
100	21	32	43	54	65	78	90	101	112	121	128	136	144
110	24	35	47	59	71	83	96	108	119	128	135	142	150
120	26	39	51	63	75	89	101	113	124	133	140	148	155
140	32	44	57	71	84	98	110	122	132	141	148	157	165
160	36	50	62	77	91	105	119	128	138	148	156	165	172
180	40	53	67	82	98	110	123	134	144	154	162	171	179
200	42	58	71	88	101	115	127	138	147	157	167	176	185

[1] Scaling length for logs, 16 feet; stump, 2 feet; top diameter inside bark, 6 inches; trim allowance per log, 0.3 foot.

TABLE 20.—*Volume*[1] *per acre by International rule (¼-inch kerf) for trees over 6.5 inches in diameter, by age and site index*

ALASKA

Age (years)	Site class VI, site index 60	Site class V, site index—			Site class IV, site index—			Site class III, site index—			Site class II, site index 160
		70	80	90	100	110	120	130	140	150	
	M bd. ft.	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*
30	-------	-------	-------	-------	-------	-------	2	4	5	6	7
40	-------	-------	3	5	8	13	16	20	24	27	30
50	4	6	10	15	20	27	34	41	47	52	57
60	6	12	17	24	32	40	49	55	63	70	75
70	9	16	24	33	41	50	59	68	77	84	90
80	13	21	30	39	48	58	68	78	88	95	102
90	15	25	34	44	55	65	75	86	96	104	113
100	19	29	39	50	61	71	83	93	103	112	121
110	22	33	43	54	66	77	89	99	109	118	128
120	24	35	47	59	71	82	94	104	114	123	133
140	30	42	53	66	80	91	103	112	122	132	142
160	33	46	59	72	86	98	109	119	128	138	149
180	37	51	64	78	92	103	115	123	133	144	155
200	40	54	69	82	97	108	119	128	136	147	159

[1] Scaling length for logs, 16 feet; stump, 2 feet; top diameter inside bark, 6 inches; trim allowance per log, 0.3 foot.

TABLE 21.—*Volume*[1] *per acre by International rule (¼-inch kerf) for trees over 11.5 inches in diameter, by age and site index*

OREGON-WASHINGTON

Age (years)	Site class IV, site index—			Site class III, site index—			Site class II, site index—			Site class I, site index—		
	100	110	120	130	140	150	160	170	180	190	200	210
	M bd. ft.	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*
30								1	2	2	4	4
40	4	5	8	11	14	17	21	23	25	30	33	35
50	15	22	28	35	41	48	54	62	71	76	84	90
60	29	38	47	59	69	77	84	93	100	109	116	124
70	43	55	65	75	85	93	103	110	120	128	135	143
80	54	66	76	87	97	105	114	123	132	140	147	157
90	62	75	85	96	105	114	124	132	141	151	159	167
100	71	83	93	103	113	122	131	141	149	159	167	177
110	76	88	99	109	119	128	138	147	157	166	176	185
120	81	93	103	114	124	135	144	154	163	172	182	192
140	89	101	111	122	133	144	153	164	173	184	194	204
160	94	107	118	129	139	151	160	171	181	193	203	214
180	99	111	123	134	145	157	166	178	189	200	212	221
200	102	115	126	138	149	161	172	184	195	207	217	228
250	109	121	134	147	158	171	184	196	206	219	231	243
300	110	125	138	150	163	176	187	201	213	226	239	250

[1] Scaling length for logs, 16 feet; stump, 2 feet; top diameter inside bark, 6 inches; trim allowance per log, 0.3 foot.

TABLE 22.—*Volume*[1] *per acre by International rule (¼-inch kerf) for trees over 11.5 inches in diameter, by age and site index*

BRITISH COLUMBIA

Age (years)	Site class VI, site index 60	Site class V, site index—			Site class IV, site index—			Site class III, site index—			Site class II, site index—		
		70	80	90	100	110	120	130	140	150	160	170	180
	M bd. ft.	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*
30	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	2	3	4
40	-------	-------	-------	-------	3	4	6	7	9	12	14	16	18
50	1	2	3	5	8	14	18	24	30	34	40	45	52
60	2	5	6	11	15	24	32	42	52	59	66	72	80
70	3	6	10	18	24	35	47	58	69	78	85	92	100
80	4	9	15	24	34	47	60	71	83	91	100	108	116
90	5	13	19	31	43	57	71	82	96	103	112	120	128
100	7	16	24	37	51	65	80	91	104	112	122	130	138
110	9	20	29	43	58	72	87	100	111	120	129	138	145
120	11	23	33	48	64	79	93	106	118	127	136	144	152
140	15	30	43	59	74	90	104	117	128	138	147	156	165
160	19	34	50	67	83	98	113	125	136	146	157	165	173
180	23	40	56	74	90	105	119	131	142	153	162	171	179
200	25	43	62	80	97	111	124	136	147	158	167	176	185

[1] Scaling length for logs, 16 feet; stump, 2 feet; top diameter inside bark, 6 inches; trim allowance per log, 0.3 foot.

TABLE 23.—*Volume*[1] *per acre by International rule (¼-inch kerf) for trees over 11.5 inches in diameter by age and site index*

ALASKA

Age (years)	Site class VI, site index 60	Site class V, site index—			Site class IV, site index—			Site class III, site index—			Site class II, site index 160
		70	80	90	100	110	120	130	140	150	
	M bd. ft.	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*
40	-------	-------	-------	-------	2	3	5	6	8	10	12
50	-------	-------	3	5	7	13	16	22	27	32	36
60	2	4	5	10	14	22	30	38	47	53	60
70	3	5	9	16	23	33	42	53	63	71	78
80	4	8	13	23	32	43	54	66	77	85	93
90	5	12	17	29	40	52	65	77	87	95	104
100	7	14	22	34	47	61	73	85	95	104	113
110	9	18	26	40	54	68	81	91	102	112	121
120	11	22	32	45	60	73	87	98	109	119	128
140	14	27	40	54	69	83	96	108	119	129	140
160	18	33	47	62	77	90	104	116	127	138	148
180	21	37	53	68	83	97	110	121	133	144	155
200	24	41	58	73	89	102	116	127	136	147	159

[1] Scaling length for logs, 16 feet; stump, 2 feet; top diameter inside bark, 6 inches; trim allowance per log, 0.3 foot.

TABLE 24.—*Volume*[1] *per acre by Scribner rule for trees over 11.5 inches in diameter, by age and site index*

OREGON-WASHINGTON

Age (years)	Site class IV, site index—			Site class III, site index—			Site class II, site index—			Site class I, site index—		
	100	110	120	130	140	150	160	170	180	190	200	210
	M bd. ft.	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*
40	3	5	6	9	11	14	16	18	20	23	27	30
50	13	17	23	28	35	42	47	54	60	66	72	77
60	24	32	40	50	58	65	72	79	86	92	100	107
70	36	47	55	64	72	81	87	95	101	109	118	124
80	46	57	66	76	82	93	100	108	116	123	132	139
90	54	65	74	84	92	102	109	118	126	134	143	150
100	60	72	81	90	99	109	118	127	134	144	152	160
110	66	77	87	96	106	116	124	133	142	152	160	169
120	71	82	92	100	111	121	130	140	148	159	168	176
140	78	90	100	108	120	131	140	150	159	170	180	188
160	83	96	105	116	127	139	148	159	169	180	189	199
180	87	100	110	122	133	145	154	165	177	188	197	208
200	91	104	115	125	137	150	160	171	182	194	204	215
250	98	111	123	134	147	160	172	183	195	207	218	230
300	101	114	127	138	151	165	176	188	200	214	224	236

[1] Scaling length for logs, 16 feet; stump, 2 feet; top diameter inside bark, 8 inches; trim allowance per log, 0.3 foot.

