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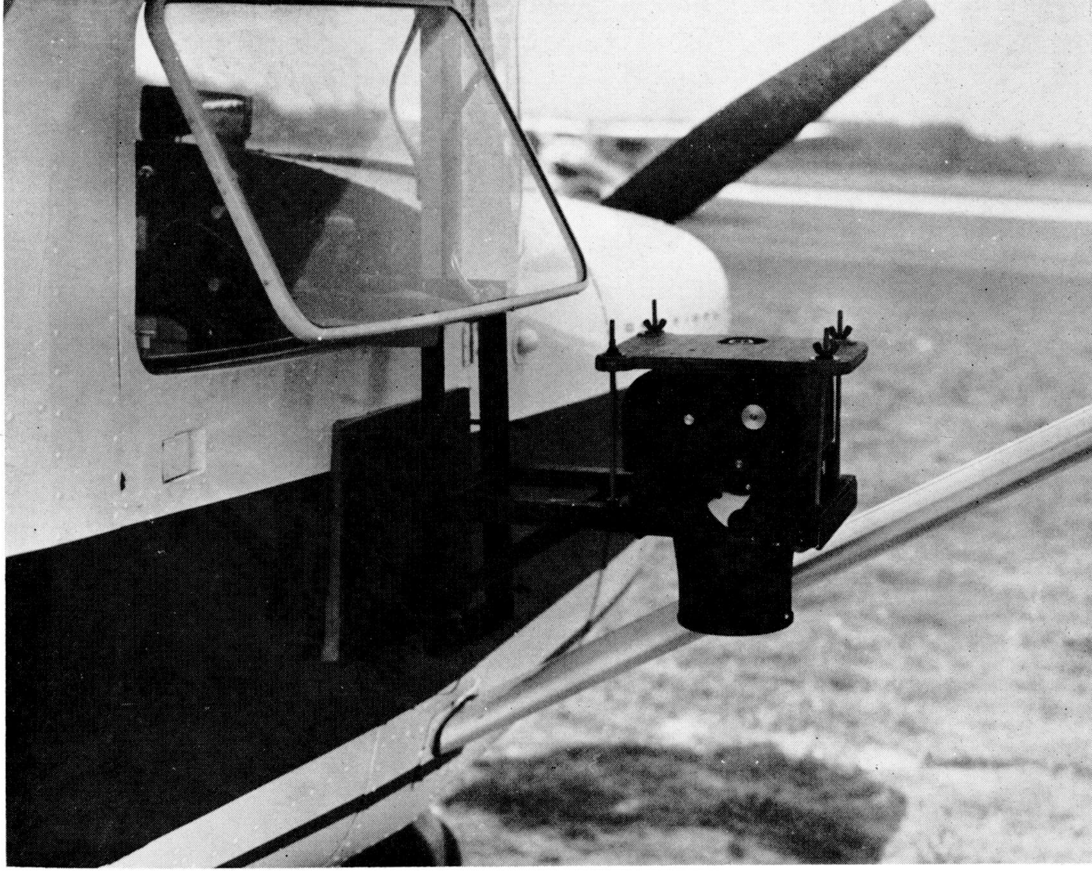

Identification of Forest Condition Classes on Near Vertical Aerial Photographs Taken with a K-20 Camera

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THE CLASSIFICATION OF FOREST COVER into condition classes is a basic operation in forest land management. Because of their high cost and relative inaccuracy, insofar as planimetry is concerned, conventional stand mapping procedures involving on-site observations are rapidly being replaced by methods employing aerial photographs. In most cases, the land managers work with existing aerial photographs such as those that are available through the U.S. Department of Agriculture. Unfortunately, the USDA photographs have a relatively small scale (1:20,000) and are made with panchromatic film, which often is not well adapted to the work of vegetation classification. Furthermore, the photographs are often several years old and usually do not show current forest conditions. Ideally, it would be desirable to have new photographs made with the most efficient film-filter-season-scale combination for each job, but the cost of such new photography on a contract basis is often prohibitive.

