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A PROCEDURE USED FOR A GROUND TRUTH STUDY OF A LAND USE MAP OF NORTH ALABAMA GENERATED FROM LANDSAT DATA

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28 FEB 1977

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • FEBRUARY 1977

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1. REPORT NO. NASA TN D-8420	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE A Procedure Used for a Ground Truth Study of a Land Use Map of North Alabama Generated from Landsat Data		5. REPORT DATE February 1977
		6. PERFORMING ORGANIZATION CODE M209
7. AUTHOR(S) Sanford W. Downs, Jr., G. C. Sharma*, and Colin Bagwell*		8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D.C. 20546		13. TYPE OF REPORT & PERIOD COVERED Technical Note
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared by Data Systems Laboratory, Science and Engineering
*Alabama A&M University

16. ABSTRACT

A land use map of a five county area in North Alabama was generated from Landsat data using a supervised classification algorithm. There was good overall agreement between the land use designated and known conditions, but there were also obvious discrepancies. In ground checking the map, two types of errors were encountered — shift and misclassification — and a method was developed to eliminate or greatly reduce the errors. Randomly selected study areas containing 2525 pixels were analyzed. Overall, 76.3 percent of the pixels were correctly classified. A contingency coefficient of correlation was calculated to be 0.7 which is significant at the α = 0.01 level. The study showed that land use maps generated by computers from Landsat data are useful for overall land use by regional agencies. However, care must be used when making detailed analysis of small areas.

The procedure used for conducting the ground truth study together with data from representative study areas is presented in this report.

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17. KEY WORDS	18. DISTRIBUTION STATEMENT STAR Category 43

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	62	$4.50

* For sale by the National Technical Information Service, Springfield, Virginia 22161

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Concluded)

A PROCEDURE USED FOR A GROUND TRUTH STUDY OF A LAND USE MAP OF NORTH ALABAMA GENERATED FROM LANDSAT DATA

INTRODUCTION

Data obtained from Landsat-1 were processed by a computer to produce a land-use map of a five country area in north Alabama for the Top of Alabama Region Council of Governments (TARCOG) which consists of DeKalb, Jackson, Limestone, Madison, and Marshall counties. The data from the November 4, 1972 overpass were recorded on computer-compatible magnetic tape and were automatically analyzed using a linear classification algorithm to produce a land use map of the area. This algorithm has been described by Bond and Atkinson [1]. The computer processing corrected the geometric distortions caused by relative motion between the satellite and the surface of the Earth, referenced the observations to geographic data — the Universal Transverse Mercator system (UTM), overlaid the UTM grid with 10 km cells, and overlaid the boundaries of the five counties comprising TARCOG, as well as classifying the land use patterns.

The land uses were assigned according to Level I of the proposed standard national land use classification system [2]. The nine land use classifications in Level I are (1) urban and built-up land, (2) agricultural land, (3) rangeland, (4) forest land, (5) water, (6) wetland, (7) barren land, (8) tundra, and (9) perennial snow or ice. The complete classification is given in Table 1. Field surveys determined that six of these land uses occur in the TARCOG area. These are urban, agriculture, forest, water, wetland, and barren. No tundra, perennial snow and ice, or rangeland was found in the area. There is one exception to this classification system; a seventh land use type was included in an attempt to substitute pasture for rangeland and detect it as a separate class rather than include it in agriculture even though cropland and pasture have the same classification in Level II of the proposed standard national land use classification system.

TABLE 1. LAND USE AND LAND COVER CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA

Level I	Level II
1 Urban or Built-up Land	11 Residential 12 Commercial and Services 13 Industrial 14 Transportation, Communications, and Utilities 15 Industrial and Commercial Complexes 16 Mixed Urban or Built-up Land 17 Other Urban or Built-up Land
2 Agricultural Land	21 Cropland and Pasture 22 Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas 23 Confined Feeding Operations 24 Other Agricultural Land
3 Rangeland	31 Herbaceous Rangeland 32 Shrub and Brush Rangeland 33 Mixed Rangeland
4 Forest Land	41 Deciduous Forest Land 42 Evergreen Forest Land 43 Mixed Forest Land
5 Water	51 Streams and Canals 52 Lakes 53 Reservoirs 54 Bays and Estuaries
6 Wetland	61 Forested Wetland 62 Nonforested Wetland
7 Barren Land	71 Dry Salt Flats 72 Beaches 73 Sandy Areas other than Beaches 74 Bare Exposed Rock 75 Strip Mines, Quarries, and Gravel Pits 76 Transitional Areas 77 Mixed Barren Land

TABLE 1. (Concluded)

Level I	Level II
8 Tundra	81 Shrub and Brush Tundra 82 Herbaceous Tundra 83 Bare Ground Tundra 84 Wet Tundra 85 Mixed Tundra
9 Perennial Snow or Ice	91 Perennial Snowfields 92 Glaciers

Note: From U.S. Geological Survey Professional Paper 964.

A set of 100 training pixels of each land use type was selected. These training sets were used to establish the spectral signature of each class which was then used by the computer to determine the land uses in the area and to generate a land use map.

The resulting land use map was produced in two forms: (1) as a computer printout and (2) as a color coded photomap. In the computer printout version, each land use was assigned a distinct symbol as shown in Table 2. Figure 1 presents a typical printout. The color-coded photomap was produced by recording the coded classification information on 70 mm film transparencies using a Optronics, Inc. P1500 Photowrite film recorder. These were combined using a color additive viewer and a positive transparency was produced. This color transparency was enlarged and printed at Johnson Space Center to obtain a 1:250 000 scale land use map of the area.

Overall land uses such as forest, large pastures, large fields, urban areas, and water were easily recognized. The map showed good overall agreement with the known land uses, but there were some discrepancies. For example, sometimes agriculture appeared in the middle of an area known to be entirely forest or an urban area would appear in the middle of a large field. This raised the questions of how frequently these discrepancies occurred and how accurately generated was the map.

TABLE 2. SYMBOLS USED TO PRINT A LAND USE MAP OF THE TARCOG AREA

Symbol	Land Use
	Urban (blank space)
*	Agriculture
I	Forest
H	Wetland
⊛	Pasture
⊗	Water
●	Barren

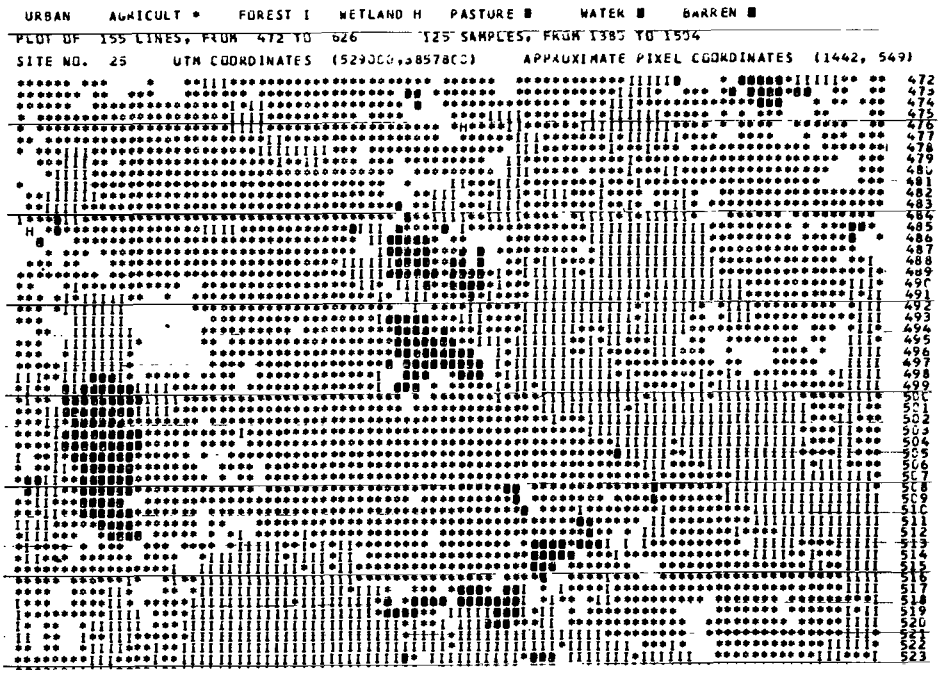


Figure 1. Typical computer printout of land use.

The purpose of this study was to formulate a method for checking the computer generated land use map with a minimum of field work, to determine the accuracy of the map, and to determine if this information can be used to improve the next generation of a land use map of the area. In this study, the computer printouts of Madison County were used to determine the land use rather than the photomap since the scale was much larger and more detailed information was presented.

METHODS AND PROCEDURES

The ground truth study was conducted on 101 randomly selected study areas located in Madison County. Each study area consisted of a 5 by 5 pixel matrix, with the center pixel located at the coordinates of the point. Thus, the 101 study area resulted in 2525 pixels to be analyzed for accuracy of the land use specified on the computer printouts. Using the method of Paludan [3], 10 km grid lines were located on the Alabama County General Highway map for Madison County. These grids were then subdivided into 1000 m UTM grids. Each vertical and horizontal grid line was assigned a number, and coordinates were selected by picking numbers from a table of random numbers. One hundred and one plots in Madison County were randomly determined by this method. The study areas were plotted on the county highway map to facilitate location in the field and also on U.S. Geographic Survey Topographic Maps, 7.5 min series.

The plot locations were also transferred from the 7.5 min topographic maps to Agricultural Stabilization and Conservation Service (ASCS) aerial photographs of the area utilizing landmarks on the topographic maps and photographs as reference marks. Computer printouts of each study area were obtained and the center pixel was located and marked together with the 5 by 5 pixel matrix. The computer printout and aerial photographs were compared using a Bausch and Lomb Zoom Transfer Scope. The use of this type instrument was necessary for accurate comparison because the scale of the photographs is 1:20 000, the vertical scale of the printout is 1:17 953, and the horizontal scale is 1:22 440.

The photograph and printout were visually fitted, using landmarks for reference, and the location of the center pixel was marked on the aerial photograph. This point was used as the center of the study area during the field work. The detailed procedures for the plotting and fitting are given in Appendix A.

The transformation matrix required to geometrically correct the Landsat data to UTM coordinates was obtained by least squares fit using Landsat and UTM coordinates as input. An error of a few pixels is inherent in this transformation.

The shift was determined and recorded for each of the plots by the method in Appendix A. Rather than measuring bearing and distance, the shift was recorded in the number of pixel widths north or south and the number of pixel widths east or west. The scaling of this transformation was such that in the geometrically corrected map, the distance between pixel centers was 57 m in the cardinal directions.

Each of the 101 study areas was visited and the center, as designated on the computer printout, was established. The location and land use of each pixel was determined and recorded. Additional ground truth information was aspect, slope, soil texture, crop and forest type. The detailed field procedures and ground truth field sheets are presented in Appendix A.

RESULTS AND DISCUSSION

A total of 2525 pixels were visited in the field, classified, and compared with the computer designations. Two types of errors were found when the study areas were visited: "shift" and "misclassification." By use of the method previously described, the error caused by shift was usually eliminated.

Most of the pixels were shifted between 2 and 3 pixel widths south and 1 and 2 widths west. Only 6 of the 2525 were shifted 5 or more widths south and only 2 were shifted 4 or more to the west. Thirteen pixels in the northeastern corner of the county were shifted between 2 and 4 widths to the east and 2 in the north central area were shifted 1 and 3 pixel widths east. A northerly shift was not found anywhere in the county. The average shift was found to be approximately 2.5 pixel widths south and 0.8 pixel widths west.

The second type of errors were misclassification errors where an area was classified as one type of land use when it was actually another land use. Of the 2525 pixels in the study, the computed designated 307 pixels as urban, 1013 as agriculture, 975 as forest, 19 as wetland, 189 as pasture, 20 as water, and 2 as barren; of these, 1702 pixels, or 67.4 percent, were correctly identified while 823 pixels, or 32.6 percent, were incorrect.

The largest number of misidentifications was agriculture classified as pasture or pasture classified as agriculture. It was evident that the procedure was not adequate for consistently distinguishing between agriculture and pasture. From the results of the study, it was evident that the land use classification attempted in this computer generated map should have only gone to Level I and that there should have been no attempt to separate pasture and agriculture.

A total of 225 pixels were designated either as pasture or agriculture when they were actually the other classification. Since agriculture and pasture are the same in Level I classification, these two groups of pixels can be pooled. When this was done, 1927 pixels, or 76.3 percent, were correctly identified and 598 pixels, or 23.7 percent, were incorrectly identified.

One possible source of apparent misclassification could be the time lapse between the time the Landsat data were obtained (November 4, 1972) and the time of the ground checkout (Summer 1975). However, precautions were used to try to eliminate this type of error. The aerial photographs that were used for ground truth were obtained in 1970 and the present land use in each study area was compared with the photographs. When the present land use differed from that in the photograph, landowners were consulted to determine when the change occurred. Therefore, the time lapse is not a major source of error.

Another form of apparent misclassification occurs because the sensors on the satellite actually detect land cover, and the desired end product is a land use map. An example of this type classification would be that a wooded subdivision would probably be classified as forest when the actual land use is urban. This fact was considered when the ground truth data were being obtained, and careful judgment was used to minimize errors of this type.

