*The Effect of Photo Scale on the Accuracy of Forestry Measurements**

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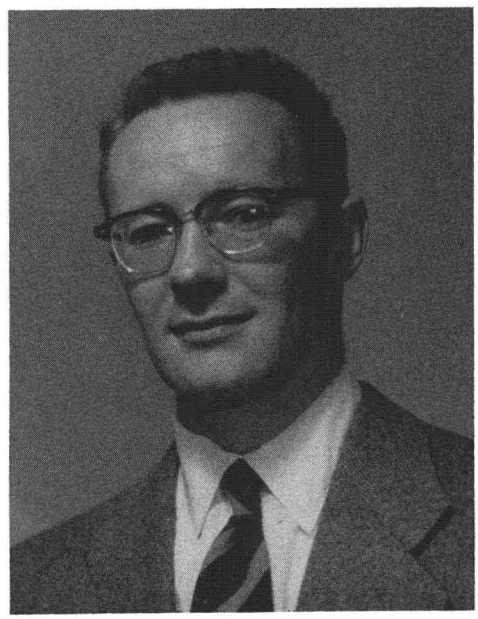
ABSTRACT: *The accuracy of tree height measurement and species identification on both panchromatic and color photographs was tested at scales ranging from 1:20,000 down to 1:2,500. Height measurement accuracy varied considerably among interpreters, but did not differ significantly with either photo scale or film type. Species identification accuracy was consistent between interpreters and no significant difference occurred between film types. However, accuracy did increase with larger photo scales and was much higher for mature stands than for immature stands. This study emphasized the desirability of standardizing as much as possible the results from different interpreters.*

INTRODUCTION

FOR a good many years, foresters have used aerial photographs as a tool in forest inventory work. Normally these range in scale between 1:20,000 and 1:12,000 and are used to stratify the field samples. If the forester does a reasonably good job of stratifying, he will find that he has reduced the number of field plots required to meet his sampling standards.

Even with this reduction, the forester still finds necessary quite a bit of arduous work in rough country. He wonders if the amount of field work can be reduced even more. Sometimes, while negotiating a particularly rough or brushy stretch, he speculates on the possibility of getting more help from the aerial photos. He knows that some of the information he wants can't be obtained from the photos he has. But if he *only* had some photos at a larger scale—!



ROBERT B. POPE

The deficiencies in available photos and the desire for something better have led the forester from time to time to suggest that an efficient forest inventory might be based on large-scale photos, taken on a sample basis, either alone or in addition to complete coverage at a smaller scale. Such a system will be justified if the sample photos provide sufficient information to pay for their cost. Determining whether they will or not is a sizeable problem, and quite a bit of work has been done on various parts of it. The results, however, have been conflicting. Some investigators have

* This paper is practically the same as that presented at the 23rd annual meeting of the Society, March 5, 1957, Hotel Shoreham, Washington, D. C. as a part of the Photo Interpretation Symposium.

found that for specific purposes certain scales are better than others. Other workers have tested various scales and have found no significant differences in the results. Not much of this kind of investigation has been done in the Pacific Northwest. Consequently, it appeared that the time had arrived for seeking a comprehensive answer to this question of scales through investigating the accuracy of various forest inventory measurements on a full range of photo scales—such measurements as tree height, crown diameter, crown closure, tree count, and species identification.

A study of this nature was begun last summer at the Pacific Northwest Forest and Range Experiment Station, U. S. Forest Service, Portland, Oregon. It is hoped that the study when completed will answer some of the questions that have been troubling northwest foresters—not the least of which is the vital question of whether to get that new pair of caulked boots, or, by using large-scale photos to reduce the field work, the old pair, can be made to do for a few more years.

The investigation can be conveniently divided into three parts. First, a study to determine the largest usable scales that can be used with available equipment. Second, to determine the effect of photo scale on interpretation accuracy, within this range of scales. And third, an evaluation of this relationship, in the light of photo cost, to determine whether or not the larger scales will pay their own way.

