NASA

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TM-80416

(E79-10208) NATURAL RESOURCES INVENTORY SYSTEM ASVT PROJECT Final Report (NASA) 129 p HC A07/MF A01 CSCL 05B

N79-25457

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G3/43 00208

EARTH RESOURCES LABORATORY

FINAL REPORT ON THE NATURAL RESOURCES INVENTORY SYSTEM ASVT PROJECT

REPORT NO. 174

APRIL 1978

NATIONAL SPACE TECHNOLOGY LABORATORIES

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ACKNOWLEDGEMENTS

The project addressed in this report was carried out through the combined efforts of the Mississippi Office of Science and Technology (OST) and cooperating state agencies; the NASA Earth Resources Laboratory (ERL); and the Lockheed Electronics Co., Inc. (support contractor to ERL).

Dr. Preston T. Bankston, Director of OST, was instrumental in the planning and organization of the project. Mr. Richard G. Barnes, Jr. of OST acted as co-manager for the project and provided key services in conducting and coordinating activities with the various cooperating state agencies. A large number of state personnel from the various cooperating state agencies were involved in the definition of applications that were demonstrated, ground truthing, and product evaluation.

Dr. Armond T. Joyce, Chief of the Land Applications Group at ERL, served as co-manager for the project with Mr. Barnes. ERL Land Applications Group personnel who conducted the data processing and analysis for the various applications demonstrated and contributed to the text of this report included Dr. R. H. Griffin, II, Dr. W. G. Cibula, Mr. J. E. Anderson, and Mr. K. D. Cashion. ERL Data Management Group personnel provided invaluable services in the design and development of computer programs and during data processing activities.

Lockheed Electronics Co., Inc. (LEC) provided support services throughout all aspects of the project. The efficiency and expertise of Mr. W. R. Bounds, Mr. B. R. Howard, Mrs. J. A. Forbes, and Mr. R. D. Vaughn of LEC were especially helpful during the project.

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ABSTRACT

The hardware/software and the associated procedures for a natural resource inventory and information system based on the use of Landsat acquired multispectral scanner digital data is described. The system is designed to derive land cover/vegetation information from Landsat data and geographically reference this information for the production of various types of maps and for the compilation of acreage by land cover/vegetation category. The system also provides for data base building so that the Landsat-derived information can be related to information digitized from other sources (e.g., soils maps) in a geographic context in order to address specific applications. These applications include agricultural crop production estimation, erosion hazard-reforestation need assessment, whitetail deer habitat assessment, and site selection. The system is tested in demonstration areas located in the state of Mississippi, and the results of these application demonstrations are presented. A cost efficiency comparison of producing land cover/vegetation maps and statistics with this system versus the use of small-scale aerial photography is made.

I. INTRODUCTION

This is the final report on a project entitled "Natural Resources Inventory System ASVT" (Application System Verification and Transfer). The objective of the project was to develop, test, and demonstrate an automated natural resources inventory and information system based on remotely sensed data oriented to state or regional use and directed at specific applications. The project was conducted by the NASA Earth Resources Laboratory (ERL) over a 39-month period beginning in July 1974. It was the first ASVT project instigated under the NASA Office of Applications ASVT program.

The project was divided into three overlapping phases. The first phase consisted of the design and development of a system (hardware, software, and procedures) for deriving land cover/vegetation information from Landsat digital data and the use of that information in the manner prescribed in the project plan. This system is described in Section II of this report. Other documents addressing system software, hardware, and procedures that were published prior to this report include NASA TR R-467, NASA TM-58200, and NASA RF 1015 (Refs. 1, 2, and 3).

The second phase involved the testing of the system for specific applications within selected demonstration areas. This work was conducted by the ERL working in conjunction with the Mississippi Office of Science and Technology and cooperating state agencies.

The specific applications to be tested and the demonstration area for each was defined in a series of meetings between representatives from various Mississippi state agencies and ERL personnel. The applications selected were agricultural production estimation, erosion hazard-reforestation needs assessment, whitetail deer habitat assessment, acreage compilation, inference mapping, theme mapping, change detection, and site selection.[1] The results of the first demonstration to be completed, agricultural production estimation, were published in NASA RF 1016 (Ref. 4). A summary of those results and the results of the remaining demonstrations are covered in Section IV of this document. As the products of each application demonstration were produced, meetings were conducted to present and review the products with state agency personnel. The adequacy of these products as discussed at the briefings and through subsequent evaluations is addressed in Section V of this document.

The third phase of the project included the training of Mississippi personnel, and the adapting and testing of computer programs on a state computer. This phase is discussed in Section II of this document.

Although the state of Mississippi was the focus for the application demonstrations in Phase II of this project, the basic objective of the ASVT was to develop a system for utilizing Landsat digital data that would have widespread utility. During the course of this project, this system for deriving land cover/

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[1]Although not conducted in the context of this ASVT project, other applications for which this system has been demonstrated are addressed in NASA TR R-472 and NASA TM 58203 (Ref. 5 and 6).

vegetation information from Landsat digital data has been implemented by the state of Georgia and the U. S. Environmental Protection Agency, and technology transfer to various other state and federal agencies commenced.

II. SYSTEM DESCRIPTION

The phrase "natural resource inventory system" is used in this report to mean the hardware, the software, and the procedures used to perform natural resource inventory with satellite acquired data. The system used to process data for this project has also been called the "low-cost data analysis system", the "Earth Resources Laboratory data analysis system", and the "Earth Resources Data Analysis System." The system designs employ a modular approach for both hardware and software to take advantage of equipment available in a user's facility, and to give the user a choice of commercially available components based upon his resource management requirements.

Hardware

The hardware associated with a natural resource inventory system such as used in this project may be separated into three general modules: an image display device, a computer with appropriate peripherals, and an output device.

Image Display Devices

Two types of image display devices were used during the project. One was a "stand-alone" device called a Portable Image Display System (PIDS), and the other was an "interactive" device called an Image Processing System (IPS).

The PIDS, shown in figure 1 , reads one band of Landsat MSS raw data from a 9-track computer compatible tape, and displays the data in colors or shades of grey on the screen of a cathode ray tube (CRT) similar to a home television set. The PIDS operates on 60 cycle, 110-115 volt AC electrical power, and

Figure 1. **Portable Image Display System (PIDS).**

is mounted on wheels for ease of movement from office to office. The necessary controls are provided to advance, reverse, or shift laterally so as to display any selected 256 scan lines by 240 elements of data on the tape. It is possible to select from 64 levels of color or grey to display the image on the TV monitor. The scale of the displayed image is such that it corresponds to an area of about 9 by 9 miles.

The primary use of the PIDS is to determine coordinates (scan line and element number) that define training samples and/or control points in the data. This is accomplished by using a "track-ball" control to position a cursor symbol, "+", anywhere within the screen. The coordinates of the cursor symbol's position are displayed by light-emitting diodes on the front panel of the PIDS. These coordinates can be manually recorded or transmitted to an output device (punched paper tape, keypunch, card punch).

In addition to displaying raw data, and determining scan line and element coordinates, the PIDS may also be used to display land cover/vegetation classifications derived from Landsat raw data. One can learn to operate the PIDS in less than an hour, and it requires little and simple maintenance.

The other type of image display device used on this project was an "interactive" device called an IPS (Image Processing System), such as the one shown in figure 2 . This device may be hard-line connected with a small general purpose computer so that the user may interact with the data processing and analysis steps. Data are read from tape into the computer to which the

Figure 2.

IPS is coupled and are reformatted for display on the IPS display screen. An area of about 18 by 18 miles encompassing 512 scan lines by 512 elements can be displayed on the screen using as many as 256 levels of color or gray.

The IPS must be installed in a fixed location, but it may be physically separated from the computer and operated as a terminal (separation of more than 50' requires line drivers). Because an investigator uses very little of the computer's capacity during time-consuming tasks such as training sample selection, an operator's console at a cost of about $3,000 can be added so that the IPS can be used in a time-sharing mode where other tasks can be performed concurrently by the computer.

The IPS is used to perform the same functions as the PIDS; however, because the IPS is interactive with a computer, the computer can be used to calculate and display statistics for each training sample as they are selected so that a real-time assessment of training sample quality can be made. In addition, the IPS provides a variety of interactive data analysis functions including automated image enhancement, enlargement of selected portions of the data, training sample coordinate storage and recall, and use of disk storage that the PIDS does not provide.

At the date of this report, the cost of a PIDS (stand-alone device) such as used at ERL is about $33,000, and the cost of an IPS such as used at ERL with an operator's console is about $39,000. However, the use of the IPS provides significant savings in operating costs when the throughput is such that the system can be wholly dedicated to the processing of Landsat MSS digital data. Consequently, when considering both capital investment and operating costs, the "interactive" image display device may be more economical than the stand-alone image display device at some rate of throughput even though the capital investment cost is higher. Therefore, the decision as to a stand-alone device or an interactive device is more likely to depend on the availability and/or organizational arrangements for the use of a computer than it is likely to depend on the intial cost of the two devices. For example, if the user only had a large, centralized computer facility at his access or if his office was physically distant from the computer, he may choose a portable stand-alone device. On the other hand, if he was considering the purchase of a small computer and/or had the physical space to locate the image display device within 50 feet of an existing computer, he would probably choose the computer interactive image display device.

Computers

Almost any small (or large) general-purpose computer may be used to derive land cover/vegetation information from Landsat digital data. Greater operating efficiency of some small computers may be achieved by adding to the systems software package a few instructions that make Landsat digital data manipulation easier.

The characteristics of minimum and desired computer configurations are shown in table 1. The minimum computer capability required is shown in the second column. If a computer of the minimum capability is used, the data processing time will be longer. It may be necessary to process the Landsat data through the computer two or more times to classify all data.

TABLE I - COMPUTER REQUIREMENTS

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 (1978 prices)	\$75,000 to \$80,000	\$120,000

Addition of computer memory is recommended when high throughput rates are required. The third column of table 1 shows the desired computer configuration, which is adequate for most potential users of Landsat data, even for State-sized survey areas.

Computer cycle time is not critical in the selection of a candidate computer. A cycle time of 1 microsecond is acceptable; but if high-volume throughput is required, cycle times of 660 nanoseconds or faster are recommended. The speed of geographical reference conversion depends on the data manipulation (multiplication and division) efficiency of the computer. Hardware or firmware floating-point processors are recommended if geographical reference conversion (i.e., conversion from Landsat scene coordinates to UTM map coordinates is required).

Although computer tape drives of any speed may be used in the system, it is recommended that tape speed be as high as possible ($\leq$ 3.05 m/sec (120 in/sec)) because most modern computers can process data very rapidly. The tape drives should be capable of reading 315- and/or 630-byte/cm (800 and/or 1600 byte/in) packing densities.

Disk drives (rotating memory devices) are required in the system to store a Landsat-size image during geographical reference conversion. A disk is also very useful for storage and quick retrieval of all software modules used in the system.

Small computers that are adeuqate for use in the system together with all the necessary peripherals may be purchased for $75,000 to $125,000, depending on throughput rates required. The operating costs for these small computers (without equipment amortization or housing) are in the range of $30 to $45 per clock hour.

Output Recording Devices

Two output recording devices, an electrostatic printer/plotter and color film recorder, were used to produce map products for the applications demonstrated as part of this project.

The electrostatic printer/plotter produces all the characters available on a standard line printer in various letter sizes and also produces as many as 16 distinct grey levels for a given print position. The output may be produced as a grey-shade map through a technique known as level slicing, or the output may be produced as separate plots for each land cover/vegetation category (thematic map), or the output may be subdivided into red-green-blue (RGB) components. The thematic maps and the RGB components may be converted to color-coded maps through either the Kwik-Proof process or the CROMALIN process (see ref. 1 for details of these two processes). Figures 5 and 10 in Section IV of this document shows photographically reduced versions of color-coded maps that were produced with the CROMALIN process.

Electrostatic printer/plotters are available from several sources and are competively priced at approximately $12,000 to $20,000 depending on speed, resolution, and grey-scale consistency. The special equipment needed for the CROMALIN process includes a laminator and a console that are priced at about $3,800. The average photographic laboratory would include the remaining equipment needed to convert gray-scale plots to a color-coded map. However, the equipment needed could be puchased for about $5,000. If negatives or positives are provided, a number of companies throughout the United States can produce color-coded CROMALIN maps at contact scale quite inexpensively.

The other output device used during this project was a HRB-Singer stand-alone color film recorder. This film recorder had a built-in capability for expansion and, when used with data previously processed with the appropriate computer software routines, can record at any specified scale without loss of resolution. The output was recorded on 241-millimeter (9.5 inch) wide negative color film which was developed and printed. These printed strips were then mosaiked together and, after appropriate lettering, were photographically reproduced to produce the color-coded maps reduced versions of which are shown in figures 6, 8, and 9 of this document. The prototype color film recorder used during this project was priced at $115,000, but is no longer available commercially.

In summary, there are various options that could be followed to assemble the hardware components of a natural resource inventory and information system as used in this project. The least expensive option could include a portable image display device, a computer and peripherals listed in column 2 of table 1, and an electrostatic printer/plotter as an output recording device for a total cost of about $125,000. The most expensive option could include an interactive image display device, a computer and peripherals listed in column 3 of table 1, and a color film recorder as an output recording device for a total cost of about $255,000. If it is assumed that most users would not require the precision inherent in the color film recorder but would prefer the efficiency of an interactive image display device and the larger computer, the total hardware cost would be about $160,000. If a computer and the peripherals generally associated with a computer were already available the approximate costs for the three possible configurations listed above would be $45,000, $154,000, and $59,000 respectively. If a small photographic laboratory were not available, the photographic equipment needed to convert Landsat-derived land cover/vegetation classifications into color-coded maps together with the equipment needed for the CROMALIN process could be purchased for about $8,800.

Software and Data Processing Procedures

The intention of this section is to describe the use of this natural resource inventory system 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 3 , which shows the data processing flow. Also, to help the reader focus on 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)[2] 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). The basic function of the PATREC programs is to generate a computer-implemented

[2] Computer-compatible tapes are available at the EROS Data Center, Sioux Falls, SD, at a cost of $200 per set.

