THE RELATIVE ACCURACY OF VARIOUS METHODS
OF COMPILING TIMBER ESTIMATES BY VOLUME TABLES

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In compiling the field notes of forest surveys and timber estimates foresters are frequently uncertain as to the best method of using existing volume tables. While the field work is in progress, measurements may be taken of representative trees, in order to check the general applicability of the volume table which it is proposed to use. However, in subsequent office work it is sometimes difficult to decide whether it is necessary to work up the volumes of the individual trees tallied in the field notes, by height and diameter, in order to secure a desired degree of accuracy. As an alternative, a local volume table may be prepared for each part of the region under consideration, by drawing a height-diameter curve from the field notes and then a diameter-volume curve, based on this first curve, and the standard volume table.

As a second alternative, a single table can be prepared in the same way to apply to the entire region.

This problem arose in connection with cruising work and the measurement of sample plots at the Aleza Lake Forest Experiment Station, and a study of the matter was made to determine the relative accuracy, and practicability of use, of the various methods referred to above.

The following material represents the compilations of the volumes of Engelmann spruce on 12 plots established at the Experiment Station in 1926. The plots, each of 0.4 acres in area, were laid out in mature stands of the spruce-balsam type typical of the Upper Fraser River district. At the time of establishment the D.B.H. and height of all trees over 4.0 inches D.B.H. on the plots was measured by caliper and abney level.

Board foot volumes were compiled for those trees on the plots of 8.0 inches and over by four different methods as follows:

- (1) The volume for each plot was determined from a standard volume table (B.C. log rule) by segregating the trees into one inch D.B.H. and ten foot height classes. This table, the one commonly used by the Forest Service during recent years for cruising work, was published in the Annual Report of the Service for 1926. It was prepared by the frustum form factor method from measurements of 851 trees taken in various parts of the spruce region of central British Columbia.

- (2) The volume for each plot was determined from the same volume table by using one inch D.B.H. classes only, and reading the corresponding volume from the column of the table entitled "Average Volume," which is the curved average volume for each D.B.H. class of all the original trees used in compiling the volume table.
- (3) The volume for each plot was determined by D.B.H. classes from a local volume table prepared from the standard table as follows:
 - (a) A curve of total height on D.B.H. was made for each plot.
 - (b) From this curve the average height of the tree of each D.B.H. class was read.
 - (c) The volume corresponding to this D.B.H. and height was read from the standard volume table, and these volumes were curved to smooth out any minor irregularities.
 - (d) The curved values formed the local table from which the volume of the plot was compiled directly by D.B.H. classes.
- (4) The volume for each plot was determined by D.B.H. classes from a local volume table for all twelve plots prepared from a D.B.H.-height curve based on the trees of all the plots as in the previous method.

As a basis for comparison of the different methods the first method is assumed to be correct. The standard volume table, when applied by one inch D.B.H. and ten foot height classes, has been found reliable for the Aleza Lake District. During the summer of 1926 two one-acre sample plots were laid out and a 100 per cent cruise made of them by one-inch D.B.H.-ten foot height classes. These plots were logged in the winter, and the trees were scaled as they were felled. The difference between the cruised and scaled volume was less than 2%.

The following table shows the results obtained by each method.

