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GROSS YIELD AND MORTALITY TABLES FOR FULLY STOCKED STANDS OF DOUGLAS-FIR

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GROSS YIELD AND MORTALITY TABLES FOR FULLY STOCKED STANDS OF DOUGLAS-FIR

By

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Increasing interest in the practice of intensive forestry has demonstrated the need for gross yield tables for Douglas-fir showing the volume of trees that die as well as volume of live trees. Net yield tables for Douglas-fir, published in 1930,^{1/} give the live volume in fully stocked stands at different ages on different sites. As in all normal yield tables, no accounting is made of the volume of trees that die as stands grow older. Presented here are gross yield tables, which include net yield and estimated mortality volume. Mortality tables constructed in the process of making the gross yield tables are also presented.

NEED

Silviculturists have long felt the need for this information. In the even-aged stands so characteristic of many forest types, most of the trees that were present in the reproduction stand must die as the trees grow older and larger. The trees that die are as much a part of the site's production as are the trees that survive. To the silviculturist interested in the biological development of the stands, the full yield--volume of live trees plus normal mortality--is the important figure.

As more intensive forestry is practiced, the forest manager also becomes vitally interested in mortality as an untapped source of raw material. If the forest crop is thought of only as the volume of merchantable wood at the end of the rotation, mortality is largely a necessary evil, and net yield tables fill management needs completely. It is true that the trees that die have likely served a useful purpose in improving the quality of the remaining trees, or have played a vital role in the stand ecology. At the same time they may, by competing

1/ McArdle, Richard E. The yield of Douglas Fir in the Pacific Northwest. U. S. Dept. Agr. Tech. Bul. 201, 74 pp. illus. Rev. 1949.

for space, have greatly restricted the size of surviving trees. In any event, in a 1-cut-per-rotation system, mortality has little apparent effect on profits. In more intensive forestry, however, intermediate harvests are a part of the management system, and mortality becomes important as a source of wood to be harvested in thinnings. The harvest may be of trees already dead or about to die (salvage), or the equivalent volume may be harvested from trees whose removal will prevent further mortality.

METHODS

The gross yield tables were developed to fill these quite obvious needs. Methods of construction, which have been previously described,^{2/} involved, briefly, determination of the number of trees that die in the normal stand, decade by decade, and the average volume of those trees. The estimated total volume of mortality for any decade is the product of the two figures. The number dying in any decade is easily calculated from normal yield tables by noting the decrease in the number alive at successive ages 10 years apart. Average volume of the dead trees is based on analysis of data from permanent sample plots that have been observed for many years. It was found that the average volume of trees that die was closely correlated to the average volume of live trees. Once the nature of the relationship was established, average volume of the trees that died in the normal stand could be estimated from the average of live trees, a figure easily calculated from yield-table data.

Mortality considered in this analysis is the so-called regular mortality: normal mortality that must occur in the development of normal stands. It is largely suppression mortality, although the occasional death of trees in the upper crown classes is also considered normal.^{3/}

Irregular mortality resulting from fires, insect and disease epidemics, or excessive windthrow is not included since the normal yield tables represent stands where such losses have not occurred. Had they occurred, the stands would not have been selected for yield-table

2/ Staebler, G. R. Extending the Douglas-fir yield tables to include mortality. Soc. Amer. For. Proc. 1954: 54-59.

3/ Staebler, G. R. Mortality estimation in fully stocked stands of young-growth Douglas-fir. Pacific Northwest Forest and Range Experiment Station, Res. Paper No. 4, 8 pp. 1953.

construction. A few of the permanent sample plots used to calculate average volume of dead trees had suffered irregular mortality. The data were retained after it was demonstrated that such losses did not affect the live tree-dead tree volume relationship.^{4/}

Mortality prior to age 20 was not estimated since no yield-table data and very little permanent-sample-plot data were available. Hence, the gross yield for 20-year-old stands is really net yield (no estimate of prior mortality), and gross yield for a 30-year-old stand is net yield at 30 plus mortality from age 20 to 30, etc.

APPLICATION

The resulting tables, having been derived from analysis of fully stocked stands, are, strictly speaking, applicable only to fully stocked stands. This is certainly true of the mortality tables (tables 2 and 3). Mortality--at least suppression mortality--is so closely related to density that mortality volumes shown would be expected to occur only in stands like those from which the data were taken.

