RELATIVE EFFICIENCY OF SOME SPECIFIC PLOT-SIZES IN ESTIMATING TIMBER VOLUMES IN SOME SPECIFIC TIMBER TYPES¹

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ABSTRACT

The following report illustrates the methods and results of making tests of the comparative efficiency of some plot-sizes in inventory work. The results of the tests showed that 1/10-acre plots are more efficient than 1/5-acre plots in inventories of 100-120-year-old Douglas fir stands; 1/10-acre plots are more efficient than 1/40-acre plots in inventories of 50-year-old Western hemlock stands; 1/5-acre plots are more efficient than 1/10-acre plots in inventories of mature uneven-aged Spruce-balsam stands; 1/4-acre plots are more efficient than either 1/20 or 1/2-acre plots in inventories of 50-year-old Douglas fir stands. In addition to these tests in well-stocked stands, an inventory of a thinned stand of 50-year-old Douglas fir showed that 1/2-acre plots are more efficient than 1/4-acre plots.

Admittedly the conclusions are limited to which is the most efficient of the two, or three, plot sizes tried in each type, and provides only an indication that an even larger, or a much smaller size, might have been more efficient than the ones tried.

INTRODUCTION

A review of literature has shown that various plot-systems have been widely used as a means of tallying stem distributions, estimating total volumes of stands, predicting growth, and determining precision of sampling. Many variations in numbers, sizes, and shapes of plots have been used by the investigators, depending on the variable to be measured, namely: numbers of trees, basal area, volume, or reproduction; and the cause of variation—age, site, species, stocking, or type. Various shapes of plots such as rectangular, circular, square, and diamond have been used in sizes which range up to ten acres. In addition, schemes of sampling varied as continuous transects of plots, systematic line plots, randomly located plots, and clusters of plots.

Uniformity trials on plot-size, shape, and arrangement have been conducted very extensively for agricultural crops. The same will eventually be necessary for forest crops, but such trials will require the planning and opinions of expert biometricians. Any large-scale program to evaluate all

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plot-sizes, shapes, and arrangements would be very costly, and a number of years might elapse before any information was available. For this reason any large-scale program could only be undertaken by very large organizations. Meanwhile, it is essential that the everyday, practicing forester obtain guiding information which will contribute to the final results of a much larger program of plot-size standardization.

Already much guiding information on plot-sizes has been accumulated by various investigators in differing areas.

Bickerstaff¹, after investigations on one-tenth and one-fifth acre plots in mixedwoods stands, recommended that, for immature stands having less than approximately 1,000 trees per acre, one-fifth acre plots should be used when sampling by line-plots. Johnson and Hixon² after comparing coefficients of variation and cruising time required for twelve different sizes and shapes of plots, concluded that one-chain by three-chain (three-tenth acre) rectangular plots are the most efficient size and shape of sample plot to use for intensive cruise work in old-growth Douglas fir. The U.S. Forest Service, Department of Agriculture³ recommended that a plot be of such a size that it contain at least 100 trees of the predominant age-class. For this purpose they recommend rectangular plots which in length should not be more than 2.5 or 3 times their width. Hazel,² basing his conclusions on 2.5-acre, 5-acre, and 10-acre plots in an all-aged pine type, found that the 2.5-acre plots were the most efficient. He suggests that the minimum size of plot used in cruising should not often contain zero volumes and that tests should be made to find the kind of plot, or sampling unit, which includes the maximum of stand variation per unit of area.

The conclusions given in the foregoing references are a valuable aid to the practicing forester who may be working in similar types. However, in types where no formal studies have been made, the forester should be in a position to build up his own guides with respect to most suitable plot-sizes. Often this can be done at very little expense. For example, an arbitrary decision is made to cruise a tract of timber using a specific size of plot, say one-fifth acre. For the added expense of tallying and compiling the trees by half-plots (one-tenth acre), some guiding information is available for the next time a similar type must be cruised. The following report illustrates the methods and results of making such tests. Admittedly, the conclusions are limited to which is the most efficient of the two, or three, plot-sizes tried, and provides only an indication that an even larger, or, alternatively, some much smaller size might have been more efficient than the ones tried. However, by a gradual system of trial and error, as opportunity presents, a pattern of efficient plot-sizes should develop.

THE MEASURE OF EFFICIENCY OF PLOT-SIZES

At times a measure of relative dispersion of values is required independent of the unit of measurement employed. Such a measure is the coefficient of variation. It is the percentage ratio of the standard deviation to the arithmetic mean. This coefficient is used chiefly in comparing two sets of values as to variability where the absolute values of the standard deviations are very

different and, therefore, not comparable measures of variability. The coefficient of variation is given by the formula:

$$V = \frac{SD}{M} \times 100\%$$

where: SD = the standard deviation of the absolute values about the arithmetic mean.

