

TECHNICAL NOTE

U.S. DEPARTMENT OF AGRICULTURE
FORESTRY-9 (previously WOOD-9)
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NATURAL RESOURCES CONSERVATION SERVICE
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CULMINATION OF MEAN ANNUAL INCREMENT FOR INDICATOR TREE SPECIES IN THE STATE OF WASHINGTON

Wood fiber growth that can be attained on a particular soil map unit or soil is of considerable importance to a land manager. The most common expression of productivity is site index (total height of trees in the dominant crown canopy at the base age, usually 50 to 100 years). Many landowners are not familiar with site index, but easily comprehend productivity in terms of volume measure. The accompanying table expresses site index in such a way. It is necessary for comparative purposes to use a method that gives one growth rate value for each site index. The method chosen is culmination of mean annual increment (CMAI).

Mean annual increment (MAI) is the average yearly volume growth per acre of a stand. This is computed by dividing the total volume by its age. As the stand increases in age, the MAI also increases until tree-to-tree competition and physiological maturity reduce the rate of increase. The point when a stand reaches its maximum MAI is called the culmination of mean annual increment (CMAI).

The CMAI for an indicator tree species on a particular soil is an expression of maximum productivity for unmanaged, even-aged stands. In conservation planning, it provides a means of discussing long-term productivity on an annual-equivalent basis. The CMAI is typically the basis of rating woodland productivity in published soil surveys and web-available reports such as the Web Soil Survey (<http://websoilsurvey.nrcs.usda.gov/app/>).

In the attached table, the CMAI (in cubic feet/acre/year) and age at which this occurs are shown for each site index (at one-foot intervals of site index) for the various indicator tree species in Washington State. An “indicator” tree species is the species that is common on a soil map unit and generally the most productive.

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NOTES

1. Culmination of mean annual increment and age at which it occurs were calculated for each species from the table and publication listed below (arranged by scientific plant name symbol). CMAI is in cubic feet per acre per year and is typically based the total stem of all trees including stump and tip. Individual references document the exact utilization standard used.

ABGR: Table 6 of Cochran, P.H. 1979. Gross Yield for Even-aged Stands of Douglas-fir and White or Grand Fir East of the Cascades in Oregon and Washington. USDA For. Ser. Res. Paper PNW-263, 17p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, OR. Table 4 is used for the basal area adjustment to volume growth.

ALRU2: Table 11 of Worthington, N.P., F.A. Johnson, G.R. Staebler and W. J. Lloyd. 1960. Normal Yield Tables for Red Alder. USDA For. Ser. Res. Paper 36, 3p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, OR.

LAOC: Table 33 of Schmidt, W.C., R.C. Chearer and A. L. Roe. 1976. Ecology and Silviculture of Western Larch Forests. USDA For. Ser. Tech. Bul. No. 1520, 96p., illus. Intermountain Forest and Range Experiment Station. Table 29 is used for the basal area adjustment to volume growth.

PICO: Tables 5-9 of Myers, C. A. 1967. Yield Tables for Managed Stands of Lodgepole Pine in Colorado and Wyoming. USDA For. Ser. Res. Paper RM-26, 20p., Rocky Mountain Forest and Range Experiment Station.

PIEN-ABLA: Edminster, C.B. 1980. Engelmann Spruce and Subalpine Fir Yield Tables. USDA Soil Conservation Service West TSC Bul. No. W38-0-17, 4p., West Technical Service Center of SCS.

PIMO3: Table 7 of Haig, I.T. 1932. Second-Growth Yield, Stand, and Volume Tables for the Western White Pine Type. USDA For. Ser. Tech. Bul. No. 323, 67p., illus. Rocky Mountain Forest and Range Experiment Station.

PIPO: Table 21 of Meyer, W.H. 1961. Yield of Even-aged Stands of Ponderosa Pine. USDA For. Ser. Tech. Bul. No. 630, 59p., illus. Pacific Northwest Forest and Range Experiment Station. Table 4 is used for the basal area adjustment to volume growth.