It is possible, however, that the gross yield tables (tables 1a, 1b, 1c, and 1d) are more widely applicable. Considerable evidence has been accumulated which shows that maximum growth, measured in terms of gross cubic-foot increment, may be obtained over a wide range of stocking. The logic of this phenomenon is easily understood: in a lightly stocked stand, less of the total production dies than is normal and more survives; the reverse is true in a more heavily stocked stand. Total production (gross increment) is conceivably the same in both instances.

Pursuing this theory, Hawley and Smith^{5/} present this tentative generalization based on available evidence: "The total production of cubic volume by a stand of given composition on a given site is, for all practical purposes, constant and optimum for a wide range of density of stocking. It can be decreased, but not increased, by altering the amount of growing stock to levels outside this range."

^{4/} See reference in footnote 2, page 2.

^{5/} Hawley, Ralph C., and Smith, David M. The practice of silviculture, 6th edition, p. 354. New York. 1954.

They further state that the generalization is valid only if "the total production of wood in the boles of all the trees in a stand is counted as growth. Total production of cubic volume includes not only the wood in the tops of the stems but also the wood produced in trees that die of suppression."

The gross yield tables provide an estimate of the total production as specified, and according to Hawley and Smith's generalization, periodic increment determined from the tables is applicable to stands varying in density. In Douglas-fir stands, the range over which full gross increment may be obtained is not known, and it is futile to speculate on just what it is until considerable experimental evidence is accumulated.

This discussion suggests some very important uses for the tables presented in this publication:

- (1) For fully stocked stands the mortality tables give the expected mortality at any stage in the development of the stands. Also given is the cumulative mortality up to any age. This information is useful to foresters planning to harvest the normal mortality. The tables give the forester some idea of the age at which losses become significant in volume, a figure that he can balance against the problems and costs involved in the operation.
- (2) Gross increment, at least so far as is now known, represents full site production, i.e., the maximum volume that the site is capable of producing. The gross yield tables are equivalent to the yields to be expected from a management program that, through thinning and salvage, captures the full production. The tables, then, may be considered as first approximations of yield tables for managed stands.
- (3) As such, the gross yield tables may be used to answer the same questions for managed stands that are answered by normal yield tables for unmanaged stands. Most important is probably the use of mean annual and current annual increments as a guide to establishment of rotations (table 4). Mortality offsets an increasing proportion of the gross increment as stands grow older. Hence, when mortality is harvested and becomes part of the forest's yield, the culmination of mean annual increment will be delayed. When the age of culmination, either in volume or value, is a controlling factor, rotations for managed stands will be longer than for unmanaged.

Table 1a
Gross Yield per Acre for Fully Stocked Douglas-fir

BASAL AREA - TOTAL STAND ^{1/}

Age	SITE CLASS				
	I	II	III	IV	V
Years	Square feet				
20	101	98	92	81	64
30	171	167	157	139	114
40	233	226	213	189	157
50	284	275	260	232	193
60	331	320	301	268	223
70	375	360	337	300	249
80	416	396	368	327	272
90	453	429	396	351	290
100	488	459	421	372	307
110	520	487	443	391	323
120	549	512	464	407	337
130	576	536	484	423	351
140	602	557	503	438	362
150	625	579	521	451	373
160	648	599	539	463	382

^{1/} All trees 1.5 inches d.b.h. and larger.

Table 1b
Gross Yield per Acre for Fully Stocked Douglas-fir

CUBIC FEET - TOTAL STAND^{1/}

Age	SITE CLASS				
	I	II	III	IV	V
<u>Years</u>	<u>Cubic feet</u>				
20	1,830	1,550	1,250	870	520
30	5,030	4,360	3,500	2,450	1,470
40	8,380	7,300	5,870	4,060	2,480
50	11,830	10,240	8,220	5,700	3,490
60	15,120	13,020	10,490	7,250	4,440
70	18,200	15,680	12,580	8,640	5,310
80	21,240	18,160	14,400	9,920	6,070
90	24,010	20,400	16,040	11,030	6,740
100	26,490	22,370	17,500	12,000	7,330
110	28,720	24,190	18,800	12,840	7,840
120	30,740	25,810	19,950	13,580	8,300
130	32,570	27,280	21,030	14,250	8,720
140	34,280	28,650	22,020	14,850	9,100
150	35,910	29,930	22,990	15,390	9,430
160	37,450	31,160	23,880	15,890	9,720

^{1/} All trees 1.5 inches d.b.h. and larger. Entire stem including stump and top.

