DAVID A. BERNSTEIN
U.S. Forest Service
Portland, Oregon 97208

Are Reforestation Surveys with Aerial Photographs Practical?

The use of large-scale aerial photos for direct tree counts in young forest plantations (under the conditions of this study) is not recommended; accuracy levels are too low and costs too high.

ABSTRACT: *The possibilities of making tree counts in young forest plantations on large-scale aerial photos were tested. Interpretation was made on both color and black-and-white prints produced by the Aeronegative system. Photographs were taken with a 12-inch focal-length camera at scales of 1:1000 and 1:500. Results indicated, as far as the techniques and equipment of this test are concerned, that tree counts on aerial photos were not sufficiently accurate to be useful. Results did not improve with increased scale or the use of color instead of black-and-white.*

INTRODUCTION

FORESTERS in the Pacific Northwest have usually been receptive to suggestions for incorporating aerial photo techniques in their measuring and mapping tasks. As a result, they have benefiitted from the increased accuracy and savings that aerial photos have given them in such areas as timber volume estimation, condition class mapping, and insect and disease damage detection. Recently, they have been asking, "How about those thousands of acres of cutover and burned-over lands we have to examine every year to determine how well they are reforesting? Couldn't we make these reforestation surveys quicker and cheaper on aerial photos?" It was in response to this question that the following test was made. Although aerial photo costs were higher than ground survey costs and results were not encouraging, some things were learned that may be helpful to those who want to investigate the aerial photo technique from a different basis.

PAST WORK

The main thrust of the investigation was whether or not useful tree counts could be made on photos. Previous experience on the Gifford Pinchot National Forest in Washington and the Siuslaw National Forest in Oregon showed that 1:5000 panchromatic photographs taken in early spring, before the deciduous brush leafed out, gave enough information to discern understocked, stocked, and overstocked areas of young coniferous trees. The test proposed to go beyond these generalized stocking evaluations. It would attempt to get an actual trees-per-acre figure, either through sample counts made on the photo alone, or through double sampling, which combines photo counts with some field checking. Preliminary studies suggested that the photo scale would have to be larger than the 1:5000 used in these plantation surveys. There was also some evidence that color would improve interpretation accuracy. Therefore, the test was designed to look into the possibilities of both color and black-and-white large-scale photographs.

Experience data on actual tree counts on reforesting areas is very limited. One study using Kodak Ektachrome Infrared Aero, a false-color film used in insect and disease survey, and Kodak Ektachrome Aero, was made on plantations in the Tillamook Burn area of northeastern Oregon.* Photos of pre-

* Smith, Carl W., 1964. "Specialized Photography and Aid to Plantation Inventory." Proceedings of the 1964 Annual Meeting of the Western Reforestation Committee. Western Forestry and Conservation Association, Portland, Oregon.

marked plots were taken at scales of approximately 1:*1000*, 1:*3000* and 1:*5000*. Trees ranged in size from 1 to 4.5 feet in height.

The best results were obtained on 1:1000 Kodak Ektachrome Infrared photographs on the older plantations. However, evergreen plants such as salal and sword fern caused substantial overcounts on this type of film. Tree-count accuracy in the younger plantations was very low on both types of film.

Another test of large-scale aerial photographs for tree counts was made on the Rogue River National Forest in Oregon using Kodak Ektachrome Infrared. Although the tree-count error of the two interpreters used was large, correlation coefficients were high. This indicates a consistent relationship between photo and ground counts of trees that might make a double-sampling scheme practical.

Procedures

The present test was also made on the Rogue River National Forest and sampled a variety of conditions. One area was an old burn. Fire-killed snags had been removed and the brush that had taken over had been bulldozed out and piled in windrows. Other areas had been logged by clearcutting methods with the logging slash partially removed by burning. Besides the planted trees, ground cover included grass, brackenfern, snow brush (an evergreen shrub with heavy foliage), gooseberry (a low deciduous shrub), manzanita (a low evergreen shrub), and willow.

