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Forest Cover Type Identification

Medium-scale panchromatic, infrared, Ektachrome, and Ektachrome Infrared aerial photos were compared.

Reliable information concerning forest cover must be available before a person can do a satisfactory job of planning for land management or before a governmental agency can set up a sound plan of action for the economic development of a forested region. Traditionally, information of this type has been obtained by on-site inspections or inventories of a number of sample plots. The cost of such on-site evaluations is high, making it necessary to keep the size of the sample small. This has a definite adverse effect on the detail with which the distribution of forest cover types can be ascertained. In turn, this lack of detail adversely effects the planning that is based on these data. Aerial photographs have been used to improve this situation but much remains to be done to increase their effectiveness. This paper describes the results of a study, conducted jointly by the Tennessee Valley Authority and Auburn University, which was designed to determine how well the forest cover types in an area of mixed hardwoods and pine in northwestern Alabama could be identified on medium scale aerial photographs.[2]

Abstract: *Photo-interpretation keys for forest cover types occurring in northwestern Alabama were developed for the following film-season combinations: panchromatic, fall; black-and-white infrared, fall; black-and-white infrared, summer; conventional color, fall; and color infrared, fall. These keys were based on the forest cover types described by the Society of American Foresters. The independent variables were topographic position (including aspect and slope) and tone or color. As tested by five interpreters on photographs at scales of 1:12,000 and 1:20,000, the overall average percentage of correct answers was only 36 percent. However, when the S.A.F. types were grouped so as to approximate the forest cover type system used by the Tennessee Valley Authority, the overall average percentage of correct answers was 61 percent. For the best interpreter this value was 74 percent. With more training and closer supervision the rate of correct identifications probably would have been considerably higher. This indicates that more information about forest cover can be obtained from aerial photographs of medium scale than has previously been thought possible.*

Objectives of the Study

The primary objective of the study was the development for each of the types of aerial photographs available to the study of a separate photo-interpretation key which would make it possible to identify forest cover types on the photographs. The secondary objective was to evaluate the keys in an objective manner so as to obtain some perspective as to their usefulness.

Initially the forest cover types defined by the Society of American Foresters (SAF, 1964) were used as the basis for the study. Later the test data were regrouped on the basis of the forest cover types used by the Tennessee Valley Authority (TVA, 1966) in

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[2] Detailed results of the study are to be found in "Photographic interpretation of forest types," an unpublished Masters-degree thesis by the senior author, which is on file in the Ralph Brown Draughon Library, Auburn University. The study was supported by funds from McIntire-Stennis Project 909, Auburn University, and the Tennessee Valley Authority supplied the photography that was taken especially for the study.

its regional timber inventories. In the latter instance the standard keys were not modified in any way. Instead each TVA type was considered to be made up of one or more SAF types and the sorting of the data was done on this basis. Consequently, the evaluation phase of the study consisted of two levels of interpretation intensity.

EXPERIMENTAL DESIGN

The study involved vertical aerial photographs taken at two scales, 1:12,000 and 1:20,000, using the following films: panchromatic (Kodak Super XX Aerographic, Type 5425): black-and-white infrared (Kodak Aerographic Infrared, Type 5424): conventional color (Kodak Ektachrome MS Aerographic, Type 2448): and color infrared (Kodak Ektachrome Infrared Aero, Type 8443). These photographs were taken in October, 1967, at approximately the peak of fall coloration.

It was recognized from the beginning that many pitfalls await those who attempt to use fall tree coloration as a guide to the species composition of forest stands. In spite of these pitfalls the decision was made to use fall photography because the incidence of photographic days in the study area is considerably greater in the fall than at any other season. This decision was reached because the sponsors of the project were of the opinion that the relatively high probability of obtaining useable photography in the fall was of overriding importance.

Preliminary study of the black-and-white infrared photographs indicated that the results with this film probably would be poorer than had been hoped for by the sponsors. As a result, an additional set of such photographs was obtained in May 1968 at a time when leaf formation was complete. Consequently, a *season* factor was introduced into the study insofar as the black-and-white infrared film was concerned.

