NASA Reference Publication 1016

The Use of Landsat Digital Data and Computer-Implemented Techniques for an Agricultural Application

Armond T. Joyce and R. H. Griffin II

JANUARY 1978

NASA

NASA Reference Publication 1016

The Use of Landsat Digital Data and Computer-Implemented Techniques for an Agricultural Application

Armond T. Joyce and R. H. Griffin II
Lyndon B. Johnson Space Center
Houston, Texas

NASA
National Aeronautics
and Space Administration

Scientific and Technical Information Office

1978

CONTENTS

TABLES

FIGURES

Figure		Page

THE USE OF LANDSAT DIGITAL DATA AND COMPUTER-IMPLEMENTED TECHNIQUES FOR AN AGRICULTURAL APPLICATION

By Armond T. Joyce* and R. H. Griffin II*
Lyndon B. Johnson Space Center

SUMMARY

This report describes the use of a resource inventory system in combining Landsat-acquired data and soils information in a specific agricultural application. The data processing techniques are detailed in a step-by-step manner for use by agencies that have a need for assessment of specific crop potential and for production estimates of upcoming harvests in local areas. The system is designed so that data analysis can be performed for other natural resource applications in addition to the one described in this report.

INTRODUCTION

This report is one of a series that addresses a project conducted by the NASA Earth Resources Laboratory (ERL) and the State of Mississippi Office of Science and Technology in cooperation with other Mississippi State agencies. The overall project, entitled "Natural Resources Inventory System ASVT" (Applications System Verification and Transfer), has two facets. One facet is the transfer of technology associated with the use of Landsat digital data and computer-implemented techniques for resource inventory. The other facet is the demonstration of various specific applications for which the system has utility. This particular report addresses the use of Landsat digital data and computer-implemented techniques for a demonstration of an agricultural application. Other reports in this series will address applications such as wildlife habitat assessment, reforestation for erosion control, site selection, and coastal zone baseline inventory.

Specifically, this report addresses the integration of information on the geographic location of agronomic crops, as derived from satellite data, with soils information digitized from U.S. Department of Agriculture (USDA) Soil Conservation Service county soils maps. It is anticipated that the

---

*NASA Earth Resources Laboratory, 1010 Gause Blvd., Slidell, La. 70458.

integration of information on crops with information on soils will have utility for (1) baseline information that would aid the county agent in his routine work, (2) an assessment of the overall agricultural potential of a region, and (3) an estimation of the upcoming harvest for major crops in localized areas as a basis for decisions by local agricultural industries. For example, a cotton gin owner may decide to invest in new equipment or to provide for different transportation arrangements in preparation for an anticipated bumper crop in his area. In other words, it is not anticipated that the procedures and computerized system employed in this study would be used for nationwide or global crop production prediction but, rather, would be used to address selected areas considered to be critical to local economies, generally from one to six counties in a prime agricultural region. If the system were to be implemented by a State or a State agency, it is anticipated that the system would be used for various applications in addition to the agricultural application. In that event, the same soils information that was digitized for use in the agricultural application could also be used for forestry, wildlife management, site selection, and other applications.

The demonstration area selected for use in the agricultural application was Washington County, which lies along the Mississippi River in west-central Mississippi. The entire county is in the highly productive, alluvial plains agricultural region of Mississippi. The major crops are soybeans and cotton, which together constituted 67 percent of all cropland and pasture in the county during the 1974 summer growing season.

As an aid to the reader, where necessary the original units of measure have been converted to the equivalent value in the Système International d'Unités (SI). The SI units are written first, and the original units are written parenthetically thereafter.

DATA PROCESSING PROCEDURES AND RESULTS

The intent of this report is to describe the use of a natural resources inventory system for an agricultural application in a step-by-step manner, corresponding to that in which data would actually be processed through the system. To facilitate this approach, the reader should periodically refer to figure 1, which shows the data processing flow. Also, to help the reader focus on the procedure itself, this report will not elaborate on the system details that are covered in other literature cited.

After the acquisition of computer-compatible tapes (CCT's)[1] containing the raw data acquired by the Landsat multispectral scanner (MSS), the first step in data processing involved the use of an ERL-developed module of six computer programs named PATREC (Pattern Recognition Analysis) (ref. 3). The basic function of the PATREC programs is to generate a

---

[1]Computer-compatible tapes are available at the EROS Data Center, Sioux Falls, S.D., at a cost of $200 per set of four. Also see references 1 and 2.

computer-implemented classification of each pixel[2] (representing 0.44 hectare (1.1 acres) on the Earth surface) from data acquired by the MSS on the Landsat. This classification process identifies each pixel as some type of land cover category. The principal land cover categories of interest for this application demonstration were cotton and soybeans.

The computer programs that make up the ERL PATREC module relate to the "supervised" technique, and the classifier algorithm is based on maximum likelihood ratio calculation and Bayesian decision rules. (See refs. 4 to 6 for basic theory and details.) Use of the supervised technique requires that the location of a number of areas of known land cover (e.g., a soybean field) be established in the data. These areas are selected for uniform homogeneous land cover (e.g., a soybean field that is uniform in respect to planting date, density, vigor, etc.). They are called "training sample areas" because, in a simplistic sense, they are eventually used to "train" the computer to recognize the same land cover elsewhere.

The potential training sample areas are established independently from the data processing operation. They may be preselected by use of relatively recent (within 5 years) aerial photography for interpretation and subsequent ground verification, or they may be located through direct field observations. In this study, both methods were used. Forest training sample areas were preselected by photointerpretation of 2-year-old color infrared (IR) photography at a 1:120 000 scale and then were visited on the ground, whereas pasture and crop training samples were located through direct ground observations. Usually, the boundary of each potential training sample area is outlined on a recent black-and-white print of an aerial photograph or on a suitable map (e.g., 7.5'-series topographic map).

The activity associated with ground observations is usually referred to as a "ground truth" operation and involves ascertaining whether the potential training sample area is uniform and homogeneous in respect to the land cover type that it was selected to represent. This activity involves recording certain observations about the training sample area on a ground truth data form. (See appendix A for some examples of ground truth data forms.)

Usually, the size of each potential training sample area is approximately 16 hectares (40 acres). The number of training samples needed varies with the number of land cover categories to be classified and the variation within each category. However, as an example, if 12 land cover categories were to be classified within a 185- by 185-kilometer (115 by 115 statute mile) area that relates to a set of four CCT's from a particular Landsat scene, one may, as a rule-of-thumb, expect to encounter variation in each

---

[2]A pixel is also referred to as a data cell, a data element, a resolution cell, and a picture element in other literature and relates to the instantaneous field-of-view of the multispectral scanner.

land cover category that may require the selection of 100 to 140 potential training sample areas.[3]

The training sample areas for this application demonstration were established as part of a statewide activity to furnish ground truth for all applications being demonstrated during the project as well as for a quasi-operational test of the system on a State government computer. The exact procedures and details of the ground-truth activities for training sample area establishment for this project will be treated in a separate document.

The total statewide effort was conducted by county agricultural extension agents, county foresters, wildlife biologists, botanists, park managers, and geologists in the various cooperating State agencies. A total of 189 State agency personnel were involved in the statewide ground-truth effort. Most of the field observations were made during the course of routine work by field personnel rather than as a separate effort.

The potential training sample areas were related to the satellite-acquired data contained on CCT's through use of an image display device (activity A, fig. 1). Various types and makes of image display devices are available for this operation, but most display the image on a cathode ray tube (CRT) similar to that of a home television set. (See ref. 3 for several devices that have been used at the ERL.) The particular image display device used for this application demonstration was a portable, "stand alone" (not computer-interactive) device (fig. 2).

As individual tapes were mounted and the image was displayed on the CRT, the operator matched the image on the CRT with the aerial photograph or map on which the training sample areas were outlined. To identify the location of a particular training sample area in the displayed digital data, the operator positioned a movable cursor (in the shape of a plus sign) on the CRT on each corner of the training sample and recorded the coordinates (scan line count and element count) of each corner. Each set of coordinates that referred to a particular training sample area was punched on cards for use in the implementation of the computer programs in the PATREC module.

Activity B in figure 1 includes the implementation of six computer programs that perform different functions in the PATREC module (ref. 3). Activity B also includes both human and machine analysis to produce tapes labeled CLSTAP in figure 1. Tapes produced at this point contain computer-implemented classifications (land cover category) of each pixel (0.44-hectare (1.1 acre) area on the ground) on the tape. Each tape encompasses approximately 8500 square kilometers (2.1 million acres) and relates to the same

---

[3]Using this example, one can calculate that 16 hectares (40 acres) times 140 training samples would amount to less than one one-thousandth of the 34 225 square kilometers (8.5 million acres) encompassed by one Landsat scene (four CCT's).

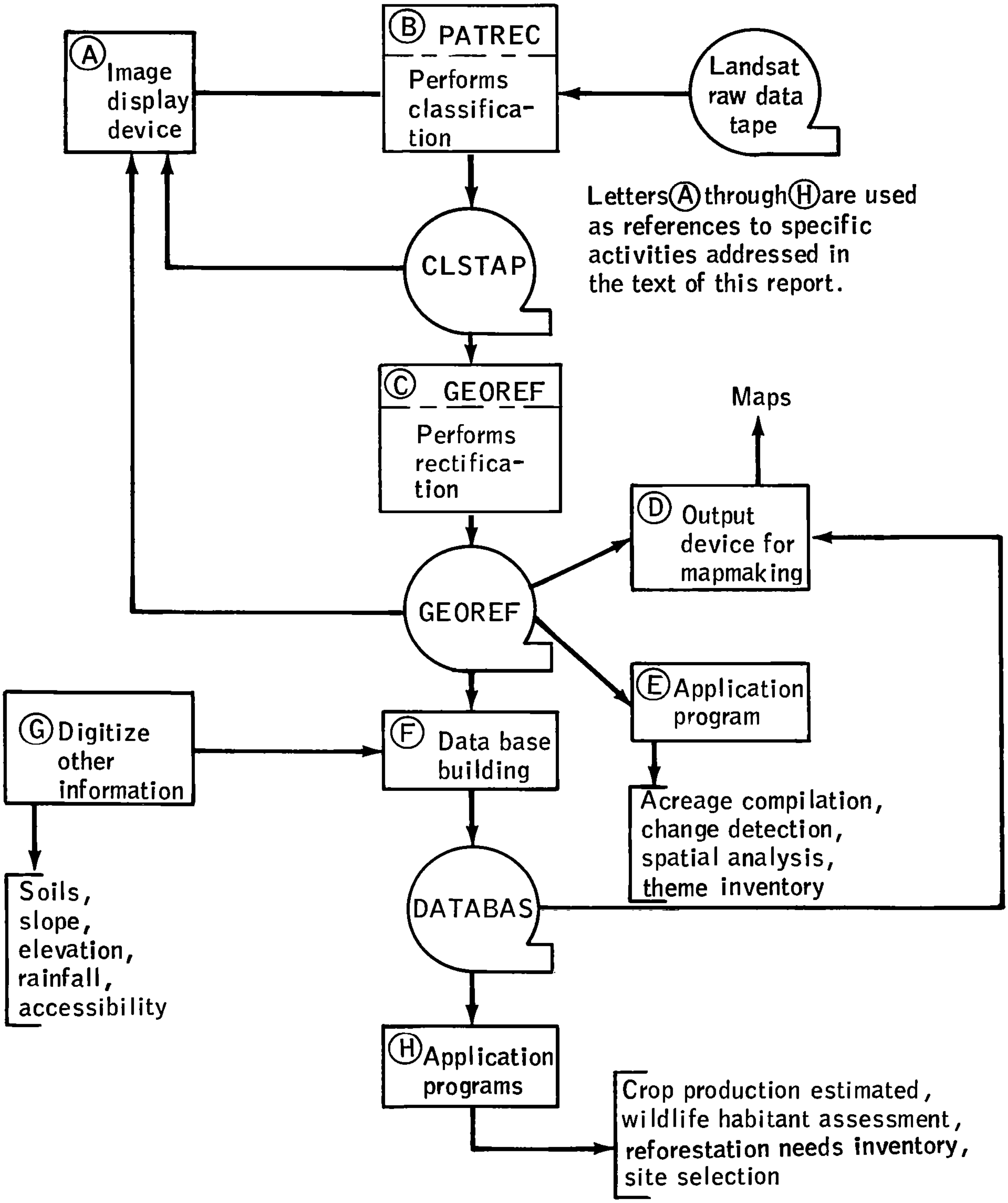


Figure 1.- Data processing flow diagram.