TABLE 25.—*Volume*[1] *per acre by Scribner rule for trees over 11.5 inches in diameter, by age and site index*

BRITISH COLUMBIA

Age (years)	Site class VI, site index 60	Site class V, site index—			Site class IV, site index—			Site class III, site index—			Site class II, site index—		
		70	80	90	100	110	120	130	140	150	160	170	180
	M bd. ft.	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*
40	--------	--------	--------	--------	--------	--------	4	6	8	10	12	13	15
50	--------	--------	--------	--------	7	11	15	20	26	30	35	39	43
60	--------	--------	5	9	14	21	27	36	43	49	55	60	66
70	--------	5	9	15	21	30	39	48	57	64	72	78	85
80	3	8	12	21	29	39	50	60	70	77	85	93	100
90	4	10	16	26	35	48	58	70	80	89	97	104	112
100	6	14	20	31	42	55	67	78	90	97	106	113	122
110	8	17	24	37	48	62	74	85	97	105	113	121	128
120	10	19	28	41	53	68	80	92	103	111	119	127	134
140	13	25	35	50	62	77	91	103	113	122	130	138	146
160	16	29	42	56	70	85	99	110	121	130	138	147	155
180	19	34	47	62	76	91	105	116	127	136	146	154	163
200	21	36	50	66	81	96	109	120	132	141	150	160	169

[1] Scaling length for logs, 16 feet; stump, 2 feet; top diameter inside bark, 8 inches; trim allowance per log, 0.3 foot.

TABLE 26.—*Volume*[1] *per acre by Scribner rule for trees over 11.5 inches in diameter, by age and site index*

ALASKA

Age (years)	Site class VI, site index 60	Site class V, site index—			Site class IV, site index—			Site class III, site index—			Site class II, site index 160
		70	80	90	100	110	120	130	140	150	
	M bd. ft.	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*
40	----	----	----	----	----	----	----	3	6	8	10
50	----	----	----	----	6	10	14	18	23	27	31
60	----	----	4	8	12	19	26	32	39	44	49
70	----	----	8	13	19	28	36	44	53	59	66
80	3	7	11	19	26	36	46	55	64	71	79
90	4	10	15	24	32	43	54	64	75	82	90
100	6	12	19	29	39	50	62	73	84	91	99
110	7	15	22	34	45	57	69	80	92	99	107
120	8	17	26	38	50	63	76	87	98	105	113
140	12	22	33	46	59	73	86	97	108	116	124
160	15	27	39	53	67	80	94	105	116	124	133
180	18	31	44	58	73	86	100	111	123	132	141
200	20	34	48	62	78	91	105	117	129	138	148

[1] Scaling length for logs, 16 feet; stump, 2 feet; top diameter inside bark, 8 inches; trim allowance per log, 0.3 foot.

DIAMETER YIELD TABLES

The possibility of using average diameter as an independent variable in place of site and age has been recognized for several years. For fully stocked stands, very high correlations have been obtained between average diameter and the familiar dependent yield variables such as basal area and volume. Table 27 presents the results of graphical correlations between pertinent dependent yield variables and average stand diameter. In using table 27 the reader should note that the independent variable—average diameter—is for all trees over 1.5 inches in diameter while several of the dependent variables have higher diameter limits.

Table 28 is also an essential part of the diameter yield tables. It has been derived from figure 17 of Technical Bulletin 544 (*7*) and shows the average heights of trees by diameter classes for stands of given average diameter. These so-called standard heights are compared with heights in an actual stand by a procedure which will be discussed in detail later. The relationship of actual to standard heights is thus introduced as a supplementary independent variable for computing more precise estimates of yield. In table 28, whenever the tree diameter class is the same as the average diameter of the stand, standard height is the same as standard average height as listed in table 27.

In 1932 the writer [3] prepared a partial set of diameter yield tables for western hemlock in British Columbia. Meyer in 1937 (*7*) presented average diameter tables as a supplement to his site index tables for western hemlock and Sitka spruce. More recently Bruce improved the application procedure and developed average diameter tables for Douglas-fir (*3*).

Bruce's volume yields (*3*) were presented as averages per tree, which must be multiplied by numbers of trees per acre to obtain estimates of volume per acre. The products of a rapidly diminishing number of trees and a rapidly increasing volume per tree lead to irregularities in the relationship of volume per acre to average diameter. Volume yields in table 27 of the present report are therefore presented as volumes per acre to facilitate application. Irregularities were removed by curving volume per acre over average diameter.

For stands of the same average diameter and standard average height, volumes per acre were somewhat lower for average diameters below 16 inches in Oregon-Washington than in British Columbia and Alaska. Volume per acre is therefore presented separately for each of the two regions. Meyer (*7*) also recognized these differences in compiling his diameter yield tables for Oregon-Washington and Alaska. The volumes reported by Meyer agree closely with those presented in table 27 up to 20 inches of average diameter. Above 20 inches Meyer's values overrun the volumes in table 27.

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[3] BARNES, G. H. VOLUME, YIELD AND STAND TABLES FOR WESTERN HEMLOCK IN BRITISH COLUMBIA. Brit. Columbia Forest Serv. 1932. (Unpublished report.)

TABLE 27.—*Normal yields based on average stand diameter for trees over 1.5 inches in diameter*

Average d.b.h. of stand over 1.5 inches d.b.h.	Trees per acre, normal	Standard average height [1]	Basal area per acre in trees over 1.5 inches d.b.h.	Volume per acre, Oregon-Washington					Volume per acre, British Columbia and Alaska				
				Total, i.e., stump and top included		International ¼-inch rule, 6-in. top diameter and 2-ft. stump height		Scribner rule, 8-in. top diameter and 2-ft. stump height	Total, i.e., stump and top included		International ¼-inch rule, 6-in. top diameter and 2-ft. stump height		Scribner rule, 8-in. top diameter and 2-ft. stump height
				Trees over 1.5 inches d.b.h.	Trees over 6.5 inches d.b.h.	Trees over 6.5 inches d.b.h.	Trees over 11.5 inches d.b.h.	Trees over 11.5 inches d.b.h.	Trees over 1.5 inches d.b.h.	Trees over 6.5 inches d.b.h.	Trees over 6.5 inches d.b.h.	Trees over 11.5 inches d.b.h.	Trees over 11.5 inches d.b.h.
	No.	*Ft.*	*Sq. ft.*	*Cu. ft.*	*Cu. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*	*Cu. ft.*	*Cu. ft.*	*M bd. ft.*	*M bd. ft.*	*M bd. ft.*
3	2, 970	31	146	2, 000	--------	--------	--------	--------	2, 400	--------	--------	--------	--------
4	2, 130	42	186	3, 600	900	4	--------	--------	4, 000	1, 500	3	--------	--------
5	1, 540	52	210	5, 000	2, 700	11	--------	--------	5, 500	3, 300	13	--------	--------
6	1, 160	61	229	6, 300	4, 300	18	5	4	6, 800	4, 900	22	6	5
7	905	69	242	7, 400	5, 800	26	10	8	8, 000	6, 400	32	13	11
8	723	76	253	8, 500	7, 200	34	16	13	9, 200	7, 700	41	20	17
9	595	82	263	9, 500	8, 500	43	24	20	10, 200	9, 000	50	29	25
10	498	89	273	10, 600	9, 800	51	33	28	11, 200	10, 300	59	40	33
11	425	95	281	11, 600	11, 000	60	44	38	12, 200	11, 600	67	51	42
12	368	101	289	12, 600	12, 100	70	57	48	13, 200	12, 900	75	62	51
13	325	107	297	13, 500	13, 200	80	69	59	14, 100	14, 000	83	71	60
14	284	112	305	14, 400	14, 200	90	80	68	14, 900	14, 900	90	81	68
15	255	117	312	15, 300	15, 000	99	89	76	15, 600	15, 600	99	90	76
16	228	122	318	16, 100	15, 900	106	98	84	16, 300	16, 300	105	98	84
17	207	127	325	16, 800	16, 700	111	105	91	17, 000	17, 000	111	105	91

