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United States Experience in the Use of Air Surveys in Forest Inventory

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1/ The material on experience in California was prepared by Robert N. Colwell, Assistant Professor of Forestry, University of California, Berkeley, California.

/ABSTRACT

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Air surveys are widely used in the United States for forest mapping and inventory purposes. Photographs are taken by both public and private agencies. For forestry, modified infra-red pictures of 1:15,840 scale are widely used as well as conventional panchromatic photography. Forest maps are largely prepared by transferring detail from the photographs with simple projector or camera lucida devices onto a control network prepared by radial line triangulation. Forest stands are classified according to vegetation type and broken down into stand-size classes on the basis of tree height, stand density, and crown diameter. Volume estimates may in some cases be made directly from the photographic information, but in most cases the photographic data are used rather to control the field survey. The intensity and location of ground sampling is determined by information obtained from the photographs. Either the stand map may be used to provide this control, or sample plots may be located directly on the aerial photographs to accomplish the same purpose where no stand map is available. In this way, much more than half of the amount of ground sampling can be eliminated without sacrificing accuracy. In California, greater emphasis is placed upon complete vegetation mapping than elsewhere in the country. A discussion of practices in this state provides an insight in techniques and problems in the western United States.

UNITED STATES EXPERIENCE IN THE USE OF AIR SURVEYS IN FOREST INVENTORY

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A general discussion of the use of air surveys in forest inventory in the United States has recently appeared in Unasylva. Also, present knowledge of the subject in this country has been summarized within the past year in book form. In the present paper, therefore, material in the above two sources will be largely omitted. Instead, the practices currently being followed in the United States will be stressed, together with those recent developments which seem both technically feasible and economically possible.

The use of air surveys in forest inventory may conveniently be considered in five parts: (1) aerial photographs, (2) aerial surveying or photogrammetry, (3) photo-interpretation, (4) forestry applications, including forest mapping and forest inventory, and (5) California experience.

Aerial Photographs

Aerial photography in the United States is largely taken by private air survey firms under government contract. Standard specifications established by a committee of the American Society of Photogrammetry are used with minor modifications. Most photographs are nine inches square.

The largest buyer of photographs is the United States Department of Agriculture which in the period 1938-1947 contracted for more than two million square miles of photography despite the fact that little photography for non-military purposes was undertaken between 1942 and 1945. These photographs were mostly taken at a scale of 1:20,000 with an 8 1/4 inch focal length lens, and in 1948 cost on the average $2.50 per square mile. They are used by the Field Production and Marketing Administration, the Forest Service, the Soil Conservation Service and other agencies.

Other major public agencies using large quantities of aerial photographs are the Geological Survey of the Department of Interior, which prefers small scale photography taken with a 5 1/2 inch or other wide angle lens for Multiplex mapping; the Department of the Army; and the Coast and Deodetic Survey of the Department of Commerce, which takes considerable photography with its own nine-lens camera. States,

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/counties,

counties, and municipalities are also purchasers of photographs. In addition, about one-quarter of a million square miles have been photographed within the last decade for private use, the major buyers being oil companies, mining companies, pulp companies, and lumber companies. Private photography for forestry use generally costs in the neighborhood of six to ten dollars per square mile for tracts more than one hundred square miles in extent. In all, about 70 per cent of the country has been photographed from the air.

Most photography is taken with panchromatic film with a yellow (minus blue) filter. For forestry purposes, however, considerable photography is taken with infra-red film, generally with a minus blue or other filter that allows a limited amount of visible as well as infra-red radiation to reach the photographic emulsion. The modified infra-red technique greatly increases the possibility of species differentiation without producing excessive contrasts, but at the expense of obscuring some subordinate detail by the black shadow. Since the introduction of this technique in 1945, the U. S. Forest Service has contracted for about thirty-seven thousand square miles of modified infra-red photography while an additional large amount has been taken for private wood-using industries and minor political divisions.