Figure 2.- Portable image display system.

185- by 46-kilometer (115 by 29 statute mile) geographic area contained on the original CCT's. However, the data contained on tapes produced at this point are not geometrically corrected to fit a given map projection.

For activity C in figure 1, the CLSTAP tape is used as input, and two computer programs in the GEOREF (geographic referencing) module developed at ERL are used to rectify the data. The rectification involves registering each pixel to the universal transverse Mercator (UTM) projection (ref. 7). The procedure involves the determination of both UTM northing and easting coordinates and Landsat data scan line and element coordinates for 3 to 10 points distributed over the four tapes in each Landsat scene. The operation was performed by visually matching the image displayed on the CRT with a map constructed with a UTM projection and determining the coordinates for 3 to 10 surface features (e.g., road intersections, bridges over water bodies) that are apparent on both the image and the map. The method involves the use of the control point coordinates that were input on cards and a formula involving a least-squares solution to perform the registration. In the course of registering each and every pixel to the UTM projection, the informational content that corresponds to each 0.44-hectare (1.1 acre) pixel is resampled and interpolated to fit a 50- by 50-meter (0.62 acre) cell through the "nearest neighbor" approach.

The rectification can be performed for an area of 1° latitude by 1° longitude (approximately 10 360 square kilometers (4000 square statute miles) during one computer run. In the course of rectifying data for a 1° by 1° area, which usually relates to portions of three or more CLSTAP tapes, all data are brought to one tape. The end result is a tape (indicated as GEOREF on fig. 1) that relates to a 10 360-square-kilometer (4000 square statute mile) area and contains the land cover computer-implemented classification in 50- by 50-meter cells having sides oriented to the cardinal directions in a grid referenced to a UTM projection (ref. 7).

The tapes produced in this manner are used for mapmaking (activity D, fig. 1), as a data source for various application algorithms (activity E, fig. 1), and as a data source for data base building (activity F, fig. 1). The data on the tapes can also be displayed as a classified image on the CRT for visual analysis. In this application demonstration, a set of four tapes corresponding to Landsat scene E1736-15582, containing data acquired by the satellite on July 29, 1974, was classified and used as input for rectification with the GEOREF computer program module.

It would have been possible to rectify data for a 1° by 1° area selected so as to center over Washington County (the application demonstration area) and, thereby, encompass the entire demonstration area with only one GEOREF tape produced through one computer run. However, because the entire Landsat scene (four raw data tapes) that encompassed the demonstration area was processed, it was decided to make two computer runs to build two GEOREF tapes so as to be able to produce a small-scale map (1:250 000 scale) encompassing most of the satellite-acquired scanner data that were processed. For this operation, CLSTAP tapes 1, 2, and 3 were used to build a GEOREF tape for a 1° by 1° area covering the east half of the Greenwood map sheet (NI 15-9 of the U.S. Army Map Service series) at the 1:250 000 scale. A second GEOREF tape was built using CLSTAP tape 1 for that small portion of the western half of the Greenwood map sheet that was encompassed by the Landsat scene. The geographic coverage of the four CLSTAP tapes relative to the Greenwood map sheet and to the demonstration area is shown in figure 3.

The rectified land cover information on the two GEOREF tapes was recorded on film, through use of a digital film recorder loaded with a roll of 23-centimeter (9 inch) wide color negative film (activity D, fig. 1), at a scale of 1:250 000.[4] Recording at this scale required two passes through the GEOREF tape corresponding to the east half of the Greenwood map sheet and one pass through the GEOREF tape containing partial data for the west half of the Greenwood map sheet, which resulted in three sections of exposed film on the roll. Subsequently, the roll of film was developed and printed, and the three sections were cut from the printed strip and matched to the Greenwood map sheet base. This layout was then photographed and reproduced at the 1:250 000 scale for project participants and in a format and size suitable for this report (fig. 4).

In figure 4, the color assignment is completely arbitrary. Although red was assigned to cells classified as cotton, any color could have been assigned. In addition, since the human eye cannot deal comfortably with more than 10 colors, it is common practice to aggregate the specific land cover types that were classified, and for which information exists on the GEOREF tape, into broader categories during the digital film recording operation. In the case of the color-coded map product generated for figure 4, the two crops of special interest, cotton and soybeans, were assigned specific colors and other land cover types that were classified were grouped into the broad categories of water, forest, and other crops and pasture. However, it is possible to use the same GEOREF tapes used to produce the map product in figure 4 to create different products by simply providing different instructions when the digital data contained on the GEOREF tape are converted to a map product. One such alternative approach is the thematic (one-crop) map which was also produced during the project and will be shown later in this report.

In addition to the flexibility for making various types of color-coded maps with digital data on the GEOREF tapes, there is also the option of making maps at various scales. For example, the same GEOREF tapes used to make the 1:250 000 map (a reduced version of which is shown in fig. 4) were used to make a map of the demonstration area, Washington County, at a scale of 1:62 500 (fig. 5). This was accomplished by following the same procedure used for the 1:250 000 map but employing a larger expansion factor during film recording. In the film recording of digital data, the data are expanded electronically (e.g., an expansion factor of 2 outputs

---

[4]See reference 3 for details on digital film recorders and an explanation of other means of producing color-coded maps from digital data.

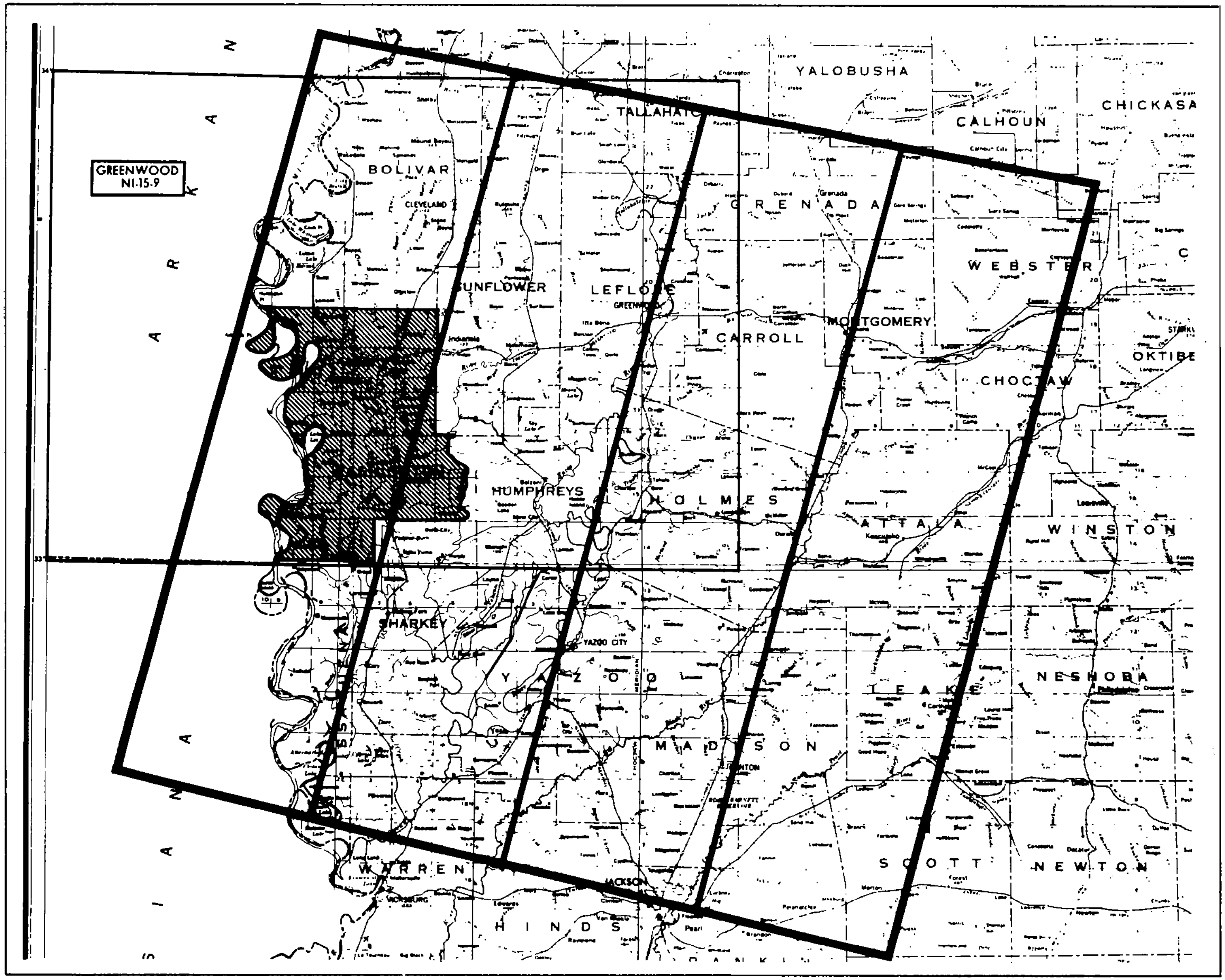


Figure 3.- Geographic coverage of four classification tapes of Landsat scene E1736-15582 (acquired July 29, 1974) relative to the demonstration area (shaded area).

