Estimation of Stand Volume From Airphotos

by

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RÉSUMÉ

La présente communication relate les progrès réalisés au Canada dans l'estimation du volume des peuplements forestiers à l'aide de photographies aériennes et expose les applications actuelles de cette méthode, soit par les gouvernements provinciaux dans les travaux d'inventaire forestier, soit par les usines de bois à pâte dans l'estimation du volume brut de bois marchand dans leurs concessions. L'auteur illustre la façon de dresser les tables de volume de peuplements d'après des photographies aériennes, au moyen des données recueillies en Alberta sur le pin de Murray. Il y est question des domaines vers lesquels la recherche future doit s'orienter pour améliorer les méthodes d'aménagement des ressources forestières, notamment la solution des problèmes que posent certains genres de couverts complexes, la mise au point de méthodes plus précises d'échantillonnage et d'analyse des données recueillies, de même que la précision que l'on peut atteindre grâce aux nouvelles techniques de cartographie et de photographie aérienne.

ESTIMATION OF STAND VOLUME FROM AIRPHOTOS

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Abstract

This paper traces the development of forest stand volume determination from aerial photographs in Canada and describes the current uses in provincial government forest inventory programs and in photo cruising operations on pulp company limits. It illustrates the aerial photo stand volume table construction technique by the use of data and materials from the Alberta lodgepole pine type. A discussion of new areas of research for improved forest management includes a treatment of problems in complex cover types, in more refined sampling designs and analysis of data, together with possible improvements in precision to be gained from new scales and types of photography.

Introduction

Stand volume estimation implies an inventory of wood volume per acre. The conventional method of making a woods inventory is to have a cruising party carry out a ground survey of a representative fraction of the forest to gain an impression of the whole forest. The method is expensive and in forests where there is great variation in volume and species composition there may be shortcomings in the results. Some Canadian industrial and government organizations are making estimates of stand volume from airphotos, 'photo cruising', by mathematically relating photo measurements of tree height, crown closure and other stand characteristics to volume data taken on the ground. The relationship is summarized in a prediction equation which is expanded into a table for office use. These estimates are as good as or better than those from ground cruising, considering the cost of survey. The purpose of this paper is to trace briefly the development of photo cruising, to illustrate the techniques and current applications of the method and then to show where new efforts are being applied.

Development of Photo Cruising in Canada

Airphotos have been employed in forest surveying in Canada for over thirty years. Much original work in the application of photographs to the estimation of wood volume was carried out in this country by the predecessors of the Department of Forestry. Early Canadian work was concerned with aerial sketching (Jenkins, 1927), and measurements of heights of trees from shadows (Seely, 1929) on oblique airphotos. In 1934 a discussion of the estimation of stand volume from airphotos was included in a review of developments of the method in Germany (Andrews, 1934). The Germans were estimating volumes from photos and using yield or volume tables to compile forest inventories. Errors of from -12% to +10% were quoted depending upon the method. Accurate measurements of stand height were made using good photography and instruments of the day. Tree counts and estimates of density were described together with the estimation of diameter at breast height (d.b.h.) from crown diameter on airphotos. The theory of the technique was presented in papers by Andrews and Trorey (1933) and Andrews (1936). However, airphoto stand-volume tables did not appear in Canada in published form until the late 1940's after additional work on vertical air photography which promised more control and precision than previous methods of photography. In the last few years there has been an increased interest in large-scale photography. For example, 70-mm film permits measurements to be made of several individual tree and stand characteristics previously unobtainable on smaller scale photography.

In the British Columbia Forest Service, airphoto volume tables are being used in operational photo cruising of portions of large working circles to estimate total gross cubic volume (Allison, 1955). At North Western Pulp and Power Limited, Hinton, Alberta, foresters are making estimates of merchantable volume in cords from photo measurements of stand height and density within recognized cover types (Appleby, 1963). The Woods Department of Bowater's Newfoundland Pulp and Paper Mills Limited at Cornerbrook also uses the photo cruise for estimates of ground volume.

