SECTION 121

MICROSCALE PHOTO INTERPRETATION OF FOREST AND NONFOREST LAND CLASSES

by

Robert C. Aldrich and Wallace J. Greentree
Pacific Southwest Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture
Berkeley, California

INTRODUCTION

The first step in an extensive forest inventory such as the nationwide Forest Survey[1] is to separate the forest from nonforest land and possibly stratify forest land by type, volume, or site classes. Until recently this was done on panchromatic or infrared-sensitive films of scales ranging from 1:15,840 to 1:30,000.[2] The benefits from photo stratification can usually be shown in terms of increased operational efficiency, lower inventory costs, and reduced sampling errors. However, two factors continue to limit the use of aerial photographs in forest inventories: One of these factors is the cost of special-purpose aerial photography; the second is the fact that where aerial photographs exist, they usually are out of date before they are needed.

If we are to get the most out of remote sensing for forestry, it must be up to date. Changes in forest area and the condition of forest lands are occurring at an increasing rate, and in highly populated areas the rate of change is becoming alarming. If we use out-of-date photographs in our inventories, conflicts may arise between photo predictions and the ground truth. If these variations are too great there will be little gain, if any, from using the photographs.

What is the solution to this problem? One possible solution is to use small-scale or even microscale aerial photographs for the first-level stratification. Certainly with such a broad area coverage, the photography costs would be reduced, and then it might become attractive to refly photography more often. For example, consider the 1:20,000

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[1] Forest Survey is a branch in the Division of Forest Economics and Marketing Research, Forest Service, U. S. Department of Agriculture, Washington, D. C. The Forest Survey was authorized by the McSweeney-McNary Forest Research Act of May 22, 1928.

[2] Color negative films are now being used for resource photography on some of the National Forests in the West.

scale photographs supplied by the Department of Agriculture, Agricultural Stabilization and Conservation Service. One of these 9- x 9-inch photographs covers an effective area of approximately 5 square kilometers (2 square miles). If the scale could be reduced to 1:60,000 it would increase the effective coverage to approximately 45 square kilometers (18 square miles)--a 9 time increase. Going even further, a 9- x 9-inch photograph from high altitude, or from space, taken at a scale of 1:400,000 would increase our coverage to approximately 2,000 square kilometers (800 square miles)--a 400 time increase.

But what kind of information will this microscale imagery provide us with and with what accuracy? The research reported in this paper is intended to help answer these questions and is part of a much broader research program seeking solutions to forest inventory problems using remote sensing tools. The test site is located in the southern piedmont land resources subregion southwest of Atlanta, Georgia (Fig. 1).

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METHODS AND PROCEDURES

GROUND TRUTH

Ground truth for the Atlanta test site consists of a combination of several scales of aerial photography and ground observation points on fifteen 4-mile-square study areas. In March 1970, 1:32,000 Ektachrome Infrared Color Film (8443)[3,4] and 1:12,000 Ektachrome (MS) Color Film (2448), developed to a negative, were taken over each of the study areas. These photographs, plus 1:2,000 and 1:12,000 color taken in April 1969, were used to delineate thirteen land-use and forest classes. Next, over two hundred random points representing all forest and agricultural nonforest classes were selected for ground examination. Among these points were fifty 0.24-hectare (0.6-acre) forest plots taken to establish forest volume, forest type, and site classes. Another eighty forest points were established to record forest types, species composition,

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[3] Trade names and commercial enterprises or products are mentioned solely for necessary information. No endorsement by the U. S. Department of Agriculture is implied.

[4] This film will be referred to during the remainder of this report as IR color.

crown density, and stand-size classifications. Eighty nonforest agricultural points were located on the ground to record agricultural use at the time of each high-altitude overflight. The details of data collection were reported by Langley, et al. (1) and Aldrich, et al. (2). Final ground truth status maps were made by combining photo interpretation with observations made on the ground.

PHOTOGRAPHY

At the outset of this study our intentions were to obtain high-altitude photography for the test site at four seasons of the year. A NASA RB-57 flight was planned for early June to represent early summer phenological development when solar radiation was at its peak. Other flights were planned for late summer, fall, and winter to represent different periods of vegetation development. So far, we have been able to obtain photography for only the early summer, late summer, and winter seasons.

The interpretation test reported here uses 1:420,000 scale IR color photography taken with a Hasselblad 70 mm camera (40 mm FL). One major problem for interpreters was caused by differences in film quality and differences in atmospheric conditions at the time of photography. These problems caused considerable variation between film images between missions. For instance, the June (Mission 131) film emulsion had a weak cyan layer. This resulted in an overall hazy blue appearance and what appears to be a poor infrared response (Fig. 2). The September (Mission 141) film was quite good, and the infrared response was enhanced by the addition of a CC-30B color correction filter. This same enhancement filter was used with the March (Mission 158) film, but there was a much more apparent vignetting effect causing the centers of the pictures to be overexposed. This resulted in some problems in resolving low contrast details during interpretation.

INTERPRETATION

Three interpreters examined the 1:420,000 IR color photographs for all primary study areas covered by each mission. One of these interpreters was a student in biological science with no previous experience in photo interpretation. The other interpreters were experienced and had worked in both the ground and photo interpretation phases of the study for two years. This experience does not bias the study results because of the interpretation techniques that we used.

Each interpreter was given a period of indoctrination and training prior to beginning the test. Two study blocks (blocks 1 and 3) not used in the test were used for training purposes. The interpreters were allowed to examine all available photography including the 1:32,000 and

1:420,000 IR color and ground truth to make correlations for interpretation purposes.