Table 3 presents an analysis of the data from the study. All pixels designated by the computer as one land use are in one "class" and are in one compartment of Table 3. Within each class the pixels are divided into "groups" according to the land use as determined during the ground truth check. Therefore, each class is divided up into seven groups, one of which is correct (i.e., designated agriculture and actually agriculture) and the other six incorrect.

TABLE 3. ANALYSIS OF COMPUTER DESIGNATED LAND USE CLASSES AND ACTUAL LAND USE CLASSES AS DETERMINED BY GROUND TRUTH VISITS OF 2525 PIXELS IN MADISON COUNTY, ALABAMA

Pixels Designated as Urban Class								
				Percent of Incorrect[d]				
		Percent of		With */⊛ and ⊛/*[e]		Without */⊛ and ⊛/*[f]		
Actual[a]	Number	Class[b]	Total[c]	In Class	In Total	In Class	In Total
U	85	27.7	3.36	-	-	-	-
*	96	31.3	3.80	43.2	11.6	43.2	16.1
I	23	7.5	0.91	10.4	2.8	10.4	3.8
H	0	0	0	0	0	0	0
⊛	97	31.6	3.84	43.7	11.8	43.7	16.2
⊗	6	1.9	0.23	2.7	0.7	2.7	1.0
●	0	0	0	0	0	0	0
Class Total	307	100.0	12.14	100.0	26.9	100.0	37.1
Pixels Designated as Agriculture Class							
U	33	3.3	1.30	9.9	4.0	22.9	5.5
*	680	67.1	26.93	-	-	-	-
I	104	10.2	4.11	31.2	12.6	72.2	17.4
H	4	0.4	0.15	1.2	0.5	2.8	0.7
⊛	189	18.7	7.48	56.8	23.0	-	-
⊗	3	0.3	0.11	0.9	0.4	2.1	0.5
●	0	0	0	0	0	0	0
Class Total	1013	100.0	40.08	100.0	40.5	100.0	24.1

TABLE 3. (Continued)

Pixels Designated as Forest Class							
		Percent of		Percent of Incorrect[d]			
				With */⊛ and ⊛/*[e]		Without */⊛ and ⊛/*[f]	
Actual[a]	Number	Class[b]	Total[c]	In Class	In Total	In Class	In Total
U	4	0.4	0.15	2.0	0.5	2.0	0.7
*	109	11.2	4.31	53.8	13.2	53.8	18.2
I	772	79.2	30.57	-	-	-	-
H	4	0.4	0.15	2.0	0.5	2.0	0.7
⊛	85	8.7	3.36	41.7	10.3	41.7	14.1
⊗	1	0.1	0.03	0.5	0.1	0.5	0.2
●	0	0	0	0	0	0	0
Class Total	975	100.0	38.37	100.0	24.6	100.0	33.9
Pixels Designated as Wetland Class							
U	1	5.3	0.03	6.7	0.1	6.7	0.2
*	0	0	0	0	0	0	0
I	3	15.8	0.11	20.0	0.4	20.0	0.5
H	4	21.0	0.15	-	-	-	-
⊛	0	0	0	0	0	0	0
⊗	11	57.9	0.43	73.3	1.3	73.3	1.8
●	0	0	0	0	0	0	0
Class Total	19	100.0	0.72	100.0	1.8	100.0	2.5

TABLE 3. (Continued)

Pixels Designated as Pasture Class								
				Percent of Incorrect[d]				
		Percent of		With */⊛ and ⊛/*[e]		Without */⊛ and ⊛/*[f]		
Actual[a]	Number	Class[b]	Total[c]	In Class	In Total	In Class	In Total	
U	2	1.2	0.07	4.7	0.2	28.6	0.3	
*	36	19.0	1.42	83.7	4.4	-	-	
I	4	2.1	0.15	9.3	0.5	57.1	0.7	
H	0	0	0	0	0	0	0	
⊛	146	77.2	5.78	-	-	-	-	
⊗	1	1.5	0.03	2.3	0.1	14.3	0.2	
●	0	0	0	0	0	0	0	
Class Total	189	100.0	7.45	100.0	5.2	100.0	1.2	
Pixels Designated as Water Class								
U	0	0	0	0	0	0	0	
*	3	15.0	0.11	60.0	0.4	60.0	0.5	
I	0	0	0	0	0	0	0	
H	0	0	0	0	0	0	0	
⊛	2	10.0	0.07	40.0	0.2	40.0	0.3	
⊗	15	75.0	0.59	-	-	-	-	
●	0	0	0	0	0	0	0	
Class Total	20	100.0	0.77	100.0	0.6	100.0	0.8	

TABLE 3. (Concluded)

Pixels Designated as Barren Class							
				Percent of Incorrect[d]			
		Percent of		With */⊛ and ⊛/ *[e]		Without */⊛ and ⊛/ *[f]	
Actual[a]	Number	Class[b]	Total[c]	In Class	In Total	In Class	In Total
U	1	50.0	0.03	50.0	0.1	50.0	0.2
*	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0
⊛	1	50.0	0.03	50.0	0.1	50.0	0.2
⊗	0	0	0	0	0	0	0
●	0	0	0	-	-	-	-
Class Total	2	100.0	0.06	100.0	0.2	100.0	0.4
Grand Total	2525	100		100		100	

a. As determined by on site inspection.
b. Percent of pixels found in each land use as determined by on site inspection.
c. Percent of all 2525 pixels which each group represents.
d. Percent of all incorrect pixels which each group represents.
e. Percent of misclassified pixels when the agriculture and pasture classes are considered separately.
f. Percent of misclassified pixels when the agriculture and pasture classes are pooled.

In this report, forest/agriculture is the notation used to indicate the group which was designated by the computer as forest but was actually determined to be agriculture during the field check. The number of pixels and their percentages in each group is shown in the second and third columns of Table 3.

Column four represents the percentage of the total. For example, the forest/forest group represents 79.2 percent of the forest class and 20.57 percent of all 2525 pixels. The next four columns, five through eight, are percentages of the incorrectly designated pixels. Column five shows the percentage which each group represents in its own class. Column six shows the percentage of all 823 pixels represented in each group.

A total of 225 pixels were designated as agriculture/pasture or pasture/agriculture which was originally considered a misclassification. By combining these two groups the number of incorrect pixels will be reduced, changing most of the figures in the "percent of incorrect" columns. These percentages were recomputed in columns seven and eight of Table 3. The "in class" percentages remained the same in all except the agriculture and pasture class, and all the "in total" percentages changed.

The computer designated 307 pixels as urban while only 85, or 27.7 percent, of these were correct. Urban/pasture and urban/agriculture contained 97 (31.6 percent) and 96 (31.3 percent) of the class while urban/forest contained 23 (7.5 percent) pixels. Urban areas contain trees, grass, bare land, roof tops, paved streets and gravel surfaces, all of which occur in other land use; thus, urban signatures may be similar to the signatures of other uses. Therefore, minor shift of signature from agriculture may cause the computer to classify land use urban where there are no houses present. This evidently happened all over the county where many open fields and several timber stands were classified as urban.

A total of 1013 pixels were designated as agriculture (40.0 percent of the total). Six hundred and eighty (67.1 percent of the 1013) were classified correctly. Agriculture/pasture contained 189 (18.7 percent) of the class. This misdesignation is easily justified because the two uses are so similar and pasture land often has a great deal of bare mineral soil and dead plant material showing. The agriculture/forest group contained 104 (10.2 percent) of the class. Study area 97 is an example of this designation. It became evident during the field examination that rock outcrops were more numerous in the northeast corner of the study area. Since many of the trees had shed their leaves, the rocks were visible to the satellite. The signature of the rocks, added to that of the plant material, may have caused the forest to be classified as agriculture or pasture.

The forest class was designated correctly more often than any other class. Of the 975 pixels designated as forest, 772 (79.2 percent) were correct. Forest/agriculture and forest/pasture accounted for 11.2 percent (109) and 8.7 percent (85) of the class, respectively. This misclassification is more difficult to explain without a detailed examination of the wavelengths reflected from both on a pixel by pixel basis. This error is probably caused by the presence of some plant community such as weeds or bushes which has a signature similar to forest. The use of additional training sets could probably improve the accuracy in this area.

Only 21 percent (4 of 19) of the pixels classified as wetland were determined to be correct during the field examination. Most (57.9 percent) of the pixels in this class were actually small rivers and streams. Wetland/forest accounted for 15.8 percent (3 of 19) of the wetland class. In the study areas, this occurred at the border between forest and water. It appears that both land uses were included in the pixel producing a conglomerate spectral signature which resembled wetland.

The pasture class contained 189 pixels. The level of success (77.2 percent) was better than all except the forest class. The pasture/agriculture group accounted for 19 percent of all misclassification in this class.

In the water class, 75 percent (15 of 20) of the pixels were designated correctly. Water/agriculture and water/pasture accounted for all mistakes in this class with 15 percent and 10 percent, respectively. These almost always occurred at the edge of a body of water; only one occurred in the middle of cropland.

The training pixels for barren were chosen in some rock quarries throughout the county. The quarries visited were always classified correctly, but no study areas fell in them. Only two barren pixels occurred in the study and both fell at the end of the Huntsville Jetport runway. One was on the pavement of the runway and the other in the grassy, pasture-like area just off the pavement.

There are 25 incorrect groups containing 823 misclassifications. Seven groups contain 86.9 percent of the incorrectly classified pixels. The largest group was agriculture/pasture containing 189 pixels (23 percent) of all misclassifications. The pasture/agriculture group contained only 36 pixels (4.4 percent) of the total incorrect pixels. These two groups, being so similar in use and contributing so much of the error, should logically be pooled and considered as the same land use.

The forest/agriculture and agriculture/forest accounted for 13.2 percent and 12.6 percent of the 823 misdesignations. This amount of cross-over in both groups is difficult to explain without analysis of the signatures themselves. It is interesting to note that grown-up fence rows often show up as a line of forest pixels in the middle of the field. An example of this situation can be found approximately 1/4 mile south of Study Area 4 (Appendix B). The forest signature is evidently very strong and overrides other nearby signatures, or the range covered by the forest signature is so broad that even very minor signature modification will throw the pixel into the forest class. The converse of this, however, is not true. An opening in the woods (i.e., a woods road) will very seldom be classified as anything except forest. Four-lane roads will most often be classified as agriculture or urban. These roads usually have wide shoulders covered with grass and a median of grass which causes the road a signature similar to agriculture.

The urban/pasture and urban/agriculture groups contained 11.8 percent and 11.6 percent, respectively, of the incorrect pixels. Often, this condition existed in large blocks in the middle of fields containing no sign of urban activities. In addition, groups of barns or houses on farm land were classified as urban. According to a strict use of the land use classification system, farm buildings should fall in the agricultural class. During the study, however, it was felt that the computer would be unable to differentiate between a subdivision and cluster of buildings on a farm. Therefore, any cluster of buildings was called urban during the field check.

As previously discussed, the agriculture/pasture and pasture/agriculture groups were combined and this effectively eliminated them as misclassifications. There were 823 misclassifications originally of which 225 were either agriculture/pasture or pasture/agriculture, leaving 598 net misclassifications. When the number of misclassified pixels is changed, all the percentages will need to be recomputed (as was done in the last two columns). The remaining incorrect groups maintain the same order of relative importance with forest/agriculture moving from 13.2 percent of the 823 pixels to 18.2 percent of the 598 incorrectly designated pixels. The other groups, as discussed above, also represent larger percentages of the total.

STATISTICAL ANALYSIS

The data obtained from 2525 pixels are summarized in Table 4. Overall 76.3 percent were correctly classified. Using these data, a contingency coefficient of correlation was calculated to be 0.7. This is significant at the α = 0.01 level (i.e., there is a highly significant correlation between the actual and designated).

The data were statistically analyzed using two different view points:

1. Type I — Knowing what a pixel actually is, what is the probability that it is correctly classified? A second part of this analysis is, if a pixel is misclassified, what is it most likely to be designated?

2. Type II — If a pixel is designated as a certain land use, what is the probability that it was correctly designated?

Analysis of Type I was used to compute the probability of correct classification of each land use category and its associated 95 percent confidence interval. These are presented in Table 5. The wide confidence interval associated with the wetland and water land use categories are due to the small sample size.

In the second part of the Type I analysis, the probability of improper classification is calculated (i.e., if a pixel is misclassified, what is it most likely to be designated?). These probabilities are presented in Table 6.

The Type II analysis is based on Bayes' Theorem and is referred to as Bayesian Analysis [4]. In this analysis, if a pixel has been designated as a certain land use, what is the probability that it is actually the land use designated? Suppose, for example, that a certain pixel has been designated as urban by the computer. It may be urban but there is a 0.133 probability that it is

TABLE 4. DISTRIBUTION OF COMPUTER DESIGNATED LAND USE CLASSES AND ACTUAL LAND USE CLASSES AS DETERMINED BY GROUND TRUTH VISITS TO 2525 PIXELS

Computer Designated Land Use	Actual Land Use						Total
	Urban	Pasture Agriculture	Forest	Wetland	Water	Barren	
Urban[a]	85	193	23	0	6	0	307
Pasture/ Agriculture	35	1051	108	4	4	0	1202
Forest	4	194	772	4	1	0	975
Wetland	1	0	3	4	11	0	19
Water	0	5	0	0	15	0	20
Barren	1	1	0	0	0	0	2
Total	126	1444	906	12	37	0	2525

a. Read across the row to determine the distribution of pixels correctly and incorrectly classified in various categories. For example, in the forest designated category, 4 were misclassified as urban, 194 were misclassified as pasture and agriculture, 772 were correctly classified as forest, etc.