Improvements in techniques in airphoto volume-table construction continue to appear in the United States and Canada. A recent development is a method of table construction using ground data only. This was an approach which was followed by the Forest Inventory Section of the Canada Department of Forestry but it was first published by Pope (1962) at the Pacific North West Forest and Range Experiment Station. The method may be an improvement over the conventional technique of photo volume table construction which involves correlation of photo measurements with volume data taken on the ground.

An Illustration of Photo Volume Table Construction

In a study of photo volume table construction in Alberta, Duffy and Meyer (1962) compiled volumes from seventy plots in different, pure, even-aged, well-stocked, 60-year-old lodgepole pine stands in the Foothills section of west-central Alberta. These plots were located on airphotos with a pinprick. The photo scale was 1:15, 840. The photography was excellent quality infrared minus blue. Three interpreters made four parallax height measurements of average stand height at each plot with an Abrams height finder and one estimate of crown closure using Moessner's Central States Forest Experiment Station crown closure scale. Thus, two bodies of data were gathered using 'doubling sampling' (that is, ground data and airphoto data). These data were used to develop a prediction equation:

Ground volume = -2710.07 + 130.51 stand height
+2.44 crown closure (total cubic feet per acre).

It was found that ground volume could be predicted from average height measurements and that crown closure was not significant; that is, it did not improve the estimation of volume. The data was then separated into three parts using soil series as the stratification criterion. For all soil types the prediction equation was:

Ground volume = -24.98 + 67.67 stand height
(total cubic feet per acre).

By isolating the plots on one soil series, significantly different

volumes were estimated than by using the composite equation for all soil series.

The volume tables which were developed in the Alberta study permit the estimate of gross stand volume in cubic feet. Currently a standard aerial-volume table is being constructed from data from 300 Department of Forestry yield plots in pine in west-central Alberta. Following Pope's method (1962) the tables will give ground volume in terms of total volume per acre in cubic feet, merchantable volume in cubic feet, board feet, and cords per acre. Two methods of table construction are to be used. Firstly, a table will be constructed using only ground estimates of stand heights. This will eliminate interpreter error from the height portion of the table and it will require the photo interpreter to make his own correction for different height classes. Secondly, by using photo heights and averaging the measurements of several interpreters, the customary method will be followed in constructing an airphoto volume table. As a further step, the feasibility of using different tables for different soil series will be tested.

Applications of Airphoto Volume Tables

The British Columbia Forest Service has carried out operational photo cruising since 1953 and, at present, surveys are completed for extensive tracts in four of the seven zones into which British Columbia is divided for inventory purposes (Allison, 1963). Local volume tables are used rather than zone volume tables. Zone tables might be satisfactory if all the work in one zone is interpreted by one man, and, if personal correction factors are applied to an interpreter's measurements in a local area. As the work progressed it was found that density measurements were not improving the estimates of ground volume and, in 1960, measurement of that factor was discontinued. Today local tables are based upon photo measurements of height only. The determination of species composition has been improved by low-level observation from helicopters in conjunction with normal-scale photography from fixed-wing aircraft. This permits better estimates to be made of total volume per acre by cover type. In 1961, operational photo cruising provided volume estimates for 83% of the mature productive area (251,500 acres) of the Narcosli Working Circle (west of Quesnel) based on 275 photo samples and 28 ground samples.

In 1962, photo estimates were used for 85,000 acres in the Nechako Working Circle (south of Vanderhoof) in types where conventional ground sampling was difficult.

In addition there is a B.C. Forest Service project on the usefulness of 70-mm helicopter photography in the construction of single tree photo volume tables for Douglas fir and lodgepole pine (Lyons, 1963).