POTR5: Baker, F.S. 1925. Aspen in the Central Rocky Mountain Region. USDA Bulletin #1291.

PSME 50yr: Chambers, C. J. and F. M. Wilson 1972. Empirical Yield Tables for the Douglas-fir Zone. Washington State Department of Natural Resources Technical Report #20R.

PSME 100yr: Table 2 of McArdle, R.E. and W.H. Meyer. 1961. The Yield of Douglas-fir in the Pacific Northwest. USDA For. Ser. Tech. Bul. No. 201, 74p., illus. Pacific Northwest Forest and Range Experiment Station.

PSMEG(1): Table 5 of Cochran, P.H. 1979. Gross Yields for Even-aged Stands of Douglas-fir and White or Grand Fir East of the Cascades in Oregon and Washington. USDA For. Ser. Res. Paper PNW-263, 17p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, OR. Table 3 is used for the basal area adjustment to volume growth.

PSMEG(2): Table 1 Kimsey, M. 2005. Technical Report to NRCS-Idaho: Development Report on Site Index Conversion, Mixed Specie[s] Cubic-Foot Yield Curves, Douglas-fir cubic foot Yield Curves, Mixed Specie MAI Curves and Table, and Douglas-fir MAI Curves and Tables. University of Idaho, Department of Forest Resources, Moscow, ID. 2005. (with reference to USDA-USFS Research Paper INT-347, July 1985. R.A. Monserud)

TSHE 50yr: Appendix 2 of Wiley, K.N. 1978. Net and gross yields for natural stands of western hemlock in the Pacific Northwest. Weyerhaeuser Forestry Paper No. 19.

TSHE 100yr: Table 12 (S.I.>100) and Table 14 (S.I. 60-99) from Barnes, G.H. 1962. Yield of Even-Aged Stands of Western Hemlock. USDA Tech. Bul. 1273, 52p., illus. Pacific Northwest Forest and Range Experiment Station.

2. In soil-site correlation work, the culmination of mean annual increment expressed in terms of cubic feet/acre/year is used as the basis for a timber-producing soil map unit’s productivity. The age of culmination is also listed.

3. CMAI for a species is developed as discussed on the front page of this Technical Note. In addition, certain soils in Major Land Resource Areas B6, B8, B9, E43 and E44 (re. <http://soils.usda.gov/survey/geography/mlra/>) may have a basal area adjustment if USDA Technical Bulletins 630 or 1520, or Research Paper PNW-263 were used in computing site index and growth for the indicator species. The indicator species is normally that principal species most common on the unit and potentially the most productive. The following procedure was used to make the adjustment.

- (1) Only ECS-005 plots are used to determine site index for the indicator species will be applicable to the adjustment.
- (2) Each plot’s basal area is divided by that normal basal area listed in Table 4 of USDA T.B. 630, Table 29 of T.B. 1520, or Tables 3 or 4 of RP-PNW 263, based on the plot’s site index and average total or breast height age, as appropriate. Interpolation will be needed in most cases.
- (3) All plot percents of normal basal area are averaged and then rounded to the nearest five percent.
- (4) The culmination of mean annual increment (CMAI) in cubic feet/acre/year based on the assigned site index is multiplied by the average, rounded percent of normal basal area to produce an adjusted CMAI.

4. The following chart can be used to convert volumes from one unit of measure to another.

Caution: Scribner board-feet, cords, and carbon* are rough approximations.