TABLE 5. PROBABILITY OF CORRECT CLASSIFICATION AND CONFIDENCE LEVEL

Land Use	Probability of Correct Classification	Confidence Interval
Urban	0.675	0.593 to 0.757
Agriculture/Pasture	0.728	0.707 to 0.749
Forest	0.852	0.831 to 0.873
Wetland	0.333	0.067 to 0.599
Water	0.405	0.246 to 0.564
Barren	*	*

*insufficient data

TABLE 6. PROBABILITY OF IMPROPER CLASSIFICATION

Actual Land Use	Probability of Designation					
	Urban	Agriculture/ Pasture	Forest	Wetland	Water	Barren
Urban	-	0.854	0.098	0.024	0.000	0.024
Agriculture/ Pasture	0.491	-	0.494	0.000	0.013	0.002
Forest	0.172	0.806	-	0.022	0.000	0.000
Wetland	0.000	0.500	0.500	-	0.000	0.000
Water	0.273	0.182	0.045	0.500	-	0.000
Barren	*	*	*	*	*	*

*insufficient data

actually agriculture/pasture, a 0.025 probability that it is actually forest, and a 0.162 probability that it is actually water. Bayesian probability of the pixel actually being the land use designated can be calculated by dividing the probability of correct classification by the sum of the probabilities of the ways that the designated land use classification could be obtained. The Bayesian probability of correct classification in each land use category is 0.678 for urban, 0.465 for agriculture/pasture, 0.618 for forest, and 0.993 for water. There were insufficient data to calculate the probabilities for the barren class. The Bayesian probability of water being correctly classified was high even though the a priori probability was only 0.405. This probability is very high because of the low probability of other classifications being improperly designated as water. Only agriculture/pasture were erroneously classified as water and then only with a probability of 0.013.

CONCLUSIONS

This study showed that land use generated by computers using a linear classification algorithm from Landsat data is useful for overall land use by regional agencies. Care should be taken in using such computer generated maps for land use interpretation of smaller areas.

During this study, a procedure was developed and utilized for checking this and similar computer generated land use maps or computer training sets with a minimum of field work. The detailed procedures for conducting such studies are outlined in the report.

It was concluded that the pasture and agriculture classes should be combined into a single class; with agriculture and pasture categories combined into a single class, an overall accuracy of 76.3 percent was observed when compared with the ground truth information. The probability of proper classification using this procedure was also computed: it was 0.675 for urban, 0.728 for agriculture and pasture, 0.852 for forest, 0.333 for wetland, and 0.405 for water. Insufficient data were available for barren land class to assign any probability values for proper classification.

The main problems evident in ground checking the computer generated map utilizing the linear classification algorithm were pixel location and misclassification of a given pixel. The location or shift problem is not critical as long as the user realizes its existence and does not have to rely on precise location for acceptable results. The problem of misclassification is more serious. The problem of misclassification could be a land cover versus land use discrepancy or a mixing of classes in the pixels that form the boundary. These problems should be considered during the computer training process and during the interpretation of land use maps.

The problem of misclassification also causes difficulty in fitting the computer generated land use map and aerial photograph.

APPENDIX A

GROUND TRUTH STUDY FOR COMPUTER GENERATED LAND USE MAPS FROM LANDSAT DATA PROCEDURE

A. LOCATION OF STUDY AREA

1. Determine the number of study areas needed.

2. Locate study areas at the intersections of the 1000 m Universal Transverse Mercator (UTM) grid using a random number table. The UTM grid is shown on most U.S. Geological Survey (USGS) topographic maps with blue tick marks along the edges. Using the 1000 m grid will simplify locating the plots on the topographic maps.

3. Locate the UTM grid on a county highway map (2 in. = 1 mile is a convenient scale). Using the method discribed in Reference 3.

B. COMPUTER PRINTOUT AND STUDY AREA LOCATION

1. Show the following: at the head of page (a) plot no., (b) UTM coordinates of sample pixel, (c) pixel location or address in computer (generally stated by numbers on the X and Y axis), (d) date the Landsat data were taken, (e) the Y coordinate along the right border, and (f) key of land use symbols (Table 2).

2. The sample pixel should be located at the center of the page.

3. If possible, get printout produced with undistorted scale.

4. The type map around each sample pixel should be confined to an 8.5 by 11 in. space.

5. Plot the sample location on the USGS 1:24 000 topographic quadrangles maps, 7.5 min series.

6. From the topographic maps, transfer the plots to ASCS, 1:20 000 aerial photographs using nearby landmarks as references.

7. Mark the locations with a red, water soluble pencil for visibility and ease of corrections.

8. Locate the indicated sample pixel on the printout and draw a red circle around it.

9. Draw the boundaries of the 25 pixel study area (i.e., 5 pixels on a side with the sample pixel at the center).

10. If desired, cut the printout apart into 8.5 by 11 in. sheets which can be conveniently carried in the field with the ground truth field sheet.

C. LAB PROCEDURE — COMPARISON OF PRINTOUT WITH AERIAL PHOTOGRAPHS

1. Use Bausch and Lomb Zoom Transfer Scope to compare computer printout and aerial photograph.

Scales ASCS photos	1:20 000
Printout	
NS	1:17 953
EW	1:22 440

The scale distortion on the printout is due to the fact that the typing characters are taller than wide. The ratio of width to height is 8/10.

2. The photo is placed on the Zoom Transfer Scope easel and the printout is placed on the table (reference Zoom Transfer Scope instructions).

3. Setting the stretch adjustment on the Zoom Transfer Scope.

a. Since the printout has different scales in the N-S and E-W directions (as previously mentioned), the printout will have to be stretched E-W or compressed N-S or the photo will have to be compressed E-W or stretched N-S. Since the Zoom Transfer Scope has only a stretch capability on the image from the easel, stretch the photo image N-S.

b. Draw a square inch on a piece of paper and place it on the table under the Zoom Transfer Scope. Draw a rectangle with sides of 0.8 in. and 1 in. on another paper and place it on the easel. The rectangle is oriented with the long sides horizontal. Adjust the stretch and zoom mechanisms until the rectangle appears to be exactly square and the same size as the square which is on the table. The easel can be moved to adjust the apparent size of the rectangle. At this point the zoom adjustment should be on "1".

4. The photo is fastened to the easel and the printout is placed on the table. Center the images of the study area.

5. Scale Adjustment:

a. The printout scale is fixed except for changing the map lens; the photo scale can be changed using the zoom adjustment.

b. Set the zoom knob to adjust photo scale to match the E-W printout scale.

6. Visually fit the photo to the printout using prominent features such as woodlands, fields, and large bodies of water. Due to minor variations in the photo scale (due to variations of flying height of the airplane) minor adjustments may be needed in the zoom setting.

7. On the printout, mark the designated study area center as located on the aerial photo. The shift can be counted using this mark.

8. On the photo, mark the location of the center pixel as given by the computer. This point will be used as the center of the study area during the field work.

9. Plot the shifted study area locations on the topographic maps.

10. The 25 pixels around the pixel designated by the computer will be used as the study area.

Optional Procedures:

a. Using the Zoom Transfer Scope, compare each pixel as designated by the computer with what is seen on the photograph. The incorrect pixels will be recorded as explained in the field procedures.

D. FIELD PROCEDURES

1. Visit each study area as shown on the aerial photograph. Use the new plot center as designated by the computer and enter information on ground truth field sheet (Fig. A-1).

2. Ground Truth Field Sheet (Fig. A-1):

   (1) Plot No. — record the number of the study area

   (2) Crew — initials of the crew members

   (3) County name

   (4) Date of field work

   (5) UTM — the UTM coordinates originally selected

   (6) Location — general, i.e., community, hollow, mountain, etc.

   (7) T__S__R__1/4__The legal location of the plot using Township Range system.

   (8) Bearing — Dist. — From — Accurate measurements for finding plot center from a nearby landmark.

   (9) Quad. Sheet — the name of the USGS 7.5 minute, quadrangle sheet.

   (10) Photo No. — number of the aerial photograph showing that study area.

   (11) Center Pixel Address — the coordinates used for locating pixels by the computer.

   (12) Pixel No. — the 25 pixels in the study area are numbered from the top left to bottom right.

   (13) Dsgn. — the land use designation assigned to that pixel by the computer.

GROUND TRUTH FIELD SHEET

For Computer Generated Type Map

Plot #(1) : Crew (2) : County (3) ____ : Date (4) ____________ : UTM (5) / ____

Location (6) ____________________ : T (7) R ____ S ____ 1/4 ____

Bearing (8) Dist. __________ From ____________________

____________________ Quad. Sheet (9) ____________

Photo # (10) ____ Centr Pixel Address (11) ____________ , ____________

Pxl #	Dsgn	Act	X	Y	Pxl #	Dsgn	Act	X	Y
1	(13)	(14)	(15)	(15)	13				
2					14				
3					15				
4					16				
5					17				
6					18				
7					19				
8					20				
9					21				
10					22				
11					23				
12					24				
					25				

Site Characteristics:

Aspect (16) : Slope (17) : Topo. Posn. (18) : Soil (19) ____________

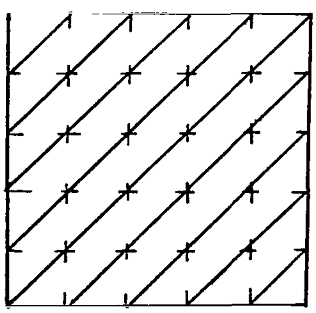
Species Characteristics as of exam date (Expressed in percentage)

Crop: Grass (20) Corn ____ Cotton ____ Beans ____ Wheat ____ Other ____

Timber: Oak-Hickory (21) : Oak-Pine ____ : Pine ____ Cedar ____ : Swamp ____

Timber Size: Repor. (22) : Sapling ____ PW ____ : ST ____________

1 cm = 57 m



(23)

NOTES:

Shift (24) N.S.
____ E.W.

Figure A-1. Ground truth field sample sheet.

(14) Act. — the land use as determined during the ground inspection.

(15) X + Y — the computer address B.1.c. of that particular pixel.

(16) Aspect — the direction the study area faces.

(17) Slope — % of slope.

(18) Topo Posn. — Topographic position, i.e., — upper, middle, lower slope, rolling, bottom, valley, swamp, etc.

(19) Soil — the general soil texture

(20) Crop — check the appropriate space

(21) Timber — check the appropriate type

(22) Timber Size — check the approximate sizes

(23) Study Area Map — the map is divided into 25 pixels which are in turn divided in half by diagonal lines. Record the computer designated land use in the upper left half and the ground determined land use in the lower right of each pixel. For convenience, this step should precede (5) through (15).

(24) Record shift using the number of pixels N-S and the number E-W (e.g., 2-1/2 S. × 2 W.)

3. Make a 5 × 5 grid on a transparent material for an aid in determining the location of the pixels in the field. Draw a 5 × 5 grid on white paper with each line spacing representing 57 m for each scale used. At a scale of 1:20 000, 0.285 cm equals 57 m; at 1:24 000, 0.2375 cm equals 57 m. Use a copying machine to transfer the grid to a transparent sheet.

4. Locate the center square of the transparency on the photograph over the shifted location to assist in finding the pixels on the ground.

5. Visit each pixel and determine land use. Record this determination in the study area map on the ground truth field sheet.

6. If a pixel was incorrectly classified by the computer, record the discrepancy.

APPENDIX B

SAMPLE DATA

Several representative study areas were chosen to be included in this report. Each one represents one or more of the major problems encountered during the study. A copy of the aerial photograph, the computer printout, and a copy of the ground truth field sheet made during the field examination are included. The reader can get a better idea of the problems from studying these data.

A. STUDY AREA 4

This study area fell in the middle of a large pasture (Figs. B-1, B-2, and B-3). None of the designated pixels were misclassified; however, several mistakes in the area made fitting difficult. Two patches of woods to the east do not show up at all and a large block of timber to the northeast is badly out of shape on the printout. Scattered all over the vicinity, large urban blocks are shown in the middle of agricultural land.

B. STUDY AREAS 21, 32, AND 92 ON GREEN MOUNTAIN

These three areas are all on the forested portion of the mountain and have relatively narrow roads running nearby (Figs. B-4 through B-10). The areas shown as agriculture, are generally small scattered fields. In a few cases these fields show up at incorrect locations, and make fitting difficult. There are approximately three swamps within 0.5 mile of the study areas, none of which show up on the printout. Wetland, however, is shown on the west side of Green Mountain. Since the satellite passes over Madison County around 9:45 a.m. CST, some of the west slopes are in shade and therefore reflect less energy which results in a signature similar to wetland.