Table 1c
Gross Yield per Acre for Fully Stocked Douglas-fir

BOARD FEET • INTERNATIONAL RULE ^{1/}
(1/8-inch kerf)

Age	SITE CLASS				
	I	II	III	IV	V
Years	Board feet				
20	4,900	2,100	200	--	--
30	24,800	16,300	8,400	2,400	--
40	49,600	36,600	23,000	9,500	1,500
50	77,000	59,200	39,700	20,100	6,000
60	102,900	80,500	56,700	31,400	11,100
70	127,900	101,000	72,900	42,100	16,600
80	153,200	120,400	87,500	51,600	22,300
90	175,800	137,900	100,300	59,800	27,700
100	196,700	154,200	111,900	67,300	32,400
110	215,200	169,700	122,400	74,000	36,500
120	232,100	184,000	131,900	79,900	40,000
130	247,700	197,100	140,800	84,900	43,100
140	262,600	209,400	149,400	89,700	46,100
150	276,500	220,700	157,400	94,400	49,100
160	289,600	231,500	165,100	98,400	51,900

^{1/} All trees 7 inches d.b.h. and larger to 5-inch top. Stump height 1.5 feet. Scaling length 16 feet with 0.3 feet trim allowance.

Table 1d
Gross Yield per Acre for Fully Stocked Douglas-fir

BOARD FEET - SCRIBNER RULE^{1/}

Age	SITE CLASS				
	I	II	III	IV	V
<u>Years</u>	<u>Board feet</u>				
20	--	--	--	--	--
30	8,000	2,600	300	--	--
40	24,900	12,100	4,500	200	--
50	45,500	28,000	12,600	3,300	30
60	65,200	44,200	24,400	8,200	1,100
70	85,100	59,800	36,300	14,300	2,400
80	105,400	74,400	47,500	20,700	4,500
90	124,500	88,400	57,600	27,000	7,100
100	141,800	101,800	66,500	32,800	9,900
110	157,400	114,300	74,500	38,200	12,600
120	171,700	125,900	81,900	43,100	15,200
130	185,200	136,600	89,200	47,500	17,700
140	197,800	146,700	96,200	51,500	20,100
150	209,700	156,300	102,800	55,200	22,400
160	221,100	165,300	109,000	58,600	24,600

^{1/} All trees 12 inches d.b.h. and larger to 8-inch top.
Stump height 2.0 feet. Scaling length 16 feet with 0.3 feet
trim allowance.

Table 2a
Periodic Annual Mortality per Acre for Fully Stocked Douglas-fir

BASAL AREA - TOTAL STAND^{1/}

Age period	SITE CLASS				
	I	II	III	IV	V
<u>Years</u>	<u>Square feet</u>				
20 - 30	1.7	1.7	1.7	1.7	1.7
30 - 40	2.1	2.0	1.9	1.9	1.8
40 - 50	2.2	2.1	2.0	1.9	1.7
50 - 60	2.3	2.1	1.9	1.8	1.6
60 - 70	2.4	2.1	1.8	1.6	1.4
70 - 80	2.4	2.0	1.6	1.4	1.2
80 - 90	2.3	1.9	1.5	1.3	1.0
90 - 100	2.2	1.8	1.4	1.1	0.9
100 - 110	2.1	1.7	1.3	1.0	.9
110 - 120	2.0	1.6	1.2	0.9	.8
120 - 130	1.8	1.5	1.2	.9	.7
130 - 140	1.7	1.4	1.1	.8	.6
140 - 150	1.6	1.4	1.1	.7	.6
150 - 160	1.6	1.3	1.1	.6	.5

^{1/} All trees 1.5 inches d.b.h. and larger.

