*Comparative Forest Aerial Photo Interpretation Results from Variable-Contrast and Single-Contrast Paper Prints**

HUGO H. JOHN, *Research Assistant*
and
MERLE P. MEYER, *Assoc. Prof.,*
Univ. of Minn. School of Forestry

ABSTRACT: *Fall panchromatic forest photography was printed at five stages of contrast on variable-contrast paper and at one contrast on single-contrast paper. The latter was considered to be an ideal print. Trained interpreters performed parallax measurements, image counts and personal evaluations on 17 one-acre forest plots on the photos. The variable-contrast prints as a group were found to be equal in quality and interchangeable with the single-contrast prints. However, variable-contrast prints were found to decrease significantly in quality as contrast approached either a maximum (high) or a minimum (flat). The best quality variable-contrast print appeared to be one which was slightly flat in tone.*

INTRODUCTION

OF SIGNAL importance in obtaining paper prints of desirable quality is an ability to control contrast in the laboratory processing. This is currently accomplished primarily through the use of a series of papers, each with its individual grade of contrast, which necessitates the maintenance of an inventory of the various grades in a relatively "fresh" state. The possible advantages of a single paper incorporating a variety of contrasts was early recognized, and in 1912 the first variable-contract paper was developed in England.

Major improvements in this medium, made in 1937 and in about 1940, resulted in a variable-contrast paper with a single emulsion incorporating a green sensitizer. The larger particles of the silver halide suspended in the emulsion are thought to absorb a greater amount of this sensitizer than the smaller particles which results in the larger particles being more sensitive to green light. Therefore, by using one of a series of filters over the light source of the printer, the sizes of the particles activated during exposure are controlled, as is the print contrast.[1] Although both single-contrast and variable-contrast paper print mediums are generally available, little is known about their comparative effects upon photo-image quality. It was the primary intent of this study to compare the vegetation photo detail quality levels produced by the two types of printing paper irrespective of any other comparative advantages or disadvantages which might be associated with them.

CONDUCT OF THE STUDY

The design and conduct of this experiment closely paralleled that of Meyer[2] and Meyer and Trantow[3] where three factors considered to adequately evaluate photo-quality were employed: (a) photo-image height measurement, (b) photo-image counts, and (c) interpreter evaluations. Northern Minnesota fall panchromatic, 8.25″ lens photography at a scale of 1:15,840 was provided by Mark Hurd Aerial Surveys, Inc. A stereo-triplicate set of negatives was selected which covered an area exhibiting a wide range of forest vegetation classes, and seventeen one-acre ground plots, which cross-sectioned the variations in vegetation, were located on the ground and measured. Five sets of photographs, with the characteristics described in

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TABLE 1

DESCRIPTION OF THE FIVE STEREO-TRIPLET SETS OF TEST PHOTOGRAPHS

Photo set code	*Paper surface*	*Paper type*	*Light source filter*	*Relative contrast**
A	semi-matte	variable contrast	#9	5 (medium contrast)
B	semi-matte	variable contrast	#7	3
C	semi-matte	variable contrast	#5	2
D	semi-matte	variable contrast	#1	1 (very flat)
E	semi-matte	single contrast	none	Approx. between 2 and 5 above by ocular comparison

* Relative contrast was determined by ocular comparisons of the contrasts within the five sets of test photographs.

Table 1, were printed from the negatives selected and the ground plot locations were carefully picked on each.

PARALLAX HEIGHT MEASUREMENTS

Five interpreters made four parallax height measurements of the dominant trees on each plot. All interpreters had previously completed at least six quarter credit hours of photogrammetry coursework, including a minimum of 36 hours of training in the use of the parallax bar. In addition, an orientation and practice period was provided before the start of the test. A split plot design (4) was used, making it possible to exercise some control over the magnitude of experimental error through the following steps: (a) randomization by interpreter, by plots, by photos; and (b) replication by 5 interpreters and by 17 plots. The interpreters did not know the true height of any trees measured during the test, nor was the character of the photography revealed to them.

IMAGE COUNTS

Three similarly-trained interpreters made the tree-crown counts. An additional 10 hours of training was provided in order to acquaint them with the use of the binocular stereoscope and three-crown count grid (2) used. Each interpreter made three repetitive counts of tree-crowns on each of the photoplot combinations, the mean of which was used in the analysis. Again, a split plot design was used and the experimental error minimized with the following steps: (a) randomization by interpreters, by plots, by photos, by azimuths; and (b) replication by 3 interpreters and by 17 plots.