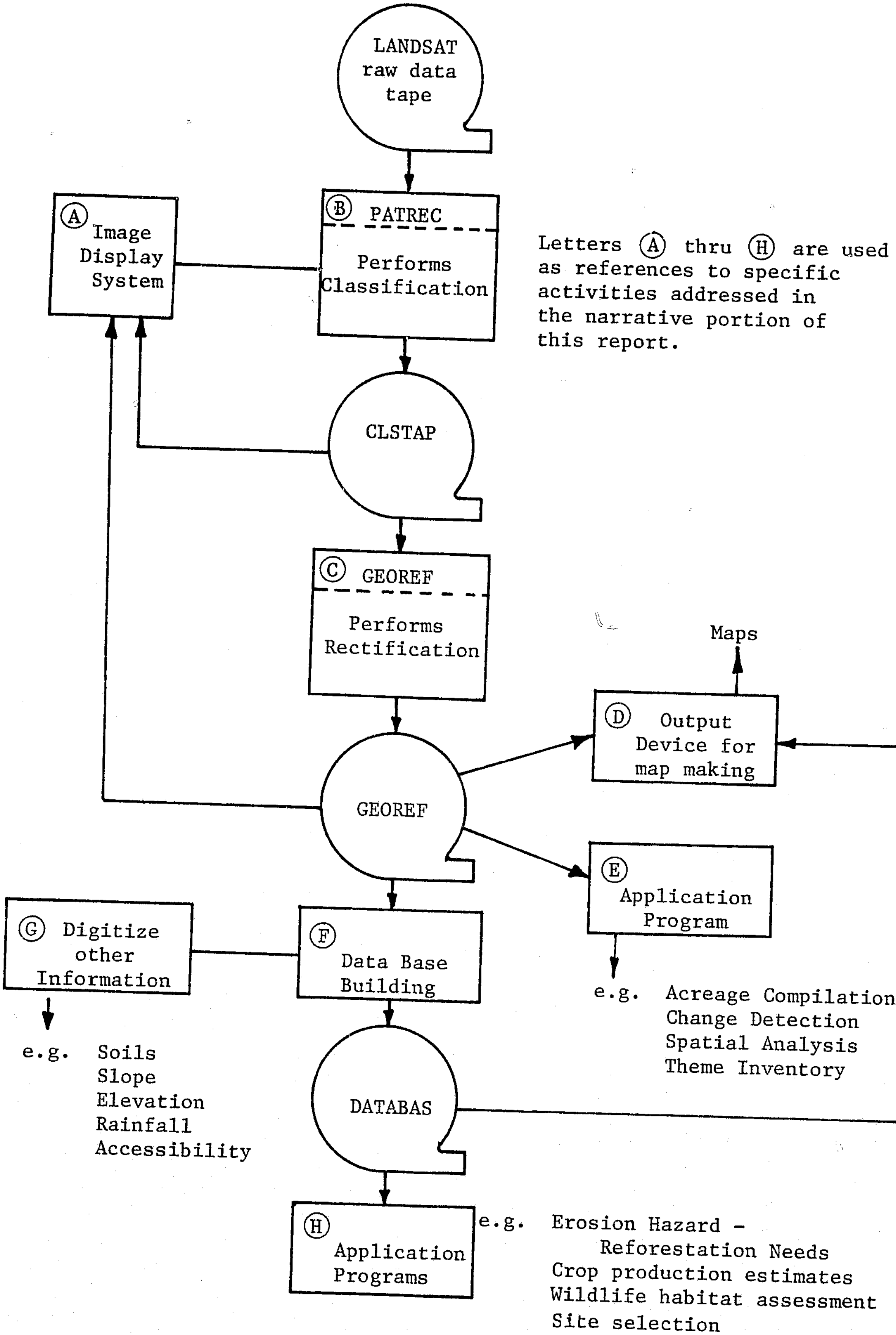

Figure 3. Data Processing Flow Dagram.

classification of each pixel[3] (representing 0.44 hectares (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 (e.g., pine forest, cotton field, etc.).

The computer programs that make up the ERL PATREC module relate to the "supervised" technique, and the classification algorithm is based on maximum likelihood ratio calculation and Bayesian decision rules. (See refs. 1 and 7 for basic theory and details.) Use of the supervised technique requires that the location of a number of sites of known land cover (e.g., a soybean field) be established in the data. These sites are selected for a 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 sites" because, in a simplistic sense, they are eventually used to "train" the computer to recognize the same land cover elsewhere.

The potential training sample sites 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. The activity associated with field observations is usually referred to as a "ground truth" operation and involves ascertaining whether the potential training sample site is

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

uniform and homogeneous in respect to the land cover type that it was selected to represent. The number of training sample sites needed varies with the number of land cover categories to be classified and the variation within each category. As an example, if 12 land cover categories were to be classified within a 185 by 185 kilometer (115 X 115 statute mile) area that relates to a set of CCT's for a particular Landsat scene, one may, as a rule of thumb, expect to encounter variation in each land cover that may require the selection of 100 to 140 potential training sample sites.

The training sample sites for the applications addressed in this report were established as part of a statewide activity. The exact procedures and details of ground truth activities are treated in a separate document (ref. 3).

The potential training sample sites were related to the satellite-acquired data contained on CCT's through use of an image display device (activity A, figure 3). 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 sites were outlined. To identify the location of a particular training sample site in the displayed digital data, the operator positioned a movable cursor on each corner of the training sample site and recorded the coordinates (scan line count and element count) of each corner. When a portable stand-alone image display was used, each set of coordinates that referred to a particular training sample site was punched on cards for use in the implementation of the computer programs in the PATREC module. When an image display device that was interactive with a computer was used, the training sample coordinates were automatically recorded in computer memory.

Activity B on figure 3 includes the implementation of computer programs that perform different functions in the PATREC module. The computer programs in the PATREC module are LANREF, DAPIDS, ISOFLD, STATS, ELLIPSE, and ASSIGN.

Program LANREF accepts the original Landsat MSS bulk tape and converts it to a format called DATTAP (data tape). The DATTAP format is more convenient to read and manipulate than the original Landsat format.

Program DAPIDS (data tape to PIDS tape conversion) accepts the DATTAP format and converts it to a DISTAP (display tape) format, which is the format expected by the PIDS. Basically, the DISTAP format consists of general header information (including scan-line count), and each picture element of the imagery is expressed as 6-bit words (64 levels). This format is flexible in that scan lines may contain as many as 2000 picture elements.

Program ISOFLD accepts as input the Landsat data in the DATTAP format, cards containing the coordinates of polygon-shaped (n-sided, where n < 100) training samples, and sample identification as defined by the user. The purposes of program ISOFLD are to isolate and extract training-sample data from Landsat data tapes and to produce a new tape in the DATTAP format that contains only training-sample data.

Program STATS accepts training-sample data from program ISOFLD in the DATTAP format only. Program STATS produces tabulations of histograms, means, standard deviations, covariance matrices, and spectral plots for each training sample. Based on a divergence criterion, program STATS also calculates the relative separability of materials to be classified. Program STATS produces signatures for each material in the form of means and covariance matrices in the SIGTAP format.

Program ELLIPSE reads signatures as determined by program STATS in the SIGTAP format, then converts each of the signatures into elliptically shaped, four-dimensional decision boundaries. The boundaries are written onto tape as decision tables in the TABTAP format for use in program ASSIGN. Programs ELLIPSE and ASSIGN are also known as program ELLTAB. These two programs were described by Jones (ref. 7), and their theory was described by Eppler (ref. 8).

Program ASSIGN reads decision tables for each classification category and stores them in computer memory. Program ASSIGN also accepts, as input, the bulk Landsat MSS data in the DATTAP format, classifies all data by a table look-up procedure based on maximum-likelihood spectral pattern recognition, and produces a land cover/vegetation classification in the DISTAP format. Program ASSIGN runs very rapidly and can classify an entire Landsat scene into 24 classification categories in approximately 1 hour, depending on the computer system used.

All of the land cover/vegetation classifications derived from Landsat data for this project were produced with program

ELLTAB; however, two other classifier programs, MAXL4 and MAXL4X, were developed at ERL during the course of this project. The MAXL4 program is based on the maximum likelihood ratio concept like the ELLTAB program, but has been optimized for the four bands of Landsat I and II MSS digital data. MAXL4X is an express version of MAXL4 (runs about four times as fast) that involves both maximum likelihood ratio computations and table lookup. The obvious (easy to classify) surface materials are identified quickly by a three channel table lookup and those pixels more difficult to classify (more likely to be confused) are classified by maximum likelihood ratio computationall

In addition, another computer program called SEARCH, which can be used with MAXL4 or MAXL4X, was developed at ERL during the course of this project to permit automated signature development. This program identifies up to 50 signatures that are spectrally distinguishable in respect to specified statistical measures. These signatures are used for classifying each pixel in the data set and the resulting classes are named as to the land cover/vegetation categories with which they correlate as determined by analysis of spectral plots, aerial photography, and/or field observations.

Activity B includes both human and machine analysis to produce tapes labeled CLSTAP in figure 3. Tapes produced at this point contain computer-implemented classifications (land cover type) of each pixel (0.44 hectare or 1.1 acres on the ground) on the tape. 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 3, 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) grid (ref. 2). The procedure involves the determination of UTM (northing, easting) grid coordinates and Landsat data (scan line and element coordinates) coordinates for 10 to 30 control points distributed over the set of tapes for a given Landsat scene. The operation was performed by visually matching the image displayed on the CRT with a map or orthophoto constructed with a UTM projection and determining the coordinates for 10 to 30 surface features (e.g., road intersections, bridges over water bodies) that are apparent on both the image and the map. The GEOREF programs involve the use of the control point coordinates 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 pixel is resampled and interpolated to fit a specified cell size through the nearest neighbor approach. In the case of this project a 50 by 50 meter cell size was specified. The rectification can be performed for an area of 10,000 square kilometers (about 3860 square miles) corresponding to 1° latitude by 1° longitude during one computer run. In the course of rectifying data for a 1° by 1° area, which may relate 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 figure 3) that 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. The tapes produced in this manner are used for making various types of maps at various scales (activity D, figure 3), and as an information source for various application algorithms (activity E, figure 1). Some of these activities, as well as the results of specific demonstrations, will be discussed in more detail in subsequent sections of this report. In addition, GEOREF tapes can also be used as an information source for data base building.

The purpose of data base building (activity F, figure 3) is to integrate the land cover information from the GEOREF tapes with information that is digitized from other sources (activity G, figure 3) in a geographical referenced manner. 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 (activity H, figure 3) will have efficient access.

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 16 subdivisions, called "forties" of a given section) by identifying the center (northing, easting) UTM grid coordinates of each unit. Although either option may be used for a particular areas 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."

The advantage of using the nongridded option for public land surveyed area 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 NW¼ NW¼, section 33, T.9s, R.6W 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 a 400 by 400 meter cell, the advantage of the nongridded option lessens as cell sizes smaller than 16 hectares (about 40 acres) are elected.

For either option, gridded or nongridded, the design of the data base provides for storing up to 30 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 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 24 variables would include information other than land cover, such as soils, slope, and aspect.

As mentioned previously, the size of the cell for the gridded option can be any multiple of 50 meters up to 400 by 400 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; and,

(4) Accuracy required for the applications as determined by the nature of the decisions to be made.

It is anticipated that the resulting choice will usually result in a data base cell size of 200 by 200 meters (approximately 10 acres) or larger being chosen for statewide data bases.

In the case of the Landsat applications demonstrated in this project, a 16.2 hectare (40 acres) cell was chosen, which would result in 30 million elements of information (1 million cells times 30 variables) if 30 variables were to be stored for the entire state of Mississippi. This information could be stored on two CCT's, one each for the areas east and west of 90^{o} longtitude.

No particular method is assumed for digitizing information other than land cover information (activity G, figure 3). 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 information from maps because the data are initially in digital form. Consequently, one may wish to employ manual techniques for encoding such stable variables as soils, slope, aspect, and elevation for which baseline information need be digitized only once. However, if compatible with the accuracy requirements for a particular application, one should consider the use of National Cartographic Information Center tapes (containing elevation information from 1:250,000 scaled contour mapping) for derivation of slope, aspect, and elevation information.

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.[4] It is not anticipated that agencies other than those engaged in nationwide digitizing of information would employ more sophisticated methods.

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[4]The data-base-building computer programs can also be employed in such manner that photo-interpreted or 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.

III. TECHNOLOGY TRANSFER

The phrase "technology transfer" is used in this report to mean the process by which the ability to use techniques developed in a research mode is passed-on to an agency that has a desire to use these techniques operationally. In this context, technology transfer has many ramifications including instructions in the implementation of procedures, software documentation, hardware specifications, and, probably most important, the understanding of the capabilities of the system to furnish information of utility to the recipient.

The main approach taken in this project was to directly involve State of Mississippi personnel in a demonstration of the utility of Landsat data using a data processing system at the Earth Resources Laboratory.

During the first meeting, representatives of the state operating agencies were given a briefing on the acquisition and processing of Landsat data to derive information for land resources applications. After this meeting, representatives from individual state agencies met with ERL personnel in a series of meetings conducted to define specific applications to be demonstrated during the course of the project, and to define the manpower needs and method of conducting ground truth information gathering. The specific demonstration applications defined and the results are the subject of Section IV of this report. The state personnel that gathered ground truth information are shown in Table 2.

