TECHNICAL DEVELOPMENTS IN AIR SURVEY AND THE INTERPRETATION OF FORESTRY DATA THEREFROM—N.Z. EXPERIENCE *

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Few countries outside Europe have as yet an adequate knowledge of the extent and composition of their forest resources. Without such knowledge it is impossible to formulate intelligent forest conservation policies and it is premature to attempt detailed forest planning. The recently developed techniques of aerial survey and air photo interpretation provide the means whereby the requisite knowledge can be gained more cheaply, more rapidly and more efficiently than ever before. It is in this sphere then, the making of cheap and accurate forest inventories, that aerial photographs find their largest use in forestry, and it is here that they are of the most importance from a national or an international point of view.

They are, however, of great and increasing value for a variety of other forestry purposes. Thus, they may be used to advantage for many types of detailed forest mapping ; for planning of communication systems and extraction routes ; for rapid surveys of fire, insect, and wind damage ; for siting sawmills, villages, and fire lookouts ; for assembling and interpreting working plans data ; and for controlling actual operations in the forest. They are a new tool which sometimes will help the forester to obtain more accurate data, very often will help him to get it more quickly, and always will give him a balanced over-all picture previously impossible to obtain.

It is not possible in a short paper of this nature to discuss the latest developments in all fields, even in Forest Survey, nor in fact is this necessary since it has already been done, most comprehensively, in two recent publications (1) (2). All that will be attempted is to describe New Zealand experience in those particular aspects of Forest Survey work where aerial photographs have proved to be of most value. For convenience sake the discussion will be under the two headings of Forest Inventory and Primary Ecological Survey. The preparation of planimetric or topographic maps, which is the basic use of aerial photographs, is common to both.

Forest Inventory

New Zealand's National Forest Survey, described elsewhere (3) is one example of many forest inventories now being carried out by a combination of air survey and ground sampling methods. The salient points are :

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1. Provision of complete photographic cover over the whole forest area. The photographs are vertical overlapping prints at a scale of 4 inches to one mile. They are taken at 10,890 feet with a $8\frac{1}{4}$ inches lens camera, and have much the same specification as to tip, tilt, overlaps, etc. as are laid down by the United States Department of Agriculture (4).

2. Delineation of forest type boundaries and of merchantability and protection forest limits on the photographs. The type boundaries may represent differences in forest association or differences in volume per acre within the same association.

3. Ground sampling to give volume per acre in each type, using a systematic double phase line plot survey.

4. Preparation of accurate type boundary maps by approved photogrammetric methods (Multiplex and Wild A6 plotter).

5. Multiplication of type areas by volume per acre averages to give final inventory figures.

In this procedure aerial photographs perform three main functions. Firstly, by providing accurate area figures, they eliminate one major source of sampling error. The whole allowable error can be thrown into the volume per acre estimate and thus the intensity of sampling necessary for any given degree of accuracy can be greatly reduced. Secondly, by drawing type boundaries, the original heterogenous forest area is divided into comparatively homogenous units—in other words, the population is stratified. The ground survey can then be designed to take this stratification into account and can concentrate the sampling in the more important and more valuable forest types. Thirdly, the photographs serve as field maps and direct the actual movements of parties on the ground.

It will be seen that aerial photographs are used to control the ground survey but not to provide any direct estimate of volume. It may be asked why this is so. The answers are perhaps peculiar to New Zealand conditions but will illustrate some of the more important limitations in the use of air photos for direct measurements. In normal ground mensuration techniques the reference points for measuring tree volume are d.b.h. and either total height, height to a fixed top diameter or merchantable height. On aerial photographs the only measurable features are total height and crown diameter. It follows that tree volumes may be obtained only if strong correlations exist between crown diameter and stem diameter, between total height and stem diameter or between total height and stem volume. Alternatively the problem may be approached by attempting to estimate crop rather than individual tree volumes. Aerial photographs can give direct measurements of density and of crown closure, and these in turn may be correlated with average stem diameter and with basal area. The success of any method measuring volume directly from photographs depends firstly on the accuracy of the measurements which can be taken, and secondly on the strength of one or more of the above-mentioned correlations. In New Zealand it is seldom possible to make accurate measurements either of total height or of crown diameter. Even if it were possible, the correlations with stem diameter, basal area or crop volume are all too weak to be of any value.

In explanation, the sub-tropical rain forests of New Zealand are so dense, particularly in the lower tiers, that ground level cannot be seen on the photographs. The shadow-height method of measuring total heights is quite inapplicable, as the shadows are lost amongst the crowns of the lower tier trees and shrubs. Parallax methods are equally unsuitable since the floating dot cannot be got down to the ground. In both cases the difficulties inherent in the nature of the vegetation are aggravated by the fact that the topography is generally steep and broken.

Total height as a reference point is thus ruled out. This in any case is of no great concern, for so variable is the incidence of upper-log defect in the commercially important podocarp species, that total height bears no consistent relationship to merchantable height and hence to merchantable volume. For some species, an approximate crown diameter/diameter relationship exists but this again is of little use if merchantable heights cannot be obtained. Further, the major timber producing species, rimu, tends in old age to become overgrown by a giant liane which ultimately kills its host and develops into a large tree itself. The rimu crown may thus consist of rimu foliage entirely, of a mixture of rimu and the liane, rata ; or of nothing else but rata. Under such circumstances, the measurement of crown diameter is meaningless.

Crown closure has not been studied, but it is difficult to see what information it could yeild. Crown closure in fact is almost always complete, but the constituent species are mixed and contain many valueless hardwoods. There is certainly no relationship between total crown closure and basal area of merchantable species ; and it would be difficult to establish any correlation between closure of the more scattered podocarp crowns and the volume which they represent.

