Thus, enthusiastic and unlimited production of air photo interpretation keys for existing world coverage is a nearly endless task, if not one of questionable value. It is likely to be more efficient to postpone making new keys until the need for specific ones is demonstrated for specific projects.

Air photo interpretation is a technique belonging to all fields of study. The procedures are similar to those of map interpretation, language translation, statistical manipulation, and field observation. Also, successful air photo interpretation is based upon the use of all available source materials, photographic and non-photographic. Therefore, the value of the technique may be overemphasized thereby doing it an injustice, in our enthusiasm to classify researchers as "photo—ists(ers)"; such analysts use other techniques and source materials and the term is the equivalent of calling a person a "hammer-carpenter." Too, there is hardly any such person as an "air photo interpreter," unless temporarily for educational or administrative purposes, because no one proposes to use just air photos, nor do many people suggest by such a title that they can identify everything seen on any coverage of the world.

It follows that the way to interpret air photos is simple in general terms. Work is carried on methodically from the general to the specific items, and from the known to the unknown features, in view of the photographic qualities available. Then we analyze topically. Thus, the more specific procedures are likely to come in the future from topical specialists (such as, geographers, city planners, geologists, foresters) who interpret air photos with breadth and depth of topical content, as well as other source materials and techniques.

*Problems in Comparing Photo Interpretation Research Results from Different Studies**

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ABSTRACT: *Quantitative data are increasingly becoming available in photo interpretation research. The task of evaluating these data for a particular study in view of other similar studies and the making of a comparative evaluation of the results, runs into problems. The author presents an example and offers suggestions to research workers in the field of photo interpretation so that research results can be compared with other similar studies.*

THE PROBLEM

IN THE past twenty years great progress has been made in all fields of photo interpretation. During this period investigators have collected data to study

* A contribution of Commission VII, Photographic Interpretation, International Society of Photogrammetry.

a specific need and to pave the way for improving efficiency of photo interpretation. The particular objective in this paper is to discuss volume estimates of forests from aerial photos and methods of improving such estimates.

The major purpose of timber cruising is to determine the total volume of wood on a given area. In such studies many characteristics of the forest are important, such as species and size of trees, condition and quality of timber, growth, destruction or cutting for wood products, area by size classes, forest types, and soil types. These items and perhaps many others are studied together with volume, but usually incidental to the study. Hence, the variability of wood volume and timber size are the critical characteristics of the forest upon which the design of a timber cruise is usually based.

Foresters have found that aerial photos are an aid in estimating wood volume and stand size. Accordingly aerial photos have become a basic consideration in the design of timber cruises. Where a high degree of accuracy is not needed, the experienced photo interpreters can omit all or a large part of the field work usually required. One investigator, Moessner (*6*), has reported exceptional accuracy but many foresters consider such reports to be chance occurrences. Even where accuracy is very important the work done by the experienced photo interpreter reduces the amount of field work several times. The accuracy with which the interpretations can be made is not fully established, however, and is a subject of much speculation, conjectures, and discussion. This is not surprising in view of the many variables which can effect the accuracy.

Methods of Estimating Wood Volume

To obtain volume foresters use aerial photos in two ways. First, some photo interpreters estimate volume directly from the aerial photos; that is, some photo interpreters furnish specific volume estimates from photo examination without field study; at present these interpreters are far in the minority. Most photo interpreters rely upon combinations of both photo and ground work. A complete break-away from ground plot examination is not now generally acceptable, but it appears that research will develop techniques that will markedly reduce the number of ground plots needed.

Certain interpreters gain an advantage in aerial photo interpretation by stratified sampling designs. By this design a heterogeneous population of volume is divided into homogeneous volume classes or stratum, and a random sample of ground plots is drawn from each of these homogeneous volume classes. The photo interpreter classifies the forest area by these homogeneous volume classes. The random samples of ground plots in each homogeneous volume class are used for estimating the mean volume of the volume class. These methods withstand rigorous examination of the critics.

Tests of Accuracy

In the 1930's there were no studies to show the accuracy of estimating volume from aerial photos. But during this period many foresters were getting interested. However it was not until after World War II that some progress was made. The standard deviation for homogeneous strata became a basis for judging the efficiency of the use of aerial photos, and is an excellent scheme when specific volumes are not estimated. When specific volumes are estimated, both on the photos and on the ground, then direct comparisons can be made between these estimates. This, of course, is a more precise test of the accuracy of photo estimates of volume than a comparison of the timber volume for a large area based on ground samples that are independent of photo techniques.

The results of such comparisons are shown in Table 1. The variance of the differences for photo estimates to ground estimates for volume are listed in the order of the increasing magnitude of photo scale. This wide range of scales appears to indicate no relation of photo scale and of the reliability of volume estimates obtained from them.

TABLE 1

VARIANCE OF DIFFERENCES BETWEEN PHOTO VOLUME AND GROUND VOLUME FOR VARIOUS PHOTO SCALES

Study	Photo Scale (Representative fraction)	Variance of differences
1	1,200	86,936
2	5,000	29,000
3	7,200	221,700
4	7,900	56,500
5	12,000	171,400
6	20,000	271,200
7	20,000	3,800
8	20,000	46,000

COMPARISON OF TESTS

A glance at the variances in Table 1 furnishes no evidence that the use of larger photo scales will result in better photo interpretation. If one stops here, that would be the logical conclusion. In fact, study 7 shows the smallest variance and the smallest scale. One should look further and see what factors, other than photo scale, influence the variance of the differences of photo estimate and ground estimate of volume. Such other factors are plot size, variability of volume, quality of aerial photography, paired or unpaired observations, photo interpretation techniques and the skill of the photo interpreter.

