AN ASSESSMENT OF THE POINT-CENTRED QUARTER METHOD OF PLOTLESS SAMPLING IN SOME NEW ZEALAND FORESTS

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SUMMARY: The point-centred quarter method of plotless sampling produces exaggerated values for mean basal area when used in most New Zealand forest types. The error appears to be related to the rather wide range of size classes present in most forest stands and probably arises from the tendency for large trees to be over-represented in samples.

INTRODUCTION

In most fields of natural science, the density of individuals is usually determined from counts in defined areas of known dimensions. When tree density is being measured, the delimitation of plots of up to a hectare or acre in area, presents some difficulties and is time-consuming. Because of the reciprocal relationship between density and nearness of individuals to one another it is necessary to know only the distance between regularly-spaced individuals to be able to calculate density. Each plant has available to it an area equal to the square of the between-plant distance. If the individuals are distributed not regularly but at random, density may still be determined from the spacing, since between-plant distances will vary at random from the mean distance.

In most, if not all, natural communities there is a departure from randomness, i.e. individuals tend to be aggregated to some degree (Greig-Smith, 1964). For most forest sampling methods this non-randomness has usually been considered to be insufficient to affect the results seriously. Mean distances may be determined by methods based on between-plant distances or, as in the point-centred quarter method, on point-to-plant distances. Since being described by Cottam and Curtis (1956), the point-centred quarter method has become accepted, along with other methods of plotless sampling, as one of the most efficient for obtaining quantitative data on forest trees.

In this method the points are usually located systematically at fixed intervals along a traverse. Around each point four quarters or quadrants are delimited and the distance is measured from the point to the centre of the nearest individual stem in each quadrant. The species and diameter of this stem are also recorded. These values enable both total and relative densities and basal areas to be determined.

The number of points required to sample a forest stand adequately, varies. Cottam and Curtis claimed that only 10 points, i.e. 40 distance measurements, provided an adequate sample for density in three different forest types. They also indicated that a sample which is adequate for density will usually be adequate for basal area; but in a stand with a wide range of size classes many more measurements are required for an adequate sample of basal area than in an even-aged stand.

Only recently has the accuracy of the quarter method for determining basal areas of forest stands in New Zealand been questioned (Franklin, *et al.*, 1965; Franklin, 1967). Franklin showed that the method consistently produced a serious over-estimation of basal area. From four different forest stands, all with a wide range of diameter size classes, he found the quarter method to under-estimate the percentage of trees in the smaller size classes and over-estimate the percentage of larger trees. This distortion resulted in values for mean basal areas using the quarter method, that were 30–50% higher than those obtained from full tallies.

Recently we have examined the accuracy of the point-centred quarter method in different forest types on seven sites: three beech (*Nothofagus*) forests in Fiordland (Norton and Mark, 1967), three in western Otago (Westerskov and Mark, 1968), and a *Beilschmiedia tawa* stand near Palmerston North. At each site complete tallies of tree stems (>4 in. diam. breast height) were made in one acre (5 x 2 chain) plots. In addition, point-centred quarter data were obtained from 50 points placed systematically within each plot (25 in the three western Otago stands). Distances were measured to the nearest inch and diameters to 0.1 inch.

RESULTS AND DISCUSSION

The estimates of density and basal area obtained with the point-centred quarter method deviate widely from actual census values in many instances (Table 1, Fig. 1). Most estimated density values are too low, but variation occurs on

FIGURE 1. *Comparison of diameter size class distribution from one-acre plots (solid lines) with values obtained by point-centred quarter samples within the same plots (broken lines). Data are for all trees from three beech forest stands in the Routeburn Valley, Western Otago (a–c), three near Lake Monowai, Fiordland (d–f), and a tawa stand near Palmerston North (g).*

either side of the true values. Mean basal area estimates are consistently high (by 7–46%) with the point-centred quarter method; and estimated total basal areas, being the product of these two values, vary accordingly, with a maximum over-estimation of 41%.

The point-centred quarter method apparently does not yield unbiased samples, i.e. each individual does not have an equal and independent chance of occurring in the sample. The method commonly under-estimates the number of small individuals and over-estimates those in the larger size classes. In the two stands, where small trees (<10 in. d.b.h.) are less than 45% of the stems, the deviation is particularly serious (Fig. 1 b and f).

The inaccuracies of the point-centred quarter method give cause to examine the underlying theory. The method is theoretically most accurate when used in randomly-distributed populations and it is probable that the bias which occurs is in some way related to the structure of the stands examined.

