E7.4-10629
CR-138739

UTILIZING ERTS IMAGERY TO DETECT PLANT DISEASES AND NUTRIENT DEFICIENCIES, SOIL TYPES AND SOIL MOISTURE LEVELS

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(E74-10629) UTILIZING ERTS IMAGERY TO DETECT PLANT DISEASES AND NUTRIENT DEFICIENCIES, SOIL TYPES AND SOIL MOISTURE LEVELS Final Report, (Tennessee Univ.) 53 p HC $5.75 CSCL 02C G3/13

N74-28865

Unclas
00629

March 1, 1974
Type III Report for Period September 29, 1972—March 1, 1974

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GODDARD SPACE FLIGHT CENTER

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1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
Type III, Final		UN650 #139

4. Title and Subtitle
Utilizing ERTS Imagery to Detect Plant Diseases and Nutrient Deficiencies, Soil Types and Soil Moisture Levels.

5. Report Date
March 1, 1974

6. Performing Organization Code

7. Author(s) W. L. Parks (P.I.), J. I. Sewell, J. W. Hilty, and J. C. Rennie

8. Performing Organization Report No.

9. Performing Organization Name and Address
University of Tennessee
Institute of Agriculture
Knoxville, Tennessee 37916

10. Work Unit No.

11. Contract or Grant No.
NAS5-21873

12. Sponsoring Agency Name and Address
National Aeronautics & Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

13. Type of Report and Period Covered
Type III, Final
Sept. 1972-March 1974

14. Sponsoring Agency Code

15. Supplementary Notes Results presented at ERTS Conferences and others (see Literature Cited). Sections of reports to be published in Tennessee Farm and Home Science.

16. Abstract

ERTS imagery may be used to delineate soil associations. It does have the capacity to divide soils into groups such that their land use and management would be similar. It offers definite potential for making grass flood-plain, wetland, river shoreline and land use change surveys. Production of volume strata and forest type from the two usable bands of ERTS imagery were of questionable value. No imagery was received for evaluation during the time of year when maize dwarf mosiac virus and southern corn leaf blight were active.

17. Key Words (Selected by Author(s))
ERTS imagery, Flood-plain, Wetland, Soil association, Volume Strata, Forest type

18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
		53	

Preface

The objectives of this study were to develop techniques for identifying from space acquired imagery soil associations, soil parent materials, drainage patterns, soil moisture, wet lands, land use and land use changes, plant diseases, forest types and volume strata in forest.

The scope of the work would involve intensive studies on sample sites within Tennessee where considerable information was available on ground truth from prior remote sensing or other studies.

It was concluded that ERTS imagery could be used to delineate soil associations, drainage patterns, wetlands, shorelines, land use and land use changes. Results on forest type and volume strata of forest were of questionable value and no evaluation of imagery relating to plant diseases were received for evaluation during the period of plant disease activity.

Many valuable uses of ERTS data have been demonstrated in this and other studies. Among these would be resource inventory, drainage patterns, water-land boundaries, wetlands, soil associations, land use, land use changes, planting dates and patterns.

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INTRODUCTION

The agricultural communities may profit in many ways through the utilization of ERTS data. The delineation of large soil associations and drainage patterns within these soil groups has many uses. Crop identification, planting sequences and harvests are other areas of useful applications. Inventoring and classifying forest stands are useful in resource development and programming. Many facets of plant community casualities such as fire, disease and insect may be detected and the extent of their injury delineated.

Perhaps one of the great applications of ERTS data lies in the resource evaluation of underdeveloped and developing countries.

Chapter 1

Utilizing ERTS Imagery to Delineation of Soil Associations

by

W. L. Parks*

Soil differences as they occur on the landscape may be detected by the ERTS data systems in a number of ways. The differences in soils may be expressed through vegetation differences where a definite soil-vegetation type relationship exists for a given area. Differences in soil moisture conditions may also be a means to detect soil differences as their location on the landscape and in the drainage patterns affect soil conditions to the extent that their reflective and absorbtive characteristics are identifiable. Moisture differences may also be reflected through vegetative cover. The slope of soils also changes their reflective characteristics as measured by the ERTS system (1,3,6).

Soil differences are best expressed spectrally when the soil has been freshly tilled and contains no vegetative cover. The spectral characteristics of soils of this area are a function of color and moisture content when the soil surface has been tilled. Imagery obtained under these conditions when soil moisture is slightly below field capacity and again when about half of the available surface moisture has evaporated will permit differentiation of soils through the series level. This has been shown to be feasible by several investigators (3,6,9,10,11).

The resolution of ERTS data system is not sufficient to detect soil series except in cases where large blocks of a series occur. However,

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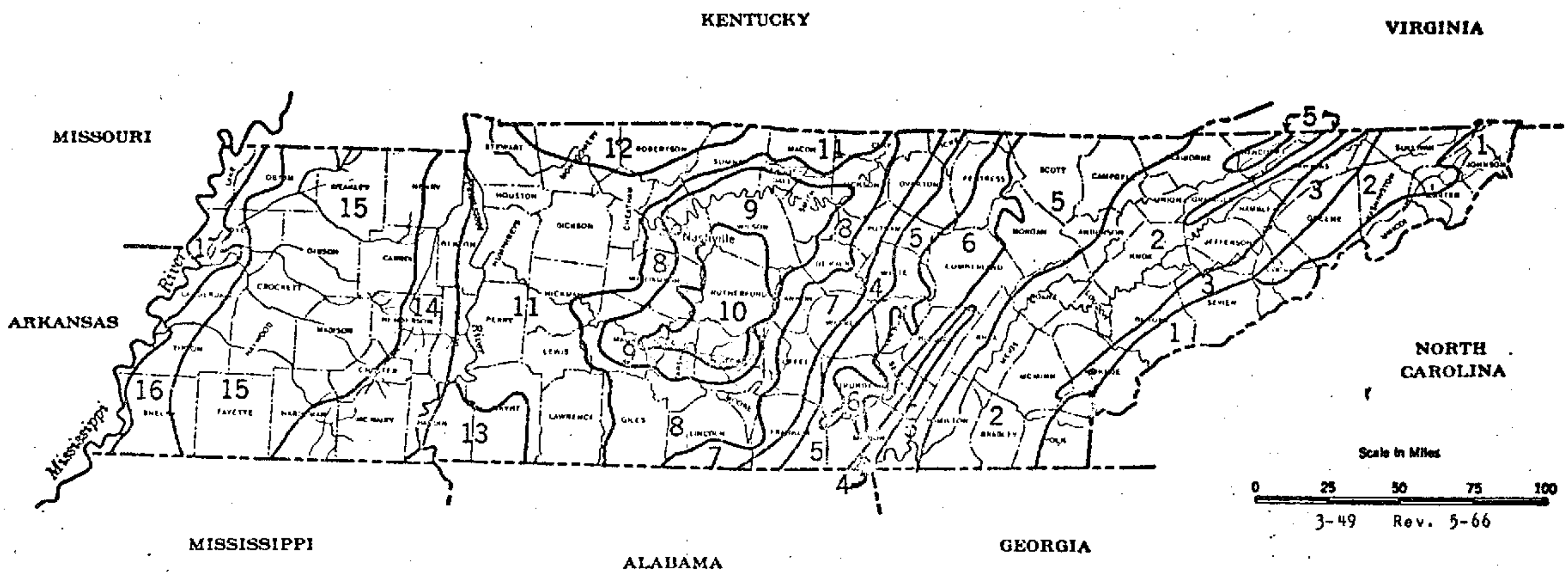
*Professor, Plant and Soil Science Department, University of Tennessee, Knoxville.

it is possible to detect soil associations from ERTS data. Soil associations are generally composed of several soil series having some similar characteristics that occur together on the landscape. Soil associations are defined in the Soil Survey Manual as a group of defined and named taxonomic soil units occurring together in an individual and characteristic pattern over a geographic region.

A generalized soil association map of Tennessee is shown in Figure 1. This map shows the general boundaries of 17 different soil associations that occur within the State. More specific soil association boundaries could be established using Channels 6 and 7 of ERTS imagery and work is progressing toward a new soil association map although it was not an original objective of this project. Examination of ERTS imagery covering the State clearly shows the many physiographic regions of the State. The soil association breakdown within each physiographic region is portrayed more clearly in some regions than others with the most difficult areas to define being the highly undulating areas.

In order to determine the extent that soils could be identified through the use of ERTS data, Obion County in the northwest corner of Tennessee was selected as the test site. The county occupies about 352,000 acres or about 550 square miles. A detailed soil survey of the county had recently been completed and was published in January, 1973 by the Soil Conservation Service and the Tennessee Agricultural Experiment Station. A soil association map of Obion County is shown in Figure 2 and it delineates 9 different soil associations. The Memphis soil association (No. 3 in Figure 2) is clearly visible in ERTS imagery. This delineation

Figure 1. General Soil Association Map of Tennessee



SOIL ASSOCIATION AREAS

1. Ramsey-Stony Land-Porters
2. Fullerton-Dewey-Dunmore-Sequoia
3. Dandridge-Whitesburg
4. Waynesboro-Cumberland-Sequatchie
5. Ramsey-Hartsells-Stony Land
6. Hartsells-Ramsey
7. Baxter-Mountview-Dickson
8. Dellrose-Mimosa-Bodine
9. Maury-Mimosa-Rockland
10. Talbott-Rockland-Cumberland
11. Bodine-Mountview-Dickson
12. Pembroke-Crider-Baxter
13. Shubuta-Waynesboro-Bodine
14. Lexington-Shubuta-Ruston-Dulac
15. Grenada-Loring-Memphis
16. Memphis-Loring
17. Commerce-Robinsonville-Sharkey