The test areas were photographed with a K-17 camera with a 12-inch focal-length lens mounted on the undercarriage of a helicopter. All areas were photographed at a scale of

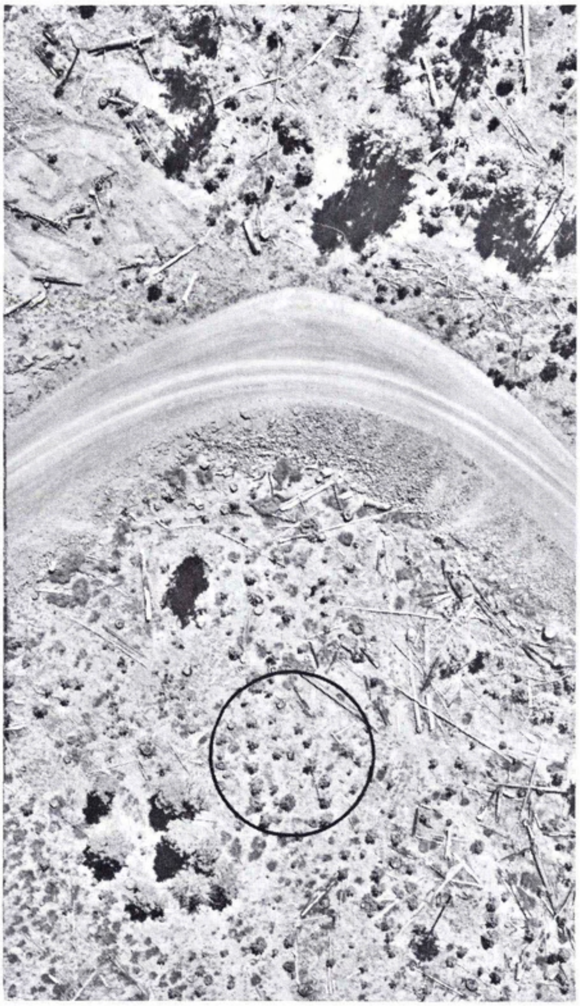

Fig. 1. One-tenth acre photo plot on Area 4. Trees are 8 to 10 feet high. Scale 1:960.

TABLE 1. PHOTO SCALE COMPARISON

Area	*Calculated Scale*	*Ground-Measured Scale*	*Affect on Area Calculation*
	Photo Scale 1:1000		
1	1050	1015	+ 7%
2	1030	1065	− 6%
3	960	1000	− 8%
4	935	935	0
5	1150	1150	0
6	1065	1120	−10%
7	1125	1170	− 8%
	Photo Scale 1:500		
1	600	625	− 8%
2	540	575	−12%

The Calculated photo scale did not differ from the ground-measured scale to any great extent. It is evident that these small differences would not appreciably affect the relationship of photo to field counts shown in Table 2, or the correlation coefficients shown in Table 3.

1:1000. In addition, two areas were also photographed at a scale of 1:500.

Kodak Ektachrome MS aerographic was processed to a color negative and both color and black-and-white prints were made. This allowed the testing of the possibilities of both types of photographs, something that had not been done on the previous two tests. Black-and-white prints processed from color negatives might not have the resolution of those made from a panchromatic film. However, two cameras for taking simultaneous panchromatic and color photographs were not available, and consequently the two types of prints from the same negative were used.

The two previous tests also, in the interests of economy, had not allowed for stereo coverage. The present test went both ways, testing for single prints and stereo coverage.