In most forests, departures from random distribution are the rule and non-randomness occurs at various intensities and scales (Greig-Smith, 1964). In some forests large trees tend to exclude smaller ones from their sphere of influence. Thus, the small members of a tree species may occur at some distance from the larger trees but in closer proximity to others of about the same size. In this situation the nearest approach to randomness is likely to be displayed by the canopy trees, whereas the greatest degree of aggregation would be among the small individuals. This is usually evident where regeneration of the dominant species occurs around the margins of large canopies. Thus, a single species may display at least two different scales of pattern. Possibly these account for the disproportionate sampling of large and small individuals when the point-centred quarter method is used. The tendency towards over-representing large stems and under-representing the small ones implies a relationship between stem diameter and probability of inclusion in a sample.

Spatial relationships among individuals are involved in the concept of "area potentially available" (a.p.a.), put forward by Brown (1965). This is the area around each tree delimited by

TABLE 1. *Comparison of values from one-acre plots with estimations based on the point-centred quarter method of plotless sampling (P.C.Q.). Deviation is expressed as percentage departure from the plot values.*

A. MONOWAI, FIORDLAND

	Mountain beech stand			*Mtn-Silver beech stand*			*Silver beech stand*		
	Plot	P.C.Q.	% Dev.	Plot	P.C.Q.	% Dev.	Plot	P.C.Q.	% Dev.
Total density (stems/acre)	252	282	**+12**	179	208	**+16**	217	204	**− 6**
Mean basal area (sq.ft./tree)	1.02	1.12	**+10**	1.47	1.57	**+ 7**	1.68	2.29	**+36**
Total basal area (sq.ft./acre)	256	317	**+24**	264	327	**+24**	364	468	**+29**

B. ROUTEBURN VALLEY, WESTERN OTAGO

	Red beech stand			*Mountain beech stand*			*Silver beech stand*		
	Plot	P.C.Q.	% Dev.	Plot	P.C.Q.	% Dev.	Plot	P.C.Q.	% Dev.
Total density (stems/acre)	195	142	**−27**	226	232	**+ 3**	318	298	**− 6**
Mean basal area (sq.ft./tree)	1.64	2.39	**+46**	1.30	1.78	**+37**	0.75	0.81	**+ 8**
Total basal area (sq.ft./acre)	320	339	**+ 6**	294	414	**+41**	240	241	**0**

C. PALMERSTON NORTH

	Tawa stand		
	Plot	P.C.Q.	% Dev.
Total density (stems/acre)	382	323	**−15**
Mean basal area (sq.ft./tree)	0.51	0.66	**+29**
Total basal area (sq.ft./acre)	197	213	**+ 8**

the perpendicular bisectors of the straight lines joining it with each of its neighbours. In terms of the point-centred quarter method it also represents the area in which the tree it contains will be the closest one to any sample point located within that area. Thus, the concept of a.p.a. is appropriate here since it is a measure of the ability of a particular tree to "catch" the points used in the quarter method. Franklin (1967), attempting to explain the inaccuracy of the point-centred quarter method in determining basal areas, suggested that randomly-located points in a stand which has a wide range of size classes have a greater chance of falling within the a.p.a. of the larger trees because they have greater a.p.a. values than smaller trees.

There appears to be no published information on a.p.a. for any New Zealand indigenous forest, nor, so far as we know, for any natural forest stands. Brown's information, which Franklin applied, came from a planted stand of *Pinus patula* at Rotoehu Forest in the North Island. However, the mapping of permanent quadrats on each of three one-acre plots in the Routeburn Valley (Westerskov and Mark, 1968) allowed a.p.a. values to be determined, by the method described by Brown (1965), for the 739 trees present (Fig. 2). Calculations of the linear regression of tree diameter on a.p.a. for each of the three plots, individually and jointly (Fig. 3), gave significant regression coefficients.

This direct relationship between a.p.a. and tree diameter, by increasing the chances of sampling the larger trees, could explain the consistently high estimates of mean basal area (7–46% in excess of the true value) obtained with the point-centred quarter method. If this relationship between a.p.a. and tree diameter is causal in the over-estimation of basal area, then combined with this effect should be another: the under-estimation of density. This should ensue from the values for mean distance being too large. The results (Table 1), however, are inconclusive on this aspect. Total density was in fact under-estimated in only four of the seven stands analysed. No explanation of this apparent anomaly can be offered.

The error in estimating total basal area may be reduced or even nullified by a low estimation of density, but when density is also over-estimated, as occurred in three of the seven stands, then the error in assessing total basal area may be much greater.