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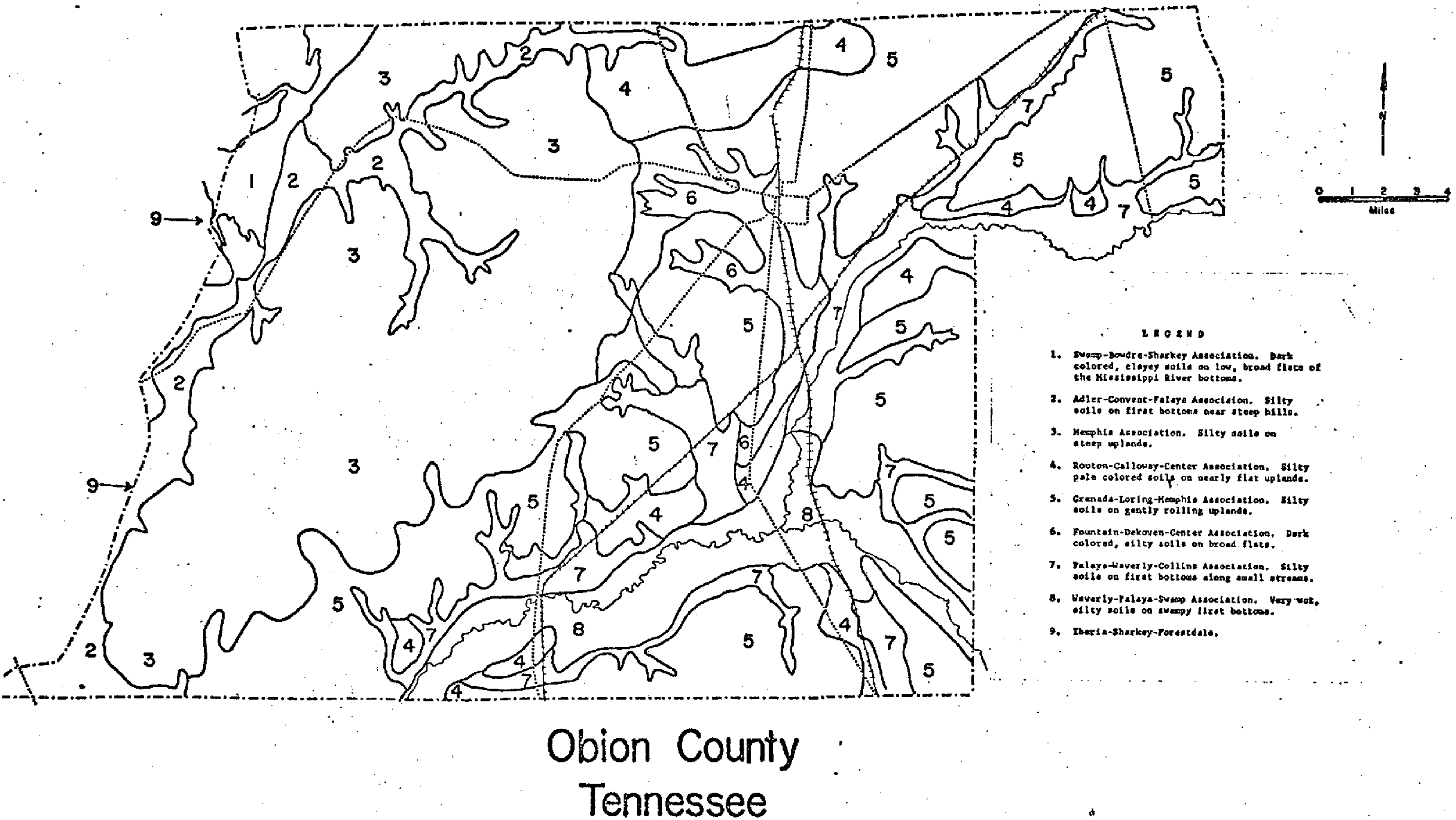

Figure 2. Soil Association Map of Obion County

is primarily through a vegetation-soil association relationship as most of the area is in pasture with small cultivated and wooded areas scattered within the overall area but the size of these are such that the ERTS imaging process intergrates them into the dominant vegetative cover of the area.

Figure 3 shows an overlay of the soil association map on Channel 7 of the 1, October, 1972 ERTS image of Obion County. This figure points out the extent of the soil association delineation within the county. In addition to the large block of the Memphis association and the Mississippi Delta, the swampy first bottom soils of the Obion River (Nos. 7 and 8) are easily detected. The more intensively cultivated soils of the area (Nos. 4, 5, and 6) tend to blend together and their delineation appears somewhat of a problem.

Inspection of the imagery, and considering the soil associations within the county, it is apparent that soils of the county could be classed into 4 groups based upon ERTS imagery (Figure 4). These groups would be

A. The Mississippi Delta Soils (Includes Nos. 1, 2 and 9 of Figures 2 and 3).

B. The Memphis Association (Includes No. 3 of Figures 2 and 3).

C. The Swampy first bottom soils along streams (Includes Nos. 7 and 8 of Figures 2 and 3).

D. The extensively cultivated upland soils (Includes 4, 5 and 6 of Figures 2 and 3).

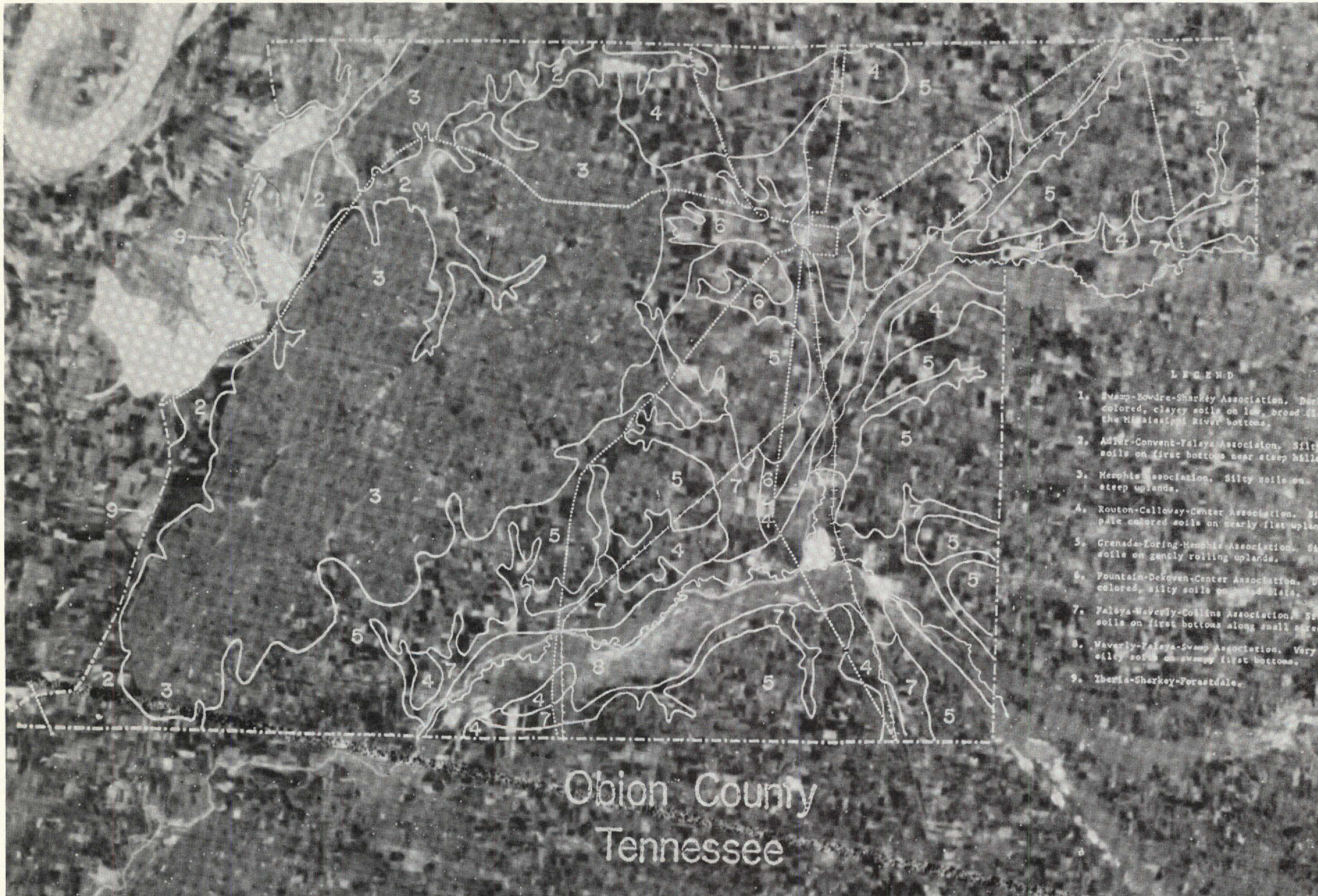

Figure 3. Channel 7 of 1, October, 1972 ERTS image with the Obion County soil association map superimposed on the image.

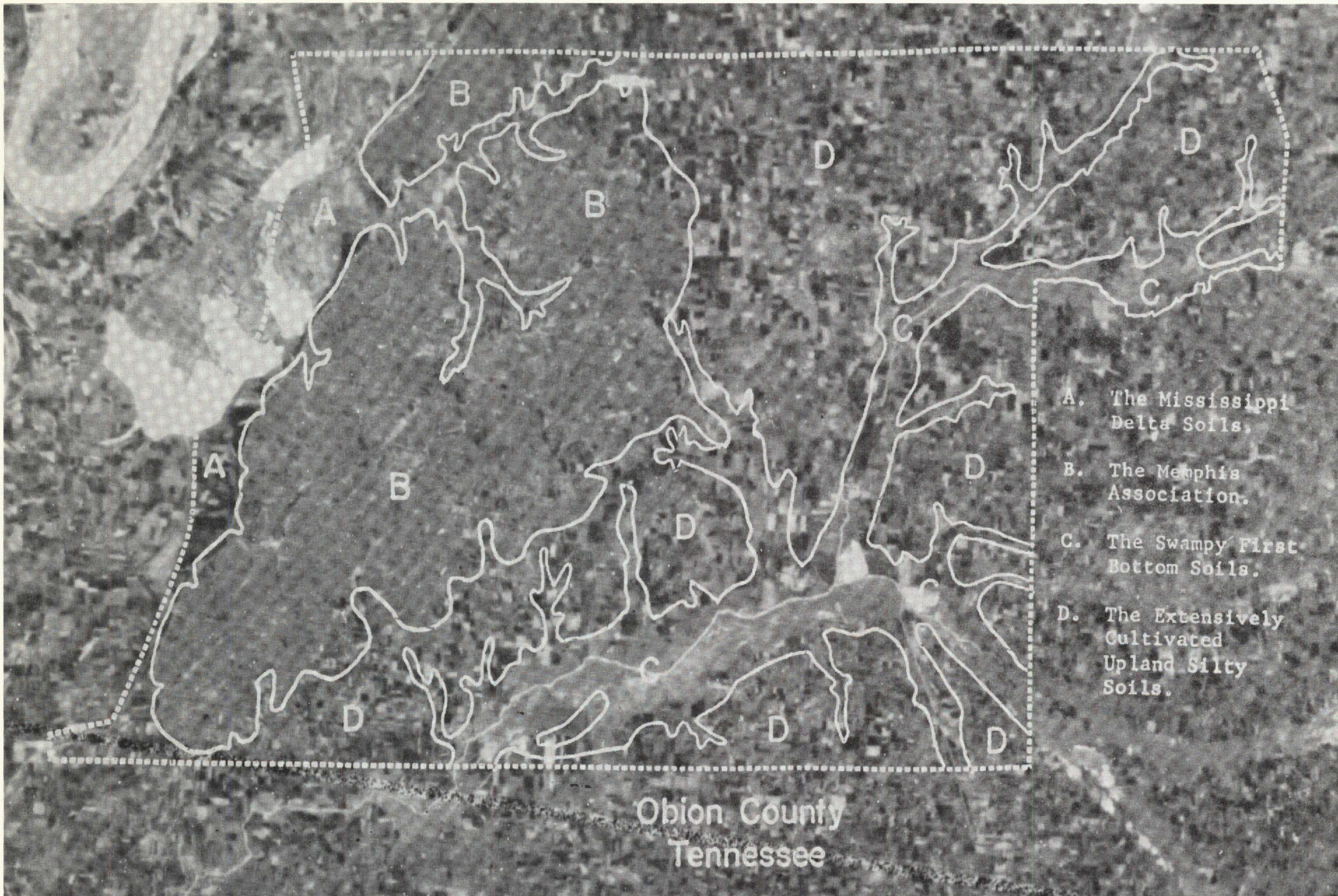

Figure 4. Four major soil groups of Obion County as delineated from Channel 7 of 1, October, 1972 ERTS image.