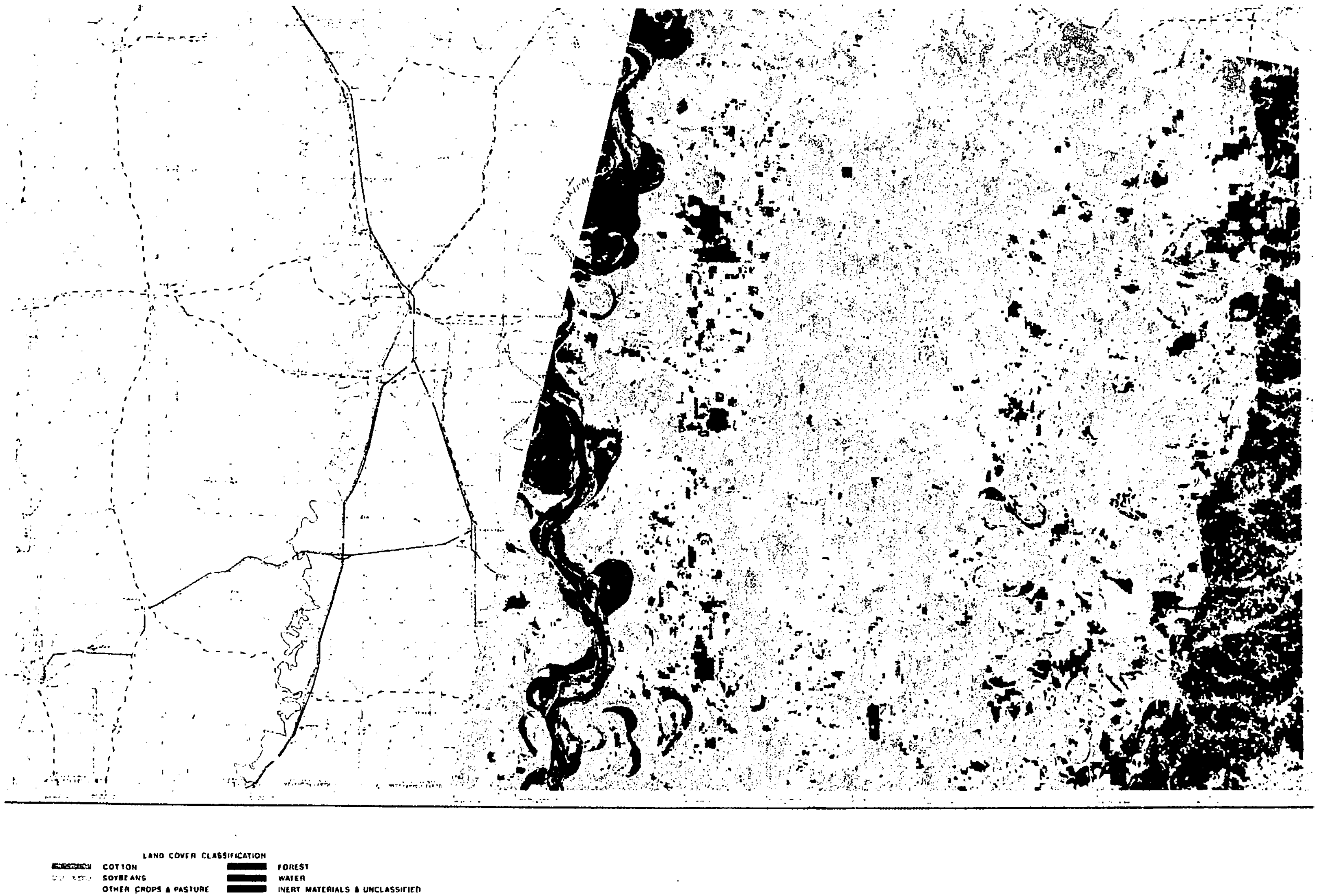


Figure 4.- Computer-implemented classification of Landsat digital data matched to Greenwood map sheet and reproduced at a scale of 1:250 000.

Figure 5.- Computer-implemented classification of Landsat digital data for the demonstration area, reproduced at a scale of 1:62 500.

the initial data by a factor of 4). This does not involve any degradation of the image, such as occurs in a photographic enlargement process.[5]

In addition to the use of the GEOREF tapes for making map products, the tapes can also be used as a data source for various application programs (activity E, fig. 1), which are used to extract and/or manipulate data on the tape for specific purposes. In this application demonstration, only one of these special-purpose computer programs, acreage compilation by land cover category, was demonstrated.

In this computer program, the boundary of any circumscribed polygonal unit (e.g., a county, a watershed, a township) is defined by the UTM northing and easting coordinates. These coordinates are input by use of punched cards to allow a computer tally of the acreage encompassed by each land cover type classified within the circumscribed land unit. The line printer output shows the number of 50- by 50-meter cells, the percentage, and the land area of each land cover type in acres and square miles. The results of the output for a particular land unit are shown in table I. The circumscribed land unit, a township within the demonstration area of Washington County, is shown on figure B-1 in appendix B. The program was also run for the entire area of Washington County, the results of which will be shown later in this report.

TABLE I.- LAND COVER COMPILATION FOR TOWNSHIP 171 (T18N, R7W),

WASHINGTON COUNTY

Land cover	Classification	Element count		Area, ha (acres; mi^2)
		Number	Percentage	
Soybeans	1	7 643	20.49	1910 (4 720; 7.4)
Cotton	2	16 972	45.49	4241 (10 480; 16.4)
Bare soil	15	194	.52	49 (120; .2)
Bermuda	17	583	1.56	146 (360; .6)
Other grass	19	9 587	25.69	2396 (5 920; 9.3)
Oak-gum-cypress	32	2 073	5.56	518 (1 280; 2.1)
Inert materials	61	259	.69	65 (160; .3)
Total	--	37 311	100	9325 (23 040; 36)

[5]The positional accuracy of the data, which in the case of the demonstration was 98 meters root mean square (rms) down track and 48 meters rms crosstrack, does not change with different scales selected for map products showing land cover.

Although not demonstrated in this application, various other special-purpose computer programs exist that use GEOREF tapes as a source of data. Some of these include "change detection," which involves comparing two GEOREF tapes created with data acquired at different points in time so as to flag areas where land cover has changed; "distribution relationship analysis," which can be used to identify "mixed forest" areas; and "theme inventory," which involves determining the location and area of specific themes such as impounded water.

The next major activity in the data processing flow (activity F, fig. 1) involves data base building, the purpose of which is to integrate land cover information from the GEOREF tapes with information that is digitized from other sources (activity G, fig. 1). It should be noted at this point that the objective of data base building is not to create a data base containing all conceivable information, but, rather, to create a data base to which the application programs will have efficient access (activity H, fig. 1).

The design of the computer programs developed at ERL provides two options for data base building. One option is called the "gridded" option, in which the land cover information from the GEOREF tapes and any information digitized from other sources (e.g., soils maps) are assigned to cells that are subdivisions of the UTM grid in multiples of 50 meters. The other option, called the "nongridded" option, allows the UTM-gridded information on the GEOREF tapes to be input to the data base for units of the public land survey system (e.g., the subdivisions called "forties"[6] of a given section) by identifying the center northing/easting UTM grid coordinates of each unit. Although either option may be used in addressing various applications for a particular land area that has been surveyed by the public land survey system, it is anticipated that the gridded option would usually be used for land areas surveyed by "metes and bounds."[7] The advantage of using the nongridded option for public land surveyed areas has to do with the relationship of ownership to the use of land. For example, a farmer may buy a forty as defined by the boundaries of the NW¼NW¼ sec. 33, T. 9 S., R. 6 W. and subsequently decide to plant that entire forty to a specific crop. Likewise, a logging operation in a forested area is likely to be conducted for a specific forty as defined by the public land survey. However, since the size of the gridded data base cell is optional (in even multiples of 50 meters up to 400 by 400 meters), the advantage of the nongridded approach lessens as cell sizes smaller than 16 hectares (40 acres) are elected. For either option, gridded or nongridded, the design of the data base provides for storing up to 26 elements of information (variables) for each of the cells.

It was anticipated that six of these variables would consist of land cover information extracted from GEOREF tapes, including four land cover classifications made with data acquired during each of the four seasons of

---

[6]"Forty" is a term used to refer to one of 16 parts of a section of land as defined by cornerstones set in the ground.

[7]Most land areas in the United States west of Ohio, with the exception of Texas, have been surveyed by the public land survey system.

the year, one land cover classification derived by merging the four seasonal classifications, and one land cover classification used to address temporary phenomena such as flooding. The remaining 20 variables would include information other than land cover, such as soils, slope, elevation, and location.

As mentioned previously, the size of the cell for the gridded option can be any multiple of 50 meters. The choice of cell size, made prior to implementation, must take into account the combined effect of various factors such as the following.

1. Accuracy of the information other than the land cover information derived from satellite-acquired data (e.g., soils maps)

2. Cost and effort involved in digitizing map source information for a particular cell size

3. Size of the land area to be addressed relative to computer disc memory capacity, data storage, and retrieval time

4. Accuracy required for the applications selected

5. Decisions to be made on the ultimate use of the information

It is anticipated that the choice selected will usually result in a DATABAS cell size of 200 by 200 meters (approximately 10 acres) or larger being chosen for statewide data bases. In the case of the Mississippi DATABAS design, a 16-hectare (40 acre) cell was chosen, which would result in 26 million elements of information (1 million cells times 26 variables) if 26 variables were to be stored for the entire State. This information could be stored on two CCT's, one each for the areas east and west of 90^{o} longitude.

No particular method is assumed for digitizing information other than land cover information (activity G, fig. 1). Anyone familiar with the process of digitizing land cover information (which is dynamic and ever-changing) from maps would discount the use of manual techniques. However, this system does not involve digitizing land cover data from maps because the data are initially in digital form. Consequently, one may wish to employ manual techniques for digitizing such stable variables as soils, slope, elevation, aspect, and average annual rainfall, for which baseline information need be digitized only once. However, a system that is primarily based on the use of satellite-acquired digital data for land cover information can also include, as part of the system, a semiautomated method (X,Y digitizer) of digitizing other information, such as soils.[8] In addition to digitizing

---

[8]This statement is not to imply that an either/or choice must be made in respect to use of satellite-acquired digital data for land cover information, because the data-base-building computer programs can be employed in such a manner that ground-acquired information can be input for small areas (e.g., urban areas, small parks, etc.), with reliance on satellite coverage for the bulk of the land area.

map source information, an X,Y digitizer could be used effectively for digitizing the northing/easting UTM coordinates that define areas of special interest for which compilations of acreage by land cover are to be made. It is not anticipated that agencies other than those engaged in nationwide digitizing of information would employ more sophisticated methods.

For this particular application demonstration, the nongridded option was used. This involved determining the northing/easting UTM coordinate in the center of each forty as defined by the public land survey system. The computer program DATABAS takes the coordinates as card input and functions so that a forty midpoint is located on a GEOREF tape and a 7- by 7-cell matrix of 50-meter cells around each midpoint is examined to determine the predominant land cover for each forty.

Although production of a map was not needed for any of the application programs (activity H, fig. 1), a map was produced by film recording to show the results of having aggregated the land cover information from the 50- by 50-meter cells on GEOREF tapes to the forty for which land cover information was stored in the data base. The land cover data base information is shown in map format in figure 6, which can be compared with the map in figure 5. Appendix B includes black-and-white density plots of land cover in one township from both a GEOREF tape and a DATABAS tape to illustrate a low-cost means of map presentation (figs. B-1 and B-2). In addition to the land cover information, the only other variable included on the DATABAS tape for this application demonstration was the soils information. The soils information was digitized from the USDA Soil Conservation Service county soils maps (ref. 8) by manual methods and punch card input.

The final step in the data processing flow of this application demonstration was to use one of the special-purpose computer programs to which the data base was designed to feed information. In this case, the main function of the computer program used was to integrate soils and land cover (crop) information and, in the same procedure, to estimate the potential production for the upcoming harvest in the county. The estimate is made by determining both the crop and the soil that are predominant in each forty, then by referencing that integrated information to a computer-stored table showing potential yield per 0.4 hectare (1 acre) by crop, soil, and management level.

Table II shows 16 of the 56 soils mapping units that were encountered on the county soils maps. After the geographically referenced data base information on crop and soil has been tabulated and calulated,[9] the resulting information is output through a line printer to show summaries by township and county. Table III shows an example of the output for one of the townships in Washington County for both soybeans and cotton, and tables IV and V show the summaries for Washington County for cotton and soybeans, respectively. The Washington County cotton harvest (table IV)

---

[9]In this application, management level B values (improved agricultural practices) were used for cotton; management level A values (normal agricultural practices), for soybeans.

