Research Note

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AERIAL VOLUME TABLES FOR PONDEROSA PINE TYPE IN THE ROCKY MOUNTAINS

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These aerial photo volume tables for ponderosa pine type result from the continuing research in direct photo estimating conducted at the Intermountain Forest and Range Experiment Station, Ogden, Utah.1/

Volume estimating by direct photo measurement requires a different approach from ground cruising. Individual trees have little meaning to the photo interpreter; he sees and measures plots or stands. His estimates are most reliable when he has learned to think in terms of mean per acre volumes as they relate to the direct photo measurements of stand height, crown diameter, and crown coverage.

Photo interpreters have difficulty in identifying species on the small or medium scale photos usually available, and since many forest types contain a mixture of hardwood or conifer species, aerial stand volume tables usually are prepared as composite tables. Such tables may be for either conifer or hardwood, depending on the predominant cover, and usually are compiled from plots having a random grouping of species.

Ponderosa pine, however, occurs as a relatively pure type over extensive areas throughout the West. Although Douglas-fir and a few other conifers may be found on some north slopes, they rarely constitute more than 20 percent of the per acre volume in this so-called pure type.

The type is easy to recognize on aerial photos. Its identifying characteristic is the tendency to grow even-aged in small groups with crown cover of the dominant stand often less than 55 percent of the acre. In the more

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1/ Moessner, Karl E. Preliminary aerial volume tables for conifer stands in the Rocky Mountains. U.S. Forest Serv., Intermountain Forest and Range Expt. Sta. Research Paper 41, 17 pp. illus. 1957.

open stands, where crown coverage of mature trees may range from 5 to 35 percent, characteristic shadows aid the interpreter in recognizing the type. Because of these silvicultural characteristics, and because tests indicate volumes significantly lower than those obtained from the composite aerial volume tables published in Research Paper 41, a separate aerial table has been prepared for ponderosa pine.

Procedure

The following tables were compiled from 84 plots measured in Idaho, Utah, Colorado, and the Black Hills of South Dakota. They relate gross board-foot and cubic-foot volumes from field measurements of 1/5-acre plots with direct photo measurements of the same plots.

Photo measurements consist of:

1. Average total height of the dominant stand.
2. Average visible crown diameter of the dominant stand.
3. Crown coverage of the dominant stand.

Photo measurements of total height were checked against the ground measurements of the three tallest trees on the 1/5-acre plot.

Gross volumes were computed from field data using total height-d.b.h. tables developed by Forest Survey and include:

1. Gross cubic volume--trees 5.0 inches d.b.h. and larger to a 4-inch top.

2. Gross board foot International ¼-inch Rule--trees 11.0 inches and larger to a variable top with a minimum of 5.5 inches.

3. Gross board foot (Scribner)--trees 9.0 inches[2/] and larger to same top diameters.

Volumes include cull trees and sound and cull portions of sound trees since the interpreter cannot recognize these conditions.

These tables were constructed by the alignment chart method of solving problems in multiple curvilinear correlations described by Bruce and Reineke.[3/] They are designed for use in direct photo estimates of ponderosa pine stands throughout the central Rocky Mountain areas. Use of a limited field sample should allow adjustment of these estimates to fit local areas.

2/ The 10-inch diameter class is used in many regional timber sales and accounts for the apparent inconsistency in the tables where a larger volume is shown for Scribner than for International ¼-inch Rule, particularly in the smaller stands.

Standard Measures of Accuracy

Standard measures of accuracy for the three tables are shown in the following tabulation:

Table	Aggregate deviation	Standard error of estimate[4/]	
	Percent	Units per acre	Percent
Gross volume Cubic feet	-0.31	±890	±40.8
Gross volume Board foot International	+1.79	±5,620	±54.3
Gross volume Board foot Scribner	-1.52	±4,884	±52.0

Tests of the Tables

A few tests of these ponderosa pine tables were made by comparing plot volumes with those obtained from field measurements and with those read from composite aerial tables published in Research Paper 41. For the most part, these plot series tests showed that mean per acre board-foot and cubic-foot volumes obtained from the ponderosa pine tables differed significantly from those obtained from the composite tables, but did not differ significantly from mean volumes obtained from ground measurements.

