GROWTH and YIELD RECORDS from well-stocked stands of DOUGLAS-FIR

A summary of data and analyses resulting from the oldest permanent growth plots in the Pacific Northwest

by R. L. WILLIAMSON

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INTRODUCTION

In the early 1900's, when American forestry was in its infancy, foresters sensed the tremendous growth potential of Douglas-fir but had only sketchy knowledge of its development in natural, young-growth stands. Industry also quickly recognized the place of Douglas-fir as the Pacific Northwest's most important timber tree—a position it continues to occupy. Since wise management of the species depended upon accurate yield forecasts, the Forest Service began early to study Douglas-fir on a systematic, regionwide basis. A primary Forest Service objective was to obtain a solid foundation for growth and yield estimates through periodic sampling of nearly pure, well-stocked stands.

From 1909 to 1939, numerous permanent sample plots were established under the direction of E. J. Hanzlik, J. V. Hofmann, R. E. McArdle, W. H. Meyer, T. T. Munger, and W. Peterson of the Pacific Northwest Forest and Range Experiment Station. Though some plots have been abandoned for various reasons, the 31 remaining have been remeasured at approximate 5-year intervals since time of establishment. In 1962, the sampled stands ranged in age from 77 to 121 years. This summary of plot records spans periods of 22 to 47 years.

Foresters with experience in sample plot establishment will appreciate the difficulties faced by earlier workers in finding stands that were "just right." The objective was 1-acre plots, but in some cases lack of stand uniformity necessitated smaller plots. Access posed problems of a magnitude seldom encountered today. In 1910, for example, a full day by stage, rowboat, and foot travel was required to cover the 30 miles separating three plots on the Willamette drainage from Eugene, Oreg.--an hour's drive by car today (Munger, 1946b).

These 31 plots--the oldest in the Douglas-fir region--have witnessed many of the growing pains associated with development of plot establishment and tree measurement techniques over the past 50 years. Some of the earliest plots were established on a surface instead of a horizontal area basis. Calipers, used in the earlier measurements, gave way to the more accurate and convenient diameter tape about 1920. Similarly, introduction of the Abney level about 1925 considerably improved height determinations formerly made by the Forest Service hypsometer. Some of the first tree tagging failed to follow a systematic pattern. This oversight elicited a number of caustic notes which were entered in the office reports by later observers.

This paper is intended to (1) acquaint the reader with the 31 surviving plots, (2) make available the wealth of statistical data derived from these plots, and (3) describe briefly some of the knowledge yielded by analysis of the plot data.

PLOT DESCRIPTIONS

One of the most striking features of these plots is their consistent substantiation of normal growth and yield predictions for natural stands of Douglas-fir. The few exceptions have been due to persistent and heavy bark beetle and root rot attack. When these attacks ceased, trends toward normality resumed.

Each plot was chosen initially for its good stocking. Underbrush, usually lacking during early measurements, has gradually increased on most plots. The implications of this trend in regard to reproduction of managed stands warrant further study.

General descriptive data of all 31 plots are outlined in table 1. Tables 2 to 8 present the cumulative statistics of the live stand through the latest field examination. Supplementary notes on plot location and history appear on the page facing each table.

Table 1.--Description of permanent sample plots

National Forest and plot numbers	Established		Legal description			Topographic features			Annual precipitation
	Year	By	Section	Township	Range[1/]	Elevation	Slope	Aspect	
						Feet	Percent		Inches
Willamette:									
1, 2, 3	1910	Munger	19	20 S.	2 E.	700	0-30	N.	48
Siuslaw:									
4, 5	1911	Hanzlik	6	16 S.	8 W.	800	15-25	S.; SW.	--
6, 7, 8	1911	Hanzlik, Meyer	--	--	--	[2/] 1,300	([2/] [3/])	W.[2/]	--
9, 10	1926	Meyer	21, 22	15 S.	9 W.	--	20-40	NE.	--
Wind River:[4/]									
4, 90	1914, 1939	Hofmann, Peterson	13	4 N.	7½ E.	1,300	5-50	W.; E.	100
5	1914	Hofmann	13	4 N.	7½ E.	1,400	65-100	E.	--
2, 9	1914, 1924	Hofmann, McArdle	34	5 N.	7 E.	2,600	2-15	E. to NE.; N. to NW.	--
Olympic:									
1, 2	1926	Meyer	34	27 N.	2 W.	100	0-60	W. to NW.	50
3, 4	1926	Meyer	24	29 N.	3 W.	200	30-60	W. to SW.	35
Gifford Pinchot:									
1 to 5	1927	Meyer	7, 8	11 N.	8 E.	1,800	0-10	S.	61
7, 9	1927	Meyer	6	12 N.	7 E.	--	0-50	S. to SE.	--
Snoqualmie:									
1, 2	1928	Meyer	16	14 N.	8 E.	2,500	15-20	SW.	81
Mt. Hood:									
1, 2, 3	1930	Meyer	14	3 S	7 E.	1,900	60	NE. to SE.	100

[1/] East or west of the Willamette meridian.

[2/] Data for plot 8, but representative of the other two.

[3/] Ridgetop.

[4/] Wind River District, Gifford Pinchot National Forest.

WILLAMETTE PLOTS 1, 2, and 3

The 53-year history of these plots covers a longer span of years than that of any other group of permanent sample plots in the Douglas-fir region. Located about 30 miles southeast of Eugene, Oreg., these plots are on a level bench above Lookout Point Reservoir on the Middle Fork of the Willamette River.

At plot establishment, Munger noted that many trees bore basal fire scars or had forked or bayonet tops from wind and ice storms. These injuries had no apparent effect on subsequent gross volume growth, however. In addition, the stands have continued normal development after a severe wind and snow storm in the 1915-20 period plus a bark beetle attack from 1935-45.

Plot 1 – 10,316 cubic feet at age 69 (1925).

Plot 3 – 11,864 cubic feet at age 69 (1925).

Table 2.--Willamette permanent sample plots 1, 2, and 3; statistics of the live stand (values on horizontal acre basis)