Subsequently, orientation meetings with field personnel

TABLE 2 -- FIELD PERSONNEL BY TYPE OF GROUND TRUTH

CATEGORY	COORDINATING AGENCY	FIELD PERSONNEL	GEOGRAPHIC AREA
CROPS, PASTURE, ORCHARDS	MS. COOP. EXTENSION SERVICE	82 COUNTY AGENTS	STATEWIDE
COASTAL WETLANDS	MS. MARINE RESOURCES COUNCIL	3 GULF RESEARCH LAB.	COASTAL ZONE
OTHER NATURAL VEGETATION	MS. FORESTRY COMMISSION	63 COUNTY FORESTERS	STATEWIDE
	MS. GAME & FISH COMMISSION	8 DISTRICT BIOLOGISTS	20 GAME MGM'T AREAS
	MS. PARK COMMISSION	15 PARK SUPERINTENDENTS	15 STATE PARKS
URBAN & BUILT-UP	MS. R&D CENTER/ECO. DEVELOP. DISTRICTS	10 ECONOMIC & DEVELOPMENT DISTRICTS	URBAN AREAS
EXTRACTIVE	MS. GEOLOGICAL SURVEY	2 JACKSON OFFICE TECHNICAL STAFF	STATEWIDE

NOTE: SEE REFERENCE 3 FOR DETAILS ON THE GROUND TRUTH GATHERING ACTIVITIES. ALTHOUGH A LARGE NUMBER OF FIELD PERSONNEL WERE ENGAGED IN GROUND TRUTH GATHERING ACTIVITIES DURING THIS PROJECT, EACH PERSON PROVIDED ONLY A SMALL AMOUNT OF HIS TIME DURING HIS ROUTINE DUTIES. THE ACCUMULATED EFFORTS OF ALL FIELD PERSONNEL INVOLVED IN GROUND TRUTHING FOR THE ENTIRE STATE WAS ESTIMATED TO BE ABOUT ONE MAN-YEAR.

were held at various locations throughout the state usually in the district offices of each agency involved. A total of 15 orientation meetings were held with from 8 to 18 field personnel participating in each meeting. Each meeting averaged about three hours with the first hour used to explain the basics of Landsat data acquisition and processing, and the last two hours used to review the contents of a ground truth package that had been prepared for each field person, explain procedures, and areas of responsibility. The ground truth package delivered to each of the field personnel consisted of (1) an air photo or photo-based land cover maps, (2) a county map with an outline of the area encompassed by the air photo, (3) various blank ground truth forms, and (4) an instruction sheet.

As ground truth information was collected by state personnel in the manner prescribed, the completed ground truth forms and air photos or maps with training sample sites delineated were returned to the coordinators and, eventually, accumulated for the entire state. The exact procedures for gathering ground truth information and results are addressed in a separate document (ref. 3).

This ground truth was, then, used to process Landsat data at ERL for the various application demonstrations addressed in Section IV of this report. As the products of each application demonstration were produced, meetings were conducted to present and review the products with state agency personnel.

Simultaneous with the involvement of state personnel in the application demonstrations, another activity was instigated to adapt computer programs used for the demonstration at ERL to a state-owned IBM 370 Model 155 computer in Jackson, MS. This activity started when ERL furnished software documentation to the Mississippi Office of Science & Technology. Two programmers, who had been hired by the Office of Science and Technology for this purpose, completed the software adaptation with some consultation but without direct assistance from ERL programmers. However, because the state did not own an image display device at this time, the state programmers used an ERL image display device for training sample selection, ground control point selection, and tape review during the testing of adapted programs.

The third activity in technology transfer consisted of training state personnel at ERL. Four state personnel from the Mississippi Research and Development Center participated in a two-week orientation course, and two state personnel participated in a one-week course at ERL. The two-week course was structured to include a detailed examination of software logic, hardware specifications, and system procedures during the first week and experience in using ERL equipment to go through each step from raw Landsat data to final products (maps and statistical compilations) during the second week. The one-week course was a streamlined version of the two-week course differing mainly in the degree of detail.

The fourth activity in technology transfer consisted of presentations and briefings about the project at numerous workshops, symposiums, and conferences held during the course of the project.

Through the ERL Regional Applications Program, the ERL is continuing to work with the Mississippi Research and Development Center and Mississippi State University to provide information on new technique developments, technical consultation for data analysis system improvements, updated software, and training.

IV. APPLICATION DEMONSTRATIONS

The system described in section II of this report was utilized to demonstrate selected applications during the course of this project. The purposes of conducting these application demonstrations were (1) to get user feedback that would serve as a basis for making improvements to product formatting and/or data processing procedures, and (2) to give user agencies examples of information derived from Landsat data so that it could be compared with information produced through other means, should such exist. The selected application demonstrations included acreage compilation, inference mapping, theme mapping and change detection, crop detection and production estimation, erosion hazard-reforestation needs assessment, whitetail deer habitat assessment, and site selection.

Acreage Compilation

The area selected for this demonstration was the Central Mississippi Planning and Economic Development District which comprises seven counties (Yazoo, Madison, Rankin, Hinds, Warren, Copiah, and Simpson) in west central Mississippi.

The CCT's corresponding to Landsat scenes 2030-15555 and 2030-15561, dated February 21, 1975, served as the baseline data for this demonstration. Each data set was classified and registered to a UTM map projection using procedures previously described to generate four GEOREF tapes.[5] The manner in which the area encompassed by the two Landsat scenes

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[5] In so doing, a small portion (about 9,964 acres) of Warren County west of 91° Longitude was excluded from the map product and acreage statistics that appear in this report.

relates to the four GEOREF areas and the seven county area is shown in figure 4. Each of the four GEOREF tapes were used to make color-coded hardcopies showing the land cover categories for which acreage was to be compiled within each county. These hardcopies were made through the "density plot/ Cromalin" technique, mosaicked together in map format, photographed and reproduced at a reduced scale for this report. The result is shown in figure 5 for which the land cover terms are defined as follows:

Water - Includes rivers, ponds, lakes, and reservoirs that are wider than 260 feet and/or larger than one acre in size.

Vegetated Wetlands - Mainly areas of relatively flat land situated along major rivers and streams covered by vegetation generally associated with frequently inundated and/or waterlogged soils.

Deciduous Forests - Includes areas that have 10% or more of the surface covered with tree crowns that are predominantly deciduous hardwoods (Angiosperms).

Brush - Areas composed primarily of low-growing, shrub-type, woody-stemmed species, but which contain up to 25% of the surface covered by crowns of scattered trees.

Pine Forests - Includes areas that have 10% or more of the surface covered with tree crowns that are predominantly pine (Angiosperms).

Winter Grasses - Those grasses that are generally grown

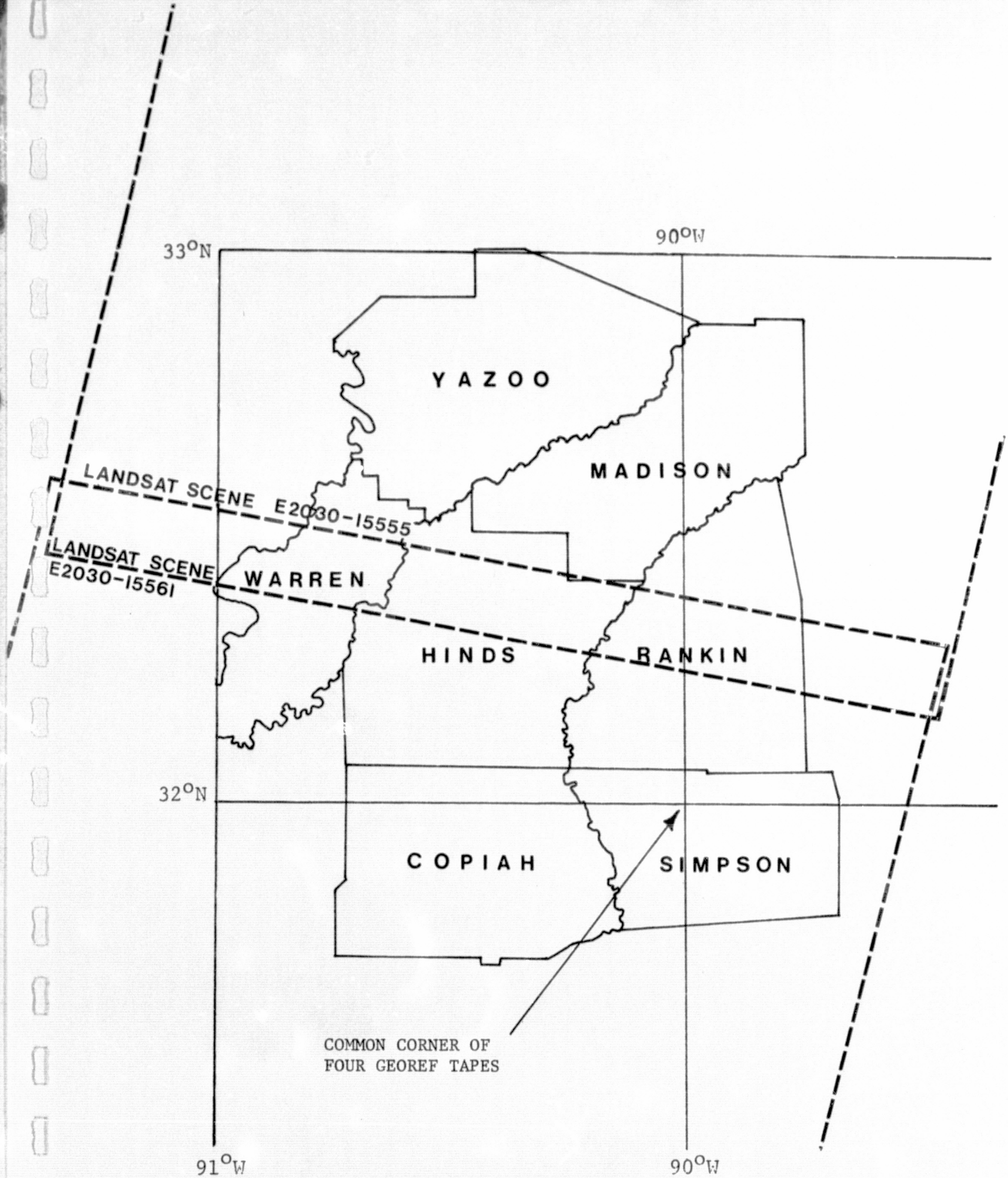
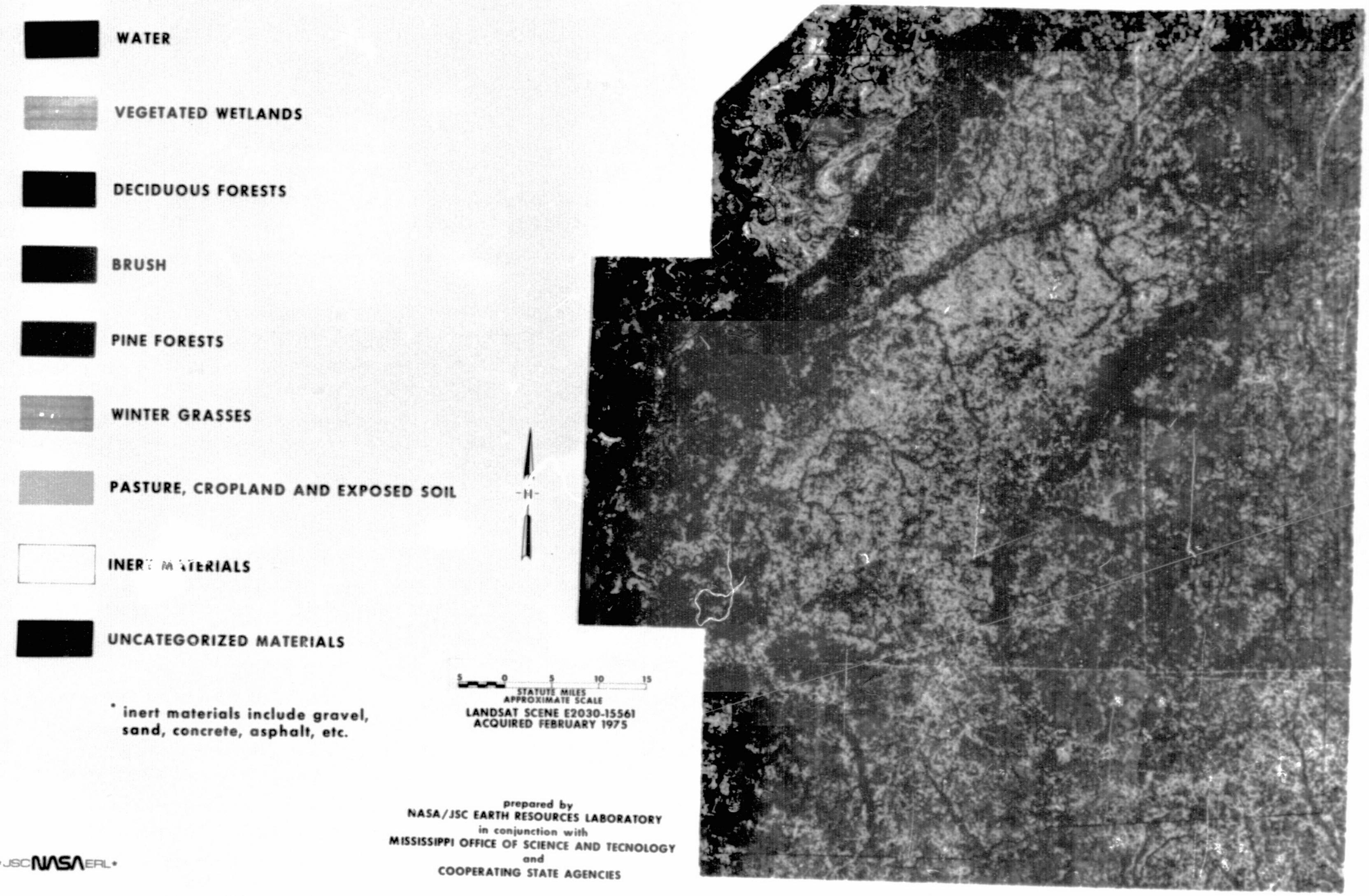


Figure 4. Seven county area as it corresponds to 4 GEOREF tapes and 2 LANDSAT scenes.

COMPUTER IMPLEMENTED LAND COVER CLASSIFICATION FROM LANDSAT MULTISPECTRAL SCANNER DATA

CENTRAL MISSISSIPPI PLANNING AND ECONOMIC DEVELOPMENT DISTRICT



* inert materials include gravel, sand, concrete, asphalt, etc.