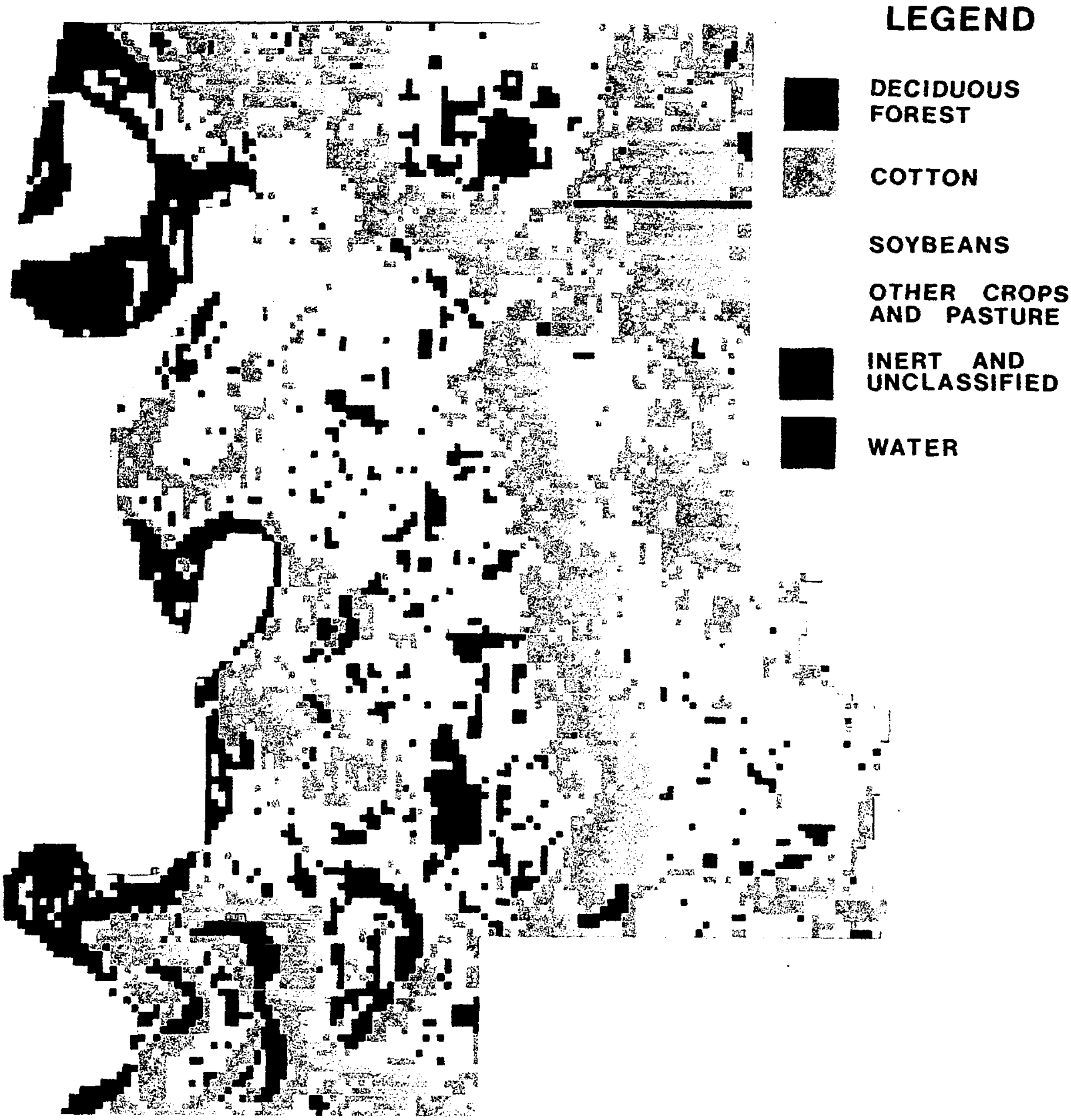


Figure 6.- Map of predominant land cover for each 400- by 400-meter (40 acre) area, produced from land cover data from 50- by 50-meter cells on GEOREF tapes.

TABLE II.- EXAMPLES OF POTENTIAL YIELDS OF COTTON AND SOYBEANS FOR TWO LEVELS OF AGRICULTURAL PRACTICE BY SOIL MAPPING UNIT

Soil		Potential yield of -			
Code	Type	Cotton lint, kg/ha (lb/acre)		Soybeans, kg/ha (bu/acre)[a]	
		Level A[b]	Level B[c]	Level A[b]	Level B[c]
1	Alligator clay, level phase	196 (175)	280 (250)	272 (10)	680 (25)
2	Alligator clay, nearly level phase	252 (225)	420 (375)	544 (20)	952 (35)
3	Alligator clay, sloping phase	252 (225)	420 (375)	544 (20)	952 (35)
4	Alligator silty clay loam, level	196 (175)	280 (250)	272 (10)	680 (25)
5	Alligator silty clay loam, nearly level	252 (225)	420 (375)	680 (25)	952 (35)
6	Alluvial land	--	--	--	--
7	Beulah very fine sandy loam, nearly level	420 (375)	504 (450)	--	--
8	Beulah very fine sandy loam, gently sloping	392 (350)	476 (425)	--	--
9	Beulah very fine sandy loam, moderately shallow	504 (450)	617 (550)	--	--
10	Bosket silty clay loam, nearly level	532 (475)	673 (600)	544 (20)	952 (35)
11	Bosket very fine sandy loam, nearly level	644 (575)	785 (700)	544 (20)	952 (35)
12	Bosket very fine sandy loam, gently sloping	532 (475)	673 (600)	544 (20)	816 (30)
13	Bosket very fine sandy loam, moderately shallow	644 (575)	785 (700)	544 (20)	952 (35)
14	Bowdre silty clay, nearly level	364 (325)	504 (450)	408 (15)	680 (25)
15	Bowdre silty clay loam, nearly level	364 (325)	504 (450)	508 (15)	680 (25)
16	Borrow pit	--	--	--	--

[a]One bushel of soybeans = 27.2 kg (60 lb).
[b]Normal agricultural practices.
[c]Improved agricultural practices.

TABLE III.- EXAMPLE OF AGRICULTURAL YIELD INFORMATION OUTPUT

(From Township 171, forties (16-hectare fields) 1 to 576)

(a) Class 1, soybeans

Soil type code	Occurrences	Area, ha (acres)		Potential yield, kg (bu) (a)	
11	6	97	(240)	130 640	(4 800)
23	7	113	(280)	114 310	(4 200)
31	1	16	(40)	21 770	(800)
35	2	32	(80)	43 550	(1 600)
40	1	16	(40)	21 770	(800)
47	35	567	(1400)	421 020	(14 000)
48	65	1052	(2600)	1 415 232	(52 000)
54	1	16	(40)	27 216	(1 000)
Total	--	1910	(4720)		(29 200)

(b) Class 2, cotton

Soil type code	Occurrences	Area, ha (acres)		Potential lint yield, kg (lb)	
7	1	16	(40)	8 165	(18 000)
11	141	2282	(5 640)	1 790 800	(3 948 000)
13	1	16	(40)	12 700	(28 000)
24	3	49	(120)	16 330	(36 000)
27	2	32	(80)	27 220	(60 000)
29	3	49	(120)	32 660	(72 000)
31	18	291	(720)	212 280	(468 000)
35	55	890	(2 200)	748 430	(1 650 000)
40	3	49	(120)	20 410	(45 000)
47	11	178	(440)	49 900	(110 000)
48	15	243	(600)	108 860	(240 000)
50	1	16	(40)	7 260	(16 000)
52	2	32	(80)	1 840	(40 000)
54	6	97	(240)	65 320	(144 000)
Total	--	4241.10	(10 480)	3 118 447.5	(6 875 000)

[a]One bushel = 27.2 kg (60 lb).

TABLE IV.- SUMMARY OF AREA AND POTENTIAL COTTON YIELD FOR WASHINGTON COUNTY

Soil type code	Occurrences	Area, ha (acres)		Potential lint yield, kg (lb)	
1	19	310	(760)	8 600	(190 000)
2	184	2 980	(7 360)	1 251 900	(2 760 000)
4	4	60	(160)	18 100	(40 000)
5	89	1 440	(3 560)	605 600	(1 335 000)
7	45	730	(1 800)	367 400	(810 000)
8	9	150	(360)	69 400	(153 000)
9	3	50	(120)	29 900	(66 000)
10	7	110	(280)	76 200	(168 000)
11	657	10 630	(26 280)	8 344 300	(18 396 000)
12	10	160	(400)	108 900	(240 000)
13	17	280	(680)	215 900	(476 000)
14	27	440	(1 080)	220 500	(486 000)
15	12	190	(480)	98 000	(216 000)
17	50	810	(2 000)	703 100	(1 550 000)
18	73	1 180	(2 920)	1 092 700	(2 409 000)
19	4	60	(160)	58 100	(128 000)
20	38	620	(1 520)	568 800	(1 254 000)
21	7	110	(280)	101 600	(224 000)
22	8	130	(320)	7 300	(16 000)
23	86	1 390	(3 440)	78 000	(172 000)
24	20	320	(800)	108 900	(240 000)
25	8	130	(320)	116 100	(256 000)
26	16	260	(640)	232 200	(512 000)
27	91	1 470	(3 640)	1 238 300	(2 730 000)
28	8	130	(320)	94 300	(208 000)
29	14	230	(560)	152 400	(336 000)
30	1	16	(40)	10 000	(22 000)
31	325	5 260	(13 000)	3 832 900	(8 450 000)
32	15	240	(600)	149 700	(330 000)
34	9	150	(360)	114 300	(252 000)
35	382	6 180	(15 280)	5 198 200	(11 460 000)
36	2	32	(80)	23 600	(52 000)
37	4	60	(160)	52 600	(116 000)
38	21	340	(840)	276 200	(609 000)
39	153	2 480	(6 120)	1 388 000	(3 060 000)
40	156	2 530	(6 240)	1 061 400	(2 340 000)
41	4	60	(160)	272 200	(60 000)
42	370	5 990	(14 800)	3 020 900	(6 660 000)
43	2	32	(80)	15 400	(34 000)
44	3	50	(120)	24 500	(54 000)
45	15	240	(600)	204 100	(450 000)
46	35	570	(1 400)	523 900	(1 155 000)
47	38	620	(1 520)	172 400	(380 000)
48	257	4 160	(10 280)	1 865 200	(4 112 000)
49	4	60	(160)	29 000	(64 000)
50	36	580	(1 440)	261 300	(576 000)
51	9	150	(360)	81 600	(180 000)
52	4	60	(160)	36 300	(80 000)
54	116	1 880	(4 640)	1 262 800	(2 784 000)
55	6	100	(240)	65 300	(144 000)
56	6	100	(240)	70 800	(156 000)
Total	---	56 310	(139 160)	35 811 600	(78 951 000)