It appears that there is some contradiction of shift between these three sites. Area 21 has a shift of 2 S while area 92, just 300 m to the south, was shifted 1 S and 1 E. The three plots are shown on three different pages because the sample pixel is always in the center of the printout. Each plot was fitted to

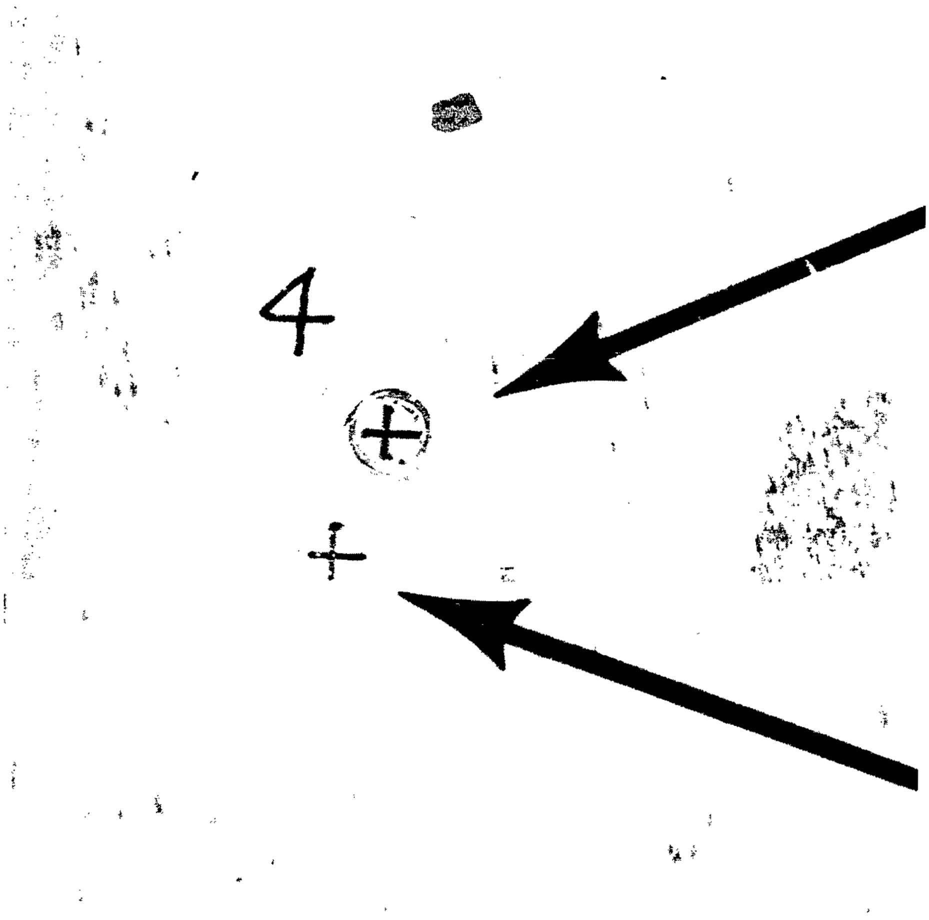


Figure B-1. Photograph of Study Area 4.

GROUND TRUTH FIELD SHEET

For Computer Generated Type Map

Plot # 4 : Crew CB : County Madison : Date 8-1-75 : UTM 437 / 8317

Location Wall Triana Road : T 15 R 2W S 16 1/4 SW

Bearing ____ Dist. ____ From ____

____ Quad. Sheet Toney ____

Photo # 5 mm 11 Centr Pixel Address 1342 , 374 ____

Pxl #	Dsgn	Act	X	Y	Pxl #	Dsgn	Act	X	Y
1					13	02	02	1342	374
2					14				
3					15				
4					16				
5					17				
6					18				
7					19				
8					20				
9					21				
10					22				
11					23				
12					24				
					25				

Site Characteristics:

Aspect ____ : Slope ____ : Topo. Posn. ____ : Soil ____

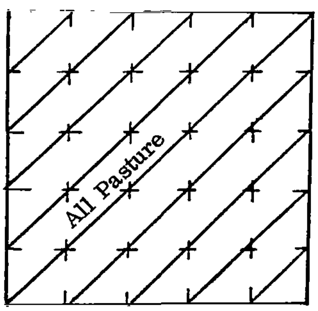
Species Characteristics as of exam date (Expressed in percentage)

Crop: Grass X Corn ____ Cotton ____ Beans ____ Wheat ____ Other ____

Timber: Oak-Hickory ____ : Oak-Pine ____ : Pine ____ Cedar ____ : Swamp ____

Timber Size: Repor. ____ : Sapling ____ PW ____ : ST ____

1 cm = 57 m



NOTES:

Shift 2 N. (S)
1 E. (W)

Figure B-2. Ground Truth Field Sheet for Study Area 4.

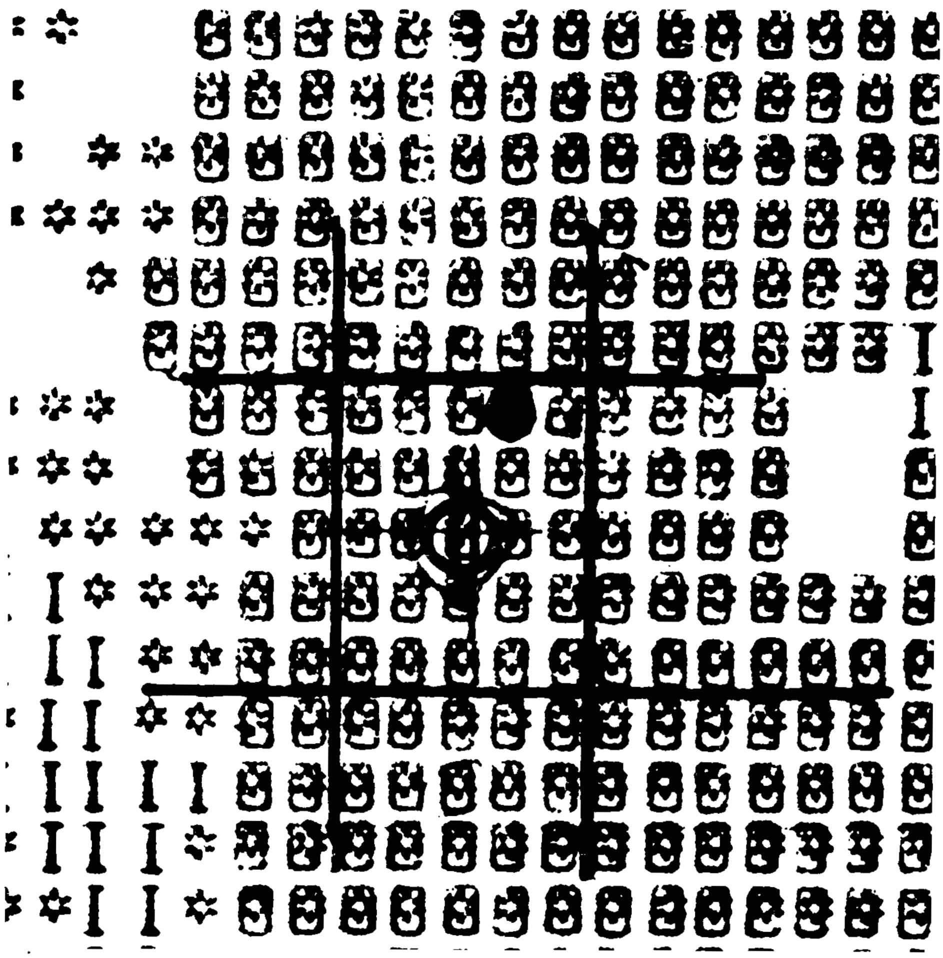


Figure B-3. Computer printout for Study Area 4.

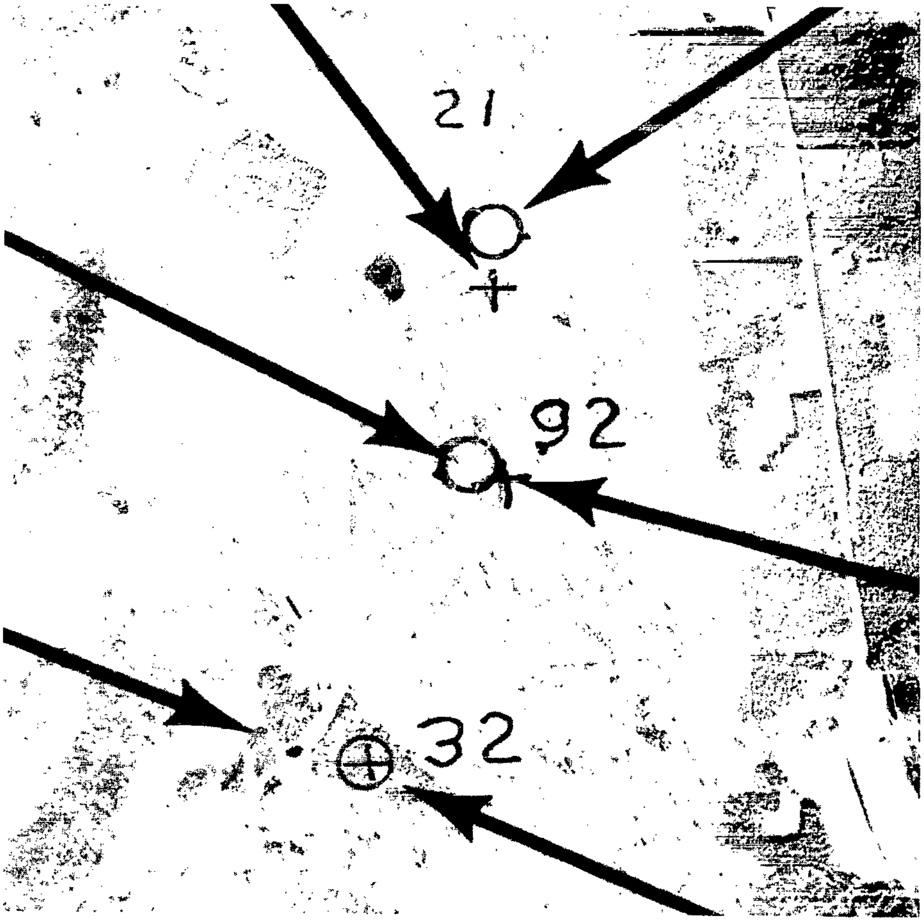


Figure B-4. Photograph of Study Areas 21, 32, and 92 on Green Mountain.

GROUND TRUTH FIELD SHEET

For Computer Generated Type Map

Plot # 21 : Crew CB : County Madison : Date 8-4-75 : UTM 439 / 5297

Location Green Mountain : T 5S. R 1E S 10 1/4 SW

Bearing W Dist. 380 m From Pavement

Quad. Sheet Farley

Photo # 5 mm 11 Centr Pixel Address 1704 , 1042

Pxl #	Dsgn	Act	X	Y	Pxl #	Dsgn	Act	X	Y
1					13	04	04	1704	1042
2					14				
3					15				
4					16				
5					17				
6					18				
7					19				
8					20				
9					21				
10					22				
11					23				
12					24				
					25				

Site Characteristics:

Aspect SW : Slope 10% : Topo. Posn. Upland (Plateau) : Soil Sandy Loam

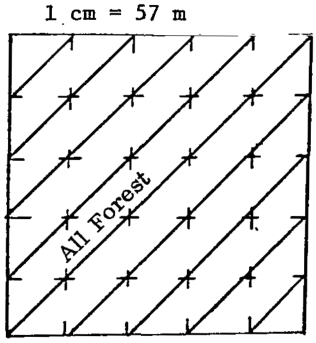
Species Characteristics as of exam date (Expressed in percentage)

Crop: Grass ____ Corn ____ Cotton ____ Beans ____ Wheat ____ Other ____

Timber: Oak-Hickory X : Oak-Pine ____ : Pine ____ Cedar ____ : Swamp ____

Timber Size: Repor. ____ : Sapling ____ PW X : ST ____

1 cm = 57 m



NOTES:

Shift 2 N.(S)
0 E.W.

Figure B-5. Ground Truth Field Sheet for Study Area 21.