M = the arithmetic mean.

The usefulness of this measure becomes apparent when one wishes to determine the number of plots necessary to sample a given tract of timber and to compare the relative efficiency of two or more different plot-sizes. In the simplest form of unrestricted random sampling, the number of plots necessary to sample a tract of timber is given by the formula:⁴

$$n = \frac{N V^2 t^2}{NE^2 + V^2}$$

where: n = the number of plots required.

N = the total number of sampling units in the population, or the total acreage divided by the area of one sample plot.

V = the coefficient of variation in per cent.

t = a statistical measure of confidence.

E = the allowable error in per cent.

To compare the relative efficiency of two different plot-sizes as units for sampling similar tracts of timber, it is merely necessary to solve the above equation for set values of E and N likely to be encountered in future work, and compare the number of plots required. However, while it is conclusive evidence to state, for example, that thirty 1/5-acre plots will provide as precise an estimate of timber volume on a certain tract as forty 1/10 acre plots, such a statement requires qualification. The cruiser must weigh his conclusion by the variable time-cost factor in establishing the different sized plots.

BASIC DATA

The objective is to compare relative efficiencies of various plot sizes for estimating timber volumes.

Basic data for this study were drawn from cruises in four Experimental Reserve areas of the British Columbia Forest Service. In these areas data were collected from samples of thirty 1/5- and 1/10-acre plots in a Douglas fir stand of total age 117 years; from samples of fifty-six 1/10- and 1/40-acre plots in a western hemlock stand of total age 50 years; from samples of seventeen 1/5- and 1/10-acre plots in an uneven-aged spruce-balsam stand; from samples of fourteen 1/2- and 1/4-acre plots and seventeen 1/20-acre plots in a fully-stocked Douglas fir stand of total age 50 years; and from seven 1/2-acre, fourteen 1/4-acre, and seventeen 1/20-acre plots in a thinned stand of Douglas fir of total age 50 years.

TIME STUDIES

Two time studies were conducted in connection with comparing the efficiency of different sized plots. One of these time studies was made to deter-

mine the average time required per chain of travel between plot boundaries, using a hand-compass, Abney clinometer, and steel tape. The average time per chain of travel was 0.88 minutes.

The other time study was made to determine the amount of time required to establish, measure, and record diameters and heights on three different sizes of plots. The results of this study are shown in Table I.

ANALYSIS OF DATA

Table II shows the results of an analysis of total volume estimates by the specific plot sizes for each type.

From this table one could conclude that certain plot sizes are more efficient than others, particularly where the ratio for the same precision is large. However, the most efficient sampling size cannot be determined solely on the basis of variation, but only when the time-cost factor has been applied. If cost is directly related to time, then, for either intensive or extensive cruises, the most efficient sampling size is determined by which takes the least time for a given sampling error.

Using the coefficients of variation from Table II, and the time factors from Table I, the plot sizes in Types 1, 2, and 3 are compared for efficiency of sampling in Table III.

Although the time factors from Table I do not apply particularly to Type 3, they have been used for relative comparisons. Any changes in the time factor for this type are assumed relative to both plot-sizes and, therefore, should not alter their relative efficiencies.

In Type 4, the time factor was not determined for the different-sized plots. Therefore, any discussion or conclusions must be limited to the comparative efficiencies based on variation alone. However, it can be discerned how each plot-size reacts in the inventory of a thinned and an unthinned stand.

If the ratio of the relative numbers of plots required for the same precision is taken as the basis for conclusions, then, either before or after thinning, the 1/20-acre units are not very efficient. There is no doubt, however, that before thinning the 1/4-acre plots are as efficient as the 1/2-acre plots. Not only are less plots required for the same precision, but from time-studies on other plot sizes, one would assume that there would also be a distinct saving in time. However, after thinning, the 1/4-acre plots lose their efficiency when compared with 1/2-acre plots, and the time factor would possibly also swing in favor of the 1/2-acre plots.

DISCUSSION

The foregoing results indicate that, for a similar precision, the choice of plot-size is dependent, not only on the number of plots required for an inventory, but also on the element of time. Where the required numbers of different sizes of plots are equal, or nearly so, the smaller-sized plot is usually chosen since the time factor per plot is less, as is total survey time. Where the required numbers of different sizes of plots are very unequal, the larger-sized plots are usually selected, since the longer time required per plot is more than offset by savings in the total number of plots required. Type 1 is a very good example of the first case. Types 2 and 3 are very good examples of the second case.