A Wild RC-8 Automatic camera, with Wild Universal Aviogon lens No. 326, was used by the TVA Division of Water Control Planning to obtain the photographs. This is a standard mapping camera with a 9×9-inch format and a six-inch focal-length lens. A Wild 500 nm, dark yellow filter (comparable to a Wratten No. 12, minus-blue, filter) was used with the panchromatic and color infrared films whereas a 700 nm, deep red filter (comparable to a Wratten No. 89B filter) was used with the black and white infrared film. In all the tests antivignetting filters were used to reduce the effect of lighting fall-off toward the edges of the photographs.

All the interpretation was done using double-weight paper prints. In the case of the color photographs it would have been preferable to use transparencies but the desires of TVA, and the physical problem of getting suitable light tables to the interpreters (in Norris, Tennessee, and Atlanta, Georgia), were considered to be of overriding importance and, consequently, prints were used in all instances. The October photographs were printed on paper with a glossy unferrotyped surface and the May photographs were printed on semi-matte paper.

The study area, a one-by-ten mile strip oriented east and west, was located in the northwestern portion of the William B. Bankhead National Forest in Lawrence County, Alabama. This area is in the region of sandstone plateaus and shale and sandstone ridges within the Ridge and Valley Physiographic Province as described by Hodgkins (1965). It also is in the transitional zone between the Central and Southern forest regions as defined by the Society of American Foresters (SAF) (1964). It is characterized by sandy flat uplands, steep slopes, and narrow streambottoms. The range in elevation is from about 600 to 1,000 feet above mean sea level. The uplands are underlain by a deep layer of limestone which can be seen as an outcrop on most slopes. The soils below the limestone outcrops are, in most cases, much less sandy than those on the upland flats. These soil differences and the differences in other ecological conditions, particularly those which influence the moisture regime, give rise to differences in forest cover types. The forest cover on the upland flats and the upper slopes is characterized by dry-site oaks (*Quercus* spp.) and pines (mostly loblolly, *Pinus taeda*, L., and Virginia pine, *P. virginiana*, Mill.), but on the lower slopes the cover consists of a mixture of moist site hardwoods with relatively little pine. The specific SAF forest cover types found on each topographic position are listed in the key, Table 1.

THE KEYS

As was previously stated, the primary objective of the investigation was the development of a photo-interpretation key for each of the available films that could be used to assist a photo-interpreter in identifying forest cover types. The keys that eventually evolved were designed for the identification of SAF forest cover types. They consist of two parts. The first part, Table 1, which is common to all the film types, is based on the topographic situation in which the unknown stand is lo-