The testing procedure was conducted in the following manner. A number of one-tenth acre plots were laid out on the ground. All live coniferous trees one foot or more in height within the plot boundary were counted. Then the plot centers were located on the aerial photos. The plot boundaries were represented on the aerial photos by means of photo aids centered on the plot center. The photo aids were circles representing one-tenth of an acre at scales of 1:1000 and 1:500. (See Figure 1)

Tree counts were made on single photos under 2× magnification and on stereoscopic pairs using an Old Delft scanning stereoscope at 4.5 magnification. All photo interpretation was performed by an experienced interpreter who had previously visited some of the test areas with the photos in hand and had familiarized himself with the ground appearance of the photo image.

Tree count errors can result not only from not being able to see trees or from having bits of green vegetation such as mosses and lichens being mistaken for small trees on color photos, but also from errors in scale determination and photo-aid scale adjustments. Errors in scale determination result in an incorrect blowup of trees per plot. However, even if the scale is correctly calculated and the tree count correctly blown up, there may be a difference between the photo scale and the scale of the photo aid used for the tree count. The resulting, somewhat different-sized, plots on the ground and the photo are reconciled with an adjustment factor. If the trees are not uniformly distributed, differences in tree counts are likely to occur.

RESULTS

A check on the accuracy of the photo scale calculation was made. Scale calculated from maps or other photographs of known photo scale was compared with the scale as determined by ground measurements. The results are in Table 1. The calculated photo scale did not differ from the ground-measured scale to any great extent. It is evident that these small differences would not appreciably affect the relationship of photo-to-field counts shown in Table 2, or the correlation coefficients shown in Table 3.

Table 2 shows the average number of trees per acre as determined by a field count, and the percentage of that field count achieved in the photo counts on the four different combinations being tested.

In general, color stereo seems to score better than the rest, but not much. There was generally poor results in Area 5. Also, the black-and-white single photo did better than

TABLE 3. CORRELATION COEFFICIENT

Area	*No. of Plots*	*Tree Heights*	*Vegetative Cover*	*B&W Single*	*Color Single*	*B&W Stereo*	*Color Stereo*
			Photo Scale 1:1000				
1	9	6″-1′	Heavy Fern	.784*	.897†	.670*	.101
2	10	1-2′	Heavy Fern	.864†	.753*	.742*	.845†
3	10	10-12′	Grass & Lgt. Fern	.742*	.833†	.895†	.847†
4	8	8-10′	Moderate Brush	.144	.373	.262	.323
5	10	2-3′	Heavy Brush	.097	.223	.073	.191
6	10	3-6′	Heavy Brush	.695*	.828†	.621	.622
7	10	13-15′	Heavy Brush	.661*	.415	.430	.789†
			Photo Scale 1:500				
1	7	6″-1′	Heavy Fern	.540	.348	.550	.533
2	7	1-2′	Heavy Fern	.729*	.516	.654	.437

* Significant at the 5% level.
† Significant at the 1% level.

TABLE 2. PHOTO-COUNT TO FIELD-COUNT DIFFERENCES
Photo Count Percentage of Field Count

Area	*Avg. Trees Per Acre*	*B&W Single*	*Color Single*	*B&W Stereo*	*Color Stereo*
		Photo Scale 1:1000			
1	418	29	31	61	103
2	672	79	76	62	90
3	159	52	66	64	65
4	412	45	58	54	63
5	625	18	33	19	30
6	187	63	47	35	56
7	278	43	47	44	58
		Photo Scale 1:500			
1	442	74	217	83	73
2	577	69	101	64	65

the color stereo photos in Area 6.

Note that, (with the exception of the large overcount in the 1:500 in Area 1 and a couple of other minor ones), photo counts are less than the field counts. The magnitude of the undercount varies, but generally the photo count is about half to three-quarters of the field count.

The direct comparison of photo count against field count does not tell the whole story. The fact that the two counts came close to each other in some instances may have been just a coincidence rather than an indication that a particular combination of photo and scale was superior to the others. On the other hand, there might have been instances with a wide disparity between actual field and photo counts but a close correlation. This could be useful in a double-sampling situation; therefore, the calculation of the correlation coefficient was chosen as a means of measuring the relationship between the field count and the photo count. Results of the correlation coefficient calculation are found in Table 3.

