Use of Twin Low-Oblique Aerial Photographs for Forest Inventories in Southeast Alaska

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ABSTRACT: *To meet economically the divergent requirements of photography for both mapping and forestry purposes, a combination of 1:40,000 vertical and 1:20,000 twin low-oblique aerial photographs were taken in an aerial survey of Southeast Alaska. The vertical photography was taken with a six-inch camera. Two 12-inch focal-length cameras were tilted right and left at 18 degrees from the vertical. These oblique photographs are being successfully used to carry out forest inventories. Forest and other land-class areas are obtained by either direct estimates from the aerial photographs or by measurements made on timber cover maps constructed from the aerial photographs.*

In the first case, a sample of points or plots is classified by photo-interpretation to obtain the percentage or proportion of each class. The proportions are then applied to total land area to determine area in each class. A light plane is used to check photo-interpretation in the field. Sampling error as well as the most efficient combination of photo and ground plots can be computed. The oblique photographs have made it possible to carry out forest inventories needed for the development of forest industries in this region.

LOW-OBLIQUE aerial photographs are being used in conducting forest inventories in Southeast Alaska. Since the use of this type of aerial photograph for forest inventory purposes has been rather limited, it is believed a description of their use may be of interest. In many cases oblique aerial photographs offer distinct possibilities in obtaining fine photographic detail coupled with economy of coverage. Katz[1] has pointed out that both image area and image scale can be increased if a camera is swung off vertical. In the Southeast Alaska survey, twin low-oblique and relatively small-scale vertical aerial photographs were taken at the same time to meet the combined objective of topographic mapping and a forest-land use inventory of the region.

AERIAL PHOTOGRAPHY

Oblique aerial photographs have not been widely used in conducting forest surveys. In Southeast Alaska tri-metrogon photography has been used to a limited extent. In Canada the Dominion Forest Service[2] has developed a procedure which employs a combination of a center vertical and two low-oblique wing photographs. Recently the U. S. Geological Survey[3] developed the Twinplex Plotter designed to utilize convergent or transverse low-oblique photography for aerotriangulation and mapping.

In 1949 the entire Southeast Alaska, an area of approximately 45,000 square miles, was photographed by Navy Squadron UPML-4.[4] The U. S. Geological Survey specified 1:40,000 scale vertical aerial photographs for mapping purposes. The U. S. Forest Service needed larger scale photography for conducting a forest inventory and preparation of timber cover maps. A scale of 1:20,000 is generally regarded as the minimum for regional surveys or broad forest type classification.[5] Coverage of the entire area with 1:20,000 vertical photography would have increased costs greatly. It also would have jeopardized completion of the project in one season as the inclement weather of this region greatly limits the probable number of

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photographic days.

A combination of vertical and oblique photographs, therefore, was specified. Photography was taken at an altitude of 20,000 feet. The vertical mapping photography was obtained with a six-inch focal-length camera. The photography for Forest Service inventory-resource use was taken with two K-17, 12-inch focal-length cameras mounted in tandem in a split mount adjustable for crab and tilt. These two cameras were tilted right and left 18 degrees from the vertical normal to line of flight (Figure 1). The combined transverse coverage of the obliques is approximately equal to that of the single six-inch focal-length camera. The two K-17 cameras were operated to obtain desired forward overlap, with the third six-inch focal-length camera synchronized to operate at every second exposure of the twin cameras.

The twin-oblique photographs used in this project were taken at a relatively high altitude and at a relatively small angle from the vertical. As a result the perspective effect is not pronounced (Figure 2) and at first casual inspection they appear to be verticals. Stereoscopic perception is effected by proper orientation under a stereoscope of any two successive exposures on the same side of the flight line. Thus a half model is formed by two successive right-hand exposures while another half model is formed by two successive left-hand exposures. There is a small overlap between any pair of right- or left-hand models along the nadir parallel (Figure 1). The nadir edge of the print should be oriented toward the observer while viewing a stereoscopic pair of photographs so that the observer is looking in the same direction the camera was trained at the time of exposure.