TABLE 1. KEY TO SOCIETY OF AMERICAN FORESTERS FOREST COVER TYPES USING TOPOGRAPHIC CONDITIONS AS CRITERIA

I. Upland Flat—Go to *A*.
A Area void of large trees, few individual crowns present—Loblolly Pine (81)[a].
A Area with many crowns visible—Go to *B*.
B No discernable slope[b] (10 percent or less)—Scarlet Oak (41); White Oak (53); Chestnut Oak (44); Post Oak-Black Oak (40); White Oak-Red Oak-Hickory (52); Virginia Pine (79); Shortleaf Pine-Virginia Pine (77); Loblolly Pine (81); Shortleaf Pine (75).
B Slope greater than 10 percent—Go to *C*.
C North aspect—Scarlet Oak (41); Chestnut Oak (44); White Oak (53); Yellow-Poplar (57); Virginia Pine (79); Shortleaf Pine-Virginia Pine (77); Shortleaf Pine (75).
C South aspect—Chestnut Oak (44); Scarlet Oak (41); Post Oak-Black Oak (40); Virginia Pine (79); Shortleaf Pine-Virginia Pine (77); Shortleaf Pine (75).
I. Not Upland Flat—Go to II.
II. Drainage—Go to *A*.
A North aspect—Yellow-Poplar-White Oak-Northern Red Oak (59); Yellow-Poplar (57); White Oak-Red Oak-Hickory (52); White Oak (53); Loblolly Pine-Hardwood (82).
A South aspect—Yellow-Poplar-White Oak-Northern Red Oak (59); White Oak-Red Oak-Hickory (52); Yellow-Poplar (57); Loblolly Pine-Hardwood (82).
II. Not Drainage,—Go to III.
III. Slope—Go to *A*.
A North aspect—Go to *B*.
B Slope less than 25 percent—Scarlet Oak (41); White Oak (53); Yellow-Poplar (57); White Oak-Red Oak-Hickory (52); Eastern Redcedar-Hardwood (48); Loblolly Pine-Hardwood (82); Loblolly Pine (81).
B Slope greater than 25 percent—White Oak-Red Oak-Hickory (52); White Oak (53); Yellow-Poplar (57); Beech-Sugar Maple (60); Scarlet Oak (41); Eastern Redcedar-Hardwood (48); Loblolly Pine-Hardwood (82); Loblolly Pine (81);
A South aspect—Go to *C*.
C Slope less than 25 percent—Scarlet Oak (41); White Oak-Red Oak-Hickory (52); White Oak (53); Chestnut Oak (44); Northern Red Oak-Mockernut Hickory-Sweetgum (56); Beech-Sugar Maple (60); Eastern Redcedar-Hardwood (48); Eastern Redcedar-Pine-Hardwood (49); Loblolly Pine-Hardwood (82); Loblolly Pine (81).
C Slope greater than 25 percent—White Oak-Red Oak-Hickory (52); Scarlet Oak (41); White Oak (53); Northern Red Oak-Mockernut Hickory-Sweetgum (56); Beech-Sugar Maple (60); Eastern Redcedar-Hardwood (48); Loblolly Pine-Hardwood (82); Loblolly Pine (81).
III. Not a slope; streambottom—Beech-Sugar Maple (60); Yellow-Poplar-White Oak-Northern Red Oak (59); Sycamore-Pecan-American Elm (94); White Oak (53); Loblolly Pine (81); Loblolly Pine-Hardwood (82).

[a] Numbers in parentheses refer to the cover type numbers in the S.A.F. system.
[b] The slope of each sample location was determined on the topographic map of the area.

cated. Four topographic positions are recognized: upland flat, drain, slope, and streambottom. These classes are described in Table 2. In addition to the topographic positions, the topographic situation involves the direction and degree of slope. This can be seen in Table 1. For each topographic situation, Table 1 contains a list of the SAF forest cover types that are apt to be present. This listing is in the order of probable appearance. The ranking was done in an attempt to reduce interpretation errors. It was felt that an interpreter would be less likely to assign a stand to a cover type if he knew that the cover type occurs only occasionally. Before making such an assignment, an interpreter probably would examine the evidence with extra care.

After the interpreter has decided on the topographic situation in which the unknown stand is located, Table 1 provides him with information as to which cover types are present. With this information, and knowing what film and season is involved, the interpreter makes use of the second part of the key, Table 3, which indicates the photographic tones or colors associated with each of the cover types. These tones and colors are described in tones of the Munsell color system (Munsell Color Co., 1966).

Crown shape, which has been used as an identification criterion, was not used in this study because the small scales made it impossible to find enough differences in crown shape to make the criterion meaningful. Furthermore, as the stands were made up primarily of mixed hardwoods and the mixtures

TABLE 2. TOPOGRAPHIC CLASSES RECOGNIZED IN THIS STUDY

1. Upland Flat—The upland portion of each ridge or flat and down the slope in any direction to a definite break in slope. If no break in slope is evident, the division is to be the point of definite forest type change as seen on the photograph. If no break in slope or type change is evident the topographic position is to be changed to a slope or drainage position at a point 25 percent down the slope.
   a. North aspect.[a,b]
   b. South aspect.
2. Drainage—All definite drainages from the headwater to the streambottom, which show a different texture or tone from the adjacent topographic positions, (see the definition of streambottom).
   a. North aspect.[c]
   b. South aspect.
3. Slope—All *slope* positions not defined by topographic positions 1 and 2. Includes slopes below definite breaks in terrain or definite changes in forest types.
   a. North aspect.
   b. South aspect.
4. Streambottom—All streambottoms which have a continuous gradient of less than 5 percent for a distance of at least one-half mile.