Because the images on 1:420,000 scale imagery are much too small to interpret by normal methods, they were enlarged approximately 13 times using a projection-viewer designed for this purpose (Fig. 3). The device was constructed using a Bell and Howell 35 mm slide projector, an adjustable mirror, and a Polacoat Lenscreen viewing surface. Enlargements of from 8 to 22 magnifications and adjustments for tip and tilt are possible using the instrument as it is presently designed.

Each 70 mm transparency was mounted in a 3 1/4- x 4-inch lantern slide for insertion in the projector. The position of the slide could be adjusted to project the portion of the area to be interpreted.

Interpreters, working independently, outlined and classified the 13 land-use and forest types along each of 18 sample strips. Interpretation always began with the June 1970 (Mission 131) imagery and progressed to the September 1970 (Mission 141) and March 1971 (Mission 158) imagery in that order. The appropriate slide was inserted in the projector and enlarged so that strip beginning and end points, scaled from the ground truth strip maps, coincided with the end points on the projected images. Interpreters were allowed to use magnifying glasses and filters (Wratten 15 and 25) whenever desired to enhance separations between some classes. The land classes were carefully mapped for each strip on acetate overlay material.

ANALYSIS

Random points selected from the ground truth records were used to check the photo interpretation. The number of points in each land-use class is listed in Table I by season of photography.

Templates were made up for each strip to show the center of each land-use class selected to check photo interpretation. These templates were drawn to scale from the ground truth strip maps. Next, the templates were laid on top of the overlays made by each interpreter and the land-use or forest classification at each point noted and recorded.

Because of distortions inherent in small-scale photographic imagery, and because of limitations in projection systems, we made certain concessions to the interpreter. If the classification shown for the interpreter was on or within 1 millimeter of the correct ground classification (on the enlarged photo), the interpreter was considered correct.

Once all data had been recorded they were punched on IBM cards for computer analysis. Computer tabulations showing the frequency of interpretation by ground classifications were used to analyze the accuracy of interpretation and to point out sources of misclassification. Because the number of observations in some classes was too small for analysis, we have combined them with the land use most closely associated. Thus, class 5 was combined with class 6, class 8 with class 9, and class 13 with class 12.

An analysis of variance was made to determine whether there was a difference between interpreters and whether the season of photography had an effect on the accuracy of interpretation. To make this analysis errors in interpretation were weighted according to the seriousness of the error. For example, a forest point called nonforest would be weighted 2. A pasture point called idle land would be weighted 1. Points correctly classified would be weighted zero. The weighted totals were summarized for interpreters and for seasons of photography.

RESULTS

While considering the results shown below, the reader should keep in mind that the photo interpretation was done on 1:420,000 scale photography. At first glance the results look rather poor. However, a comparison between these results and the results of studies made in the past using conventional 1:20,000 scale photography shows some good correlations. This comparison is made in the CONCLUSION AND DISCUSSION section of this report.

LAND-USE CLASSIFICATION

Forest land was separated from nonforest land classes with better than 96 percent accuracy (Fig. 4). As might have been expected the agricultural uses resulted in the poorest land-use classification. Active agriculture (crops and plowed fields) was classified correctly most often on the June photography, but even then the interpreters were right on the average of only 51 percent of the time. On March photography the accuracy dropped to a low of 19 percent. Pasture land is interpreted correctly in 90 percent of all chances on March photography. On June and September photography the accuracy drops to 73 and 75 percent, respectively. Regardless of the season, idle and abandoned land is mapped correctly in approximately 30 percent of the cases. Orchards (pecan and peach) are correct in fewer than 8 percent of the total number of chances.

Urban land, including improved roads, highways, power lines, pipe lines, and land areas in and around communities and cities not qualifying as forest or agriculture, is classified correctly over 97 percent of the time on June photography. The accuracy in September was 94 percent. In March the accuracy fell to 87 percent because some improved roads and highways could not be seen against highly reflective backgrounds.

Water, including small farm ponds, can be detected 91 percent of the time in September (Fig. 4). Less accuracy occurs on June and March photography primarily because of poorer definition due to overexposure of center portions of the photographs.

There were very few forest points misclassified as nonforest (Fig. 5). The season of photography had little effect on the results, and there is little indication that the classification errors can be attributed to anything more than random interpreter error. By taking more care and by improving our training materials we could expect to reduce these errors to almost zero.

Nonforest points were occasionally called forest. This was a particularly serious problem in the idle, abandoned, and orchard land classes. Idle and abandoned land appears a dark gray tone and moderately rough in texture, very much like low-stocked upland hardwood. This similarity is caused by clumps of weeds, blackberries, and noncommercial tree species scattered around with accumulated dead plant debris. It is easy to overestimate the stocking of forest trees and misclassify the land as a result. Another problem is orchards. Pecan and peach orchards look very much like upland hardwoods or abandoned agriculture. For this reason, most orchards were called either forest or idle and abandoned land. Orchards are extremely limited in the test areas, and as a result we had only a small number of samples. It is possible that with more extensive areas in this class, we could have shown better results.

There were very few misclassification errors in the urban and water classes. The most frequent cause of errors in urban classification was small wooded areas (green belts) or garden crops within urban centers (towns). Another cause of misclassification was poor contrast between roads and surrounding agricultural land caused by overexposure, particularly on the March photography. Water was misclassified in almost every instance because of the poor contrast (turbid) water has with surrounding classes particularly in overexposed portions of the photographs.