18	187	132	330	17,400	17,400	117	111	97	17,600	17,600	117	111	97
19	172	136	336	18,100	18,100	121	118	103	18,200	18,200	121	118	103
20	157	140	341	18,800	18,800	126	122	108	18,800	18,800	126	123	108
21	143	144	346	19,400	19,400	129	128	113	19,400	19,400	129	128	113
22	133	148	351	20,000	20,000	133	132	118	20,000	20,000	133	132	118
23	123	151	356	20,500	20,500	138	137	123	20,500	20,500	138	137	123
24	114	154	360	21,000	21,000	141	141	128	21,000	21,000	141	141	128
25	107	158	365	21,500	21,500	146	146	132	21,500	21,500	146	146	132
26	100	161	369	22,100	22,100	149	149	137	22,000	22,000	149	149	137
27	94	164	373	22,600	22,600	153	153	141	22,600	22,600	153	153	141
28	89	167	378	23,100	23,100	157	157	145	23,100	23,100	157	157	145
29	83	170	382	23,600	23,600	161	161	149	23,600	23,600	161	161	149
30	79	173	386	24,100	24,100	165	165	153	24,100	24,100	165	165	153
32	71	180	396	25,100	25,100	173	173	161					
34	64	186	405	26,000	26,000	180	180	169					
36	59	192	414	27,000	27,000	188	188	177					
38	54	199	422	28,000	28,000	195	195	184					
40	49	206	430	28,800	28,800	204	204	192					

[1] Standard average height for all regions is the average stand height for Oregon-Washington and British Columbia. Height data from Alaska sample plots were not used.

TABLE 28.—*Standard heights for tree diameter classes in a stand based on average diameter of all trees over 1.5 inches*

Tree d.b.h. (inches)	Total height when average d.b.h. of stand is—															
	2 in.	4 in.	6 in.	8 in.	10 in.	12 in.	14 in.	16 in.	18 in.	20 in.	22 in.	24 in.	28 in.	32 in.	36 in.	40 in.
	Ft.	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*
2	14	27	29	29	------	------	------	------	------	------	------	------	------	------	------	------
4	------	42	49	50	50	48	46	43	------	------	------	------	------	------	------	------
6	------	53	61	65	68	70	67	67	63	60	55	49	------	------	------	------
8	------	60	71	76	79	83	84	84	84	81	78	74	------	------	------	------
10	------	64	78	84	89	93	96	97	99	99	99	97	95	------	------	------
12	------	------	82	91	96	101	104	108	112	112	114	112	112	------	------	------
14	------	------	87	95	101	108	112	116	119	122	123	123	125	------	------	------
16	------	------	90	100	107	112	118	122	125	129	132	132	134	131	------	------
18	------	------	------	103	110	117	123	127	132	135	138	138	142	142	130	------
20	------	------	------	106	114	120	126	132	136	140	144	145	150	151	142	130
22	------	------	------	107	117	123	129	134	140	144	148	148	155	158	153	144
24	------	------	------	------	------	126	132	137	142	147	151	154	160	164	161	155
26	------	------	------	------	------	------	134	139	144	149	154	157	164	169	169	165
28	------	------	------	------	------	------	135	140	146	151	157	159	167	173	175	173
30	------	------	------	------	------	------	137	142	148	153	159	161	170	176	180	181
32	------	------	------	------	------	------	138	144	149	154	160	163	172	180	184	187
34	------	------	------	------	------	------	------	145	151	156	162	165	174	184	188	193
36	------	------	------	------	------	------	------	146	153	158	163	166	175	187	192	197
38	------	------	------	------	------	------	------	------	------	------	165	168	176	189	196	202
40	------	------	------	------	------	------	------	------	------	------	------	------	177	192	200	206
42	------	------	------	------	------	------	------	------	------	------	------	------	------	195	203	210
44	------	------	------	------	------	------	------	------	------	------	------	------	------	196	205	212
46	------	------	------	------	------	------	------	------	------	------	------	------	------	198	207	216
48	------	------	------	------	------	------	------	------	------	------	------	------	------	------	209	218
50	------	------	------	------	------	------	------	------	------	------	------	------	------	------	211	220
55	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	226
60	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	230

APPLICATION OF YIELD TABLES

Only the site index tables can provide an estimate of future yield for a nonstocked area or for a stand with an average diameter less than 3 inches. When average diameter is 3 inches or greater, either the site index tables or the average diameter tables may be used to predict future yields.

Information on stand age and stocking is used in making yield predictions with both the site index and the average diameter tables. A third element—stand height—is also used in both methods although it is used indirectly as site index in one case and directly as average stand height in the other. Yield predictions by diameter tables use a fourth element of information—average diameter—which is not used by the site tables.

In fully stocked stands the difference between normal average diameter (as shown in tables 5 and 6) and actual average diameter is relatively small, but in understocked stands the actual average diameter is invariably larger. Volume yields of understocked stands are therefore frequently underestimated. Similarly, volume yields of overstocked stands are often overestimated.

Changes in Stocking

Both the site index tables and the average diameter tables require an estimate of future stocking for a prediction of future stand volume. Present stocking cannot be used as the estimate of future stocking, because there is a tendency for both understocked and overstocked stands to approach normal stocking in time.

The rate of this change is difficult to determine, because reliable data are obtainable only from periodic measurements of permanent sample plots. Relatively few such plots have been established to date in immature western hemlock stands. Fifteen permanent plots were available for the Oregon-Washington region, but these were mainly well-stocked stands in the 80-year age class. Ranges in degree of stocking and age were therefore narrow. Some additional data consisting of 80 permanent line plots in a 40-year-old stand were secured from British Columbia. Although the range in age of these plots was also very narrow, the range in stocking was broad.

Using these limited data, Newport[4] established a regression (fig. 3) which relates decadal changes in stocking to stocking at the start of the decade. As his basis for stocking, Newport used the percentage relation between actual number of trees and normal number as shown in table 27. His regression led to table 29 which provides estimates of future stocking for stands over multiple decades. A stand which has a present stocking of 50 percent, for example, is expected to increase to a stocking of 92 percent in the next 60 years. Examination of figure 3 and table 29 reveals that understocked stands increase in stocking as age increases while overstocked stands decrease.