INTERPRETER EVALUATIONS

Each time that a plot was interpreted, whether by parallax measurement or crown count, the individual interpreter evaluated the plot according to pre-established standards of relative preference. This rating was based on comparative lack of eyestrain, confidence in resolving tip or base level, and confidence in resolving individual objects. Between interpreters there was no known communication concerning the tests.

TEST RESULTS

PARALLAX HEIGHT-MEASUREMENTS

Algebraic errors between ground tree-height measurements and the parallax height measurements were used in the analysis. Bartlett's test for homogeneity of variance between photos was nonsignificant; this permitted use of analysis of variance and "*F*" tests. The results, portrayed in Table 2, reflect those of Meyer[2] and Allison[5] in that no significant differences between photo sets in the measurement of tree-heights were found.

IMAGE COUNTS

Figure 1 summarizes the results of the tree-crown counts. Bartlett's test of homogeneity determined the variances between photos to be homogeneous and analysis of variance and "*F*" tests was performed (Table 3). A significant difference between the mean number of crowns counted on the five photo sets was found, and there was not a significant interaction between photos and plots. This indicated the difference between photos to be consistent for all plots or for all tones and contrasts represented by these plots. However, it was not possible from this analysis to determine which photo means were significantly different from other photo means. In order to obtain a ranking of these means which was statistically valid, the four degrees of freedom associated with the between-photos sums of squares were partitioned into meaningful,

TABLE 2

ANALYSIS OF VARIANCE OF THE MEAN ERRORS (ALGEBRAIC) INCURRED IN THE PARALLAX HEIGHT MEASUREMENT TEST

Source of variation	*Degrees of freedom*	*Mean squares*	*Computed F*	*Tabular F* 1%	5%
Main plots					
Between plots	16	1,549.228	9.072**	2.30	1.80
Between interpreters	4	1,580.758	9.256**	3.62	2.51
Main plot error	64	170.775			
Sub-plots					
Between photos	4	14.208	0.615	3.39	2.40
Photo x plot	64	25.863	1.200	1.60	1.41
Sub-plot error	272	23.091			

** Significant at the 1% level.

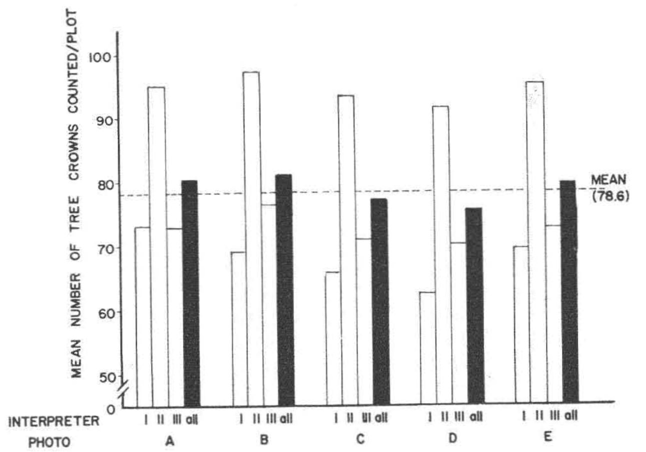

FIG. 1. Summary of mean numbers of tree crowns counted by interpreters and photos.

TABLE 3

ANALYSIS OF VARIANCE OF THE MEAN NUMBER OF TREE CROWNS COUNTED

Source of Variation	*Degrees of freedom*	*Mean squares*	*Computed F*	*Tabular F* 1%	5%
Main plots					
Between plots	16	14,433.056	9.597**	2.62	1.97
Between interpreters	2	16,896.258	11.234**	5.34	3.30
Main plot error	32	1,503.969			
Sub-plots					
Between photos	4	293.626	8.855**	3.44	2.43
Photos x plots	64	41.992	1.266	1.59	1.39
Sub-plot error	136	33.159			

** Significant at the 1% level.

Table 4

Results of Individual Degree of Freedom Tests for Differences Between Photo-Crown Count Means

Source of variation	*Degrees of freedom*	*Mean squares*	*Computed F*	*Tabular F*	
				1%	5%
Between photos	4	293.626	8.855**	3.44	2.43
Photos E vs. Photos A, B, C, and D	1	18.040	0.544	6.81	2.91
Photos D vs. Photos A, B, and D	1	750.475	22.633**	6.81	3.91
Between photos A, B, and C	2	202.994	6.122**	4.75	3.06
Linear	1	235.539	7.103**	6.81	3.91
Quadratic	1	170.449	5.140*	6.81	3.91
Sub-plot error	136	33.159			

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

individual degrees of freedom or individual comparisons.