FOREST CLASSIFICATION

The accuracy of forest classification varies considerably by type and by season of photography (Table II). Photo interpreters were relatively consistent with one possible exception. Interpreter A was inexperienced and apparently had insufficient training in relating the differences in infrared response on March photography to vegetation types. Despite this, we would have to say that photo interpretation on March photography resulted in the best forest type classification. Interpreters B and C were able to classify pine type correctly 81 percent of the time. However, these two interpreters could classify pine-hardwood type correctly only 33 percent of the time; this low level of accuracy is not unusual even on conventional 1:15,840 and 1:20,000 scale photography. Part of the difficulty is in defining the percentage of pine in the stand.[5] We have found that with the better resolution of 1:12,000 scale and larger scale color and infrared color photography this classification becomes easier and more accurate to identify.

The greatest advantage of high-altitude photography taken in March is the greater accuracy of hardwood type classifications. On the average 60 percent of the stands called bottomland hardwood and 66 percent of the stands called upland hardwoods were classified correctly (Fig. 6). In contrast to this, only 43 percent of the bottomland hardwood was correct on June photography, and only 8 percent was correct on the September photography. The accuracy of upland hardwood interpretation does not appear to vary significantly by the three seasons tested.

There were very few forest points misclassified as nonforest land (Fig. 7). Regardless of the season, no fewer than 96 percent of forest points were correctly classified as forest. Thus, errors in forest type classification were largely errors in judgment of stand stocking. For instance, on the average, interpreters classified 19 percent of the pine stands as upland hardwood on June photography. On September photography the error was 14 percent, and on March photography the error was 14 percent. These are relatively consistent errors and the most serious errors in forest misclassification. They may be reduced in the future by improving photo resolution and developing better keys and definitions of forest types.

The greatest errors in pine-hardwood type classifications were in calling pine-hardwood mixtures upland hardwood (Fig. 7). Sixty-two percent of the pine-hardwood stands were called upland hardwood on June photography, 53 percent on September photography, and 43 percent on March photography. It is apparent that as the percentage of pine is reduced in mixed stands, the greater is the chance for calling the stand hardwood. Also, when deciduous trees (hardwoods) are leafless, there is a

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[5] Pine-hardwood: 25-50 percent of the dominant stand is in pine; the remainder is composed of hardwood (deciduous) tree species.

greater chance of seeing pine in mixed stands and a greater chance of calling the stands correctly.

Bottomland hardwood type was often called upland hardwood type (Fig. 7). On the other hand, only occasionally (average of 11 percent) was an upland hardwood stand called bottomland hardwood. Misclassification of bottomland hardwood as upland hardwood was greatest in September and the least in March--77 percent as compared to only 24 percent. Therefore, when we want to distinguish between upland and bottomland types, winter photography is most useful.

The results of an analysis of variance show no significant difference between either interpreters or season of photography (Table III). However, season of the year came very close to being significant at the 95 percent level of significance. It was so close that by intuitive reasoning we feel that season did affect the results of this test. Whether or not this effect was due to differences in quality of photography or due to real differences between the land classes we cannot truly say. A summary of the weighted data in Table IV indicates that early summer had the highest scores (poorest interpretation) and winter the lowest scores (best interpretation) with the exception of the one inexperienced interpreter. His total score was higher and indicated that his training on winter photography had not been adequate.

CONCLUSION AND DISCUSSION

It is always difficult to evaluate the results of a study such as this without some basis for comparison. For instance, how well would interpreters do on conventional 1:20,000 scale panchromatic photographs?

A search of the literature shows only two studies that can be used for comparison. In the first (3), interpreters used basically the same set of criteria to classify land use in southwest Georgia on 1:20,000 panchromatic photographs. In this example 95.5 percent of all forest classifications were correct. This compares with the 96 percent or better accuracy shown in this report. The second study taken from the literature shows the expected accuracy for forest type classification on 1:20,000 scale photography (4). This test made by the TVA in 1952 showed that interpreters could classify three types (pine, mixed, and hardwood) correctly 74 percent of the time. When the forest types used in the present study are combined in a similar way, we can show that 71 percent of the type classifications were correct if made on March photography.

Although these comparisons can hardly be considered conclusive, they should lend some credence to these conclusions:

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1. Microscale IR color photography (1:420,000) can be interpreted within reasonable limits of error to estimate forest area.

2. Forest interpretation is best on winter photography with 97 percent or better accuracy. The greatest source of error is in calling abandoned agricultural land forest land, but this error is minimized on winter photography.

3. Broad forest types can be classified on microscale photography. For instance, pine type is correctly identified more than 80 percent of the time on winter photography and at least 70 percent of the time regardless of season. Pine-hardwood cannot be correctly identified better than 25 percent of the time (winter photography) and probably should not be attempted on microscale photography in the future. Bottomland hardwood is correctly classified 60 percent of the time on winter photography but cannot be separated from upland hardwoods at other seasons of the year. Upland hardwood is usually classified correctly 70 percent of the time regardless of season.

4. Active agricultural land is classified most accurately on early summer photography; in this test 51 percent of active cropland and plowed fields were correctly classified. The most frequent error was interpreting cropland as pasture. Fortunately, only a very small percantage of the cropland category was misclassified forest land, and on winter photography this error was at a minimum.

5. Only 6 percent of all nonforest observations (including urban and water) were misclassified as forest. Winter time was the best season for minimizing these errors.