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[4] Newport, Carl Allen. DIAMETER YIELD TABLES VERSUS SITE-INDEX YIELD TABLES FOR WESTERN HEMLOCK. 51 pp., illus. Corvallis, Oreg. 1950. (Unpublished thesis, Oreg. State Univ.)

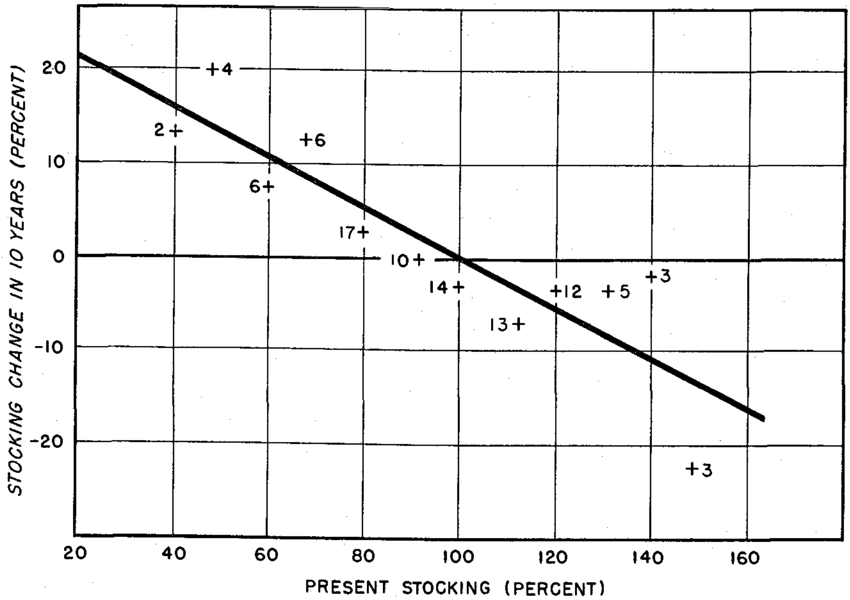

FIGURE 3.—Decadal changes in stocking.

TABLE 29.—*Estimated stocking*[1] *at future intervals, for specified present density, in percent of normal*

Present stocking (percent)	Stocking at—					
	10 years	20 years	30 years	40 years	50 years	60 years
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
20	42	58	69	77	83	87
30	49	63	73	80	85	89
40	56	68	77	83	87	90
50	63	73	80	85	89	92
60	71	79	84	88	91	93
70	78	84	88	91	93	95
80	85	89	92	94	95	96
90	93	95	96	97	98	99
100	100	100	100	100	100	100
110	107	105	104	103	102	101
120	115	111	108	106	104	103
130	122	116	112	109	106	104
140	129	121	116	112	109	106
150	137	127	120	114	110	107
160	144	132	123	117	112	109

[1] Stocking as used here is the percentage relationship between actual and normal number of trees as defined in table 27 for a particular average stand diameter.

For several other species, rate of change in stocking is related to stand age as well as present stocking. Young stands change more rapidly than older stands. Since the age range of the hemlock permanent plot data was very restricted, however, the age variable could not be used. Results of Newport's analysis must therefore be considered as incomplete, and further refinements must await the accumulation of additional data.

Estimating Present and Future Volumes With the Site Index Tables

One method of using the site index tables to calculate present stand volumes and to predict future stand volumes is illustrated in the following example:

Assume that a stand in Oregon has been examined with these results:

Average age of dominant and codominant trees	60 years.
Average height of dominant and codominant trees.	102 feet.
Average basal area per acre of trees over 1.5 inches.	221 square feet.

To calculate present and future stand volumes proceed as follows:

1. From table 1 find site index	140 (rounded).
2. From table 7 find normal basal area per acre in trees over 1.5 inches.	300 square feet.
3. Calculate present stocking	(221/300) (100) = 74 percent.
4. From table 12 find present normal cubic-foot volume in trees over 1.5 inches.	13,100 cubic feet.
5. Calculate estimated present cubic-foot volume in trees over 1.5 inches.	(13,100) (0.74) = 9,694 cubic feet.

(Estimated present volumes for the other measurement standards can be calculated by the same procedure).

6. From table 29 find stocking at 100 years	92 percent.
7. From table 12 find cubic-foot volume in trees over 1.5 inches at age 100 for a normal stand.	17,400 cubic feet.
8. Calculate estimated cubic-foot volume per acre in trees over 1.5 inches at age 100.	(17,400) (0.92) = 16,008 cubic feet.

(Estimated future volumes for the other measurement standards can be calculated by the same procedure.)

Field data required for estimates of future stand volumes can be obtained by any of several sampling procedures. Usually, plots are established on a systematic grid within the stand in question. Aerial photos are frequently used to define the limits of the stand. Variable radius plots (*2*) are efficient sampling units for the estimate of basal area per acre.

Measurements of from 10 to 20 trees in the dominant and codominant crown classes will probably be sufficient for age and height estimates. These trees should be distributed fairly uniformly throughout the stand and can be taken on a subsample of the plots used for basal area estimate. Ratio of dominant to codominant trees in this sample should be approximately the same as the ratio of all dominant and codominant trees in the stand. Note that ages of individual trees are breast height ring counts plus 7 years if the stand is in Oregon-Washington or 8 years if in British Columbia or Alaska.

Arithmetic averages of ages and heights can be used to provide a crude estimate of site index for the entire stand, as in the example given. A more precise estimate of site index can be obtained from a curve of height over diameter for dominant and codominant trees and then reading the height on this curve corresponding to the estimated average diameter of all dominant and codominant trees in the stand. This more precise average height is, of course, dependent on a tally of all trees by crown classes on all plots used for the estimate of basal area per acre.

In the example, the relationship between actual and normal per acre volumes could have been used in place of the relationship between actual and normal basal areas as a measure of stocking. However, basal area is frequently more convenient and perhaps just as effective.

Estimating Present and Future Volumes With the Average Diameter Tables

Use of the average diameter tables for estimating present and future stand volumes is illustrated in the following example.

Assume the following information is available from an examination of a stand in Oregon:

Average number of trees per acre over 1.5 inches ---- 207 trees.
Average diameter of trees over 1.5 inches ---------- 14.0 inches.
Average age of dominant and codominant trees ------ 60 years.
Actual diameters and heights of sample trees: [1]

D.b.h. (inches):	*Actual height* (*feet*)	*Standard height from table 28, p. 36* (*feet*)
11	90	100
13	89	108
15	111	115
14	100	112
15	90	115
13	100	108
12	85	104
14	90	112
12	91	104
15	94	115
Total	940	1,093

[1] When data are taken in the field, average stand diameter is not known precisely. An estimate of it can be made, however, and sample trees should be chosen within a few inches plus and minus of estimated average diameter.