LANDSAT SCENE E2030-15561
ACQUIRED FEBRUARY 1975

prepared by
NASA/JSC EARTH RESOURCES LABORATORY
in conjunction with
MISSISSIPPI OFFICE OF SCIENCE AND TECNOLOGY
and
COOPERATING STATE AGENCIES

•JSC NASA ERL•

Figure 5.

as a late fall/winter pasture or hay crop (e.g., winter rye).

Pasture, Cropland, and Exposed Soil - Other pasture grasses, fallow fields, crops, crop stubble, and exposed soils generally used for crops and pasture.

Inert Materials - Areas wider than 260 feet and/or larger than one acre with the surface predominantly covered by buildings, roadways, parking lots, airport runways, sand bars, gravel/sand pits, or exposed soil not generally used for crops and pasture.

Uncategorized Materials - Materials for which a spectral signature was not developed and/or materials that fell outside imposed statistical limits of confidence.

In addition to the GEOREF tapes, the computer program used for acreage compilation requires input information that defines the geographic boundary of each area of interest (in this case, a county) in terms of UTM grid coordinates (northing, easting). In the case of this demonstration, such coordinates were determined by using an X-Y digitizer and moving the cursor around the county boundary as defined on 1:250,000 scaled topographic maps (Quad sheets) constructed with a UTM projection. Generally, the shortest straight-line segment between any two adjacent coordinates in the resulting polygon was 1/10th of an inch. In situations where the county is encompassed by two or more GEOREF tapes, it is necessary to form a polygon for the portion of the county that falls on each GEOREF tape. As can be seen in figure 4, this demonstration resulted in digitizing county boundary coordinates in a manner that one polygon encompassed the area in Hinds and Warren counties, four polygons were necessary to encompass the area in Simpson county, and two polygons were necessary for each of the remaining four counties.

The coordinates defining each polygon are then key-punched on cards, and these cards, along will control cards and GEOREF tapes, serve as the input to the computer program used for acreage compilation. This computer program works in a manner that the data on the tape encompassed by each polygon on the given tape is located. The computer makes a tally of the number of 50 by 50 meter GEOREF cells in each polygon by land cover class; calculates the percentage within each class; applies factors to convert the number of cells in each land cover class to acreage and square miles; and outputs these compilations through a line printer. The compilations on the line printer output can, then, be aggregated into broader land cover categories; and, in the cases when a county area equated with more than one polygon, be summarized for each county. This was done for the acreage corresponding to the land cover categories shown in figure 5 with the results shown in table 3. As a check on the accuracy of the computation of total acreage, a comparison was made with acreage statistics derived by the U. S. Census Bureau (ref. 12). This comparison shown on the last 3 lines of table 3, showed the two sources to be different by only 0.02% for the seven county area.

TABLE 3. ACREAGE BY LAND COVER CATEGORY COMPILED FOR SEVEN COUNTIES OF CENTRAL MISSISSIPPI PLANNING AND DEVELOPMENT DISTRICT

	Copiah	Hinds	Madison	Rankin	Simpson	Warren	Yazoo	TOTAL
Water	925	5797	15824	20445	1413	30344	16367	91,115
Vegetated Wetlands	1171	4990	12106	6508	1584	16402	22217	64,978
Deciduous Forests	97863	148556	121450	179656	96731	145293	166144	955,693
Pine Forests	206793	79691	71600	142554	141287	25574	59527	727,026
Winter Grasses	61731	80348	50207	41777	34009	35910	57926	361,908
Brush	53530	54577	37427	37913	33108	59921	65940	342,416
Pasture, Cropland & Exposed Soils	75383	173111	137871	76719	70687	42100	148854	724,725
Inert Materials	3609	11622	12036	6229	2322	18432	34401	88,651
Uncategorized	1029	4589	9250	5946	1156	10443	17556	49,969
Totals Derived From Landsat	502034	563281	467771	517747	382297	384419	588932	3,406,481
Totals From Census Bureau Statistics	499800	561300	480600	512000	375700	375336[B]	600900	3,405,636
% Difference [A]	0.4	0.4	2.7	1.1	1.8	2.4	2.0	0.02

[A] $\% \text{ Difference} = \dfrac{\text{Census Acreage}}{\text{Census Acreage} - \text{Landsat Acreage}} \times 100$

[B] Does not include 9964 acres in Warren county west of 91° Longitude.

A check on the acreage computation by land cover category was made by comparing the results of deriving land cover information from Landsat data with the results of interpreting land cover from 1:120,000 scaled color-infrared photography. This was accomplished by determining the predominant land cover within every fifth "forty" (20% sample) through photo-interpretation and comparing this with the predominant land cover as derived from Landsat data. The results showed that these two sources of information were in agreement as to land cover category for 83% of the seven county area.

The reader should note that, even though this demonstration focused on compiling acreages by land cover for counties, the same GEOREF tapes and procedure can be used to compile acreage for any land unit (e.g., a watershed, a township) that can be defined with UTM grid coordinates. However, if the land unit was substantially smaller than a county, it would be desirable to digitize the UTM grid coordinates defining the boundary through use of larger scale (1:24,000 or 1:62,500) maps than the 1:250,000 scaled maps used for this demonstration. The use of the larger scale maps would increase the precision with which the boundaries could be digitized because the shortest polygon segment (distance between two coordinates in sequence) could be decreased (e.g., 1/10th inch on a 1:250,000 scale map equals 2,083 feet on the ground, versus 1/10th inch on a 1:24,000 scale map equals 200 feet on the ground).

The reader should also note, even though an X-Y digitizer was used for this demonstration to digitize UTM coordinates that defined county boundaries, manual means could also be used should an X-Y digitizer not be available. There is no difference in the precision with which coordinates can be determined by the two methods. The main advantage of using the X-Y digitizer is that the task can be accomplished faster with less human error than when coordinates are read from a map.

Inference Mapping

Under natural conditions, the species, frequency, and vigor of vegetation encountered at a given point is related to the environmental factors that interplay at that point. Consequently, given information about these relationships, it is often possible to use a vegetation classification to make inferences about some other environmental factor and/or ecological zone. This technique is referred to as "inference mapping" in this report. The technique has been demonstrated for mapping potential breeding sites for the salt marsh mosquito (ref. 13). It has also been applied to the determination of salinity zones in a Louisiana marsh (ref. 6). This project included a demonstration of the technique for salinity zone mapping for the western portion of the Mississippi coastal area.

The first step was to produce a vegetation classification for the Mississippi coastal area with Landsat data in the manner described in Section II of this report. Landsat data corresponding to Frames 1806-15451 and 1807-15505 acquired on October 7 and 8, 1974 was used for this demonstration. The GEOREF tapes were used for film recording with a digital film recorder (activity D, figure 3) to produce a vegetation map at a scale of 1:250,000 for project participants.

In order to produce a salinity zone map, the same two GEOREF tapes were film recorded again. However, colors were reassigned so that the same color was assigned to each species or species association that corresponded to a particular marsh salinity regime -- saline, brackish, or fresh. The correlation of salinity regimes with vegetation species and species associations, which was based on studies of the Louisiana marsh (refs. 14 and 15), was as follows:

Saline Marsh - *Spartina alterniflora*

- *Juncus roemerianus*/*Distichlis spicata*

Brachkish Marsh - *Spartina patens*/*Juncus roemerianus*

Fresh Marsh - *Typha spp.*

- *Sagitarria spp.*

- *Cladium jamaicense*

The GEOREF tapes were film recorded at a scale of 1:125,000 with the color assignment to depict the three marsh salinity zones and other non-marsh vegetation/land cover categories. After layout and lettering, the resulting map was photographically reproduced at a scale compatible with the format of this report (see figure 6).

Theme Mapping and Change Detection

Existing within Landsat-derived land cover classifications is information about many and varied surface materials and conditions; however, sometimes there is a need for definitive information about only one class, or material. This subject

MARSH SALINITY ZONES INFERRED FROM LANDSAT DERIVED VEGETATION CLASSIFICATION - WESTERN MISSISSIPPI GULF COAST

SALINE MARSH
BRACKISH MARSH
FRESH MARSH
WATER

DENSE PINE FOREST
SPARSE PINE FOREST WITH GRASS UNDERSTORY
DECIDUOUS FOREST
GRASSLAND/PASTURE

CROPLAND/EXPOSED SOIL
INERT MATERIALS WITH HIGH REFLECTANCE
INERT MATERIALS WITH LOW REFLECTANCE
UNCATEGORIZED

LANDSAT FRAME 1807–15505 ACQUIRED 8 OCTOBER 1974

APPROXIMATE SCALE

N

NSTL NASA ERL

Prepared by
NASA EARTH RESOURCES LABORATORY
in conjuction with
MISSISSIPPI OFFICE OF SCIENCE AND TECHNOLOGY
and
COOPERATING STATE AGENCIES

Figure 6.

material can be defined as the "theme" and "thematic" products generated. The products may be acreage tabulations from a line printer and/or pictorial graphics which can overlay readily available maps.

Any surface material or condition previously classified and stored on a GEOREF tape may be used for a thematic demonstration. An extractive class, defined in this case, as gravel or sand, was selected for this application. The geographic area of interest was near Crystal Springs within Copiah County, MS.

The area was identified for data processing by determining the corner control point coordinates of UTM in northings and eastings, and specifying (also in northings and eastings) where tick marks were to be located on the map overlay product. The only other required information was the desired map scale and the class number(s) of the theme as it relates to the listing of classified materials on the GEOREF tape.

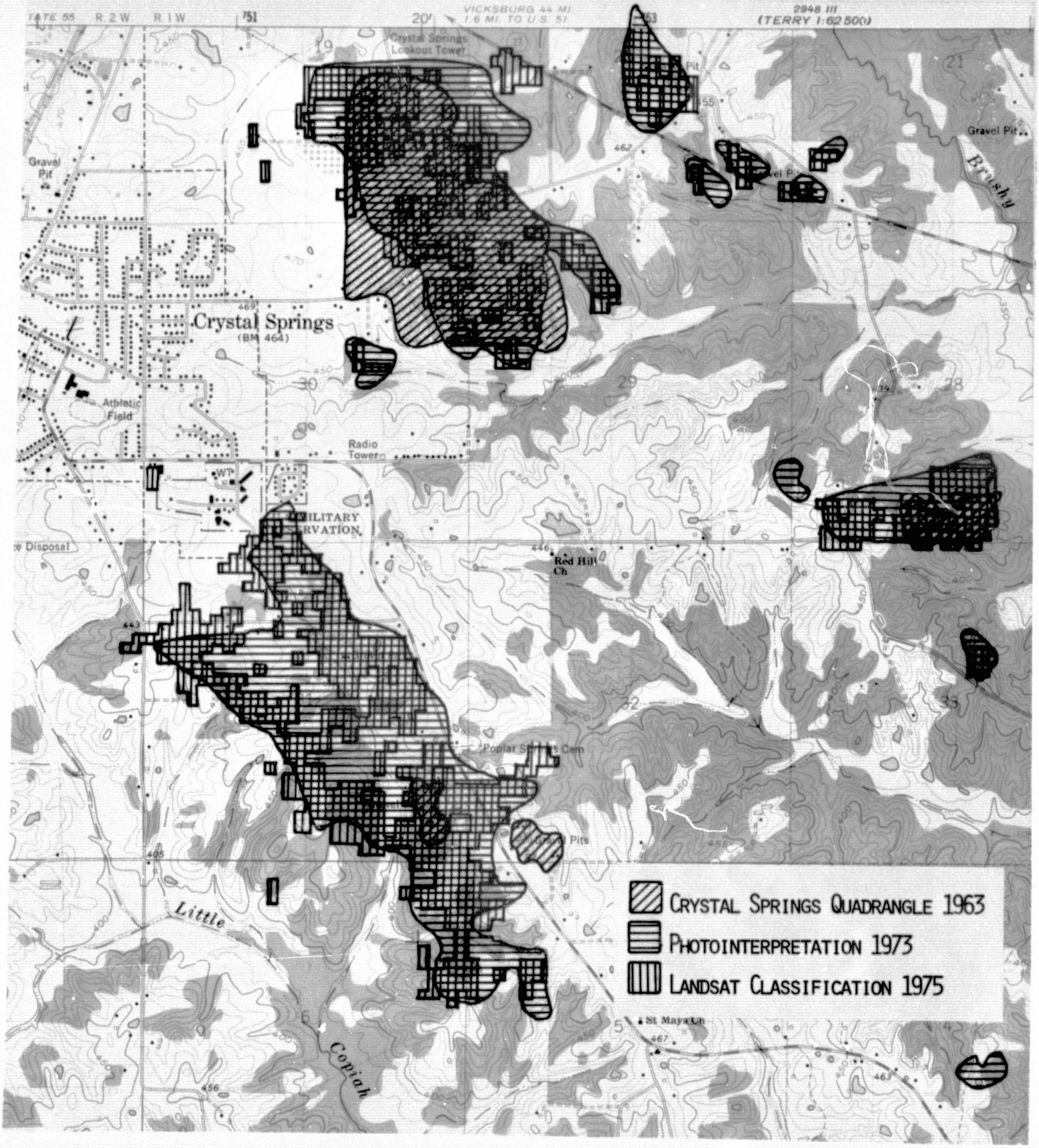
Three scales were used for the thematic overlay: 1:250,000; 1:63,360; and 1:24,000. The grey level plot of the theme and tick marks were generated with an electorostatic printer/plotter on translucent paper which permitted it to be superimposed on the appropriate map by referencing the overlay tick marks to those on the map.

After a thematic overlay is produced, change detection studies can be conducted by comparing the overlay with existing base maps on which the theme was shown. This was done in the course of this project by comparing the "extractive" theme overlay derived from 1975 Landsat data with the location of "extractive" areas as shown on a portion of the 7½ min. Crystal Springs quadrangle and as interpreted from aerial photography acquired in 1973. The results of this comparison are shown in figure 7 with the extractive areas as derived from 1975 Landsat data shown with vertical lines, the extractive area as delineated from 1973 aerial photography shown with horizontal lines, and the extractive areas as delineated on the 1963 quadrangle map shown with diagonal lines.