Cu. Meters/ Hectare/Yr	=	Cu. Ft./Ac./Yr	=	Scribner Bd. Ft/Ac/Yr	=	Cords/Ac/Yr
0.07	=	1	=	5	=	0.01
1.00	=	14	=	70	=	0.17
1.40	=	20	=	100	=	1.24
5.94	=	85	=	425	=	1.00

***1 cubic foot (average species) ~ 34 lbs air dry x 0.50 = 17 pounds carbon**

TABLE. Culmination of Mean Annual Increment, CMAI (in cubic feet/acre/year) and AGE AT WHICH OCCURS

Site Index	ABGR		ALRU2		LAOC		PICO		PIEN-ABLA		PIMO3		PIPO		POTR5		PSME 50yr		PSME 100yr		PSMEG(1)		PSMEG(2)		TSHE 50yr		TSHE 100yr		
	CMAI	AGE	CMAI	AGE	CMAI	AGE	CMAI	AGE	CMAI	AGE	CMAI	AGE	CMAI	AGE	CMAI	AGE	CMAI	AGE	CMAI	AGE	CMAI	AGE	CMAI	AGE	CMAI	AGE	CMAI	AGE	
30					31	70					67	105																	
31					32	70					69	105																	
32					34	70					70	105																	
33					36	70					72	105																	
34					37	70					74	105																	
35					39	70					76	105																	
36					40	70					77	105																	
37					42	70					79	105																	
38					43	70					81	105																	
39					45	70					82	105																	
40					46	70	25	100	28	150	84	105	30	60									16	149					
41					48	70	26	100	29	150	86	105	31	60									18	147					
42					50	70	27	100	30	145	87	105	32	60									20	146					
43					51	70	29	100	31	145	89	105	32	60									22	145					
44					53	70	30	100	32	140	91	105	33	60									23	144					
45					55	70	31	100	34	140	92	105	34	60									25	143					
46					56	70	32	100	35	140	94	105	35	60									27	142					
47					58	70	33	100	36	135	96	105	36	60									29	141					
48					60	70	35	100	37	135	98	105	36	60									31	140					
49					61	70	36	100	38	130	99	105	37	60									33	139					
50	57	121			63	70	37	100	39	130	101	105	38	60								29	116	35	138	150	90		
51	59	121			65	70	38	100	40	130	103	105	39	60								30	115	37	136	152	90		
52	60	121			67	70	39	100	41	130	104	105	40	60								32	115	39	135	153	90		
53	62	121			69	70	41	100	42	125	106	105	40	60								34	114	41	134	154	90		
54	64	121			70	70	42	100	43	125	108	105	41	60								35	114	43	133	156	90		
55	66	120			72	70	43	100	44	125	110	105	42	60			49	90	24	70	36	113	45	132	157	90			
56	68	120			74	70	44	100	46	125	111	105	43	55			51	90	25	70	38	112	47	131	159	90			
57	70	120			76	70	45	100	47	125	113	105	44	55			53	90	26	70	40	112	50	130	160	90			