To calculate present volumes and volumes at stand age 100 proceed as follows:

1. Use table 28 to find standard heights corresponding to actual heights and calculate the height factor for adjusting volumes.

$$\frac{\text{Sum actual heights}}{\text{Sum standard heights}}=\frac{940}{1{,}093}=0.86$$

2. Find normal number of trees from table 27 for an average diameter of 14 inches and calculate stocking.

$$\frac{\text{Actual number of trees}}{\text{Normal number of trees}}=\frac{207}{284}(100)=73 \text{ percent}$$

3. Use normal volume in table 27 to calculate estimated present volume in cubic feet per acre for trees over 1.5 inches in diameter.

$$(14{,}400)(0.73)(0.86) = 9{,}040 \text{ cubic feet}$$

(Estimated present volumes for the other measurement standards can be calculated by the same procedure.)

4. Use table 5 to estimate future average diameter at age 100. Thus a diameter of 14.0 inches at 60 years is found midway between columns 7 and 8 in table 5. Interpolation between the same columns at age 100 results in $(20.9+20.2)/2=20.5$ inches. Table 5, a site index table, is used in this way merely for convenience. There should be no inference that site index is 155 for the stand in the example, because the 14-inch present average diameter reflects not only the effect of site but also the effect of past stocking.

5. Estimate stocking at age 100 by interpolation in table 29 at 92 percent.

6. Use future normal cubic-foot volume in trees over 1.5 inches from table 27 for average diameter 20.5 inches to calculate estimated future volume.

$$(19{,}100)(0.86)(0.92) = 15{,}112 \text{ cubic feet}$$

(Estimated future volumes for the other measurement standards and for other regions can be calculated by the same procedure.)

METHODS OF COMPILATION

Site Index Yield Tables

Methods of compiling site index yield tables in the United States have been developing over the past 20 years or more. Later and more precise methods are contained in Bruce and Schumacher's textbook "Forest Mensuration" (*4*). In general, the same methods were used in this study. However, because of the wide geographical range from which the basic data were collected, and because the diameter yield tables were to be developed at the same time, some departures from the standard methods were made to reduce compilations to a minimum. A brief description of the procedure used is therefore presented.

Site Classification

Failure of the original site index curves of 1937 to define site satisfactorily was discussed in the introduction. The combining of all data for the two species, hemlock and spruce, from such a wide geographical range extending from southern Oregon to southeastern Alaska, was suspected as being the chief cause of this failure. In Wilson's preliminary investigation (see Introduction), therefore, the basic data were reclassified according to region and species composition. Alaska, British Columbia, and Oregon-Washington were selected as geographical strata. Five species-composition groups were used.

Western hemlock by basal area (percent):
- 80–100
- 60–80
- 40–60

Sitka spruce by basal area (percent):
- 80–100
- 60–80

The hemlock data were thus classified into nine classes and the spruce into six. An attempt was made to determine differences in the shape of the height over-age-curve for each of these classes. The heights of dominant and codominant hemlock trees only were used for the hemlock classes; the heights of spruce only, for the spruce classes. With the data subdivided into these 15 classes, the trends of the curves were poorly defined. However, comparisons among the classes yielded the following observations and conclusions:

1. For hemlock there were apparently no differences in either level or form among the curves for the species composition groups. For spruce there apparently were differences among curves for species composition groups.

2. When the percentage composition groups were combined for hemlock, the height-over-age curves from the different regions occupied different levels. The Oregon-Washington curve assumed the highest position, reaching a level of 153 feet at 100 years. The British Columbia curve reached 127 feet and the Alaska curve 104 feet at 100 years. This indicated a greater frequency of better sites at the southern range than at the northern range of western hemlock. When these curves were adjusted [5] to pass through a level of 130 feet at an age of 100 years, their form was very similar. This indicated that separate regional curves were not needed and that the differences in level were due only to differences in average site among the three regions.

3. There was considerable difference in the form of the hemlock and spruce curves, the spruce curve continuing to rise at a much higher rate after an age of 100 years than the hemlock curve. This indicated the need for a separation of species in the evaluation of site.

After completion of these preliminary analyses, the height-over-age curves for dominant and codominant hemlock trees were prepared according to standard procedures described by Bruce and Schumacher (*4*). Analysis of the coefficient of variation of plot dispersion around the "Master" curve of height over age offered little evidence that this coefficient was correlated with age. The level of each final site index curve is located at a constant ratio of the level of all other curves throughout its length.

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[5] Each place curve was adjusted to pass through a height of 130 feet at 100 years. The Oregon-Washington curve was reduced throughout its length by the ratio of 130/153 or by 85 percent. The British-Columbia curve was raised by the ratio of 130/127 or by 102 percent, and the Alaska curve by 130/104 or 125 percent so that the form of the curves could be compared directly.

Average Diameter

Information on average diameter in tables 5 and 6 was developed basically by standard procedures (*4*). Studies were made, however, to determine possible differences among regions. Since regional differences were found to exist, the complete procedure is described below:

1. Separate curves of average diameter over stand age without regard to site were prepared for Oregon-Washington, British Columbia, and Alaska. The three curves had a common form, but lay at different levels because of differences in average site among regions.
2. Since the Oregon-Washington curve was represented by more plots and extended over a greater age range, it was used as a standard. Percentage relationships of the British Columbia and Alaska curves were computed to this standard at 10-year intervals throughout their age range. For a given region the variation among percentages was small, and there was little evidence that the percentage figures were correlated with stand age. Average percentages over the entire age range of the curves were therefore computed. The British Columbia curve was 72.7 percent and the Alaska curve 57.0 percent of the standard Oregon-Washington curve.
3. British Columbia and Alaska curves were then replotted at their respective levels of 72.7 and 57.0 percent of the Oregon-Washington curve. These curves fitted the raw data points very satisfactorily, confirming a similar form for the curves of all three regions.
4. Curves of average diameter over stand age were then prepared for individual site index classes, according to standard procedures. Site index, stand age, actual average diameter, and standard average diameter (Oregon-Washington) were tabulated for each plot. Ratios of actual to standard average diameter for individual plots were used to compute an average ratio for all plots in each site index class. Average ratios were then plotted over site index in figure 4. Curves through the plotted points removed irregularities among site index classes.
5. At first a separate curve of average ratio over site class was plotted for each of the three regions, but the British Columbia and Alaska curves were so nearly identical that they were combined into a single curve.
6. The ratio for a given region and site index (from the curves in fig. 4) was then multiplied by the Oregon-Washington standard average diameter for a given stand age to provide individual values for tables 5 and 6.

Examination of figure 4 discloses that for a given site the average diameters of stands in Oregon and Washington are considerably larger than in British Columbia and Alaska. For example, on site index 150 the average diameters are estimated to be 0.98 and 0.80, respectively, of standard average diameter.