This would be considered a good grouping of the soils of a county similar to Obion. It represents areas where major land use and management would come into play in reaching the maximum utilization of the land resources within the region. The soils in Nos. 4, 5, and 6 were all developed from loess parent material and differ mostly in slope and internal drainage. The major portion of these soils is fairly well drained and is suitable for intensive agriculture, which is their present use.

Figures 5 and 6 show the computerized delineation of the Memphis Association, the Delta soils and Reelfoot Lake. A full grey scale is shown in Figure 5, while Figure 6 shows the same imagery through the data slicing procedures that permit sharper refinement of soil association boundaries.

The data for Figures 5 and 6 were received in the 9 x 9 positive transparency format and were converted to digital through the use of a scanning microdensitometer. A precision tape of this image was also obtained and an evaluation of it is shown in Figures 7 and 8. Figure 7 shows a full grey scale of the same area and Figure 8 shows the area through the data slicing procedure as used for the data in Figure 6.

Examination of these data show that the soils of the area may be divided into four groups as was shown the data analysis procedure using the positive transparency format. Generally, the data obtained from the tape did not greatly improve the individual Channel evaluation. Its advantages lie in Channel combinations, Channel differences, and computer overlays.

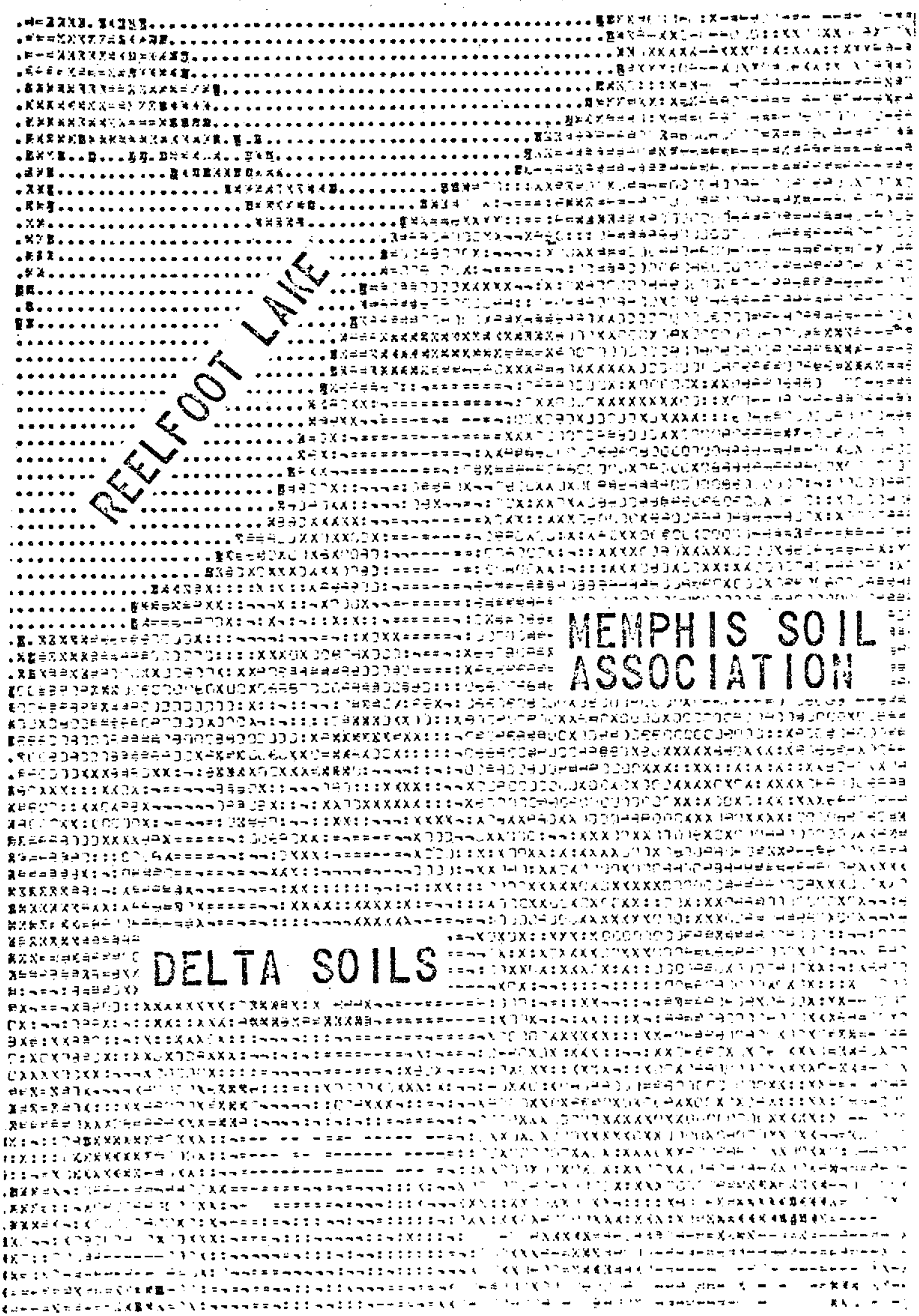

Figure 5. Full scale computer printout from Channel 7 of October 1, 1972 ERTS imagery showing Reelfoot Lake, Delta and Memphis soil associations in West Tennessee.

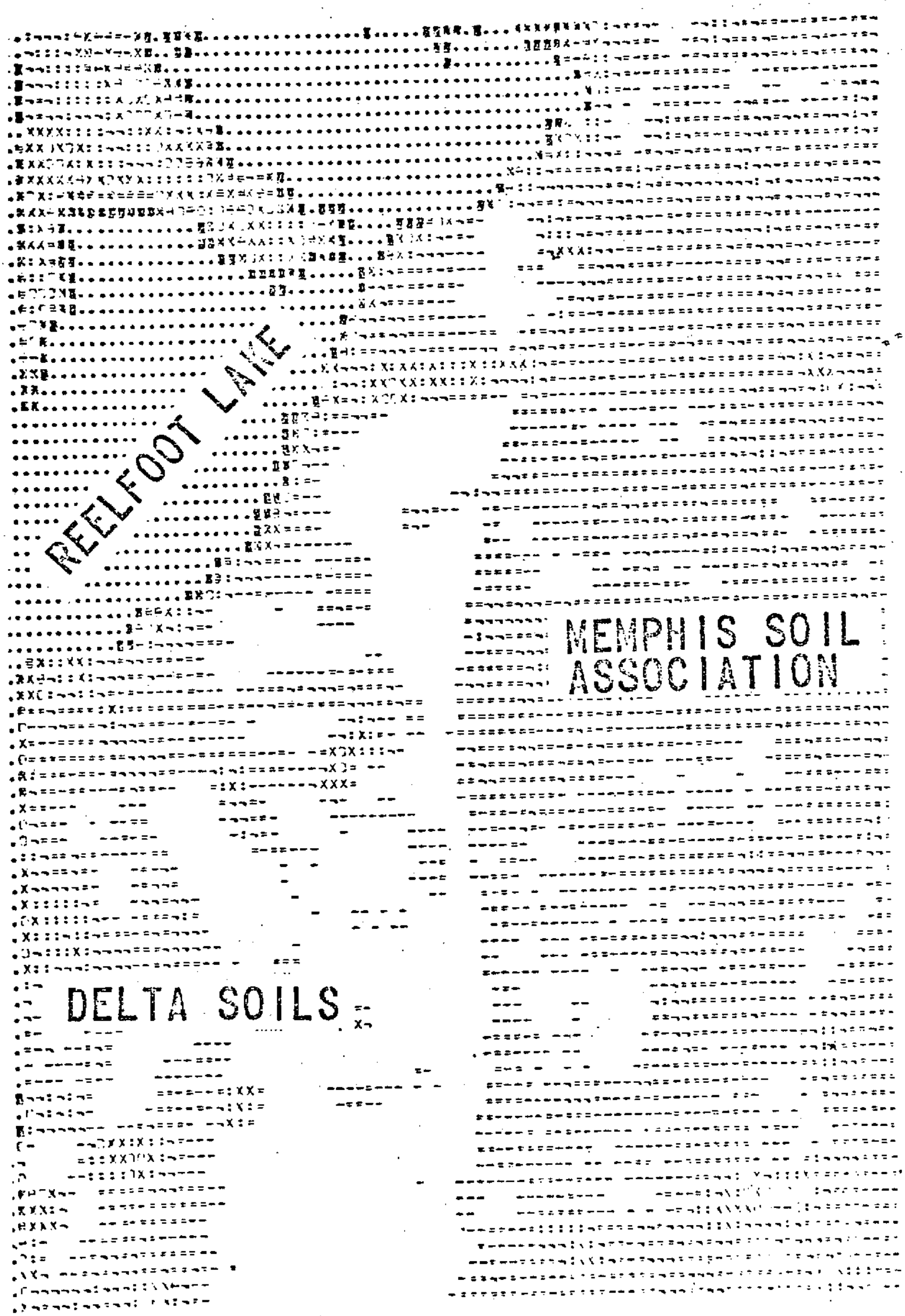

Figure 6. Computer printout from Channel 7 of October 1, 1972 ERTS image using data slicing technique to more clearly separate Reelfoot Lake, Delta and Memphis soil associations in West Tennessee.