The 1:20,000 scale is used in many cases for forestry work, especially where existing U. S. Department of Agriculture photographs must be employed. Most foresters, however, prefer the 1:15,840 (four inches to the mile) scale which is sufficiently large for fairly precise photo-interpretation yet sufficiently small for economy. By far the largest amount of photography specifically for forest survey purposes is taken at this scale. Several projects have been undertaken at a scale of 1:12,000. The added precision of photo-interpretation obtained, though, generally does not justify the additional cost of photography and of all subsequent operations. The use of larger scale photography is limited to small tracts.

The 8 1/4-inch focal length lens is most generally used for forest survey. The 6-inch lens has proven excellent over flat terrain because of the greater exaggeration of the vertical dimension obtained, but its use results in excessive distortion of the pictorial image where the relief exceeds a few hundred feet. In very mountainous terrain, the 12-inch lens has proven most satisfactory for the common forestry scales.

Most forestry photography is taken in the season of full foliage because of the importance of deciduous hardwoods throughout the eastern United States, and the concentration of good flying weather in the summer in the western United States. Photography, when leaves are off the

/deciduous

deciduous trees, is restricted to those areas where the deciduous trees are of no economic value and to times when the snow cover is light or non-existent.

Aerial Surveying

Photogrammetric techniques are now employed by practically all major map-making agencies. In forest survey the standard techniques are generally used, although emphasis is placed on relatively crude methods that will yield satisfactory results at the lowest costs. Radial line plots, generally carried out with the slotted or mechanical templets, are almost universally used to bridge ground control to form a network of photographic control points. The standard commercial quotation on a radial line layout is one dollar per photograph, exclusive of ground control.

Simple instruments are widely used to transfer planimetric detail from the contact prints to the radial line control network. Most commonly used are the Saltzman or other types of reflecting projector, Multiscope, Radial Planimetric Plotter, and camera lucida devices of the Sketchmaster type. Such devices range in cost from slightly more than one hundred to about two thousand dollars, and permit the transfer of planimetric detail of from three to thirty square miles per man-day, depending upon the scale of the photographs, instrument used, amount of detail, and desired accuracy.

One consulting firm in the Pacific Northwest is successfully using the Multiplex system for topographic and planimetric mapping, but the instrument is too expensive and the rate of production too low to justify the device except where the terrain is rough and the forest values high. For topographic mapping, the new Kelsh plotter which is undergoing development by the U. S. Geological Survey, is a relatively low cost instrument capable of doing much of the work previously done by the Multiplex. Other low cost topographic mapping instruments are also finding increased use.

Photo-interpretation

Photo-interpretation of forest tree and stand detail is largely confined to the identification of species and site, and the measurement of area, tree height, crown diameter, crown closure, and crown counts. In the last few years, considerable information has been gathered as to the precision of such photo-interpretation. For accurate work, trained interpreters must be familiar with local forests and must have high quality photographs of recent date. If only poor quality or out-of-date photographs are available, conventional ground methods will frequently give better results at lower costs.

/The widespread

The widespread use of infra-red photography has greatly simplified the problem of distinguishing hardwoods from softwoods and has made possible the indentification of several important species. The Lake States Forest Experiment Station and Region 9 of the U. S. Forest Service, among others, have been active in developing keys for the identification of broad forest types on photographs and in preparing stereograms illustrating these types. On the other hand, efforts to make a highly precise breakdown of the forest into types have largely been unsuccessful. For example, the Northeastern Forest Experiment Station in a test of type mapping in Maine found that about half of the stands were incorrectly typed when a large number of possible classifications were set up. Similarly, bald cypress cannot readily be distinguished from black gum in southern swamps, nor can the various southern pines be distinguished from one another in many instances.

The identification of site has been studied by the Central States Forest Experiment Station and others. It is now believed that site can be recognized to the extent that it is correlated with topography, major variation in soil moisture, and those geological and soil characteristics that are visible in the stereoscopic image. The identification of species and site requires an ecological approach, and can be most successfully done by a trained ecologist or forester with extensive field experience in the region being studied.

Recent tests by the Harvard Forest and others have demonstrated clearly that tree heights can be accurately measured by simple parallax devices, and that crown diameters can be equally well evaluated with simple micrometer scales. With good quality 1:15,840 photographs, average tree height errors should not exceed five feet nor average crown diameter errors exceed three feet. The evaluation of crown closure and the counting of number of crowns per unit area, however, are subject to greater error. Pending further developments, these two items should only be grouped into fairly broad strata.

