SAMPLE PLOTS AND THE ANGLE-COUNT METHOD

B. BAY*

SYNOPSIS

A continuous inventory for determining timber volume is carried out in N.Z. Forest Products Ltd. forests using the angle-count method. This method and its field application are described. This is compared with methods using rectangular and circular sample plots and it is concluded that the angle-count method has advantages for this work.

Introduction

This paper is intended as a description of the angle-count method of volume assessment using sample plots of indefinite areas as used in 27–35-year-old *Pinus radiata* stands of N.Z. Forest Products Ltd. As a background to this description a brief comparison will be made with other sample-plot designs.

The concept of a sample plot incorporates the idea of a fractional sample of the whole stand. Random sampling is known to give a better statistical basis for analysis of results, but systematic sampling is generally preferable. While some statistical reliability may be sacrificed by using systematic sampling, this method gives results sufficiently reliable for general use in forest management (cf. Spurr, 1952). It has the added advantage of speed and convenience in the laying out of plot pattern and in the location of plots on the ground.

The intensity of sampling is determined by the degree of accuracy required, and by the time available for the project. Whatever the intensity of sampling may be, the shape and type of sample plot must be considered before any sampling programme is commenced.

Plot Shapes

Sample plots can be classified in three major groups of shapes: rectangular plots, circular plots and plots of indefinite area. For practical purposes the size of the first two groups of plots is normally kept to approximately ¼–½ acre.

Rectangular plots. The laying out of these plots involves the measurement of corner angles and diagonals. This is a slow process and quite subject to error. Smaller square plots can be laid out more quickly by laying out the two measured diagonals at right angles to each other.

Circular plots can be used in younger stands where the plot size is no greater than approximately ¼ acre. The usual method of using a tape for laying out the plot can be replaced by more convenient

* N.Z. Forest Products Ltd., Tokoroa.

methods. Where a high degree of accuracy is required lightweight sectional metal tube can be used. The use of a tube is more cumbersome but still more accurate and convenient than the use of a tape. For work of moderate precision circular plots can also be laid out using a simple range finder designed on the same principles as those used in the design of camera range finders.

Plots of variable area are related to Bitterlich's angle-count method which permits the calculation of basal area per acre on a count of trees. As the name indicates, the plot is of indefinite area, and is not laid out physically on the ground.

Angle-count Method

The method was developed by Bitterlich in 1948 (W. Bitterlich, Die Winkelzahlprobe. *Forestry Abstracts 10*:2314).

The instrument used (e.g. an optical wedge) has a constant reference angle A such that tan A = a/b.

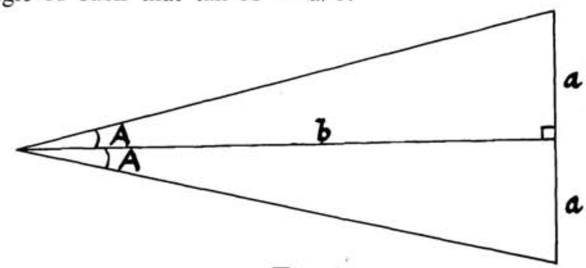

Fig. 1

A 360° sweep is made of an area of forest with the instrument sighted at d.b.h. on the trees. All trees which subtend an angle to the eye greater than or equal to 2A are counted. By multiplying the count by a constant (the *B*asal *A*rea *F*actor) and allowing for slope, BA per acre can be obtained. The mathematical basis of the method follows:

If R (fig. 2) is the maximum distance within which z trees all of radius r are counted then:

$\sin A = r/R$ .... (1)

Two different cases are considered:

(a) *All trees of radius r.* The number of trees per acre in relation to the number of sq. ft. per acre is equal to the number of trees per plot in relation to the number of sq. ft. per plot. Thus:

Trees per acre/43,560 = Trees per plot/sq. ft. per plot.

Trees per acre $= 43{,}560\ (z/\pi R^2)$ .... (2)

Also basal area per acre = basal area per tree × trees per acre.