During the coming year we will continue photo interpretation tests using high-altitude aerial photography. Multiseasonal color and IR color photography taken at a 1:120,000 scale will be interpreted and analyzed in a manner similar to that used in this report. We will also concentrate on developing a photo interpretation key for microscale photo interpretation of forest and nonforest classifications.

REFERENCES

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3. Aldrich, R. C. 1953. Accuracy of land-use classification and area estimates using aerial photographs. Jour. Forestry. 51(1):12-15.

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TABLE I. - NUMBER OF RANDOM CHECK POINTS IN EACH LAND-USE CLASS BY SEASON OF PHOTOGRAPHY

SEASON	LAND USE[1]													TOTAL
	1	2	3	4	5	6	7	8	9	10	11	12	13	
Early Summer (June)	69	37	40	54	5	23	30	10	35	4	22	13	1	343
Late Summer (Sept)	59	33	16	45	7	8	20	6	22	0	18	7	0	241
Winter (March)	60	28	36	47	15	23	28	9	29	3	21	11	1	311

[1] 1 - Pine
2 - Pine-hardwood
3 - Bottomland hardwood
4 - Upland hardwood
5 - Crop
6 - Plowed field
7 - Pasture
8 - Idle
9 - Abandoned
10 - Orchard
11 - Urban
12 - Turbid water
13 - Clear water

TABLE II. - ACCURACY OF FOREST TYPE CLASSIFICATION
BY PHOTO INTERPRETER AND BY SEASON

SEASON[1]	PHOTO INTERPRETER	FOREST TYPE[2, 3] 1 (P)	2 (PH)	3 (BH)	4 (UH)
		- - - - percent correct - - - -			
June	A	71	0	55	61
	B	70	11	25	72
	C	67	0	48	71
	Mean	69	4	43	68
September	A	79	12	6	74
	B	83	15	13	67
	C	81	33	6	71
	Mean	81	20	8	70
March	A	67	7	53	55
	B	80	28	64	79
	C	82	39	64	64
	Mean	76	25	60	66

[1] Seasons tested:

June - early summer
September - late summer
March - late winter

[2] Forest type:

Pine (P) - 1
Pine-hardwood (PH) - 2
Bottomland hardwood (BH) -
Upland hardwood (UH) - 4

[3] The number of observations by forest type is shown in Table 1.

TABLE III. - ANALYSIS OF VARIANCE FOR THREE INTERPRETERS AND THREE PHOTOGRAPHIC MISSIONS

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROBABILITY OF F[1]
Interpreters	323.5557	2	161.7778	2.2331	0.7768
Season	876.2217	2	438.1108	6.0475	0.9383
Error	289.7783	4	72.4446	----	----
Total	1489.5557	8	-----	----	----

[1] This value must be equal to or greater than 0.9500 to be significant at the 95 percent level of significance or equal to or greater than 0.9900 to be significant at the 99 percent level of significance.

TABLE IV. - TOTAL WEIGHTED INTERPRETATION SCORES FOR THREE INTERPRETERS BY SEASON OF PHOTOGRAPHY

SEASON OF PHOTOGRAPHY	WEIGHTED SCORES[1]		
	INTERPRETER 1	INTERPRETER 2	INTERPRETER 3
Early Summer (June)	122	122	118
Late Summer (September)	105	107	91
Winter (March)	116	90	90