TABLE I — AVERAGE CRUISING TIME REQUIRED ON VARIOUS-SIZED PLOTS

Size of Plot	Average Time Required on one Plot (Minutes)
1/40-acre	11.17
1/10-acre	17.37
1/5-acre	24.75

TABLE II — ANALYSIS OF TOTAL-VOLUME ESTIMATES FOR SPECIFIC
PLOT-SIZES IN DIFFERENT TYPES

Type	Type 1 Douglas fir 100-120 yrs.	Type 2 Western Hemlock 50 yrs.	Type 3 Spruce-Balsam Uneven-aged	Type 4 Douglas fir 50 yrs. Before Thin. After Thin.
Site Index	100-190	120-150	80-110	150-170
Plot Size (Acres)	1/5 1/10	1/10 1/40	1/5 1/10	1/2 1/4 1/20
Basis Number of Plots	30 30	56 56	17 17	14 14 17 17
Mean Volume per Acre (cu. ft.)	14322 14501	7498 7439	7506 7454	9628 9421 9896 5828 5800 6357
Coefficient of Variation	45 47	27 35	31 38	14 13 22 11 17 26
* Ratio of Relative Number of Plots for same Precision	100 109	100 168	100 150	100 86 247 100 239 559

* For sampling of infinite population only.

TABLE III—EFFICIENCIES OF SAMPLING FOR DIFFERENT INTENSITIES OF CRUISE*

Type	Survey	Plot Size (Acres)	Precision (Percent) (Odds 2 out of 3)	Area in Type (Acres)	Number Plots Required	Approx. Spacing (Chains)	Time Required to Establish Plots (Hours)
1	Intensive	1/5	5	100	70	4	32.98
		1/10	5	100	82	3	27.01
		1/5	5	1000	80	11	45.90
		1/10	5	1000	88	11	39.67
	Extensive	1/5	20	100	5	14	3.09
		1/10	20	100	5	14	2.47
		1/5	20	1000	5	45	5.36
		1/10	20	1000	6	41	5.34
2	Intensive	1/10	5	100	28	6	10.57
		1/40	5	100	48	4	11.75
		1/10	5	1000	29	20	16.90
		1/40	5	1000	49	14	19.18
	Extensive	1/10	20	100	2	22	1.22
		1/40	20	100	3	18	1.35
		1/10	20	1000	2	71	2.66
		1/40	20	1000	3	58	3.92
3	Intensive	1/5	5	100	36	5	17.49
		1/10	5	100	55	4	19.15
		1/5	5	1000	38	16	24.59
		1/10	5	1000	57	14	28.20
	Extensive	1/5	20	100	2	22	1.47
		1/10	20	100	4	16	2.10
		1/5	20	1000	2	71	2.91
		1/10	20	1000	4	50	4.09

*Corrected for finite population.

Discussions of Types 1, 2, and 3 have dealt with only one phase of plot use, namely, inventory, and where one plot-size may be appropriate for this purpose, it may fail completely for other purposes such as thinning projects or growth studies. Type 4, however, does give some indication of the effects of thinning on the selection of plot-size for inventory before and after thinning. The 1/20-acre plots, as shown by Table II, do not give the required precision, unless extremely large numbers of plots are used, either before or after thinning. Combining the factors of number of plots and time, the 1/4-acre plots fill the necessary requirements of inventory before thinning. However, after thinning the 1/2-acre plots appear to be the most logical choice. For such a project, then, the 1/2-acre plot would probably be chosen as the

sampling unit best suited to meet all the requirements. Consideration must also be given as to whether the size of plot selected will be adequate for future inventories of the stand and whether it will fulfill requirements other than inventory. These problems can only be solved by costly uniformity trials, or by trial and error, with carefully analyzed data as were used in this study.

CONCLUSION

Admittedly, the conclusions are limited to which is the most efficient of the two, or three, plot-sizes tried, and provides only an indication that an even larger, or some much smaller size, might have been more efficient than the ones tried. However, by a gradual system of trial and error, as opportunity presents, a pattern of efficient plot-sizes should develop.

In the summary then, the following are the main results of the data analyzed in this report:

(1) For intensive inventories in well-stocked 100 to 120-year-old stands of Douglas fir (Site Index 100—190) the 1/10-acre plots are more economical than 1/5-acre plots.

(2) For extensive inventories in the same Douglas fir type, the 1/10-acre plot is slightly favored as a sampling unit.

(3) For intensive and extensive inventories in 50-year-old stands of Western hemlock (Site Index 120—150) the 1/10-acre plots are more economical than the 1/40-acre plots.

(4) For intensive and extensive inventories in the uneven-aged spruce-balsam type (Site Index 80—110) the 1/5-acre plots are much more efficient than the 1/10-acre plots.

(5) In 50-year-old Douglas fir stands (Site Index 150—170) the 1/20-acre plot is not a suitable size for inventory purposes, and although 1/4-acre plots are satisfactory in this type of well-stocked stand before thinning, they are not as suitable as 1/2-acre plots in sparsely stocked stands, or after removal of approximately 40 per cent of the basal area by thinning.

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