These findings show that for a given site and age there are more but smaller trees in British Columbia and Alaska than in Oregon and Washington. A slower rate of diameter growth in British Columbia and Alaska may be explained by more profuse reproduction and earlier

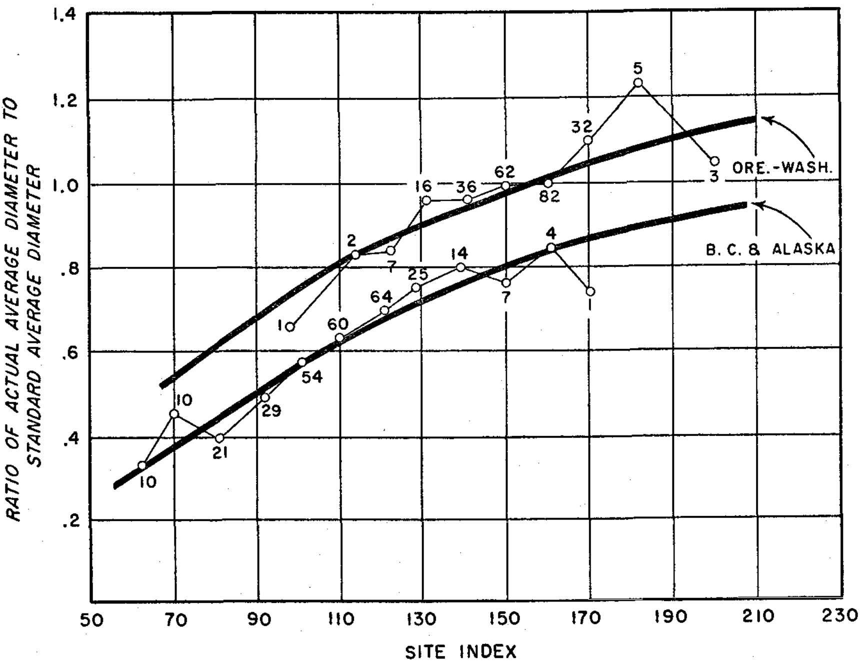

FIGURE 4.—Curves of average diameter ratio over site index.

and more intense competition among trees. It also explains a statement by Taylor (*8*) that pure hemlock stands in Alaska have a low yield because of overstocking and consequent stagnation. Meyer (*7*), on the other hand, reports that stands of hemlock in Oregon and Washington ". . . do not tend to stagnate as Taylor has observed them to do in Alaska. They thin out readily from natural causes, and maintain a healthy condition and high growth rates."

Number of Trees Per Acre

Average diameters, as determined by procedures described in the previous section, and the curve in figure 7 (p. 49), led to a tentative number of trees per acre for each combination of stand age and site index. These tentative values were then curved over stand age and site index to remove irregularities, and final values from the curves were entered in tables 3 and 4. The method used to establish the curve in figure 7 is described on page 48 as a part of the procedure for developing the average diameter yield tables.

Average Height of Stand

Information on average height of stand for Oregon and Washington was developed indirectly by modifying Meyer's curve of average height of trees larger than 2.5 inches over average height of dominant and codominant trees (*7*). Meyer's curve was satisfactory except at

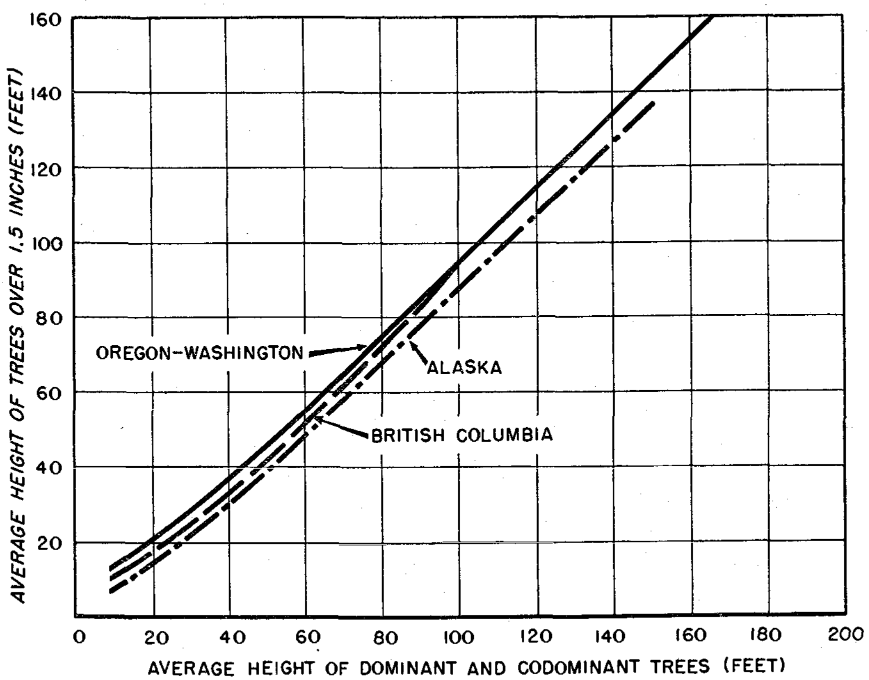

FIGURE 5.—Relation between average height of dominant and codominant trees and average height of all trees in the stand over 1.5 inches in diameter.

the lower part. When average height of dominant and codominant trees was greater than 60 feet, the average height of all trees over 1.5 inches in diameter was found to coincide with the average height of trees over 2.5 inches, and this portion of Meyer's curve was accepted. Average height of trees over 1.5 inches was slightly less than that of trees over 2.5 inches when average height of dominant and codominant trees was less than 60 feet. The lower end of Meyer's curve was therefore modified.

For British Columbia and Alaska, curves of average height of trees larger than 1.5 inches over average height of dominants and codominants were developed directly. There was no previous curve for British Columbia, and a previous curve for Alaska (*7*) failed to agree with the basic data used in the current work. The three separate curves are presented in figure 5.

The relationships established in figure 5 were used to obtain average stand height for trees over 1.5 inches from average height of dominant and codominant trees by site index classes.

Basal Area

Basal area per acre of the stand of trees 1.5 inches and over was computed by multiplying the basal-area-per-tree equivalent of the average diameter by the number of trees per acre. These computed values were plotted over age by site index classes, and smooth curves were drawn to remove minor irregularities.

Cubic-Foot Yield in Trees Above 1.5 Inches in Diameter

In developing the diameter yield tables, a single curve was drawn for cubic-foot volume per acre over average diameter. This curve was used with average diameters by site index and stand age as shown in tables 5 and 6 to produce preliminary estimates of cubic-foot volumes. These preliminary estimates would be correct only if average height and site index were unrelated for a specific average diameter. However, Bruce (*3*) found that average heights for stands of a given average diameter vary with site, being lower on poor sites and higher on good sites. The preliminary estimates of cubic volume were therefore adjusted, using a procedure devised by Bruce for Douglas-fir. Preliminary volume per acre as determined above was then multiplied by the ratio of average height of the trees in a given age-site class to the standard average height of trees having the same average diameter as shown in table 27.

For example, in Oregon-Washington, average height in table 9 for age 50 and site index 100 is 59 feet. Corresponding average stand diameter from table 5 is 8.6 inches; and, interpolating to the nearest foot in table 27, the standard average height of stands with average diameter of 8.6 inches for all sites is 80 feet. The average height at age 50 on site index 100 is therefore $\frac{59}{80}$ or 0.74 of the standard height shown in table 27. Ratios similar to the one just computed were determined for all the tabular age-site classes. Examination of the results disclosed that age had practically no effect on the ratios. Averages for all age groups were therefore curved over site index (fig. 6). As read from figure 6, the adjustment ratio for Oregon-Washington and for site index 100 is 0.76. Normal volume from table 27 for Oregon and Washington corresponding to an average stand diameter of 8.6 inches and a standard height of 80 feet is 9,100 cubic feet in trees over 1.5 inches. Adjusted volume for age 50 and site 100 in table 12 is, therefore, $0.76 \times 9{,}100 = 6{,}900$ cubic feet.