After a gravel/sand extractive operation is initiated, the expansion of the extractive area usually takes place in a manner that the trees of commercial value are removed first. Then, the remaining trees, debris, and/or brush is dozed into piles and burned, after which the top soil together with grass and annual plants is removed to expose the gravel and/or sand. As expansion operations are proceeding at some rate, areas from which gravel and/or sand has been extracted are being abandoned. These abandoned areas may remain exposed, may fill-in with water, or may become revegetated. In some cases, abandoned areas may be reopened due to new demand for gravel or sand. Taking the nature of an extractive operation into account together with the fact that the extractive theme as derived from Landsat data includes only areas essentially devoid of vegetation, allows one to make various deductions from figure 7 about change. These deductions can be summarized as follows:

(1) Areas showing a coincidence of all three types of lines (horizontal, vertical, and diagonal) were exposed in 1963 and were still exposed in 1975 implying that they were

FIGURE 7. EXTRACTIVE THEMATIC COMPARISON
CRYSTAL SPRINGS, COPIAH COUNTY, MS.
SCALE 1:24,000



either still active or did not revegetate naturally after being abandoned.

(2) Areas with only vertical lines have become active and/or had the vegetation removed since 1973.

(3) Areas with only horizontal lines are likely to have been subjected to some alteration of the natural vegetation short of topsoil removal since 1963 but were not yet active extractive areas in 1975. (Although it is possible that these areas could have become active extractive areas since 1963 and reverted back to vegetation by 1973, this event is not likely).

(4) Areas with only diagonal lines had been exposed in 1963 but since that time have become revegetated and/or filled-in with water.

(5) Areas with a coincidence of both horizontal and vertical lines are likely to have become active extractive areas since 1963.

(6) Areas with a coincidence of both horizontal and diagonal lines had been exposed in 1963, were still detectable as extractive areas in 1973, but, by 1975, had sufficient vegetation cover or surface water so as not to be classified as exposed areas through use of Landsat data.

A more automated manner of monitoring changes since July, 1972 (launch of Landsat I) consists of comparing two GEOREF tapes containing land cover/vegetation information derived from Landsat data acquired at different times. Computer programs have been developed to allow two GEOREF tapes to be compared to build a tape that can be used for output in map format showing either a "changed to" or "changed from" condition. Although this capability was not demonstrated during the course of this ASVT project, it is anticipated that the procedures for detecting land cover change in this manner will have been tested and documented by the end of fiscal year 1978.

Agricultural Crop Detection and Production Estimation

This application demonstration addresses the integration of information on the geographic location of agronomic crops as derived from satellite data with soils information as digitized from Soil Conservation Service county soils maps. It is anticipated that the 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) the assessment of the overall agricultural potential of a region, and (3) the estimation of the upcoming harvest for major crops in localized areas as basis for decisions by local agro-industry. For example, a cotton gin owner may decide to invest in the upgrade of his machinery, make different transportation arrangements, etc., 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 nation-wide or global crop production prediction; but, rather, would be used to address selected areas considered to be key to local economies, generally relating to from one to six counties in a prime agricultural region.

In the case of the agricultural application being addressed in this section, the demonstration area was Washington County, Mississippi. Washington County lies along the Mississippi River in west-central Mississippi. The entire county falls in the highly productive, alluvial plains agricultural region of Mississippi. The major crops are soybeans and cotton, together comprising 67% of all cropland and pasture in the county during the 1974 summer growing season.

A set of 4 tapes corresponding to Landsat scene E-1736-15582 containing data acquired by Landsat I on July 29, 1974, was classified and used as input for rectification with the GEOREF computer program module. The resulting GEOREF tape was then used to build a data base with the "non-gridded" option in which the land cover information on the GEOREF tape was input to the data base for "forties" as defined by the public land survey system.[6] In addition to the land cover information, the only other variable read into the data base for this application demonstration was the soils information. The data base soils information was digitized from the Soil Conservation Service county soils maps by manual methods and punch card input (ref. 9).

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

[6]The term "forties" refers to the sixteen subdivisions of a section of land, each of which would be forty acres in area if a given section conformed to its theoretical size of one square mile.

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, estimate the potential production for the upcoming harvest in the county. The latter function is carried out by determining both the land cover (crop) and soil that is predominant in each "forty", and referencing that integrated information to a computer stored table of "potential yield per acre" by crop, soil, and management level. An example of the table showing 16 of the 56 soils mapping units that were encountered on the county soils maps is shown in Table 4. After the computer matches the geographically referenced data base information on crop and soil to the table and performs calculations[7], the resulting information is output through a line printer to show summaries by township and county. Tables 5 and 6 shows the summary for Washington County for cotton and soybeans respectively. Table 5 shows the cotton harvest to have been estimated at 78,951,000 pounds for Washington County, Table 6 shows the soybean harvest to be estimated at 1,897,200 bushels for Washington County. In addition to use for crop production estimation, the output showing crop and soil combinations can be analyzed to determine both how various soils are being utilized and for a general assessment of agricultural potential.

Although additional map making is not essential, this system can also be used to produce various types of maps from

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

TABLE 4 Potential yields of Cotton and Soybeans for two levels of agricultural practice by soil mapping unit.

CODE	SOIL	POTENTIAL YIELDS PER ACRE			
		COTTON (lbs)		SOYBEANS (bu)	
		A[1]	B[2]	A[1]	B[2]
1	ALLIGATOR CLAY, LEVEL PHASE	175	250	10	25
2	ALLIGATOR CLAY, NEARLY LEVEL PHASE	225	375	20	35
3	ALLIGATOR CLAY, SLOPING PHASE	225	375	20	35
4	ALLIGATOR SILTY CLAY LOAM, LEVEL	175	250	10	25
5	ALLIGATOR SILTY CLAY LOAM, NEARLY LEVEL	225	375	25	35
6	ALLUVIAL LAND	---	---	---	---
7	BEULAH VERY FINE SANDY LOAM, NEARLY LEVEL	375	450	---	---
8	BEULAH VERY FINE SANDY LOAM, GENTLY SLOPING	350	425	---	---
9	BEULAH VERY FINE SANDY LOAM, MOD. SHALLOW	450	550	---	---
10	BASKET SILTY CLAY LOAM, NEARLY LEVEL	475	600	20	35
11	BASKET VERY FINE SANDY LOAM, NEARLY LEVEL	575	700	20	35
12	BASKET VERY FINE SANDY LOAM, GENTLY SLOPING	475	600	20	30
13	BASKET VERY FINE SANDY LOAM, MOD. SHALLOW	575	700	20	35
14	BOWDRE SILTY CLAY, NEARLY LEVEL	325	450	15	25
15	BOWDRE SILTY CLAY LOAM, NEARLY LEVEL	325	450	15	25
16	BORROW PIT	---	---	--	--

1. Normal agricultural practices.
2. Improved agricultural practices.

TABLE 5 COMPUTER OUTPUT SHOWING COUNTY SUMMARY OF ACREAGE/YIELD FOR COTTON

	CLASS	SOIL TYPE	OCCURRENCES	ACREAGE	POTENTIAL YIELD (lbs.lint)
COTTON	2	1	19	760.	190000.
		2	184	7360.	2760000.
		4	4	160.	40000.
		5	89	3560.	1335000.
		7	45	1800.	810000.
		8	9	360.	153000.
		9	3	120.	66000.
		10	7	280.	168000.
		11	657	26280.	18396000.
		12	10	400.	240000.
		13	17	680.	476000.
		14	27	1080.	486000.
		15	12	480.	216000.
		17	50	2000.	1550000.
		18	73	2920.	2409000.
		19	4	160.	128000.
		20	38	1520.	1254000.
		21	7	280.	224000.
		22	8	320.	16000.
		23	86	3440.	172000.
		24	20	800.	240000.
		25	8	320.	256000.
		26	16	640.	512000.
		27	91	3640.	2730000.
		28	8	320.	208000.
		29	14	560.	336000.
		30	1	40.	22000.
		31	325	13000.	8450000.
		32	15	600.	330000.
		34	9	360.	252000.
		35	382	15280.	11460000.
		36	2	80.	52000.
		37	4	160.	116000.
		38	21	840.	609000.
		39	153	6120.	3060000.
		40	156	6240.	2340000.
		41	4	160.	60000.
		42	370	14800.	6660000.
		43	2	80.	34000.
		44	3	120.	54000.
		45	15	600.	450000.
		46	35	1400.	1155000.
		47	38	1520.	380000.
		48	257	10280.	4112000.
		49	4	160.	64000.
		50	36	1440.	576000.
		51	9	360.	180000.
		52	4	160.	80000.
		54	116	4640.	2784000.
		55	6	240.	144000.
		56	6	240.	156000.
TOTAL CLASS 2 -				139160.	78951000.

TABLE 6 COUNTY SUMMARY OF ACREAGE/ YIELD FOR SOYBEANS

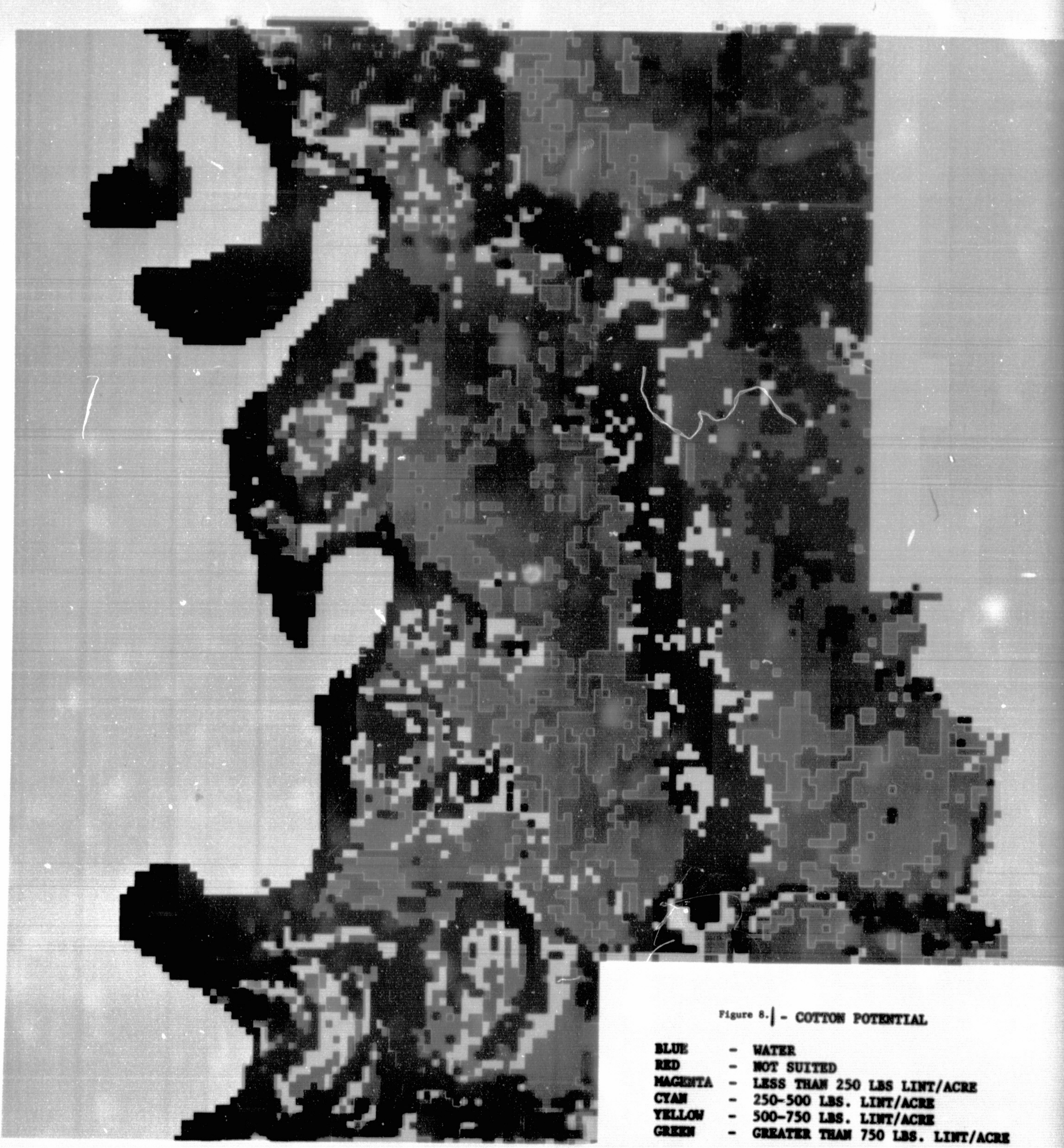
	CLASS	SOIL TYPE	OCCURRENCES	ACREAGE	POTENTIAL YIELD (bushels)
SOYBEANS	1	1	190	7600.	76000.
		2	203	8120.	162400.
		4	1	40.	400.
		5	10	400.	10000.
		7	10	400.	2000.
		8	4	160.	800.
		10	1	40.	800.
		11	30	1200.	24000.
		12	1	40.	800.
		13	2	80.	1600.
		14	14	560.	8400.
		15	3	120	1800.
		17	14	560.	16800.
		18	3	120.	3600.
		19	1	40.	1200.
		20	3	120.	3600.
		22	5	200.	1000.
		23	222	8880.	133200.
		24	7	280.	4200.
		26	4	160.	4000.
		27	16	640	12800.
		29	7	280.	5600.
		31	85	3400.	68000.
		32	6	240.	3600.
		34	4	160.	3200.
		35	27	1080.	21600.
		37	1	40.	800.
		38	1	40.	800.
		39	3	120.	2400.
		40	52	2080.	41600.
		41	1	40.	600.
		42	43	1720.	34400.
		43	1	40.	600.
		46	3	120.	600.
		47	601	24040.	240400.
		48	1111	44440.	888800.
		49	3	120.	3000.
		50	10	400.	10000.
		51	1	40.	1000.
		54	93	3720.	93000.
		55	6	240.	7200.
		56	1	40.	600.
TOTAL CLASS I				112160.	1897200.

the information in the data base that may be desired for visual analysis. One example of such maps is shown in Figures 8 and 9.