Site Index	ABGR		ALRU2		LAOC		PICO		PIEN-ABLA		PIMO3		PIPO		POTR5		PSME 50yr		PSME 100yr		PSMEG(1)		PSMEG(2)		TSHE 50yr		TSHE 100yr	
	CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE	
58	72	120			78	70	47	100	48	120	115	105	44	55			55	90	28	70	41	111	52	129	161	90		
59	74	120			80	70	48	100	49	120	116	105	45	55			57	90	29	70	42	111	54	129	163	90		
60	76	120	50	35	81	70	49	100	50	120	118	105	46	55			59	90	30	70	44	110	56	128	164	90	56	70
61	78	119	51	35	83	70	51	100	51	120	120	105	47	55			61	90	31	70	46	109	58	127	166	90	58	70
62	79	119	53	35	85	70	53	100	53	120	121	105	48	55			63	90	33	70	47	109	60	126	167	90	61	70
63	81	118	55	35	87	70	55	100	54	115	123	105	49	55			64	90	34	70	49	108	63	125	169	90	63	70
64	83	117	56	40	89	70	57	100	55	115	125	105	50	55			66	90	35	70	51	107	65	124	170	90	65	70
65	85	116	58	40	91	70	60	100	56	115	127	105	50	50			68	90	36	70	52	106	67	123	172	90	67	70
66	87	116	60	40	93	70	62	100	58	115	128	105	51	50			70	90	38	70	54	106	69	122	173	90	70	70
67	89	115	61	40	95	70	64	100	59	115	130	105	52	50			72	90	39	70	56	105	72	121	175	90	72	70
68	91	114	63	40	97	70	66	100	60	110	132	105	53	50			74	90	40	70	58	104	74	121	176	90	74	70
69	93	114	65	40	99	70	68	100	62	110	134	105	54	50			76	90	41	70	59	104	76	120	178	90	76	70
70	95	113	66	40	101	70	70	100	63	110	135	105	55	50			79	90	43	70	61	103	79	119	180	90	78	60
71	97	112	68	40	103	70	72	100	64	110	137	105	56	50			81	90	44	70	63	102	81	118	181	90	80	60
72	98	112	70	40	105	70	74	100	66	110	139	105	58	50			83	90	45	70	65	102	83	117	183	90	83	60
73	100	111	72	40	107	70	75	100	67	105	141	105	59	45			84	90	47	70	67	101	86	116	184	90	85	60
74	102	111	73	40	109	70	77	100	68	105	143	105	61	45			86	90	48	70	69	101	88	116	186	90	87	60
75	104	110	75	40	111	70	79	100	70	105	144	100	62	45			89	90	49	70	71	100	91	115	188	90	89	60
76	106	109	77	40	113	70	81	100	71	105	146	100	63	45			91	90	51	70	73	99	93	114	189	90	91	60
77	108	109	79	40	116	70	83	100	72	105	148	100	65	45			93	90	52	70	75	99	96	113	191	90	93	60
78	110	108	80	40	118	70	84	100	73	100	150	100	66	40			94	90	54	70	77	98	98	112	192	90	95	60
79	112	108	82	40	120	70	86	100	75	100	152	100	68	40			96	90	55	70	79	98	101	112	194	90	97	60
80	114	107	84	40	122	70	88	100	76	100	154	100	69	40	48	80	98	90	58	70	81	97	103	111	197	90	100	60
81	116	106	86	40			90	100	78	100			71	40	49	80	100	90	60	70	83	96	106	110	197	90	102	60
82	118	105	87	40			92	100	79	100			72	40	50	80	102	90	61	70	86	96	108	109	199	90	104	60
83	120	104	89	40			94	100	81	95			74	40	51	70	103	90	62	70	88	95	111	109	201	90	106	60
84	122	103	91	40			96	100	82	95			75	40	52	70	105	90	63	70	90	94	113	108	203	90	108	60
85	124	102	92	40			98	100	84	95			77	40	53	70	107	90	64	70	92	94	116	107	204	90	110	60
86	125	100	94	40			100	100	85	95			79	40	54	70	109	90	66	70	95	93	119	106	206	90	112	60

