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AERIAL PHOTO VOLUME TABLES FOR DOUGLAS-FIR IN THE PACIFIC NORTHWEST

by

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The aerial photo volume tables in this report are tools to be used in obtaining better timber inventories. Volume estimates based on tables such as these, properly field checked, are generally cheaper than ground cruises of comparable accuracy. Photo volume tables also permit rough volume estimates to be made from aerial photos alone when limited time, bad weather, or inaccessibility precludes field work.

HOW TO USE THE TABLES

The general principles of using aerial photo volume tables are described in previous publications.[1/] [2/] However, there are a few practical problems which have not been adequately covered, and therefore deserve special mention here.

When the interpreter makes his estimates of stand height and crown density on the photos, it is important that he use the same definitions as those employed in constructing the volume table.

1/ American Society of Photogrammetry. Manual of photographic interpretation. 868 pp., illus. Menasha, Wis.: The George Banta Co., Inc. 1960.

2/ Spurr, Stephen H. Photogrammetry and photo-interpretation. 472 pp., illus. New York: The Ronald Press Co. 1960.

The stand height used in the accompanying tables (tables 1 and 2) is defined as the average height of the dominants and codominants, as measured in the field. In the even-aged stands for which the tables were made, it is quite easy for an interpreter to select the dominant and codominant trees. Most of the trees he sees are in these two crown classes, for experience has shown that few intermediate or suppressed trees are visible on aerial photographs.

However, in uneven-aged stands, crown classes do not have much meaning. A recommendation for this situation is to estimate the average height of all trees contributing substantially to the stand volume.

In constructing these tables, stand height was measured in the field, while in application it must be measured on the photos. And tests have shown that the photo height estimates made by most interpreters differ substantially from the field heights. Whenever photo volume estimates are being adjusted by means of field checks, this difference, or bias, can be safely ignored. However, when volumes are being estimated from photo samples alone, it is desirable to eliminate this height-measurement bias. Each interpreter should determine his own adjustment factors by measuring, both on the photos and in the field, a sample of stands throughout the range of heights. Each field height is plotted over the companion photo height, and a curve is fitted through the points. The interpreter then has a basis for correcting his photo height measurements before using the volume table.

In the dense stands of the Pacific Northwest, it is often impossible to measure stand height at the plot because the ground cannot be seen. Here the interpreter must exercise his ingenuity, estimating the ground reading by interpolation, or measuring nearby stands with a similar appearance.

The crown density estimates used in constructing these volume tables are based on all trees in the major canopy. This is an easy definition to apply in even-aged stands, for it includes all visible trees except the occasional ones well below the general canopy level. When it is desired to apply the tables to uneven-aged stands, the same procedure used for stand heights should be followed. That is, crown density estimates should include only those trees believed to contribute to the volume.

Table 1.--Aerial photo stand volume table for even-aged Douglas-fir in the Pacific Northwest

(In hundred cubic feet per acre)[1/]

Stand height[2/] (feet)	Crown density (percent)[3/]								
	15	25	35	45	55	65	75	85	95
40	5	8	11	13	14	15	15	14	13
50	7	11	15	18	20	21	22	21	20
60	9	15	20	24	27	29	30	29	28
70	12	19	25	31	34	37	39	39	38
80	14	24	31	38	43	46	48	49	49
90	17	28	38	45	52	56	59	61	61
100	21	33	45	54	61	67	72	74	75
110	24	39	52	63	72	79	85	88	90
120	28	45	60	73	83	92	99	103	106
130	31	51	68	83	95	106	114	120	124
140	35	57	77	94	108	121	130	138	143
150	40	64	86	105	122	136	148	157	163
160	44	71	96	118	136	153	166	177	185
170	49	79	106	130	152	170	185	198	208
180	54	87	117	144	168	188	206	220	232
190	59	95	128	158	184	208	227	244	257
200	64	104	140	173	202	228	250	269	284
210	70	113	152	188	220	249	274	295	313
220	75	122	165	204	239	271	298	322	342
230	81	132	178	220	259	293	324	351	373
240	87	142	192	238	280	317	351	380	406
250	94	152	206	256	301	342	379	411	439
260	100	163	221	274	323	367	408	443	474

[1/]Gross volume, in trees 5.0 inches and larger, from stump to top limit of 4.0 inches d.i.b. Volume tables from U.S. Dept. Agr. Handb. 92.