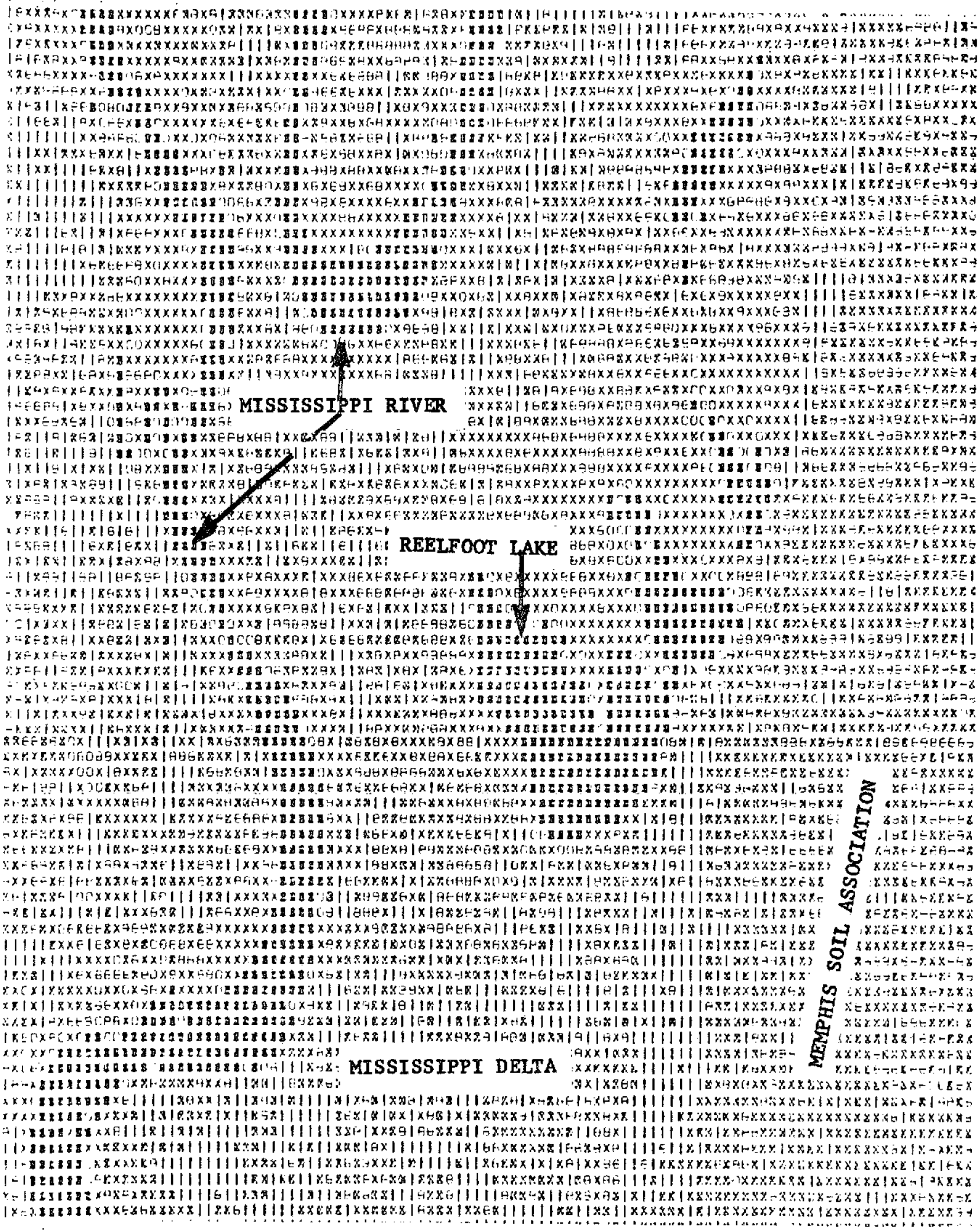

Figure 7. Computer printout from Channel 7 of October 1, 1972 ERTS precision tape using full grey scale to show Mississippi River, Reelfoot Lake, Delta and Memphis soil association in West Tennessee.

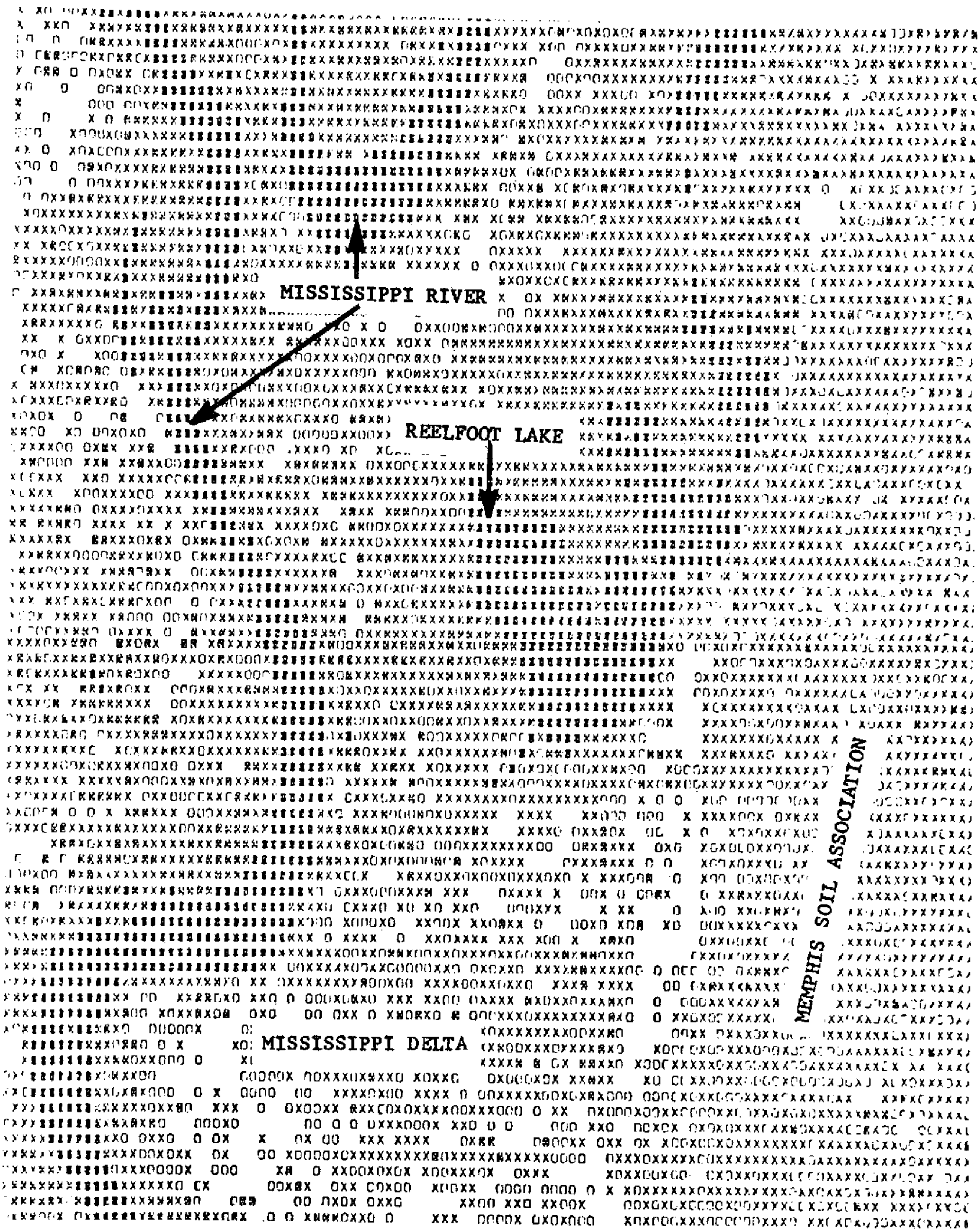

Figure 8. Computer printout from Channel 7 of October 1, 1972 ERTS precision tape using data slicing technique to more clearly separate Mississippi River, Reelfoot Lake, Delta and Memphis soil association in West Tennessee.

It may be concluded that ERTS imagery is adequate for the delineation of major soil associations. It does have the capacity to group soils into categories such that their land use and management would be similar within a given category. It would be of great value in preparing more accurate soil association maps of the states and would be extremely valuable in land use-development decisions in developing countries.

Chapter 2

DETECTING SOIL MOISTURE, DRAINAGE PATTERNS, EROSION, AND SEDIMENTATION

John I. Sewell and James B. Wills*

Introduction

Areas selected for study were in Middle and West Tennessee. These included the Ames Plantation near Grand Junction (Fayette and Hardeman Cos.), the West Tennessee Experiment Station at Jackson (Madison Co.), the Mississippi River area of Upper West Tennessee (Lake Co.), and Nashville and vicinity (Davidson Co.). 1972 ERTS imagery of 13 Sept., 1 Oct., 5 Nov., and 6 Nov. were most nearly free of cloud cover and most valuable for a variety of analyses. Aerial photographs of high quality were obtained of all West Tennessee sites by NASA-Houston on 18 Aug., 1972 and 4 May, 1973.

Analysis techniques included: visual studies of contact prints and enlargements of aerial photographs and space imagery, visual analyses of microdensitometry developed from ERTS transparencies, visual comparisons of all photographs and imagery with ground data, and studies of soil association maps. Studies of the following specific terrain and land-use features were made: flood plains, soil-moisture conditions, agricultural land-use unit identification and location, vegetated areas, water features, and changes in river shorelines and islands. Details of the basic procedures employed were reported by Sewell and Parks (15).

Procedures and Results

Ames Plantation and vicinity. The Ames Plantation has an area of 18,000 acres, of which approximately 2,000 acres are under cultivation with the remainder

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in permanent pasture and forest. Agricultural land-use units of greater than 100 acres could, from enlargements of high-quality ERTS imagery, generally be defined and located. This was especially true when a major definitely identifiable landmark (such as a lake or river) was available for use as a reference point.

Figure 9 (top), a 3.4 photographic enlargement of a black-and-white NASA-Houston negative print at 25,000 ft above ground level, gives a portion of the Ames Plantation vicinity on 18 Aug., 1972. Figure 9 (bottom), a 3.0 enlargement of a 1 Oct., 1972 channel 7 ERTS image of a large area including Ames Plantation, designates Holder Lake (A), a bend in the Wolf River (B), and the Ames Plantation area (C). In comparing the ERTS image with the NASA-Houston photo, three terrain features on the ERTS image were identified as the Caravell Bottoms (D, 178 acres), a field area (E), a field area (G, 130 acres), and a farm pond (F). The water, wet areas, and flood plain of the wooded Wolf River drainageway (B) are represented by the lighter tones of the ERTS image negative print, which clearly shows the visual detail afforded by the channel 7 image in delineating water features and flood plains. Lakes can be clearly identified.

The digital scanning microdensitometer and accompanying software developed by the University of Tennessee Department of Electrical Engineering was utilized to locate and study areas of particular interest which could be positively identified by aerial photos and ground studies. The microdensitometer quantitatively measured optical density of space-obtained imagery which was then recorded on computer tape. The resulting computer printout, in effect, produced an enlargement of up to 100 times that of the area scanned. The computer printouts have a maximum optical density range of 256 units. ERTS channels 5 and 7 appeared to give the best results for microdensitometer scans to investigate soil moisture conditions. Table 1 presents the results of a computer printout analysis of the 1 Oct., 1972 imagery which was of excellent quality.