Then from (2):

Basal area per acre $= \pi r^2 \times 43{,}560\ (z/\pi R^2)$

$= 43{,}560\ z\ r^2/R^2$. Then from (1)

$= 43{,}560\ z \sin^2 A$ .... (3)

(b) *All trees of different radii.* The maximum distance within which trees of different radii will be counted will vary, but the ratio

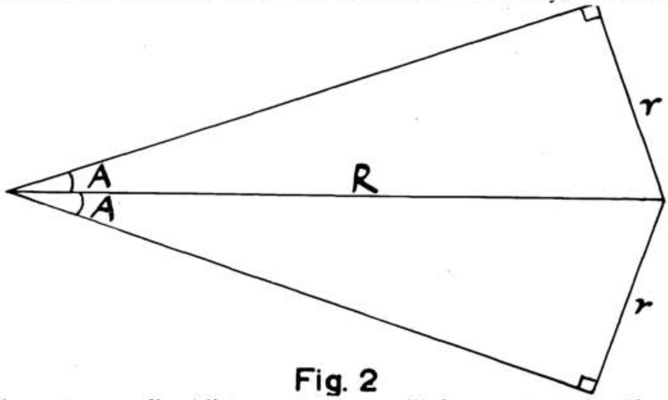

Fig. 2

sin A = tree radius/distance to tree will be constant for the particular instrument used.

Let $k = 43{,}560 \sin^2 A$.

Then from (3), summing for all trees,

$$\text{Total basal area per acre} = k\,\Sigma\,(z) = k\,Z$$

where Z = total number of trees counted in a sweep.

This constant, referred to above as B.A.F., can be determined for the instrument as follows:

A rectangle of a convenient width (e.g. 12 in.) is placed on a wall. The instrument is moved away from this rectangle until the displaced section of the rectangle (in the case of an optical wedge) appears just to touch the edge of the rectangle. The distance from wedge to rectangle is recorded and the B.A.F. calculated from the formula B.A.F. = $43{,}560 \sin^2 A$. $\text{Sin}^2 A$ can be determined from fig. 3, where d = distance in feet and w = width of target in feet and the reference angle of the instrument is A.

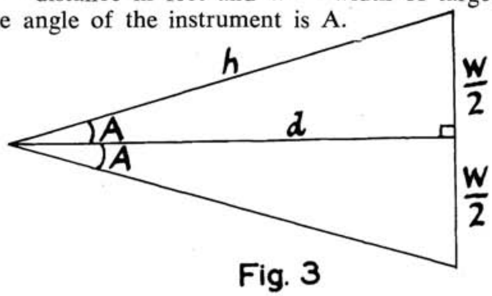

Fig. 3

Then $h = \sqrt{d^2 + w^2/4}$

$$w/2 = \sin A \sqrt{d^2 + w^2/4}$$

$$\sin^2 A = (w^2/4)/(d^2 + w^2/4) = 1/(1 + 4\,(d/w)^2)$$

Thus $\text{B.A.F.} = 43{,}560 \times 1/(1 + 4\,(d/w)^2)$

Field Application of Angle-count Method

The method is used in a continuous inventory for determining the timber volume in the older stands of N.Z. Forest Products Ltd. forests. The forests are divided into five blocks, one block being measured per year.

The intensity of sampling is 2½% or one plot to 40 acres.

The systematic sampling is based on a 1 in. grid transferred from 20 chains to 1 inch contour maps to 20 chains to 1 inch aerial photographs. This work is done with a Zeiss Sketchmaster.

The plots are located in the field from the aerial photographs by pace and compass. On volume-assessment work parties of three men are used of whom only the party leader needs to have some forestry experience. The rest of the party can be made up of unskilled men of average intelligence.

Around the plot centre three sets of tree-measurement data are recorded: (1) The d.b.h. of fifteen green trees nearest the plot centre are measured with a diameter tape; (2) heights of the five trees nearest the plot centre are measured with a Suunto hypsometer; and (3) the information required for calculating basal area is obtained from two independent sightings on a 360° sweep with the instrument sighted at d.b.h. on the trees.

From the data obtained by operations (1–3) above, together with a slope correction made for the basal area, the following formula is used for calculation of volume per acre. These data are computed electronically on an IBM 650 computor. The volume tables used were those prepared by Duff (1954).

Numbers in parentheses refer to stages (1–3) above in collection of data.

$$\text{Volume per acre} = \frac{\text{B.A. per acre (3)} \times \text{vol. of 5 trees (1, 2)}}{\text{B.A. of 5 trees (1)}}$$

The number of trees per acre is derived from

$$\frac{\text{B.A. per acre (3)}}{\text{Total B.A. 15 trees (1)}} \times 15$$

Description of Instruments

The diameter tape and 100 ft tape are of the usual type.

The Suunto hypsometer consists of a light-weight metal casing which contains two adjacent scales swinging in an oil bath. The scales are calibrated in percentages and degrees and are read directly at the time of sighting the tree. Using the percentage scale, tree heights can be obtained by direct reading of the scale when the horizontal distance to the tree is 100 ft.

