Photogrammetric Brief

J. H. G. SMITH*
Y. C. CHIAM*
University of British Columbia
Vancouver 8, B. C., Canada

Studies of Tree Stocking and Use of Crown-Width Ratios to Refine Estimates of Stand Density

INTRODUCTION

THE NEED TO develop expressions which are statistically sound and compatible with the biological relationships governing growth and yield was illustrated by Smith (1965). Since then several studies have been made to investigate the utility of ratios of crown width in feet *CW* to diameter at breast height in inches *D* and of tree height in feet *H* to *CW*. Such studies have been helpful in clarifying some aspects of stocking and density.

STOCKING

Stocking is best understood as the proportion of an area occupied by tree crowns. Estimation of percentage crown closure *C* by use of conventional methods can be improved by application of the *tree cramming* or tree *counting* methods illustrated by Pope (1960). Then, on logical grounds, stand volume ought to vary directly as the proportion of the area *stocked* with trees which has been indicated by percentage crown closure. Although stand volume per acre should also increase directly with average tree height, many empirical studies such as that of Bonnor (1966) have shown statistically the need to consider both positive and negative terms with *H* and *C* in addition to *HC*. We believe that much of the biological basis for this unstable statistical system exists in the difficulty of estimating the cumulative effects of stand density within the area stocked.

DENSITY

Density is an expression of the degree of crowding within the area occupied by trees. Commonly, the stocking and stand density aspects have been confounded by the desire of mensurationists to express the net effects of both factors on a per-acre basis. Although this approach may lead to few problems in stands that have followed a relatively constant natural or managed regime of stocking and stand density, it is obviously inadequate for use in simulation and other studies which estimate stand values from individual tree rather than plot data (Smith, 1966, 1967). Without additional knowledge about the degree of crowding resulting from changes in stocking and stand density throughout the life of a tree, estimates based upon measurements of tree crowns can be greatly in error at extremes of stand density.

As foresters ought to be aware of the full range of possibilities from management of growth of isolated trees to growth of extremely dense stands, measures of the degree of crowding within areas occupied by trees are necessary. Anyone who has trouble with the idea of separating the elements of stocking from those of stand density should consider the concept advanced by Paillé and McGreevy (1970). They compared forests with cheese:

> "In a slice of Cheddar, density can be measured everywhere, with almost any sample size because there is full stocking and uniform distribution of material. In a slice of Swiss cheese, however, holes have to be taken out before evaluating absolute density (expressed as a number of individuals per unit area), and the area reduced accordingly; effective density is thus measured. Samples from this clumpy material should not be located in holes, and their size should vary with the degree of clumpiness of the cheese."

TYPING

Mapping procedures will vary with minimum type size used. Practical aspects of this mixing of stocking and density have been clarified by the Alberta Forest Service which has recognized conglomerate types since 1965. In a personal communication (MacDonald, 1970), attention was drawn to the desirability of basing

> "the average volume per acre estimate on the merchantable areas, and then to estimate from

* Professor and Graduate Student, respectively, Faculty of Forestry.

the photograph, the percentage of the total area which is merchantable. Hence if a B4ASw type was composed of 40 percent solid spruce areas in the form of several pockets each averaging 20,000 fbm per acre, while the remainder of the type was pure aspen, then notes would pertain to B4Sw acres on 40 percent of the area."

Practically speaking, also, most studies of growth and yield recognize that there will be minor outcrops of rock, and creeks, and swamps which are too small to be mapped but, nevertheless, consistently reduce yield. Allowances of from five to 15 per cent have been suggested, commonly, for such reductions from yields expected at full stocking. Photo-interpreters should pay more attention to this aspect and develop methods for estimating portions of stands which are not likely to become stocked, as a supplement to their estimates of portions of types actually stocked and described by crown closure.

Some Results

Two studies at the U. B. C. Research Forest have shown that aerial photographs can be measured with sufficient precision that estimates of stand density can be added as a new dimension to crown closure observations (Wang, 1965; Chiam, 1967). Chiam (1967) estimated H with a standard error of the mean of 4.8 feet, CW with a standard error of the mean of 0.9 feet, and C with a standard error of the mean of 2.5 per cent. He also found that ground and aerial photo estimates of crowding were highly correlated, and concluded that the ratio H/CW was the best indicator of both stocking and density. The photo-interpretation and photo-mensuration aspects of Chiam's work were followed by a thorough analysis of the influence of stocking and density upon growth and yield of trees and stands of coastal western hemlock by Osborn (1968). Osborn concluded that the best measures of stand density were ratios of crown width and live crown length with total tree height, although stand basal area per acre was only slightly less significant. Yield increased directly in proportion to the fraction of area occupied by trees (stocking) and curvilinearly with degree of crowding (stand density) within the area occupied. Osborn found that mean annual net volume increment did not culminate even at stand densities of 500 square feet of basal area per acre. Although the natural stands available for study at Haney were quite variable, few represented the full range of open to normal stand densities. Therefore, elaboration of some aspects of these studies will depend on results that only will become available in several decades from spacing trials established in the late 1950's.

Conclusions

In some stands for which the history of establishment is well known, measurement of crown width ratios may not contribute additional information. However, in most natural stands we believe that separation of the elements of stocking from density, and careful interpretation of crown ratios, will introduce important biological components and thereby improve estimates of growth and yield.

Literature Cited

Bonnor, G. M. 1966. Provisional aerial stand volume tables for selected forest types in Canada. Canada Forestry Branch Dept., Ottawa, Public. No. 1175, 24 p.

Chiam, Y. C. 1967. The use of aerial photographs to distinguish between stocking and density of western hemlock stands on the University of British Columbia Research Forest, Haney, British Columbia. Univ. of B. C., Fac. of For., M. F. thesis, 234 p.

Osborn, J. E. 1968. Influence of stocking and density upon growth and yield of trees and stands of coastal western hemlock. Univ. of B. C., Fac. of For., Ph. D. thesis, 396 p. Mimeo.

Paillé, G. and M. McGreevy, 1970. Integrated use of stocking, density and spatial pattern for definition of forest growth. Univ. of B. C., Fac. of For., Mimeo. 14 p.

Pope, R. B. 1960. Ocular estimation of crown density on aerial photographs. *For. Chron.* 35(1): 89–90.

Smith, J. H. G. 1955. Biological principles to guide estimation of stand volumes. *Photogr. Eng.*, 2661: 87–91, 1960.

Smith, J. H. G. 1966. Studies of crown development are improving Canadian forest management. *Proceedings Sixth World Forestry Congress*, Vol. II: 2309–2316.

Smith, J. H. G. 1967. Simulating stand growth and yield to improve decisions made by forest managers. Univ. of B. C., Fac. of For., Mimeo. 8 p.

Wang, Y. M. 1965. Use of a series of aerial photographs to estimate growth of trees and stands. Univ. of B. C., Fac. of For., M. F. thesis, 143 p.