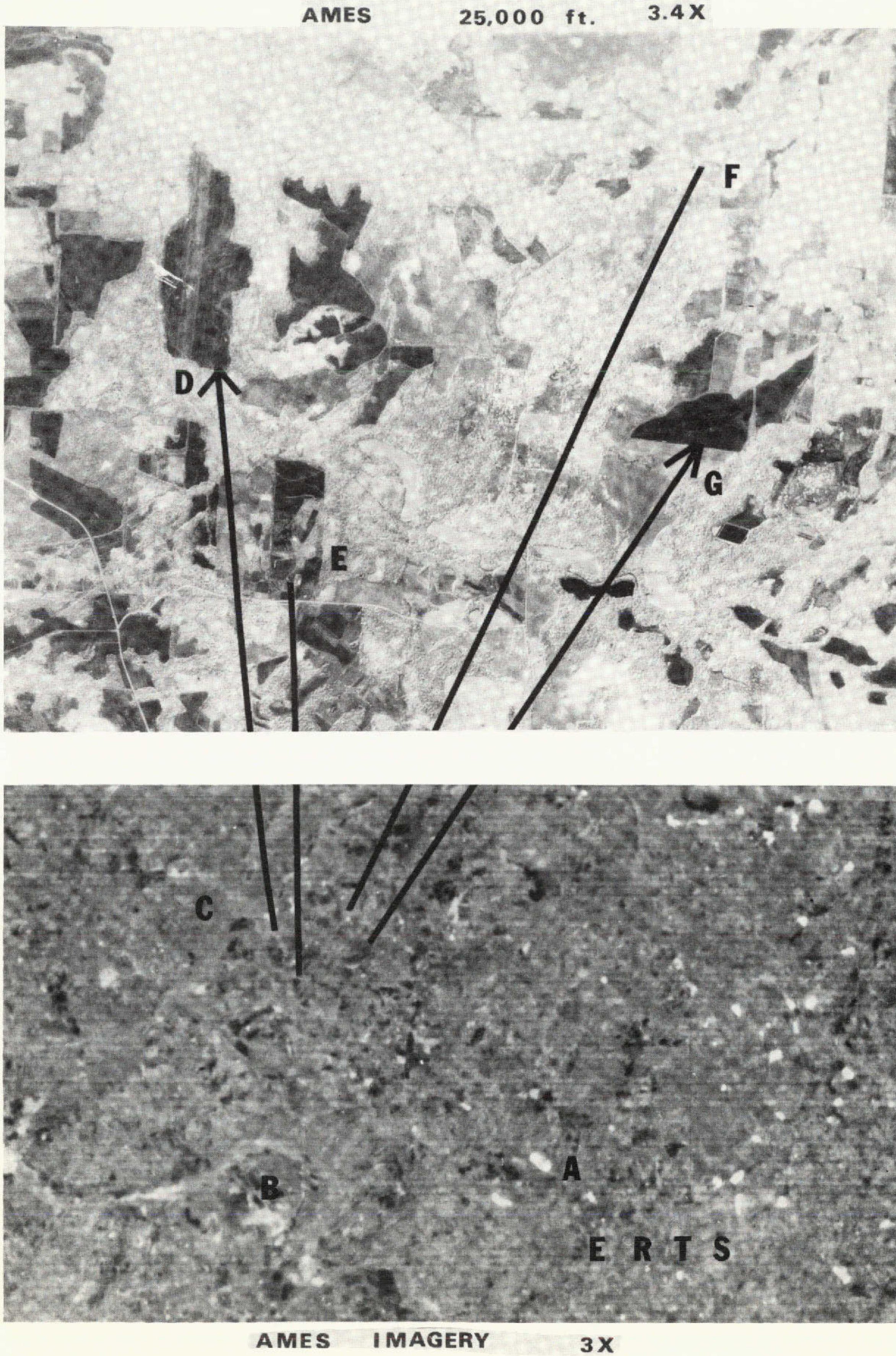


Figure 9. Black-and-white aerial negative print of Ames Plantation vicinity (top) and ERTS image (bottom) identifying Holder Lake (A), bend in Wolf River (B), field areas (D,E,G), and farm pond (F).

TABLE 1. Results of Computer Printout Analysis for 1 Oct. 1972 Imagery of Ames Plantation

MSS Channel	Density Subrange*	Land Use, Terrain Features, or Crops
	Density Range 140-190	
4	140-153	Pasture
4	154-169	Cropland
4	180-188	Forest
4	190	Water
	Density Range 150-240	
5	168-196	Cropland
5	218-238	Forest
5	240	Water
	Density Range 115-160	
6	115-133	Cropland
6	124-133	Pasture
6	133-144	Area around house and barn
6	144-157	Forest
6	159-160	Water
	Density Range 100-140	
7	105-120	Cropland
7	121-132	Forest
7	140	Water

*Optical densitometer is capable of 256 incremental density separations.

If density values appearing on each transparency were divided into four groups, the following results were found to hold true for each channel: water had the highest density value; forest land occupied the next highest level; cropland (mainly soybeans and cotton) usually had the third highest density level; and pasture had the lowest density value. Comparisons were based on ground studies of the test area. Channel 6 appeared to give the most information for making separations based on density ranges.

A visual study of color-composite imagery dated 1 Oct., 1972 indicated that soil moisture and soil temperature differences were better delineated by the color imagery than by the black-and-white imagery of the same area and date. Color imagery also gave a much better delineation between field boundaries of different crops. This could aid greatly in locating smaller crop areas which are difficult to locate on the black-and-white imagery.

Using the color-composite imagery, the crops and land features have been color coded with the following results: dark blue, water; bright red, cropland; purplish red, forest; and green, wet areas of cropland. Relating to soil temperature, the following apparent results were obtained from visual analyses of the color-composite imagery: dark red, warmest areas; purplish red, warm areas; green, moderately cool; and blue, coolest areas.

West Tennessee Experiment Station. The West Tennessee Experiment Station has a 125-acre, graded, bottom-land field lying in the flood plain of the Forked Deer River. Previous studies of this area were reported by Sewell et al (14) and Allen and Sewell (2). An enlargement of the channel 7 image of 6 Nov., 1972 (Figure 10) delineates from the surrounding terrain Interstate Highway 40 (A) and Jackson, the bottom-land field (B), water-filled gravel pits (C), the Forked Deer River flood plain (D), and a cultivated area (E) on a terrace formation above the flood plain. For comparison with the ERTS image of Figure 10, a NASA-Houston positive enlargement (Figure 11) of 18 Aug., 1972 at 25,000 ft gives the West Tennessee

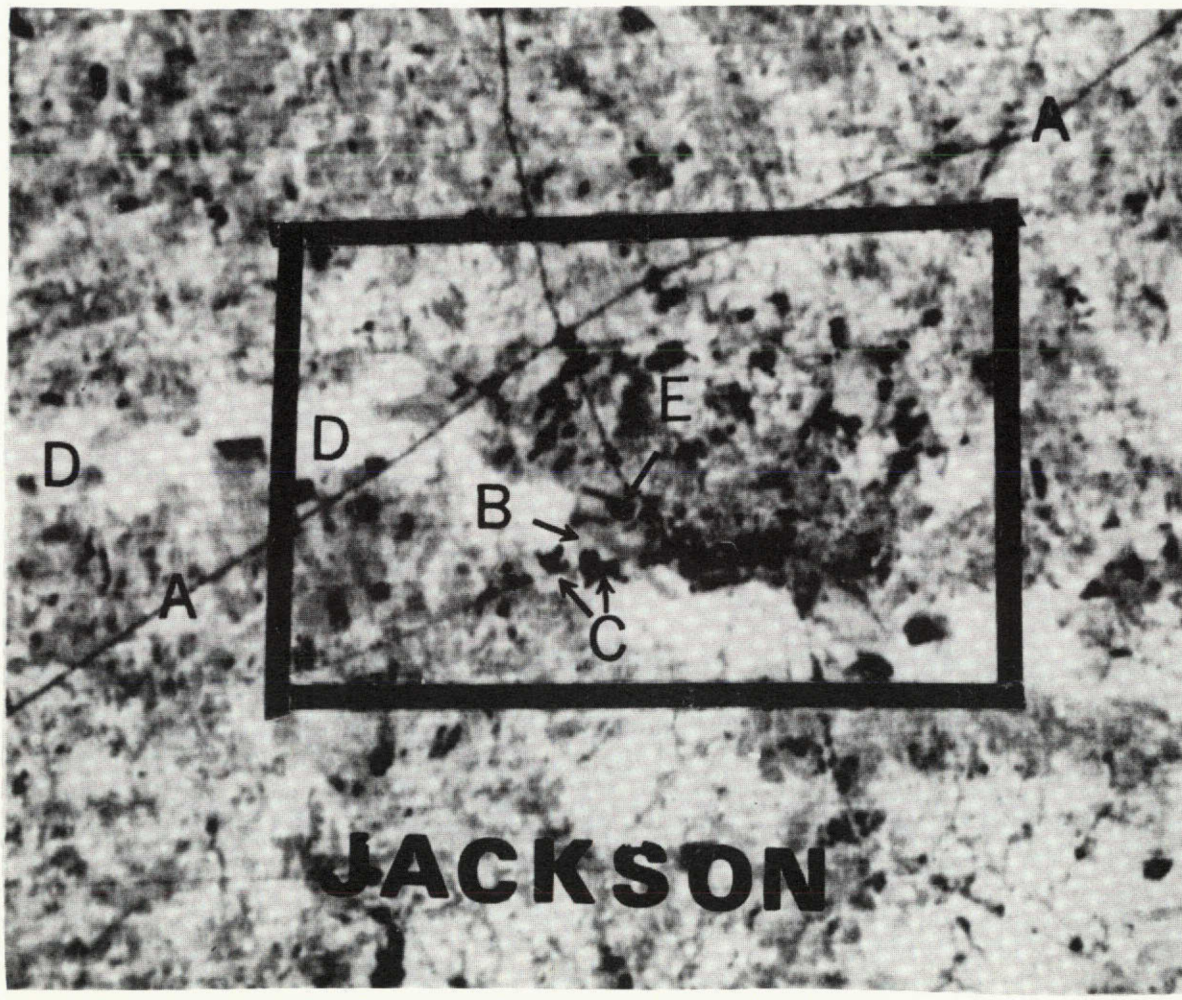
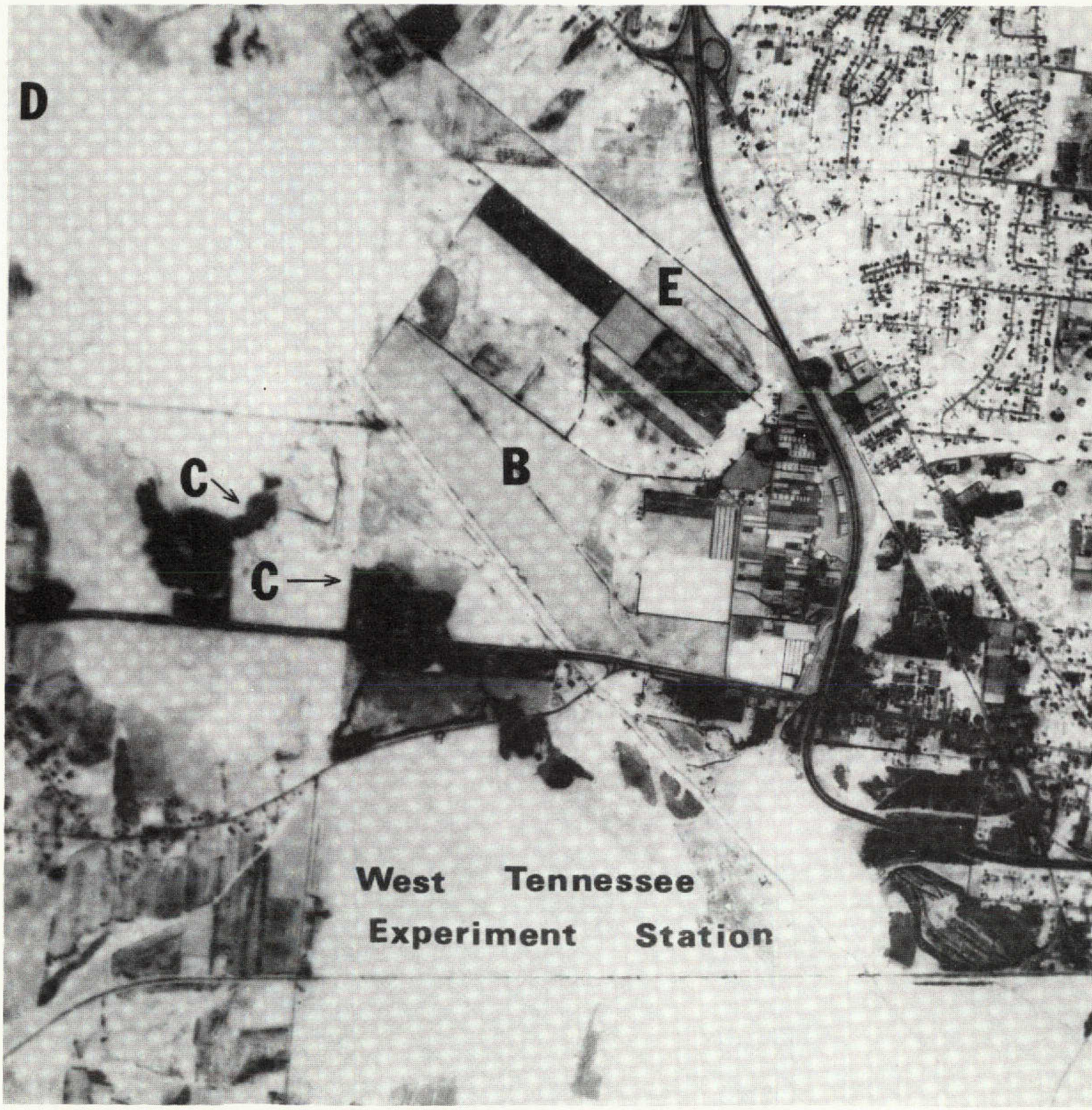


Figure 10. Channel 7 image of West Tennessee Experiment Station and vicinity on 6 November, 1972. Features include Interstate 40 (A), bottom-land field (B), gravel pits (C), Forked Deer River flood plain (D), and cultivated area on terrace formation (E).



