Research Note

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THE ACCURACY OF STAND HEIGHT MEASUREMENTS ON AERIAL PHOTOS IN THE ROCKY MOUNTAINS

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THE QUESTIONS

Stand height is one of the most useful measurements foresters can make on aerial photos. Height correlates well with volume, and thus becomes important to the aerial estimator. Heights can be measured on photos much faster than on the ground. The pocket stereoscope and parallax wedge are far cheaper to use than the Abney level, but what of their comparative accuracy in rough country?

Problems of Measuring Heights

Most studies comparing photo with field height measurements consider individual trees and have been made in areas east of the Great Plains or in Canada. Little has been written about the accuracy to be expected from photo measurements of stand height of coniferous stands of the Rocky Mountains. Spurr[1/] has pointed out that the height of a conifer is more difficult to measure than the height of a hardwood since the tips of tapered crowns characteristic of conifers are often too small to register on the 1:20,000 scale photos in common use. Rogers[2/] has shown that tree height measurements by parallax may have errors up to 25 feet in areas of high relief, if no corrections are made for elevation differences. However, the tops of clumps or stands of conifers have a density not presented by individual trees and in most cases do resolve. Also, it is possible to make adjustments for differences in elevation, even where these differences must be estimated. The question is: Can the heights of conifer stands in the Rocky Mountains be measured by parallax on available aerial photos with sufficient accuracy to justify the use of this procedure?

1/ Spurr, Stephen H. Aerial photographs in forestry, p. 237. Ronald Press Company, New York. 1948.

2/ Rogers, Earl J. Use of parallax wedge in measuring tree heights on vertical photos. Research Note No. 1, Northeastern Forest Experiment Station. 1946.

THE ANSWERS

To answer this question of accuracy we compared aerial photo measurements with field measurements on 68 forest inventory plots in southern Idaho. We determined the average height of the dominant stand on each 1/5-acre field plot from Abney level readings made on the plot. A trained photo interpreter measured the total height of the dominant stand on each acre surrounding the field plot center. He used a pocket stereoscope and a parallax wedge and made measurements on photos used by the field crew, without prior knowledge of the field plot data. For the purposes of this study we assumed the 1/5-acre field plot would be representative of the 1-acre plot measured on photos.

The Results Are Encouraging

In the case of the common 9x9-inch 1:20,000 scale Department of Agriculture photos, the standard error of estimate[3] was 10.7 feet. It was 5.1 feet for U. S. Geological Survey 1:28,000[4] scale photos, and for 1:31,500 scale enlargements of 1:40,000 mapping photos only 10.8 feet. Correlation between photo and field heights was 0.81 for the 1:20,000 scale, 0.94 for the 1:28,000 scale, and 0.74 for the 1:31,500 scale.

The following tabulations indicate the relative accuracy of photo versus field stand heights:

I. Comparison of averages of all stands measured

Scale of photos	Focal length	Number of stands	Average height of all stands		
			Photo	Field	Difference
	Inches		Feet	Feet	Percent
1:20,000	8.25	29	57.1	57.4	-0.52
1:28,000	5.25	15	37.5	37.0	+1.35
1:31,500	6.00	24	55.5	56.2	-1.25

II. Comparison of individual stand measurements

Scale of photos	Number of stands	Mean deviation photo vs field	Standard error of estimate photo vs field	Coefficient of correlation
		Feet	Feet	
1:20,000	29	7.8	10.7	0.81
1:28,000	15	4.0	5.1	0.94
1:31,500	24	7.7	10.8	0.74

3/ This measure of the variation of photo stand heights about a line formed by corresponding field stand heights indicates the maximum error two times in three, when estimating individual stand heights by this procedure.

4/ The accuracy of parallax measurements is closely related to the focal length of the camera and the flying height of the plane. In this case the 1:28,000 scale photos were flown at 12,300 feet using a 5.25-inch F.L. camera while the 1:20,000 photos were flown at 13,700 feet with an 8.25-inch camera. The difference is largely due to this.

How significant are these differences? Because of the way in which the data were collected this aspect of the problem was examined only on the 24 locations where 1:31,500 scale photos were used. On 15 of the 24 there was no significant difference at the 5-percent level between mean stand height measured on photos and that obtained from tree heights recorded by the field crew. Most stands have a considerable variation in the height of the dominant trees. Other studies in the Rocky Mountains indicate mean standard deviations of field heights from 1/5-acre plots in excess of 6 feet. The standard deviations on the 24 plots considered averaged 7 feet, compared to the standard error of estimate from photos of about 10 feet. Photos flown to specifications which would reduce the standard error of estimate below the standard deviation of the stands should allow us to determine mean stand heights from photos almost as precisely as from field plots.