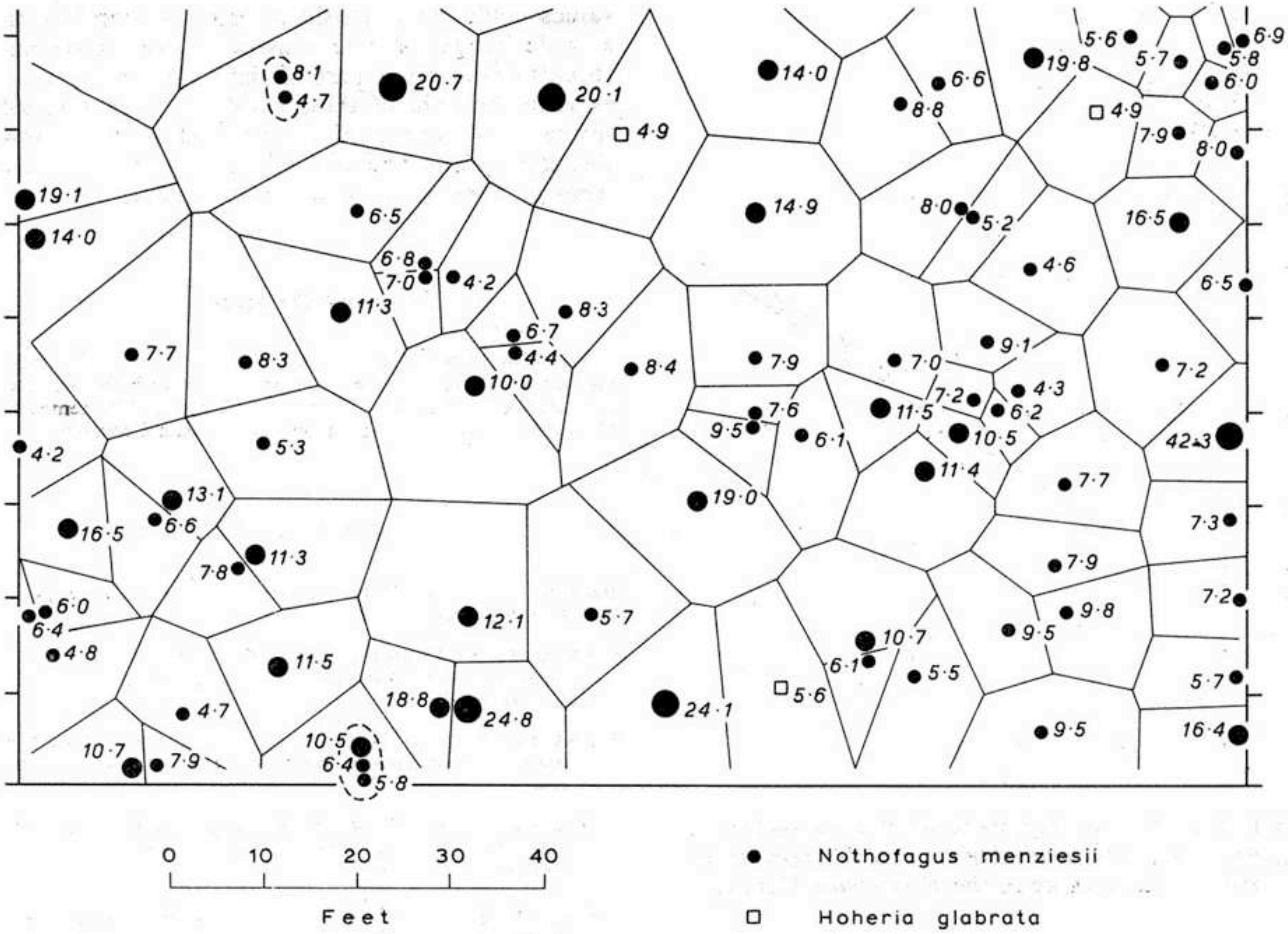

FIGURE 2. *Part of the one-acre permanent quadrat in silver beech forest from the Routeburn Valley showing tree loction and diameter (inches) plus the "area potentially available" around each tree.*

CONCLUSIONS

In most types of New Zealand forest, the point-centred quarter method of plotless sampling produces values for mean basal areas that are erroneous and unacceptably large, exceeding the true value by up to 46%. Total density estimations may also be seriously but not consistently in error. Predictably, density values should be too low. Values for total basal area, being the product of mean basal area and density, are therefore usually in error also. This error may be reduced or even cancelled out by a low estimation of density compensating for the over-estimation of mean basal area.

The reasons for the shortcomings of the method are not altogether obvious, but appear to be related to the rather wide range of size classes that occur in most New Zealand forests. We have established for three beech forest stands that the area potentially available to a tree (which measures its ability to "catch" the point-centred sample points) tends to increase with the diameter of the tree. The probability of large trees being included in a point-quarter sample would therefore be increased. Values for mean basal area from all seven stands measured, substantiate this.