25,000 ft. Aug. 72

Figure 11. Aerial photograph of West Tennessee Experiment Station area giving bottom-land field (B), water-filled gravel pits (C), the Forked Deer River flood plain (D), and the terrace formation field area (E).

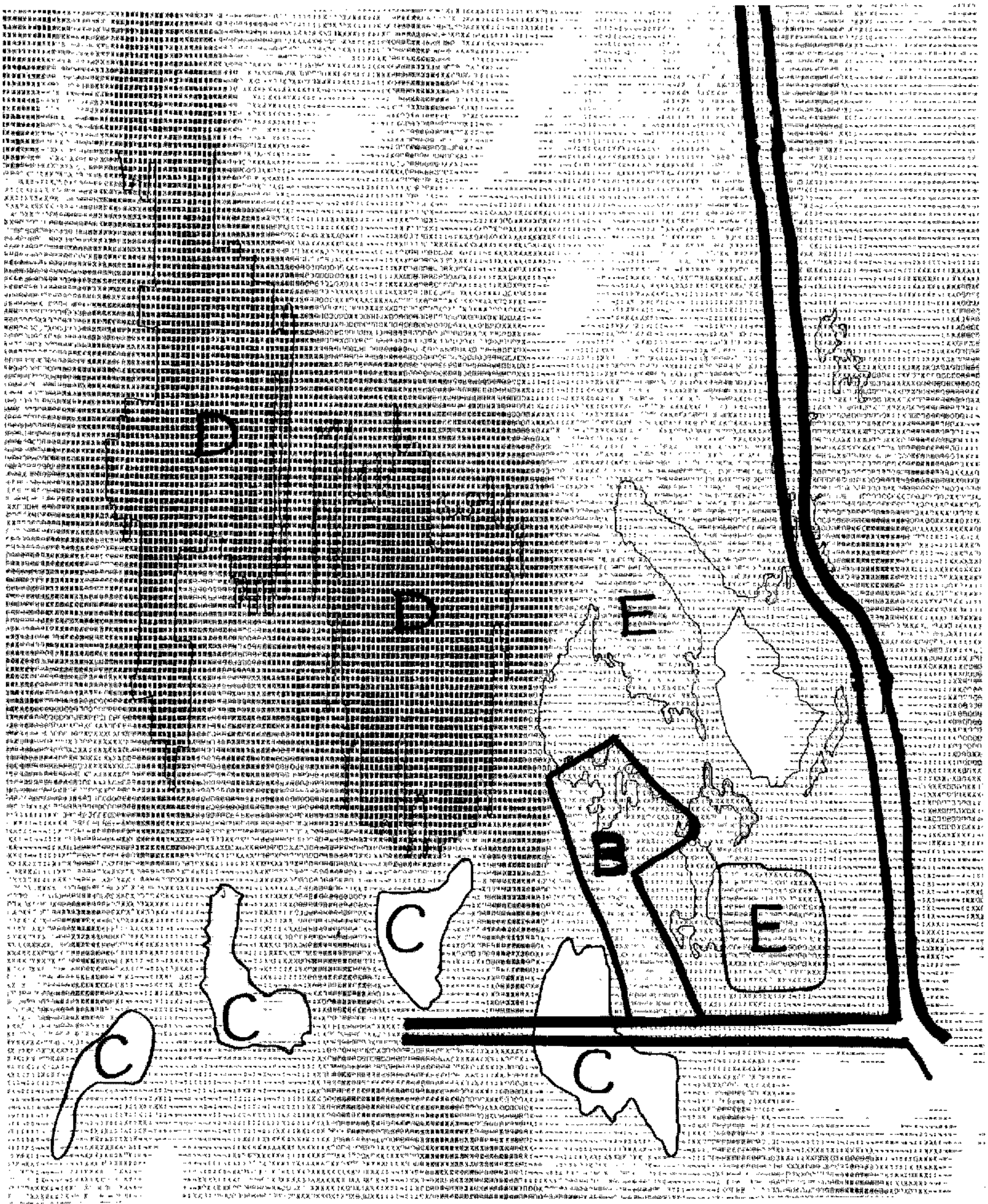


Figure 12. Computer printout of 6 November, 1972 channel 7 ERTS image of West Tennessee Experiment Station area giving bottom-land field (B), water-filled gravel pits (C), flood plain (D), and terrace formation field area (E).

Experiment Station bottom-land field (B), the water-filled gravel pits (C), the flood plain (D), and the terrace field area (E). A computer printout (Figure 12) developed from optical density values of the 6 Nov., 1972 channel 7 image outlined many of the same features which are denoted by the symbols of Figures 10 and 11. The printout suggests the inherent advantages possible through optical density "slicing" or separating into ranges. All microdensitometry and density printouts were developed by the University of Tennessee, Knoxville Electrical Engineering Department.

Mississippi River Area. A photographic enlargement (Figure 13) of the 13 Sept. channel 7 ERTS image of the Mississippi River (A) area of Upper West Tennessee was analyzed. Low-level aerial photographs and a U. S. Department of Agriculture Soil Survey (16) of Lake County presenting conditions in 1965 were excellent sources with which to compare the ERTS imagery. The shorelines of both Reelfoot Lake (B) and the Mississippi River (A) are very distinct. Area C represents forests, and typical cultivated lands are denoted by D. Small inlets of water located adjacent to the lake and the river can be readily identified. In 1965 an alluvial deposit (F) was not nearly so pronounced as in 1972. Some of the islands which are mapped on the 1965 Mississippi River Soil Survey do not appear (G) on the 1972 ERTS image; also, other small islands not mapped in 1965 were present (E) in 1972. These differences represent changes in the sizes, shapes, and even the locations of the islands between 1965 and 1972.

This is an excellent example of how ERTS imagery could be used in analyzing erosion and sedimentation along rivers and in rapidly mapping changes in river channels. This could provide up-to-date information which could be of great help in updating river navigation charts and maps. Also, since ERTS imagery periodically covers large areas, its imagery could be valuable in making rapid gross estimates of flood damage over a large area.

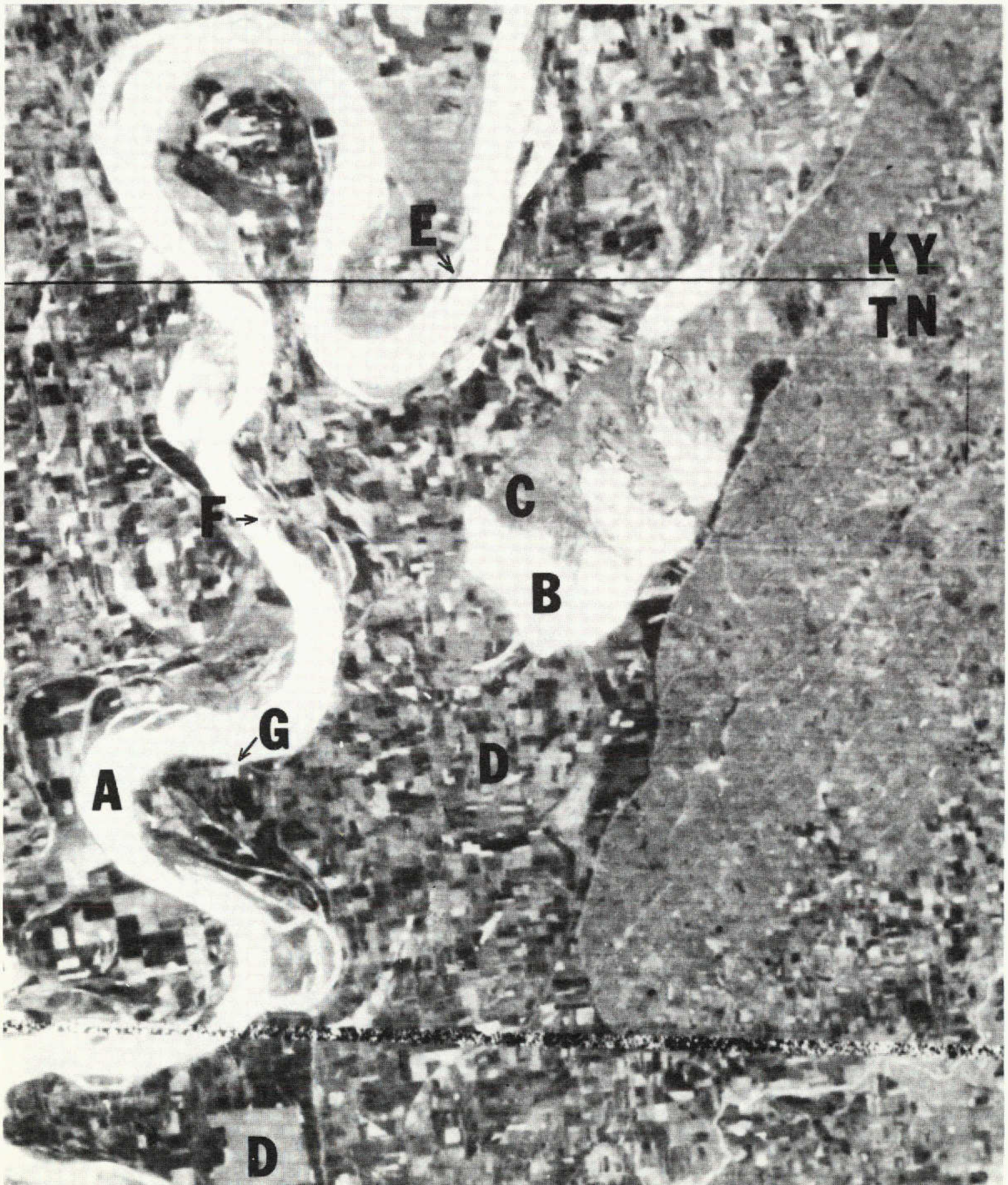


Figure 13. Channel 7 ERTS image on 13 September, 1972 of Mississippi River area of upper West Tennessee outlining Mississippi River (A), Reelfoot Lake (B), forest (C), cultivated lands (D), island (E), and alluvial deposit (F).