Site Index	ABGR		ALRU2		LAOC		PICO		PIEN-ABLA		PIMO3		PIPO		POTR5		PSME 50yr		PSME 100yr		PSMEG(1)		PSMEG(2)		TSHE 50yr		TSHE 100yr	
	CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE	
87	127	99	96	40			102	100	87	95			80	40	55	70	111	90	67	70	97	92	121	106	208	90	114	60
88	129	98	97	40			104	100	88	90			82	40	56	70	113	90	68	70	99	91	124	105	209	90	116	60
89	131	97	99	40			106	100	90	90			83	40	58	70	114	90	69	70	102	91	127	104	211	90	118	60
90	133	96	101	40			108	100	91	90			85	40	59	70	116	90	70	70	104	90	129	104	213	90	120	60
91	135	95	102	40			110	100	93	90			87	40			118	90	72	60	107	89	132	103	215	90	122	60
92	137	95	104	40			112	100	95	90			88	40			120	90	73	60	109	88	135	102	217	90	124	60
93	139	94	106	40			114	100	96	90			90	40			122	90	74	60	112	87	138	102	218	90	126	60
94	141	93	108	40			115	100	98	90			92	40			123	90	75	60	114	86	140	101	220	90	128	60
95	143	92	109	40			117	100	100	90			94	40			125	90	77	60	117	84	143	100	222	90	130	60
96	145	92	111	40			119	100	102	90			95	40			128	90	78	60	120	83	146	100	224	90	133	60
97	147	91	113	40			121	100	104	90			97	40			130	90	79	60	122	82	149	99	226	90	135	60
98	149	90	115	40			123	100	105	90			99	40			132	90	81	60	125	81	152	98	227	90	137	60
99	151	90	116	40			124	100	107	90			100	40			134	90	82	60	127	80	155	98	229	90	139	60
100	153	89	118	40			126	100	109	90			102	40			136	90	84	60	130	79	158	97	230	90	142	60
101	155	88	120	40					111	85			104	40			138	90	85	60	133	78			233	90	144	60
102	157	88	121	40					113	85			106	40			140	90	86	60	136	78			235	90	145	60
103	159	87	123	40					114	85			108	40			141	90	88	60	139	77			237	90	147	60
104	161	87	125	40					116	85			110	40			143	90	89	60	142	76			239	90	149	60
105	163	86	127	40					118	85			112	40			145	90	91	60	145	76			241	90	151	60
106	165	85	128	40					120	85			114	40			147	90	92	60	148	75			243	90	153	60
107	167	85	130	40					122	85			116	40			149	90	94	60	151	74			245	90	154	60
108	169	84	132	40					123	85			118	40			150	90	95	60	154	73			246	90	156	60
109	171	84	133	40					125	85			120	40			152	90	97	60	157	73			248	90	158	60
110	173	83	135	40					127	85			122	40			154	90	98	60	160	72			250	90	160	50
111			137	40					129	80			124	40			156	90	100	60					252	90	162	50
112			138	40					130	80			126	40			158	90	101	60					254	90	164	50
113			140	40					132	80			128	40			160	90	103	60					256	90	166	50
114			142	40					134	80			130	40			162	90	105	60					258	90	168	50
115			144	40					136	80			132	40			163	90	106	60					260	90	170	50

Site Index	ABGR		ALRU2		LAOC		PICO		PIEN-ABLA		PIMO3		PIPO		POTR5		PSME 50yr		PSME 100yr		PSMEG(1)		PSMEG(2)		TSHE 50yr		TSHE 100yr	
	CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE	
116			145	40					138	80			133	40			167	90	108	60					262	90	172	50
117			147	40					140	80			135	40			169	90	110	60					264	90	174	50
118			149	40					141	80			137	40			171	90	111	60					266	90	176	50
119			150	40					143	80			139	40			173	90	113	60					269	90	178	50
120			152	40					145	80			141	40			175	90	115	60					271	90	180	50
121													144	40			176	90	116	60					273	90	182	50
122													146	40			178	90	118	60					275	90	184	50
123													148	40			180	90	119	60					277	90	186	50
124													151	40			182	90	121	60					279	90	188	50
125													154	40			184	90	122	60					281	90	190	50
126													156	40			186	90	124	60					283	90	192	50
127													159	40			188	90	125	60					285	90	194	50
128													161	40			190	90	127	60					287	90	196	50
129													164	40			191	90	128	60					290	90	198	50
130													166	40			193	90	129	60					292	90	200	50
131													168	40			195	90	131	60					294	90	202	50
132													170	40			197	90	133	60					296	90	204	50
133													173	40			199	90	134	60					298	90	205	50
134													175	40			201	90	136	60					301	90	207	50
135													177	40			203	90	138	60					303	90	209	50
136													179	40			207	90	139	60					305	90	211	50
137													181	40			209	90	140	60					307	90	213	50
138													184	40			210	90	142	60					309	90	214	50
139													186	40			212	90	144	60					312	90	216	50
140													188	40			214	90	145	60					314	90	218	50
141													190	40			216	90	146	60							220	50
142													192	40			218	90	148	60							222	50
143													195	40			220	90	149	60							224	50
144													197	40			222	90	150	60							226	50