[1] Lowest score is best interpretation

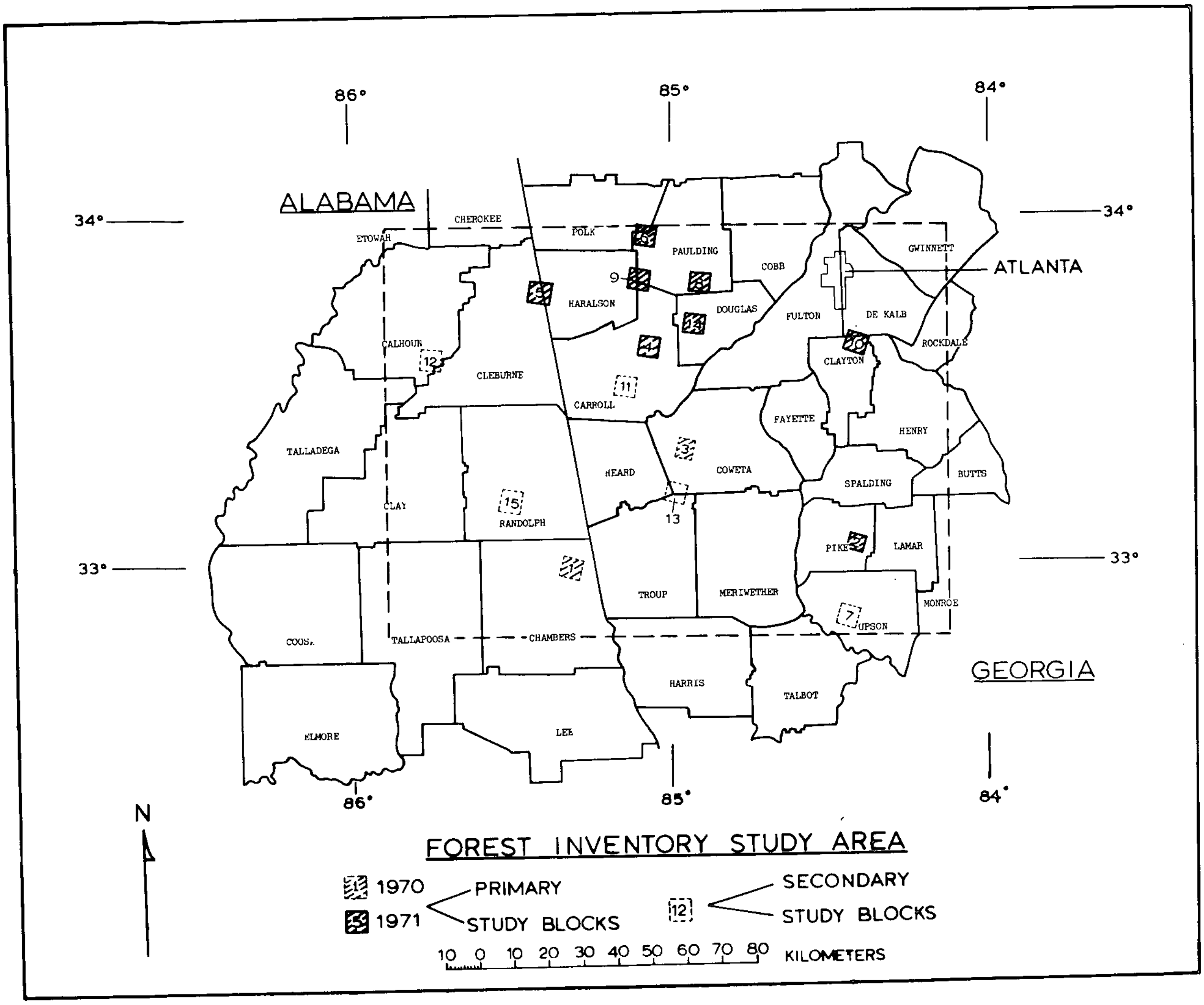

Figure 1.- The Atlanta test site includes all or portions of 27 counties in Alabama and Georgia. Eight intensive study areas used in this report are shown with heavy hatch marks and solid boundaries. Two additional intensive study areas (hatch marked) were dropped for insufficient high-altitude photographic coverage. The remaining study blocks (secondary) will be used to test interpretation models in another phase of the study.