Only where all these factors are about the same, can studies be compared. There are no acceptable or reliable schemes to make data comparable when plot size, variability of volume, photo quality, observations, photo interpretation techniques and skill of interpreters are not the same. Such comparisons selected by the author after careful study, do show smaller variances for the larger scales. This is very evident for comparable studies 1 and 3 by Losee (*4*) for scales of 1,200 and 7,200 respectively. Here the variance of the larger 1,200 scale is 0.39 of the variance of the smaller 7,200 scale. In another case, study 5 by Dilworth (*2*) and study 6 by Pope (*7*) are comparable. Here the variance of the larger 12,000 scale is 0.63 of the smaller 20,000 scale. These studies indicate that larger scales in aerial photos will improve accuracy of photo interpretation for volume. However, there are no comparable studies between 7,200 and 12,000 photo scales. But if it is assumed that the reduction in variance is at the same rate in this zone, then the data will show the variance ratio to have a trend as appears in Figure 1. This assumed trend (dashed line) will give a variance ratio for the 7,200 scale of 0.41 and 0.13 for the 1,200 scale. By using the 0.39 relation, established by Losee's studies (1 and 3), the variance ratio for the 1,200 scale is computed as 0.16, which is 0.03 higher than the theoretical ratio computed from the trend of studies 5 and 6. This represents the trend for a given combination of factors that affect variance of differences.

Studies 2 by Rogers (*8*), 4 by Dahl (*1*) and 8 by Moessner (*6*) cannot be compared with any other studies. The techniques used by Rogers and Moessner prevent valid comparisons with other studies. Rogers used Sonne continuous strip aerial photographs, and difficulties were encountered in evaluating scale for these photos. Hence, this study cannot be compared with others. Dahl used $\frac{1}{3}$ acre plots and worked in Eucalyptus forests of Australia of different variability, which isolates this study from all the rest. Moessner's study uses tracts of forests which vary from 40 to 640 acres in size, and applies different techniques which isolates his work from comparison with any others.

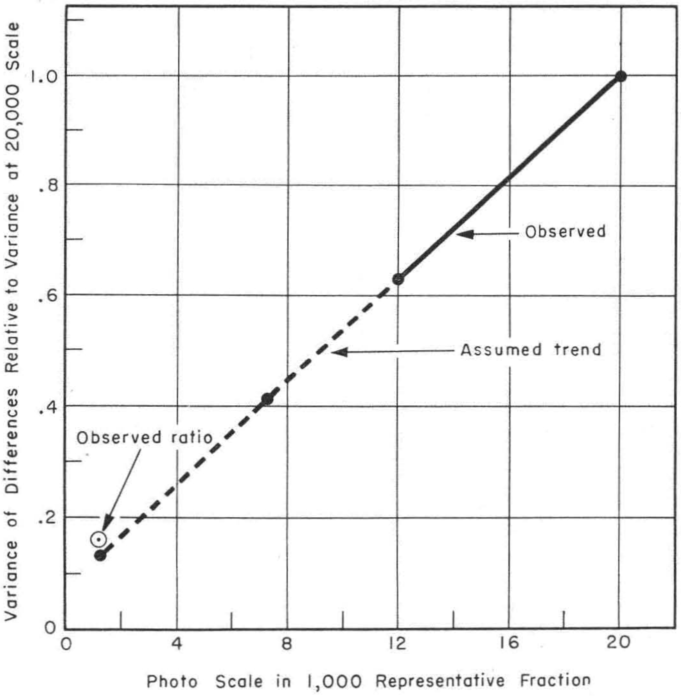

FIG. 1. Variance of differences between photo and ground volume relative to variance of 20,000 scale for various photo scales.

RECOMMENDATIONS

Until more comparable data become available this rationalization indicates a logical trend from these studies. Imperfect as it is, this imperfection directs attention to the need for investigators to take greater caution in their study or work plans. These plans should consider how others may benefit from their studies; then their work should be so designed that comparable data are obtained. Where the factors are due to natural causes (variability of volume), the investigator has no control, but for variables such as plot size, photo quality, paired or unpaired observations, photo interpretation techniques and skills of the interpreter, the investigator has some control. For these items the investigator should attempt insofar as practical to design the studies so that they are comparable.

There will be some reluctance by investigators to organize uniform research methods, but if this is not done much will be lost and the publication of research results will have reduced value.

This is not be be considered as criticizing past research. Photo interpretation research is a new and active field. The approach to problems has been heterogeneous because of lack of organization and experience. In many fields of endeavor, the great demand, for reliable information about photo interpretation challenges the investigators. This demand creates more studies. The experience herein illustrated shows the need for better planning. Perhaps the International Society of Photogrammetry or the American Society of Photogrammetry, making use of the vast organization, will decide to organize or to set up a committee that will study all phases of this problem and that will recommend organized approaches to research in fields of photo interpretation. The utilization of past studies in this very brief and limited study has caused the author to recommend a uniform plot size of 1/5 acre (1/10 hectare) and that these plots be paired for studies involving subject matter like volume estimates on aerial photos. Other items that influence the variance studies such as variability of volume, techniques in photo interpretation, skill of photo interpreters, and quality of aerial photos should be controlled so that studies can be compared and our knowledge increased.

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