In addition, these tables were used by the five photo interpreters who made aerial estimates of ponderosa pine volumes on cutting compartments of the Boise Basin Experimental Forest, and on sales in the Black Hills National Forest in 1958. Summarized in a recent paper,[5/] these data clearly indicate that properly trained photo interpreters using these ponderosa pine tables can make excellent aerial estimates throughout much of the ponderosa pine type.

3/ Bruce, D., and L. H. Reineke. Correlation alinement charts in forest research: a method of solving problems in curvilinear multiple correlation. U.S. Dept. Agr. Tech. Bul. 210, 87 pp., illus. 1931.

4/ Defined as the standard deviation of the difference between paired photo and field plot volumes, expressed in units per acre or as a percent of the average plot volume. The standard error of estimate indicated for these aerial tables is large because 1-acre plots measured on photos were compared with 1/5-acre plots measured on the ground. The true value of these tables is somewhat better than these errors indicate.

5/ Moessner, Karl E. Estimating timber volume by direct photogrammetric methods. Soc. Amer. Foresters Proc., pp. 148-151. 1959.

AERIAL VOLUME TABLE--PONDEROSA PINE

Gross cubic-foot volume per acre by average stand height, crown diameter, and crown cover

1- TO 10- (5) FOOT CROWN DIAMETER

Average stand height (feet)	Crown cover (percent)									
	5	15	25	35	45	55	65	75	85	95
	Ten cubic-feet									
25	--	--	--	2	11	20	30	40	47	54
30	--	--	7	17	28	38	48	56	64	72
35	--	14	26	37	47	56	65	74	82	88
40	22	35	47	58	67	75	84	93	99	105
45	52	64	76	87	95	103	111	119	125	131
50	81	92	102	111	119	128	136	144	152	160
55	96	107	118	127	135	143	152	162	172	182
60	109	120	130	139	148	159	170	182	194	206
65	119	129	140	152	164	176	188	200	214	230

11- TO 20- (15) FOOT CROWN DIAMETER

25	--	--	--	12	22	31	40	48	55	62
30	--	4	16	28	39	48	55	62	70	78
35	10	23	36	48	58	67	75	83	90	97
40	31	44	55	66	76	84	92	99	106	113
45	61	73	84	94	103	111	119	126	132	138
50	89	100	111	120	128	136	144	153	163	173
55	103	115	125	134	143	152	163	174	185	196
60	116	126	137	148	159	170	182	195	210	225
65	126	137	148	160	173	186	201	217	233	249
70	137	148	162	176	190	205	223	241	258	275
75	161	176	194	214	235	255	275	290	305	319
80	190	213	237	262	282	299	315	330	345	357
85	245	275	295	317	335	350	365	380	395	405
90	299	321	342	362	380	396	410	422	434	445
95	353	373	392	410	426	440	453	465	475	485
100	403	423	441	457	471	483	495	506	516	525
105	430	449	466	481	494	505	516	527	537	545
110	457	475	491	506	517	528	538	548	558	567
115	482	499	515	529	540	551	561	571	580	589
120	506	523	537	550	562	572	582	591	600	608

21- TO 30- (25) FOOT CROWN DIAMETER

Average stand height (feet)	Crown cover (percent)									
	5	15	25	35	45	55	65	75	85	95
	Ten cubic-feet									
25	--	--	10	22	32	42	50	58	66	73
30	1	15	27	38	48	57	66	75	82	89
35	21	35	47	58	68	76	84	92	98	10[illegible]
40	43	54	65	76	86	94	102	109	116	123
45	72	84	94	104	112	120	128	135	142	149
50	98	109	120	129	137	145	155	165	175	185
55	113	124	134	144	154	165	176	188	200	214
60	125	136	147	158	171	184	199	215	231	245
65	136	148	161	174	188	204	222	240	258	275
70	146	160	176	193	210	227	245	264	283	297
75	173	190	213	236	257	276	294	310	324	336
80	208	234	260	282	301	318	333	348	362	375
85	270	293	315	336	353	369	384	399	411	422
90	317	340	361	381	398	412	425	438	450	461
95	369	393	413	430	443	456	469	481	492	500
100	417	437	455	471	485	496	507	518	529	537
105	445	463	480	496	507	518	529	539	549	557
110	472	488	503	517	539	541	552	561	570	578
115	496	512	528	542	552	562	572	582	592	600
120	520	535	550	563	574	584	594	604	613	620
125	541	556	571	584	594	604	613	622	631	640
130	562	576	590	602	612	622	632	641	649	657
135	580	594	607	618	628	638	648	658	666	674
140	598	611	624	636	646	655	664	673	682	690
145	614	627	640	652	662	672	682	691	699	707
150	630	643	656	667	677	687	697	706	714	722

Note: Stand height, crown diameter, and crown cover from photo measurements of field plots. Volumes from field measurements computed by Forest Survey total height-d.b.h. cubic-foot volume tables.