Equation for table: $V = 0.9233HD + 0.0070H^2D - 0.0086HD^2 - 179$

Where: V = volume, cubic feet per acre; H = stand height in feet; and D = crown density in percent

Multiple correlation coefficient (R) = 0.904

Standard deviation around regression (sometimes called standard error of estimate) = 3,777 cubic feet per acre, or 29.2 percent of the mean plot volume.

Based on 282 plots of one-fifth acre, largely in western Oregon.

[2/]Average height of dominants and codominants. Field measurements used in constructing table.

[3/]Includes all trees in the major canopy (occasionally excluding small trees definitely below the general canopy). Average photo estimate of several experienced interpreters used in constructing table.

Table 2.--Aerial photo stand volume table for even-aged Douglas-fir in the Pacific Northwest

(In thousand board feet per acre)[1]

Stand height[2] (feet)	Crown density (percent)[3] 15	25	35	45	55	65	75	85	95
50	1	3	4	5	5	4	3	1	--
60	2	5	7	8	8	8	6	4	--
70	4	8	10	12	13	12	11	8	4
80	6	11	14	17	18	18	16	14	10
90	8	14	19	22	23	24	23	20	16
100	10	18	23	28	30	31	30	28	24
110	13	22	29	34	37	39	39	37	34
120	16	26	34	41	46	48	49	48	44
130	19	31	41	49	54	58	60	59	56
140	22	36	48	57	64	69	72	72	70
150	25	41	55	66	75	81	85	86	85
160	29	47	63	76	86	94	99	101	101
170	33	53	71	86	98	107	114	118	118
180	37	60	80	97	111	122	130	135	137
190	41	67	89	108	125	138	148	154	158
200	46	74	99	121	139	154	166	174	179
210	50	82	109	134	154	172	185	196	202
220	55	90	120	147	170	190	206	218	226
230	60	98	132	161	187	209	228	242	252
240	66	106	143	176	205	230	250	267	279
250	71	116	156	192	223	251	274	293	308
260	77	125	168	208	242	273	299	320	337

[1]Gross volume, Scribner Decimal C, in trees 11.0 inches and larger. Trees 11.0 to 20.9 inches scaled in 16-foot logs to top d.i.b. of 50 percent of the scaling diameter of butt log. Trees 21.0 inches and larger scaled in 32-foot logs to top d.i.b. of 60 percent of the scaling diameter of the butt log. Volume tables used: Mason, Bruce, and Girard, based on total height and form class.

Equation for table: $V = 0.9533D^2 + 3.2313HD + 0.0716H^2D - 0.0883HD^2 - 3285$

Where: V = volume, board feet per acre; H = stand height in feet; and D = crown density in percent

Multiple correlation coefficient (R) = 0.918

Standard deviation around regression (sometimes called standard error of estimate) = 26,312 board feet per acre, or 34.8 percent of the mean plot volume.

Based on 282 plots of one-fifth acre, largely in western Oregon.

[2]Average height of dominants and codominants. Field measurements used in constructing table.

[3]Includes all trees in the major canopy (occasionally excluding small trees definitely below the general canopy). Average photo estimate of several experienced interpreters used in constructing table.

So far, not enough data have been collected in hemlock or true fir types to determine whether volume tables for these types are different. However, the Douglas-fir volume tables have been tested on 51 plots in hemlock types and 33 in true fir types, with some indication that these types have higher volumes than Douglas-fir. Tentatively it is suggested that these volume tables be multiplied by the following factors whenever the types can be identified as hemlock or true fir:

	Cu. ft.	Bd. ft.
Type:		
Western hemlock	1.17	1.23
True fir	1.55	1.36

HOW THE TABLES WERE CONSTRUCTED

Basic Data

The basic data for these volume tables were gathered on 282 plots of one-fifth acre scattered throughout western Oregon and a portion of southwestern Washington. Plots were confined to even-aged stands having a predominance of volume in Douglas-fir trees. Each plot was measured in the field to obtain volume, height, and site index data. Plot centers were marked on recent 1:12,000-scale panchromatic photos. Crown density and average crown diameter for each plot were estimated on the photos by two experienced interpreters. Whenever their estimates of density differed by more than 10 percent, or average crown diameter by more than 5 feet, additional estimates were obtained from several other interpreters. In either case, averages of the photo estimates were used in constructing the tables.