These maps were made to show the inherent potential of the soils for producing cotton and soybeans by assigning a separate color to each soil that fell within a particular "potential yield" category. These potential yield categories are arbitrarily chosen and could be changed to be any particular range. Shown as overlays to Figures 8 and 9 are the locations of each respective crop as was determined from the satellite acquired data. These "thematic" (one-crop) overlays were made by film recording from the GEOREF tapes in a manner that the crop in question was arbitrarily assigned a common neutral color. This capability demonstrates the flexibility in making maps from digital data on computer compatible tapes. In comparing the thematic overlay of cotton with the potential yield map, it is interesting to note the close correlation of cotton with the 500 to 750 pound lint per acre actegory (yellow) indicating that Washington County cotton farmers are very cognizant of these soils' productivity for cotton.

The accuracy of the land cover classification was verified in several ways.

First, the predominant land cover was photo interpreted using 1:120,000 scale color IR photography for every fifth "forty" in Washington County. 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



Location of cotton as derived from satellite data.

Location of soybeans as derived from satellite data.

through use of the computer programs mentioned earlier in this report. 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 check 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 "forties" of the 10,780 forties in the county; thereby, constituting a 20% sampling. The results showed that 1722 or 92% of the "forties" categorized as cropland or pasture were correctly classified through the use of satellite acquired multispectral scanner 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 effect of commission and omission errors resulted in 87% of the total number of forties being 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 classification of cotton and soybeans. First, the acreages 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 were compared with the county statistics for "harvested acreage" as published by the Crop Reporting Service. The results showed 112,065 acres of soybeans and 119,340 acres of cotton tallied for the county from the GEOREF tapes. These figures can be compared with 122,700 acres of soybeans and 113,000 acres of cotton as was reported for the county by the Crop Reporting Service publication.[8]

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 5 and 6. This change took place during data base building when the computer made a tally of the land cover shown for individual 50 meter 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 (112,160 acres) as was determined directly from GEOREF tapes (112,065), but the cotton acreage carried into the data base was 139,160 acres versus the 119,340 acres determined from GEOREF tapes. It is though that this disparity is not a discrepancy, but, rather, is related to the practice of planting skip-row cotton in Washington County. For example, if a 40-acre field is planted by alternating six rows of cotton and four skipped rows, the result is 24 acres of cotton in a 40-acre field

[8]The reader should understand that the method of estimation employed by the Crop 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 $\pm$ 10%.

that is dedicated to cotton growing. Consequently, it is thought 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 acreage reported by the Crop Reporting Service depict net acreage.

A second method used to verify the accuracy of the computer implemented classification consisted of determining how the pixels within 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 it systematically classifies each pixel. 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% were classified as cotton while 2.7% were misclassified as soybeans and 7.2% were misclassified as grass. Of the 261 pixels within soybean training samples, 98.8% were classified as soybeans, 0.4% were misclassified as cotton, 0.4% were misclassified as grass, and 0.4% misclassified as bare soil. The complete results of this tally, including all land cover categories classified, is shown in Table 7.

As a means of further substantiating the accuracies of the

TABLE 7 SCORECARD OF COMPUTER IMPLEMENTED CLASSIFICATION WITHIN TRAINING SAMPLE AREAS BY LAND COVER CATEGORY IN PERCENT

CLASS NAME	TOTAL PTS	OAK-HICKORY	CORN	COTTON	SOY-BEANS	WATER	URBAN	OAK-GUM	GRASS	RICE	PECAN	BARE	UNCL.
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			0.4	98.8				0.4			0.4	
WATER	913					99.7							0.3
URBAN	116			1.7	7.7		65.5		19.0			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		
BARESOIL	87								5.7			94.3	

cotton and soybean classification, the 1:62,500 scaled map and the acreage compilations by township were evaluated by Mississippi Cooperative Extension Service personnel. 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 by the scorecard (see Table 7).

Erosion Hazard-Reforestation Needs Assessment

This application demonstration addresses computer implemented techniques for (1) deriving land cover information from multi-spectral scanner data acquired by the Landsat satellite, (2) geographically referencing land cover information to soils, topographic, and rainfall information digitized from existing source maps, and (3) the use of the modified Musgrave's equation for soil loss prediction. It is anticipated that the output will be useful for (1) assessing the overall erosion hazard in a given watershed, (2) adding efficiency to field surveys conducted to locate areas in need of reforestation for erosion control, and (3) to provide input to a model which would permit resource managers to predict the possible result of change in land use with respect to future erosion problems.

The demonstration area was three townships in Yalobusha County, Mississippi. Yalobusha County is situated in north central Mississippi, and contains two major man-made water bodies - Enid and Grenada Lakes. Of the 322.6 thousand acres in the county, 57% (184.5 thousand acres) is considered commercial forest land with the remainder used mainly for agronomic crops and pasture. With the exception of the Holly Springs National Forest and wetlands areas upstream from the lakes, land use patterns show an intermingling between forestry, agronomic crop, and grazing land uses.

In the case of this application demonstration, the actual classification of the data for Landsat scene 2030-15552 was accomplished through a technique known as geographic signature extension. The possibility for employing geographic signature extension arises in a situation where two or three cloud-free scenes of data are acquired on a particular pass under uniform atmospheric conditions over the area of concern. This situation is most often encountered when the passage of a strong cold weather front precedes a Landsat pass by one or two days. Such a situation was encountered on February 21, 1977 at the time that data was needed for this demonstration. Consequently, it was decided to use this opportunity to demonstrate the results of geographic signature extension in the context of this application demonstration. In this particular case, signatures were developed for each vegetation/land cover class using tapes corresponding to Landsat scene E2030-15561; then, these signatures were used to derive a land cover classification for the demonstration area which was located within Landsat scene E2030-15552 about 110 miles uptrack from the set of tapes used for signature development.

The reader should, therefore, be conscious of the fact that whenever results are mentioned, they are based on land cover classes derived through the geographic signature extension technique.

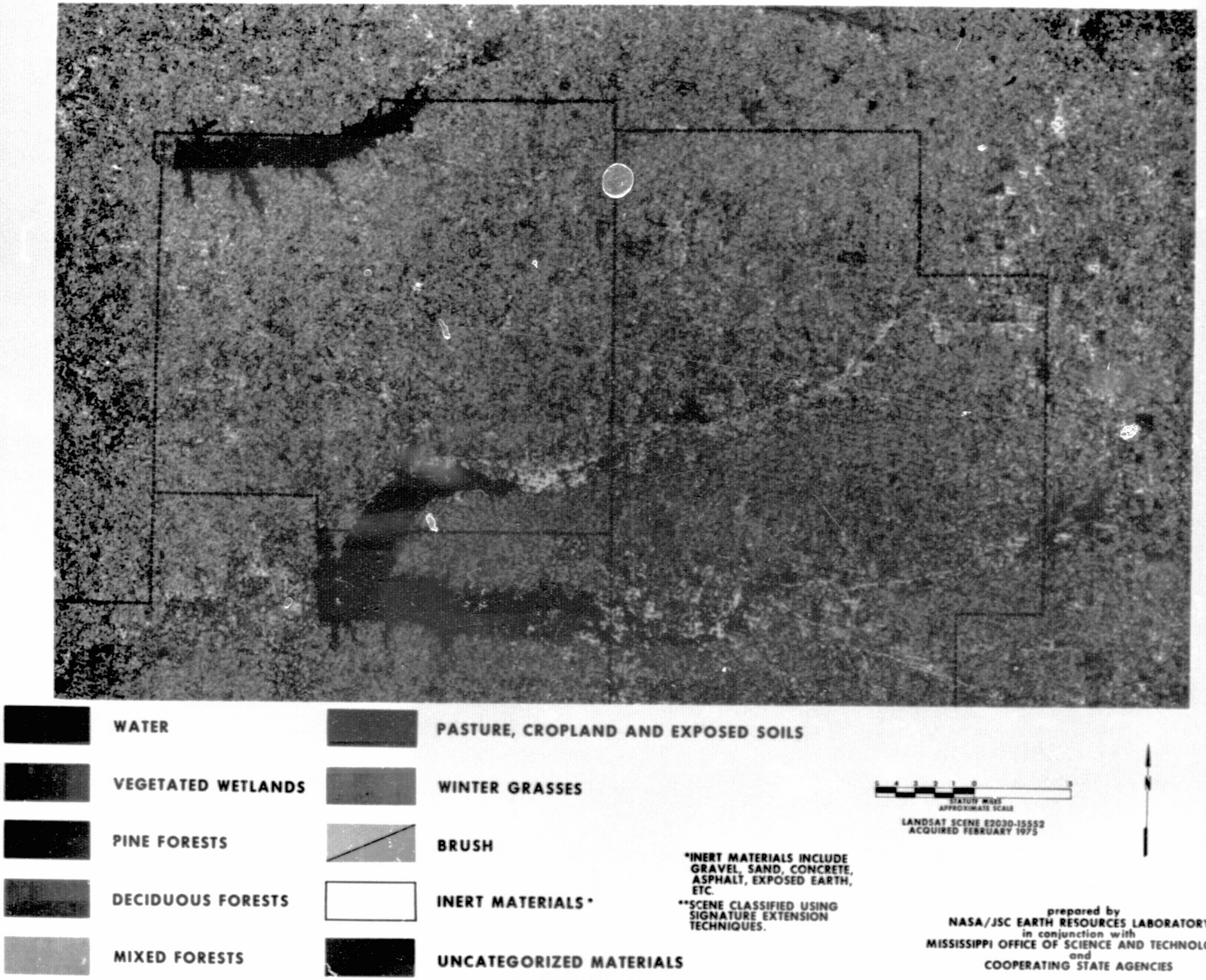
After the land cover/vegetation classification was rectified through use of the two computer programs in the GEOREF module, the GEOREF tape was used to produce a map at a scale of approximately 1:125,000 through use of the density plot/CROMALIN Technique. This map product was mounted on a layout board and, after lettering and legend color chips were affixed, the layout was photographed and printed at the 1:125,000 scale for project participants and in 8½" by 11" format for this report (see figure 10). Yalobusha County, within which the three townships selected for the demonstration are located, is outlined with the dashed line encompassing parts of the two large lakes shown in figure 10.

In the case of this particular application demonstration, the non-gridded data base building option was utilized. This involved determining the northing/easting UTM coordinate in the center of each "forty" in each of the 3 demonstration townships as defined by the public land survey system. The data base building computer program takes the coordinate information as card input and functions in a manner that a "forty" mid-point is located on a GEOREF tape and a 7-cell by 7-cell matrix of 50 meter cells around each midpoint is examined to determine the predominat land cover for each "forty".

In addition to the predominant land cover type for each "forty", the digitized slope and soils mapping unit were read into the data base. Slope for each "forty" was determined from 7½' topo maps using a transparent "slope scale". This scale was used to determine the average slope for the 10 acre area of greatest slope

COMPUTER IMPLEMENTED LAND COVER CLASSIFICATION FROM LANDSAT MULTISPECTRAL SCANNER DATA**

CALHOUN, GRENADA, AND YALOBUSHA COUNTIES, MISSISSIPPI



*INERT MATERIALS INCLUDE GRAVEL, SAND, CONCRETE, ASPHALT, EXPOSED EARTH, ETC.

**SCENE CLASSIFIED USING SIGNATURE EXTENSION TECHNIQUES.

prepared by
NASA/JSC EARTH RESOURCES LABORATORY
in conjunction with
MISSISSIPPI OFFICE OF SCIENCE AND TECHNOLOGY
and
COOPERATING STATE AGENCIES

Figure 10.

within each "forty" which was then digitized. Soils information was digitized from SCS county soils maps.

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 (Activity H in Figure 3). In this case, the main function of the computer program was to integrate land cover information with soils, slope, and rainfall factors in such a manner that the potential erosion hazard for all "forties" within the three demonstration townships could be calculated. This was accomplished through the implementation of the computer version of the Modified Musgrave's Equation.

In its basic form, the Modified Musgrave's Equation is:

$$E = KCR \frac{(S)^{1.35}}{10} \frac{(L)^{.35}}{(72.6)}$$

where E - Sheet erosion in tons/acre/year
K - Soil erodability value
C - Cover factor (Crop Management Factor)
R - Rainfall Index
S - Land Slope in Percent
L - Length of Slope in Feet

Actual values for each of the independent variables (right hand side of the quation) were obtained from an SCS publication (USDA-SCS, 1963). The soils erodability value (K) varies with soil type and expresses a relative "erodability potential" index. Soil types encountered in this study and their corresponding K values are presented in Table 8.

The cover factor (sometimes referred to as the crop management factor) relates to the capacity of the cover type to prevent or suppress erosion. Bare soil has a "C" value of 1.0, which, when

TABLE 8 -- Soils Erodability Values for Soils Encountered in the 3 Township Demonstration Areas.

Data Base Code	Soil Type	"K"
142	Ariel silt loam, occasionally flooded	.32
143	Arkabutla silt loam, occasionally flooded	.32
144	Arkabutla silt loam, frequently flooded	.37
145	Bonn silt loam	.49
148	Calloway silt loam, 0 to 2% slopes	.49
150	Cascilla silt loam, frequently flooded	.43
151	Collins silt loam, occasionally flooded	.43
152	Collins silt loam, frequently flooded	.43
153	Deerford complex, 0 to 2% slopes	.37
154	Gillsburg silt loam, occasionally flooded	.43
155	Gillsburg silt loam, 0 to 2% slopes	.43
157	Grenada silt loam, 2 to 5% slopes	.43
158	Loring silt loam, 2 to 5% slopes, eroded	.37
159	Loring silt loam, 5 to 8% slopes, eroded	.37
160	Loring silt loam, 5 to 8% slopes, severely eroded	.37
162	Loring silt loam, 8 to 12% slopes, severely eroded	.37
163	Loring Complex, gullied areas	.37
168	Oaklimeter silt loam, occasionally flooded	.43
169	Oaklimeter silt loam, frequently flooded	.43
170	Providence silt loam, 2 to 5% slopes, eroded	.37
171	Providence silt loam, 5 to 8% slopes, eroded	.37
172	Providence silt loam, 8 to 15% slopes, eroded	.37
174	Providence-Smithdale Complex, 8 to 12% slopes, severely eroded	.37
176	Providence-Smithdale Complex, gullied areas	.32
177	Providence-Smithdale Association, hilly	.32
178	Sweatman-Smithdale Association, hilly	.32

taken in context with its functions as a linear multiplier in the Modified Musgrave's Equation, represents the least amount of erosion protection or suppression possible. All other "C" values are less than 1.0 (but non-negative) and hence, when incorporated into the basic equation, serve to reduce the predicted soils loss. The land cover categories are derived from Landsat data for this study, with their corresponding "C" values are presented in Table 9.