Based on 84 field plots measured in Idaho, Utah, Colorado, and the Black Hills.

Aggregate deviation: Table 0.31 percent low.

Standard error of estimate: ±41 percent of the average plot volume.

Forest Survey, Intermountain Forest and Range Experiment Station,
Ogden, Utah, 1958.

AERIAL VOLUME TABLE--PONDEROSA PINE

Gross board foot volume per acre (International ¼-inch) by average stand height, crown diameter, and crown cover

1- TO 10- (5) FOOT CROWN DIAMETER

Average stand height (feet)	Crown cover (percent)									
	5	15	25	35	45	55	65	75	85	95
	Hundred board-feet									
35	--	--	--	--	1	2	4	5	6	7
40	--	1	3	5	6	7	9	11	13	14
45	3	4	6	8	10	12	14	17	20	22
50	6	8	10	13	16	19	23	28	32	34
55	10	13	16	20	24	28	33	38	42	44
60	16	20	25	30	35	40	45	50	54	56
65	25	31	36	41	46	51	57	63	68	72

11- TO 20- (15) FOOT CROWN DIAMETER

30	--	--	--	--	--	1	2	4	5	6
35	--	1	2	4	5	6	8	10	12	13
40	4	5	7	9	11	14	17	20	23	25
45	7	9	12	15	18	21	25	30	34	36
50	12	15	19	24	28	32	36	41	45	48
55	19	23	29	34	39	44	49	54	58	61
60	29	34	39	44	49	54	60	66	72	76
65	40	45	51	57	63	69	76	83	90	94
70	52	58	65	72	78	84	91	100	108	112
75	71	77	85	95	103	110	117	126	133	137
80	95	105	114	122	130	137	144	151	158	162
85	130	138	146	155	162	168	175	184	191	195
90	168	176	186	195	202	209	215	221	226	230
95	198	207	217	225	231	237	245	254	261	265
100	222	230	240	249	257	265	273	281	288	293
105	242	251	261	271	279	287	295	304	312	318
110	263	275	286	296	305	314	323	332	339	345
115	284	295	305	315	325	334	343	353	361	367
120	304	314	325	335	345	354	363	372	380	386

21- TO 30- (25) FOOT CROWN DIAMETER

Average stand height (feet)	Crown cover (percent)									
	5	15	25	35	45	55	65	75	85	95
	Hundred board-feet									
40	6	8	11	14	16	19	22	27	31	34
45	11	14	17	21	25	29	33	38	42	45
50	17	22	27	32	36	40	45	51	56	59
55	27	31	36	42	47	52	58	65	70	73
60	36	41	47	53	59	65	71	78	83	87
65	49	55	63	69	75	81	88	97	105	110
70	63	69	76	83	90	98	107	115	122	126
75	80	88	99	109	117	123	130	138	144	149
80	110	119	128	137	144	150	157	165	171	175
85	142	150	159	167	175	182	190	198	204	208
90	184	191	200	208	214	220	227	235	241	246
95	213	220	228	236	244	251	259	269	276	280
100	235	244	255	264	272	279	287	296	304	308
105	258	267	277	286	295	303	312	322	329	335
110	280	290	300	311	320	329	338	348	355	360
115	298	308	319	330	340	349	358	368	375	380
120	320	330	340	351	360	369	377	385	393	399
125	340	350	361	371	380	388	396	406	414	420
130	362	372	382	391	400	409	418	427	435	441
135	381	390	400	411	420	428	436	445	453	459
140	401	410	421	431	440	447	455	464	472	478
145	420	430	440	449	458	466	474	483	490	496
150	440	449	460	470	478	485	493	502	510	516

Note: Stand height, crown diameter, and crown cover from photo measurements of field plots. Volumes from field measurements computed by Forest Survey total height-d.b.h. board-foot (International ¼-inch) table.