A possible solution to this problem would be for the land management organization to obtain its own photographs using rented aircraft and its own camera equipment. Conventional camera equipment, however, is expensive, heavy, and complex. It is difficult to mount in an aircraft without modifications that would be undesirable to the aircraft owner. This has brought about increasing interest in both small camera aerial photography and in modification of existing equipment to permit the taking of suitable photographs from light aircraft, which would be available at convenient times for use over small areas. Small camera photography could be used independently or to supplement and up-date large format photographs that are out of date. In light of such interest, this study was designed to explore one path possibly leading to a rapid and economical method of obtaining aerial photographs useful to the land manager.

OBJECTIVES OF THE STUDY

The primary objective of the study was to determine whether or not the K-20 aerial reconnaissance camera, which produces 4 x 5-inch negatives, can be used to obtain near vertical photographs that would be useful for stand classification. A second objective was to determine which of several film-filter-scale combinations would be best adapted to the work of stand classification when the photographs were taken with the K-20 camera.

MATERIALS USED

Camera. A K-20, Day Reconnaissance, aerial camera was used to take the photographs. This is a hand-held, manually operated camera. It has a 6⅜-inch focal length lens with apertures ranging from f/4.5 to f/22 and a between-the-lens shutter with speeds of 1/125, 1/250, and 1/500 second. The camera is capable of handling rolls of 5¼ inch film up to 20 feet in length. Virtually every type of aerial film, both black-and-white and color, is available for use in this camera. There is an electrically driven equivalent, the K-25, which should provide results similar to those obtained with the K-20.

Camera mount. A special mount for the K-20 camera was designed and built by the senior author for use on high wing light monoplanes of the Cessna 150 type (8). The mount, see cover photo, permitted positioning the camera vertically on the side of the aircraft in such a way that it could be operated manually. Because of manual operation, an intervalometer could not be used and the intervals between exposures had to be timed with the sweep second hand of a watch.

Films, filters, and scales. Two black and white films, Kodak Super XX Aerographic Panchromatic (No. 5425) and Kodak Infrared Aerographic (No. 5424), were chosen for the study. A Wratten No. 12 (Minus blue) filter was used with both films. Photographs were taken at two scales, 1:2,500 and 1:5,000, referenced to mean ground elevation. Exposure settings were calculated using the Kodak Aerial Exposure Computer. Using an Armed Forces type B-5 developing tank, all film used in the pro-

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ject was processed according to manufacturer's instructions *(2)*. Because no suitable contact printer was available, contact prints were made on Kodak Polycontrast Paper with the appropriate Polycontrast filters. The paper was placed in direct contact with a negative and exposed with light from an enlarger. The prints were finished so as to produce a glossy, unferrotyped surface.

Interpretation equipment. All the interpretation work was done under pocket stereoscopes of the Abrams CF-8 type. Abrams Height Finders were used to determine tree heights and Moessner Crown Density Scales *(5)* were used as aids in estimating stand density.

THE STUDY AREA

The study area is located approximately 4 miles north of Loachapoka, in western Lee County, Alabama. The area lies at a mean altitude of about 700 feet and is in the transition zone between the Piedmont and Upper Coastal Plain physiographic provinces *(3)*. The ground surface is gently rolling with a total relief of about 150 feet. The forest cover is mixed pine and hardwoods. The pines are mostly loblolly (*Pinus taeda* L.) and shortleaf (*P. echinata* Mill.). The hardwoods are those typical of the region, such as southern red oak (*Quercus falcata* Micxh.), water oak (*Q. nigra* L.), white oak (*Q. alba* L.), hickories (*Carya* spp.), sweetgum (*Liquidambar styraciflua* L.), yellowpoplar (*Liriodendron tulipifera* L.), and white ash (*Fraxinus americana* L.).

The study area was divided into two parts, one for determination of relationships between ground truth and photo-images, the other for the testing phase of the study. The first of these areas was designated the "learning area" and the second the "testing area."

THE FOREST COVER CLASSIFICATION SYSTEM

An unlimited number of forest cover classification systems could be devised. However, the most important information to be provided is species composition, size of individual trees, and density of the stands. The system devised for this study recognizes all three of these elements. Table 1 summarizes the system and shows the code designations used. Table 2 provides further information on the tree size classification system.