Rainfall index (R) for the entire county was given as 350 (ref. 10). This value related the duration and intensity of storms over a time period to their ability to cause erosion of exposed soils. The larger the "R" value, the greater the ability to create erosion.

Land slope (S) was derived, as was previously mentioned, from 7½' topographic maps using a slope scale. It was decided to find the worst 10 acre area in each "forty" (with respect to percent slope) and use this value as the "S" factor in equation (1) when the predicted erosion was calculated. In addition, slope length was established as 660', which corresponds to one side of the 10 acre area used to determine the slope percent.

The actual computer program may compute two values for potential erosion (E) for any particular "forty". The first calculation assumes that there is no vegetative cover on a particular area and hence sets "C" = 1.0. The resulting calculation of "E" reflects a "baseline" erosion potential for the soil type, slope, etc., for that particular forty. This

TABLE 9 -- "C" Values for the Land Cover Categories Used In this Demonstration.

Land Cover Category	"C"
Forest, Dense (70% to 100%)	.001
Forest, Sparse (10% to 70%)	.004
Pine Plantations (less than 20% covered) and Brushland	.014
Pasture/Grass, Dense (40% to 100%)	.02
Pasture/Grass, Sparse (10% to 40%)	.20
Cropland	.35
Barren/Extractive	1.0

value for "E" is compared to a "critical" value of erosion (set at 25 tons/acre/year for this demonstration). If it is less than this critical value (which may be changed) computation ceases, for the critical value defines that point above which reforestation is to be considered. Since the "baseline" value for "E" was calculated with maximum "C" (1.0), any inclusion of land cover would reduce "E". Unless specific values for each forty are desired (which would result in a voluminous amount of computer output), such a recalculation of "E" with the true "C" value is unnecessary. No printout is made at this time. If the calculated value of "E" is greater than the critical value when "C" = 1.0, the computer prints the township and forty number, incorporates the true "C" value, and recalculates "E". If, at this time, the recalculated "E" falls below the critical value, the computer moves on to the next forty. If on the other hand, "E" still exceeds the critical value, the computer "flags" the forty by printing out the calculated "E" value. This procedure is repeated until all forties in the area of interest have been examined. An example output is included as Table 10. This output shows a potential erosion hazard. These numbers, ranging from 1 to 8, refer to various ranges of predicted soil losses and are used to simplify the output. The corresponding predicted erosion range values used are given in Table 11.
In addition, on the output shown, the critical value was set at 25 tons/acre/year (potential erosion hazard = 5), such that all forties with potential erosion hazards of 5 or greater were flagged (after incorporation of the true "C" value). This value,

TABLE 10 -- Output from Applications Software Designed for the Reforestation-Erosion Potential Demonstration.

Township Code [1]	Forty Number [2]	Potential Erosion Hazard [3]	(Soil Loss Calculated in Tons/Acre/Year)[4]
996	305	8	
996	306	8	
996	307	8	
996	308	6	
996	309	8	
996	310	8	
996	311	8	
996	312	8	
996	313	8	
996	314	8	** Erosion Hazard - 5 Calculated Soils Loss = 30.
996	315	8	
996	318	7	
996	319	7	
996	320	8	
996	322	8	** Erosion Hazard - 5 Calculated Soils Loss = 27.
996	323	8	** Erosion Hazard - 5 Calculated Soils Loss = 30.
996	324	8	** Erosion Hazard - 8 Calculated Soils Loss = 40.
996	325	8	
996	326	8	
996	327	8	

[1] Townships are identified with a code rather than with the public land survey designation. In this example, township 996 is Twp. 11S, Rge. 5W.

[2] "Forties" are coded according to the scheme shown in Figures 6, 7, and 8.

[3] "C" value equals 1 (bare soil).

[4] "C" value corresponds to actual land cover.

TABLE 11

Potential Erosion Hazard Values and Their

Assigned Erosion Potential Ranges

	Potential Erosion Hazard	Potential Erosion Range (T/AC/YR)
	1	0 - 10
	2	10 - 15
	3	15 - 20
	4	20 - 25
↑ CRITICAL ↓	5	25 - 30
	6	30 - 35
	7	35 - 40
	8	40+

as well, as the potential erosion hazard ranges were specified for this demonstration and could be changed to a different value by simply replacing one input card.

The results of the complete output for the 3 townships are presented in Figures 11, 12 and 13. In these figures, those forties "flagged" by the computer as exibiting a potential erosion hazard with actual land cover as previously described are shaded. The figures also indicate the scheme for computer coding of "forties" within a township. It is expected that these figures would be used in conjunction with field maps to determine the actual reforestation needs in the field. While the computer flags forties, areas less than this may actually be in need of reforestation, since slope related features were developed for a 10-acre sub-unit of the "forty". However, by directing the field personnel to a specific "forty", the utility of the system would be reflected in a significant reduction in the cost of field operations.

Several additional calculations can be made at this time, based on the information pertaining to the three townships, which point out some interesting relationships between the variables in the modified Musgrave's equation. Two cases will be considered:

Case I

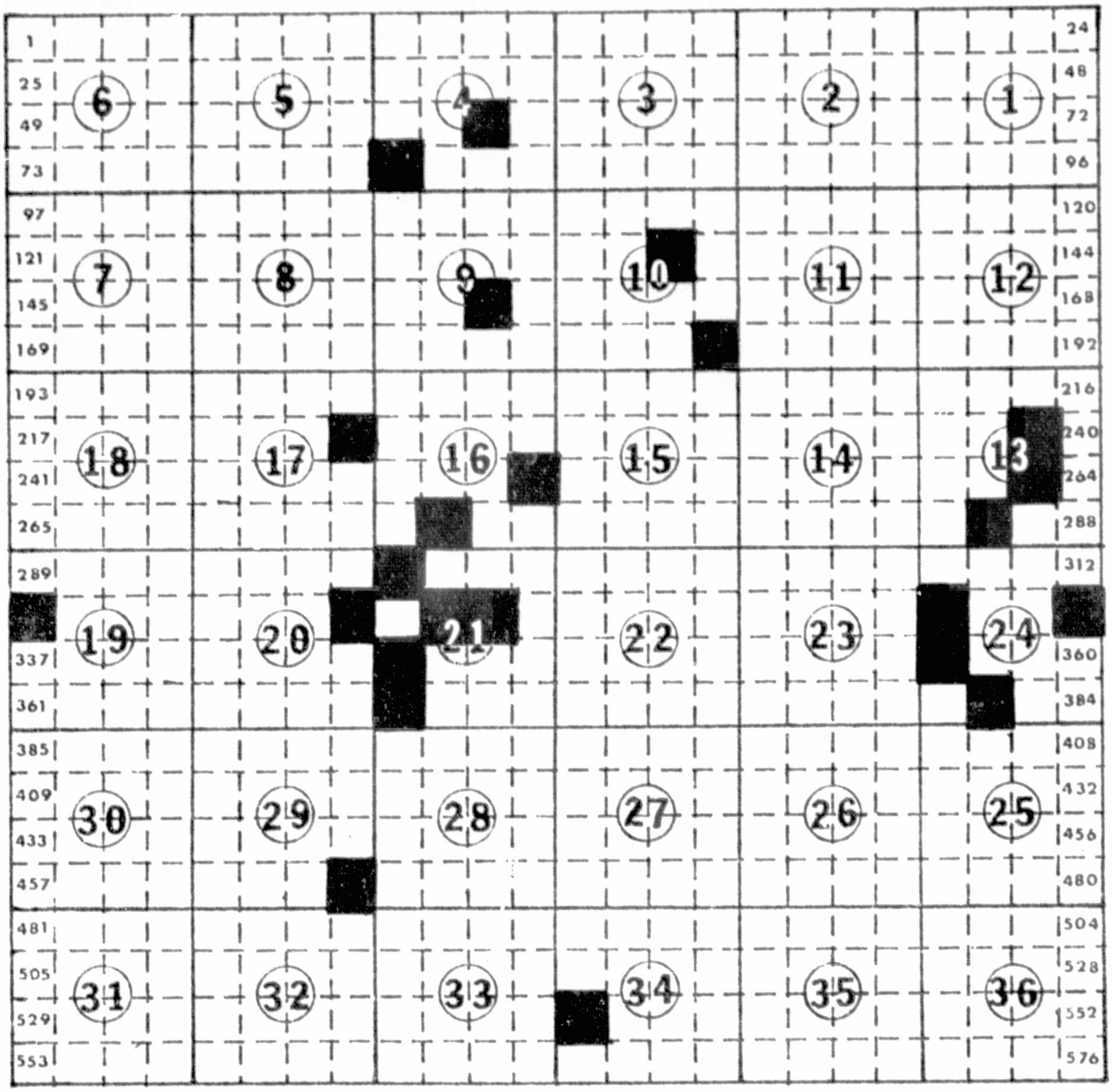
Given $K = .49$ (implies high erosion potential)
$R = 400$
$S = 50\%$
$L = 660'$

Solve for "E" (sheet erosion in tons/acre/year)

When:

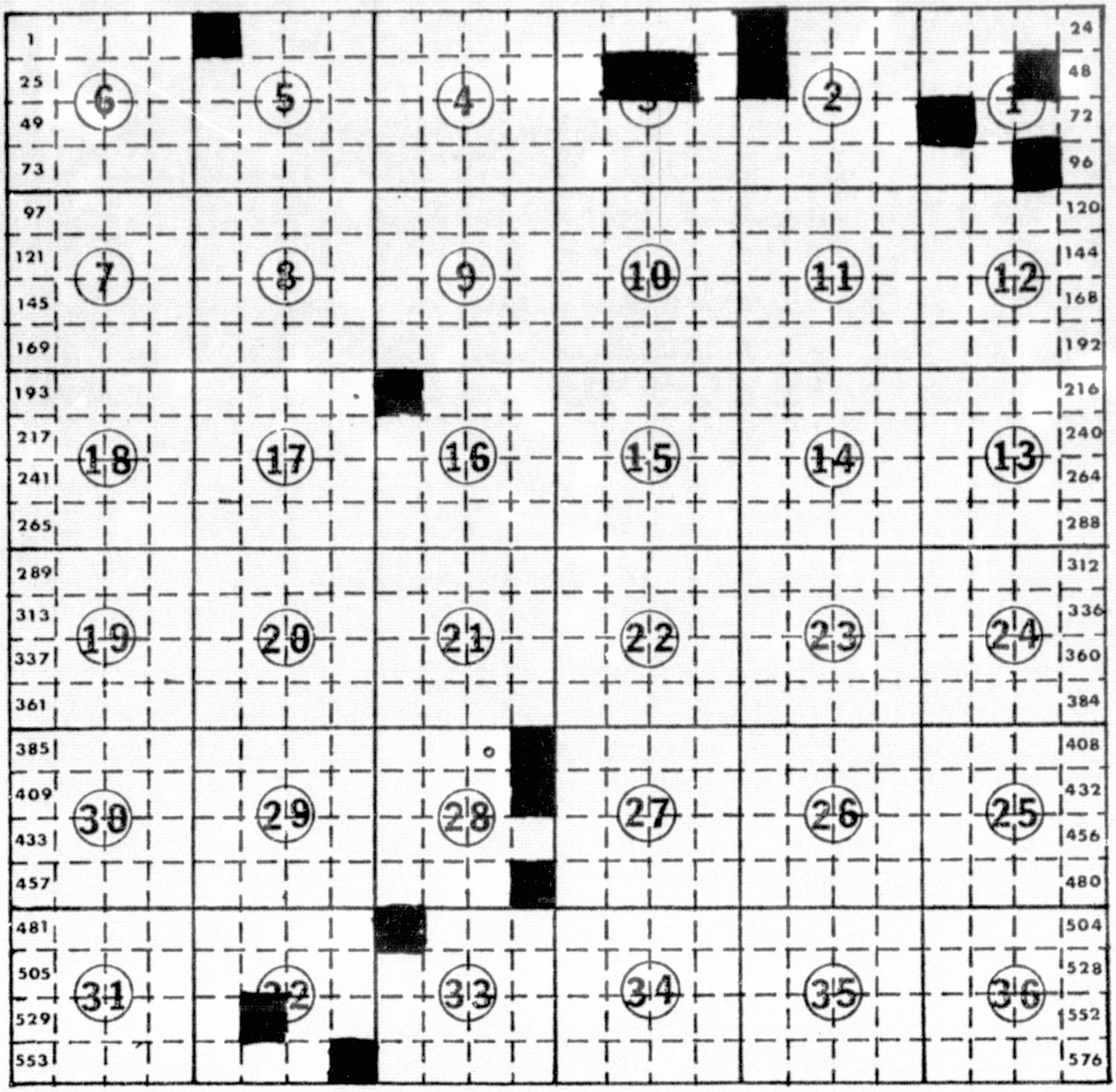
C =	.001	.004	.014	.02	.2
E =	.515	2.059	7.208	10.297	102.968

FIGURE 11 -- Chart showing forties (shaded squares) that were flagged for field examination of reforestation needs in Twp. 11S, Rge. 5W.