TABLE V.- SUMMARY OF AREA AND POTENTIAL SOYBEAN YIELD FOR WASHINGTON COUNTY

Soil type code	Occurrences	Area, ha (acres)		Potential yield, kg (lb) (a)	
1	190	3 080	(7 600)	2 068 420	(76 000)
2	203	3 290	(8 120)	4 419 880	(162 400)
4	1	16	(40)	10 890	(400)
5	10	160	(400)	272 160	(10 000)
7	10	160	(400)	54 430	(2 000)
8	4	60	(160)	21 780	(800)
10	1	16	(40)	21 780	(800)
11	30	490	(1 200)	653 180	(24 000)
12	1	16	(40)	21 780	(800)
13	2	32	(80)	43 560	(1 600)
14	14	230	(560)	228 610	(8 400)
15	3	50	(120)	48 990	(1 800)
17	14	230	(560)	457 230	(16 800)
18	3	50	(120)	97 980	(3 600)
19	1	16	(40)	32 670	(1 200)
20	3	50	(120)	97 980	(3 600)
22	5	80	(200)	27 220	(1 000)
23	222	3 590	(8 880)	3 625 170	(133 200)
24	7	110	(280)	114 310	(4 200)
26	4	60	(160)	108 860	(4 000)
27	16	260	(640)	348 360	(12 800)
29	7	110	(280)	152 410	(5 600)
31	85	1 380	(3 400)	1 850 690	(68 000)
32	6	100	(240)	97 980	(3 600)
34	4	60	(160)	87 120	(3 200)
35	27	440	(1 080)	587 870	(21 600)
37	1	16	(40)	21 780	(800)
38	1	16	(40)	21 780	(800)
39	3	50	(120)	65 340	(2 400)
40	52	840	(2 080)	1 132 190	(41 600)
41	1	16	(40)	16 330	(600)
42	43	700	(1 720)	936 230	(34 400)
43	1	16	(40)	16 330	(600)
46	3	50	(120)	16 330	(600)
47	601	9 730	(24 040)	6 552 260	(240 400)
48	1111	17 980	(44 440)	24 189 260	(888 800)
49	3	50	(120)	81 650	(3 000)
50	10	160	(400)	272 160	(10 000)
51	1	16	(40)	27 220	(1 000)
54	93	1 510	(3 720)	2 531 090	(93 000)
55	6	100	(240)	195 960	(7 200)
56	1	16	(40)	16 330	(600)
Total	---	45 390	(112 160)	51 634 200	(1 897 200)

[a]One bushel = 27.2 kg (60 lb).

is estimated at 35 811 600 kilograms (78 951 000 pounds); the Washington County soybean harvest (table V) is estimated at 51 634 metric tons (1 897 200 bushels). In addition to its use for crop production estimation, the output showing crop and soil combinations by township (table III is one example) can be analyzed to determine how various soils are being utilized and to assess the general agricultural potential.

Although additional mapmaking is not essential, this system can also be used to produce various types of maps from the information in the data base that may be desired for visual analysis. Figures 7 and 8 are examples of such maps and were made to show the inherent potential of the soils for producing cotton and soybeans. A separate color was assigned to each soil within a particular potential yield category. These potential yield categories are arbitrarily chosen; any particular range can be selected. The overlays to figures 7 and 8 show the location of each respective crop as determined from the satellite-acquired data. These thematic (one-crop) overlays were made by film recording from the GEOREF tapes; the crop in question was arbitrarily assigned a specific color, and all other land cover categories were assigned a common neutral color. This capability demonstrates the flexibility in making maps from digital data on CCT's. A comparison of the thematic overlay of cotton with the potential yield map (fig. 7) shows the close correlation of actual cotton lint production with a high-yield category (560 to 840 kg/ha (500 to 750 lb/acre)). This high correlation indicates that Washington County cotton farmers are very cognizant of the productivity of these soils for cotton.

The essence of the Natural Resources Inventory System is the use of land cover information in a computerized system without reliance on mapped input or output. However, an example of the system's flexibility for mapmaking is shown in figure 9, which is a generalized soil association map of Washington County made by film recording from the DATABAS tapes. The basic information on soils mapping units stored on the tapes was assigned specific colors to show the soils associations and series to which the mapping units pertain.

PRODUCT ADEQUACY ASSESSMENT

The accuracy of the land cover classification was verified in several ways. First, the predominant land cover of every fifth forty in Washington County was determined through photointerpretation by using 1:120 000-scale color IR aerial photographs. The resulting categorization of each forty was then compared with the results that were extracted from the GEOREF tapes and read into the data base through use of the computer programs. During this comparison, each forty for which there was disagreement as to land cover category (as determined by the two methods) was flagged and, subsequently checked in the field to determine the actual land cover. In all cases, the field checks revealed that one of the two sources was correct (as opposed to neither one being correct), thereby substantiating that those forties in agreement and therefore, not field checked, had a very high probability of being categorized as the actual land cover. The total effort involved 2156 of the 10 780 forties in the county, which constituted a 20-percent sampling. The results showed that 1722 or 92 percent of the forties categorized as

Figure 7.- Location of various potential-yield categories of cotton as determined by soils data in Washington County, Mississippi. The corresponding overlay contained in the pocket in the inside back cover shows the location of cotton as determined from satellite-acquired data.

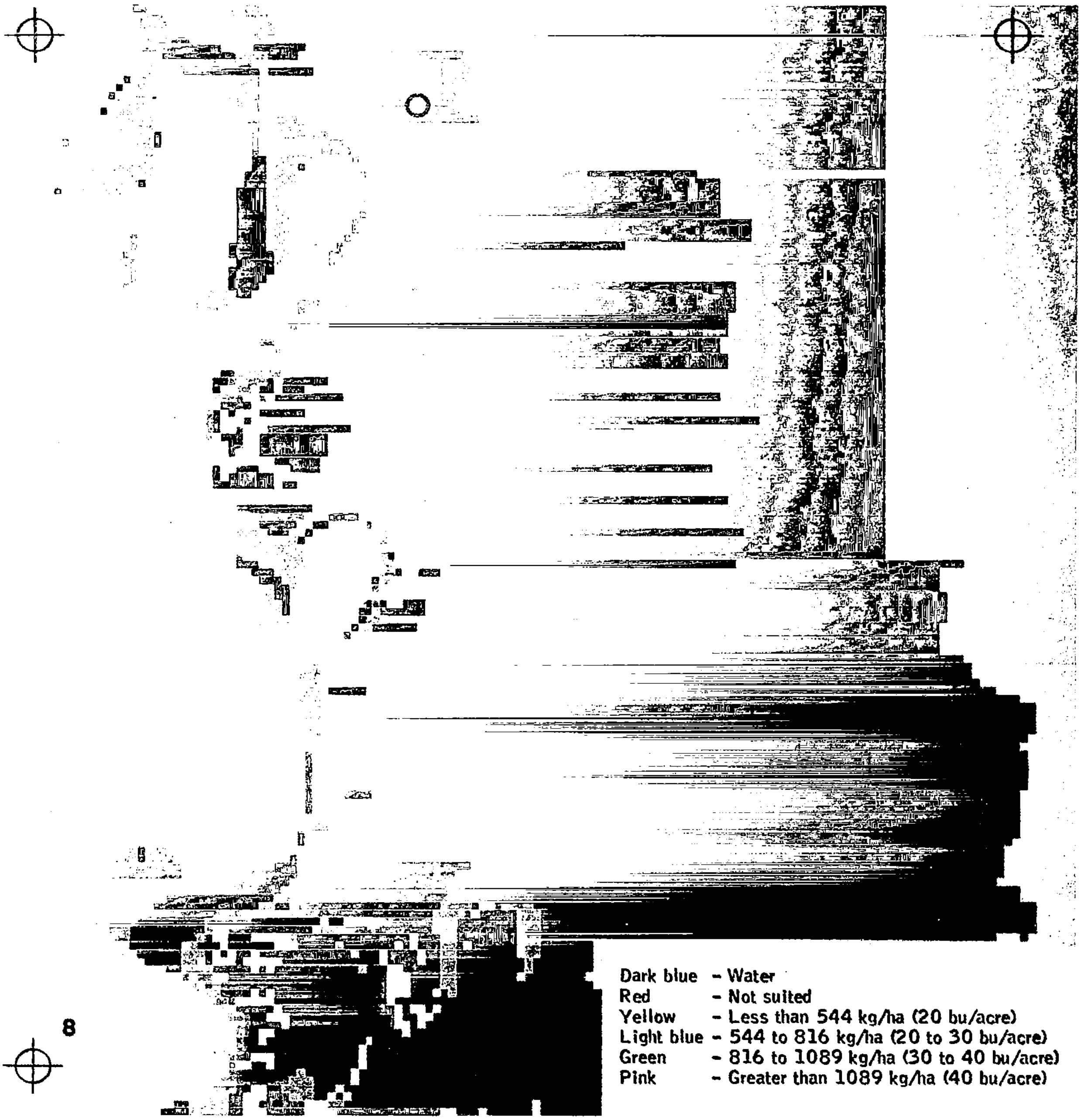
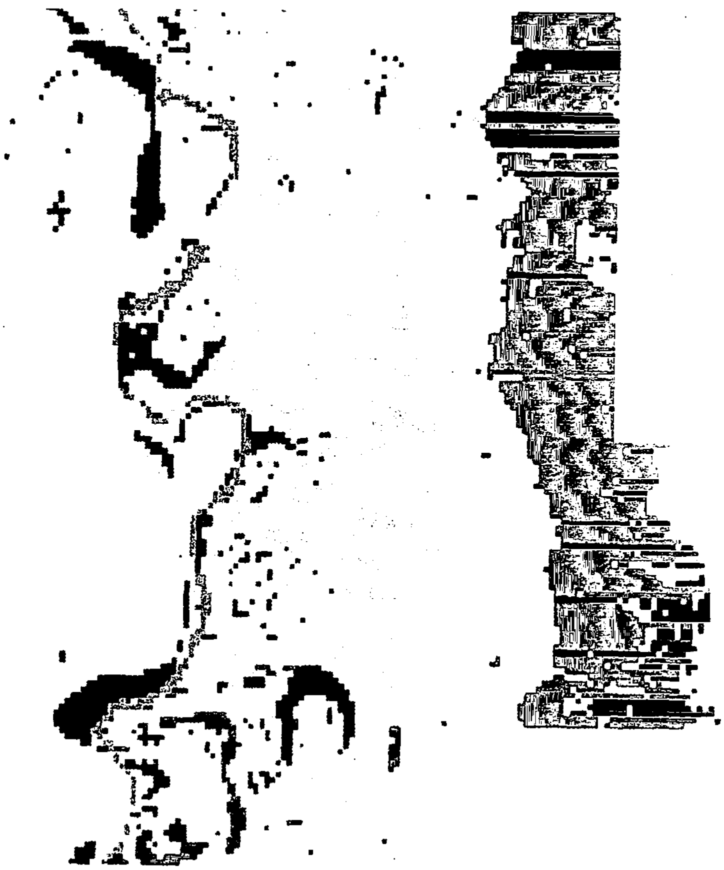


Figure 8.- Location of various potential-yield categories of soybeans as determined by soils data in Washington County, Mississippi. The corresponding overlay contained in the pocket in the inside back cover shows the location of soybeans as determined from satellite-acquired data.