TABLE 1. CLASSIFICATION SCHEME USED FOR THE INTERPRETATION OF CONDITION CLASSES ON AERIAL PHOTOGRAPHS

Forest cover type		Size classes		Density; crown closure	
Code	*Name*	*Code*	*Name*	*Code*	*Pct.*
P	Pine[1]	1	Sawtimber	A	81-100
BH	Branchbottom hardwoods[2]	2	Poles	B	61-80
PBH	Pine-branchbottom hardwoods[3]	3	Pulpwood	C	41-60
UH	Upland hardwoods[4]	4	Saplings	D	6-40
PUH	Pine-upland hardwoods[5]	5	Reproduction	E	0-5
OFR	Old field restocking[6]				

[1] S.A.F. (1962) Forest Cover Types 75 (shortleaf pine), 80 (loblolly pine-shortleaf pine), and 81 (loblolly pine).
[2] Types 87 (sweetgum-yellowpoplar) and 104 (sweetbay-swamp tupelo-red maple).
[3] Type 82 (loblolly pine-hardwood)
[4] Types 40 (post oak-black oak), 52 (white oak-red oak-hickory), and 72 (southern scrub oak).
[5] Type 76 (shortleaf pine-oak)
[6] Usually loblolly pine and/or sweetgum, but other species were present in small numbers.

TABLE 2. CRITERIA FOR THE IDENTIFICATION OF VEGETATIVE SIZE CLASS

Size class	Range in D.B.H.	Range in tree height	Crown sizes
	In.	*Ft.*	
1—Sawtimber	14 and larger	60-100	Large and broadly rounded
2—Poles	10-13	40-60	Intermediate in size and roundness
3—Pulpwood	5-9	20-40	Small and narrowly rounded
4—Saplings	1-4	10-20	Very small and pointed
5—Reproduction	Less than 1	1-10	No definite crown
U—Mixture of all size classes above			

PROCEDURE

Photography. All the photographs were made during the summer of 1964. They were taken only on days classed as photographic days, that is, days when the air was free of haze and clouds. Air turbulence, which often was severe on these days, made it difficult to fly straight and level. Consequently, it is likely that most, if not all, of the photographs contained considerable amounts of tilt. Since the photographs were not to be used for metric purposes and since no difficulty was encountered in viewing the photographs stereoscopically, the authors felt that the tilt was not a problem.

A line between two clearly identifiable points was drawn across the "learning area." This line was 2½ miles long and was deliberately located so as to cross as many conditions as feasible. It served as the centerline of the strips of photographs taken with each of the film-scale combinations. A similar line was established in the "test area" and, when photographs were taken, both lines were flown to assure that photographic conditions for the two areas would be comparable.

Exposure intervals were such as to obtain 60 per cent endlap when the long dimension of the photograph was oriented parallel to the flight line.

Ground truth. The boundaries of the stands in the actual "learning" and "test" areas were located and delineated on contact prints of standard USDA photographs, but no attempt was made to assign the stands to condition classes using these photographs. All these assignments were made in the field by the senior author following on-site visits. In the learning area these visits were made prior to any photo-interpretation using the test photographs. In the test area, however, the stands were visited and classified only after the senior author had completed his photo-interpretation of the area. Only in this way could the probability of bias be eliminated from his part of the work.

Photo-interpretation — learning phase. Information gained from intensive study of the photographs and from the on-site visits was used as the basis for developing written descriptions of the condition classes as they appeared on the different film-scale combinations. Stereograms showing each of the condition class-film-scale combinations also were prepared. These descriptions and prepared stereograms were used by the interpreters in their training and testing operations.

Three interpreters participated in the study. Two were the authors of this paper and the third was a senior student in forest management who was highly interested in the use of aerial photographs. All three interpreters had perfect scores when given the Moessner Floating Circles Test *(6)*, indicating that all were able to see stereoscopically without difficulty.

Prior to the testing phase of the work, each interpreter worked with the photographs, the written descriptions, and the stereograms of the learning area in order to familiarize himself with the procedure. When an interpreter felt competent to proceed, he began work on the test.

Photo-interpretation — testing phase. Twenty sampling points were randomly located on every second photograph of the 1:2,500 infrared set. This resulted in 500 points on 25 photographs. With a multiscope, these points were transferred to all the other sets of photographs of the test area. Each point was used as the center of a circular sample plot. The plots on the 1:2,500 photographs had a radius of 0.2 inch, while those on the 1:5,000 photographs had a radius of 0.1 inch.