[a] "North aspect" includes aspects with azimuths from true north from 316° to 135°. "South aspect" includes aspects with azimuths from 136° to 315°.

[b] The aspect of each sample location is defined as the direction of the natural flow of water from the point. In the case of multiple aspects an average is used.

[c] The aspects of watersheds or drainages are defined as the direction of flow of water in the main channel of the streams.

had to be evaluated on a tree-by-tree basis, the often used criterion of stand texture was of little value. Consequently, the keys were developed only on the basis of topography and tone or color.

TESTING PROCEDURE

Four five-acre test areas were located in each of the four topographic position classes recognized in the key. Five interpreters[3] were used in the test. The interpreters were instructed first to determine the topographic position, Table 2, and then the aspect and slope. This was done by using the photographs in conjunction with high quality topographic maps.[4] The instructions then stated that the interpreter should refer to Table 1 and determine which cover types were apt to be present. Finally, the interpreter was instructed to match the tones or colors of the unknown with those listed in Table 3 in order to determine which cover type was present. Each interpreter was instructed to give a first and second choice of the type in each test area. The second choice was requested to indicate whether the interpreter was at least on the right track to a correct identification if his first choice was incorrect.

As the SAF forest cover types are highly detailed and not well suited to most forest inventory situations, it was decided, as was previously mentioned, to proceed with the analysis of the SAF types as originally planned but then to group the SAF types into the broader types used by TVA in its regional inventories and to reanalyze the data in terms of this new base. Table 4 shows how the grouping was done. As a result of this decision there are two sets of data to be considered in the following discussion.

ANALYSIS AND DISCUSSION

The evaluation phase of the study was based on a scoring system that awarded two points for a correct first choice, one point for an incorrect first choice but a correct second choice, and zero when both choices were incorrect. Table 5 summarizes these scores by showing the number and percent of *two* scores, *one* scores, and *zero* scores by interpreters and by type classification systems, across all film-season-scale combinations. This table indicates that the SAF types are too finely divided to be distinguishable under the conditions of this test. For the SAF types the rate of correct identifications was only 36 percent whereas with the broader TVA types the rate was 61 percent.

As it is probable that under normal operating conditions only the most talented photo-interpreters would be assigned to work of this type, it may be instructive to see how well the best of the five interpreters performed. Table 5 indicates that across all film-season-scale combinations Interpreter 5 had the highest scores, 39 percent for the SAF types and 74 percent for the TVA types.

[3] Three interpreters were supplied by T.V.A., while Region 8, U. S. Forest Service, supplied two.

[4] U. S. Geological Survey 7½-minute quadrangles, at a scale of 1:24,000.

TABLE 3. PHOTOGRAPHIC COLOR AND TONE GUIDE TO THE SAF FOREST COVER TYPES FOR THE FIVE FILM-SEASON COMBINATIONS. BASED ON THE MUNSELL COLOR CLASSIFICATION SYSTEM