Table 2b

Periodic Annual Mortality per Acre for Fully Stocked Douglas-fir

CUBIC FEET - TOTAL STAND^{1/}

Age period	SITE CLASS				
	I	II	III	IV	V
<u>Years</u>	<u>Cubic feet</u>				
20 - 30	28	25	20	18	14
30 - 40	60	50	42	32	23
40 - 50	80	65	55	42	28
50 - 60	94	76	62	45	29
60 - 70	108	86	64	44	28
70 - 80	119	92	62	42	27
80 - 90	124	92	60	40	25
90 - 100	122	90	58	37	24
100 - 110	117	87	57	34	22
110 - 120	113	84	55	32	20
120 - 130	108	81	54	30	19
130 - 140	103	78	52	27	17
140 - 150	98	74	50	24	15
150 - 160	93	71	48	22	14

^{1/} All trees 1.5 inches d.b.h. and larger. Entire stem including stump and tip.

Table 2c
Periodic Annual Mortality per Acre for Fully Stocked Douglas-fir

BOARD FEET - INTERNATIONAL RULE^{1/}
(1/8-inch kerf)

Age period	SITE CLASS				
	I	II	III	IV	V
<u>Years</u>	<u>Board feet</u>				
20 - 30	40	30	--	---	--
30 - 40	220	140	100	30	--
40 - 50	390	250	160	80	10
50 - 60	560	350	210	140	50
60 - 70	730	430	260	170	60
70 - 80	910	520	300	170	80
80 - 90	960	600	330	170	80
90 - 100	970	660	360	160	80
100 - 110	950	690	370	160	90
110 - 120	930	700	380	160	80
120 - 130	910	690	390	150	80
130 - 140	890	680	390	150	80
140 - 150	860	660	380	150	90
150 - 160	830	640	380	140	80

^{1/} All trees 7 inches d.b.h. and larger to 5-inch top. Stump height 1.5 feet. Scaling length 16 feet with 0.3 feet trim allowance.

Table 2d
Periodic Annual Mortality per Acre for Fully Stocked Douglas-fir

BOARD FEET - SCRIBNER RULE ^{1/}

Age period	SITE CLASS				
	I	II	III	IV	V
<u>Years</u>	<u>Board feet</u>				
20 - 30	--	--	--	--	--
30 - 40	50	20	--	--	--
40 - 50	90	40	20	--	--
50 - 60	180	80	40	10	--
60 - 70	370	120	50	20	--
70 - 80	600	180	70	30	10
80 - 90	680	300	80	40	10
90 - 100	700	400	110	40	10
100 - 110	700	460	140	50	10
110 - 120	690	480	180	50	10
120 - 130	690	480	230	40	20
130 - 140	680	480	250	40	20
140 - 150	670	470	250	40	20
150 - 160	660	450	240	40	20

^{1/} All trees 12 inches d.b.h. and larger to 8-inch top.
Stump height 2.0 feet. Scaling length 16 feet with 0.3 feet trim allowance.

Table 3a
Cumulative Mortality per Acre for Fully Stocked Douglas-fir

BASAL AREA - TOTAL STAND^{1/}

Age	SITE CLASS				
	I	II	III	IV	V
<u>Years</u>	<u>Square feet</u>				
30	17	17	17	17	18
40	38	37	36	36	36
50	60	58	56	55	53
60	83	79	75	73	69
70	107	100	93	89	83
80	131	120	109	103	95
90	154	139	124	116	105
100	176	157	138	127	114
110	197	174	151	137	123
120	217	190	163	146	131
130	235	205	175	155	138
140	252	219	186	163	144
150	268	233	197	170	150
160	284	246	208	176	155

^{1/} All trees 1.5 inches d.b.h. and larger.

Table 3b
Cumulative Mortality per Acre for Fully Stocked Douglas-fir

CUBIC FEET - TOTAL STAND^{1/}

Age	SITE CLASS				
	I	II	III	IV	V
Years	Cubic feet				
30	280	250	200	180	140
40	880	750	620	500	370
50	1,680	1,400	1,170	920	650
60	2,620	2,160	1,790	1,370	940
70	3,700	3,020	2,430	1,810	1,220
80	4,890	3,940	3,050	2,230	1,490
90	6,130	4,860	3,650	2,630	1,740
100	7,350	5,760	4,230	3,000	1,980
110	8,520	6,630	4,800	3,340	2,200
120	9,650	7,470	5,350	3,660	2,400
130	10,730	8,280	5,890	3,960	2,590
140	11,760	9,060	6,410	4,230	2,760
150	12,740	9,800	6,910	4,470	2,910
160	13,670	10,510	7,390	4,690	3,050

^{1/} All trees 1.5 inches d.b.h. and larger. Entire stem, including stump and tip.