Based on 84 field plots measured in Idaho, Utah, Colorado, and the Black Hills.

Aggregate deviation: Table 1.79 percent high.

Standard error of estimate: ±54 percent of the average plot volume.

Forest Survey, Intermountain Forest and Range Experiment Station,
Ogden, Utah, 1958.

AERIAL VOLUME TABLE--PONDEROSA PINE

Gross board-foot volume per acre (Scribner) by average stand height, crown diameter, and crown cover

1- TO 10- (5) FOOT CROWN DIAMETER

Average stand height (feet)	Crown cover (percent)									
	5	15	25	35	45	55	65	75	85	95
	Hundred board-feet									
30	--	--	1	2	3	4	5	6	7	7
35	2	3	4	5	5	6	7	8	9	9
40	4	5	6	7	8	9	10	12	15	17
45	6	7	8	9	10	13	17	21	23	26
50	9	10	13	17	20	23	27	31	33	36
55	16	20	24	28	31	34	38	41	42	43
60	27	30	35	38	41	43	45	47	48	50
65	38	41	43	45	47	49	52	55	58	60

11- TO 20- (15) FOOT CROWN DIAMETER

30	2	3	4	5	5	6	7	8	9	9
35	4	5	6	7	8	9	10	12	15	17
40	7	8	9	10	11	14	18	22	25	27
45	9	10	13	17	21	24	27	30	33	35
50	15	18	22	26	30	34	37	40	42	43
55	26	29	33	37	40	42	44	46	47	48
60	37	40	42	44	46	48	50	53	56	59
65	44	46	48	51	54	57	61	65	69	72
70	51	54	58	62	66	70	75	81	86	90
75	62	67	72	77	82	88	94	100	105	110
80	78	84	90	96	102	108	115	122	129	135
85	106	113	120	127	135	144	154	163	171	178
90	140	149	158	167	176	184	191	197	202	205
95	184	191	197	202	206	210	214	218	221	224
100	210	214	218	222	226	230	235	239	243	246
105	220	224	228	232	236	241	246	250	254	257
110	231	236	240	244	248	253	258	264	270	275
115	240	245	250	255	260	266	273	279	285	290
120	251	256	261	267	274	281	289	297	305	311

21- TO 30- (25) FOOT CROWN DIAMETER

Average stand height (feet)	Crown cover (percent)									
	5	15	25	35	45	55	65	75	85	95
	Hundred board-feet									
40	9	10	13	16	19	22	26	29	32	35
45	13	17	21	25	28	31	34	37	40	42
50	23	27	31	34	37	40	42	44	46	47
55	33	37	41	43	44	46	48	50	53	56
60	43	45	47	49	52	55	58	62	65	68
65	49	52	55	58	62	66	71	76	81	85
70	59	63	67	73	77	82	88	94	100	105
75	73	79	85	91	97	103	109	115	121	127
80	91	98	105	112	118	125	133	141	148	155
85	120	129	139	148	157	166	175	182	188	193
90	162	172	180	187	192	197	203	208	211	214
95	197	202	207	212	215	218	223	227	230	233
100	219	223	227	231	235	239	245	249	253	257
105	228	233	238	243	247	251	256	261	266	271
110	239	245	250	255	260	266	272	278	284	289
115	250	255	260	266	272	279	287	295	303	310
120	262	268	275	282	289	298	308	320	330	338
125	275	283	291	299	307	318	333	349	362	373
130	288	297	308	320	332	345	362	380	397	410
135	308	320	335	350	365	382	404	426	445	460
140	335	354	373	391	410	431	457	478	499	519
145	372	390	410	431	453	475	497	520	542	562
150	407	429	451	472	493	513	533	553	573	592

Note: Stand height, crown diameter, and crown cover from photo measurements of field plots. Volume from field measurements computed by Forest Survey total height-d.b.h. board-foot (Scribner) volume tables.

Based on 84 field plots measured in Idaho, Utah, Colorado, and the Black Hills.

Aggregate deviation: Table 1.5 percent low.

Standard error of estimate: ±52 percent of the average plot volume.

Forest Survey, Intermountain Forest and Range Experiment Station,
Ogden, Utah, 1958.