Type Number	*Color Codes for Species in Types*	
	Infrared Color	*True Color*
40	5R6/10-10RP/8	5GY8/4-7.5GY6/2
41	2.5R6/10[a] 10RP6/10	10GY7/2
44	10RP5/8	2.5Y8/4
48	7.5R3/6-HWD[b]	2.5G4/2-HWD
49	7.5R3/6-7.5R2/4-HWD	2.5G4/2-5G6/2-HWD
52	10RP6/8-RO-7.5R5/4[c] 5B3/1	7.5GY7/2-RO-5GY6/2 7.5YR6/2
54	10RP6/8	7.5GY7/2
56	10RP6/8-7.5R5/4 5B3/1	7.5GY6/2-5GY6/2 7.5YR6/2
57	2.5R6/8	5GY7/2
59	2.5R6/8-10RP6/8-10RP6/8	5GY7/2-7.5GY7/2-7.5GY7/2
60	5R6/10 5R5/12	5GY7/2
75	7.5R2/4	2.5G5/2
77	7.5R2/4-HWD	2.5G5/2-HWD
79	7.5R2/4	2.5G5/2
81	7.5R3/6 5RP4/2	7.5GY6/2 2.5G5/2
82	7.5R3/6-HWD	7.5GY6/2-HWD
94	7.5R6/10-7.5R6/10	7.5YR7/4-7.5YR7/4

[a] Variations in color codes are listed below the primary code.
[b] The hardwood mixture designation is used when there are no predominant hardwood species or species groups.
[c] The red oak mixture designation is used when species of the red oak group are evident but not in sufficient numbers to be one of the predominant species.

Even for this interpreter the score for the SAF types is so low that no organization would consider it satisfactory for forest inventory purposes. On the other hand the score for the TVA types is sufficiently high to indicate some potential practical value. If the near misses are considered, this interpreter was only completely wrong in 13 percent of the instances where the TVA types were used.

The scores achieved by the interpreters, for both the SAF and TVA cover types, were subjected to analyses of variance.[5] Topographic position was found to be a highly significant contributor to correct identification for both sets of data. Further analyses of the data by topographic classes, using Duncan's new multiple range tests, indicated that the greatest difficulty was encountered, as might be expected, along the streambottoms and drainages where the vegetative cover is most

[5] The experimental design was completely random with a factorial arrangement of fixed treatment effects, equally replicated.

TABLE 4. DESCRIPTION OF THE TVA FOREST COVER TYPES WHICH OCCURRED ON THE STUDY AREA, WITH THEIR SAF EQUIVALENTS

TVA Type		*SAF Type*	*Description*
No.	*Name*	*Equivalents*	
110	Shortleaf Pine	75	Shortleaf pine composes 50 to 100 percent of the forest stand.
111	Loblolly Pine	81	Loblolly pine composes 50 to 100 percent of the forest stand.
112	Virginia Pine	79	Virginia pine composes 50 to 100 percent of the forest stand.
241	Elm-Ash-Maple	94	Forests in which elm, ash, soft maple or hackberry comprise a plurality of the stocking. Common associates are blackgum, boxelder, eastern cottonwood, honeylocust, river birch, sycamore and black willow.
250	Oak-Hickory	40, 41, 44, 52, 53, 56	Comprised primarily of white oaks, red oaks, and hickory. Other species are elm, maple, black walnut, and yellow-poplar.
260	Beech-Birch-Maple	60	Commonly American beech or sugar maple predominate though yellow birch may be found in the mountains. In association can be basswood, northern red oak, red maple, elm, black cherry, and yellow-poplar.
261	Yellow-Poplar	57, 59	Yellow-poplar is pure or predominates. Associates are black locust, red maple, sweet birch, sweet-gum, cucumber-tree, northern red oak and other moist-site species.
380	Pine-Hardwood	77, 82	Yellow pine, either pure or mixed, comprises 25 to 49 percent of the forest stand.
390	Eastern Redcedar-Hardwood	48	Eastern Redcedar comprises 25 to 40 percent of the forest cover. The primary hardwood species include oaks, ashes, and hackberry. Associated species are loblolly and Virginia pines, winged elm, black locust, dogwood, and other hardwoods.
391	Eastern Redcedar-Pine-Hardwood	49	Eastern Redcedar, and shortleaf or Virginia pine comprise 25 to 49 percent of the stand. The primary hardwoods are the red oaks. The associated species include hickories, American elm, and other hardwoods.