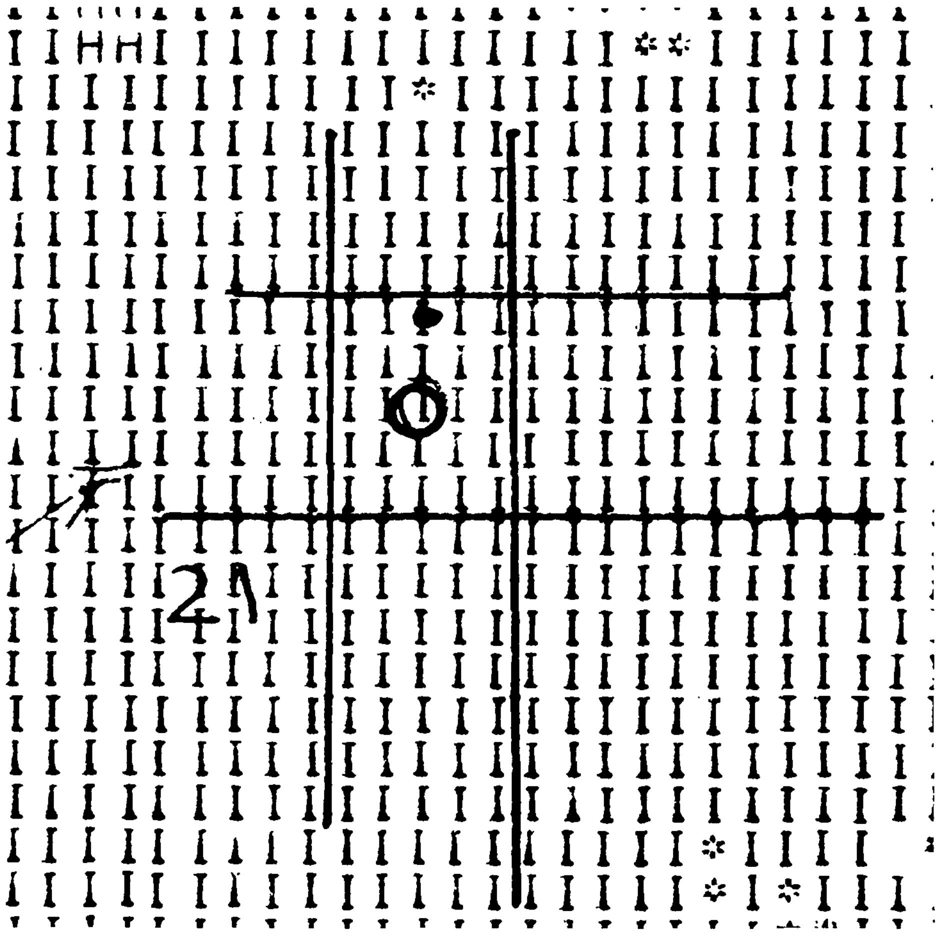


Figure B-6. Computer printout for Study Area 21.

GROUND TRUTH FIELD SHEET

For Computer Generated Type Map

Plot # 32 : Crew CB : County Madison : Date 8-4-75 : UTM 437 / 8290

Location Green Mountain : T 5S R 1E S 16 1/4 NE

Bearing NE Dist. 120 m From Rim Road and 100 m S.

Quad. Sheet Farley

Photo # 5 mm 11 Centr Pixel Address 1700 , 1054

Pxl #	Dsgn	Act	X	Y	Pxl #	Dsgn	Act	X	Y
1					13	04	04	1700	1054
2					14				
3					15				
4					16				
5					17				
6					18				
7					19				
8					20				
9					21				
10					22				
11					23				
12					24				
					25				

Site Characteristics:

Aspect S : Slope 1-2% : Topo. Posn. Plateau Upland : Soil Sandy Laom

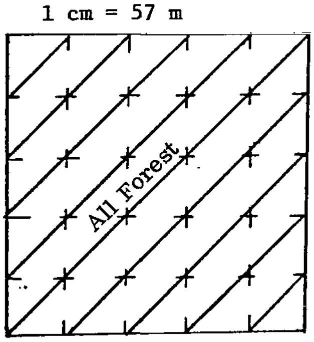
Species Characteristics as of exam date (Expressed in percentage)

Crop: Grass ____ Corn ____ Cotton ____ Beans ____ Wheat ____ Other ____

Timber: Oak-Hickory X : Oak-Pine ____ : Pine ____ Cedar ____ : Swamp ____

Timber Size: Repor. ____ : Sapling ____ PW X : ST ____

1 cm = 57 m



NOTES:

Shift 0 N.S.
2 E.(W)

Figure B-7. Ground Truth Field Sheet for Study Area 32.

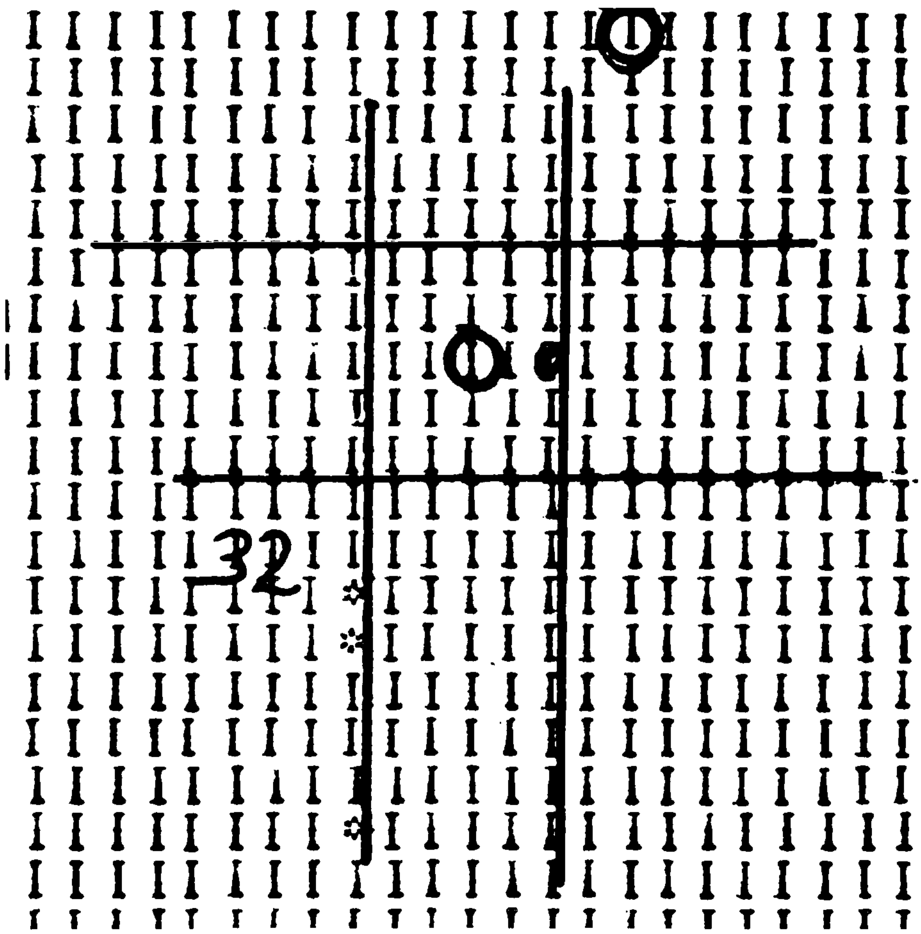


Figure B-8. Computer printout for Study Area 32.

GROUND TRUTH FIELD SHEET

For Computer Generated Type Map

Plot # 92 : Crew CB : County Madison : Date 8-4-74 : UTM 439 / 8294

Location Green Mountain : T 5S R 1E S 16 1/4 NE

Bearing E Dist. 300 m From Rim Road and 270 m N. from Road

Quad. Sheet Farley

Photo # 5 mm 11 Centr Pixel Address 1704 , 1047

Pxl #	Dsgn	Act	X	Y	Pxl #	Dsgn	Act	X	Y
1					13	04	04	1704	1047
2					14				
3					15				
4					16				
5					17				
6					18				
7					19				
8					20				
9					21				
10					22				
11					23				
12					24				
					25				

Site Characteristics:

Aspect W : Slope 5-10% : Topo. Posn. Plateau Hollow : Soil Sandy Loam

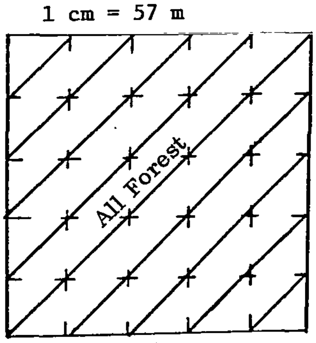
Species Characteristics as of exam date (Expressed in percentage)

Crop: Grass ____ Corn ____ Cotton ____ Beans ____ Wheat ____ Other ____

Timber: Oak-Hickory X : Oak-Pine ____ : Pine ____ Cedar ____ : Swamp ____

Timber Size: Repor. ____ : Sapling ____ PW X : ST ____

1 cm = 57 m



NOTES:

Shift 1 N.(S)
1 (E)W.

Figure B-9. Ground Truth Field Sheet for Study Area 92.

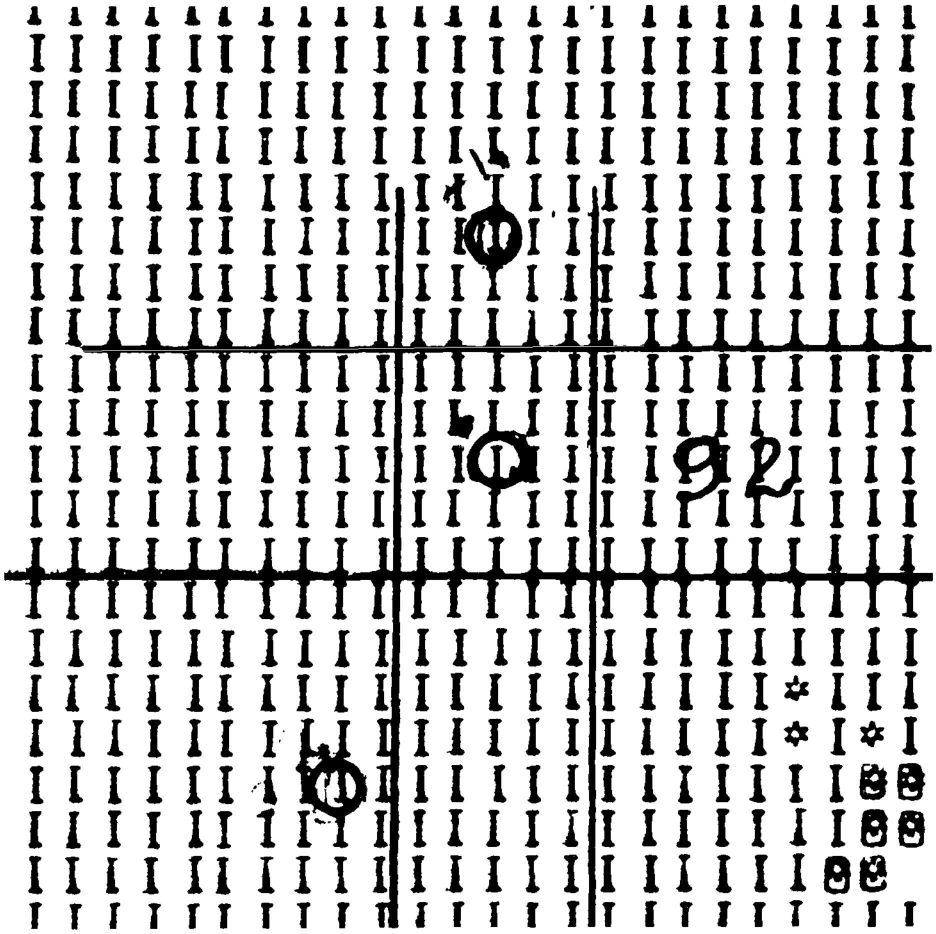


Figure B-10. Computer printout for Study Area 92.

the photo separately and differences in human judgment might explain the variation in shift even between plots in both sides of the county. There is, however, some argument against this conclusion because definite trends were noted in various areas.

C. STUDY AREA 45

This plot fell in the middle of a subdivision in Huntsville (Figs. B-11, B-14, and B-13). The pixels were classified as either urban or agriculture. The agriculture is incorrect but can be explained fairly easily. The grass on the lawns is always mowed closely so the ground underneath is visible in many places. In addition, pavement has a signature similar to soil. In an agricultural field in which a crop is being grown, some bare soil will show between the plants. It appears that the combination of soil and plant material will give the pixel the signature similar to agriculture.

There is no easy explanation for the fact that none of the trees in the neighborhood were classified as forest. In some areas, the tree cover is fairly heavy and extensive. Often, trees in a pasture caused the computer to designate the pasture as woodland, and narrow fence rows showed up as lines of forest pixels.

D. STUDY AREA 51

This was a particularly hard area to fit on the Zoom Transfer Scope (Figs B-14, B-15, and B-16). The major woodland outlines are apparent; however, the boundaries are very confused, so many fields are misclassified and the land use pattern is so confused that it is difficult to find a consistent pattern in the printout. One area might fit while another next to it does not fit at all.

This type of problem was encountered on many of the plots, especially those in the western half of the county where there were no mountains with definite shapes.