Plot No.	Month and year measured	Age, years	Growth period, years	Horizontal area, acres	Site index, feet	Site quality	Stand 2.6 inches and more in d.b.h.: Number of trees		Basal area, square feet		Average d.b.h., inches		Average height of conifers, feet	Volume of conifers, cubic feet	Conifer stand: 6.6+ inches d.b.h.		11.6+ inches d.b.h.		Dominants and codominants	
							Conifers	Hardwoods	Conifers	Hardwoods	Conifers	Hardwoods			Number of trees	Volume, board feet (International ¼-inch rule)	Number of trees	Volume, board feet (Scribner rule)	Average d.b.h., inches	Average height, feet
1	4/10	54	--	1.00	157	II-	188	28	181.2	8.7	13.3	7.6	103	7,354	165	48,420	100	29,010	18.3	119
	5/15	59.5	5.5		153	II+	175	13	197.2	4.0	14.3	7.5	116	8,709	159	60,270	106	37,440	19.9	131
	6/20	64.5	5		157	II-	149	9	207.0	3.5	16.0	8.4	126	9,528	143	68,590	110	44,070	21.6	137
	3/25	69	4.5		160	II-	141	7	218.2	2.8	16.9	8.6	132	10,316	138	74,260	111	49,280	20.5	139
	4/30	74	5		161	II-	137	7	225.0	3.1	17.4	9.0	136	11,162	133	82,564	112	54,128	20.7	143
	10/34	79	5		166	II	127	7	239.1	3.0	18.6	8.9	145	12,483	126	92,652	111	63,754	21.2	151
	10/39	84	5		168	II	121	8	249.0	3.2	19.4	8.6	149	13,301	120	100,011	109	70,145	22.3	156
	10/45	90	5		170	II	112	7	257.1	3.4	20.4	9.4	157	14,165	111	108,194	106	77,713	23.7	163
	12/50	95	6		170	II	110	7	270.5	3.4	21.2	9.4	158	15,225	110	116,899	105	84,666	24.2	166
	10/55	100	5		170	II	103	7	271.4	3.4	22.1	9.4	162	15,510	102	119,686	101	87,686	24.3	--
2	4/10	54	--	1.00	162	II-	214	8	215.3	1.6	13.6	6.1	105	8,796	201	59,235	124	34,710	18.4	119
	5/15	59.5	5.5		173	II	198	5	231.7	.8	14.6	5.4	117	10,274	189	71,460	127	44,040	21.1	133
	6/20	64.5	5		171	II	160	4	226.9	.6	16.1	5.2	126	10,536	160	74,920	122	47,860	21.9	138
	3/25	69	4.5		162	II-	151	3	238.7	.6	17.2	6.1	132	11,324	151	80,370	125	53,860	19.9	138
	4/30	74	5		168	II	149	3	255.1	.1	17.6	2.5	136	12,485	149	91,411	125	60,620	21.1	144
	10/34	79	5		177	II+	136	3	255.5	.6	18.6	6.1	145	13,274	136	98,579	120	67,242	21.2	151
	10/39	84	5		168	II	114	6	239.1	.9	19.6	5.3	150	12,788	114	96,211	107	67,716	22.3	156
	10/45	90	5		170	II	116	3	254.6	.8	20.0	6.8	154	13,917	108	106,811	103	77,153	23.4	163
	12/50	95	6		170	II	109	3	259.7	.8	20.9	6.8	158	14,654	101	112,404	100	81,917	24.0	166
	10/55	100	5		170	II	106	3	261.8	.8	21.3	7.1	160	14,954	97	115,300	95	84,641	24.4	--
3	4/10	54	--		151	III+	190	18	214.7	5.3	14.4	7.3	108	8,833	171	59,280	118	36,380	19.4	121
	5/15	59.5	5.5	.98	158	II-	175	8	233.2	2.2	15.6	7.1	121	10,406	168	72,820	124	46,410	21.3	133
	6/20	64.5	5	.98	--	--	157	7	237.2	2.0	16.7	7.2	128	10,934	154	78,090	120	50,940	22.1	138
	3/25	69	4.5	.98	171	II	147	6	251.3	1.7	17.7	7.2	134	11,864	147	86,070	120	57,290	21.4	140
	4/30	74	5	1.00	159	II-	145	3	263.2	.8	18.2	7.0	137	12,741	145	94,155	120	63,312	21.8	144
	10/34	79	5	1.00	165	II-	131	4	260.7	.9	19.1	6.4	146	13,628	131	101,314	115	69,694	21.7	152
	10/39	84	5	1.00	168	II	127	7	271.6	1.2	19.8	5.6	150	14,536	127	109,504	112	76,893	22.4	156
	10/45	90	5	1.00	170	II	118	2	273.1	.2	21.0	4.7	155	15,052	112	115,212	105	83,022	23.6	162
	12/50	95	6	1.00	170	II	110	2	274.7	.2	21.4	4.5	159	15,508	103	119,320	98	87,000	24.4	167
	10/55	100	5	1.00	170	II	114	2	283.7	.3	21.3	5.0	159	16,216	100	125,272	97	92,263	24.9	--

SIUSLAW PLOTS 4 to 10

Plots 4 and 5, in the Deadwood Creek drainage near Alpha, Oreg., lie on a spur ridge with parts of the plots extending off the ridgetop onto steep ground. The same is true of plots 6 and 7, which lie on the ridge between Saddle Mountain and Three Buttes, about 900 feet south of the road from Pawn. Plot 8, near plots 6 and 7, and plots 9 and 10, on a bench next to Five Rivers near Paris, are all on gentle, uniform ground.

Unfortunately, the trees on plots 6 and 7 were not tagged in 1911 when the plots were established. At age 38, these were the youngest stands in the growth and yield plots, and 15 years passed before the trees were tagged in 1926. Plots 6 and 7 were very dense and suffered severe losses from windthrow and snowbreak.

In the same period, plots 9 and 10 suffered even heavier mortality from a variety of causes, losing about 30 percent of their cubic volume. The recovery of these stands at ages of around 90 years is of particular silvicultural interest. A stand map was prepared for plot 9 in 1926.

Plot 5 – Showing stand density at age 65 (1926).

Plot 10 – Average diameter 23.1 inches at age 67 (1926

Table 3.--Siuslaw permanent sample plots 4, 5, 6, 7, 8, 9, and 10; statistics of the live stand (values on horizontal acre basis)

Plot No.	Month and year measured	Age, years	Growth period, years	Horizontal area, acres	Site index, feet	Site quality	Stand 2.6 inches and more in d.b.h.								Stand 6.6+ inches d.b.h.			Stand 11.6+ inches d.b.h.		
							Number of trees		Basal area, square feet		Average d.b.h., inches		Average height of conifers, feet	Volume of conifers, cubic feet	Number of trees		Volume of conifers, board feet (International ¼-inch rule)	Number of trees		Volume of conifers, board feet (Scribner rule)
							Conifers	Hardwoods	Conifers	Hardwoods	Conifers	Hardwoods			Conifers	Hardwoods		Conifers	Hardwoods	
4	8/11	50		0.399	170	II	298	60	292.8	11.9	13.4	6.0	102	11,980	273	18	79,290	185	0	48,350
	9/16	55	5		172	II	273	38	329.4	9.1	14.9	6.6	112	14,150	263	18	96,870	192	0	61,620
	10/21	60	5		167	II	238	25	346.6	6.7	16.4	7.0	120	15,520	233	12	109,000	190	0	71,870
	9/26	65	5		167	II	228	23	364.1	6.5	17.1	7.2	125	16,890	223	12	120,450	192	0	81,510
	9/31	70	5		176	II+	218	23	392.1	6.9	18.2	7.4	138	19,435	213	15	142,770	190	2	100,840
	9/36	75	5		175	II	198	10	408.4	4.5	19.2	9.0	145	21,120	198	10	157,390	185	0	111,110
	9/41	80	5		174	II	180	10	420.5	4.5	20.8	9.0	151	22,125	180	10	167,159	175	0	119,726
	10/46	85	5		174	II	180	10	446.4	4.5	21.3	9.0	155	24,253	180	10	184,868	175	0	134,028
	9/51	90	5		--	--	173	10	463.2	5.3	22.2	9.8	159	25,716	173	10	196,086	168	0	143,848
5	8/11	50		.455	175	II	382	0	236.3	--	10.6	--	102	9,895	336	0	63,390	110	0	26,370
	9/16	55	5		177	II+	347	0	255.1	--	11.6	--	109	11,180	331	0	74,450	134	0	35,500
	10/21	60	5		162	II-	297	0	256.3	--	12.6	--	116	11,625	290	0	79,590	145	0	42,290
	9/26	65	5		160	II-	286	0	267.0	--	13.1	--	119	12,395	279	0	86,210	152	0	47,890
	9/31	70	5		160	II-	268	0	280.0	--	13.8	--	124	13,415	266	0	95,850	154	0	54,940
	9/36	75	5		160	II-	230	0	281.8	--	15.0	--	131	14,110	228	0	101,810	151	0	62,280
	9/41	80	5		159	II-	202	0	285.6	--	16.1	--	135	14,328	200	0	104,938	149	0	67,283
	10/46	85	5		164	II-	189	0	288.3	--	16.7	--	144	15,474	189	0	114,835	147	0	75,298
	9/51	90	5		--	--	185	0	298.1	--	17.2	--	147	16,218	185	0	120,224	147	0	81,013
6	8/11	38		.932	188	I-	199	9	187.2	3.8	13.1	9.0	95	7,060	181	4	44,920	101	2	25,280
	9/16	45	5		--	--	183	5	208.2	3.6	14.4	11.1	105	8,415	177	5	56,130	115	3	33,760
	10/21	48	5		--	--	156	0	(1/)	(1/)	(1/)	(1/)	(1/)	(1/)	153	0	(1/)	131	0	(1/)
	9/26	53	5		187	I-	150	1	241.9	.6	17.2	10.0	127	11,225	149	1	80,110	131	0	53,880
	9/31	58	5		190	I-	142	0	259.4	--	18.8	--	137	12,655	142	0	92,950	130	0	63,240
	9/36	63	5		192	I-	128	0	265.6	--	19.5	--	148	13,910	128	0	103,820	126	0	73,710
	9/41	68	5		190	I-	109	0	256.4	--	20.7	--	152	13,550	109	0	101,819	108	0	73,024
	10/46	73	5		194	I-	104	0	270.3	--	21.8	--	162	15,278	104	0	117,360	103	0	86,007
	9/51	78	5		--	--	98	0	274.8	--	22.7	--	166	15,762	98	0	121,548	98	0	90,310
7	8/11	38		.441	188	I-	236	11	151.0	5.7	10.8	9.6	87	5,445	202	11	32,520	82	7	14,440
	9/16	43	5		--	--	161	14	156.2	9.2	13.3	11.1	102	6,270	161	14	40,920	93	7	22,120
	10/21	48	5		--	--	138	0	(1/)	(1/)	(1/)	(1/)	(1/)	(1/)	138	0	(1/)	120	0	(1/)
	9/26	53	5		185	I-	132	5	190.4	4.5	16.3	13.5	124	8,805	132	5	62,320	107	5	39,880
	9/31	58	5		187	I-	120	5	205.4	4.5	17.7	13.5	134	9,960	120	5	72,480	109	5	49,070
	9/36	63	5		194	I-	111	2	219.2	2.0	19.0	13.8	147	11,455	111	2	85,380	104	2	59,690
	9/41	68	5		190	I-	79	2	199.4	1.9	21.5	13.8	154	10,587	79	2	79,684	79	2	57,793
	10/46	73	5		196	I-	77	2	217.1	1.8	22.7	13.8	165	12,367	77	2	95,217	77	2	67,925
	9/51	78	5		--	--	75	0	227.6	--	23.6	--	168	13,163	75	0	101,677	75	0	76,303
8	9/26	53		1.000	178	II+	234	0	244.8	--	13.8	--	114	10,985	232	0	75,880	147	0	44,400
	9/31	58	5		178	II+	228	0	266.4	--	14.6	--	122	12,480	227	0	88,550	151	0	53,320
	9/36	63	5		172	II	191	0	265.6	--	16.0	--	127	12,760	191	0	91,430	150	0	58,810
	9/41	68	5		173	II	168	0	273.3	--	17.3	--	134	13,493	168	0	98,546	148	0	66,047
	11/46	73	5		169	II	153	0	281.8	--	18.4	--	137	14,030	153	0	103,532	142	0	70,970
	9/51	78	5		--	--	147	0	293.5	--	19.1	--	140	14,882	147	0	110,396	138	0	76,875
9	9/26	74		1.000	193	I-	117	0	286.4	--	21.2	--	163	16,340	117	0	125,790	115	0	91,620
	9/31	79	5		193	I-	102	0	273.5	--	22.2	--	168	16,025	102	0	124,290	102	0	92,100
	9/36	84	5		198	I	86	0	266.0	--	23.8	--	178	16,370	86	0	128,780	86	0	98,090
	9/41	89	5		195	I-	53	0	185.0	--	25.3	--	183	11,452	53	0	90,850	53	0	69,346
	10/46	94	5		195	I-	50	0	191.8	--	26.5	--	187	12,075	50	0	96,030	50	0	74,514
	9/51	99	5		--	--	48	0	197.4	--	27.5	--	190	12,620	48	0	100,568	48	0	78,679
10	9/26	67		1.000	201	I	126	0	270.0	--	19.8	--	161	15,305	126	0	117,320	122	0	84,740
	9/31	72	5		210	I+	106	0	258.0	--	21.2	--	173	15,580	106	0	121,330	105	0	90,040
	9/36	77	5		203	I	87	0	245.1	--	22.8	--	176	14,860	87	0	116,460	87	0	87,610
	9/41	82	5		205	I	52	0	177.2	--	25.0	--	185	11,130	52	0	87,936	52	0	67,448
	10/46	87	5		203	I	52	0	189.9	--	25.9	--	189	12,099	52	0	96,374	52	0	74,991
	9/51	92	5		--	--	51	0	199.0	--	26.7	--	192	12,831	51	0	102,444	51	0	80,072