SHARKEY-TUNICA-BOWDRE | MISSISSIPPI RIVER/LAKES
ALLUVIAL LAND | COMMERCE-ROBINSONVILLE-CREVASSE
DOWLING-MHOON | FORESTDALE-ALLIGATOR
BORROW PITS | AIRPORT-GREENVILLE
DUNDEE-BOSKET-BEULAH-SOUVA | SWAMP

Figure 9.- General soils map of Washington County, made by film recording from DATABAS tapes, color-coded to reflect soils associations and series to which computer-stored mapping units pertain.

cropland or pasture were correctly classified through the use of satellite-acquired MSS data and computer-implemented classification techniques. Of the 156 forties categorized as cropland or pasture that were incorrectly classified, 73 were misclassified as forest, 57 were misclassified as inert materials, and 26 were misclassified as water bodies. Of the 278 forties not in the cropland or pasture category, 93 were misclassified as crops or pastures. The combined number of commission and omission errors showed that 87 percent of the total number of forties were classified correctly.

Because the aerial photography used for the accuracy check method described above was not acquired during the cotton and soybean growing seasons, two other methods were used to verify the accuracy of the cotton and soybeans classifications. First, the land area of each crop as compiled for the entire county through use of the acreage compilation computer program that uses the GEOREF tapes as a data source was compared with the county statistics for harvested acreage as published by the Mississippi Crop and Livestock Reporting Service (refs. 9 and 10). The results showed 45 351 hectares (112 065 acres) of soybeans and 48 295 hectares (119 340 acres) of cotton tallied for the county from the GEOREF tapes. These figures can be compared with 49 655 hectares (122 700 acres) of soybeans and 45 730 hectares (113 000 acres) of cotton reported for the county by the Mississippi Crop and Livestock Reporting Service publication.[10]

The reader may note that the acreage determined from the GEOREF tapes is not the same as the acreage carried into the data base as shown in tables IV and V. This change took place during data base building when the computer made a tally of the land cover shown for individual 50- by 50-meter (0.62 acre) GEOREF cells within the forty to determine, through plurality, the predominant land cover for the forty. The result was that the data base shows practically the same acreage for soybeans (45 390 hectares (112 160 acres)) as was determined directly from GEOREF tapes (45 350 hectares (112 065 acres)), but the cotton acreage carried into the data base was 56 316 hectares (139 160 acres) versus the 48 295 hectares (119 340 acres) determined from GEOREF tapes. It is believed that this disparity is not a discrepancy but, rather, is related to the practice of skip-row planting of cotton in Washington County. For example, if a 16-hectare (40 acre) field is planted by alternating six rows of cotton and four skipped rows, the result is 9.7 hectares (24 acres) of cotton in a 16-hectare field that is dedicated to cotton growing. Consequently, it is believed that the cotton acreage shown for the data base depicts the total acreage dedicated to cotton farming in Washington County; whereas, both the cotton acreage derived from GEOREF tapes and the area reported by the Crop and Livestock Reporting Service depict the net area.

A second method used to verify the accuracy of the computer-implemented classification consisted of determining how the pixels within

---

[10]The method of estimation employed by the Mississippi Crop and Livestock Reporting Service is designed to attain a specified accuracy at the State level; and, although the resulting statistics are published for counties, the accuracy at the county level is generally considered to be around ± 10 percent.

the training sample areas were eventually classified. The reader should understand that even though the training sample areas were used to "train" the computer to recognize the same land cover elsewhere in the data, the computer is not able to "recognize" which pixels were included in training sample areas when each pixel is systematically classified. Consequently, after the classification has taken place, it is possible to use a computer program that locates the original training sample areas in the data on the CLSTAP tapes and determines how each pixel was eventually classified. The results show that of the 111 pixels within cotton training sample areas 90.1 percent were classified as cotton while 2.7 percent were misclassified as soybeans and 7.2 percent were misclassified as grass. Of the 261 pixels within soybean training samples, 98.8 percent were classified as soybeans, 0.4 percent were misclassified as cotton, 0.4 percent were misclassified as grass, and 0.4 percent were misclassified as bare soil. The complete results of this tally, including all land cover categories classified, are shown in table VI.

As a means of further substantiating the accuracy of the cotton and soybean classifications, the 1:62 500-scale map and the acreage compilations by township were evaluated by Mississippi Cooperative Extension Service personnel.[11] Their conclusion was that the map and statistics, when viewed in relation to their knowledge of actual planting practices during the 1974 crop season, appeared to be within the accuracy limits indicated in table VI.

ADDITIONAL COMMENTS

The main consideration during the development of computer programs and techniques used in this demonstration was to establish the hardware/software system and associated procedures needed to use Landsat digital data and other digitized data (e.g., soils) to address specific applications. Consequently, no field studies were made to verify the accuracy of the crop yield information shown in table II or to certify the level of agricultural practices assumed for this application demonstration.[12] However, the computer programs were designed to use card input so that information from other sources (such as the crop yield by soils or the yield information for a given soil, in table II), could be replaced by merely punching a new card (should more accurate information become available) without any need to make changes in the computer program.

---

[11]A much more detailed evaluation dealing with map product adequacy, utility of statistical information, cost, etc. was performed by Cooperative Extension Service personnel. The results of this evaluation will be integrated with results of evaluations by other Mississippi State and local agencies and will be provided in the final report for this project.

[12]Although no field studies were made for this purpose, there was no reason to suspect that the yield information or the level of agricultural management assumed was incorrect.

Similarly, it would also be possible to develop soils/yield data as shown in table II and card decks for both a "worse than average" and "better than average" weather situation by matching past records of actual yield by soil with historical weather records. If this were done, a decision could be made as to which card deck would be used based on field personnel assessment of the weather situation during the growing season for which data was being processed. During data processing, it would also be possible to make a decision as to the appropriate level of agricultural practices (level A, normal agricultural practices, or level B, improved agricultural practices) on a township basis as opposed to a decision on the county basis, as was made in this project.

It should also be recognized that the data processing system and procedures used in this project could be used to address potential forest production by substituting a card deck with forest yield by soils information for the agronomic crop yield by soils information used in this application demonstration. In addition, projected forest production could be estimated if forest age were to be digitized and stored as one of the 30 variables provided for in the data base design.

The costs for several possible configurations of system hardware are detailed in reference 3 and in appendix C. However, in summary, these capital investment costs would be less than $50 000 (image display device and electrostatic printer-plotter) as a minimum if a computer and peripherals are already available. It is the objective of this project to document operating costs in the final report; however, tentative operating costs developed in a research environment indicate that the operating costs including field work, data processing (as indicated by the flow

TABLE VI.- PERCENTAGE OF PIXELS AS CLASSIFIED WITHIN

TRAINING SAMPLE AREAS BY LAND COVER CATEGORY

Training sample land cover category	Number of pixels	Percentage of pixels classified by land cover category for -											
		Oak-hickory	Corn	Cotton	Soy-beans	Water	Urban	Oak-gum	Grass	Rice	Pecan	Bare Soil	Unclassified
Oak-hickory	615	90.1	--	0.3	1.3	--	0.8	4.4	0.8	--	--	0.2	2.1
Corn	6	--	100	--	--	--	--	--	--	--	--	--	--
Cotton	111	--	--	90.1	2.7	--	--	--	7.2	--	--	--	--
Soybeans	261	--	--	.4	98.8	--	--	--	.4	--	--	.4	--
Water	913	--	--	--	--	99.7	--	--	--	--	--	--	0.3
Urban	116	--	--	1.7	7.7	--	65.5	--	19.0	--	--	.9	5.2
Oak-gum	37	--	--	--	--	--	--	97.3	--	--	--	2.7	--
Grass	52	--	--	--	--	--	--	1.9	98.1	--	--	--	--
Rice	15	--	--	--	6.7	--	--	--	--	93.3	--	--	--
Pecan	12	--	--	--	16.7	--	--	--	16.7	--	66.6	--	--
Bare soil	87	--	--	--	--	--	--	--	5.7	--	--	94.3	--

diagram in fig. 1), and mapmaking are less than $0.39/km^2 ($1/mi^2) for the land cover information component. Furthermore, there is considerable potential for cost reductions through geographic signature extension, development of faster computer algorithms, and automated training-sample selection.

One of the main advantages in both cost and time of the data processing system used for this application demonstration was the use of satellite-acquired digital data for land cover information, thereby, eliminating the need to digitize such dynamic information from a map or photographic base as is required by other approaches.

The costs of digitizing other data, such as soils, from map sources vary according to the digitizing method used. Although the system used in this application demonstration does not presuppose any particular digitizing technique, even manual encoding from the map source is a feasible alternative for such static variables as soils, slope, elevation, and annual rainfall that would be digitized only once.

Although it is believed that the utility of satellite data as reported for this application demonstration justifies the operational use of data generated by the satellites currently in orbit (Landsat I, launched July 1972, and Landsat II, launched January 1975), it is reasonable to assume that a decision to implement such a system would involve consideration of the use of Landsat C (scheduled for launch in February 1978) and Landsat D (currently proposed for launch in 1981). In this context, it should be recognized that the plan to provide the user with rectified raw data from Landsat C and D is conducive to an increase in classification accuracy through the sequential analysis of several sets of raw data acquired between planting time and advanced plant growth stages. Also, the addition of the thermal band to the Landsat C multispectral scanner and the proposed Landsat D thematic mapper scanner may prove to be useful for investigating vegetation stress (caused by insects, disease, or drought) as another factor to be considered in crop production estimation.

CONCLUDING REMARKS

Landsat multispectral scanner data in digital form was used in combination with digitized data from other sources in a computerized system to make estimates of soybean and cotton crop production for Washington County, Mississippi. The effort was a demonstration project for such forecasting on a local level (about one to six counties).

Cross checks of the land-cover classifications and crop estimations were made with aerial color infrared photography, with crop statistics from the Crop Reporting Service, and with internal checks of the data against itself. These tests all showed the computer-implemented categorization to be of adequate accuracy.

This report carefully described the steps needed to process the Landsat digital data and use it in combination with digitized data from other sources. Steps were shown for processing the combined data to produce thematic maps, crop inventories, and estimates of crop production prior to harvest. More advanced uses were suggested.

Costs and hardware required were noted. Ways of minimizing costs were suggested. Finally, it was demonstrated that this system can be implemented with resources and personnel existing at a state level.

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas, September 8, 1977
177-52-89-00-72

REFERENCES

1. Thomas, Valerie L.: Generation and Physical Characteristics of the ERTS MSS System Corrected Computer Compatible Tapes. NASA TM X-70426, July 1973.

2. Earth Resources Technology Satellite Data Users Handbook. Goddard Space Flight Center, Greenbelt, Md., document 76SDS4258, Sept. 2, 1976.

3. Whitley, Sidney L.: Low-cost Data Analysis Systems for Processing Multispectral Scanner Data. NASA TR R-467, Oct. 1976.

4. Whitley, Sidney L.: A Procedure for Automated Land Use Mapping Using Remotely Sensed Multispectral Scanner Data. NASA TR R-434, Jan. 1975.

5. Jones, Clay: Implementation of an Advanced Table Look-up Classifier for Large Area Land-Use Classification. Proceedings of the Ninth International Symposium on Remote Sensing of the Environment, vol. II, Environmental Research Institute of Michigan, Ann Arbor, Mich., 1974, pp. 813-824.

6. Eppler, W. G.: An Improved Version of the Table Look-up Algorithm for Pattern Recognition. Proceedings of the Ninth International Symposium on Remote Sensing of the Environment, vol. II, Environmental Research Institute of Michigan, Ann Arbor, Mich., 1974, pp. 793-812.

7. Graham, Marcellus H.: Digital Overlaying of the Universal Transverse Mercator Grid with Landsat-Data-Derived Products. NASA TM 58200, Aug. 1977.

8. Washington County, Mississippi. U.S. Department of Agriculture Soil Conservation Service, Soil Survey Series 1958, no. 3, May 1961.