Maximum Usable Photo Scale

The first study—the maximum usable photo scale—has been completed. The tests were made with the kind of equipment commonly used for forestry purposes. The aircraft was a Cessna 170-B, and the camera a K-17 with 12-inch lens. It was found that for mature timber stands in the Pacific Northwest, the largest scale at which satisfactory photographs could be obtained with normal 60 percent overlap was about 1:8,000 or 1:10,000. At larger scales the excessive parallax of the tall trees led to unconfortable stereoviewing. By increasing the overlap to 75 or 80 per cent, however, the usable scale range was extended down to 1:5,000.

The use of a 24-inch lens enables good pictures to be obtained at scales of 1:2,000 or 1:3,000. At this point the scale was limited, not by excessive parallax, but by objectionable image motion, since the maximum shutter speed on this lens is 1/150 second. To see how far the usable scale could be extended for special purposes, an image-motion-compensation magazine was borrowed. With this piece of equipment and the 12-inch lens, excellent photographs at a scale of 1:500 were obtained over areas of brush and small trees, where excessive parallax was not a problem.

Thus the scale limits for the study had been set. The largest would be 1:2,500 with a 24-inch lens; at the other extreme the scale would be 1:20,000—the smallest that foresters generally use. As it was already getting towards the end of the photography season, it was decided to make only an exploratory study. The purpose was to discover some of the problems of testing large-scale photographs, and to learn whether or not a full-scale study appeared worthwhile.

Test areas in both mature and immature timber were photographed with panchromatic and color films at scales ranging from 1:10,000 down to 1:2,500. Standard 1:20,000 panchromatic photography was also available.

Tree Height Measurements

A variety of measurements are being made on these photos by three experienced interpreters, but the only data available so far are the species determinations and tree height measurements. Tree heights were measured by the parallax method using an Abrams Height Finder. The trees ranged from 50 to 250 feet high and were scattered throughout the stand—some were near openings where the ground could be seen, and others at varying distances from the nearest opening.

Figure 1 shows the results of the tree height-measurements. The measure of accuracy here is the standard error of estimate. It defines the range within which about two-thirds of the height-measurement errors fall, after the systematic error has been removed. The average height of the trees is about 150 feet, so an error of 20 per cent represents about 30 feet. The most important conclusion from these results is that there is no significant over-all relationship between height-measurement errors and either photo scale or film type. The trend is different for each interpreter. It is apparent that in this test the size of

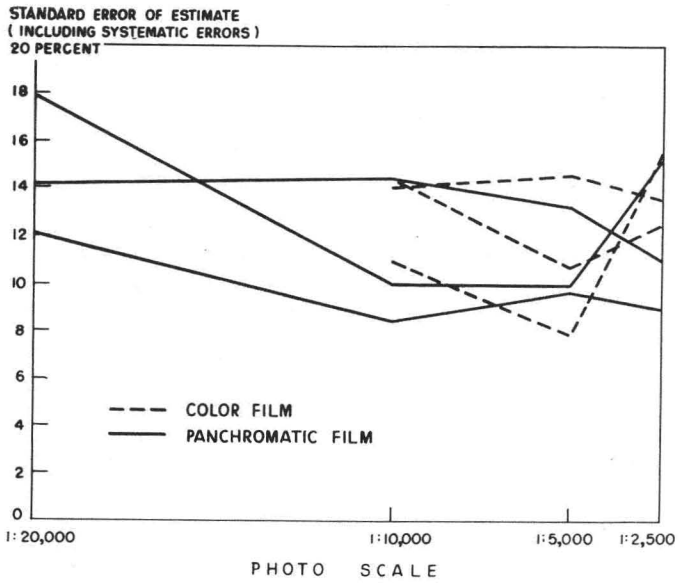


FIG. 1. Accuracy of tree height measurements obtained by three interpreters.

the errors depends more on the individual interpreter than on the photo scale or film type.