1/ Measurements erratic.

WIND RIVER PLOTS 2, 4, 5, 9, and 90

Plots 2 and 9 are adjacent to the Carson-Guler road, about 11 miles from Hemlock Ranger Station near Carson, Wash. Plots 4, 5, and 90 are along Panther Creek near the Warren Gap road, about 7 miles from the Ranger Station.

These stands have suffered recurrently from wind and ice storms and from bark beetle attacks. Heavy mortality has occurred consistently since 1924, and stand deterioration has been evident since 1935–stand age 94 years. Bark beetle attacks have been the chief obstacle to recovery, conditions being so severe that part of plot 5 was clear cut when an adjacent patch of killed and infested timber was harvested. These plots have obviously suffered somewhat more than "normal" mortality.

The 47-year data record for plots 2, 4, and 5 provided an opportunity to smooth out the curve of the erratic losses due to mortality and derive some consistent expressions of mean and periodic annual increment. Adjusted gross volumes were obtained through regression analysis of volume-basal area ratios with respect to age. Regression analysis also revealed that mortality increased with stand age, though age accounted for only 10 percent of the total variation. Gross growth for the 47-year period agreed closely with gross yield tables (Staebler, 1955b), but the periodic annual increment curve was skewed negatively relative to the gross yield table curve. This skewness reflected the heavy mortality, below stand age 100, noted previously. This mortality also reduced net growth rates to about 70 percent of normal.

Plot 4 – 12,140 cubic feet at age 88 (1929).

Plot 9 – After heavy mortality in 1919-29 period (1929).

Table 4.--Wind River permanent sample plots 2, 4, 5, 9, and 90; statistics of the live stand[1/] (values on horizontal acre basis)

Plot No.	Month and year measured	Age, years	Growth period, years	Horizontal area, acres	Site index, feet	Site quality	Stand 2.6 inches and more in d.b.h.: Number of trees, Conifers	Number of trees, Other than Douglas-fir	Basal area, square feet, Conifers	Basal area, square feet, Other than Douglas-fir	Average d.b.h., inches, Conifers	Average d.b.h., inches, Other than Douglas-fir	Average height, feet	Volume, cubic feet	6.6+ inches d.b.h.: Number of trees	6.6+ inches d.b.h.: Volume, board feet (International ¼-inch rule)	11.6+ inches d.b.h.: Number of trees	11.6+ inches d.b.h.: Volume, board feet (Scribner rule)	Dominants and codominants: Average d.b.h., inches	Dominants and codominants: Average height, feet
2	1914	72		0.995	150	III+	160	8	219.8	2.2	15.4	7.1	112	9,247	146	63,390	116	42,270	19.6	124
	1919	77	5		147	III+	149	7	236.3	2.1	16.8	7.4	123	10,625	141	75,310	117	50,400	19.7	132
	9/24	83	6		144	III	145	7	256.1	2.1	17.7	7.4	130	11,953	139	86,090	121	58,850	21.1	138
	9/29	88	5		142	III	131	5	254.0	.8	18.8	5.5	130	11,524	126	83,468	112	57,320	21.5	136
	9/34	93	5		140	III	110	5	228.5	1.0	19.5	6.0	133	10,681	104	77,799	97	54,357	21.9	139
	9/39	98	5		145	III	108	4	238.6	.9	20.1	6.4	139	11,427	103	84,406	97	59,175	22.4	144
	5/45	103	5		146	III+	110	8	251.9	.8	20.5	4.2	141	12,293	100	91,106	96	64,514	23.8	148
	8/50	109	6		--	--	108	13	255.5	.9	20.9	4.1	140	12,582	95	92,878	94	66,557	24.2	149
	8/55	114	5		147	III+	93	7	234.6	.9	21.5	4.9	142	11,441	86	85,029	84	60,726	24.3	150
	9/60	119	5		144	III	92	7	243.7	1.2	22.1	5.7	145	11,982	86	89,579	83	64,265	25.0	153
4	1914	72		.975	144	III	185	10	215.0	4.0	14.5	8.1	--	8,952	177	59,910	127	37,400	18.5	121
	1919	77	5		--	--	176	8	231.0	2.6	15.4	7.3	--	10,047	170	69,670	132	44,660	17.4	124
	9/24	83	6		--	--	171	7	249.1	2.5	16.2	8.1	--	11,344	166	80,510	132	52,640	20.8	135
	9/29	88	5		--	--	158	7	254.1	2.5	17.2	8.1	--	12,140	154	87,000	128	59,440	21.0	140
	9/34	93	5		--	--	151	8	257.5	3.0	17.7	8.3	--	12,265	148	88,645	123	59,630	21.7	141
	9/39	98	5		148	III+	143	11	264.8	4.5	18.4	8.7	138	12,924	137	95,295	120	65,807	22.3	147
	5/45	103	5		152	III+	129	11	258.1	4.9	19.7	--	146	13,191	124	98,337	112	68,268	23.4	154
	8/50	109	6		155	III+	122	16	253.6	4.5	20.0	--	147	12,588	111	94,287	98	65,872	24.8	156
	5/56	114	5		151	III+	113	17	249.3	5.1	20.1	7.4	150	12,727	96	95,842	91	67,845	24.7	159
	9/60	119	5		153	III+	112	21	253.0	6.8	22.6	7.8	159	13,049	101	97,856	88	70,304	24.8	163
5	1914	72		.938	144	III	157	6	232.4	.8	16.5	4.9	--	10,292	150	72,330	127	48,130	20.3	133
	1919	77	5		--	--	154	6	253.7	1.2	17.4	6.0	--	11,490	148	81,880	131	55,630	19.3	132
	9/24	83	6		--	--	151	6	275.7	1.5	18.3	6.4	--	12,651	148	91,710	132	63,200	21.8	138
	9/29	88	5		--	--	145	6	289.9	1.5	19.1	6.4	--	13,712	143	99,930	132	68,810	22.4	143
	9/34	93	5		--	--	127	10	266.6	2.2	19.6	6.4	--	12,820	123	94,180	115	66,310	22.8	144
	9/39	98	5		150	III+	114	9	254.0	1.0	20.2	7.7	143	12,323	109	91,578	102	64,433	23.6	149
	5/45	103	5		152	III+	107	12	248.7	3.8	22.1	--	154	12,265	102	91,249	95	64,715	26.0	162
	8/50	109	6		153	III+	112	20	268.4	3.7	22.3	--	155	12,765	101	95,290	93	67,984	27.2	163
	5/56	114	5	[2/] .885	152	III+	115	29	258.5	8.4	20.2	7.3	145	12,995	98	97,757	88	70,404	25.3	158
	9/60	119	5		150	III+	120	33	271.0	10.6	20.4	7.7	143	13,577	99	101,553	89	73,067	25.9	159
9	9/24	83		1.000	128	III-	210	18	227.6	6.6	14.0	8.2	--	9,190	187	60,700	137	37,830	19.9	118
	9/29	88	5		121	IV+	197	18	232.9	7.9	14.7	9.0	103	9,139	179	60,619	137	38,378	19.1	114
	9/34	93	5		119	IV+	182	19	227.1	8.6	15.1	9.1	107	9,172	168	61,518	131	39,414	19.1	117
	9/39	98	5		122	IV+	165	17	220.7	8.2	15.6	9.4	112	9,210	156	63,020	124	40,858	19.4	121
	5/45	103	5		122	IV+	164	20	229.7	9.0	16.0	8.9	113	9,711	156	66,759	124	43,473	19.2	123
	8/50	109	6		--	--	170	26	221.6	12.4	15.5	9.3	112	10,292	157	71,569	127	46,625	19.8	125
	8/55	114	5		122	IV+	164	25	247.1	13.1	16.6	9.8	116	10,765	154	74,975	126	49,445	20.2	127
	9/60	119	5		120	IV+	152	22	240.3	11.8	17.0	9.9	118	10,476	145	73,506	120	48,824	20.3	128
90	9/39	98		1.000	154	III+	138	33	285.0	43.9	19.5	15.6	146	14,756	131	110,751	123	77,908	22.0	152
	5/45	103	5		156	II-	132	30	295.0	43.9	20.3	--	149	15,463	125	116,951	119	83,577	22.4	155
	8/50	109	6		157	II-	133	30	309.5	44.1	20.7	--	150	16,518	125	123,668	118	88,811	24.1	159
	5/56	114	5		159	II-	122	32	304.9	49.9	21.1	16.9	155	16,470	115	128,082	110	93,475	25.9	167
	9/60	119	5		156	II-	118	31	306.7	46.8	21.8	16.6	158	16,869	108	129,648	105	95,653	25.4	166