9. Cotton: Acreage, Yield, and Production by Counties, 1974. Mississippi Crop and Livestock Reporting Service, 1975.

10. Soybeans: Acreage, Yield, and Production by Counties, 1974. Mississippi Crop and Livestock Reporting Service, 1975.

APPENDIX A

GROUND TRUTH DATA FORMS

This appendix provides samples of the ground truth data forms used for various applications programs. Figure A-1 shows the form used for crops and pasture; figure A-2, forest or brush; figure A-3, extractive land uses; figure A-4, marsh areas.

GROUND TRUTH DATA FOR CROPS AND PASTURE

TAKEN BY__________ DATE__________

TRAINING SAMPLE #__________ MAP OR AIR PHOTO INDEX #__________

ESTIMATED FIELD SIZE: _____ ft X _____ ft. or __________ ACRES

LOCATION__________
County 1/4 1/4 Section Township Range

GENERAL CONDITION(1) __________

DESCRIPTION (if not crop or pasture)__________

CROP OR PASTURE SPECIES(2) __________ VARIETY (if known)__________

PLANTING TECHNIQUE(3) __________ PLANT HEIGHT (to closest ft)__________

ROW WIDTH__________ PHYSIOLOGICAL STATE(4) __________

ROW DIRECTION__________ VISUAL ASPECT(5) __________

PERCENT GROUND COVER ( ) 0% to 20% ( ) 40% to 60% ( ) 80% to 100%
( )20% to 40% ( ) 60% to 80%

WEED INFESTATION (species & %, if greater than 20%)__________

DISEASE INFESTATION (kind & %, if greater than 20%)__________

INSECT INFESTATION (kind & %, if greater than 20%)__________

SOIL CONDITION(6) __________

SOIL MOISTURE(7) __________

SOIL TYPE(8)(if available)__________

OTHER COMMENTS (if needed)__________

(1) e.g. crop, pasture, stubble, plowed, fallow.
(2) e.g. soybean, bahia grass, etc.
(3) e.g. row, skip row, drilled, broadcast.
(4) e.g. flowering, heading, mature, etc.
(5) e.g. chlorotic, wilted, etc.
(6) e.g. freshly cultivated, rough, smooth, etc.
(7) e.g. moist, dry, waterlogged, etc.
(8) series, texture, color, slope, etc.

Figure A-1.- Ground truth data form for crops and pasture.

GROUND TRUTH DATA FOR FOREST/BRUSH VEGETATION

TAKEN BY: ______________________________ DATE ______________

TRAINING SAMPLE # ____________________ MAP OR AIR PHOTO INDEX # ________

ESTIMATED FIELD SIZE: ________ ft X ______ ft. or ________________ ACRES

LOCATION ____

County 1/4 1/4 Section Township Range

KIND OF VEGETATION (check one)
( ) Natural Forest
( ) Forest Plantation
( ) Brush Vegetation

If Natural Forest, indicate:

(1) Major forest type (check one)

( ) Maple-Beech-Birch ( ) Elm-Ash-Cottonwood ( ) Aspen-Birch
( ) Oak-Hickory ( ) Loblolly-Shortleaf ( ) Oak-Pine
( ) Oak-Gum-Cypress ( ) Longleaf-Slash ( ) Mixed Hardwood

(2) Species composition (to nearest 25%)

Species	%
______	___
______	___
______	___
______	___

(3) Average age class of upper canopy trees (check one)

( ) Less than 20 years ( ) 50 to 100 years
( ) 20 to 50 years ( ) over 100 years

(4) Average height class of upper canopy trees (check one)

( ) Less than 20 feet ( ) 50 to 100 feet
( ) 20 to 50 feet ( ) over 100 feet

(5) Slope

( ) 0% to 10% ( ) 30% to 50%
( ) 10% to 30% ( ) 50% or more)

(6) Predominant Aspect

( ) North ( ) South ( ) East ( ) West

If Forest Plantation, indicate (1) Species ______________ (2) Spacing ________

(3) Row Direction ________ (4) Ave. age: ______ (5) Ave. height: ________

If Brush Vegetation, indicate species composition to nearest 25%.

Species	%	Species	%
______	___	______	___
______	___	______	___

Figure A-2.- Ground truth data form for forest or brush.

GROUND TRUTH DATA
Extractive Land Uses

OBSERVATIONS MADE BY ______________________________ DATE ______________

IDENTIFIER NO.* ______________ Approx. Size _____ X _____ (feet) or _______ acres.

COUNTY ______________________________

LOCATION (if known) ____
Township   Range   Section   Quarter   Forty

ACTIVITY TYPE
( ) Sand pit
( ) Gravel pit
( ) Stone, dimension
( ) Stone, crushed
( ) Lime
( ) Cement
( ) Clay
( ) Chert & Tripoli
( ) Lignite
( ) Heavy mineral
( ) Other
____
____

Is area ( ) in-production or ( ) abandoned?

If abandoned, is area ( ) barren or ( ) revegetated?

Is the area likely to contain impounded water during all or a significant part of year ( ) yes ( ) no?

How much time did it take to make observations and fill out this form (min. and/or hours) ____________________.

*Observations should only be made on extractive areas that are at least 600 feet by 600 feet, or approximately 10 acres. Once such an area is located, its location should be delineated on an aerial photo or map sheet with colored pen or pencil, and an identifier cross-reference number should be recorded on the aerial photo or map beside the delineated area and on the ground truth data form.

Figure A-3.- Ground truth data form for extractive land uses.

GROUND TRUTH FORM FOR MARSH VEGETATION

1. Sample number______________.

2. Date: ________________.

3. Time: ________________.

4. Vegetation type:

   (1) pure stand (monotypic)________________.

      (a) species:____________________.

   (2) intermixed (less than 6 vascular species present) ________________.

      (a) dominant species:____________________, ________________.

   (3) intermixed (more than 6 vascular species present) ________________.

      (a) dominant species:____________________, ________________.

      (NOTE: If a species comprises less than 5% of vegetation do not regard as major or dominant component.)

5. Homogeneity:

   (1) sub-elements (defined)

      (a) vegetation differences (clumps, patches, zones) ________________.

      (b) barren areas ________________________________.

      (c) open water ________________________________.

      (d) sparse vegetation/barren ________________________.

      (e) sparse vegetation/water ________________________.

      (f) other (describe) ____________________________.

   (sub-elements (size)

      (a) less than 10 feet ____________________________.

      (b) more than 10, but less than 20 ____________________.

      (c) more than 20, but less than 40 ____________________.

      (d) more than 40, but less than 60 ____________________.

Figure A-4.- Ground truth data form for marsh areas.

(3) distribution (of sub-elements in study area).

(a) evenly ______________________________.

(b) center ______________________________.

(c) peripheral ______________________________.

(4) density (of vegetation as % of surface area).

(a) dense > 90 ______________________________.

(b) intermediate < 70 ______________________________.

(c) sparse < 50 ______________________________.

6. Height of plants (stands).

(1) approximate height of major units:

(a) species ______________, height ______________.

(b) species ______________, height ______________.

(c) species ______________, height ______________.

(2) approximate height of minor units:

(a) species ______________, height ______________.

(b) species ______________, height ______________.

7. Status of vegetation:

(1) approximate (%) of dead-standing material.

(a) major units (species) ______________________________.

(b) minor units (species) ______________________________.

8. Stage of growth:

(1) major units

(a) dormancy (winter-no leaves) ______________________________.

(b) dormancy (winter-leaves dead-standing) ______________________________.

(c) seedlings ______________________________.

(d) immature ______________________________.

(e) mature ______________________________.

(f) anthesis ______________________________.

Figure A-4.- Continued.

(g) vigor ______________________________.

(1) excellent ______________________________.

(2) fair ______________________________.

(3) poor ______________________________.

9. Surface of substratum:

(1) covered by algae ______________________________.

(2) covered by small vascular plants ______________________________.

(3) covered by detritus ______________________________.

(4) barren ______________________________.

(5) substrate type

(a) mud ______________________________.

(b) sand ______________________________.

(c) sandy/mud ______________________________.

10. Water level.

(1) standing on surface of marsh ______________________________.

(a) covered by tidal water ______________________________.

(b) covered by river overflow ______________________________.

(c) combination of both (a & b) above ______________________________.

(d) permanent or semi-permanent ______________________________.

(2) Depth of water on marsh surface ______________________________.

11. Comments:

Figure A-4.- Concluded.

APPENDIX B

TOWNSHIP CODING DIAGRAM AND TOWNSHIP 171 DENSITY PLOTS

A diagram of the coding for townships in Washington County, Mississippi, is shown in figure B-1. Figure B-2 shows a computer-implemented, 50-meter-cell density plot of land cover classifications in township 171; figure B-3 shows a 16-hectometer (40 acre) cell density plot of the same area.