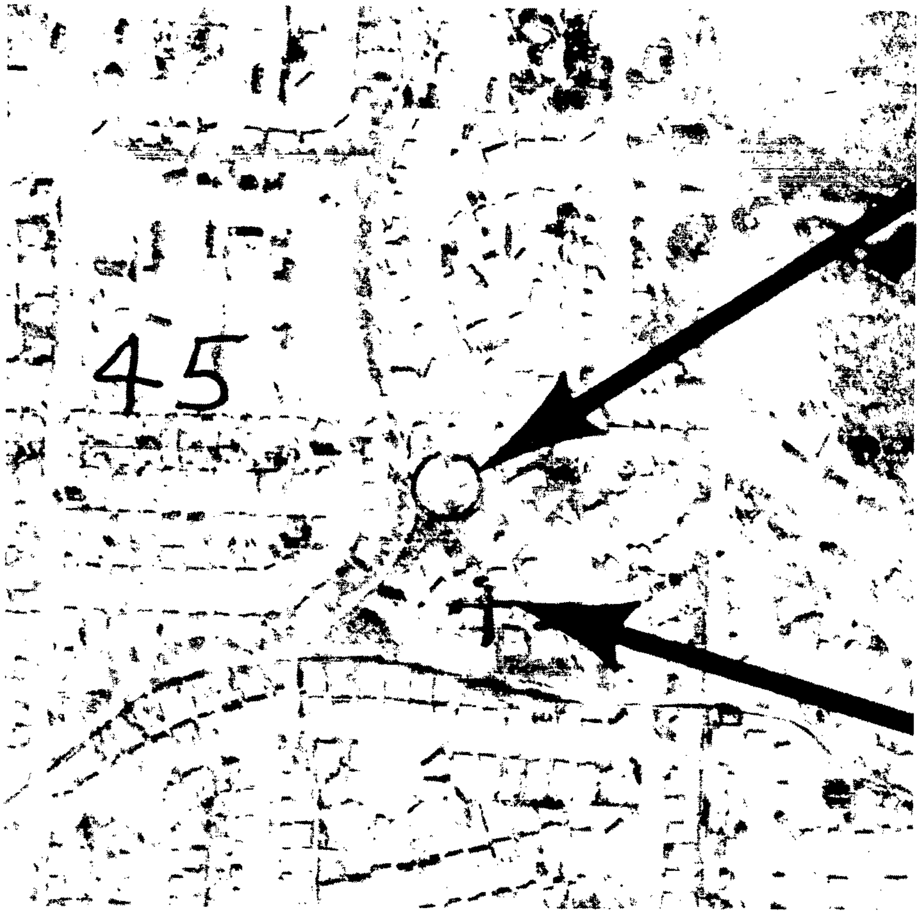


Figure B-11. Photograph of Study Area 45.

GROUND TRUTH FIELD SHEET

For Computer Generated Type Map

Plot # 45 : Crew CB : County Madison : Date 7-25-75 : UTM 404 / 8426

Location Clearmont Dr, Huntsville : T 4S R 1E S 6 1/4 NE

Bearing ____ Dist. ________ From ____________________

____________________ Quad. Sheet Huntsville

Photo # 5 mm 60 Centr Pixel Address 1642 , 816

Pxl #	Dsgn	Act	X	Y	Pxl #	Dsgn	Act	X	Y
1	01	01	1640	814	13	01	01	1642	816
2	01	01	1641	814	14	01	01	1643	816
3	01	01	1642	814	15	02	01	1644	816
4	01	01	1643	814	16	01	01	1640	817
5	01	01	1644	814	17	02	01	1641	817
6	01	01	1640	815	18	01	01	1642	817
7	02	01	1641	815	19	02	01	1643	817
8	01	01	1642	815	20	01	01	1644	817
9	01	01	1643	815	21	01	01	1640	818
10	01	01	1644	815	22	01	01	1641	818
11	01	01	1640	816	23	01	01	1642	818
12	02	01	1641	816	24	02	01	1643	818
					25	01	01	1644	818

Site Characteristics:

Aspect W : Slope 5% : Topo. Posn. Lower Slope : Soil ________

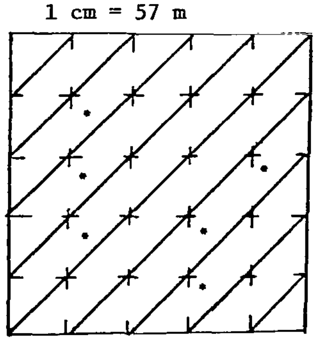
Species Characteristics as of exam date (Expressed in percentage)

Crop: Grass ____ Corn ____ Cotton ____ Beans ____ Wheat ____ Other ____

Timber: Oak-Hickory ____ : Oak-Pine ____ : Pine ____ Cedar ____ : Swamp ____

Timber Size: Repor. ____ : Sapling ____ PW ____ : ST ________

1 cm = 57 m



NOTES: Subdivision
Grass in lawns designated as agriculture.

Shift 2 N.(S) 0 E.W.

Figure B-12. Ground Truth Field Sheet for Study Area 45.

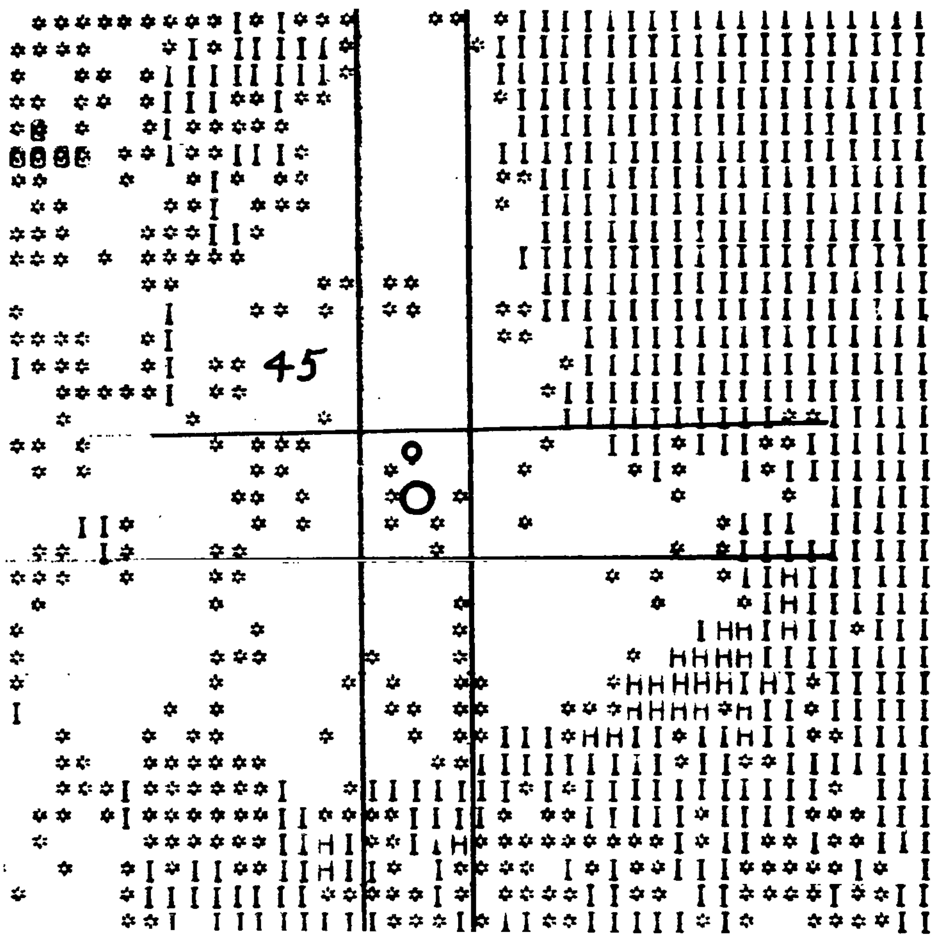


Figure B-13. Computer printout for Study Area 45.

Figure B-14. Photograph of Study Area 51.

GROUND TRUTH FIELD SHEET

For Computer Generated Type Map

Plot # 51 : Crew CB : County Madison : Date 8-6-75 : UTM 261/8408

Location ______ : T 4S R 2W S 11 1/4 ____

Bearing N Dist. 400 m From On Section Line From Road

______ Quad. Sheet Madison

Photo # 5 mm 171 Centr Pixel Address 1391 , 847

Pxl #	Dsgn	Act	X	Y	Pxl #	Dsgn	Act	X	Y
1	02	04	1389	845	13	02	04	1391	847
2	04	04	1390	845	14	04	04	1392	847
3	04	04	1391	845	15	04	04	1393	847
4	04	04	1392	845	16	02	02	1389	848
5	04	04	1393	845	17	02	02	1390	848
6	02	04	1389	846	18	04	04	1391	848
7	02	04	1390	846	19	04	04	1392	848
8	02	04	1391	846	20	04	04	1393	848
9	04	04	1392	846	21	02	02	1389	849
10	04	04	1393	846	22	02	02	1390	849
11	02	02	1389	847	23	02	04	1391	849
12	02	02	1390	847	24	02	02	1392	849
					25	04	04	1393	849

Site Characteristics:

Aspect W : Slope 10% : Topo. Posn. Mid Slope : Soil Clay Loam

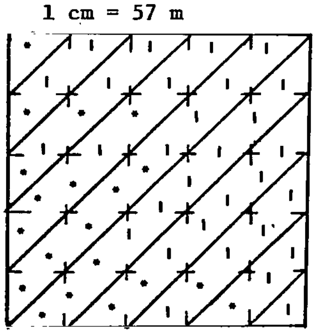
Species Characteristics as of exam date (Expressed in percentage)

Crop: Grass ____ Corn ____ Cotton ____ Beans ____ Wheat ____ Other ____

Timber: Oak-Hickory ____: Oak-Pine ____: Pine X Cedar ____: Swamp ____

Timber Size: Repor. ____: Sapling ____ PW X : ST X

1 cm = 57 m



NOTES: Fields reverting to forest

Shift 1/2 N.(S)
3 E.(W)

Figure B-15. Ground Truth Field Sheet for Study Area 51.

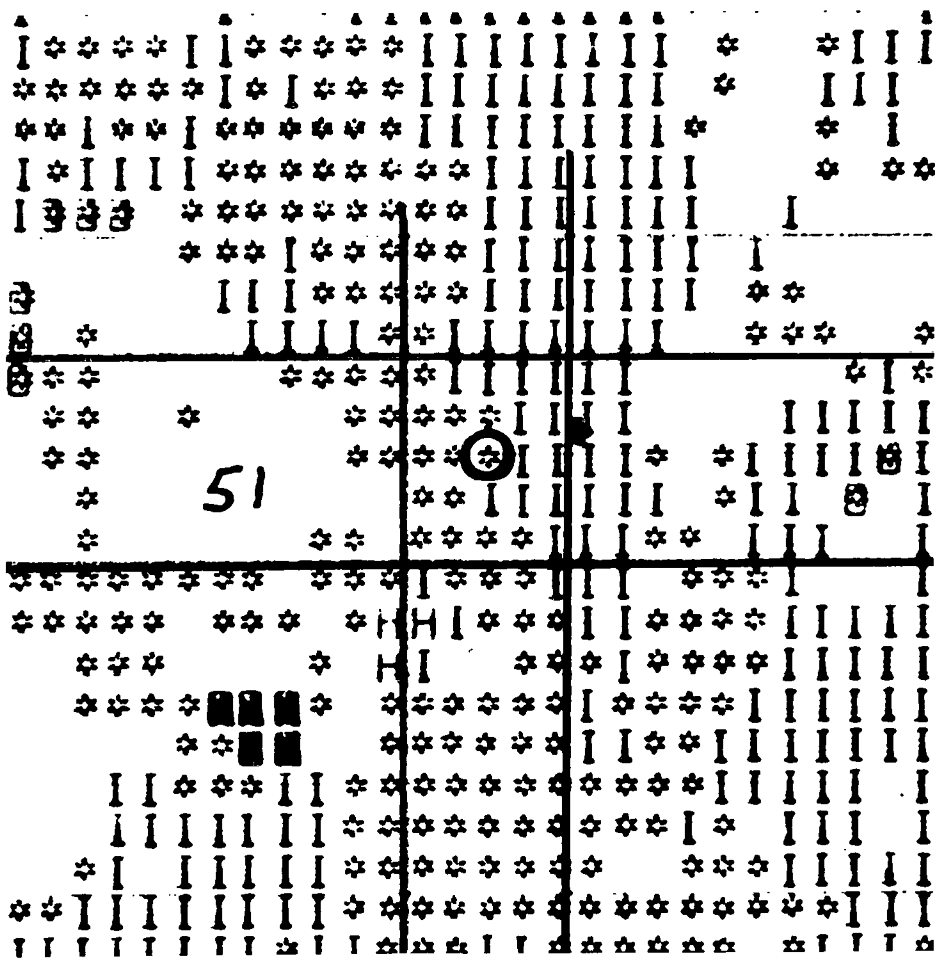


Figure B-16. Computer printout for Study Area 51.

E. STUDY AREA 74

This is an example of the situation where ponds were misclassified (Figs. B-17, B-18, and B-19). Evidently no shallow ponds were included in the training sets and that signature is thrown into the agriculture or pasture classification. The combination of algae and a muddy bottom give a signature similar to agriculture. Some sites (See Study Area 4) had ponds which showed up as wetland, but no farm ponds were observed which were classified as water.

F. STUDY AREA 79

This is another example of shallow water being misclassified (Figs. B-20, B-21, and B-22). The main channel of the Flint River (just south of the plot) and the slough were classified as wetland. The river flows rapidly and, therefore, should not have a lot of algae to make it look like a pond (see Study Area 74). It is interesting to note, however, that the Tennessee River (in the lower left corner) is classified as water except for a few pixels along the bank. This would indicate that the shallow water with a muddy bottom will often show up as wetland.

G. STUDY AREA 97

This was another difficult site to fit (Figs. B-23, B-24, and B-25). Part of the reason was that the nearest border between mountain woodland and valley pasture is almost 1 mile away and the urban area on top of the mountain does not show up at all. Approximately 450 m to the west of the plot are the grounds of the Burritt Museum. The museum grounds should show up as a slightly distorted tear drop containing approximately 10 pixels. The closest thing to that form on the printout is a north-south string of five pixels designated as agriculture.

There are seven pixels within the study area which are incorrect regardless of how the fit is made. They are classified as agriculture in the middle of a forest. The most probable reason for this is the presence of large rock outcrops in the area. The spectral signature of the rocks could combine with that of the surrounding trees to give a combined signature similar to agriculture. The lone agriculture pixel in the upper left corner of the study area could be the grass and pavement along the road. It is common for highways to show up as agriculture as evidenced by US 431 crossing the mountain to the south of the study area.