Each of the 500 field plots was visited by the senior author, who evaluated and recorded the ground truth concerning the condition class.[1] Nineteen forest condition classes were found to be present. Four sample plots were randomly selected from each of these nineteen classes for use in the photo-interpretation test.

Each of the interpreters attempted to classify the sample plots on all sets of photographs. In order to minimize the "memory carry-over" of information from one set of photographs to another, each interpreter interpreted only one set each day. The interpreters were not told how many plots were in each condition class nor were they informed of their scores until all the tests were completed.

Scoring. Scoring was carried out at two levels. At the first level overall accuracy of each interpretation was graded, while at the second each of the three elements of the classification system was graded individually.

The overall grading system was based on the idea that tree size and stand density values were meaningless if the forest cover type was not correctly identified. Consequently, the score for an interpretation that was completely correct was set at two. When the cover type was incorrectly identified, the score was zero regardless of how well the size and density components were judged. If the cover type was correctly identified but the size component or the density component was in error by only one class the score was 1½. If both the size and density components were in error the score was zero. Thus, for each interpretation a score of either 2, 1½, or 0 could be assigned.

The individual component scoring system was set up so that the effect of film, scale, and interpreters on each of the classification components could be evaluated. Consequently, each component was scored without regard to the accuracy of the evaluation of the other two components. A correct species identification was given a score of one. An incorrect species identification was given a score of zero. A correct tree size or stand density evaluation was given a score of one. If in either of these cases the correct value was missed by only one class the interpretation was given a score of ½. An estimate with an error greater than one class received a score of zero.

Method of analysis. The primary experimental design of the study was a factorial with mixed factors and with equal subclasses. Films, scales, and condition classes were considered fixed while the interpreters were assumed to be randomly selected from a population of similar interpreters.

DISCUSSION

The 19 condition classes shown in Table 3 were encountered in the test area. It can be seen that most were in the larger size classes and heavier density classes. This skewed distribution of the sample resulted in the test being essentially incomplete. A broader, more representative, sample would be necessary before a true picture of the effectiveness of the procedure could be obtained.

TABLE 3. CONDITION CLASSES ENCOUNTERED IN THE TEST AREA

Species Group	Density	Size					
		1	*2*	*3*	*4*	*5*	*U*
Pine (P)	A		X	X			
	B		X	X			
	C		X				
Branch hwds (BH)	A	X	X	X	X		
	B	X	X	X			
Upland hwds (UH)	A			X			
	B		X				
PBH	A		X				
PUH	A			X			
	B		X	X	X		

Table 4 lists the mean accuracy percentage of interpretation by condition classes and film-scale combinations across all three interpreters. These mean per cent accuracy values refer to the arithmetic mean of the per cent of the total possible score achieved by the interpreters. In general, the results are poor. In only one case, for P3A on panchromatic photographs at a scale of 1:5,000, did the mean accuracy reach 90 per cent. On the other hand, in several cases the mean accuracy was zero. These results are sufficiently poor that one might feel justified in dismissing the procedure out of hand as a practical tool. However, a further examination of the factors involved in the experiment should be made before making a final judgment of the procedure.

Table 5 shows the overall analysis of variance for the study. The results of this analysis indicate that the interpreters differed in their ability to identify the condition classes and that some condition classes were relatively

[1] Since the senior author was to be used as a test photo-interpreter, he interpreted all 500 plots on each of the sets of photographs prior to going into the field and obtaining the ground truth.

more easy to identify than others. It does not appear to show either that the film type or the photographic scale

TABLE 4. ACCURACY OF INTERPRETATION OF CONDITION CLASSES BY FILM-SCALE COMBINATIONS

Condition class	Panchromatic film		Infrared film	
	1:2,500	1:5,000	1:2,500	1:5,000
	Pct.	*Pct.*	*Pct.*	*Pct.*
P2A	50	63	69	58
P2B	44	56	75	73
P2C	54	40	54	48
P3A	54	90	73	81
P3B	56	42	31	60
BH1A	6	21	63	13
BH1B	6	6	21	4
BH2A	0	15	37	25
BH2B	33	0	48	35
BH3A	0	6	25	15
BH3B	0	6	58	23
BH4A	48	56	35	48
UH2B	23	8	25	31
UH3A	35	19	25	15
PBH2A	13	21	21	21
PUH2B	42	6	42	52
PUH3A	29	21	67	44
PUH3B	33	15	25	71
PUH4B	13	8	10	29
Means	28.4	26.3	42.3	39.3
Pan mean	27.3%			
Infrared mean	40.8%			
1:2,500 mean	35.3%			
1:5,000 mean	32.8%			