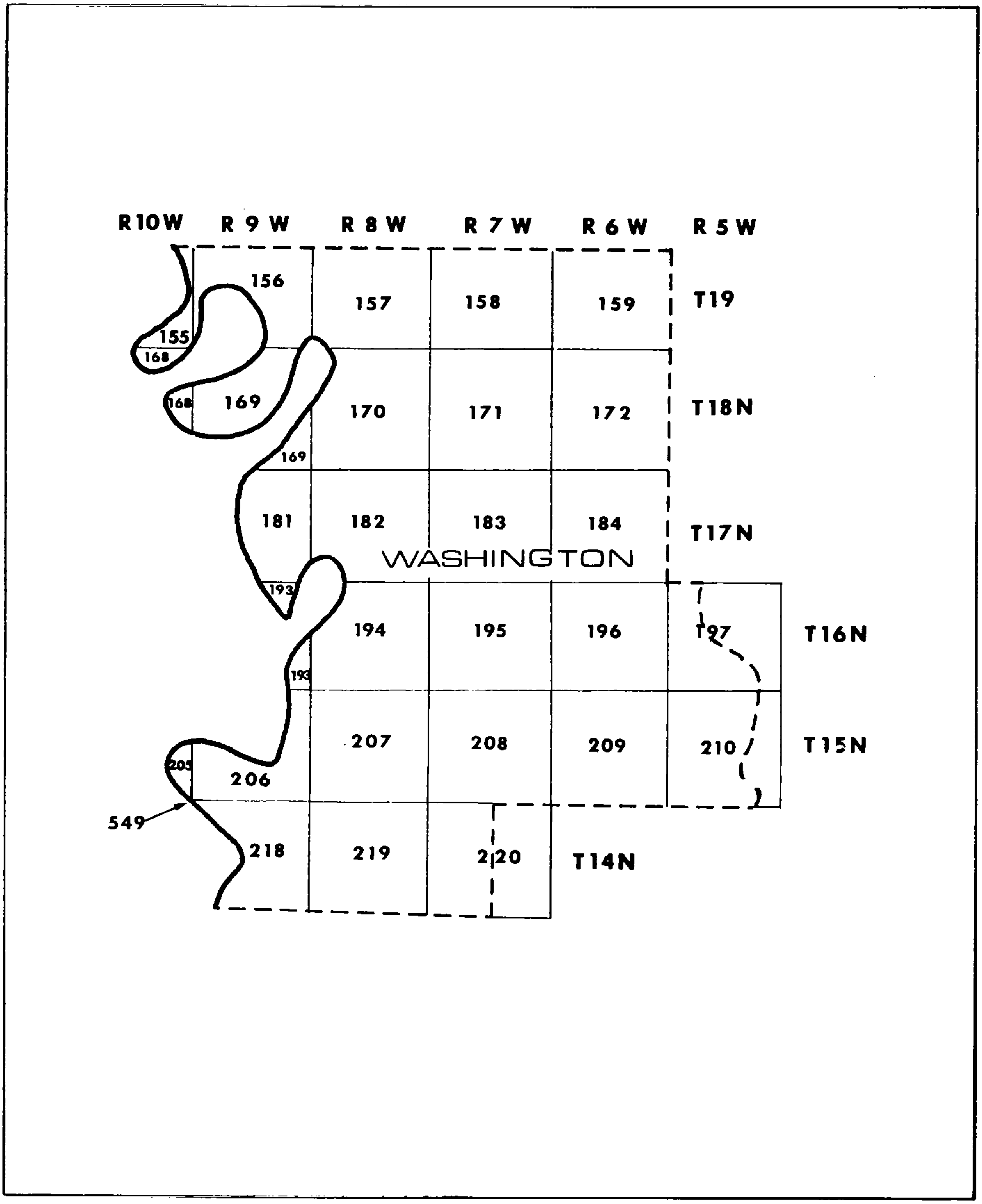
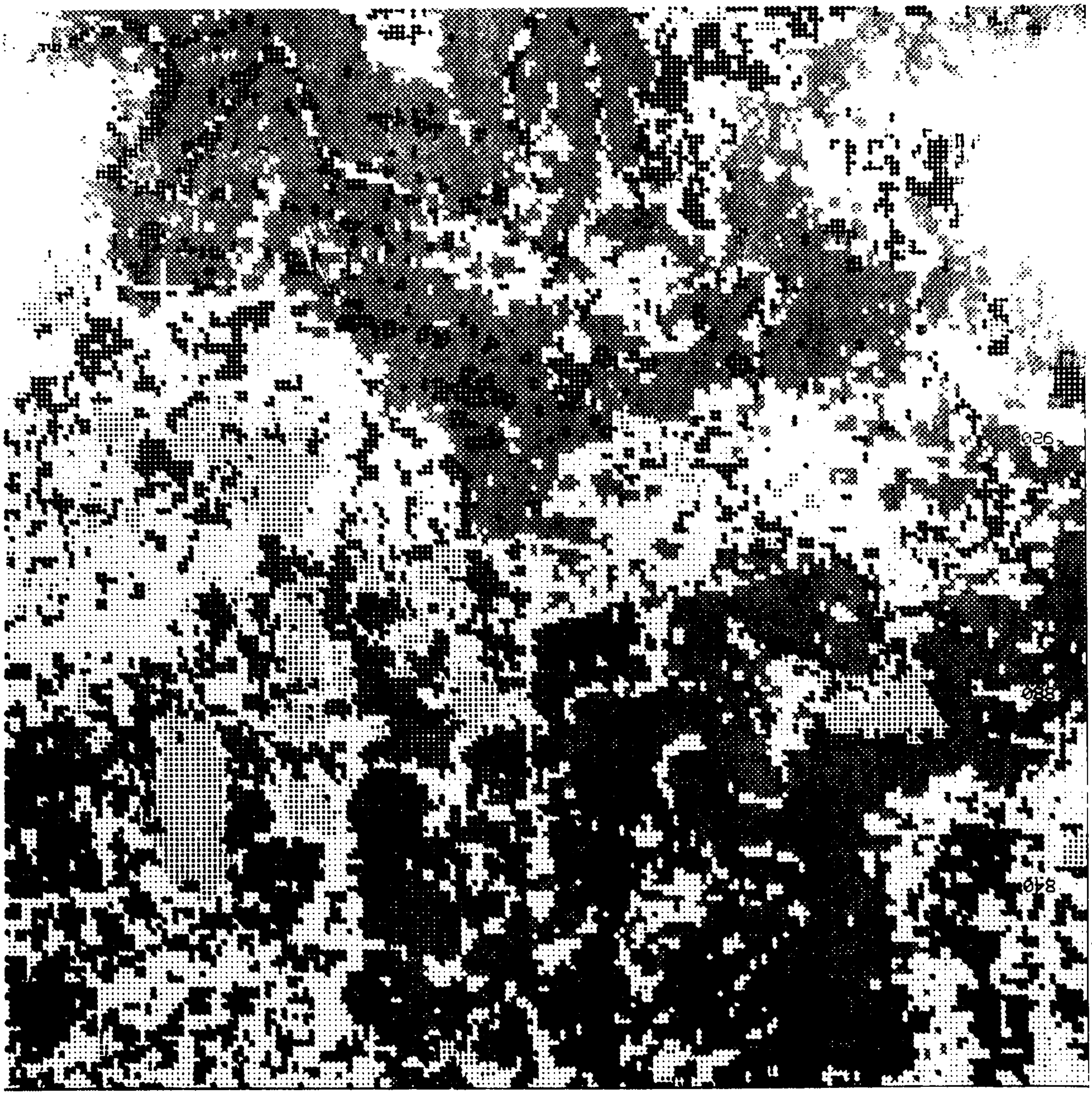


Figure B-1.- Diagram of township coding in Washington County, Mississippi.



Soybeans (1)
Cotton (2)
Oak-gum-cypress (32)
Other (15,17,19,61)

Figure B-2.- Computer-implemented, 50-meter-cell density plot of land cover classifications in township 171.

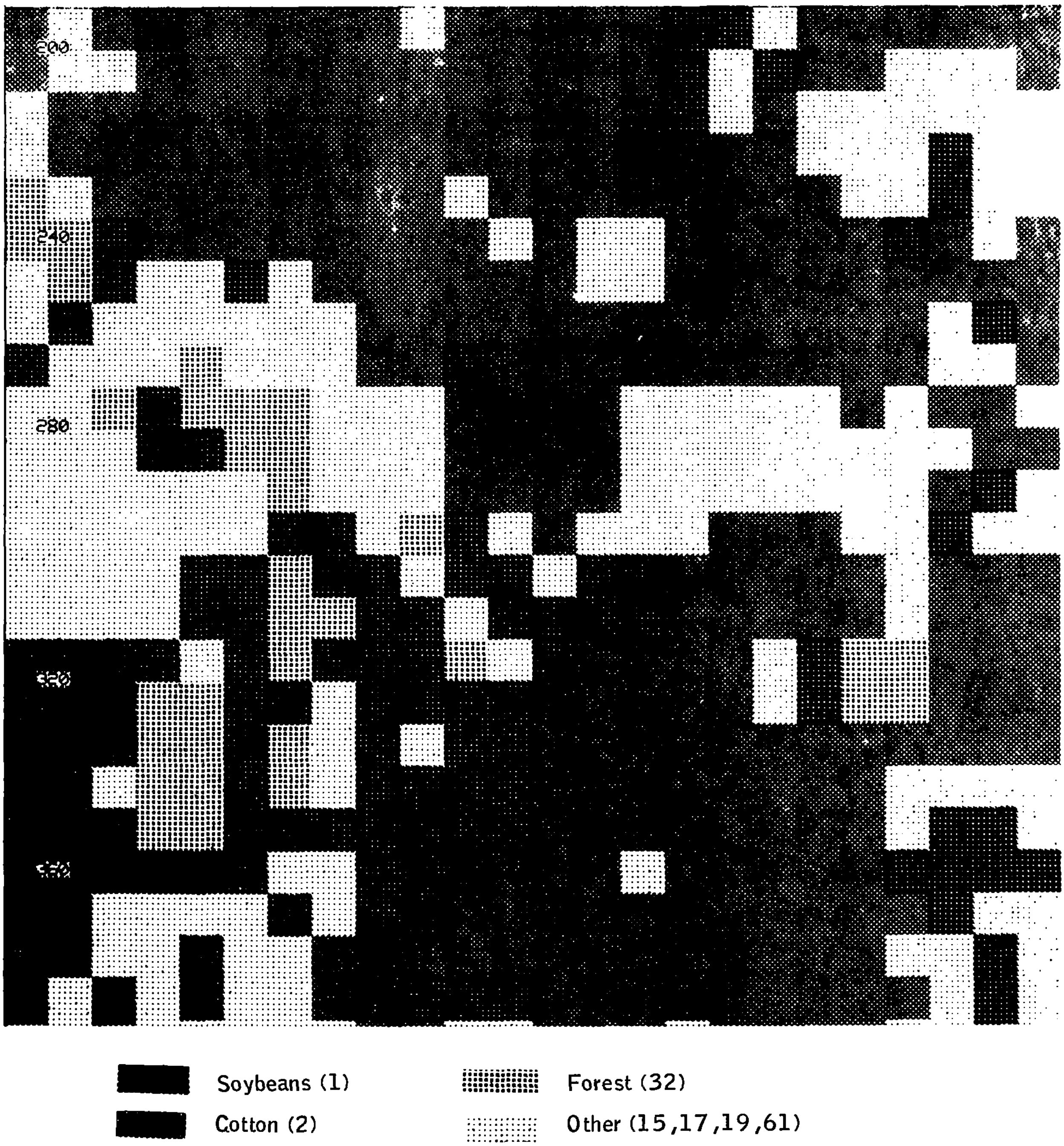


Figure B-3.- Computer-implemented, 16-hectare (40 acre) cell density plot of land cover classifications in township 171.

APPENDIX C

COMPUTER REQUIREMENTS FOR LOW-COST DATA ANALYSIS SYSTEM

The following table shows the minimum and desired requirements for computer hardware in a low-cost data processing system.

Characteristic	Requirements	
	Minimum	Desired
Central processor unit with operator's console	Required	Required
Memory	16 000 16-bit words	64 000 16-bit words (dual port)
Tape drives (computer-compatible tape)	Two 7- or 9-track drives	Two 9-track drives, 3.05 m/sec (120 in/sec), 315 bytes/cm (800 bytes/in)
Disk (rotating memory device)	12 000 000 16-bit words	46 000 000 16-bit words
Line printer	Required	Required
Electrostatic printer	Not required	Required
Card reader	Required	Required
Floating-point hardware	Not required	Required
Microprogrammable writable control storage	Not required	Required
Operating executive system	Not required	Required
FORTRAN compiler	Required	Required
Approximate cost (1975 prices)	$75 000 to $80 000	$150 000

1. Report No. NASA RP-1016	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle THE USE OF LANDSAT DIGITAL DATA AND COMPUTER-IMPLEMENTED TECHNIQUES FOR AN AGRICULTURAL APPLICATION		5. Report Date January 1978
		6. Performing Organization Code JSC-12897
7. Author(s) Armond T. Joyce and R. H. Griffin II		8. Performing Organization Report No. S-477
		10. Work Unit No. 177-52-89-00-72
9. Performing Organization Name and Address Lyndon B. Johnson Space Center Houston, Texas 77058		11. Contract or Grant No.
		13. Type of Report and Period Covered Reference Publication
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Agricultural applications procedures are described for use of Landsat digital data and other digitized data (e.g., soils). The results of having followed these procedures are shown in production estimates for cotton and soybeans in Washington County, Mississippi. Examples of output products in both line printer and map formats are included, and a product adequacy assessment is made.

17. Key Words (Suggested by Author(s)) Agriculture; Soils; Crop production estimates; Information system; Remote sensor; Multispectral scanner; Earth resources; Pattern recognition; Thematic mapping	18. Distribution Statement STAR Subject Category: 43 (Earth Resources)

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	47	$4.00

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