The results of these comparisons are shown in Table 4. The first comparison revealed no significant difference between photos printed on variable-contrast paper and those printed on single-contrast paper. The variable-contrast photos printed with a #1 filter (set D) were found to be significantly different from all other photos printed on variable-contrast paper. A significant quadratic relationship was found between photo sets A, B and C.

INTERPRETER EVALUATIONS

These data were analyzed only on a basis of frequency of selection. This is summarized in Table 5 and reveals definite preferences on the part of the interpreters for the best (photo set A) and poorest (photo set D). Photo sets B, C, and E are relegated to intermediate position without any pronounced trend other than the possibility that photo set B has the nod for second best. Comparison of this table with Figure 2 is most interesting in that the personal preferences, at least on the extreme ends, correlate quite well with the relative success of the crown counts on individual photo types.

Discussion and Conclusions

In this study, photo-image quality has been evaluated by the indirect methods of parallax measurements and crown counts since it is felt that these measurements are closely allied with photo-image quality in forest aerial photography. All tests were analyzed on a

Table 5

Summary of Photo Interpreter Evaluation Test by Photo Sets and Relative Ranking

Interpreter rating	*Photo set contrast*				
	Variable				*Single*
	*A (high)**	*B*	*C*	*D (lowest)***	*E*
	Frequency of selection				
1—best	((71))	25	25	10	19
2	23	((60))	40	19	((43))
3	16	((52))	((56))	22	((42))
4	24	21	((51))	39	((47))
5—poorest	27	13	16	((71))	31

* Highest contrast print.
** Lowest contrast print.
(( )) Indicates frequency of selection peaks.

relative basis since no standards for comparison were available. A range of tonal contrasts was presented on the variable-contrast photo sets as compared to only one on the single-contrast set, which had a degree of contrast falling within the range exhibited by the variable-contrast sets (Table 1). It may well be questioned, therefore, as to how the contrast of this single-contrast set was selected and how nearly, in truth, it approximated being the best possible such print for forest interpretation purposes obtainable from this type of paper.

The selection of a slightly flat-contrast level for the "ideal" conventionally-printed single-contrast paper prints to be used for control in this experiment represented a decision on the part of the authors for which there is little documented support. The best defense seems to be the regularity with which highly experienced forest photo interpreters tend to select it—one such case of which was documented by Meyer.[2] Admittedly, this is not a very strong argument, nevertheless it represents the only contrast level for which any consistent support has been obtained, subjective though this evidence may be.

The explanation offered for this action, and belief, is that a good print of this type and contrast category tends to increase the range of gray scales present in the picture without seriously reducing contrast between images and their background. Admittedly, the tonal edge is a great deal more subtle than in a more contrasty picture, but the argument presented is that more detail is recorded than is the case in a more or less contrasty photo. Increased contrast will usually result in greater tonal difference between large *groups* of vegetative individuals (e.g., between a stand of black spruce and a stand of paper birch), however, this heightened contrast also appears to destroy small details in each case. That is to say, the spruce stand will become more nearly black in tone and the birch stand more nearly white overall—with the subsequent loss of a considerable number of minute, individual tree image details within the stand which are essential to the interpreter. Consequently, most experienced forest photo interpreters appear willing to forego some of the dramatic tonal differences between large groups of photo images in order to get better overall rendition of such characteristics as size, texture, pattern and shape.