Cubic volumes for British Columbia (table 13) were developed in the same way, but an additional adjustment was necessary for Alaska (table 14). In table 27, average height of stands in Oregon-Washington and British Columbia was used as the standard height for all regions. Cubic volumes shown for Alaska in table 27 are for stands of given average diameter and of standard height. In Alaska the average height of stands of a given average diameter is much less than the standard; hence ratios of average stand height in Alaska to standard stand height by diameter classes were used as additional adjustment factors in calculating volumes for table 27. If the example used previously for Oregon-Washington were for Alaska, the site adjustment ratio from figure 6 for site index 100 would be 1.015. The additional adjustment ratio for the difference between average stand height in Alaska and standard height from table 27 is $54/64 = 0.844$. The normal volume for a diameter of 6.4 inches in Alaska is 7,280 cubic feet. Estimated volume for site index 100 and for age 50 is therefore:

$$7{,}280 \times 1.015 \times 0.844 = 6{,}250 \text{ cubic feet.}$$

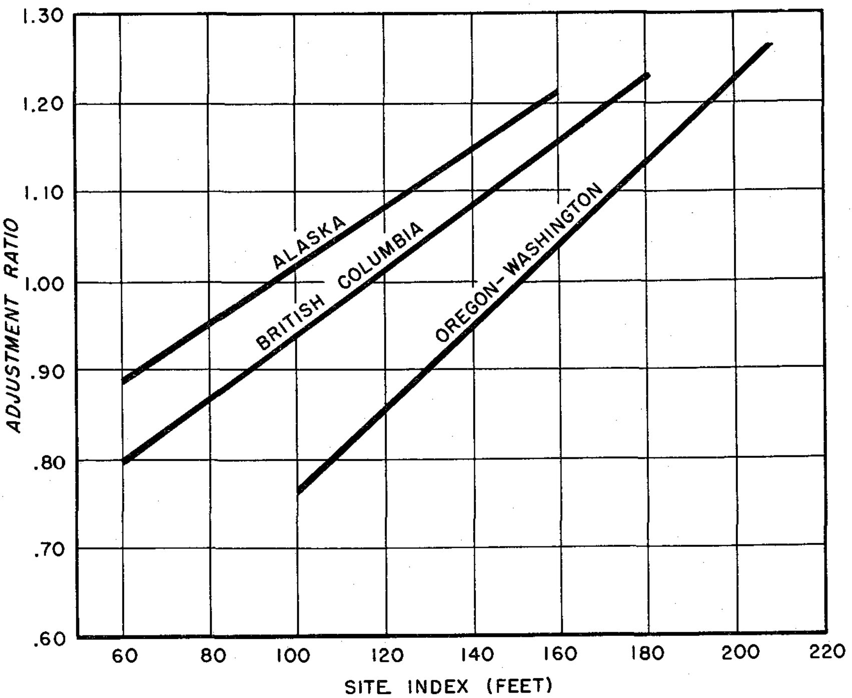

FIGURE 6.—Relation between height ratio and site index where height ratio is average height divided by standard height.

Subsequent harmonizing of these cellular values resulted in the tabular value of 6,000 cubic feet for this specific age and site (table 14).

Stand Volumes in Trees Above 6.5 Inches and in Trees Above 11.5 Inches

Additional volume yields are reported in tables 15 through 26 by various standards of measurement and for parts of the entire stand of trees other than the part above the 1.5-inch diameter limit. All of this information for Oregon-Washington was developed by procedures described in the preceding section. The same procedures were also used for British Columbia and Alaska to develop volume yields in trees over 11.5 inches by the Scribner rule. For British Columbia and Alaska, cubic-foot yields of trees over 6.5 inches, and International board-foot yields in trees over 11.5 inches were developed from the basic plot data by computing ratios of these volumes to corresponding volumes in trees over 1.5 inches and 6.5 inches, respectively. These ratios were curved over average stand diameter. Average diameters from tables 5 and 6 led to specific ratios from the curves for each combination of age and site. These ratios were then applied to volumes in tables 13 and 14 to produce volumes for tables 16 and 17. Similarly, ratios applied to tables 19 and 20 led to tables 22 and 23.

Diameter Yield Tables

Information in table 27 resulted from using plot data in a series of graphical analyses. Average diameter was the independent variable for each of these analyses, and the dependent variables were number of trees per acre, average total tree height, basal area per acre, and volumes per acre according to various standards. All of these variables are defined in the column headings of table 27.

Number of Trees Per Acre

As for other species, the logarithm of number of trees per acre over 0.5 inches is linearily related to the logarithm of average stand diameter. Preliminary graphical analysis indicated that this relationship did not vary appreciably among regions. This was to be expected because all basic plots were presumably fully stocked, and only regional differences in the concept of full stocking could lead to differences in number of trees. Data from Oregon-Washington, British Columbia, and Alaska were therefore combined, and the following regression equation was established mathematically: Log $N=4.366120-1.668551 \log D$, where N is the number of trees per acre over 0.5 inches and D is the average stand diameter of all trees over 0.5 inches. A similar relationship based on trees over 1.5 inches was identical for large average diameters but curved below the first regression in the small average diameters. The extent of this curving was determined graphically, and a final curve showing the relationship between number of trees per acre over 1.5 inches and average stand diameter for trees over 1.5 inches was prepared (fig. 7).

Basal Area Per Acre in Trees Over 1.5 Inches

The curve of number of trees over average diameter led directly to estimates of basal area per acre. The basal area equivalent of average diameter was simply multiplied by number of trees per acre. Values obtained in this way were plotted over average diameter, and minor irregularities were removed by curving. The final curve was checked against the actual plot data. For obvious reasons, there are no regional differences in the basal area per acre information.

Standard Average Height

Preliminary analysis indicated that average heights for stands of the same average diameter in Oregon-Washington and British Columbia were considerably different from average heights in Alaska (fig. 8). The composite curve of average height over average diameter for Oregon-Washington and British Columbia extended over the greatest range of diameters, was based on the greatest amount of data, and was most clearly defined. It was, therefore, accepted as the standard curve, and so-called standard average heights from this curve are presented in table 27.