TABLE 5. ANALYSIS OF VARIANCE OF THE PHOTO-INTERPRETATION DATA

Source	d.f.	S.S.	M.S.	F
Films (F)	1	18.961	18.961	9.37N.S.
Scales (S)	1	0.145	0.145	0.07N.S.
Condition classes (C)	18	112.910	6.273	3.42***
Interpreters (I)	2	15.474	7.737	24.10***
F × S	1	0.121	0.121	0.36N.S.
F × C	18	18.690	1.038	1.25N.S.
F × I	2	3.899	1.949	6.07***
S × C	18	14.173	0.787	1.47N.S.
S × I	2	4.152	2.076	6.47***
C × I	36	66.026	1.834	5.71***
F × S × C	18	18.655	1.036	2.43*
F × S × I	2	0.673	0.336	1.05N.S.
F × C × I	36	29.872	0.830	2.59***
S × C × I	36	19.327	0.537	1.67**
F × S × C × I	36	15.411	0.427	1.33N.S.
Error	684	219.311	0.321	
Total	911	557.790		

* Significant at the 0.05 level of probability.
** Significant at the 0.01 level of probability.
*** Significant at the 0.005 level of probability.
N.S. Non-significant at the 0.05 level of probability.

had any effect on the rate of correct interpretations. However, the situation with respect to films and scales is not this simple because the interactions between films and interpreters (F × I) and between scales and interpreters (S × I) are significant, indicating that the interpreters reacted differently to both films and scales. In addition, the film type means shown in Table 4 were sufficiently different that the lack of significance in the F-test was unexpected. Furthermore, the C × I, F × C × I, and S × C × I terms in the analysis of variance are significant, indicating that the interpreters reacted differently to the different condition classes. In general, some condition classes were easy to identify while others were difficult. Superimposed on this overall pattern were interpreter patterns, which differed from one another but not sufficiently to mask completely the overall pattern. These results warrant a study of the individual interpreters to see if some reasons for the results can be determined.

Table 6 displays the independent analysis of variance for each interpreter. In all three cases there was a significant difference between films. This appears more reasonable than the result of the overall analysis when one considers the magnitude of the difference between film type means shown in Table 4, which indicate that generally better results were obtained using infrared film. The probable reason for the lack of significance in the overall analysis of variance is that the F × I term instead of the error term was used to test the films. Apparently since the F × I term was large (it was highly significant), the film component of variance alone was too small to be detected. When the interpreters were separated and error terms used for testing, the film effects were easily detected.

TABLE 6. ANALYSES OF VARIANCE OF THE PHOTO-INTERPRETATION DATA KEEPING THE INTERPRETERS SEPARATE

Source	d.f.	S.S.	M.S.	F
Interpreter A				
Film (F)	1	1.895	1.895	6.45*
Scale (S)	1	2.056	2.056	6.99**
Cond. class (C)	18	56.602	3.145	10.70***
F × S	1	0.398	0.398	1.35N.S.
F × C	18	13.105	0.728	2.48***
S × C	18	9.257	0.514	1.75*
F × S × C	18	14.727	0.818	2.78***
Error	228	67.000	0.294	
Total	303	165.040		
Interpreter B				
Film (F)	1	16.582	16.582	34.55***
Scale (S)	1	1.451	1.451	3.02N.S.
Cond. class (C)	18	36.166	2.009	4.19***
F × S	1	0.211	0.211	0.44N.S.
F × C	18	19.262	1.070	2.33**
S × C	18	16.456	0.914	1.90*
F × S × C	18	10.071	0.559	1.16N.S.
Error	228	109.500	0.480	
Total	303	209.700		
Interpreter C				
Film (F)	1	4.382	4.382	23.31***
Scale (S)	1	0.790	0.790	4.20*
Cond. class (C)	18	86.163	4.787	25.46***
F × S	1	0.185	0.185	0.98N.S.
F × C	18	16.196	0.900	4.79***
S × C	18	7.788	0.433	2.30***
F × S × C	18	9.268	0.515	2.74***
Error	228	42.813	0.188	
Total	303	167.580		

* Significant at the 0.05 level of probability.
** Significant at the 0.01 level of probability.
*** Significant at the 0.005 level of probability.
N.S. Non-significant at the 0.05 level of probability.