TABLE 5. THE NUMBER AND PERCENTAGE OF EACH SCORE[a] RECEIVED BY EACH INTERPRETER FOR EACH SYSTEM OF COVER TYPE IDENTIFICATION ACROSS ALL FILMS, SCALES, AND TOPOGRAPHIC POSITIONS

Interpreters		*System*					
		SAF			*TVA*		
	Score	*0*	*1*	*2*	*0*	*1*	*2*
1	No. of Occurrences[b]	90	19	51	56	25	79
	Percent	56	12	32	35	16	49
2	No. of Occurrences	85	21	54	38	29	93
	Percent	53	13	34	24	18	58
3	No. of Occurrences	76	23	61	36	23	101
	Percent	48	14	38	23	14	63
4	No. of Occurrences	72	29	59	32	30	98
	Percent	45	18	37	20	19	61
5	No. of Occurrences	77	21	62	21	20	119
	Percent	48	13	39	13	13	74
Total	Number	400	113	287	183	127	490
	Average of 5 interpreters	50	14	36	23	16	61

[a] Scoring interpretation of forest types:
0—incorrect
1—incorrect first choice—correct second choice
2—correct first choice

[b] The total number of occurrences for each system used was 160 for each interpreter. The *percent* figure represents the number of occurrences for each score compared to the total occurrences.

TABLE 6. DUNCAN'S NEW MULTIPLE RANGE TEST OF DIFFERENCES BETWEEN MEAN SCORES, USING THE T.V.A. COVER TYPES[a]

Panchromatic (Fall)	*IR, B & W (Fall)*	*Color Infrared (Fall)*	*Ektachrome (Fall)*	*IR, B & W (Spring)*
1.175	1.394	1.431	1.438	1.481

[a] Any two means underlined by the same line are not significantly different at the 0.05 level of probability.

complex. Many species of trees are present in topographic situations of this type and their proportional importance in the stands changes through relatively wide ranges over short distances on the ground. Few of the stands can be assigned without question to SAF cover types, even by individuals doing the work on the ground within the stands. Under these conditions it is not surprising that errors in classification were made, particularly when the criteria available involved only tone or color.

Differences between interpreters became significant only where the data were sorted into the TVA forest cover type classes. As might be expected, some interpreters had better scores than the others. However, due to a number of factors, the performance levels achieved probably are lower than would be true under conditions of production photo-interpretation. Faulty reading or comprehension of the instructions, coupled with a lack of time for programmed instruction and practice, undoubtedly caused some of the errors of interpretation. One of the interpreters proved to be color-blind insofar as green-olive-brown was concerned and was unable to distinguish much on the conventional color photography but was better than average with the photographs taken on the other films. Memory bias undoubtedly had an effect which could not be controlled under the circumstances of the test. All these items and others tended to reduce the overall accuracy of the test. However, it is probable that most differences could be controlled or eliminated in production photo-interpretation through proper supervision, the use of naturally gifted interpreters, and a training program that would provide an experience backlog for the ones doing the work. Under such circumstances the end results should be better than those obtained in this test.

As was expected, the results obtained from the panchromatic photographs were significantly poorer than those obtained with the other photographs. This can be seen in Table 6. Contrary to expectations, however, was the lack of any clear-cut superiority of the color photographs, either conventional or infrared, over the black-and-white infrared photographs. As a matter of fact, the highest mean score was associated with the black-and-white infrared photographs taken in May. These results were all the more unexpected because the black-and-white infrared photographs were taken through a deep red filter. In the experience of the authors such photographs usually are highly contrasty with a subsequent loss of detail in the highlights and shadowed areas. These photographs, however, resembled those usually obtained with a minus-blue filter.

The May photographs were particularly good. Detail was visible at every level in the forest canopy from the top to the ground. This often is not true even if a minus-blue filter is used. It is possible that this particularly good illumination was the result of the photographs being taken under a *high overcast*. The photographs were taken under these circumstances because previous commitments prevented the photographic crew from waiting until the weather was clear. It is possible that the cloud cover diffused the light, weakening the shadows and causing backlighting in places which normally are shadowed. If such weather conditions were repeatable with a reasonably high frequency it is possible that it would be found that such conditions would be preferable over the usually desired clear weather for B&W infrared photography of forest areas.