SPECIES-IDENTIFICATION

To get their "eye in" on species-identification, the interpreters first studied trees in the general area of the test plots. They then attempted to determine the species on a series of test trees scattered throughout the plots.

Figure 2 shows the results of the species-identification test. The measure of interpretation accuracy is the average percentage of trees correctly identified. The reason for the question mark for the 1:20,000 panchromatic photography is that only a few of the test trees at that scale could be located. Some of the outstanding or isolated trees could be found; the rest were lost in the middle of the stand. The general area, however, was examined and it was concluded that only rarely could any differences between species be distinguished. So it was estimated that, at the most, 20 per cent of the species could be correctly identified.

On the remaining scales, the trees could be located, and an attempt made to identify them. An analysis of variance showed that there was no significant difference in accuracy of species-identification between interpreters or films. However, there was a great difference between mature and immature timber. Apparently the characteristic shape and branching patterns that distinguish mature trees do not show up so well on young trees. There appears to be a substantial increase in the accuracy of species-identification from 1:20,000 to 1:10,000 photos, and there is an indication that accuracy increases with the larger scales. This is significant at the 10-per cent level but not at the 5-per cent level normally used to establish statistical significance.

DISCUSSION

It would be interesting to know the reasons for these results. Why was there no increase in height-measurement accuracy with the larger scales, and why was there no difference in species-identification accuracy between color and panchromatic films? The answers to questions like these will require additional analysis of the data, and probably additional studies, so that the various causes of error can be isolated. Meanwhile, here are some speculative answers to these two questions.

When all the possible sources of error in tree height-measurement are considered, quite a list can be made:

1. Accidental errors of interpreter and instrument.
2. Errors of photo scale determination.

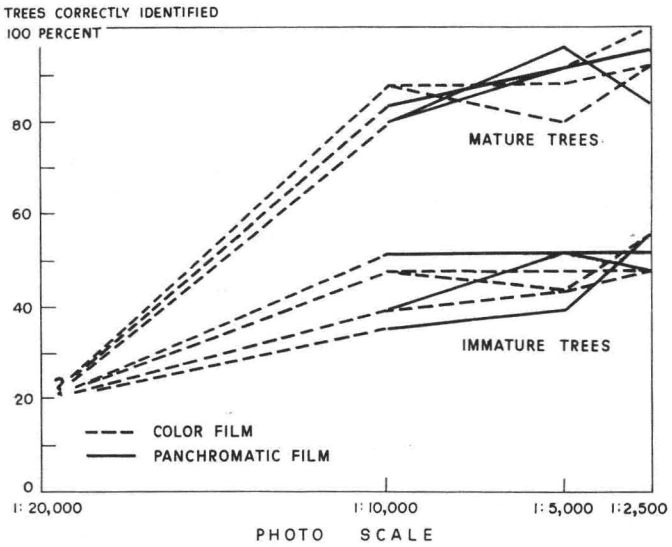


FIG. 2. Accuracy of tree species identification obtained by three interpreters.

3. Difference in altitude of plane between camera stations.
4. Failure of tree tip to resolve.
5. Wind movement of tree top.
6. Tree crowns obscuring ground.
7. Brush or other vegetation obscuring ground.
8. False stereo on ground points.
9. Tip and tilt.

The first four have been fairly well covered in the literature to date. This study does not provide an evaluation of the size of these errors, but it is difficult to see where they could be responsible for 20 to 25-foot errors, particularly on the large-scale photos.

The fifth cause, wind movement of tree top, probably doesn't often cause very serious errors. However, it is interesting because it is seldom thought of as a source of tree height-measurement errors. This study produced definite evidence that it does sometimes occur, for certain tree shadows were found to be floating above the ground.

The next three causes of error result in wrong parallax readings for the ground at the base of the tree. These probably aren't related to photo scale, but they can result in large height-measurement errors—as much as 50 feet in mature stands. Errors of this size may be sufficient to obscure any real tendency for height-measurement accuracy to be related to photo scale.