The Suunto is of light weight (4 ounces), small of size (2¾ × 2 × ⅝ in.), and speedy in operation. Above all it gives consistent readings of high accuracy mainly because there is nothing to turn, set or lock, and, in addition to this, the instrument is of simple construction and good manufacture.

Several instruments have been designed to obtain the B.A. per acre information. Two instruments, the reflectorscope and the optical wedge, have been used in volume assessment of the company's forests. Of these the optical wedge is by far the cheapest and most accurate in operation.

The optical wedge bends light rays coming from a tree so that a section of the tree appears displaced to one side. Trees with the displaced section appearing to touch the edge of the trees are counted and their total halved. When the displaced section appears completely outside the trees they are not counted. The optical wedge is mounted in a ¾ in. long tube of ebonite. This can be screwed on to a 10 in. long light-weight metal tube of 1¼ in. diameter making it possible to interchange optical wedges with different B.A.F.

There are other instruments which can be used for the same purpose, notably a stick with a vertical slotted metal sight at the end, and the human thumb held at arm's length. The stick is a little cumbersome and the sight subject to inaccuracy resulting from damage. The use of the thumb held at arm's length has as the main disadvantage the physical variation in the capacity to hold it at a standard position during the day's work.

Discussion

Before comparing the three major groups of sample plots it is necessary to calculate the area of the average plot of the angle-count method.

Assuming an average d.b.h. of 18 in., sin A is calculated from $\sin^2 A = 1/(1 + 4 (d/w)^2)$. d and w are known for each individual instrument from the determination of B.A.F. As an example let $d = 50$ ft and $w = 1$ ft thus:

$$\sin^2 A = 1/(1 + 4 (50/1)^2)$$
$$= 0.0001$$
$$\sin A = 0.01$$

From $\sin A = r/R$, where $r = 18$ in., the plot radius, R, is calculated

$$0.01 = 1.5/R$$
$$R = 150 \text{ ft}$$

Then area of average plot $= \pi \times R^2 = 1.62$ acres.

As mentioned above the following measurements are recorded:

d.b.h. 15 green trees nearest the centre
Height 5 green trees nearest the centre
2 sweeps
Slope and aspect

The time spent on these measurements varies according to stand conditions and the B.A.F. of the instrument used in determining

B.A. per acre. With a B.A.F. of 4.36, time spent on measurements is approximately 30 minutes. During this time between 30 and 80 trees are tallied in a sweep in addition to a number of trees which have been checked but not recorded owing to their d.b.h./distance-to-tree ratio being too great.

In the case of ½ acre rectangular plot the number of trees to have d.b.h. measured is approx. 40–50. In addition to this the height of at least 5 trees must be measured.

In younger stands where the circular plot is more readily applied the number of trees to be measured is approximately 50–80 on ¼ acre plot. In addition to this 5–10 heights must be measured. By using an optical wedge with a B.A.F. greater than that used for older stands the time spent on these measurements can be reduced considerably. The effect of increasing the B.A.F. is that a smaller number of trees are recorded in the sweep and physically measured near the plot centre.

With regard to the accuracy and speed of obtaining field data at the same level of sampling intensity, the angle-count method outweighs the rectangular and circular plots. Even if the tree measurements took the same time for each group, the angle-count method has the advantage that the laying out of the plot has been eliminated and no loss of accuracy has been incurred.

Admittedly considerable time is often spent on clearing undergrowth away to make a free view for the sweeps. However, a great part of this clearing work would be necessary also in the case of rectangular and circular plots.

The superiority of the angle count method is not confined to the field work alone. As can be seen from the formula used in determining B.A. per acre, volume per acre, and trees per acre the office procedure has been simplified considerably. The number of individual units used as the basis for calculation has been greatly reduced.

The accuracy of the angle-count method is claimed to be of the same order as that of stem by stem measuring, provided that the sighting is properly done, that too many borderline readings are not found, and that the stand is not so dense as to make it impossible to see enough trees from one point (Spurr 1952, p. 395). This latter difficulty can be overcome by the use of a wedge of suitable optical value to include a reasonable number of trees in each sweep in a corresponding smaller plot.

It is apparent then that the angle-count method, when used carefully, has as its main advantages over measurement in defined plots:

Elimination of error in plot layout.

Saving of time used in plot layout.

Saving of time in walking to all trees for physical measurement.

The need for only one skilled man per party.

Easily portable equipment.

A smaller number of units of data for calculation, e.g., a total basal area is obtained in one calculation.

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