A note[5/] published by Central States Forest Experiment Station records a similar test. Part of the basic data for that note was a series of 38 stand height measurements made by the same photo interpreter on 9x9-inch 1:20,000 scale photos of southern Indiana. The photo measurements were not significantly better than those obtained in the Rocky Mountain test and the standard error of estimate was about the same.

There Are Problems

The accuracy of stand height measurements on aerial photos is related to the ability of the interpreter to match the floating line of his wedge with the ground level and with the point he considers to be the average height of the dominant trees. Most interpreters find it is easy to determine the level of dense flat-topped crowns common to hardwoods, but much more difficult to see and measure the ground line. The same effects occur in dense evenaged stands of conifers where the tips resolve but few holes can be found through which the interpreter can match ground level. On the other hand, the tips of the crowns in open conifer stands are hard to define but the ground level is usually quite obvious. One condition tends to compensate the other and therefore stand height measurements may be about as precise in the conifers of the Rockies as in the hardwoods of the East provided rough corrections are made for estimated differences in ground elevations.

5/ Moessner, Karl E., F. Dean Brunson, and Chester E. Jensen. The accuracy of stand height measurements on air photos. Station Note No. 59, Central States Forest Experiment Station. March 1950.

Complex Equipment Is Not Needed

Foresters often wonder whether the accuracy of height measurements might not be considerably improved by the use of more complex equipment instead of the pocket stereoscope and parallax wedge used in this test. Spurr[6/] quotes a series of height measurements made in Germany using a Zeiss Stereoplanigraph and other precise photogrammetric means on large-scale (1:4,000-5,000) photos. These tests resulted in a standard error of estimate of about 2 percent, a high degree of accuracy. Comparable preciseness[7/] on the 1:20,000 scale photos used in the Rocky Mountain test would result in a standard error of estimate of about 14 percent. The error obtained by pocket stereoscope and parallax wedge was 16 percent. The more complex photogrammetric equipment is chiefly designed for mapping purposes, where its advantages far outweigh its cost. But in the rather simple measurement of average stand heights this experiment as well as many others seems to indicate little advantage over the parallax wedge in the hands of a trained interpreter.

Summary

This study indicates that: 1. Stand heights can be estimated almost as well from parallax measurements made on aerial photos, as from a few Abney level readings made in the field. 2. Average stand heights can be measured on aerial photos in this region about as precisely as in the more level areas of the East if correction is made for elevation, and therefore should be equally usable.

PROCEDURE FOLLOWED

The photos used were of three different scales, flown with cameras of three different focal lengths:

Scale:	1:20,000 (Approx.)	F.L. 8.25 inches
Scale:	1:28,000 (Approx.)	F.L. 5.25 inches
Scale:	1:31,500 (Approx.)[8/]	F.L. 6.00 inches

All photos were 9x9 inches.

6/ Spurr, Stephen H. Op.cit., p. 241.

7/ Accuracy is largely dependent upon the parallax and scale of photos and focal length of the camera used. Using a 6-inch mapping camera, 1:4,000 scale photos would have a factor of about 0.6-foot elevation change per 0.001-inch parallax difference. Using an 8.25-inch camera 1:20,000 scale photos with the same parallax would have a factor of about 4.5 feet. Comparable preciseness in instrument and skill in operator would result in spot heights with an error of estimate approximately seven times as great.

8/ These were enlargements to 1:31,500 from 6-inch F.L., 1:40,000 contact scale photos flown for mapping purposes.

Stands consisted of Douglas-fir, Engelmann spruce, lodgepole pine, juniper, aspen, and noncommercial hardwoods. Most of the conifers had narrow, rather pointed crowns. The stands were well distributed through a range of about 20 to 90 feet in height. Mean height of all stands was about 53 feet with a standard deviation of 18 feet. The stands were scattered through mountainous area with elevation differences averaging about 1,500 feet on a single photo. As in many parts of the Rockies precise contour maps were not available and both the average scale of the photo pair, and the elevation differences of the stands measured had to be estimated from the few elevations recorded on planimetric maps.

The following rough method was used by the interpreter in estimating the parallax factor:[9/]

1. The elevation of the principal points of the photo pair was estimated from the best available sources and the approximated mean scale was then computed for the photo base.

2. Using this scale and the length of the photo base a parallax factor was read from a previously prepared table.[10/]

3. This factor was adjusted when the estimated difference in elevation between the measured stand and the mean datum of the photo base approached 500 feet.

9/ The elevation change in feet for each 0.001-inch difference in parallax measured on the photos.

10/ This table, familiar to many foresters, gives elevation difference in feet for each 0.001-inch parallax difference by scale of photo and length of photo base.