Many simple interpretive devices have been designed, particularly by the several U. S. Forest Experiment Stations. Parallax wedges, micrometer wedges, crown density scales, dot acreage grids, and scale rules are available at cost on transparencies from a number of agencies and are widely used. There is, nevertheless, considerable room for improvement in the designing and engineering of these simple photogrammetric aids.

The general trend in photo-interpretation seems to be along the lines of using specially trained personnel and requiring detailed and careful work. For instance, the Central States Forest Experiment

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Station, among others, uses highly trained photo-interpreters who spend several minutes analyzing each plot established on aerial photographs and who are required to tabulate a series of determinations and measurements made on this plot. The work is best done by a forester with highly trained vision and an ecological background. The average photogrammetrist does not have the woods knowledge to do this work satisfactorily.

Forestry Applications

Aerial photographs are a useful tool in many aspects of management. The major systematized uses to which they are put are in forest mapping and forest inventory. In both, aerial photographic methods are being rapidly accepted as standard.

The value of aerial photographs in forest mapping is obvious, especially if the photographs are specially taken to emphasize forest type differences. Photo-interpreters ordinarily experience little difficulty in recognizing type lines or in distinguishing broad types. Considerable error is likely to be encountered, however, if he tries to map all the minor variations in composition. The comments made concerning species identification in the previous section apply here.

In general, the most satisfactory forest stand maps made from aerial photographs are those in which the stands are classified on the basis of those variables actually recognizable on the aerial photographs, particularly forest type, stand height, stand density, and topographic site. Such a classification need not appear on the final map. A merchantability or stand-size classification may well be substituted for it at this stage. Efforts to map directly from aerial photographs into merchantability classes have proved less satisfactory, although this procedure is frequently adopted for economic and practical reasons. In any event, considerable field checking is necessary to insure accuracy. The checking may be done before or after the photographic work. One consulting firm uses a light aircraft to check the stand map prepared from photographs, but most field checking is made from automobiles and concentrated along road-side areas.

Costs of forest mapping from aerial photographs are low. The combined costs of photo-interpretation, planimetric mapping, field checking, and drafting, - but excluding the cost of photography, and radial line control plot, - range from about five to twenty dollars per square mile.

/Little actual

Little actual volume estimation from aerial photographs is done, although experiments at the Harvard Forest indicate that such estimates if carefully made will be within fifteen percent of the total gross volume under many conditions. In general, the photographs are used to determine the areas of the various forest classes or strata and to provide a rough estimate of class volume for the purpose of stratifying the field survey.

Two general approaches are used, one in which the photographs are used to prepare a forest stand map and the map is then used to control the field survey; and one in which plots are established and evaluated on the aerial photographs, calculated numbers of these plots then being relocated and measured in the field. The first, or stand approach, is that used in most intensive surveys, such as are carried out by pulp companies and other private concerns. Tests at the Harvard Forest indicate that the use of aerial photographs to determine stand class areas and to stratify the field cruise reduces by approximately two-thirds the amount of ground work necessary for a given degree of accuracy. This type of approach has been adopted to extensive forest surveys by the Lake States Forest Experiment Station. Their area sampling technique involves the random selection of forty-acre tracts or quarter-sections of 160 acres. These chosen areas are type-mapped to provide information concerning the distribution and areas of forest classes. The same areas are then sampled on the ground, a procedure in which the intensity of sampling is determined by the volume, value, and variation of each class being sampled. Simply by varying the sampling pattern, the same procedure may be used for any desired intensity of cruise designed to give any desired accuracy.

The photo-plot type of cruise has been used for small tracts with satisfactory results, but finds its major application in regional forest surveys. The techniques evolved by the Northeastern Forest Experiment Station typify its operation. First, a large number of plots are systematically distributed over the aerial photographs. In a typical survey unit, one plot is allocated to each 475 acres. These are classified into forest and non-forest land. The forest plots are studied under a stereoscope and classified according to forest type and stand-size class. About one-tenth of these plots are then located in the field, and accurate measurements of volume, growth, cull, site, quality etc. are determined. The percentage of photo-plots visited in the field varies with the value and variance of the forest class, being

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highest for high value and heterogeneous classes and lowest for low value homogeneous classes.