The characteristics of these obliques

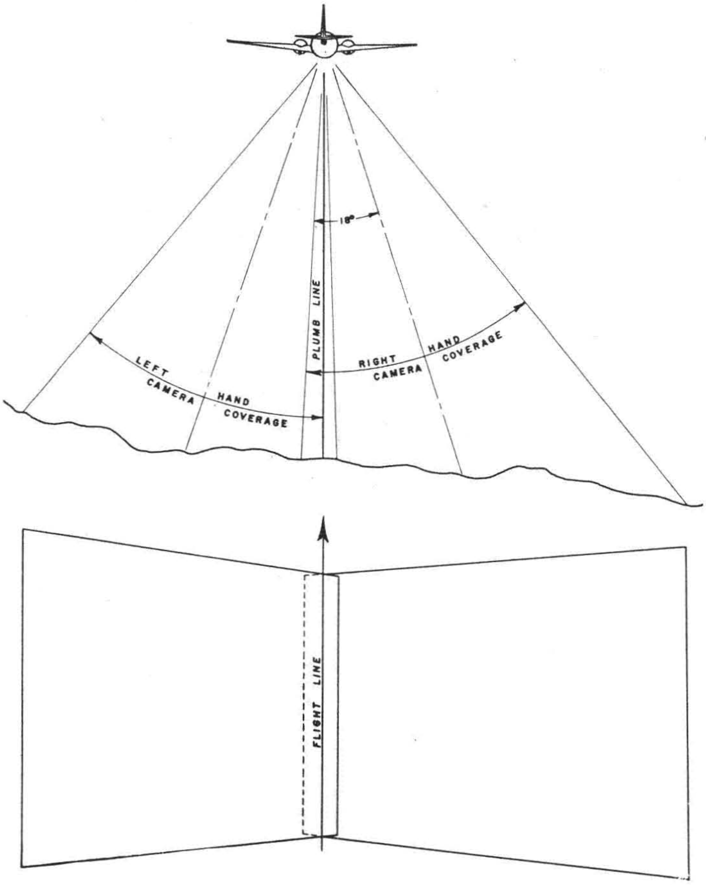

FIG. 1. Transverse coverage twin low-oblique photographs.

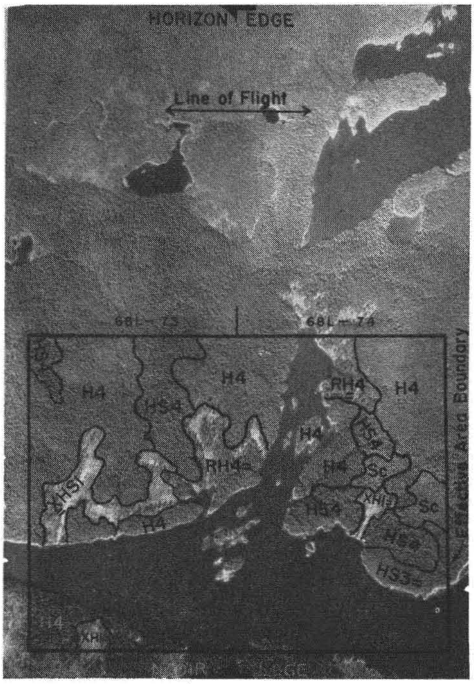

FIG. 2. Reduced 1:20,000—18° oblique aerial photograph with timber type delineations. *Legend:* H4 = Western hemlock old-growth sawtimber, RH4 = Residual western hemlock old-growth sawtimber, HS4 = Western hemlock-Sitka spruce old-growth sawtimber, HS3 = Western hemlock-Sitka spruce young-growth sawtimber, XHS1 = Cutover western hemlock-Sitka spruce restocked with seedlings and saplings, Sc = Scrub non-commercial forest.

have not presented any significant technical difficulties for use in forest interpretation. No attempt is made to construct base maps from the obliques as the companion 1:40,000 verticals can be used for this purpose. A training handbook,[6] perspective grids, and tables giving horizontal and vertical scale equivalents for various positions on the photograph, have been prepared for the use of photo-interpreters. Tree heights are determined by parallax wedge for the area along the nadir parallel and by direct measurement of tree image in the horizon half of the print (Figure 2).

USE OF OBLIQUES IN FOREST SURVEY

The use of aerial photographs for classification of timber stands provides the forester with means of segregating or stratifying forest stands. This breaking down of forest areas into more uniform components reduces the amount of field sampling necessary, and results in more accurate forest inventories at lower costs.