The only other feature which can be measured on photos is stand density and this does show some promise in New Zealand. At present it is not being measured since photo-interpretation has not reached the stage where individual species can be recognized with certainty. If the use of different films and filters permitted more accurate species recognition, the whole design of the forest survey would be drastically altered ; in this case stand density could be got directly from the photos and thus another major source of sampling error eliminated from the ground survey. Without doubt stand density in New Zealand is the major component in volume per acre variance and, far more than any other factor, determines the size of the sample which must be taken. If accurate tree counts, by species, could be made on the photographs, the amount of field work necessary would be reduced to negligible proportions.

It will be seen that the techniques of estimating volumes directly from air photographs have not proved to be of use in the dense mixed sub-tropical forests typical of New Zealand. The limitations of these techniques are very real and it is only for certain forest types, and under certain restricted conditions, that they are completely successful. This point is stressed for some recent forest literature suggests that they may have a wide and general application ; in fact the reverse is the case.

A final consideration. The limitations of aerial photographs, in a sense are one of their advantages. As has been stressed, their use in conjunction with ground survey provides the most efficient means of deriving certain types of forestry data. It would be a great pity if aerial photo techniques were so perfected that the forester never or rarely had to go onto the ground for normal mensurational purposes. That would be the final triumph of the desk over the dirt forester and would vitiate the advantages which air photos undoubtedly possess. Like statistical method, aerial photography is a tool to be used with discretion, judgment and great common sense.

Primary Ecological Survey

In countries where there have been recent climate and soil changes or where, as in New Zealand, these changes are still occurring, the existing forests will not be climatic associations. They will instead be in a process of adjustment to present climate and soil conditions and as plant associations they will be unstable. Management of such forests is possible only if they can be split into their constituent associations, if the ecological status of each can be defined, and if the direction and rate of change can be measured. Here the bird's-eye aerial view is indispensable, for not only does it enable the present distribution to be mapped in detail, but also, as one writer has put it, "it portrays the whole forest area as a composite unit instead of as random items along a line of march." Such a tool has never before been in the hands of forest ecologists, who more often than not have been forced to proceed with intensive ecological studies unrelated to any comprehensive framework of fact or theory. Primary ecological survey with all that it implies is now both possible and practicable.

New Zealand has been quick to realize this and has evolved a Forest Survey procedure which combines extensive ecological survey with the more straightforward appraisal of timber resources. Extra time and costs are involved but are justified by the results. Thus, for one major forest region, the present distribution of associations, interpreted in terms of climate, topography and soil, has been successful in explaining the ecological changes taking place, and in determining the exact course of plant succession (5). The practical significance is that those forest associations which are amenable to silvicultural treatment can be delimited, and that forest management can proceed with the sure knowledge that it is based upon a sound ecological foundation. This represents a major achievement in the exacting task of placing New Zealand's indigenous forests on a sustained yield basis; it would not have been possible without the intelligent use of suitable air photographs.

It will be seen that basically New Zealand's forest survey, by placing a great deal of emphasis on vegetation and soil in its field sampling, is approaching what should be the ideal resource survey in undeveloped areas. Herein lies its greatest weakness, for a full regional survey can properly be undertaken not by foresters alone but by a team of specialists in different fields. A country's vegetation and soil are of concern, amongst pure scientists, to the botanist, the pedologist and the geologist; and in the applied realm to the agriculturist, the hydrologist, the soil conservator and the land use administrator. All are working fundamentally to the same end, which is the wisest possible use of natural resources. All can derive great benefit from the combined use of air photographs and systematic ground study. Their interests and their problems overlap. For various reasons, therefore, their efforts should be combined and the complete evaluation of any soil-based resource should be done by an integrated team of specialists in the relevant fields. This approach is recommended to all undeveloped countries who have not yet undertaken a comprehensive regional survey. It is the only efficient way to collect *all* the data necessary to implement a national policy of "conservation by wise use."

Summary

Recent developments in air survey and air photo interpretation now make it possible to carry out rapid and efficient surveys of a nation's forest resources. The basic use of aerial photographs is in map making, and by providing accurate forest type and condition-class maps, they enable area figures to be obtained without recourse to sampling methods. They are further of very great value in controlling the field sampling for volume estimation. On occasions they may be used to obtain direct estimates of volumes without going on to the ground at all. Their contribution to the design of the National Forest Survey is described briefly; and their limitations for direct volume estimates, with particular reference to New Zealand conditions, are stressed.

By providing a bird's-eye view of the distribution of associations in virgin forests, aerial photographs are a useful tool in the hands of forest ecologists; they enable primary ecological survey to be done more thoroughly and more efficiently than ever before. New Zealand experience in this use of photographs is described.

References

(1) Sisam, J. W. B. *The Use of Aerial Survey in Forestry and Agriculture.* Imperial Agricultural Bureau. Joint Publication No. 9. 1947.

(2) Spur, S. H. *Aerial Photographs in Forestry.* The Ronald Press Company, New York. 1948.

(3) Thomson, A. P. *The National Forest Survey in New Zealand.* Fifth Empire Forestry Conference. London, 1947.

(4) Woodward, L. A. and Schlatter, E. J. *Specifications for Vertical and Oblique Photographs.* The Manual of Photogrammetry. Pitman Publishing Corp. New York, 1944.

(5) Holloway, J. T. *Ecological Investigations in Nothofagus Forests in New Zealand.* Seventh Pacific Science Congress. New Zealand. 1949.