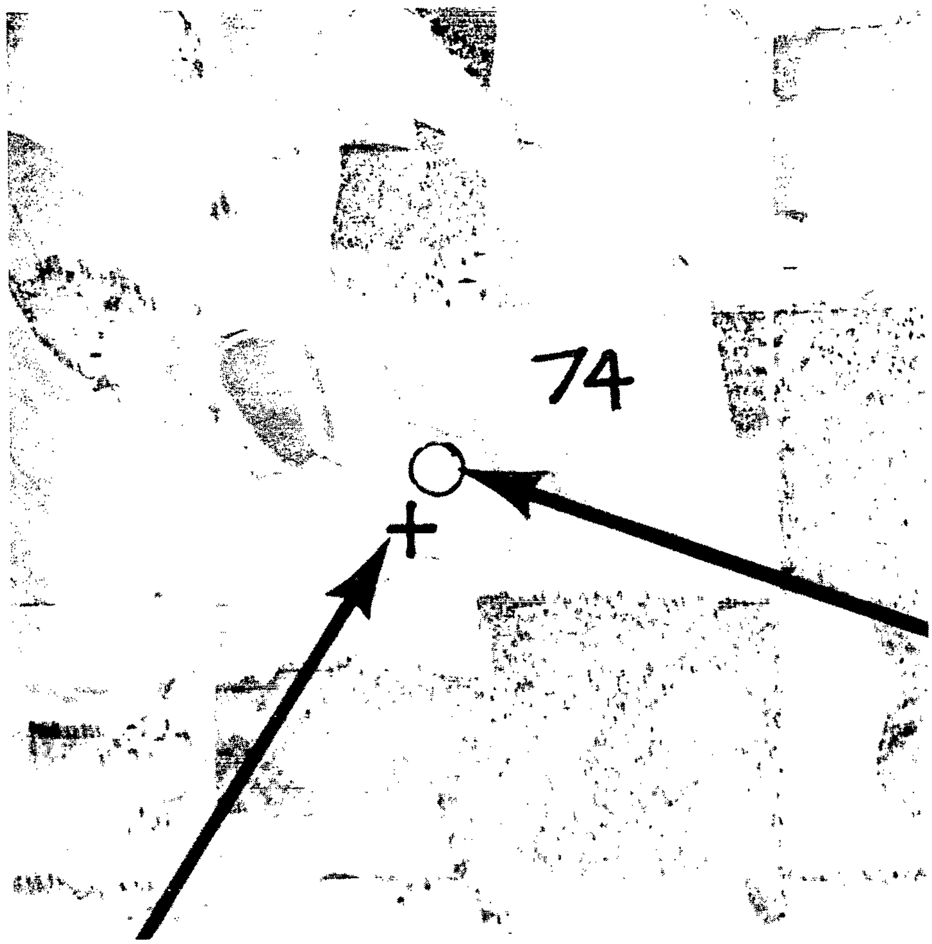


Figure B-17. Photograph of Study Area 74.

GROUND TRUTH FIELD SHEET

For Computer Generated Type Map

Plot # 74 : Crew CB : County Madison : Date 8-1-75 : UTM 209 /8229

Location S of Dozier Rd : T 1S. R 2W S 19 1/4 NE

Bearing E Dist. 38 m From Road AWS S 70 m from Rd

Quad. Sheet Ardmore

Photo # 5 mm 215 Centr Pixel Address 1300 , 389

Pxl #	Dsgn	Act	X	Y	Pxl #	Dsgn	Act	X	Y
1	02	02	1298	387	13	01	05	1300	389
2	01	02	1299	387	14	01	05	1301	389
3	01	05	1300	387	15	02	02	1302	389
4	01	05	1301	387	16	02	02	1298	390
5	01	05	1302	387	17	02	02	1299	390
6	02	02	1298	388	18	01	02	1300	390
7	01	02	1299	388	19	01	02	1301	390
8	01	05	1300	388	20	04	02	1302	390
9	01	05	1301	388	21	01	02	1298	391
10	01	05	1302	388	22	01	02	1299	391
11	02	02	1298	389	23	02	02	1300	391
12	02	02	1299	389	24	01	02	1301	391
					25	01	04	1302	391

Site Characteristics:

Aspect ____ : Slope ____ : Topo. Posn. Pond : Soil Clay Loam

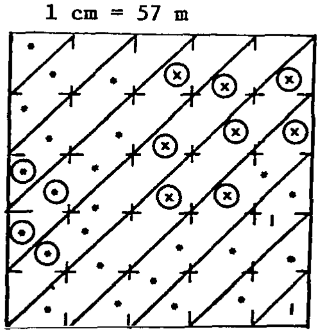
Species Characteristics as of exam date (Expressed in percentage)

Crop: Grass ____ Corn ____ Cotton ____ Beans ____ Wheat ____ Other ____

Timber: Oak-Hickory ____ : Oak-Pine ____ : Pine ____ Cedar ____ : Swamp ____

Timber Size: Repor. ____ : Sapling ____ PW ____ : ST ____

1 cm = 57 m



NOTES:

Shift 2 N.(S)
1 E.(W)

Figure B-18. Ground Truth Field Sheet for Study Area 74.

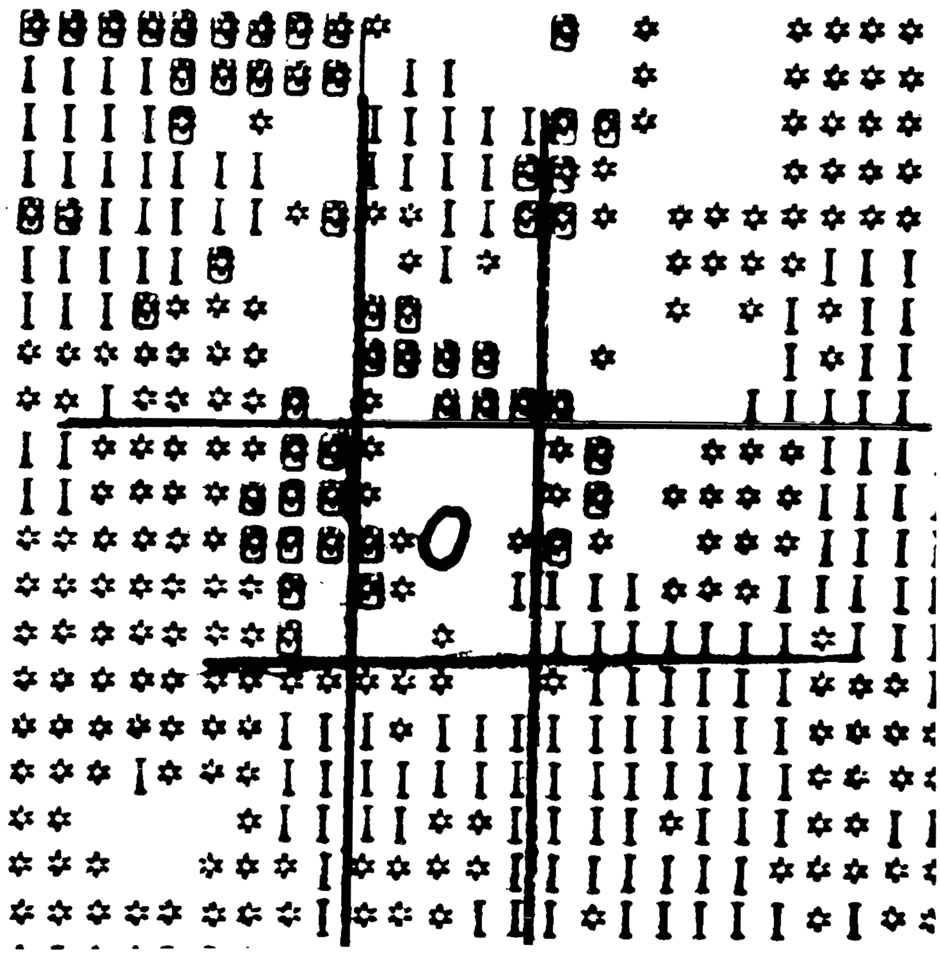


Figure B-19. Computer printout of Study Area 74.

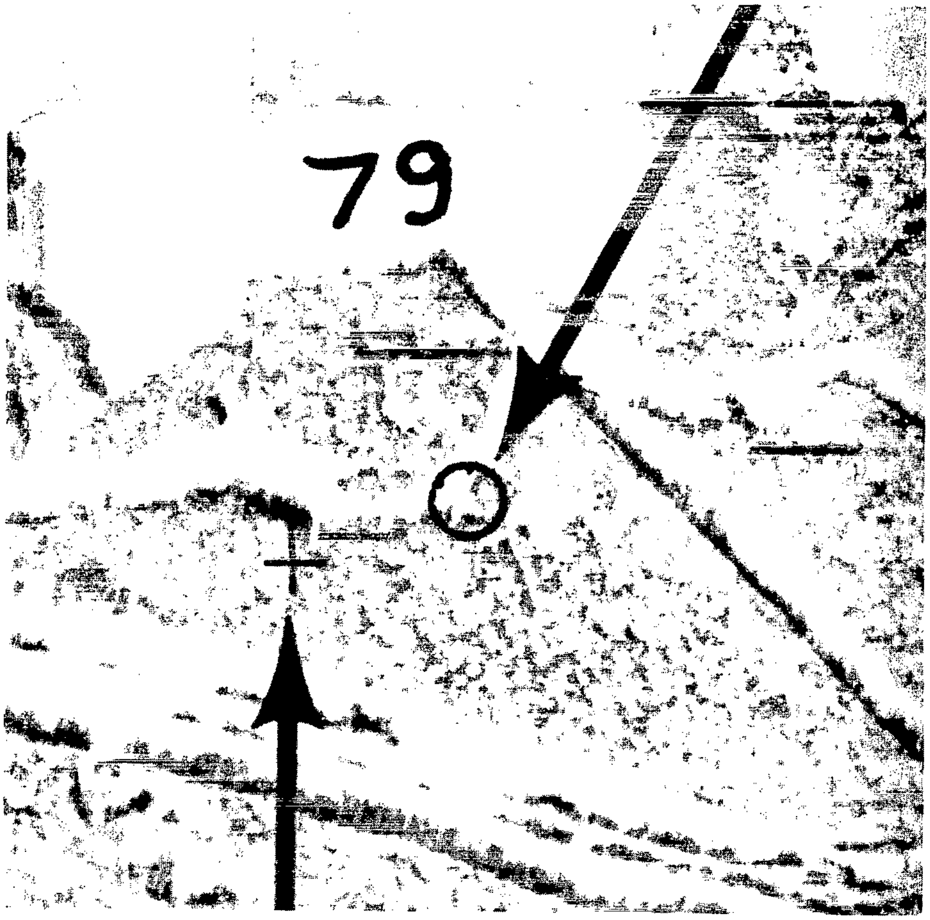


Figure B-20. Photograph of Study Area 79.

GROUND TRUTH FIELD SHEET

For Computer Generated Type Map

Plot # 79 : Crew CB : County Madison : Date 8-4-75 : UTM 455 /8190

Location Flint River – Hobbs Island : T 6S R 1E S 14 1/4 NW

Bearing E Dist. 250 m From On Section Line and 210 m S.

Quad. Sheet Farley

Photo # 4 mm 163 Centr Pixel Address 1732 , 1230

Pxl #	Dsgn	Act	X	Y	Pxl #	Dsgn	Act	X	Y
1	06	05	1730	1228	13	04	04	1732	1230
2	06	05	1731	1228	14	04	04	1733	1230
3	06	05	1732	1228	15	04	04	1734	1231
4	04	04	1733	1228	16	06	04	1730	1231
5	04	04	1734	1228	17	04	04	1731	1231
6	04	04	1730	1229	18	04	04	1732	1231
7	04	04	1731	1229	19	04	04	1733	1231
8	04	04	1732	1229	20	04	04	1734	1231
9	04	04	1733	1229	21	06	05	1730	1232
10	04	04	1734	1229	22	06	05	1731	1232
11	04	04	1730	1230	23	02	04	1732	1232
12	04	04	1731	1230	24	02	04	1733	1232
					25	02	04	1734	1232

Site Characteristics:

Aspect ______ : Slope Level : Topo. Posn. Creek Bank : Soil Loam and Silt

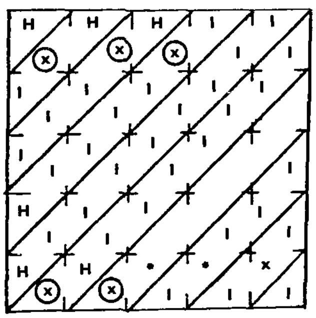
Species Characteristics as of exam date (Expressed in percentage)

Crop: Grass ____ Corn ____ Cotton ____ Beans ____ Wheat ____ Other ____

Timber: Oak-Hickory ____ : Oak-Pine ____ : Pine ____ Cedar ____ : Swamp Oak-Gum

Timber Size: Repor. ____ : Sapling ____ PW X : ST X

1 cm = 57 m



NOTES:

Shift 1 N.(S)
3 E.(W)

Figure B-21. Ground Truth Field Sheet for Study Area 79.