Site Index	ABGR		ALRU2		LAOC		PICO		PIEN-ABLA		PIMO3		PIPO		POTR5		PSME 50yr		PSME 100yr		PSMEG(1)		PSMEG(2)		TSHE 50yr		TSHE 100yr	
	CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE		CMAI AGE	
145													199	40			224	90	152	60							228	50
146													201	40			226	90	153	60							230	50
147													203	40			227	90	154	60							232	50
148													206	40			229	90	156	60							234	50
149													208	40			231	90	157	60							236	50
150													210	40			233	90	158	60							238	50
151													212	40			235	90	159	60							240	50
152													215	40			237	90	161	60							241	50
153													217	40			239	90	162	60							243	50
154													220	40			241	90	163	60							244	50
155													222	40			243	90	164	60							246	50
156													224	40			244	90	165	60							248	50
157													227	40			246	90	167	60							249	50
158													229	40			248	90	168	60							251	50
159													232	40			250	90	169	60							252	50
160													234	40					170	60							254	50
161																			171	60							256	50
162																			172	60							258	50
163																			173	60							260	50
164																			174	60							262	50
165																			176	60							264	50
166																			177	60							266	50
167																			178	60							268	50
168																			179	60							270	50
169																			180	60							272	50
170																			181	60							274	50
171																			182	60							276	50
172																			183	60							278	50
173																			184	60							279	50

Site Index	ABGR	ALRU2	LAOC	PICO	PIEN-ABLA	PIMO3	PIPO	POTR5	PSME 50yr	PSME 100yr	PSMEG(1)	PSMEG(2)	TSHE 50yr	TSHE 100yr	
	CMAI AGE	CMAI AGE	CMAI AGE	CMAI AGE	CMAI AGE	CMAI AGE	CMAI AGE	CMAI AGE	CMAI AGE	CMAI AGE	CMAI AGE	CMAI AGE	CMAI AGE	CMAI AGE	
174										185	60			281	50
175										186	60			283	50
176										187	60			285	50
177										188	60			287	50
178										189	60			288	50
179										190	60			290	50
180										191	60			292	50
181										192	60			294	50
182										193	60			296	50
183										194	60			297	50
184										194	60			299	50
185										195	60			301	50
186										196	60			303	50
187										197	60			305	50
188										198	60			306	50
189										199	60			308	50
190										200	60			310	50
191										201	60			312	50
192										202	60			314	50
193										202	60			316	50
194										203	60			318	50
195										204	60			320	50
196										205	60			322	50
197										206	60			324	50
198										207	60			326	50
199										208	60			328	50
200										208	60			330	50
201										209	60			332	50
202										210	60			333	50

Site Index	ABGR	ALRU2	LAOC	PICO	PIEN-ABLA	PIMO3	PIPO	POTR5	PSME 50yr	PSME 100yr	PSMEG(1)	PSMEG(2)	TSHE 50yr	TSHE 100yr		
	<i>CMAI AGE</i>	<i>CMAI AGE</i>	<i>CMAI AGE</i>	<i>CMAI AGE</i>	<i>CMAI AGE</i>	<i>CMAI AGE</i>	<i>CMAI AGE</i>	<i>CMAI AGE</i>	<i>CMAI AGE</i>	<i>CMAI AGE</i>	<i>CMAI AGE</i>	<i>CMAI AGE</i>	<i>CMAI AGE</i>	<i>CMAI AGE</i>		
203										211	60				335	50
204										211	60				336	50
205										212	60				338	50
206										213	60				340	50
207										214	60				341	50
208										214	60				343	50
209										215	60				344	50
210										216	60				346	50