The situation with respect to scales was more complex than that with films. Interpreter B did about as well with one scale as with the other. However, Interpreter A did better with the smaller scale while Interpreter C did better with the large scale. These compensating effects, and the degree of compensation, can be judged by observing the extremely small magnitude of the F-value (0.07) for scales in the overall analysis of variance. A possible explanation for these results is that Interpreter B was so familiar with the photographs and the ground conditions after setting up the descriptive material and stereograms that the scale effect was negligible in his case. Interpreter A had a great deal of experience with small scale photography (1:15,840 and 1:20,000) and found difficulty in shifting to the large scales. Interpreter C had no previous experience to confuse him and did better with the photographs with larger images.

Table 7 shows the per cent accuracy of interpretation of condition classes by film-scale-interpreter combinations. The evidence in this table is very strong that some condition classes were relatively easy to identify while others were extremely difficult. Furthermore, a definite interrelationship between condition classes and interpreters is evident, as was indicated in the overall analysis of variance by the highly significant C × I term. Since each condition class designation is composed of three elements and an error in any one of these elements would lower the interpretation score, the percentage scores shown in Table 7 cannot be evaluated in detail. To make such an evaluation possible, each element of the condition class description was studied independently of the other two elements. The results of these studies are shown in Tables 8, 9, and 10, which are concerned, respectively, with cover type, size class, and density class.

TABLE 7. ACCURACY OF INTERPRETATION OF CONDITION CLASSES BY FILM-SCALE-INTERPRETER COMBINATION

Scale	Interpreter	Condition class																		
		P2A	P2B	P2C	P3A	P3B	BH 1A	BH 1B	BH 2A	BH 2B	BH 3A	BH 3B	BH 4A	UH 2B	UH 3A	PBH 2A	PUH 2B	PUH 3A	PUH 3B	PUH 4B
		Per cent																		
Pan film																				
1:2,500	A	25	37	37	19	13	0	0	0	0	0	0	69	19	0	0	0	56	87	13
	B	63	37	63	63	75	19	19	0	100	0	0	75	0	44	37	13	31	13	25
	C	63	56	63	81	81	0	0	0	0	0	0	0	50	63	0	0	0	0	0
1:5,000	A	69	63	37	87	50	50	19	44	0	0	19	18	0	0	0	0	37	25	0
	B	37	50	31	87	0	13	0	0	0	19	0	87	0	31	63	19	25	19	25
	C	81	56	50	94	75	0	0	0	0	0	0	0	25	25	0	0	0	0	0
Infrared film																				
1:2,500	A	50	81	37	50	19	44	19	13	0	13	63	31	19	0	25	63	63	13	13
	B	87	56	56	87	19	69	13	75	75	19	63	50	56	75	25	63	100	63	19
	C	69	87	69	81	56	75	31	25	69	44	50	25	0	0	13	0	37	0	0
1:5,000	A	75	69	37	75	87	0	0	0	0	0	19	44	37	0	0	75	63	81	25
	B	37	75	44	87	19	37	13	75	81	25	25	100	25	44	63	69	69	56	63
	C	63	75	63	81	75	0	0	0	25	19	25	0	31	0	0	13	0	75	0

All of the interpreters did relatively well with the pure pine stands, with the accuracy rate ranging from 45 to 100 per cent and averaging 79 per cent. This accuracy rate is what one would expect from theoretical considerations and past experience. The difference between the scale means is small and is largely the result of a poor performance of Interpreter A when using the panchromatic, 1:2,500 photographs.

The presence of enough hardwoods in a stand to affect the cover type designation caused an enormous amount of trouble. Furthermore, different interpreters did not respond to these difficulties in the same way. Interpreter B did much better than either of the others, while Interpreter A did better than Interpreter C. This ranking was not unexpected. Interpreter B was responsible for the development of the condition class descriptions and the stereograms. Consequently, he was intimately familiar both with the photographic characteristics and with ground conditions. In his case, the major question was why his scores were not higher.