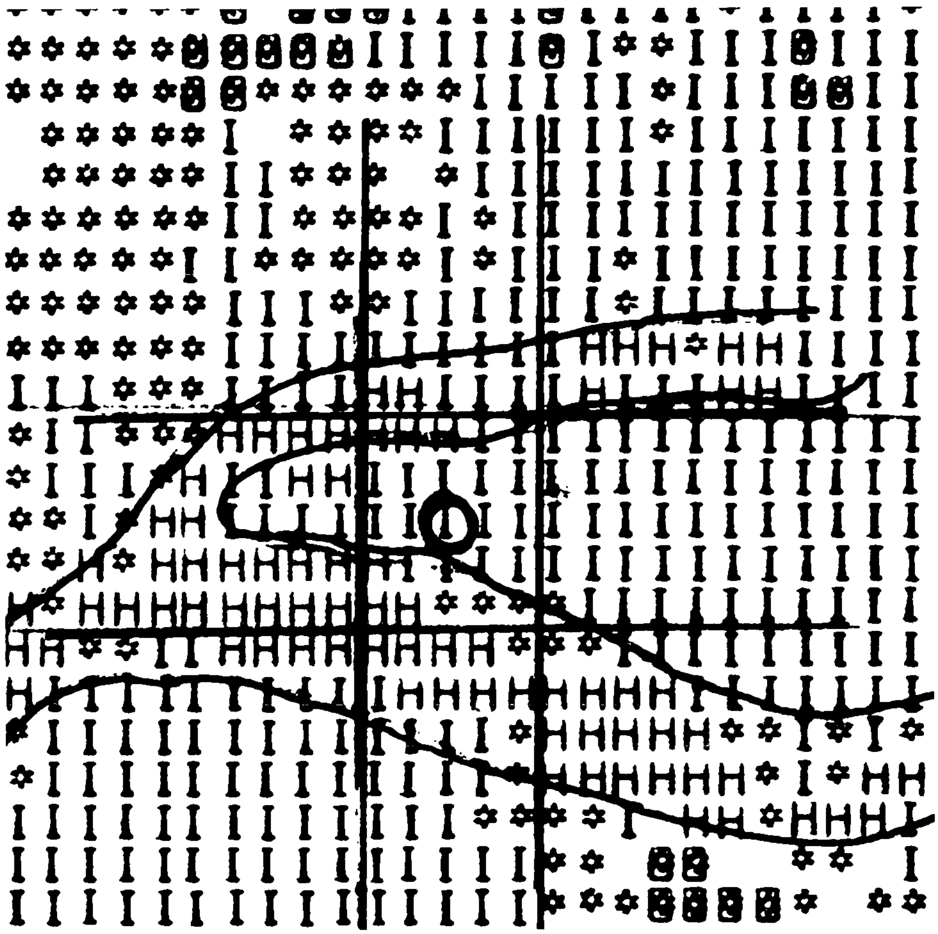


Figure B-22. Computer printout for Study Area 79.

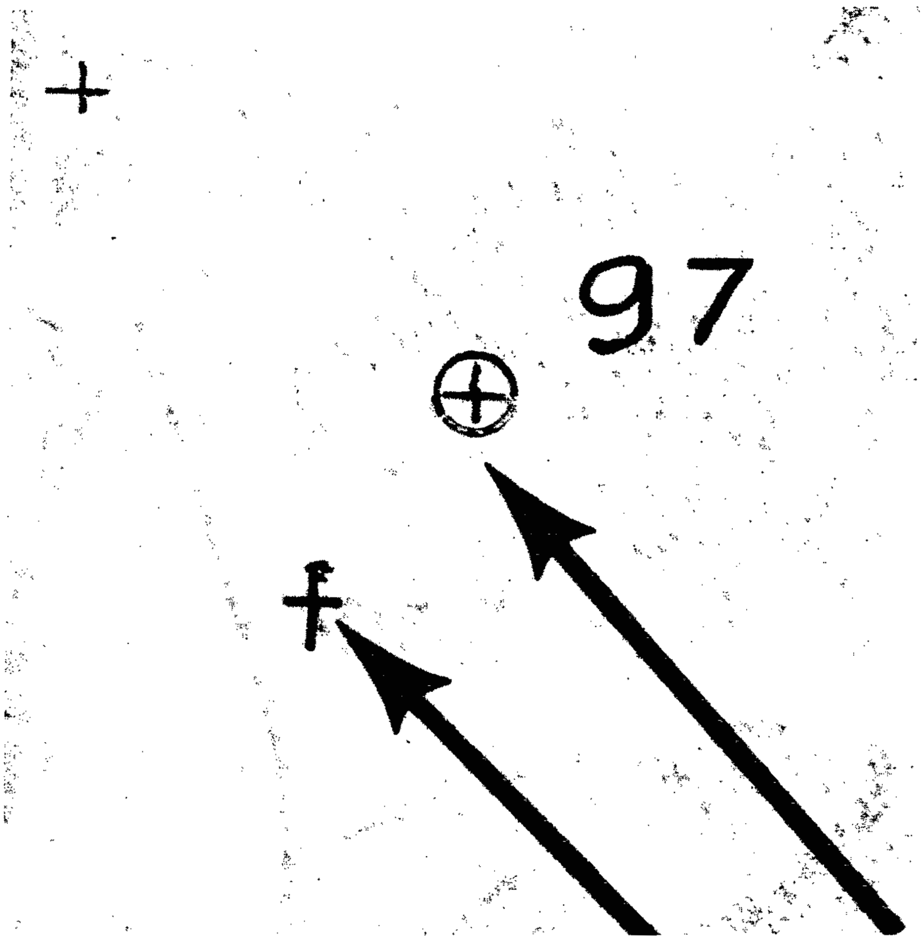


Figure B-23. Photograph of Study Area 97.

GROUND TRUTH FIELD SHEET

For Computer Generated Type Map

Plot # 97 : Crew CB : County Madison : Date 7-25-75 : UTM 427 /8418

Location Hale Hollow : T 4S R 1E S 4 1/4 SW

Bearing ____ Dist. ____ From In Woods

Quad. Sheet Huntsville

Photo # 5 mm 18 Centr Pixel Address 1683, 830

Pxl #	Dsgn	Act	X	Y	Pxl #	Dsgn	Act	X	Y
1	02	04	1681	828	13	02	04	1683	830
2	04	04	1682	828	14	02	04	1684	830
3	04	04	1683	828	15	02	04	1685	830
4	04	04	1684	828	16	04	04	1681	831
5	02	04	1685	828	17	04	04	1682	831
6	04	04	1681	829	18	04	04	1683	831
7	04	04	1682	829	19	04	04	1684	831
8	04	04	1683	829	20	04	04	1685	831
9	02	04	1684	829	21	04	04	1681	832
10	02	04	1685	829	22	04	04	1682	832
11	04	04	1681	830	23	04	04	1683	832
12	04	04	1682	830	24	04	04	1684	832
					25	04	04	1685	832

Site Characteristics:

Aspect SE : Slope 50% : Topo. Posn. Mid Slope : Soil Rocky Loam

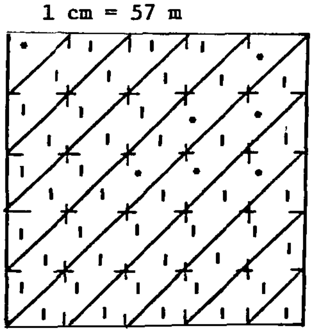
Species Characteristics as of exam date (Expressed in percentage)

Crop: Grass ____ Corn ____ Cotton ____ Beans ____ Wheat ____ Other ____

Timber: Oak-Hickory ____ : Oak-Pine ____ : Pine ____ Cedar ____ : Swamp ____

Timber Size: Repor. ____ : Sapling ____ PW ____ : ST ____

1 cm = 57 m



NOTES: Deciduous forest and cedar glade

Shift 3 N.(S.) 2 E.(W.)

Figure B-24. Ground Truth Field Sheet for Study Area 97.

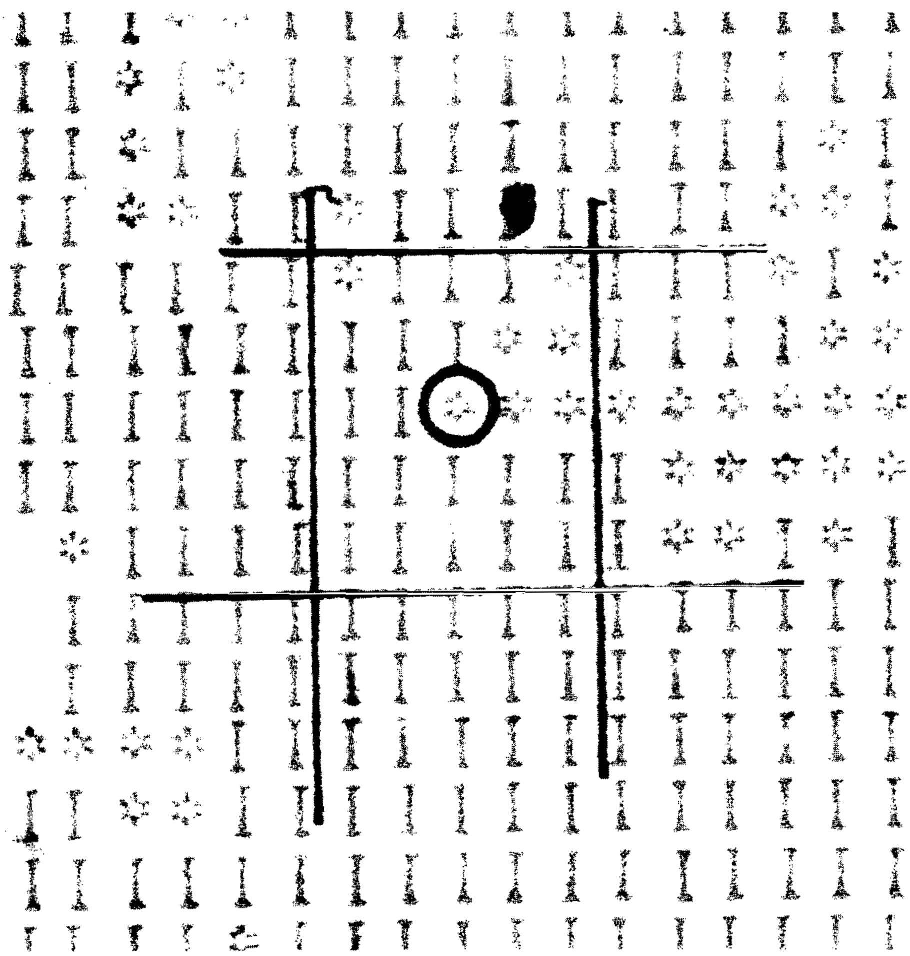


Figure B-25. Computer printout of Study Area 97.

APPENDIX C

LANDSAT-1

The Landsat-1 (formerly ERTS-1) satellite was launched on July 23, 1972. It circles the Earth in a near polar orbit at an altitude of 920 km (570 miles). The nature of the orbit allows the satellite to cover almost the entire globe once every 18 days and then to repeat the coverage.

Landsat-1 carries a remote sensing system called a multispectral scanner subsystem (MSS). The MSS is an optical-mechanical sensing system which detects reflected energy in four spectral bands:

500 - 600 nm

600 - 700 nm

700 - 800 nm

800 - 1100 nm.

The data can be transmitted to the Earth in real-time or recorded on tape recorders for transmission back to Earth at a later time. On the ground, the data can be used to construct photo-like images or recorded on magnetic tape for automatic analysis by computers. Each image recorded by Landsat covers an area on the surface of the Earth that is 185 by 185 km (100 by 100 n. mi). There is approximately 10 percent overlap in consecutive frames. The resolution cell is approximately 80 by 80 m (260 by 260 ft).

For a more complete description of the Landsat satellite and the on-board sensor system, the reader is referred to the booklet Landsat [5] and the Landsat Data Users Handbook [6].

REFERENCES

1. Bond, A. D., and Atkinson, R. J.: An Integrated Feature Selection and Supervised Learning Scheme for Fast Computer Classification of Multi-Spectral Data. Remote Sensing of Earth Resources, vol. 1 (F. Shahrokhi, ed.), University of Tennessee, Tullahoma, Tennessee, 1972, pp. 645-672.

2. Anderson, J. R., Hardy, E. E., Roach, J. T., and Witmer, R. E.: A Land Use and Land Cover Classification System for Use with Remote Sensor Data. Geological Survey Professional Paper 964, U.S. Government Printing Office, Washington, D.C., 1976.

3. Paludan, C. T. N.: Procedure for Locating 10 km UTM Grid on Alabama County General Highway Maps. NASA TM X-64953, Marshall Space Flight Center, Alabama, 1975.

4. Brunk, H. D.: An Introduction to Mathematical Statistics, Second Edition. Blaisdell Publishing Co., New York, New York, 1965.

5. Landsat, 1976-0-215-332, U.S. Government Printing Office, Washington, D.C., 1976.

6. Landsat Data Users Handbook. Document 78SDS4285, NASA-GSFC, Greenbelt, Maryland, 1976.

NASA-Langley, 1977

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