One major phase of a forest inventory is area determination of various land-use classes. Forest land is further classified according to type, density, and stand-size classes. Areas can be obtained by delineation of boundaries between the various classes on the aerial photographs (Figure 2) and transferring these boundaries to a base map where area can be determined by polar planimeter or dot grids. Area can also be determined by estimating directly from photographs by dot classification, as outlined by Wilson.[7] Both systems are used with oblique photographs in Southeast Alaska.

The use of a timber cover map for area determination is usually confined to the more intensive inventories of timber stands to be logged in the near future. The boundaries of the various classes are delineated on the obliques by stereoscopic examination. A rectifying, double-reflecting projector is used to transfer the type boundary to the base map. Manuscripts of standard topographic maps prepared by the U. S. Geological Survey from the companion 1:40,000 vertical photographs provide the base map source material. Hypsographic, cultural, and hydrographic features are used to augment the control of the projected photographic image on the base map.

For estimates of area direct from the aerial photographs, dot templets are superimposed on the photograph and the location pin-pricked thereon. In most cases the points are first located on the 1:40,000 verticals. The breakdown of non-forest and forest land is made on the verticals. The points classified as forested or forest land are transferred to the obliques for detailed classification. This method speeds up photo-interpretation work by reducing the number of photographs which must be handled where there are large areas of barren land such as icefields and mountain tops. A dot templet constructed on a perspective grid can be used directly on the obliques if required. The proportion or percentage of points in each class is multiplied by total land area to obtain the area of each class.

Tests indicate that with these procedures, errors due to relief displacement are within acceptable minimums. The characteristics of topography and timber occurrence in Southeast Alaska also tend to minimize error due to relief displacement. The orientation of flight lines with the long axis of the islands and mountain ranges, and sidelap allowances during photography, tend to compensate for relief changes. Moreover, since the commercial timber area in this region is confined to the lower elevations with a normal maximum of 2,000 feet, relief displacement is further minimized.

The system of direct estimates of area by point classification can be subjected to rigid checks to minimize technique or interpretation error. The points can be located on the ground and the photo-classification checked. In the Southeast Alaska survey, provision is made for field checking a random sample of points classified on the photographs. It was recognized that in borderline cases, or where photographic detail was obscure, accurate classification would not be possible. In such instances the interpreter adds the sub-classification "doubtful" to his classification of the point.

All "doubtful" plots are field checked, employing a light two- or three-place plane of sufficient horsepower to have a rapid rate of climb. Low stalling speed is desirable, since ability to fly at slow speeds over the points to be checked is important. Points to be checked are spotted on a flight map. The aerial photographs on which the points are located are assembled in consecutive order on a clip board. Plots are readily located from the air by comparing photographic features with those on the ground. Classification is usually determined when the plane is flying from 300 to 500 feet above the plot. The observer records his classification in code-form directly on the photograph.

Ground checks of aerial classification have shown that, in this region, the experienced aerial observer can identify timber type and density. A good estimate of the accessibility of the timber from a logging viewpoint, average tree or log height, and volume can also be made.

After field checking, classification of areas determined by photo-interpretation is corrected by applying a factor or ratio determined from a comparison of photo and field classification of the random sample selected for field checking. Point classification lends itself well to this type of adjustment which provides a means of checking and correcting photo-interpretation errors.

The area determination is subject to a sampling error inasmuch as it was obtained by a sampling process. This sampling error can be determined. When information on factors affecting sampling errors is available from previous or preliminary surveys, the number of points which must be classified to obtain the desired limit of sampling error can be computed. Sampling error tends to be increased by photo-interpretation errors which have the effect of increasing the variability of the sample. The formula used to calculate sampling error in Southeast Alaska was developed by Chapman* and is as follows:

$$s(\Sigma P_i p_{ij}) = \sqrt{\Sigma P_i^2 \frac{(p_{ij}q_{ij})}{N_{ti}} + \frac{1}{N_s}\left[\Sigma P_i p_{ij}^2 - (\Sigma P_i p_{ij})^2\right]}$$

$$Ac = Ag(\Sigma P_i p_{ij})$$

where

Ac = total area in a particular class

Ag = gross area of unit

P_i = proportion of all photo plots which fall in a particular class

$q = 1 - p$

p_{ij} = proportion of field plots for a particular photo class that fall in a particular ground class

The subscript "i" refers to any particular photo class and "j" refers to any particular ground class

$s(\Sigma P_i p_{ij})$ = standard error expressed as a per cent

N_{ti} = number of field plots which fall in a particular class

N_s = total number of photo plots

It can be seen that if other factors are known, or can be approximated on the basis of experience or preliminary surveys, the total number of photo plots can be computed by substitution.