At the beginning of the study it was assumed that correlations between photographic grey tones and tree species would be weaker than between shades of color and tree species and, consequently, the color photographs would yield higher mean scores than would the black-and-white photographs. This apparently was a false hypothesis. However, it is possible that it would have been true if color transparencies rather than paper prints had been used. There is no question that a loss of brilliance, and some color shift occurs if paper prints are made from transparencies. However, because of the constraints placed on the study, which were mentioned earlier, transparencies could not be used in the analysis even though they were available. In any event, the evidence of this study indicates that the results obtained with color prints were no better than those obtained with black-and-white infrared photographs.

The testing personnel preferred the larger scale (1:12,000) but in the end the larger scale yielded results that were no better than the smaller scale. There really is no explanation for this phenomenon other than that both are relatively small scales and the larger of the two simply provided no more useable information concerning the forest cover than did the smaller scale. If scales of 1:5,000 or larger had been used it is possible that sufficient additional information would have been made available to influence significantly the interpretation scores. However, the information concerning the lack of improvement in going from a scale of 1:20,000 to a scale of 1:12,000 is valuable as it indicates that small scales might as well be used, thus reducing the cost of the photography.

CONCLUSIONS

The results of this study indicate that many of the forest cover types distinguished by the SAF and occurring in northwestern Alabama differ so little in appearance on medium-scale photographs, regardless of the film used, that it is difficult, if not impossible, for a photo-interpreter to separate them. This is particularly true along stream bottoms, branches, and in cove situations. However, if certain of these types are grouped together into broader cover types, such as those used by TVA in its regional timber inventories, the broader types can be distinguished from one another, provided that the interpreters are (1) equipped visually for the work, (2) well-trained and experienced, and (3) well supervised.

The keys used to assist the photo-interpreters in this work should be based primarily on ecological criteria, such as topographic position, which can be evaluated on the photographs and, secondarily, on photographic characteristics such as tone or color.

Panchromatic film yielded results that were definitely inferior to those obtained with the other films. It would be unwise to use it for classifying forest cover into cover types. Because of its relatively low cost, black-and-white infrared film probably would be the most desirable film to use for work of this type.

The evidence is too scanty for any definite conclusions regarding the proper filter to use with the black-and-white infrared film. Sufficient information was obtained, however, to make it plain that a deep red filter will yield excellent photographs for forest cover evaluation, at least under the conditions of this study.

The evidence is not sufficiently strong to support a definite statement that early summer black-and-white infrared photographs are to be preferred over fall black-and-white infrared photographs. However, there is a hint that this is correct. Fall coloration is only a transitional stage in the annual cycle of the forest and occurs over a very limited span of time. Furthermore, the color-changing process does not progress uniformly in all trees or in all species of trees. Consequently, many phases of the process are present at any given instant of time. This gives rise to anomalies which greatly complicate the work of photo-interpreters working with photographs taken at this season of the year. Because of these factors and the data shown in Table 6, it is probable that results obtained using summer photographs would be superior to those obtained using fall photographs.

The evidence indicates that under the conditions of this study, not enough additional information is gained in shifting photographic scales from 1:20,000 to 1:12,000 to justify the added cost of the latter photography. Consequently, it would be best to use scales from the small end of this range so as to keep photographic costs as low as possible.

In summary, the study described in this paper yielded results that indicate that, *with proper planning and execution of the work*, reasonably accurate stratification of the forest cover into usefully detailed cover types can be made using medium scale aerial photographs. This should be of considerable value to organizations such as the TVA which are concerned with regional inventories in which the location of the timber is an important factor. Much more detailed maps can be prepared using aerial photographic evidence than can be prepared using data obtained from widely spaced grid locations. Herein lies the value of the results of this study.

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