The correlation coefficient table does not indicate that any particular combination is superior to the others. Rather, the results are erratic; a given combination will have a highly significant correlation in one area and a very poor correlation in another.

It appears that factors other than print color, use of stereo, and scale might be influencing results. Brush cover, photo-aid scale adjustments, and the presence of other vegetation which could be misidentified as trees, are possible sources of error.

The presence of brush does seem to have a marked effect on results. This is in spite of the fact that the photographs were taken in early spring before the deciduous brush had leafed out. Nearly all the coverage where the ground cover was fern show at least a significant correlation. On the other hand, few of the areas with heavy brush had significant correlation, even where the trees were comparatively large.

The size of the reproduction seemed to have very little effect on the results. The results on Area 3, with trees 10 to 12 feet in height, were not a great deal better than Area 2 with trees one to two feet high. Tree counts on trees 3 to 6 feet high (Area 6) were more accurate than counts of trees 8 to 10 feet high (Area 4).

The poor results on Area 4, where the trees were rather large and clearly seen on the photographs, are difficult to account for. Perhaps photo-aid scale adjustments were a factor here.

In this study, there was no clear advantage in going from 1:1000 to 1:500 scale photographs. On the contrary, results on the 1:500 photographs were quite a bit poorer than they were on the smaller scale. One possible explanation is that the interpreter *saw too much* on the larger-scale photographs. Mosses and other bits of vegetation seem to have been mistaken for small trees. At a smaller scale, they might not have been noticed.

Color seems to offer a slight improvement over black-and-white but not to any definite extent. Neither does there seem to be any noticeable gains in using stereo coverage instead of single photos. Results on color single and color stereo are about the same.

What are the possibilities of direct aerial photo tree counts? Under the conditions tested it seems that they are impractical. Not only are they considerably less accurate than ground surveys, but they do not furnish reliable information on vigor, species, and size. They are also more expensive. The estimated cost for photographs and interpretation per one-tenth acre plot in a plantation survey of 20 plots ranges from $1.64 with black-and-white to $1.93 with color. This is using a helicopter as the aircraft. If a slow-flying, fixed-wing aircraft could be used, costs may be reduced to $0.80 and $1.09. In as much as an actual operational survey was not conducted, the costs are estimated. They are based on a simulated operation from a local airport and covering a group of 40-acre plantations in the test area.

Ground survey costs were estimated to be $0.75 per plot.

How about a double-sampling scheme using both photo and field plots? In some instances, the correlation coefficients obtained in this study were high enough to suggest that a satisfactory estimate of the average number of trees per acre could be obtained by this method. Such a scheme would reduce the amount of field work needed to achieve a given precision. However, with the cost estimates obtained in this study, a double sample would cost more than a straight field plot survey of comparable precision.

What about a better camera? It seems likely interpretation accuracy could be improved with one of the better lenses now available. The biggest question, however, is that of costs. The photo-plot costs would have to be drastically reduced—to something like 20 percent of the field plot costs—for even double-sampling to be financially feasible. Some savings could be effected through the use of a smaller-scale of photographs, for instance 1:2000, and by scheduling plantation photography in connection with other photographic missions. These actions still probably would not close the gap. However, other considerations can have a bearing. Plantation photography can furnish the basis for mapping out the stocked and nonstocked areas. Stocked-area maps are often needed and mapping by ground methods is expensive. The costs of plantation photography used for both tree counts and mapping could possibly approximate that of ground tree counts and mapping.

Conclusions

The use of large-scale aerial photographs for direct tree counts in young forest plantations, under the conditions of this study, is not recommended. Accuracy levels are too low and costs are too high to warrant its use. It is suggested that future studies in the use of aerial photographs in tree plantation assessment be directed toward seeking a photo scale that would be small enough for efficient mapping.