Interpreter A had widespread experience in photo-interpretation but not the intimate knowledge of the ground conditions or of the photography used in this study possessed by Interpreter B. As was mentioned in the section on procedure, each interpreter was introduced to instructional material prior to the test and worked with this material until he judged himself competent to go on with the test. It is likely that Interpreter A, because of his previous experience, felt himself ready to proceed before he was completely prepared. Probably the greatest problem he had was adjusting to the small ground area covered per photograph. His previous experience was largely with 9 × 9-inch photographs taken at scales of 1:15,840 or 1:20,000. With the former of these scale-format combinations each photograph covers approximately 5 square miles, while in the second each photograph covers about 8 square miles. In contrast, one of the 4 × 5-inch photographs at a scale of 1:2,500 covers only 0.3 square mile and, at a scale of 1:5,000, 1.2 square miles. When the photographs are viewed stereoscopically only about 0.2 or 0.8 square mile is seen at one time and the interpreter finds difficulty in tracing out drainage systems, particularly in areas of low relief. Contributing to this problem is reduced stereo-exaggeration in the small format photographs. The base-height ratio in the case of 9 × 9-inch photographs, taken with a 6-inch lens at 1:15,840 or 1:20,000, is approximately 0.58, while with an 8.25-inch lens it is approximately 0.43. With the 4 × 5-inch photographs used in this study the base-height ratio was only approximately 0.31. This tended to flatten noticeably the stereo-image and made the detection of drainages difficult. Without the broad view needed for judging the character of the topography it is not surprising that there was considerable confusion between upland and branchbottom hardwoods. This, of course, would be expected to extend into the mixed hardwood classes. Although examination of the data in Table 9 cannot confirm this hypothesis, the original data imply this type of confusion. It is probable that the situation could be greatly improved if the small format, large scale photographs were used in conjunction with accurate topographic maps or with small scale, large for-

Table 8. Accuracy of Interpretation of Forest Cover by Film-Scale-Interpreter Combinations

Scale	Interpreter	Cover types P	BH	UH	PBH	PUH
		Per cent				
Pan film						
1:2,500	A	45	18	13	0	50
	B	75	39	25	50	31
	C	90	0	75	0	0
1:5,000	A	75	46	0	0	19
	B	55	18	25	75	25
	C	100	0	50	0	0
Infrared film						
1:2,500	A	70	39	25	50	56
	B	85	75	75	25	69
	C	95	75	0	25	13
1:5,000	A	90	14	37	0	88
	B	70	64	50	75	75
	C	95	18	25	0	31
Pan mean		73	20	31	21	21
Infrared mean		84	48	35	29	55
1:2,500 mean		76	41	35	25	36
1:5,000 mean		81	27	31	25	40
Overall mean		79	34	33	25	38

Table 9. Accuracy of Interpretation of Size Classes by Film-Scale-Interpreter Combinations

Scale	Interpreter	Size Classes 1	2	3	4
		Per Cent			
Pan film					
1:2,500	A	44	52	66	81
	B	50	73	79	75
	C	37	67	77	69
1:5,000	A	50	55	68	88
	B	50	77	87	94
	C	56	59	73	69
Infrared film					
1:2,500	A	50	58	60	94
	B	50	78	79	50
	C	87	61	64	69
1:5,000	A	75	52	59	81
	B	50	70	75	87
	C	6	58	89	57
Pan mean		48	64	75	79
Infrared mean		53	63	71	73
1:2,500 mean		53	65	71	73
1:5,000 mean		48	62	75	79
Overall mean		50	63	73	76

mat photographs of any age. In any case, the photo-interpreters must have a feel for the terrain. If maps or small scale photographs are not available, this feeling for the terrain will have to be developed by studying a number of adjacent photographs and extending the drainage pattern from one to the next.

Interpreter C was faced with all of the problems mentioned above. In addition, since he had no past experience, he was dependent entirely on his training program. Hindsight leads one to the conclusion that this training regime was perhaps inadequate or that the reference materials might have been improved. No attempt was made to develop an identification key which would have systematized the search for clues as to the identity of the cover type. If such a key, stressing the importance of the

Table 10. Accuracy of Interpretation of Density Classes by Film-Scale-Interpreter Combinations

Scale	Interpreter	Density Classes A	B	C
		Per cent		
Pan film				
1:2,500	A	60	69	38
	B	81	72	38
	C	35	71	75
1:5,000	A	61	76	50
	B	81	69	25
	C	40	69	25
Infrared film				
1:2,500	A	47	69	37
	B	87	56	25
	C	50	71	50
1:5,000	A	60	78	50
	B	89	65	13
	C	54	81	25
Pan mean		60	71	42
Infrared mean		65	70	33
1:2,500 mean		60	68	44
1:5,000 mean		64	71	38
Overall mean		62	71	38

drainage pattern, had been used it is likely that all interpreters would have been more accurate in identifying cover type.