Table 3c
Cumulative Mortality per Acre for Fully Stocked Douglas-fir

BOARD FEET - INTERNATIONAL RULE^{1/}
(1/8-inch kerf)

Age	SITE CLASS				
	I	II	III	IV	V
<u>Years</u>	<u>Board feet</u>				
30	400	300	--	--	--
40	2,600	1,700	1,000	300	--
50	6,500	4,200	2,600	1,100	100
60	12,100	7,700	4,700	2,500	600
70	19,400	12,000	7,300	4,200	1,200
80	28,500	17,200	10,300	5,900	2,000
90	38,100	23,200	13,600	7,600	2,800
100	47,800	29,800	17,200	9,200	3,600
110	57,300	36,700	20,900	10,800	4,500
120	66,600	43,700	24,700	12,400	5,300
130	75,700	50,600	28,600	13,900	6,100
140	84,600	57,400	32,500	15,400	6,900
150	93,200	64,000	36,300	16,900	7,800
160	101,500	70,400	40,100	18,300	8,600

^{1/} All trees 7 inches d.b.h. and larger to 5-inch top. Stump height 1.5 feet. Scaling length 16 feet with 0.3 feet trim allowance.

Table 3d
Cumulative Mortality per Acre for Fully Stocked Douglas-fir

BOARD FEET - SCRIBNER RULE ^{1/}

Age	SITE CLASS				
	I	II	III	IV	V
Years	Board feet				
40	500	200	--	--	--
50	1,400	600	200	--	--
60	3,200	1,400	600	100	--
70	6,900	2,600	1,100	300	--
80	12,900	4,400	1,800	600	100
90	19,700	7,400	2,600	1,000	200
100	26,700	11,400	3,700	1,400	300
110	33,700	16,000	5,100	1,900	400
120	40,600	20,800	6,900	2,400	500
130	47,500	25,600	9,200	2,800	700
140	54,300	30,400	11,700	3,200	900
150	61,000	35,100	14,200	3,600	1,100
160	67,600	39,600	16,600	4,000	1,300

^{1/} All trees 12 inches d.b.h. and larger to 8-inch top.
Stump height 2.0 feet. Scaling length 16 feet with 0.3 feet trim allowance.

Table 4a
Mean Annual Gross Increment Per Acre
for Fully Stocked Douglas-fir

BASAL AREA - TOTAL STAND^{1/}

Age	SITE CLASS				
	I	II	III	IV	V
Years	Square feet				
20	5.0	4.9	4.6	4.0	3.2
30	5.7	5.6	5.2	4.6	3.8
40	5.8	5.7	5.3	4.7	3.9
50	5.7	5.5	5.2	4.6	3.9
60	5.5	5.3	5.0	4.5	3.7
70	5.4	5.1	4.8	4.3	3.6
80	5.2	5.0	4.6	4.1	3.4
90	5.0	4.8	4.4	3.9	3.2
100	4.9	4.6	4.2	3.7	3.1
110	4.7	4.4	4.0	3.6	2.9
120	4.6	4.3	3.9	3.4	2.8
130	4.4	4.1	3.7	3.3	2.7
140	4.3	4.0	3.6	3.1	2.6
150	4.2	3.9	3.5	3.0	2.5
160	4.1	3.7	3.4	2.9	2.4

^{1/} All trees 1.5 inches d.b.h. and larger.