The last source of error as listed—tip and tilt—appears to be one of the major causes for the size of the errors in the large-scale 24-inch photos. Tip along the line of flight results in an erroneous measure of the parallax base. A three degree tilt along the line of flight results in an error of about nine per cent with a six inch lens, but this increases to about 35 per cent with a 24-inch lens.

Many foresters have expressed the hope that color photography would enable them to identify tree species with greater accuracy. The reasons for the lack of difference between color and panchromatic films in this study need to be investigated. Until data are available for a complete analysis, however, some guesses will have to be made.

One possible reason is that, on the average, the color transparencies were not as sharp as the panchromatic prints. This no doubt is largely due to the slower shutter-speeds and larger lens-apertures required for proper exposure of color film. Faster color films and processing adjustments should eliminate this disadvantage shortly.

A second possible reason is that the finer differences in color do not seem to show up well on medium or small-scale color transparencies. Perhaps this is due to the haze, or to the fact that the tree images are so small the human eye cannot distinguish minor changes in hue. On the large-scale photos a great variety of colors shows up. However, it doesn't seem to be necessary here, for crown shape and branching pat-

tern enable the various species to be distinguished as well on panchromatic film.

The Job Ahead

The measurements of crown diameter, canopy density, tree count, and reproduction count have not yet been analyzed. When these results have been added to those of tree height-measurement and species identification, they should provide a preliminary evaluation of the possibilities of large-scale aerial photos. This exploratory study should also provide information on designing a study of this type; such information will prove valuable if further tests are made on a more comprehensive basis.

One of the most important lessons learned from this study is the necessity for standardizing as much as possible the results from different interpreters. The variation in results from interpreter to interpreter emphasizes the importance of this link in the photo interpretation chain, and it points up the danger of drawing conclusions from the results of one interpreter. No general recommendations for photo interpretation techniques can be made until there is assurance that the results will be predictable for most interpreters. Consequently, before additional studies of this nature can be undertaken, more must be learned about this human element, the interpreter, and how to obtain more consistent results with him. A sizeable job lies ahead.

Abstracts of Discussion Symposium Papers of Steen, Kent and Pope

EARL J. ROGERS,
Moderator of Symposium

1. *Steen's* Paper

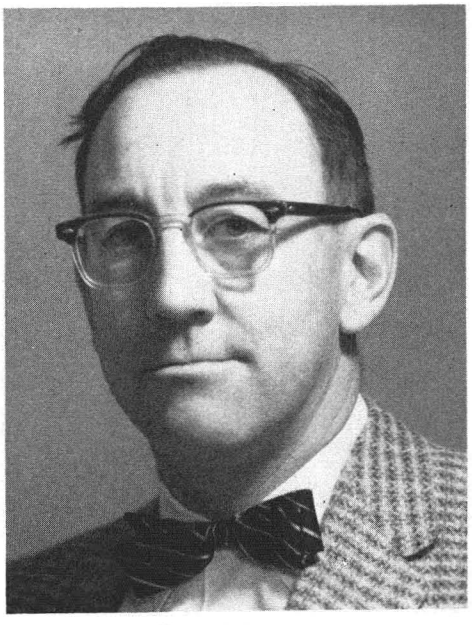
A question was raised about the advantage of technical training to photo interpretation. While no tests have been made it is the belief of Steen that such training would be advantageous where the field of interpretation involves a subject matter in which the interpretor is trained.

A questioner in the audience suggested that the subject matter used in the tests was a concern of difference in difficulty. Some attempts have been made to determine the degree of difficulty of subject matter but according to Steen no conclusions have been reached.

Steen and Moessner reported their opinions as to how long a key is necessary to an interpreter. Each believed that a key is useful only for training in the case of simple subjects because the interpreter soon memorizes all the features in a key. However, this may not be true for more complex and complicated subjects.

The level of probability used as significant was asked for. An answer could not be furnished.

Another question concerned the photo scales used in the tests. Steen reported that tests were made on several, ranging from 1:5,000 to 1:20,000.



Earl J. Rogers