Generally, as can be seen in Table 9, size classes were easier to identify than were the cover types. As one probably should expect on the basis of theory and previous experience, neither film type nor photographic scale appeared to influence the rate of correct interpretations. Although the rate of correct identifications of size classes was considerably better than the rate for cover types, it remained low. The apparent reason for this lay in the criteria used for classification. These were tied to timber utilization categories which may or may not be closely associated with tree size, particularly as the trees are seen on the photographs. Tree height is a valuable criterion for classifying stands at all stages of development. However, it must be remembered that the difference in total height between pulpwood and sawtimber stands may be small. In order to distinguish between the two classes, a second criterion such as the average crown diameter of the dominant-codominant portion of the stands is needed. In this study, no provisions were made for the fact that heights of utilization classes overlap or that definite dimensions of crown diameters could be measured. It is probable that size class identification would have been improved if these had been taken into account.

Another complication of size class identification was that many of the stands had uneven canopies. This was far more evident on the photographs than on the ground. This led the interpreters to class these stands as uneven-aged when they had been classified on the ground as even-aged. Comparison of rates between size classes in Table 9 illustrated this factor. Stands of small trees, which tend to be quite uniform, were correctly classified more often than were stands of large trees, which tend to be less uniform. An identification key based on tree height and crown diameter dimensions and illustrated with prepared stereograms might have helped increase the rate of correct interpretations.

As in the case of the size classes, the rate of correct identifications of density classes, Table 10, was approximately two out of three. This was not unexpected since stand density evaluation from aerial photographs is known to be erratic, particularly when it is done in the manner chosen for this study. Complicating the problem was the fact that the so-called true crown closure was visually estimated. This estimation from the ground may have been poorer than the one from photographs. Two provisions could have been made to improve the procedure. The photographic crown closure should have been measured or estimated objectively by some such procedure as the one developed by Losee *(4)*, or one using a dot-grid. With the large-scale photographs used in this study, either of these procedures would have been feasible. Another means of increasing accuracy could have been using the moosehorn *(9)* or other device to make an objective evaluation of crown closure on the ground.

In short, too much reliance was placed on subjective evaluations of crown closure, both on the ground and on the photographs in this study.

CONCLUSIONS AND RECOMMENDATIONS

The question posed by the main objective of the study, "Can photographs taken with a K-20 camera be used for stand classification purposes?", cannot be answered unequivocably from the evidence obtained. However, a testing procedure that can be used as the basis for further studies which should provide the information needed to answer the question has been developed.

There was good evidence that infrared film would yield better results than would panchromatic, a result to be expected under conditions of mixed hardwoods and softwoods. On the other hand, there was little evidence to indicate that one photographic scale was any better than the other. However, the smaller scale might prove better in the long run because the larger ground area covered per photograph would permit an easier understanding of the drainage system of the area. An added benefit of the smaller scale would be to lower photographic cost.

Certain recommendations can be made regarding future studies of this type.

(1) The descriptive material used to guide the interpreters should be organized into a key. This key should contain as many stereograms of condition classes as possible.

(2) Whenever possible, the critical items in the key should be evaluated by objective (actual measurement) rather than subjective (estimation) procedures. Grey scales, such as that in the Munsell color system *(7)*, should be used to express grey tones. Tree heights should be measured with a floating dot instrument. Crown diameters should be measured with a micrometer wedge or tube magnifier. Stand densities should be estimated by Losee's procedure or with a dot grid.

(3) The key should be given preliminary tests and any ambiguities should be resolved prior to the final test.

(4) The interpreters who test the procedure should have a thorough indoctrination over a fairly lengthy period prior to the test. During this period they should be closely supervised by the project leader and should not be permitted to proceed to the testing phase until the project leader is satisfied that they have attained competence.

(5) The developer of the procedure should not be one of the test interpreters.

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