[1/] 1956 values for plots 4, 5, and 90 were revised in 1960. All other values for 1956 and prior are taken from the 1956 office report.

[2/] Area reduced for portion of plot included in adjacent area clear cut about 1953.

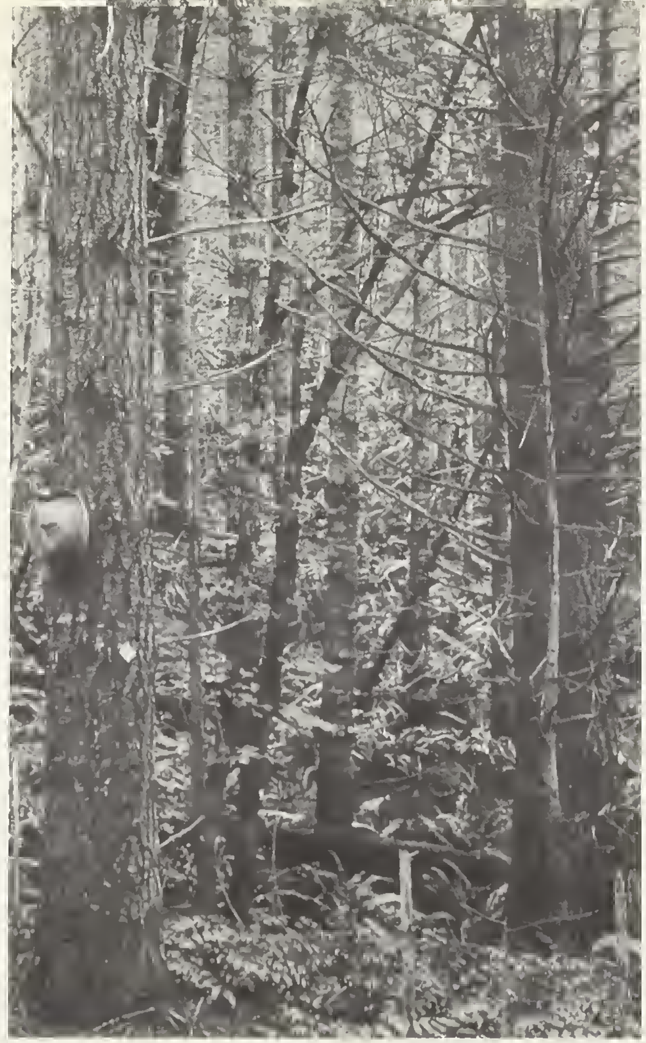
OLYMPIC PLOTS 1 to 4

Plots 1 and 2 are adjacent to U.S. Highway 101, about 3 miles south of Quilcene, Wash. Plots 3 and 4 are about 5 miles south of Blyn, on the Jimmiecomelately Creek road.

Back in the Prohibition Era while plot 4 was being established by Walter Meyer and his helpers, a local bootlegger, who had two 50-gallon stills within 100 feet, was on tenterhooks, not knowing whether to hover around or to get clear out of the country.

Poria weirii root rot has killed many trees on all of the plots since 1941 and on plot 3 is responsible, together with considerable wind and ice storm damage, for steadily decreasing plot values relative to normal values.

Stem maps are available for Olympic plots 1 and 2.



Plot 1 – At age 51; showing largest tree on plot (1926).

Plot 3 – At age 42; nearly normal stocking is evident (1926).

Table 5.--Olympic permanent sample plots 1, 2, 3, and 4; statistics of the live stand (values on horizontal acre basis)