The absence of a significant difference in the parallax height measurements between photo sets indicated the absence of any material effect due to emulsion or contrast. Also,

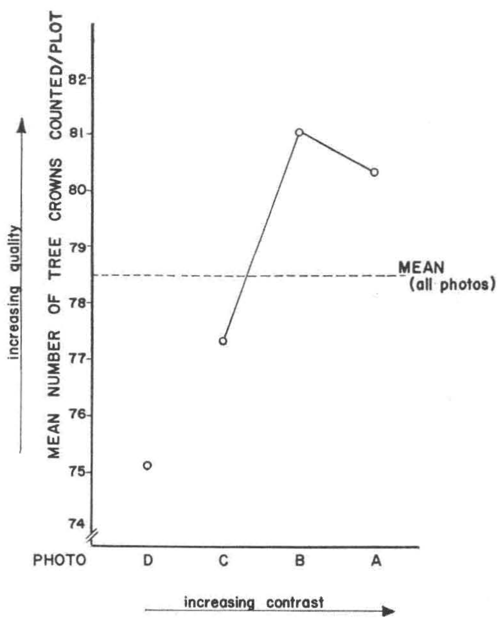

FIG. 2. Results of individual comparisons of tree crown count means showing the significant quadratic relationship between Photo sets A, B and C.

the lack of a significant difference between the single-contrast prints and the variable-contrast prints in the crown-count test indicates that one can be substituted for the other without significant loss in image quality as herein described.

Of particular interest in the crown count test was the effect of contrast on the relative photo-image quality. Figure 2 shows the relationship between quality and contrast—quality being expressed in the numbers of crowns counted with the assumption that the greater the number counted on a photo, the better the quality of that photo. A significant quadratic relationship was found between quality and contrast, and indicates that quality increases with increased contrast to a particular point, beyond which any increase in contrast results in quality decrease. The point at which maximum quality was found corresponds, ocularly, to a *slightly flat* print.

For the conditions tested, therefore, it appears that substitution of variable-contrast printing paper for single-contrast paper for the same negative(s) can be made]provided the ability of the printer operator is the same with both types of paper.

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REFERENCES

1. Neblette, C. B., 1952, "Photography—Its Materials and Processes." Van Nostrand Co., New York. 5th Ed., 490 pp.
2. Meyer, M. P., 1957, "A Preliminary Study of the Influence of Photo Paper Characteristics upon Stereo Image Perception." *Photogrammetric Engineering*, vol. XXIII, no. 1, p. 149–155.
3. ——— and Trantow, L. H., 1957. "Some Observed Effects of Variation in Photo Paper Emulsion and Tone upon Stereo Perception of Tree Crowns." PHOTOGRAMMETRIC ENGINEERING, vol. XXIII, no. 5, p. 896–899.
4. Snedecor, G. W., 1956, "Statistical Methods." Iowa State College press, Ames. 5th ed., 535 pp.
5. Allison, G. W., 1956, "The Accuracy of Tree Height Measurements on Various Qualities of Aerial Photographs." *Forestry Chronicle*, vol. 32, no. 4, p. 444–450.

*A Test of Polaroid Variable-Color Filters for Forest Aerial Photography**

MERLE P. MEYER, *Associate Professor, Univ. of Minn. School of Forestry,*
and
LOUIS H. TRANTOW,
Operations Mgr., Santa Barbara Plant, Mark Hurd Aerial Surveys, Inc.

ABSTRACT: *Polaroid variable-color filters were used with Tri-X film to examine northern Minnesota conifer-deciduous tree tonal relationships in the green and yellow portions of the reflected spectrum. Although some improvements over summer panchromatic were obtained, the variable-filter photography was inferior to conventional summer infrared minus-blue and fall panchromatic minus-blue photography of the area tested.*

DESPITE trials of a variety of film-filter combinations for forestry photography, only infrared and panchromatic minus-blue have successfully survived the test of repeated field applications. However, neither is ideal under all conditions and each has its own limitations—factors which have encouraged continued search for better film-filter combinations.

It has been illustrated by Colwell[1] that a knowledge of the spectral reflectance characteristics of vegetation, sensitivity range of film, and filter transmission quality permits reasonably valid predictions of photo appearance. Spectral reflectance diagrams of tree species,[2] for example, indicate a wide separation of conifer-hardwood reflectance in the infrared zone, a factor exploited by infrared photography. A secondary zone of conifer-hardwood separation in the 500–600 millimicron zone (green to yellow) is also present. It therefore seemed reasonable to assume that, given a film sensitive in this zone, and a filter capable of screening out the wave-length above and below it, tonal separation of conifers and hardwoods would result. The purpose of the study was to explore this possibility.

Polaroid variable-color filters were selected for use and a special lens mount (Figure 1) was fabricated. Three Polaroid elements, a green and a yellow variable (dichroic) and a neutral linear polarizer, were employed. The color filters were locked into position in the mount and the neutral polarizer placed in a movable ring having an arc of movement

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