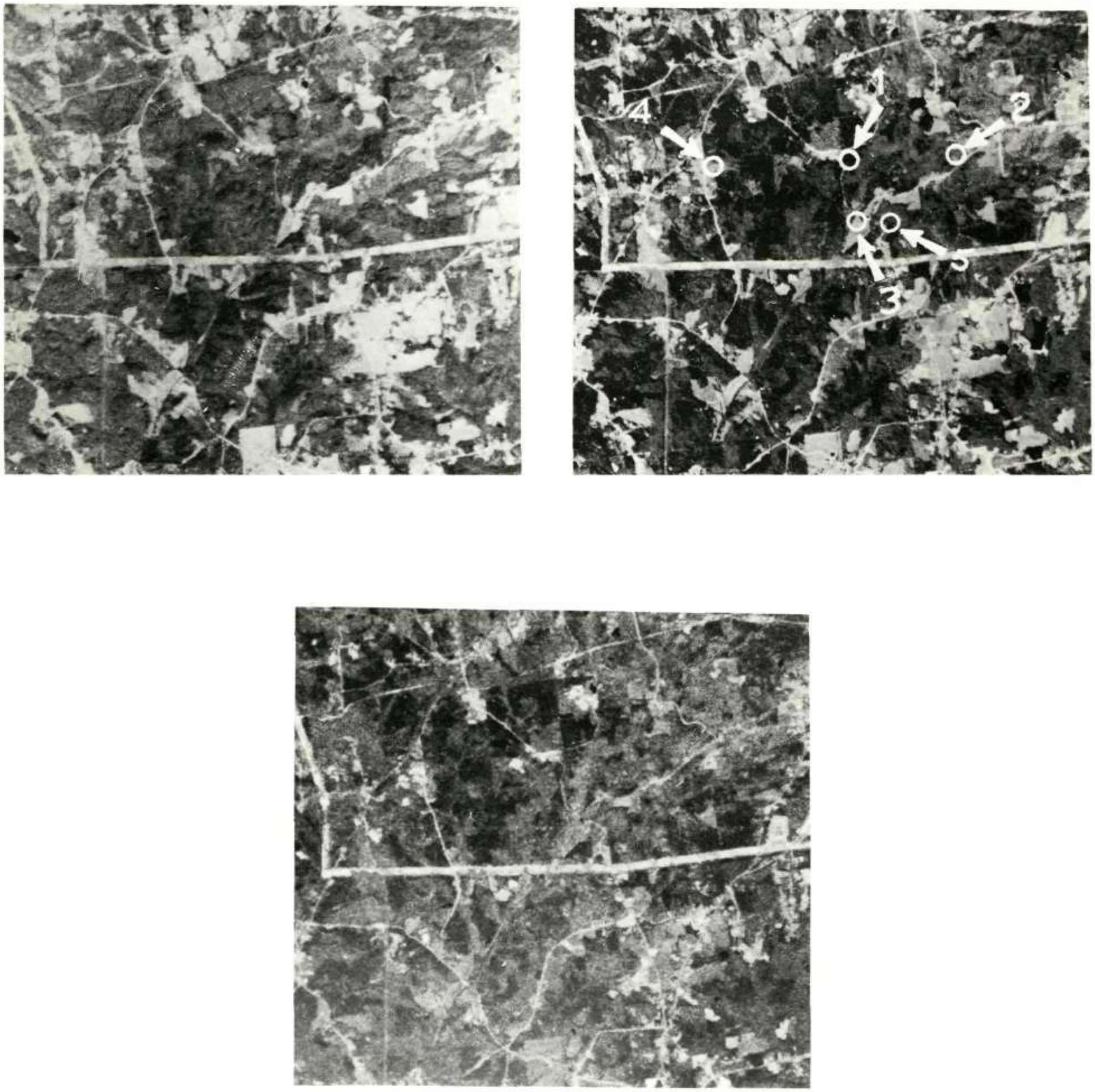

Figure 2.- These three 1:420,000 scale IR color photographs for study block 14 represent the quality of imagery used in this study: (A) June 8, 1970, (B) September 14, 1970, (C) March 5, 1971. Three forest and two nonforest classes are pointed out in (B): (1) pine, (2) upland hardwood, (3) pasture, (4) abandoned, and (5) bottomland hardwood.

Figure 3.- This projection-viewer was used to enlarge 1:420,000 scale photographs to coincide with 1:32,000 ground truth strip maps; (A) Bell and Howell 35 mm projector, (B) adjustable mirror, (C) adjustable viewing surface, (D) focusing adjustment, and (E) pulley for adjusting mirror distance for scaling purposes.

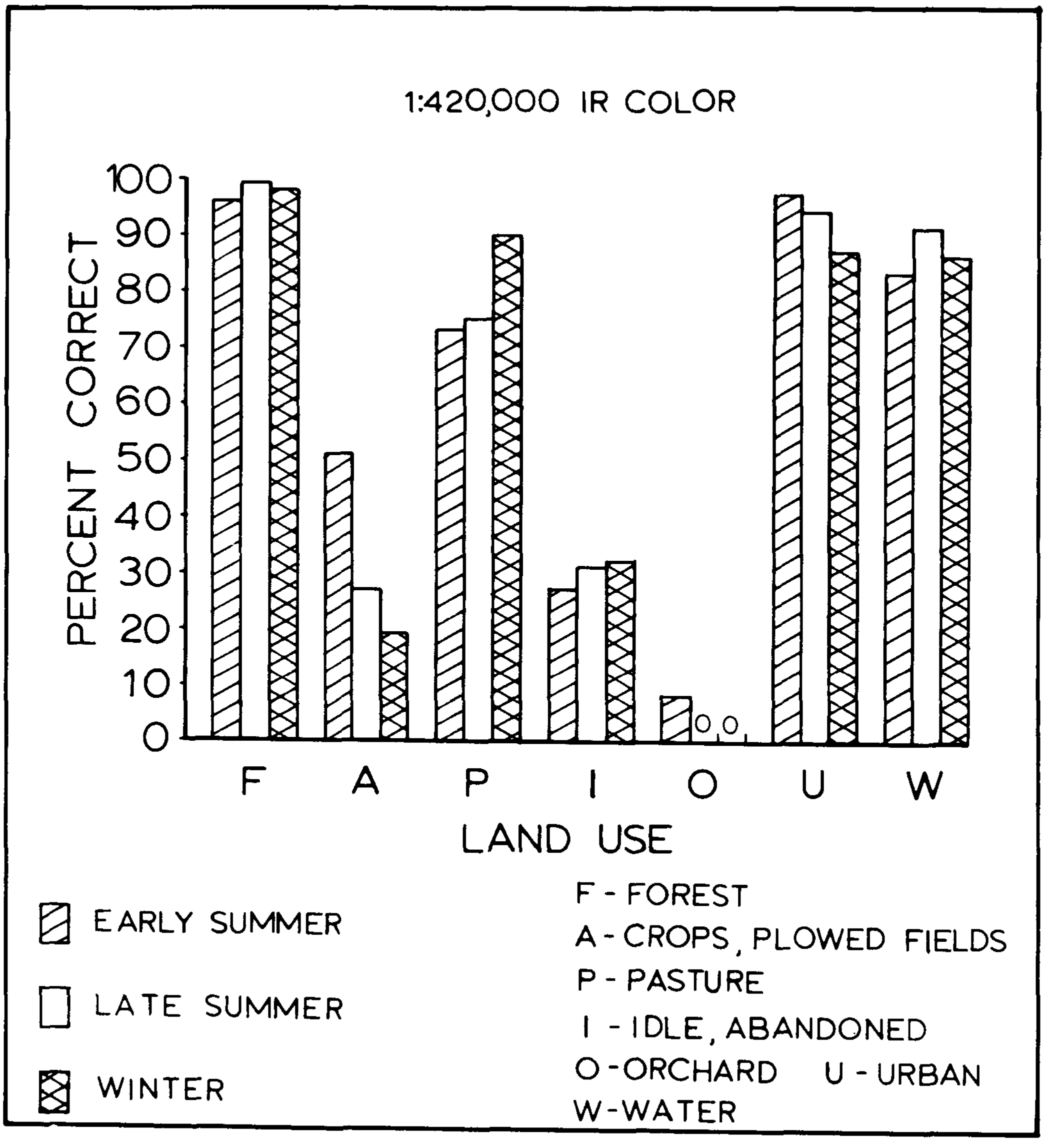

Figure 4.- The average accuracy is shown for three interpreters classifying land use on 1:420,000 IR color photographs taken during three seasons. Note that only in crops and plowed fields is there a significant difference that might be attributed to season. June, or early summer photography, appears to give the greatest accuracy.