Nashville and vicinity. The 5 Nov., 1972 channel 7 scan of Middle Tennessee and the Nashville area (Figure 14) was analyzed visually and by computer printout of optical density data. In the visual analysis of the Nashville vicinity, the small, mostly rectangular-shaped areas varied in gray density from light, almost white to very dark, almost black; but most of the immediate area (B) surrounding the metropolitan district was light gray. However, several areas were very dark in texture. In relating the dark areas to a map of Nashville, they were found to correspond to parks and golf courses. Richland Golf Course (D) and McCabe Golf Course (E) are shown. The dark areas on the image, therefore, represented open, grass-covered areas. Water features also appeared as light tones; the Cumberland River (A) and Marrowbone Lake (C) are easily identified.

The computer printouts of the ERTS imagery of the Nashville area were difficult to analyze. The computer printouts did define the optical densities of each small increment of the imagery, but they enlarged the imagery to such an extent that some of the definition and clarity was lost when compared with the original image. However, lakes were clearly identified by the printout.

Conclusion

ERTS imagery offers definite potential for making gross flood-plain, wetland, river shoreline, and land-use change surveys. For example, urban sprawl, land drainage or flooding, obstructions to river navigation, and major land-use changes could be most valuable to a wide range of planning agencies.

The general outline of single-use land areas exceeding 100-125 acres could normally be defined on cloud-free ERTS images, although establishing a distinct field boundary would appear almost impossible. As suggested by the paucity of high-quality imagery received, unfavorable atmospheric conditions at the time of flight coverage would present, at least for humid areas, a major obstacle to studies requiring sequential, seasonal, or timely coverage.

Figure 14. Upper Middle Tennessee ERTS image of 5 November, 1972 outlining Cumberland River (A), Nashville (B), Marrowbone Lake (C), Richland Golf Course (D), and McCabe Golf Course (E).

While optical density subranges for land uses were rather definitely established for the 1 Oct. Ames Plantation imagery, studies of imagery of other dates indicated that these subranges can be expected to change with seasons, atmospheric conditions, and other extraneous variations within dates. Thus, spot-check ground surveys would appear necessary for each image data analyzed.

CHAPTER 3

Differentiation Between Healthy and Diseased Corn and the Presence and Spread of Maize Dwarf Mosaic Virus and Southern Corn Leaf Blight

by

J. W. Hilty*

No ERTS imagery was received covering the target area during the time of year when studies on maize dwarf mosaic virus and southern corn leaf blight are active so no report on this phase of the ERTS investigations are possible. Prior results from aircraft imagery on plant disease studies are reported in Agricultural Experiment Station Bulletin No. 505.

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CHAPTER 4

Prediction of Forest Land-Use from ERTS-Imagery

J.C. Rennie and E.E. Birth*

Forest land-use can be classed by species composition or volume class or both. Classification of forest land-use has at least two important applications in evaluation of forest resources. First, these classes can serve as the basis for stratification of forest lands to improve the efficiency of timber inventories. A second use is that such classifications, repeated over time, may be used to assess the change in the size and composition of the forest resource.

Multispectral satellite imagery offers a data source for classification of forest land-use over extensive areas of the earth's surface. Objectives of this study with ERTS-1 imagery are 1) to determine the utility of satellite imagery to predict forest land-use when field observations are used as ground truth and 2) to determine the utility of satellite imagery to predict forest land-use when aircraft imagery is used as ground truth.

Test Site

The test site for this study was Polk County, Tennessee, which is located in the southeastern corner of the state. The eastern three-fourths of the county are mountainous, being in the Appalachian Mountains, while the western fourth is gently rolling farmland in the Great Valley.

Polk County was chosen as a test site because it has extensive forested areas suitable for this study and two rivers traversing it, which could be used for registration. Also, there exists considerable T.V.A. and U.S.F.S. information on its forest resource.

*Assistant Professor and Graduate Research Assistant, Department of Forestry.

Description of Imagery

ERTS-1 imagery

One set of acceptable ERTS-1 imagery covering Polk County was obtained between the launch date and 31 March 1973. This multispectral scanner imagery (observation identifier 1084-15433) was acquired on 15 October 1972; its central point coordinates were 34°33'N and 83°57'W.

Supplimentary aircraft imagery

Medium altitude aircraft imagery was flown on 23 March 1973 by N.A.S.A. using a C-130 at an altitude of 23,600 ft. The flight line was from 35°2.3'N, 84°30.0'W to 35°17.0'N, 84°30.0'W. In addition to infrared scanner imagery (8µm to 14µm), four Hasselblad 70mm cameras were used to obtain coverage with the following film/filter combinations: 2402/25, 2402/57, 2443/12 and 2424/89B.

Procedures

The aircraft imagery was the basis for locating ground plots to obtain field data. Both aircraft imagery interpretations and ground data were used to evaluate the ERTS-1 imagery for predicting forest land-use.

Interpretation of aircraft imagery

Enlargements of the three rolls of black and white photo images were prepared to a size convenient for handling and interpretation. After three days of cursory ground truth collection, it appeared that Roll No. 18 (2402 film with #25 filter), frames 24-33, was the most easily interpreted as to forest type. It was anticipated that the ERTS-computer system would interpret three types - pine, hardwood and mixed pine-hardwood.

Roll No. 18 photos were interpreted on a Zeiss Stereopret with the photos oriented by the procedure shown in the Zeiss manual, except that there were no fiducial marks on the photos and the principal point was located from the corners of the photograph, a procedure that is inexact but sufficient for this purpose.

Two scale determinations were made for each photograph using points that could be identified on TVA and USGS 7-1/2" quadrangle topographic maps. At the scale of this photography, geodetic control might be identifiable by strips or blocks in areas where good maps are not available. The Stereopret pantograph was set such that mean photo scale would be enlarged to 1:24,000. Where types were correlated with elevation, the use of mean photo scale for the entire strip would introduce a bias, but examination of the photos indicated that each of the types existed in roughly equal proportions at all elevation. The result of using mean photo scale was that a portion of the stand areas were inflated in area and an approximately equal portion of the areas were deflated in area.

On Roll No. 18 there was little or no difference between types in terms of texture, but the tone for the different types was substantially different. The major streams and a portion of the cleared areas had a distinct tone and could be mapped out of the forest acreage. After the interpretation by the three types and non-forested area, each of the interpreted models was matched with the appropriate 7-1/2" quadrangle topographic map and it was noted that rivers and power-line rights-of-way were accurately mapped, while roads and fields were less accurately located.

Roll No. 21 of the NASA flight (2424 film with #89B filter), frames 001 through 009, showed a great deal of texture, including individual tree crowns or groups of crowns, and little or no tonal variation that appears to be correlated with type. Non-forested areas; i.e., in particular cleared fields, were much more distinct than on Roll No. 18, while clear-cut forested areas were less distinct except for reduced texture.

After orientation matching that of Roll No. 18, Roll No. 21 was interpreted for five different classes of cubic foot volume per acre as follows:

Class 1 - less than 200 cu. ft. per acre

Class 2 - 200 to 1000 cu. ft. per acre

Class 3 - 1000 to 1400 cu. ft. per acre

Class 4 - 1400 to 2200 cu. ft. per acre

Class 5 - more than 2200 cu. ft. per acre

The volume classes used were derived from the TVA July, 1970, Forest Inventory Statistics for Polk County, and Class No. 3 was defined to include within its range the mean cubic foot volume according to TVA. This mean volume could just as well have been arrived at by a very few sample plots located at random through-out the county.

The interpretation for volume class was done on .15" row spacing x .167" column spacing photo scale grids, and the notes were kept on 1" grid drafting film. At the scale of the type interpretation, there were approximately 40 interpreted points per square inch, but since this was not an exact scale factor, the drafting film chart was not a map, but rather a convenient positional notation. The right hand portion of the left hand photo in the model was marked with lines parallel to the flight line and spaced at .45" in order to control photo position for the interpretation and transfer the interpretation to the drafting film chart.

Subsequent to the collection of field data, forest type was interpreted on Roll No. 20 (2443 film with #12 filter). The interpreter was not recently familiar with the forest types of this portion of Polk County. The types were plotted on T.V.A. 7-1/2" quadrangle topographic maps and then transferred to tracing paper.

Selection and location of ground samples

Lists were prepared by column and stereo model for each volume stratum. From these lists 19 sample stands were selected in each type by list sampling. This sample size was expected to result in a sampling error of 5% at this stage of the inventory.

Since the position of the stand on the list was taken from a specific position on the chart, it was possible to locate these stands on the ground, particularly since both Roll 21 and Roll 18 photography were available to assist in identifying the stands and their location in the terrain.

Inventory of sample stands

Within each of the 19 sample stands per type, 9 prism points were established from which a sub-sample of trees to be measured was drawn. This design is described as APT-3 by Grosenbaugh in STX 1-11-71 (4).

The inventory on the ground consisted of:

a. Locating the center of selected stands.

b. Establishing the central point of 9 equally spaced points with grid intervals of 2.5 chains.

c. Predicting heights in terms of 8-foot sections (half-log intervals) of BAF 10 prism-selected trees for comparison with the random number list in selecting sample trees.

d. Measuring these trees, including culls with estimated height greater than the corresponding random number or greater than the maximum height for 3P sampling for eventual calculations of cubic foot volume outside bark. A Wheeler pentaprism optical caliper was used to measure the diameter outside bark at numerous points on the merchantable portion of the bole.

The ground inventory of a 5-chain square area within a stand tended to avoid the edges of stand as interpreted because the interpretation was based upon a grid approximately 10 chains square. This approach was intended to be comparable to the ERTS scanner-computer system, which was expected to "slice" at levels rather than interpret a continum of types and volume classes.

Summarization of field data

Frequency counts of the "in" trees from the nine sample points were made for each stand. When 70% or more of the stems were hardwood or pine, the stand was assigned to the hardwood or pine type, respectively; otherwise it was classified as being in the mixed type. Since the "in" trees were selected with a BAF 10 prism, the basal area of pines and hardwoods is proportional to the frequencies and the assignment to species type is based on relative basal area of pines and hardwoods.

Assignment of ground visited stands to a volume stratum was on the basis of the following formula from Grosenbaugh (5):

$$\text{Volume (cu. ft./acre)} = \frac{BAF}{NP} * \sum_{1}^{NP} \sum H * \frac{\sum_{1}^{n} \left(\frac{V}{BA * H} \right)}{n}$$

Where BAF = basal area factor of prism used in selection of trees, 10 sq. ft./A. in this work

NP = number of sample points per stand, 9 in this work

ΣH = aggregate estimated height of all prism selected trees at a sampling point

n = number of trees on which stem measurement were acquired

V = cubic foot volume of measured tree

BA = basal area of measured tree

H = estimated height of measured tree

Interpretation of ERTS-1 imagery

The portion of the four bands of ERTS-1 imagery covering Polk County was scanned with a Technical Operations Scandig Model 25 high speed, digital, x-y scanning microdensitometer. At sampling points 100μm in diameter on a 100μm x 100μm grid, the optical density was determined on a scale having 256 density levels. The output was stored on magnetic tape with a Kennedy Model 3110 9-track digital tape recorder. Using the computer program OPSCAN (8), gray-scale maps were produced for registration of the bands of imagery, location of ground plots with respect to ERTS-1 imagery and determination of density levels on each band for plot locations.

Location of ground plots on gray-scale computer maps of ERTS-1 imagery was accomplished by first transfering their location to 10 division/inch x 10 division/inch graph paper, then to specially prepared 10 division/inch x 16.667 division/inch graph paper and finally to the computer maps. Use of this non-typical size was necessary to transform the East-West scale to conform with that of the computer maps, while keeping the North-South scale constant. Two prominent water bodies were used to register the plot location map with the computer maps. The gray scale level was read for the element onto which each ground plot was located.