Plot No.	Month and year measured	Age, years	Growth period, years	Horizontal area, acres	Site index, feet	Site quality	Stand 2.6 inches and more in d.b.h.: Number of trees		Basal area, square feet		Average d.b.h., inches		Average height of conifers, feet	Volume of conifers, cubic feet	Conifer stand: 6.6+ inches d.b.h.		11.6+ inches d.b.h.		Dominants and codominants	
							Coni-fers	Hard-woods	Coni-fers	Hard-woods	Coni-fers	Hard-woods			Number of trees	Volume, board feet (International ¼-inch rule)	Number of trees	Volume, board feet (Scribner rule)	Average d.b.h., inches	Average height, feet
1	9/26	51		1.00	130	III-	411	33	185.7	5.32	9.1	5.4	76	6,265	252	34,100	88	14,460	13.2	92
	9/31	56	5		132	III-	377	23	198.2	4.99	9.8	6.3	80	6,945	256	39,990	98	18,640	13.6	99
	9/36	61	5		130	III-	347	18	210.2	4.48	10.6	6.8	85	7,725	254	47,300	104	23,260	14.4	102
	9/41	66	5		126	III-	307	11	221.4	3.42	11.3	7.6	89	8,194	250	50,161	112	25,976	15.3	103
	12/46	71	5		125	III-	282	9	228.1	2.30	12.2	6.8	94	8,726	239	55,457	117	30,382	15.8	106
	4/57	81	10		130	III-	273	5	257.4	1.64	13.1	7.8	103	10,544	227	70,141	129	42,049	17.1	118
2	9/26	51		1.00	130	III-	389	14	176.3	1.71	9.1	4.7	74	5,925	271	32,190	57	10,590	12.9	92
	9/31	56	5		133	III-	349	8	181.1	1.17	9.8	5.2	84	6,585	271	39,480	72	14,370	12.9	100
	9/36	61	5		136	III	334	7	193.3	1.00	10.3	5.1	91	7,325	266	44,970	89	19,180	13.7	107
	9/41	66	5		134	III-	295	4	198.3	.43	11.1	4.4	95	7,710	253	48,574	102	22,601	14.4	110
	12/46	71	5		130	III-	274	5	205.8	.81	11.7	5.5	99	8,142	248	52,725	109	26,521	14.6	111
	4/57	81	10		128	III-	249	3	220.8	.62	12.8	6.1	104	9,292	222	62,023	120	36,289	15.7	116
3	10/26	42		.75	127	III-	611	103	148.7	13.54	6.7	4.9	67	4,440	244	17,880	19	1,970	9.6	79
	9/31	47	5		125	III-	563	92	155.6	15.96	7.1	5.6	73	5,125	265	23,140	33	4,000	9.9	84
	9/36	52	5		120	IV+	508	49	169.0	8.60	7.8	5.7	75	5,475	275	26,920	47	6,980	10.7	86
	9/41	57	5		122	IV+	457	41	176.8	8.35	8.4	6.1	79	6,320	284	33,132	64	9,913	11.3	92
	12/46	62	5		119	IV+	385	27	171.8	8.10	9.0	7.5	84	6,242	263	35,032	68	11,689	11.8	94
	4/57	72	10		118	IV+	324	20	182.5	8.82	10.2	9.0	92	7,070	252	42,501	87	17,351	13.2	101
4	10/26	42		.75	126	III-	929	15	191.6	2.69	6.1	5.7	68	5,920	289	19,650	8	980	9.0	78
	9/31	47	5		125	III-	732	16	192.4	2.99	6.9	5.9	74	6,370	331	25,780	19	2,340	9.4	84
	9/36	52	5		123	IV+	633	12	199.9	2.63	7.6	6.3	77	6,803	346	32,719	37	5,443	10.2	88
	9/41	57	5		122	IV+	547	12	206.0	2.39	8.3	6.0	83	7,466	341	38,613	64	9,905	10.8	92
	12/46	62	5		119	IV+	464	12	207.0	2.52	9.0	6.2	87	7,683	337	42,977	79	13,105	11.5	94
	4/57	72	10		116	IV+	397	4	227.0	1.68	10.3	8.8	92	8,780	324	50,475	99	20,245	12.5	99

GIFFORD PINCHOT PLOTS

1 to 5, 7, and 9

These plots lie in two groups: plots 1 to 5 in the Cispus River drainage, 10-1/2 miles southeast of Randle, Wash., and plots 7 and 9 on the Kiona Peak trail about 3 miles northwest of Randle.

The Cispus River group provides a striking, and aesthetically pleasing, example of the maximum yields attainable in natural stands. At the last measurement (average age 83 years, and site index 177), they averaged 90,211 board feet, Scribner rule, per acre.

All of these plots were stem-mapped at establishment.

Plot 3 – At age 50 (1927).

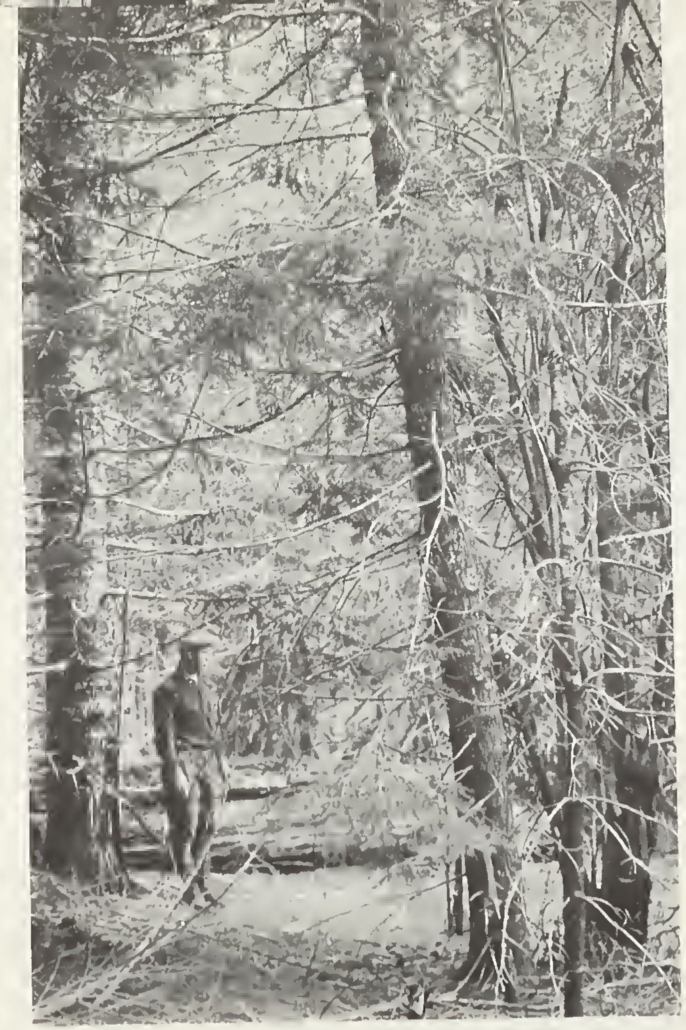
Plot 7 – A magnificent stand underway at age 50 (1927).

Table 6.--Gifford Pinchot permanent sample plots 1-5 (Camp Creek), 7 and 9 (Kiona Peak); statistics of the live stand (values on horizontal acre basis)