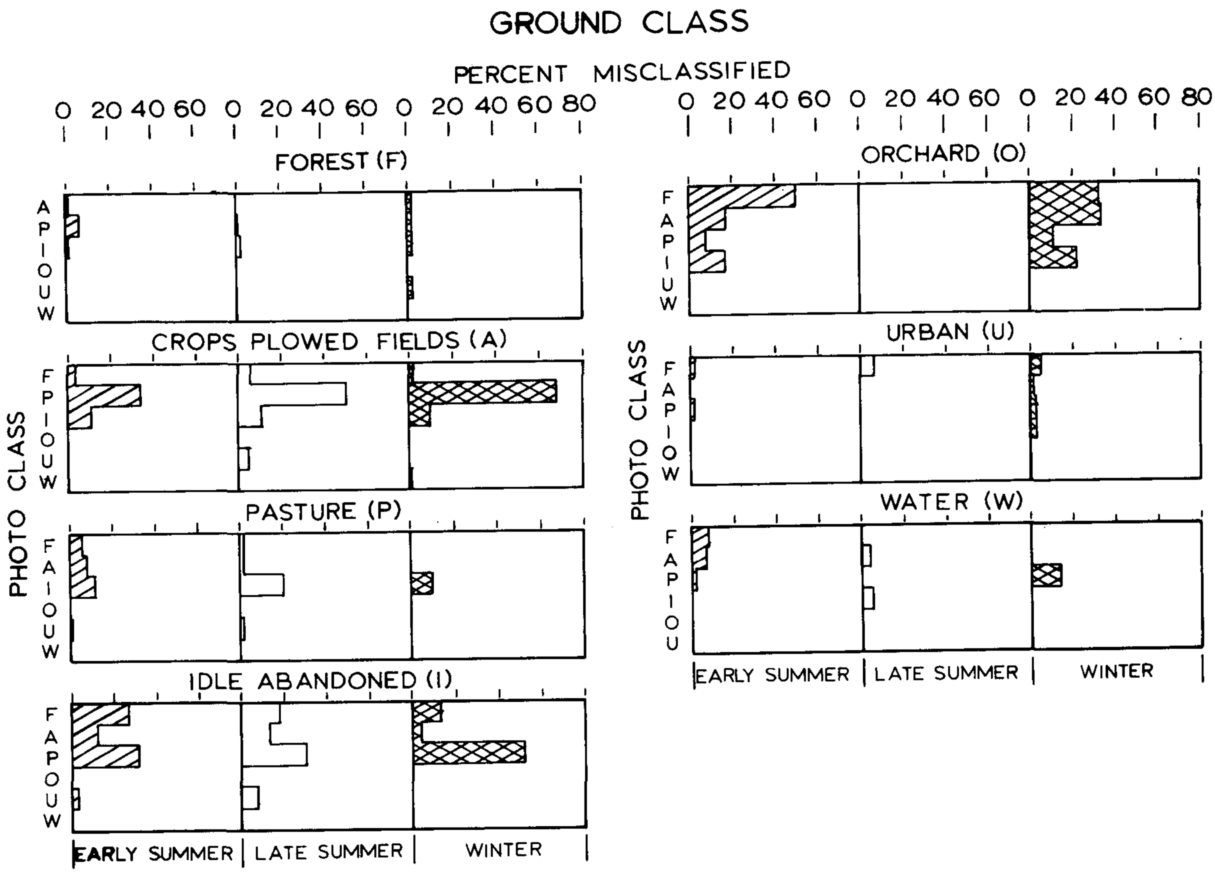

Figure 5.- This chart indicates the percentage (average of three interpreters) of all nonforest points that were misclassified by land use and season of photography. Note that active cropland and plowed fields and the idle and abandoned land are most often misclassified as pasture land.