Practically all users seem highly satisfied with the accuracies of forest inventories combining both photographic and field work. The use of photographs not only reduces the amount of field work necessary for the same degree of accuracy, but also reduces the costs of the entire inventory by fifty per cent or more. Extensive inventories may be made for as little as five dollars per square mile, excluding the costs of photography, while highly precise intensive surveys may be made for about fifty dollars per square mile, also excluding photography.

California Experience

The use of aerial photographs for forestry purposes in the Pacific Coast states differs from that in the rest of the country in that greater emphasis is placed on vegetation mapping.

Vertical photographs are more useful than obliques for most forestry purposes in California. Photos taken during the late spring and summer months are preferred to those taken at other times of the year. Tests were recently conducted in the two chief timber-producing regions of California (the redwood region of the north coast and the pine region of the interior) for the purpose of determining the most useful film-filter combination for forestry purposes, with special emphasis on requirements for the Forest Survey. Panchromatic film used with a yellow (minus-blue) filter was found to yield slightly more information of the type needed for the California Forest Survey than does panchromatic film used with a green filter, and much more than is obtainable from infra-red minus-blue photography. Much of the information desired by foresters can be more easily and accurately interpreted at the 1:15,000 photo-scale than at 1:20,000. The 1:20,000 photo-scale, however, has proved satisfactory for planimetric and topographic mapping of forested areas in California with the required degree of accuracy.

In making planimetric maps from aerial photos, the U. S. Forest Service in California plots a network of field control points on a Polyconic grid, scale 1:24,000 and then establishes the positions of photogrammetric control points by mechanical radial triangulation. Planimetric detail is then transferred from photos to the map with the aid of a KEK plotter.

/In making

In making inventory of California's timber resource as part of the nationwide Forest Survey, the Forest Service first classifies vegetation with the aid of aerial photographs. From stereoscopic study alone are obtained (a) the kind of vegetation cover or other condition occupying the land, (b) the age structure of tree stands based on the proportions of age classes present, (c) the densities of timber stands and all woody vegetation, and (d) the segregation of timber croplands from other lands. Then from ground observations, aided by whatever the photos can reveal, is obtained the species composition of the vegetational areas. This classification provides the area inventory of the various timber and other vegetation types, gives a stratification of timber stands that minimizes the ground sampling needed to reliably estimate timber volumes and growth, and provides an "in place" delineation of the vegetation classes that makes the Survey locally useful.

In California, the U. S. Forest Service makes use of aerial photos for timber cruising in the following ways: (1) The area to be cruised is first stratified on aerial photos as to its age class and density; (2) with the aid of the photos a planimetric map is prepared on which the strata are plotted; (3) the photos and map are used to plan the direction, spacing and location of cruise strips with due regard to topography, timber density and accessibility; (4) survey crews use the photos in the field while determining timber volumes, growth and merchantability on the cruise strips. The overall cost of this method usually is not more than fifty percent as great as that of the conventional ground method.

/BIBLIOGRAPHY

BIBLIOGRAPHY

In addition to the references below, current material on forest aerial survey may be found in Photogrammetric Engineering, published by the American Society of Photogrammetry, P. O. Box 18, Benjamin Franklin Station, Washington, D. C.; Journal of Forestry, published by the Society of American Foresters, Mills Building, Washington 6, D. C.; and the various publications of the U. S. Forest Service.

American Society of Photogrammetry. Manual of photogrammetry. New York, Pitman Publishing Corp. 1944, 841 p.

Garver, Raymond D. "Aerial photographs in forest surveys", in Journal of Forestry, v 46, no 2 (Feb. 1948) 104-106

International Photogrammetry Congress. "Report of Commission I - Photography", in Photogrammetric Engineering, v 14, no 2 (June, 1948) 229-279

Spurr, Stephen H. "Aerial photographs in forestry". New York. The Ronald Press Co. 1948, 340 p.

----------"Aerial photography", in Unasylva, v 2, no 4 (July-August, 1948) 183-194