Summary of Volumes

Engelmann Spruce, on 12 sample plots

Aleza Lake Experimental Forest

Method of Volume Estimation

Plot No.	(1) Based on DBH and T.H. from standard volume table.		(2) Based on DBH only, from average Vol. of Volume Table		(3) Based on DBH only, from local table for each plot		(4) Based on DBH only from local table for all 12 plots	
	Volume	Error %	Volume	Error %	Volume	Error %	Volume	Error %
1	8889	Taken as correct	8489	- 4.5	8970	+0.9	7743	-12.7
2	4313		4978	+15.4	4307	-0.1	4616	+ 7.0
3	5142		5503	+ 7.2	5036	-2.0	5065	- 1.5
4	6266		6857	+ 9.4	6260	-0.1	6238	- .4
5	5504		5867	+ 6.6	5677	+3.1	5365	- 2.5
6	7490		8218	+ 9.7	7596	+1.4	7580	+ 1.2
7	4609		4357	- 5.5	4569	-0.9	3967	-13.9
8	5414		6265	+15.7	5380	-0.6	5681	+ 5.0
9	5671		6274	+10.6	5608	-1.1	5661	- 0.2
10	4516		5339	+18.2	4546	+0.7	4852	+ 7.5
11	6000		7675	+27.9	6044	+0.7	7036	+17.2
12	3508		3452	- 1.6	3552	+1.3	3126	-10.9
Total	67322	0.0	73274	+ 8.8	67545	+0.3	66930	- 0.6

Application of the Different Methods

1. The first method requires a tally of all the trees by one inch D.B.H.-ten foot height classes and while this may be desirable in sample plot work, it has been found too costly in ordinary cruising practice even when the heights are estimated by eye. Even in sample plot work, when there are few trees per plot, this method may lead to errors, since the actual tree heights may not average the even ten foot height classes. In very accurate sample plot work a modification should be employed in which each tree is recorded to the nearest 10th inch in diameter and to the nearest foot of height, and the volumes for each tree interpolated accordingly.

2. The second method is the least accurate of any and is not recommended except in rare cases for rough estimates over large areas such as is required in reconnaissance surveys. Over a large area the volumes of average trees for the different diameters classes stand a greater chance of conforming to the average volumes of the volume tables and in such a case there might be some justification of this method.

3 The third method is best suited for making estimates over small areas such as sample plots. In the above compilations the height curve is based on the height of every tree on the plot, but on a small plot where site conditions are uniform there is little variation between the heights of trees of the same diameter class and if only three or four trees of each diameter class are measured a sufficiently accurate curve can usually be obtained. Any small errors which occur will compensate over a number of plots.

4. The fourth method is really a modification of the third. While the latter gives an accurate volume per plot the fourth gives practically the same results over all the plots. This method is best adapted to forest reserve surveys where accurate estimates over small lots is not of particular importance. If sufficient heights are taken over the whole area cruised it will give a fair estimate over the area as a whole, but if the local table be applied to a small lot within the area serious errors may occur.

In the above compilations, the D.B.H.-height curves used in making up the local volume tables are based on all the trees to which the table is later applied, so that the curved heights read from these curves and hence the volume tables derived from them are true averages for the material under consideration. If, however, these trees are regarded as sample trees representative of a large field of material the averages obtained by curving will only approximate a true average. By statistical methods it may be determined how many such sample trees should be measured in order to obtain curves within any limit of error.

The plus and minus deviations of the actual heights from the curved heights was determined for each tree and on plotting, the frequency distribution was found to be normal. The average deviation was then calculated and the standard deviation calculated from the approximation formula $S D = 1.25 A D$ was found to be 9.06. Since the distribution of the deviations was practically the same over the small and large diameter classes, this method of calculating the standard deviation was deemed sufficiently accurate for all practical purposes.

Knowing the standard deviation, the standard error calculated from the formula (std. error = $\frac{\text{Std.Dev.}}{n}$) becomes $\frac{9.06}{383} = .46$,

and taking 3 times the standard error as the limit of precision it can be said with reasonable confidence that the average height as given by the curve is within 1.4 feet of the true average.

The number of measurements required in order to obtain averages within a given maximum error and the corresponding maximum error which would occur in the volume table is as follows.

Maximum Error in Height Curve	Number of Samples Req'd.	Maximum Error in Vol. Table.
0.5 feet	2730	0.8%
1.0	750	1.6%
1.5	330	2.4%
2.0	185	3.2%
3.0	82	4.8%

In the above examples the average deviation was 7.26 and the standard deviation 9.06. In cases where the deviations were greater than these a greater number of sample trees would have to be measured in order to secure the same precision. As a general rule however, 1000 sample trees should give a sufficient degree of accuracy.