Plot No.	Month and year measured	Age, years	Growth period, years	Horizontal area, acres	Site index, feet	Site quality	Stand 2.6 inches and more in d.b.h.: Number of trees		Basal area, square feet		Average d.b.h., inches		Average height of conifers, feet	Volume of conifers, cubic feet	Conifer stand: 6.6+ inches d.b.h.		11.6+ inches d.b.h.		Dominants and codominants	
							Conifers	Hardwoods	Conifers	Hardwoods	Conifers	Hardwoods			Number of trees	Volume, board feet (International ¼-inch rule)	Number of trees	Volume, board feet (Scribner rule)	Average d.b.h., inches	Average height, feet
Camp Creek																				
1	4/27	50		1.00	179	II+	227	0	255.8	--	14.4	--	117	10,800	224	74,330	156	44,650	17.5	125
	5/32	55	5		176	II+	205	0	271.3	--	15.6	--	124	12,490	204	88,140	154	56,270	18.2	130
	4/37	60	5		179	II+	180	0	286.1	--	17.1	--	133	13,900	180	101,700	158	67,900	19.2	139
	5/43	66	6		172	II	164	0	297.5	--	18.2	--	143	15,375	164	113,770	152	77,830	20.8	148
	11/52	76	10		177	II+	150	0	322.4	--	19.9	--	159	19,405	150	140,841	146	100,742	21.8	163
	9/57	81	5		181	II+	140	0	326.0	--	20.7	--	160	18,629	140	143,074	137	103,412	22.9	166
2	4/27	50		1.00	156	II-	295	0	223.7	--	11.8	--	95	8,520	263	55,200	120	27,900	16.1	109
	5/32	55	5		160	II-	282	0	246.4	--	12.7	--	106	10,080	258	66,920	130	37,350	17.0	118
	4/37	60	5		158	II-	236	0	258.3	--	14.2	--	114	10,920	228	73,750	138	44,430	18.2	122
	6/43	66	6		166	II	192	0	266.7	--	16.0	--	136	12,605	192	90,491	141	57,831	19.3	138
	11/52	76	10		166	II	172	0	290.5	--	17.6	--	143	15,110	172	112,259	138	75,078	20.3	151
	9/57	81	5		175	II	163	0	302.1	--	18.4	--	150	16,325	163	122,554	135	84,344	21.3	159
3	4/27	50		1.00	168	II	256	0	243.7	--	13.2	--	109	10,180	253	68,000	142	36,920	16.6	117
	5/32	55	5		164	II-	250	0	267.9	--	14.0	--	114	11,680	250	79,110	153	45,380	17.4	121
	4/37	60	5		171	II	215	0	279.3	--	15.4	--	124	12,980	215	91,710	153	57,000	18.5	133
	5/43	66	6		167	II	188	0	289.0	--	16.8	--	132	14,039	188	101,654	150	66,034	19.5	139
	11/52	76	10		170	II	152	0	294.0	--	18.8	--	150	16,042	152	121,085	137	83,914	20.7	155
	9/57	81	5		174	II	131	0	281.9	--	19.9	--	154	15,353	131	116,464	124	82,029	22.1	159
4	4/27	56		.75	155	II-	223	20	205.7	2.6	13.0	4.8	106	8,460	187	55,010	112	32,410	18.0	116
	5/32	61	5		158	II-	207	20	222.4	3.0	14.0	5.3	113	9,590	181	65,000	115	39,900	18.6	124
	4/37	66	5		166	II	191	20	242.1	3.7	15.2	5.8	124	11,110	173	79,040	113	50,190	19.8	136
	5/43	72	6		161	II-	158	21	254.9	4.6	17.2	6.3	134	12,288	153	89,284	110	58,791	21.1	143
	11/52	82	10		168	II	139	17	276.1	7.4	19.1	9.1	149	14,792	139	111,690	113	77,868	22.3	160
	9/57	87	5		172	II	140	16	288.0	5.0	19.4	7.6	151	15,414	131	116,845	107	82,350	23.3	162
5	9/27	53		1.00	163	II-	186	27	237.8	7.9	15.2	7.3	110	9,600	180	64,900	131	40,330	18.6	118
	5/32	57	4		164	II-	180	23	248.2	7.4	15.9	7.7	118	10,770	176	75,060	133	47,170	18.8	124
	4/37	62	5		171	II	164	12	263.7	5.1	17.2	8.8	130	12,380	162	88,720	131	58,550	20.0	136
	5/43	68	6		167	II	138	9	275.2	4.7	19.1	9.8	138	13,389	138	98,286	125	67,292	21.9	144
	11/52	78	10		182	II+	121	5	295.7	3.2	21.3	10.8	165	17,042	120	131,249	117	95,608	23.1	169
	9/57	83	5		185	II+	116	4	305.0	2.8	22.0	11.4	166	16,542	115	135,450	114	98,919	24.4	171
Kiona Peak																				
7	9/27	52		1.00	171	II	257	15	212.2	9.1	12.3	10.6	110	9,220	234	62,820	133	33,470	16.5	123
	5/32	56	4		170	II	245	13	230.2	8.5	13.1	11.0	115	10,370	224	71,600	141	40,550	16.8	127
	4/37	61	5		171	II	216	11	238.8	7.3	14.2	11.1	124	11,270	200	80,340	142	48,490	17.9	134
	5/43	67	6		175	II	213	2	260.9	1.4	15.0	11.5	130	13,177	188	95,164	145	60,772	19.4	146
	11/52	77	10		176	II+	192	0	286.9	--	16.6	--	147	15,901	173	119,216	141	80,872	21.1	163
	9/57	82	5		179	II+	178	0	294.4	--	17.4	--	150	15,786	163	123,389	138	85,339	21.6	164
9	9/27	58		1.00	130	III-	413	3	222.2	.3	9.9	4.1	83	7,940	261	46,550	113	22,810	15.1	99
	5/32	62	4		127	III-	376	3	231.8	.3	10.6	4.1	88	8,460	255	51,240	125	27,170	15.4	101
	4/37	67	5		131	III-	320	1	237.7	.2	11.7	6.0	96	9,460	249	60,430	133	33,080	16.2	108
	5/43	73	6		135	III	300	1	256.5	.2	12.5	6.0	102	10,983	245	67,186	140	38,905	17.2	117
	11/52	83	10		130	III-	272	1	280.5	.2	13.7	6.3	110	12,176	234	83,044	151	49,956	17.6	124
	9/57	88	5		137	III	256	1	289.8	.2	14.4	6.3	116	13,001	226	90,270	149	56,129	18.6	130

SNOQUALMIE PLOTS 1 and 2

These plots are on Skate Creek about 4 miles south of Longmire, Wash. Having only about 60 percent of the normal number of trees at establishment, they were chosen to contrast with the denser Gifford Pinchot plots. It is interesting to observe that, on a Scribner volume basis, the Snoqualmie plots were 408 and 291 percent of normal in 1928, and in 1957 they were 127 and 95 percent of normal, respectively.



Plot 1 – In 1928.

The openness of these plots contrasts well with the denser Gifford Pinchot plots.

Plot 2 – In 1928.

Table 7.--Snoqualmie permanent sample plots 1 and 2, Skate Creek; statistics of the live stand (values on horizontal acre basis)

Plot No.	Month and year measured	Age, years	Growth period, years	Horizontal area, acres	Site index, feet	Site quality	Stand 2.6 inches and more in d.b.h.								Conifer stand					
							Number of trees		Basal area, square feet		Average d.b.h., inches		Average height of conifers, feet	Volume of conifers, cubic feet	6.6+ inches d.b.h.		11.6+ inches d.b.h.		Dominants and codominants	
							Coni-fers	Hard-woods	Coni-fers	Hard-woods	Coni-fers	Hard-woods			Number of trees	Volume, board feet (International ¼-inch rule)	Number of trees	Volume, board feet (Scribner rule)	Average d.b.h., inches	Average height, feet
1	5/28	42		0.50	130	III	388	6	182.7	2.2	9.3	8.3	72	5,140	214	27,590	92	13,890	14.2	81
	5/32	46	4		128	III	374	6	205.4	2.2	10.0	8.3	79	6,200	222	34,070	110	18,490	14.5	85
	4/37	51	5		138	III	296	4	218.2	2.0	11.6	9.2	90	7,420	216	44,700	120	26,130	15.6	97
	6/43	57	6.5		145	III	284	2	238.7	1.8	12.4	13.0	99	8,850	208	56,748	130	35,260	17.0	108
	10/52	67	9.5		1/ 143	III	242	2	251.1	1.8	13.8	13.0	106	9,986	190	66,396	130	41,678	17.8	118
	8/57	72	5		141	III	230	2	261.5	1.8	14.4	13.0	2/ 110	10,928	184	75,092	130	48,482	18.8	128
2	5/28	42		.75	137	III	318	0	167.3	--	9.8	--	74	5,010	160	26,950	79	14,560	15.5	85
	5/32	46	4		133	III	313	0	185.6	--	10.4	--	79	5,780	169	32,970	91	18,780	15.9	88
	4/37	51	5		142	III	257	0	198.7	--	11.9	--	91	6,760	161	41,500	102	25,310	16.8	100
	6/43	57	6.5		149	III	239	0	218.0	--	12.9	--	102	8,097	162	52,768	113	33,474	17.9	112
	10/52	67	9.5		1/ 154	III+	216	0	234.3	--	14.1	--	106	9,564	153	65,313	109	42,507	19.1	127
	8/57	72	5		156	II-	208	0	237.2	--	14.5	--	2/ 112	10,166	149	71,571	104	47,913	20.1	136

1/ Determined in 1957 by using average height of the dominants and codominants measured for height. Applied to curves in Bulletin 201.

2/ Smaller sample of trees used for construction of height curve in 1957.

MOUNT HOOD PLOTS 1, 2, and 3

Located on the Devils Peak Way Trail near Rhododendron, Oreg., these plots were established to compare the development of stands of different densities. On the basis of average diameter, plots 1, 2, and 3 were 87, 111, and 101 percent of normal, respectively. This comparison has been thwarted by severe wind damage to plot 1, which lies on an exposed slope. On the basis of age and site index, all plots were considerably understocked, in number of trees, in 1930. It was thought to be extraordinary, then, that they should have Scribner volumes so much in excess of normal (221, 217, and 174 percent). We know now, of course, that below-normal stocking in number of trees is often associated with above-normal board-foot volume.

Plot 1 – In 1930.

Plot 2 – In 1930.