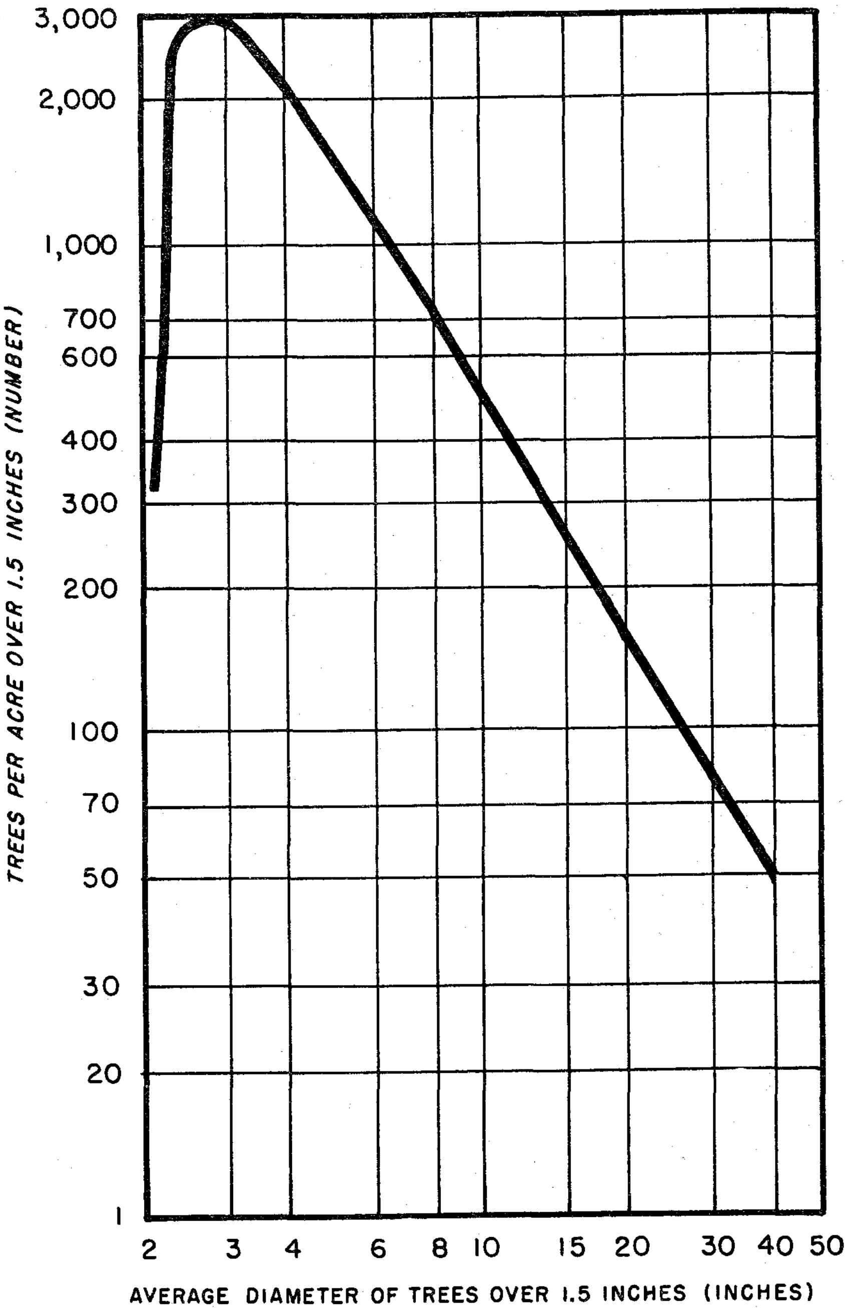

FIGURE 7.—Relation between number of trees per acre and average stand diameter for trees over 1.5 inches.

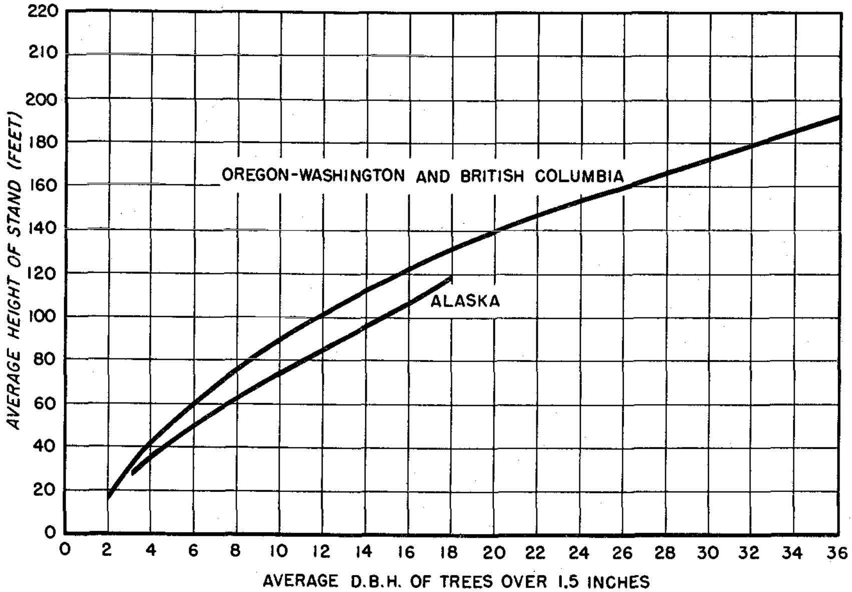

FIGURE 8.—Relation between average height and average diameter of trees over 1.5 inches.

Heights of individual stands will vary from standard, depending on site index and stocking. Stands having either shorter or taller average tree heights will have smaller or greater volumes per acre, when number of trees remains the same. In estimating volume yield for a stand, proportional adjustments must be made in the tabulated volumes to account for this departure from the standard. This adjustment procedure has been presented in the section on application. It should be noted that all volumes shown in table 27 correspond to standard heights. Since average stand heights in Alaska are less than standard, the volumes shown for Alaska are above average for that region. This anomaly is, of course, corrected through the application procedure.

Volumes Per Acre

A curve of average volume per tree over average diameter was drawn, using the Oregon-Washington data only. Volumes per acre for that region were then computed by multiplying volume per tree by normal number of trees per acre for a given diameter class. To remove minor irregularities, these per acre volumes were curved over average diameter.

For British Columbia the curve of volume per tree over average diameter was slightly higher than for Oregon-Washington, and the curve for Alaska was considerably lower. This was to be expected because of regional differences in average stand height. There was a possibility, however, that the curves might be made to coincide if they were all adjusted to represent the same average stand height.

This conjecture was tested by Robinson,[6] who adjusted the volumes for all units of measurement, as follows:

1. Average volume per tree for each diameter class of British Columbia and Alaska was multiplied by the ratio of standard height (as recorded in table 27) to actual average stand height.
2. Adjusted volume per tree was then multiplied by normal number of trees per acre as interpolated from table 27 for corresponding average diameter. The product represents volume per acre when average stand height is equal to the standard height of table 27.

Thus for the 12-inch diameter class in Alaska: average diameter of plots was 12.1 inches; average stand height was 89 feet; average volume per tree by the Scribner rule was 128 board feet; and normal number of trees per acre (from table 27) was 364. Adjusted volume was, therefore, $128 \times \frac{102}{89} \times 364 = 53{,}400$ board feet per acre.

Application of this procedure provided volume data for all three regions with a common base. After plotting adjusted volume over average diameter for each region, several differences were disclosed: The Alaska curves were consistently higher than the Oregon-Washington curves. Differences in board feet varied from about 50 percent at 7 inches of diameter to only 1 percent at 18 inches of diameter. In cubic feet the differences were more constant over the diameter classes and averaged about 7 percent. British Columbia curves were also higher than the Oregon-Washington curves, but differences were somewhat smaller. These comparisons led to the conclusion that average volume per tree and average volume per acre vary among regions even when average diameter, average height, and number of trees per acre remain constant.

Although adjusted volumes for British Columbia were in general slightly lower than those for Alaska, the average difference was less than 3 percent in board feet (Scribner rule) and less than 2 percent in cubic feet. Since these differences are small, and probably not statistically significant, only two sets of volumes are presented in table 27, one for Oregon-Washington and the other for Alaska and British Columbia. Attention is again directed to the fact that volumes shown for British Columbia and Alaska are adjusted volumes for stands having standard average heights as tabulated. Average height in British Columbia and Alaska will be less than standard. Routine application of the tables will automatically adjust for height differences.

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