Analysis

Multiple regression analysis was used to determine the volume table equations that relate the various stand characteristics to per-acre volumes. The dependent variables used were:

y_1--Gross cubic-foot volume per acre in trees 5.0 inches and larger, from stump to top limit of 4.0 inches d.i.b. Volume tables from U.S. Department of Agriculture Handbook 92.

y_2--Gross board-foot volume per acre, Scribner Decimal C, in trees 11.0 inches and larger. Trees 11.0 to 20.9 inches scaled in 16-foot logs to top d.i.b. of 50 percent of scaling diameter of butt log. Trees 21.0 inches and larger scaled in 32-foot logs to top d.i.b. of 60 percent of scaling diameter of butt log. Volume tables used: Mason, Bruce, and Girard, based on total height and form class.

The basic independent variables tested as predictors of stand volume were:

x_1--Stand height (H). Average height of the dominants and codominants, in feet, based on Abney level measurements in the field.

x_2--Crown density (D). Crown density of the major canopy, in percent (occasionally excluding small trees definitely below the general canopy level), based on averaging the photo estimates of several interpreters.

x_3--Average crown diameter (C). Average of the dominants and codominants, in feet, based on averaging the photo estimates of several interpreters.

x_4--Site index. Average height of the dominant and codominant Douglas-firs at 100 years, based on field measurements of several trees at each plot. (This variable was introduced as a matter of research interest, even though as yet it cannot be accurately determined on aerial photos.)

In addition to these, five other independent variables were made up of squares and cross-products of the basic variables to take care of curvilinearity and interaction. These were:

x_5--Height squared (H^2).

x_6--Crown density squared (D^2).

x_7--Height times density (HD).

x_8--Height squared times density (H^2D).

x_9--Height times density squared (HD^2).

Separate regression analyses were made for cubic-foot volume and board-foot volume, using an electronic computer program.[3] This program solves each of the 511 possible equations relating volume to one or more of the independent variables. Included in the program output are the regression coefficients for each equation, and the data necessary for the selection of those equations which are the best predictors of stand volume.

During the data collection phase of the study, three geographic strata were sampled: The Cascade Range of Oregon and southern Washington, the Oregon Coast Ranges, and southwestern Oregon. The purpose here was to learn if geographic area had any influence on the volume tables.

An initial inspection of the basic data indicated that there were no differences among geographic strata with respect to the volume table characteristics. Therefore, all data were pooled to make one set of volume tables. The validity of this has been confirmed by testing the pooled tables separately on the plots from each stratum. The mean tabular and field volumes differed by only small amounts which were not significant.

The Volume Table Equations

The selection of the final volume table equations, one for cubic feet and one for board feet, was based on several considerations. Of primary importance was the contribution of each variable to the prediction of stand volume, and the practicability and cost of measuring the variable. Also considered was the compatibility of the two equations--that is, the selected equations were checked to make sure that the resulting board-foot/cubic-foot ratios were reasonable when compared with ratios obtained from the basic data.

The final equations selected contain only the variables of stand height and crown density, plus several combinations of these two. Site index <u>did</u> contribute significantly to the prediction of stand volume. However, it was eliminated from the final equations because it cannot

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[3] Grosenbaugh, L. R. The elusive formula of best fit: A comprehensive new machine program. U.S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 158, 9 pp., illus. 1958.

be accurately measured on aerial photos. Average crown diameter contributed a small but significant amount to the board-foot equation, but added nothing to the cubic-foot equation. In total, the measurement of crown diameter on the photos was not worth the effort.

The final equations selected, along with their correlation coefficients and standard errors of estimate, are shown at the foot of the volume tables. It should be kept in mind that the high correlation coefficients are partly a result of using field-measured stand heights. In practice, when the tables are used to estimate volumes, the errors of measuring stand height on the photos will result in somewhat lower correlation coefficients and a corresponding increase in the standard errors of estimate.

There is one feature of the board-foot volume table which has not appeared in other published tables, and which may startle foresters familiar with photo volume estimation. In the lower height classes, stand volume reaches a maximum in the middensity classes, dropping off as density increases. At first glance this would appear to be illogical.

Whether or not this reverse trend of volume actually occurs is not known, but there are two possible explanations for it.

First, the multiple regression analysis provides a family of curves which fit the data best on the average. There is no assurance that these curves will necessarily fit every part of the data perfectly.

The second point is that there is a biological explanation which might account for this seemingly strange trend. Examination of the field data for some of the lower height classes indicates that the stands are mixtures of sawtimber and poletimber trees. In the lower and middle density classes, many of the trees are sawtimber size, but as density increases, tree diameter decreases, and fewer trees are of sawtimber size. This tends to reduce the board-foot volume.