Table 8.--Mount Hood permanent sample plots 1, 2, and 3; statistics of the live stand (values on horizontal acre basis)

Plot No.	Month and year measured	Age, years	Growth period, years	Horizontal area, acres	Site index, feet	Site quality	Stand 2.6 inches and more in d.b.h.[1/]								Stand 6.6+ inches d.b.h.			Stand 11.6+ inches d.b.h.		
							Number of trees		Basal area, square feet		Average d.b.h., inches		Average height of conifers, feet	Volume of conifers, cubic feet	Number of trees		Volume of conifers, board feet (International ¼-inch rule)	Number of trees		Volume of conifers, board feet (Scribner rule)
							Conifers	Hardwoods	Conifers	Hardwoods	Conifers	Hardwoods			Conifers	Hardwoods		Conifers	Hardwoods	
1	4/30	45		1.0	132	III-	344	20	172.2	3.4	9.6	5.6	77	5,798	234	5	31,936	95	0	13,267
	10/34	50	5		132	III-	306	20	183.9	4.2	10.5	6.2	85	6,659	228	7	39,326	111	0	19,271
	9/39	55	5		133	III-	249	20	185.1	4.6	11.7	6.5	90	6,968	207	7	43,550	116	0	23,414
	3/45	60	5		134	III-	211	19	193.6	4.6	13.0	6.7	100	7,635	195	7	49,706	123	0	28,136
	5/52	67	7		--	--	187	19	205.7	5.0	14.2	7.0	112	8,417	178	8	56,207	128	1	34,028
2	4/30	45		1.0	124	IV+	464	29	220.8	6.0	9.3	6.2	77	7,144	380	10	37,717	78	0	9,755
	10/34	50	5		124	IV+	416	27	232.8	6.4	10.1	6.6	83	8,165	370	11	47,395	112	1	16,866
	9/39	55	5		128	III-	368	21	242.2	4.3	11.0	6.2	88	8,811	347	9	53,455	131	0	22,673
	3/45	60	5		129	III-	325	22	248.9	6.4	11.9	7.3	95	9,657	310	12	61,267	159	1	30,232
	5/52	67	7		--	--	305	20	263.3	6.1	12.6	7.5	101	10,607	293	10	68,952	164	2	35,894
3	4/30	45		1.0	124	IV+	417	64	200.3	14.6	9.4	6.5	77	6,709	300	21	32,543	81	1	11,301
	10/34	50	5		124	IV+	383	56	210.2	15.4	10.0	7.1	83	7,449	300	24	43,236	101	2	17,142
	9/39	55	5		135	III	325	43	218.1	13.7	11.1	7.6	92	8,261	278	24	51,370	123	2	23,390
	3/45	60	5		139	III	295	33	230.3	11.8	12.0	8.1	100	9,355	257	21	60,873	137	2	31,347
	5/52	67	7		--	--	281	22	247.5	9.1	12.7	8.7	106	10,358	246	15	69,545	149	2	38,913

1/ For 1930, 1934, and 1939, trees 0.5 inch and more in d.b.h. were included.

KNOWLEDGE GAINED FROM PERMANENT GROWTH AND YIELD PLOTS

To the best of the author's knowledge, all published information derived from the plots is summarized in the following section. No attempt has been made to cover publications other than those based on direct analysis of plot data.

The articles are discussed by subject matter, chronologically within each subject. Remarks are confined to the main ideas in each article.

NORMAL YIELD TABLES

Probably the most significant publication to which these plots contributed data is Technical Bulletin 201, "The Yield of Douglas-fir in the Pacific Northwest" (McArdle et al., 1949), which includes Bruce's "A Revised Yield Table for Douglas-fir" (1948). This has been a standard reference of foresters since its publication. Subsequent data obtained from the growth and yield plots have generally substantiated the yield tables.

TRENDS TOWARD NORMALITY

Meyer (1933) pioneered work in this direction for Douglas-fir. The permanent sample plots had not been established long enough to allow consideration of the effect of age, but he was able to demonstrate the effect of existing normality percentage on future normality and derived regression equations for the standard units of measure according to the form:

$$\text{change (\%)} = a + b\ \text{(present normality)}.$$

Briegleb, in a later analysis (1942) was able to use age as another independent variable. His regression equations of the form,

$$\text{change (\%)} = a + b\ \text{(age)} + c\ \text{(normality)},$$

provided multiple correlation coefficients above 0.6 (43 degrees of freedom) for cubic-foot, International board-foot, and Scribner board-foot standards of normality.

GROWTH OF DOUGLAS-FIR

Reporting of growth data from permanent sample plots in Douglas-fir stands began with a presentation by Munger (1915) at the annual meeting of the Society of American Foresters. The Willamette plots had then been established for 5 years.

Meyer (1928) reported further on the growth of these plots and observed how distribution of stand diameter class frequency changed with time. He noted that all plots showed a trend in frequency distribution from a skewness toward the small diameters in young stands, through a nearly normal distribution, to a skewness toward the larger diameters as the stands matured. A thorough discussion of diameter distribution series in even-aged stands became available in a subsequent publication (Meyer, 1930).

Munger (1946b) had the opportunity to review the Willamette plots after 35 consecutive years of experience with them. A most valuable contribution of these plots has been a detailed life history typical of stands occurring over millions of acres in the Pacific Northwest. Although they had suffered occasional heavy losses from fire, insects, snowbreak, and wind, they had an average volume per acre of over 78,000 board feet, Scribner rule, at age 90, thus demonstrating the recuperative powers of natural stands. Despite periodic annual volume growth ranging from 286 to minus 99 cubic feet per acre, the plots have substantiated the generalization that the various measures of stocking for a particular stand all trend toward normality.

The Douglas-fir Second-Growth Management Committee (1947) analyzed 25,000 individual tree measurements, covering 35 years' experience with the permanent growth and yield plots, to develop stand table projection methods for well-stocked Douglas-fir stands. This analysis derived diameter growth and Scribner and cubic-volume growth according to site index, crown class, d.b.h., and stand age. The tables in the reference were for site III only and illustrated the following general conclusions in regard to cubic-volume growth:

1. When trees of a certain d.b.h. but of differing ages and crown classes are considered, growth and growth percent decrease with increasing age and increase with increasing dominance.

2. When trees of a certain age and crown class are considered, growth increases with d.b.h. Growth percent, however, decreases with increasing size, except for the older age classes where there is little differentiation.

Over all site classes, a study such as this provides an unexcelled view of the growth dynamics of natural, even-aged, well-stocked stands of Douglas-fir.

Spurr (1952), in assessing various stand characteristics as direct estimators of cubic volume per acre, bypassed tree volume tables and used the plot data to make regression analyses of volume on different combinations of basal area, total height (dominants and codominants), age, site index, and basal area times height. Basal area, total height, and the product of these two provided the most accurate estimates; age and site index, the least accurate. Further, the height times basal area estimate alone gave a standard error of 6 percent.

He also analyzed the plot data to test rate of cubic-volume growth against several stand characteristics. Site index and stand age had the highest correlation with volume growth. The correlation coefficient was 0.765 (33 degrees of freedom). Average diameter of the stand made a slight improvement in the estimate.

In a discussion of trends of basal area per acre with stand age, Spurr used the permanent plot data to show the linearity of gross basal area with time. The curvilinear trend of net basal area reflected the increasing significance of mortality as stands get older.

A linear regression analysis of eight factors related to net basal area growth showed that basal area itself is the best single indicator. The addition of age as an independent variable improved the correlation somewhat but, for all practical purposes, basal area alone was suitable.

Staebler (1954) used data from some of the 78-year-old Gifford Pinchot plots as an argument to retain thrifty young stands at least to the culmination of mean annual increment. The average annual value growth percent of 9.9, achieved by these plots in going from 52 to 78 years old, might be considered adequate by any owner. Furthermore, mean annual increment and value per thousand board feet were still increasing.

Johnson (1955) used the plot remeasurements to compare the accuracy of seven common methods for volume growth prediction. The best method assumed that well-stocked stands put on normal growth. The other methods gave biased results or had a larger standard deviation than did the normal-growth method. This confirms Spurr's conclusions, noted previously, in regard to cubic-volume growth.

Worthington and Staebler (1961), in examining some of the permanent sample plots, found that trees below the average diameter of the stands had 27 percent of the total basal area, though they contributed only 16 percent of the total basal-area growth. The implication was that thinnings could remove about 25 percent of stand basal area in the smaller trees with little sacrifice in increment.

The same authors also found a definite relation between crown class and the live crown—total height ratio. The ratio increases with dominance.

MORTALITY

Johnson (1953) examined the permanent plot records for mortality. He found that the mortality on all plots averaged 83 cubic feet or 284 board feet (Scribner) per acre per year, a figure significant enough to alert forest-land owners.

Staebler (1953) found that reasonable estimates of mortality for any particular diameter class in the permanent plot stands could be made on the basis of stand age, site index, and d.b.h. Separate equations were required, one for intermediate and suppressed trees and one for dominants and codominants. A strong correlation coefficient, 0.715 (68 degrees of freedom), for the intermediate-suppressed equation reflected the more regular mortality due to suppression in well-stocked stands. The dominant-codominant equation had a weak correlation coefficient, 0.266 (68 degrees of freedom), reflecting the irregular mortality in the dominant portion of stands.