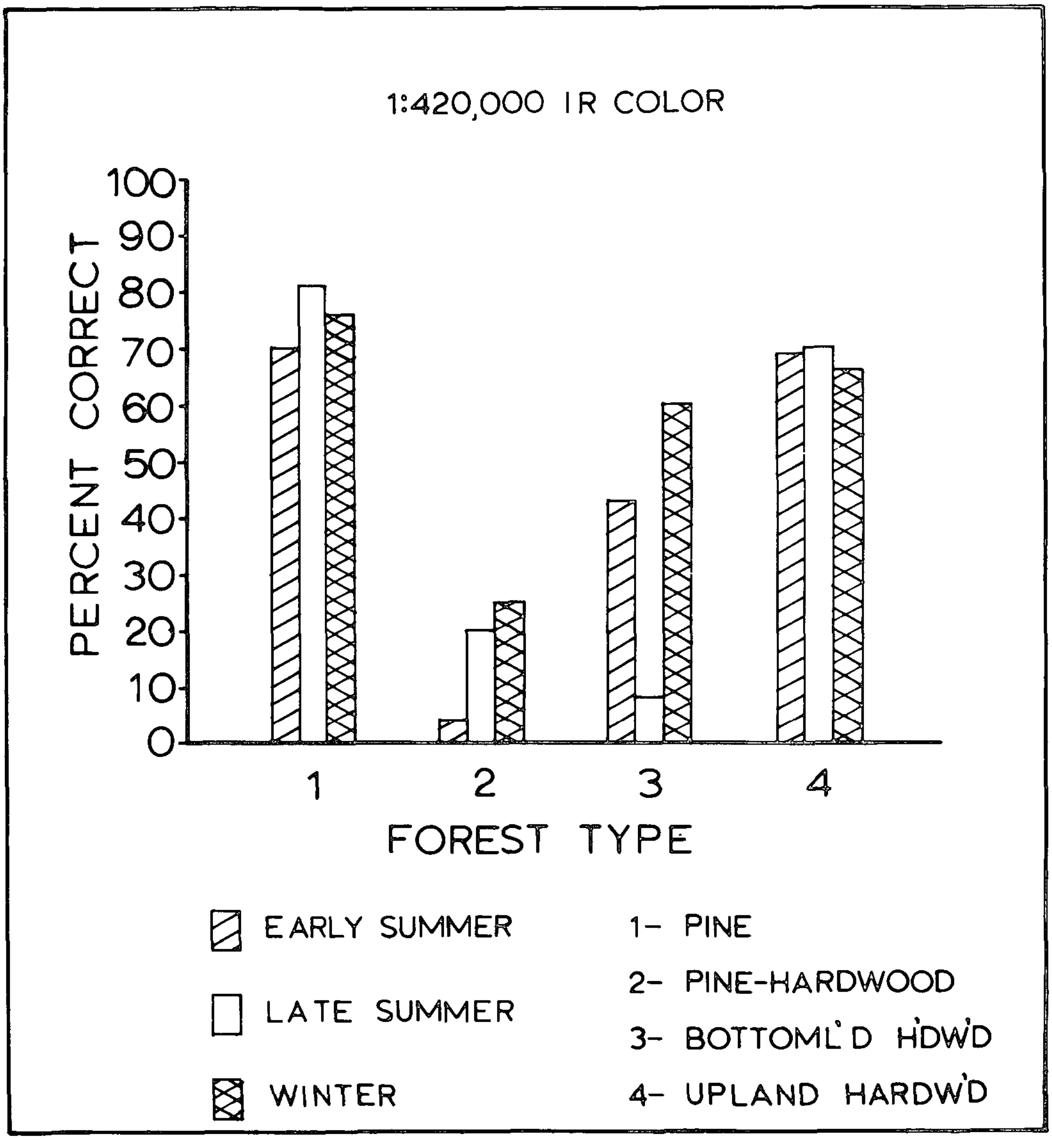

Figure 6.- This chart shows the average accuracy for three interpreters classifying forest types on 1:420,000 IR color photographs taken during three seasons. Note that forest types are generally most accurate on March photography.

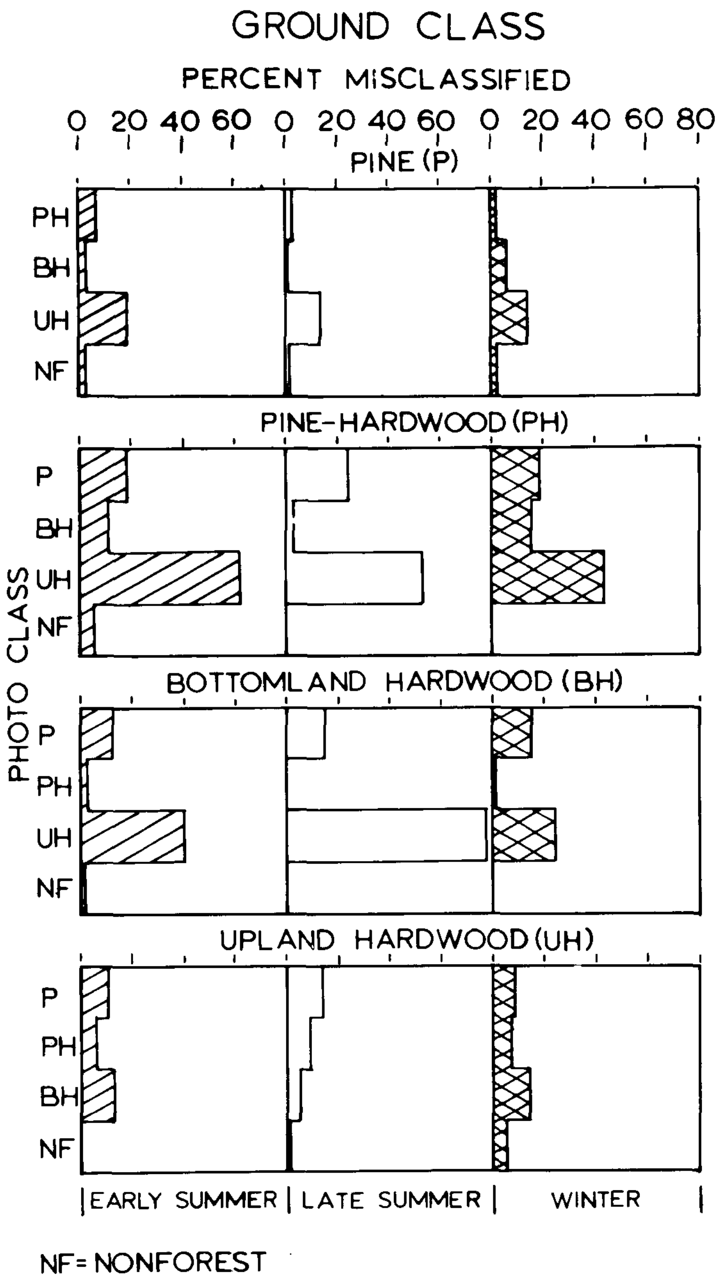

Figure 7.- The percentage (average for three interpreters) of all forest points that were misclassified by type and season of photography. Note that pine-hardwood and bottomland hardwood types are most frequently misclassified. In both cases they are usually called upland hardwood by interpreters.