Analysis of data from ERTS-1 imagery

The gray-scale levels for the points on the ERTS-1 imagery computer maps corresponding to ground plots were examined using discriminant analysis (13). To meet the first objective of the study, discriminant functions were developed to predict species composition and volume stratum using the species composition and volume classed of the ground plots as training sets. In addition, it seemed reasonable that the data recorded on the aircraft imagery should be correlated to the data recorded on the ERTS-1 imagery. To test this hypothesis and meet the second objective, the species composition and volume strata interpreted from the aircraft imagery were used as training sets for discriminant functions applied to the ERTS-1 imagery.

Results

Comparisons of photo interpretation of aircraft imagery with the ground inventory are presented in Tables 2,3, and 4. Results of the discriminant analyses developed for prediction volume strata and forest type using ground data for training are presented in Tables 5 and 6, while results of discriminant analyses using aircraft imagery for training are presented in Tables 7, 8, and 9.

Prediction of volume stratum from the aircraft imagery resulted in 21 correct interpretations and 24 interpretations within one stratum for the 56 ground points visited (Table 2). The number of points correctly interpreted is determined by summing the number of stands in the same volume stratum by ground-based assignment as imagery-based prediction for all volume strata.

Success at predicting forest type or species composition from aircraft imagery was considerably lower than for volume strata. Using the 2402 film with #25 filter, only 13 stands were placed in the forest type estimated from the ground data (Table 3). Because of this poor correspondence, the 2443 film with #12 filter was used to develop a second forest type map; here, the imagery-based interpretation agreed with the ground data for 26 stands (Table 4).

Table 2: Comparison of predicted volume strata from 2424 film with a #89B filter and actual volume strata from ground inventory.

Observed volume classes	Imagery-based prediction <200 cu ft/A	200-1000 cu ft/A	1000-1400 cu ft/A	1400-2200 cu ft/A	>2200 cu ft/A
<200 cu ft/A	0	0	0	1	0
200-1000 cu ft/A	1	4	3	2	1
1000-1400 cu ft/A	1	0	1	7	0
1400-2200 cu ft/A	1	1	9	14	3
>2200 cu ft/A	0	2	2	1	2

Table 3: Comparison of predicted species composition from 2402 film with #25 filter and actual species composition for 56 plots examined on the ground.

Observed forest type	Imagery-based prediction Hardwood	Pine	Mixed
Hardwood	3	9	7
Pine	4	1	4
Mixed	12	7	9

Table 4: Comparison of predicted species composition from 2443 film with #12 filter and actual species composition for 56 plots examined on the ground.

Observed forest type	Hardwood	Pine	Mixed
Hardwood	5	2	10
Pine	0	8	1
Mixed	5	11	13

The computer-produced maps for bands 4 and 5 of the ERTS-1 imagery lacked the detail for registration with bands 6 and 7. Registration between bands 6 and band 7 was possible, but not as precise as desired for accurate transfer of ground plot locations. Thus, the discriminant analyses have only the optical density levels from bands 6 and 7 as independent variables.

Two groups of training sets were available for developing discriminant functions for the ERTS-1 imagery: the ground observations and the interpretations of the aircraft imagery. Using the ground observation, 29 correct classifications of volume stratum and 15 additional classifications within one class of the ground-based estimate resulted where 55 points were considered (Table 5). Species composition agreed with the ground observations for 34 of 56 points on the ERTS-1 imagery (Table 6).

Table 5: Comparison of observed and discriminant analysis predicted volume strata for ERTS-1 imagery where 55 ground-assigned volume strata served as training set.

Observed volume classes	Volume strata predicted with discriminant analysis			
	200-1000 cu. ft./A.	1000-1400 cu. ft./A	1400-2200 cu. ft./A.	>2200 cu. ft./A.
200-1000 cu. ft./A.	2	1	8	0
1000-1400 cu. ft./A.	0	1	8	0
1400-220 cu. ft./A.	2	0	25	1
>2200 cu. ft./A.	0	1	5	1

Table 6: Comparison of observed and discriminant analysis predicted species composition for ERTS-1 imagery where 56 ground-assigned species compositions served as training set.

Observed forest type	Species composition predicted with discriminant analysis		
	Hardwood	Pine	Mixed
Hardwood	8	1	9
Pine	0	1	8
Mixed	4	0	25

Using the aircraft imagery as training sets resulted in fewer correct predictions than were found with ground observations as training sets. Volume stratum was predicted correctly for 19 points and within one stratum for 15 more points where 56 were being considered (Table 7). For both sets of aircraft imagery used to interpret species composition, 25 of 56 stands were correctly classified (Tables 8 and 9).

Table 7: Comparison of discriminant analysis predicted volume strata for ERTS-1 imagery and interpreted volume strata from aircraft imagery (2424 film with a #89B filter) where 56 photo-interpreted points served as training set.

	Volume strata predicted with discriminant analysis				
Photo-interpreted volume classes	<200 cu. ft./A	200-1000 cu. ft./A.	1000-1400 cu. ft./A.	1400-2200 cu. ft./A.	>2200 cu. ft./A.
<200 cu. ft./A.	0	0	0	1	2
200-1000 cu. ft./A.	1	0	1	0	5
1000-1400 cu. ft./A.	1	1	2	2	10
1400-2200 cu. ft./A.	1	1	2	13	7
>2200 cu. ft./A.	1	0	0	1	4

Table 8: Comparison of discriminant analysis predicted species composition from ERTS-1 imagery and interpreted species composition from aircraft imagery (2402 film with a #25 filter) where 56 photo-interpreted points served as training set

	Species composition predicted with discriminant analysis		
Photo-interpreted forest type	Hardwood	Pine	Mixed
Hardwood	9	9	1
Pine	3	13	1
Mixed	6	11	3

Table 9: Comparison of discriminant analysis predicted species composition from ERTS-1 imagery and interpreted species composition from aircraft imagery (2443 film with #12 filter) where 56 photo-interpreted point served as training set

Photo-interpreted forest type	Species composition predicted with discriminant analysis		
	Hardwood	Pine	Mixed
Hardwood	2	6	2
Pine	4	14	2
Mixed	3	13	9

Conclusions

Results of the analyses of aircraft imagery show no strong relationships between predicted forest types or volume strata, and the observed levels of the corresponding variables. Discrepancies between the aircraft imagery interpretations and ground observations arose due to the season in which the imagery was obtained. Being flown in early spring, it recorded the forest vegetation in a state of considerable flux. This appears to be a partial explanation for the large number of stands predicted as pine on the aircraft imagery and then being classified as hardwood or mixed from the ground observations. When the imagery was flown, yellow-poplar was in leaf while most other hardwoods were still without foliage; this, and the similarity in stand structure between yellow-poplar and pine, could result in a considerable number of misinterpretations. Thus, much care must be used in scheduling flights or selection of imagery to insure maximum differentiation between images of forest types. On the color-infrared (2443 film with #12 filter), it was possible to identify the yellow-poplar; however, this did not improve the results to an acceptable level.

Prediction of volume strata and forest type from the two usable bands of ERTS-1 imagery were also of questionable value. Two factors appear to be acting to cause this lack of correspondence. First, different imagery aquisition times may explain why poorer results were found with aircraft imagery training sets than with ground observation training sets. That is, better correspondence was found between ground observations and ERTS-1 imagery predictions than between early-spring aircraft imagery observations and mid-autumn ERTS-1 imagery predictions. However, this does not reject the hypothesis that satellite imagery predictions with aircraft imagery training sets would yield at least as good results as predictions with ground observations as training sets where the aircraft imagery and satellite imagery are taken during the same season.

The second cause of the poorer results with ERTS-1 imagery appears to be the lack of good photogrammetry possible with the data processing system used. Scale determination varied from map to map and within each map. Within-map differences were due to the difficulty in locating corresponding points on the computer maps and the T.V.A. maps. Between-map differences were due to differences in representations of the prominent features, such as lakes and rivers, used for scale determination. Without reliable map scales, location of training set points and subsequent response level determinations become questionable. The variation in representation of prominent features also made registration difficult; good registration is needed to assure determinations of optical density levels are being made on the same point from one band to another.

Further problems arise with each new generation of data. The contact prints, Figure 15, made from the second generation data, the imagery negative, show considerably more detail than the computer maps produced from the same imagery negatives. Of particular importance are the lakes and rivers visible on imagery of bands 4 and 5, but not evident on the computer maps. Loss of these features resulted in the loss of these two bands of ERTS-1 imagery for the analyses described.

It appears that some of these problems would be avoided, or at least minimized, if first generation data in the form of magnetic tapes were used in the analyses of ERTS-1 imagery for forest land-use classification. With this data form, registration would be assured, scale determination simplified and information on ground situations subject to fewer degradations. Results of this research are reported in Rennie and Birth (12).

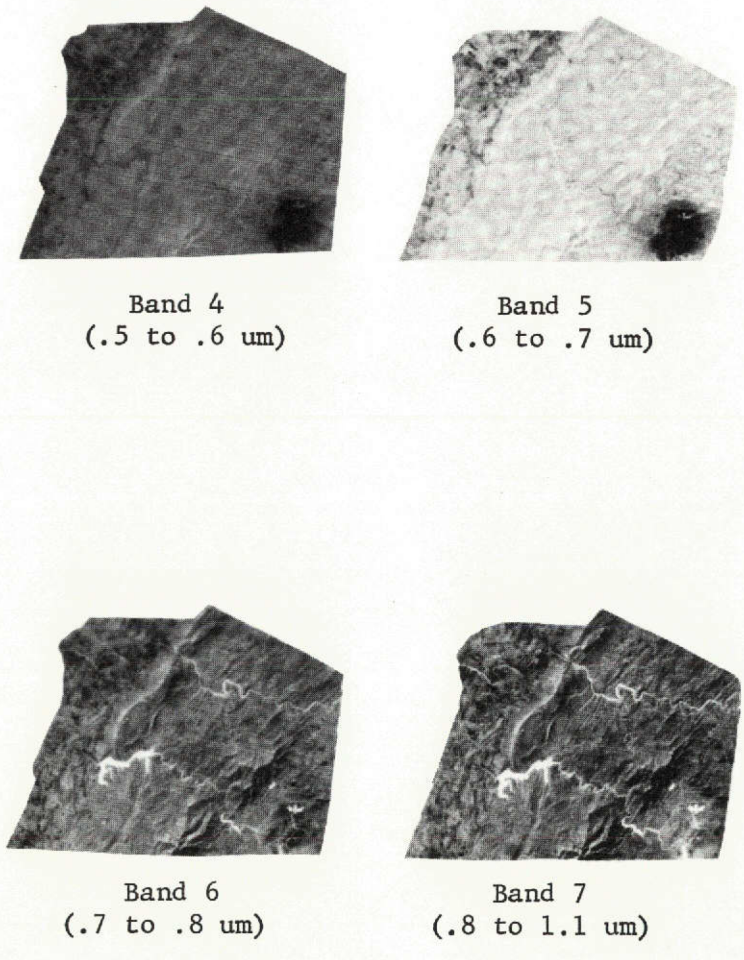

Figure 15: Contact prints of four bands of ERTS-1 imagery from 15 October 1972 with Polk County, Tennessee, deliniated

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