GROSS YIELD TABLES

Munger (1946a) wrote on the cumulative mortality and gross growth of these plots. His article was the first attempt to derive gross yield tables for Douglas-fir, but he felt that the data were too limited for his figures to be applicable over all site and age classes.

Staebler (1955a) expressed average volume of trees that die during any particular decade as a function of the average volume of trees living at the beginning of that decade. Limitations on age and size range of timber prohibited development of a curvilinear regression. Therefore, two linear regressions were combined to fit the data. This work led to Staebler's "Gross Yield and Mortality Tables for Fully Stocked Stands of Douglas-fir" (1955b). These gross yield figures provide a goal for forest managers.

ESTIMATING STAND AGE

As used in McArdle's (1949) Douglas-fir yield tables, stand age was determined by averaging dominant and codominant trees in the ratio of 1 to 4. In analyzing the plot data, Johnson (1954) found that estimates of stand age, reliable enough for use with the yield tables, could be made from dominant-tree measurements only:

Subtract 1 year for dominants 30 to 80 years old

Subtract 2 years for dominants 81 to 130 years old

Subtract 3 years for dominants 131 to 180 years old

HEIGHT GROWTH AND SITE INDEX

Staebler (1948) proposed measuring heights of only dominant trees for determination of site index. More reliable identification of dominants plus clearer visibility of their tops reduces both bias and measurement time in field work. He used data from the growth and yield plots to arrive at a factor for converting from height of dominants only to that of dominants and codominants.

Spurr (1952) felt that, in general, actual growth from permanent sample plots would develop better site index curves than harmonized data from temporary plots. He used the height and age measurements from the permanent plots to construct natural site index curves for Douglas-fir. A comparison of these curves with the yield table curves shows that the natural site curves have a shallower gradient in the younger age classes.

In Spurr's analysis of the plot data, age was found to be the single factor best related to height growth. With two factors, however, total height itself and site index had the best correlation. If site index of a stand is known, the need to find stand age in predicting height growth is eliminated. Otherwise, the correlations substantiate the general use of site index curves for height-growth prediction.

LEVELS OF GROWING STOCK

Munger (1945) offered the accrued experience of permanent sample plot remeasurements as a guide to identifying and enumerating reserve trees under low-thinning practice.

Briegleb (1952) used data from the Wind River growth and yield plots plus other sources to substantiate two related hypotheses: (1) that, for trees of a given breast-high diameter, the shorter ones have larger crowns than the taller; and (2) that, for trees of a given height, those with greater breast-high diameter have the larger crowns.

An analysis of measurements from thinned stands in Prussia, Denmark, and western Washington yielded an equation estimating, for average diameter, the desirable number of trees in percent of normal as a function of stand height in percent of normal. Briegleb's article presents tabular solutions to the equation as a guide to thinning practice. One principal advantage of this approach is its consideration of stand history. For example, a 60-year-old stand that had never before been thinned would be differentiated from a similar stand reduced in stocking by repeated thinnings.

ECOLOGY

Spilsbury and Smith (1947) used tree-measurement and ground-cover observations on the growth and yield plots, as well as on numerous other areas, in their pioneering work on using ground-cover species as indicators of Douglas-fir site quality. In the United States, they were concerned primarily with the humid temperate areas on the west slopes of the Coast Ranges and of the Cascade Mountains. They established definite vegetational trends by site types. The key to site quality was not the presence or absence of certain species, but rather the relative dominance of certain species in relation to others. For instance, while salal may be abundant over all sites, it is dominant in the ground cover only on the poorer sites.

FUTURE PLOT MANAGEMENT AND DISPOSITION OF DATA

Due to the shift in silvicultural emphasis from unmanaged to managed stands, the Pacific Northwest Forest and Range Experiment Station is shifting some of its responsibility for future remeasurement and maintenance of these plots.

The University of Washington has agreed to take over the maintenance and remeasurement of the plots located in the State of Washington. Copies of all remeasurement data will be furnished to the Experiment Station.

DISPOSITION OF EXISTING DATA

Office reports will continue to be on file and available to the public at the Pacific Northwest Forest and Range Experiement Station in Portland, Oreg.

In addition to the tables presented here, these reports include tables of periodic and mean annual increment, periodic mortality, and relationship of plot values to normal stand values.

Basic individual tree data is being punched on data-processing cards so that this wealth of tree-growth information can be made available to all Northwest forest research agencies for a wide variety of future analyses. Scientists interested in using this data should write the Director of the Pacific Northwest Forest and Range Experiment Station for information on availability and use of a set of cards.

LITERATURE CITED

Barnes, G. H.
1931. The importance of average stand diameter as a factor in forecasting timber yields. British Columbia Dept. Lands Forest Serv., 24 pp., illus.

Briegleb, Philip A.
1942. Progress in estimating trend of normality percentage in second-growth Douglas-fir. Jour. Forestry 40: 785-793, illus.

______ 1952. An approach to density measurement in Douglas-fir. Jour. Forestry 50: 529-536, illus.

Bruce, Donald.
1948. A revised yield table for Douglas-fir. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta., 17 pp.

Douglas-fir Second-Growth Management Committee.
1947. Management of second-growth forests in the Douglas-fir region. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta., 151 pp., illus.

Johnson, Floyd A.
1953. Mortality studies in young fir plots show great annual wood losses. The Lumberman 80(7): 146.

______ 1954. Estimating stand age for Douglas-fir. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 103, 2 pp.

______ 1955. Predicting future stand volumes for young well-stocked Douglas-fir forests: a comparison of methods. Jour. Forestry 53: 253-255, illus.

McArdle, Richard E., Meyer, Walter H., and Bruce, Donald.
1949. The yield of Douglas fir in the Pacific Northwest. U.S. Dept. Agr. Tech. Bul. 201 (Rev.), 74 pp., illus.

Meyer, Walter H.
1928. Rates of growth of immature Douglas fir as shown by periodic remeasurements on permanent sample plots. Jour. Agr. Research 36: 193-215, illus.

______ 1930. Diameter distribution series in evenaged forest stands. Yale Univ. School Forestry Bul. 28, 105 pp., illus.

______ 1933. Approach of abnormally stocked forest stands of Douglas fir to normal condition. Jour. Forestry 31: 400-406, illus.

______ 1937. Yield of even-aged stands of Sitka spruce and western hemlock. U.S. Dept. Agr. Tech. Bul. 544. 86 pp., illus.

Munger, Thornton T.
1915. Five years' growth on Douglas fir sample plots. Soc. Amer. Foresters Proc. 10: 423-425.

______ 1945. The number and diameter of trees on permanent sample plots in the Douglas-fir type. U. S. Forest Serv. Pac. NW. Forest & Range Expt. Sta., 7 pp.

______ 1946a. Cumulative mortality and gross growth on certain permanent sample plots in young Douglas-fir. U. S. Forest Serv. Pac. NW. Forest & Range Expt. Sta., 6 pp.

______ 1946b. Watching a Douglas-fir forest for thirty-five years. Jour. Forestry 44: 705-708.

Spilsbury, R. H., and Smith, D. S.
1947. Forest site types of the Pacific Northwest. A preliminary report. Dept. Lands and Forests, Brit. Columbia Forest Serv. Tech. Pub. T. 30, 46 pp., illus.

Spurr, Stephen H.
1952. Forest Inventory. 476 pp., illus. New York: The Ronald Press Co.

Staebler, George R.
1948. Use of dominant tree heights in determining site index for Douglas-fir. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 44, 3 pp., illus.

______ 1953. Mortality estimation in fully stocked stands of young-growth Douglas-fir. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Paper 4, 8 pp.

______ 1954. Management pays added profits in young Douglas fir. The Timberman 55(4): 74-76, illus.

______ 1955a. Extending the Douglas-fir yield tables to include mortality. Soc. Amer. Foresters Proc. 1954: 54-59, illus.

______ 1955b. Gross yield and mortality tables for fully stocked stands of Douglas-fir. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Paper 14, 20 pp., illus.

Worthington, Norman P., and Staebler, George R.
1961. Commercial thinning of Douglas-fir in the Pacific Northwest. U.S. Dept. Agr. Tech. Bul. 1230, 124 pp., illus.

GPO 985-823

Williamson, R. L.
1963. Growth and yield records from well-stocked stands of Douglas-fir. Pac. NW. Forest & Range Expt. Sta. U.S. Forest Serv. Res. Paper PNW-4, 24 pp., illus.

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