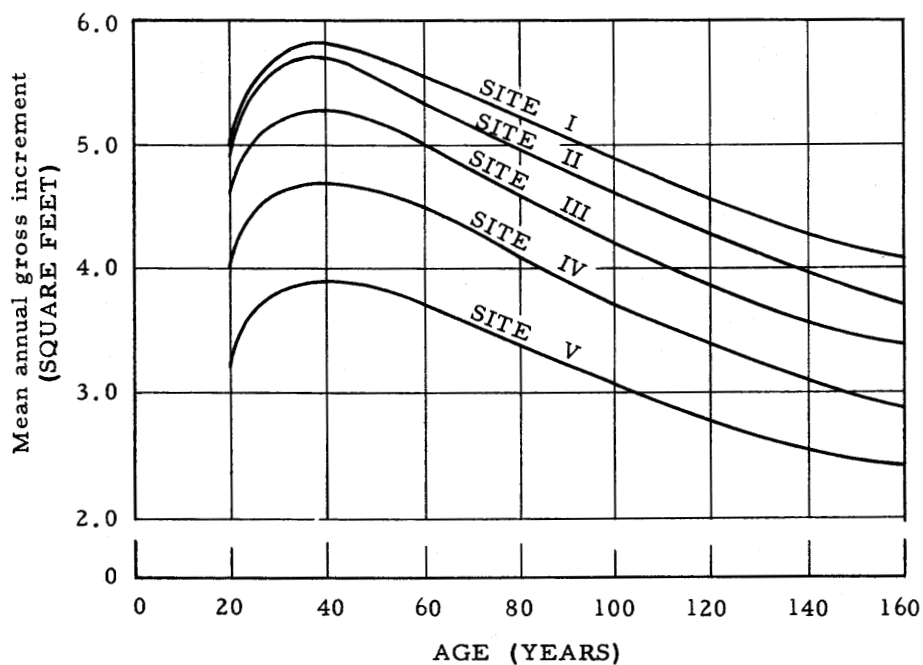


Table 4b
Mean Annual Gross Increment per Acre
for Fully Stocked Douglas-fir

CUBIC FEET - TOTAL STAND ^{1/}

Age	SITE CLASS				
	I	II	III	IV	V
Years	----- Cubic feet -----				
20	92	78	62	44	26
30	168	145	117	82	49
40	210	183	147	102	62
50	237	205	164	114	70
60	252	217	175	121	74
70	260	224	180	123	76
80	266	227	180	124	76
90	267	227	178	123	75
100	265	224	175	120	73
110	261	220	171	117	71
120	256	215	166	113	69
130	251	210	162	110	67
140	245	205	157	106	65
150	239	200	153	103	63
160	234	195	149	99	61

^{1/} All trees 1.5 inches d.b.h. and larger. Entire stem including stump and top.

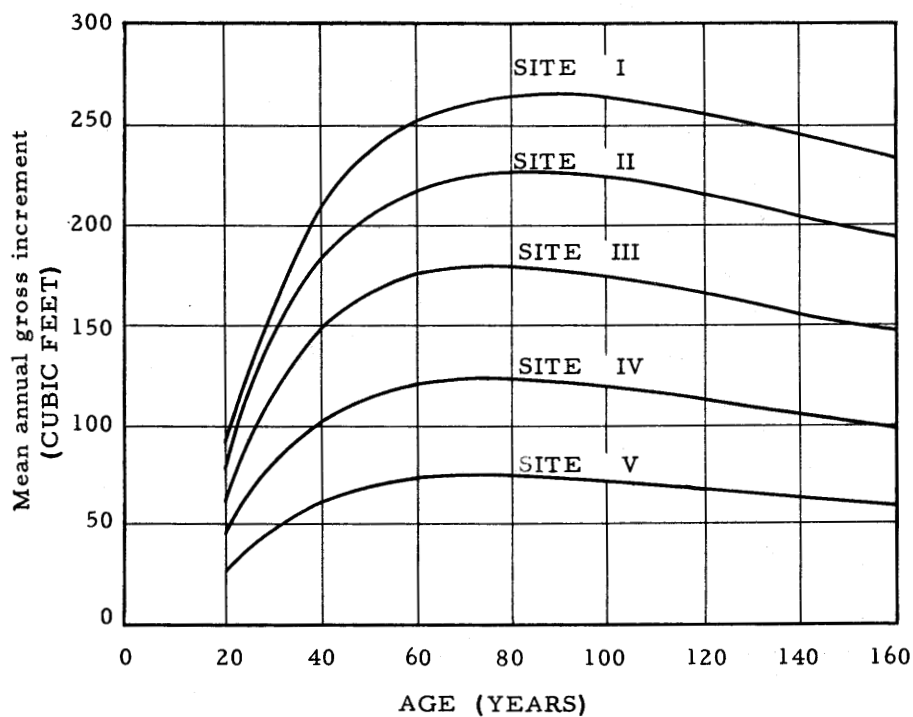


Table 4c
Mean Annual Gross Increment per Acre
for Fully Stocked Douglas-fir

BOARD FEET - INTERNATIONAL RULE^{1/}
(1/8-inch kerf)