Usually the forester is most interested in

* Chapman R. A., Statistician, Division of Forest Economics, Forest Service, U. S. Department of Agriculture.

lands which are potentially capable of producing commercial timber products, and sampling error is usually defined in terms of commercial forest land. The volume of timber on these lands can be computed if the total acreage of commercial forest land and the average volume per acre of timber are known. The latter value is obtained by measuring trees on sample plots. It can be seen that total volume is subject to a sampling error which is the product of a sampling error for area and sampling error for volume.

Since area is obtained by photo-interpretation with aerial checking, the cost per photo-plot is quite low in comparison to on-the-ground volume sampling, which, in Southeast Alaska, involves costly boat and ground travel. For example, the cost of classifying a photo-plot, including checking by airplane, may range from 40 to 50 cents per plot, while the average cost of ground volume plots is approximately 100 to 125 dollars. Therefore, we can afford to classify a great many photo-plots to reduce sampling error for the area estimate which will then be reflected in the number of volume plots required. The most economical ratio of photo-plots to volume-plots can be determined by calculating the break-even point where an increase of photo-plots is not reflected in a significant reduction of the number of volume-plots. In Southeast Alaska a ratio of 30 to 50 photo-plots for each ground plot has been found to yield the most economical results. On a recent survey of a unit comprising a total area of 3,800,000 acres, 5,830 photo-plots and 190 field volume-plots were used.†

In addition to land-use and timber classification, the photographs are used during the course of the inventory for locating field volume plots on the ground and selecting most feasible routes of travel. In many cases, timber cover maps are made of areas of particular importance as an adjunct to the inventory where the point-classification system is used. This article has described the use of low-oblique aerial photographs in only one specific phase of forest and resource administration. These photographs are also used as working tools in many other ways.

Literature Cited

1. Katz, Amron H., "Contributions to the Theory and Mechanics of Photointerpretation from Vertical and Oblique Photographs." Photogrammetric Engineering, V. 16, pp. 339–386, 1950.
2. Seeley, H. E., "The Forestry Tri-camera Method of Air Photography." Dominion Forest Service, *Forest Air Survey Leaflet* No 3, Ottawa, Canada, 11 pp., illus., 1948.
3. U. S. Geological Survey., "Twin Low-oblique Photography and the Twinplex Plotter." *Geological Survey Circular* 222, 18 pp., illus.
4. Pollock, Thomas F., "Aerial Survey of Southeastern Alaska." Photogrammetric Engineering, V. 15, pp. 276–287, 1948.
5. Spurr, Stephen H., "Aerial Photographs in Forestry." 340 pp., illus., New York, 1948.
6. Andersen, H. E., "The Use of Low-Oblique Aerial Photographs in Timber Surveys." Alaska Forest Research Center. 26 pp., mimeo., 1953.
7. Wilson, R. C., "The Relief Displacement Factor in Forest Area Estimates by Dot Templets on Aerial Photographs." Photogrammetric Engineering, V. 15, pp. 225–236, 1949.

† A field volume plot consists of three rectangular (1×2 chains) one-fifth acre plots spaced at two-chain intervals, and oriented across the general slope of the ground.

Forest Photogrammetry and Aerial Mapping—A Bibliography, 1887–1955

A comprehensive bibliography dealing with the forestry use of aerial photographs, articles on aerial photography written by foresters, articles on forest terrestrial photogrammetry, and aerial sketching, has been compiled by Professor Stephen H. Spurr of the University of Michigan. Divided into ten sections, it gives the bibliographic citations of articles and books by periods of years and geographical area. It has 60 mimeographed pages and is bound in a lithographed cover. A limited number of copies available for free distribution from the School of Natural Resources, University of Michigan, Ann Arbor, Michigan.