In Alberta, North Western Pulp and Power Limited has found that one photo cruiser can complete the work in the same time as eight full-time cruisers (Appleby, 1963) and produce the same results. It is anticipated that as the photo cruising technique is improved, better pulpwood inventory data will be gained. The North Western general tables are based on data from 3,000 continuous forest inventory (c.f.i.) plots. The plots were sorted into height classes within density classes of different major cover types. Curves of merchantable plot volume over height were plotted for each density class within a given cover type and tables were written from the curves. Volume estimates in terms of merchantable volume per acre in cubic feet are compared with actual scaled volume and estimate errors are compiled. Estimates which are consistently higher or lower are used to make adjustments in the tables for local areas.

The Alberta Department of Lands and Forests has a cooperative project under way with the Canada Department of Forestry, the purpose of which is to develop airphoto volume tables for the lodgepole pine type. Further study is planned on the application, levels of accuracy, and cost comparisons with conventional ground methods (Lee, 1963).

In addition, stereograms for permanent sample plots are being developed by the Alberta Department of Lands and Forests for classification of forest types into saw log, pole size and pulpwood stands as basic information for management planning. This is classification on photos by direct comparison with stereo views of typical stands.

The Forest Inventories Section of the Department of Forestry is constructing airphoto volume tables from nearly 2,000 plots in Alberta, the Northwest Territories, Ontario and Quebec (Bonnor and Aldred, 1963). Using ground measurements of stand height and crown closure, stand tables are being calculated for 25 to 35 major cover types. In other work with 70-mm photography (scale: 25-feet-to-the-inch) individual tree measurements are being used to derive more accurate stand volume figures. The species of the individual tree is listed together with photo measurements of height, crown size, and stem diameter (where possible). Relationships were established between these data and ground measured diameter. The cubic volume of the tree is then found by entering suitable standard volume tables with height and diameter at breast height. Per-acre volumes are compiled for a given cover type and can be used to calculate the volume of a particular stand.

The chief problems in this work are the accurate determination of scale and the variable correlation between crown dimensions and diameter at breast height in different species.

Aerial photography in Newfoundland was first applied to forestry in 1934 in the mapping of large portions of pulpwood limits. Using photos and maps as inventory tools, Bowater's Newfoundland Pulp and Paper Mills completed a survey of their limits. At present, stand volumes are estimated on plot locations marked by grids on photographs. The estimates are made by ocular observation using the stereoscope; no stand measurements are made (Snow, 1963).

New Work in Stand Volume Estimation

New work is going on in the areas of species identification — for better cover type definition (Sayn-Wittgenstein, 1960 and 1961), e.g., 70-mm photography (Seely, 1962; Avery, 1962) and different types of film (Springer, 1963). Improved ground and photo-sampling designs and statistical analysis will result in better estimates of ground volume; and the possibility of developing photo volume tables for specific soil survey units will warrant further attention. However, increased efforts are required to train and maintain photo interpreters of high calibre and to keep closer scrutiny on the adequacy of results and cost figures in photo cruising.

The most accurate prediction of volume is likely to be made in the estimation of total cubic foot volume in pure, even-aged stands of coniferous species such as jack pine, black spruce or lodgepole pine. In mixed wood stands, interpretation of cover type and photo measurements are more difficult and, therefore, lower levels of precision may be expected. Similarly, the estimate of merchantable volume will involve greater errors because of arbitrary diameter limits.

With regard to photo scale, it has been shown that four-inches-to-the-mile (1:15,840) is a good scale for general forestry use i.e. mapping, volume inventory, and cover typing. Even though there have been no dramatic improvements over four-inches-to-the-mile photography, some developments in 70-mm show promise for individual tree measurement. Different jobs will require different specifications for scale and type of film and new work in these fields might await a thorough appraisal of currently used methods in the major cover types.

The use of photo volume tables in photo cruising has not yet reached full swing in Canada. This is because of insufficient research and application in forest inventory operations and because of an inadequate understanding of the theory and practice, the limitations of the method, and the cost savings that can be expected. Further exploitation of the techniques of photo cruising will bring out savings in costs and time as well as improved forest inventory data in some cover types.

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