We cannot justify continued use of the point-centred quarter method of obtaining absolute

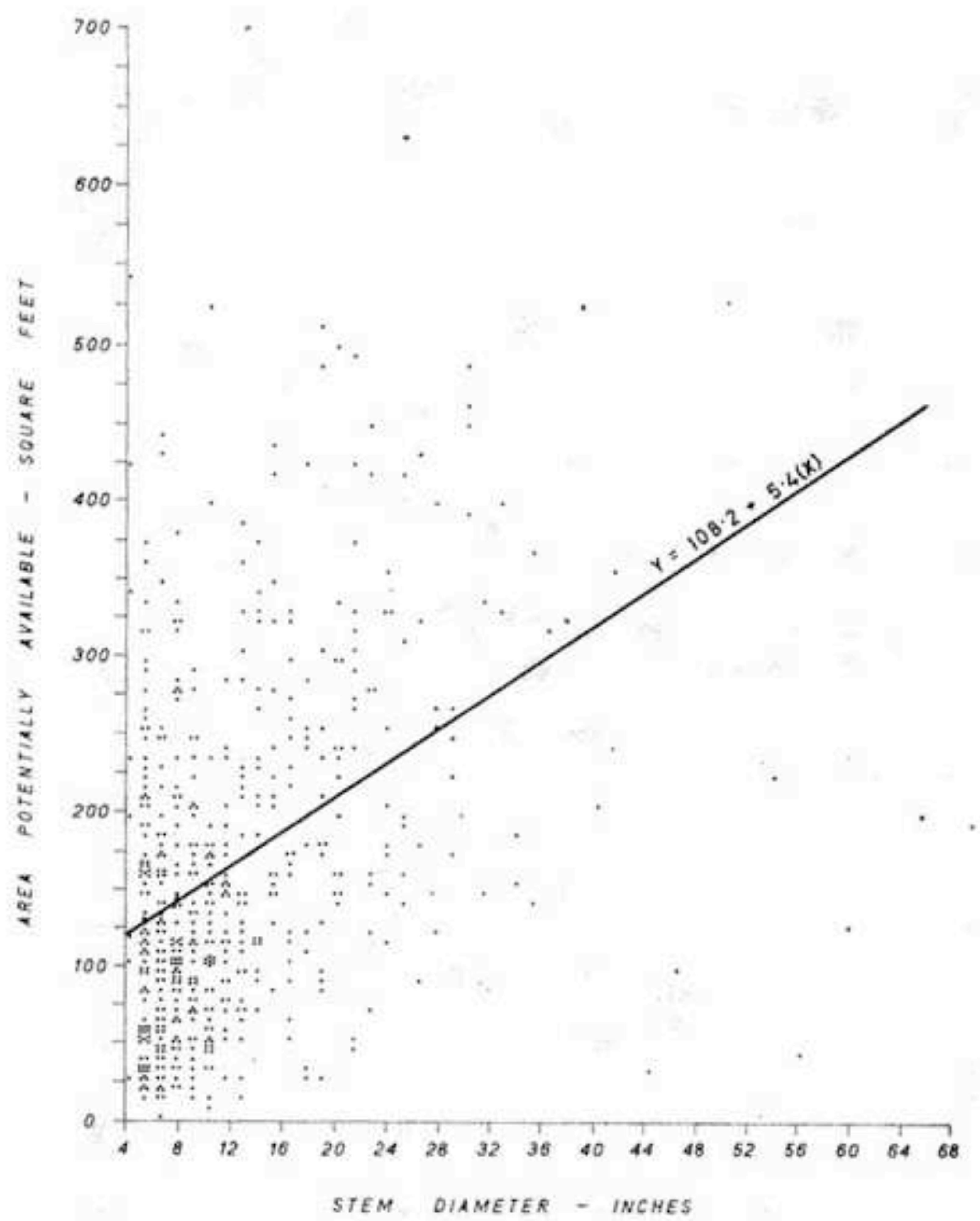

FIGURE 3. *Linear regression of tree diameter on "area potentially available" for 739 trees from three one-acre plots in the Routeburn Valley.*

values of basal area and density, at least in types of forest similar to those which we have examined. It has been claimed that relative values of these two criteria, obtained with the point-centred quarter method, are valid regardless of distribution patterns (Greig-Smith, 1964; p. 52). But such values could be seriously in error in stands with a wide range of size classes where individual species span only a part of the total range. However, in the light of these results, we recommend further field testing of the method both in New Zealand forests and abroad, as well as in other types of vegetation for which it has been used.

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