Age	SITE CLASS				
	I	II	III	IV	V
Years	Board feet				
20	245	105	10	--	--
30	827	543	280	80	
40	1,240	915	575	238	38
50	1,540	1,184	794	402	120
60	1,715	1,342	945	523	185
70	1,827	1,443	1,041	601	237
80	1,915	1,505	1,094	645	279
90	1,953	1,532	1,114	664	308
100	1,967	1,542	1,119	673	324
110	1,956	1,543	1,113	673	332
120	1,934	1,533	1,099	666	333
130	1,905	1,516	1,083	653	332
140	1,876	1,496	1,067	641	329
150	1,843	1,471	1,049	629	327
160	1,810	1,447	1,032	615	324

^{1/} All trees 7 inches d.b.h. and larger to 5-inch top.
Stump height 1.5 feet. Scaling length 16 feet with 0.3 feet trim allowance.

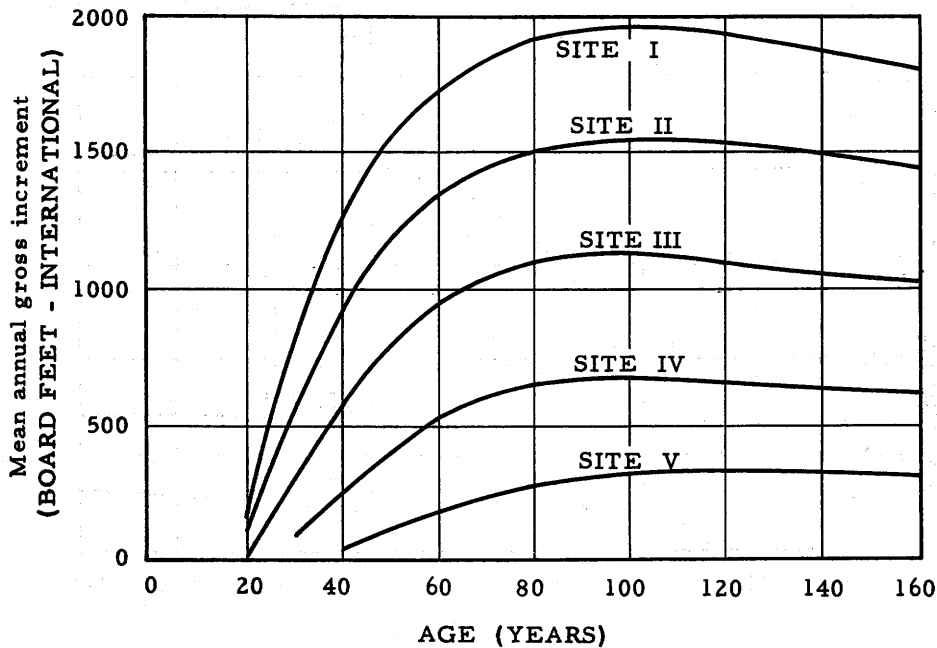


Table 4d
Mean Annual Gross Increment per Acre
for Fully Stocked Douglas-fir

BOARD FEET - SCRIBNER RULE^{1/}

Age	SITE CLASS				
	I	II	III	IV	V
Years	Board feet				
20	--	--	--	--	--
30	267	87	10	--	--
40	622	302	112	5	--
50	910	560	252	66	--
60	1,087	737	407	137	18
70	1,216	854	519	204	34
80	1,318	930	594	259	56
90	1,383	982	640	300	79
100	1,418	1,018	665	328	99
110	1,431	1,039	677	347	115
120	1,431	1,049	682	359	127
130	1,425	1,051	686	365	136
140	1,413	1,048	687	368	144
150	1,398	1,042	685	368	149
160	1,382	1,033	681	366	154

^{1/} All trees 12 inches d.b.h. and larger to 8-inch top.
Stump height 2.0 feet. Scaling length 16 feet with 0.3 feet trim allowance.