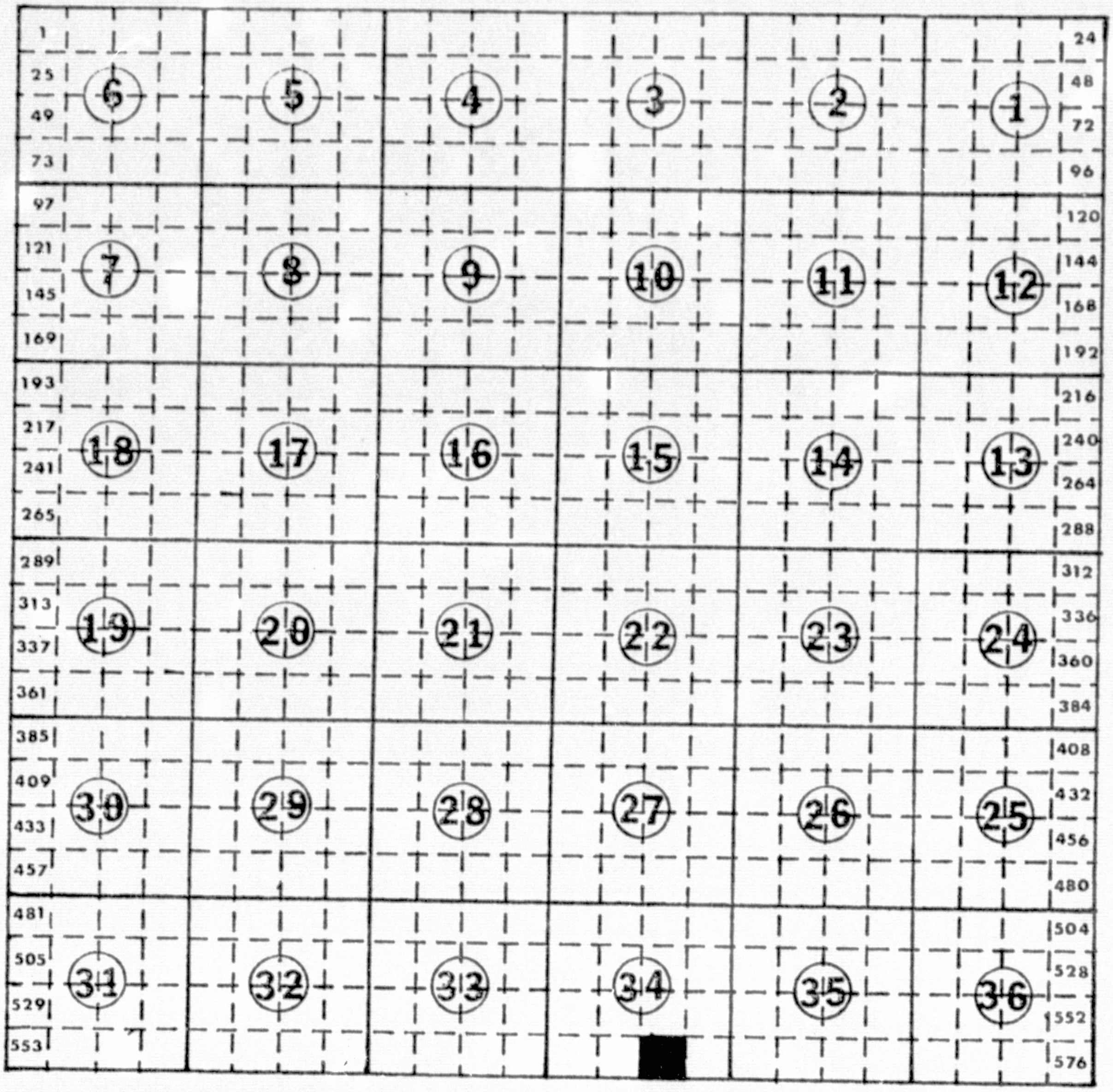
NOTE: Circled numbers are section numbers.

FIGURE 12 -- Chart showing forties (shaded squares) that were flagged for field examination of reforestation needs in Twp. 24N, Rge. 5E.



NOTE: Circled numbers are section numbers.

FIGURE 13 -- Chart showing forties (shaded squares) that were flagged for field examination of reforestation needs in Twp. 24N, Rge. 7E.



NOTE: Circled numbers are section numbers.

It should be noted in this case that all variables (K, R, S) were set to maximum with respect to influencing the amount of expected erosion. Even so, the only "C" value which would cause "E" to exceed the 25 tons/ac/yr critical value is 0.20 (or greater). This includes sparse pasture/grass (.20), cropland (.35) and Barren/Extractive (1.0). So for all forties in the three townships, the computer could only flag sparse pasture/grass, cropland, and barren/extractive land cover types.

Case II

Given: E = 25 t/ac/yr
K = .49
R = 400
L = 660

Solve for "S" (slope expressed as %)

When:

C =	.001	.004	.014	.02	.20
S =	887	318	125	96	18

In the case of this demonstration area where slopes of greater than 50% were not encountered, the land slope becomes a critical factor (for E = 25 tons/acre/year) when the "C" value reaches .20 (same as in Case 1). This means that only croplands, pasture/grass (sparse), and barren/extractive areas would be flagged due to a slope manifested problem (even under the artificially poor conditions as imposed by the values of the other variables). Increasing "E" to values greater than 25 tons/acre/year will correspondingly increase allowable maximum slope in the above case.

From the above two cases, it can be concluded that only those areas designated as sparse pasture/grass, cropland, or barren/extractive will be flagged in the townships investigated as being in need of reforestation, due to high predicted erosion levels.

The accuracy of the land cover classification derived for this demonstration was determined as follows.

First, the predominant land cover was photo interpreted using 1:120,000 scale color IR photography for every fifth "forty" in the three townships used in the demonstration. 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 mentioned earlier in this report. During this comparison, each "forty" for which there was disagreement between the phto interpretation and the Landsat data as to land cover cateogry was flagged. The second step was to make a random selection of 10% of all "forties" flagged for each type of disagreement, and to locate these "forties" on 1:24,000 scaled maps for field verification. In all cases, the field verification revealed that one of the two sources (Landsat or aerial photography) was correct (as opposed to neither one being correct); substantiating that those "forties" in agreement and, therefore, not field checked, had a high probability of being categorized as the actual land cover. Results of the field verification were incorporated into results of the first step to arrive at an estimated composite land cover classification accuracy of 81%. After products had been generated for this demonstration, various Mississippi agencies were briefed on the results. Map products were disseminated along with an evaluation form which, among other things, asked the evaluators to assess the land cover classification accuracy. All evaluators who were able to address this question responded that the overall classification accuracy was better than the 81% estimate indicated by the ERL assessment.

In addition, to comments on classification accuracy, all evaluators who commented on procedures expressed a preference for the Universal soil loss prediction equation rather than the Modified Musgrave's Equation used in this demonstration. The only factor used in the Universal equation that is not used in the Musgrave's Equation is the "erosion-control practice" factor (P) which relates to specific agricultural practices (e.g., contour plowing, up and down slope operations, etc.)[9]. This factor would have to be incorporated into the data base before the Universal equation could be applied in its intended form. It is the author's opinion that it would not be realistic to assume that information on this variable could be incorporated into the Mississippi data base because there are no existing source maps from which this information could be digitized nor are there any routine operations conducted to get this information. However, the factor could be dealt with by using a P factor that is considered to be appropriate for the agricultural practices that are typical for a given area, and holding it constant when data is processed for that area. All other factors in the Universal equation appear in the Musgrave's Equation. Consequently, the

[9]See reference 10 for details of the Universal soil loss prediction equation.

entire system and procedures described in this report through data base building (Activity G in Figure 3) could be used for either equation. To employ the Universal equation it would be necessary for a computer programmer to expend a small effort to modify the program for Activity H in Figure 3.

Whitetail Deer Habitat Assessment

This application demonstration addresses a geographically referenced, computerized integration of four factors deemed to be important determinants of potential whitetail deer habitat in forested environs. The four factors were: (1) forest overstory vegetation, (2) ground level/understory vegetation accessible to deer, (3) forest overstory crown closure (density), and (4) the interspersion of various land cover and vegetation types. Information on all of these variables, except the ground level/understory vegetation, can be derived from the multispectral scanner data acquired by the Landsat satellite through use of computer implemented techniques. Information on the ground level/understory vegetation can be inferred from information on soils, aspect, elevation, and rainfall. However, because of the flat nature of the terrain within the area used for the particular demonstration addressed in this report, only data digitized from soil maps was used to infer ground level/understory vegetation.

In the case of the whitetail deer habitat assessment application being addressed in this report, the demonstration area was a newly acquired area called the Pascagoula Heritage Area. The area is about 33,000 acres in size, and is situated in Jackson and George counties on the Mississippi coastal plains in the

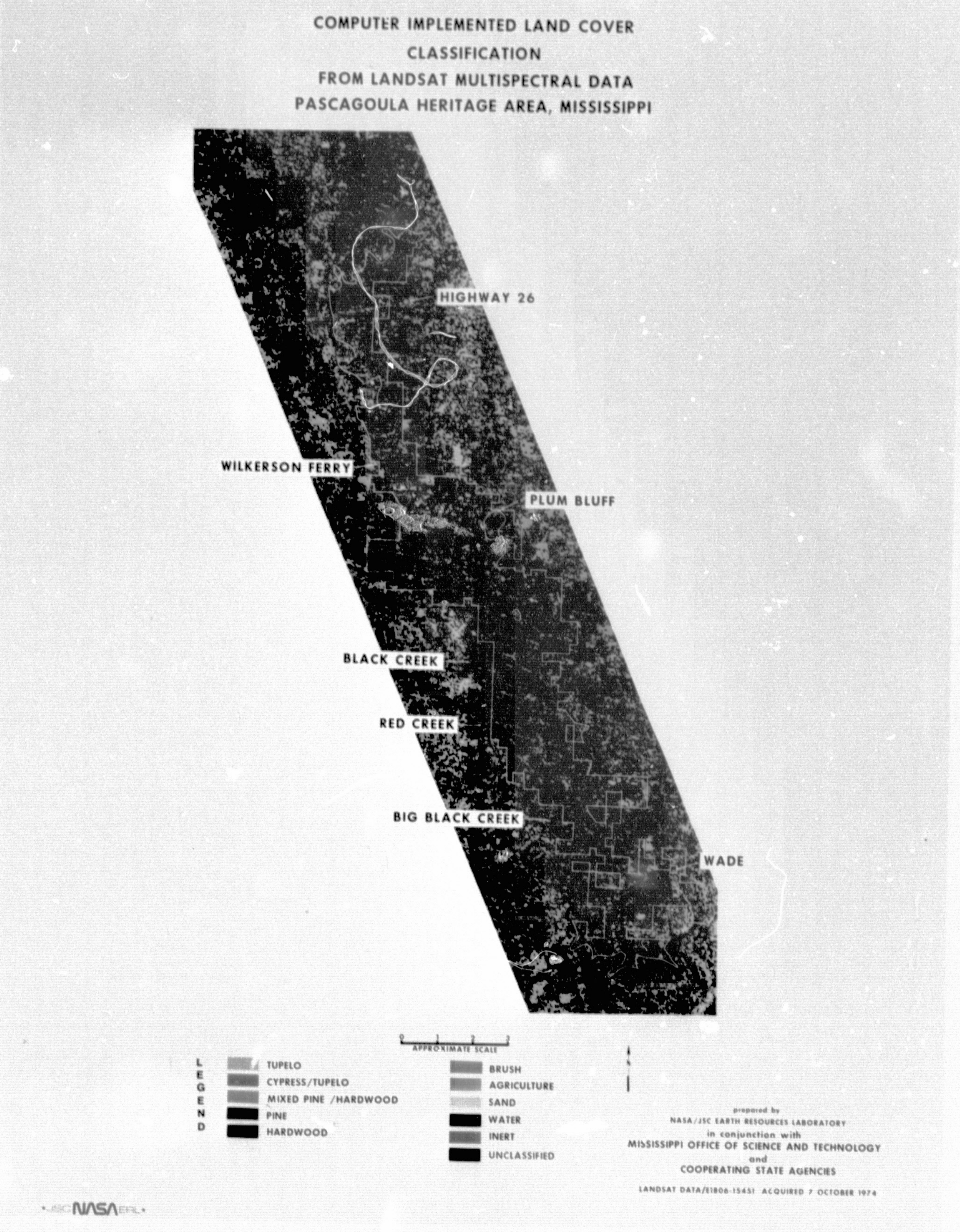
Pascagoula river drainage.

A set of 4 tapes corresponding to Landsat scene E1806-15451 containing data acquired by the satellite on October 7, 1974 was classified and used as input for rectification with the GEOREF computer program module.

The rectified land cover/vegetation information on the GEOREF tape was recorded on film through use of a digital film recorder loaded with a roll of 9-inch wide color negative film at a scale of 1:62,500. Subsequently, the roll of film was developed and printed, and the 9-inch wide sections were cut from the printed strip and mosaiced together. After lettering, the layout was photographed in a 8½ by 11 inch format for this report (see Figure 14). The approximate boundary of the demonstration area is shown with a yellow line within which excluded areas are crosshatched. The scale is shown with a line graduated into one mile units. The acreage of each land cover/vegetation class on the map is shown in table 12.

In the case of this application demonstration, the gridded data base building option was utilized because the demonstration was mainly forestland, and because the non-gridded data base building option was being demonstrated in the other applications demonstrations conducted during the course of the project.

After the data base was built with the land cover/vegetation information derived from Landsat data, an accuracy verification of the vegetation/land cover component was performed. This was done by photo-interpreting 1:120,000 scale color infrared aerial photography to determine the predominant vegetation/land cover



COMPUTER IMPLEMENTED LAND COVER
CLASSIFICATION
FROM LANDSAT MULTISPECTRAL DATA
PASCAGOULA HERITAGE AREA, MISSISSIPPI
HIGHWAY 26
WILKERSON FERRY
PLUM BLUFF
BLACK CREEK
RED CREEK
BIG BLACK CREEK
WADE
0 1 2 3
APPROXIMATE SCALE
LEGEND
TUPELO
CYPRESS/TUPELO
MIXED PINE /HARDWOOD
PINE
HARDWOOD
BRUSH
AGRICULTURE
SAND
WATER
INERT
UNCLASSIFIED
prepared by
NASA/JSC EARTH RESOURCES LABORATORY
in conjunction with
MISSISSIPPI OFFICE OF SCIENCE AND TECHNOLOGY
and
COOPERATING STATE AGENCIES
LANDSAT DATA/E1806-15451 ACQUIRED 7 OCTOBER 1974
JSC NASA ERL

Figure 14.

TABLE 12 Acreage By Vegetation/Land Cover Category

LAND COVER	ACREAGE
Tupelo	1,266
Cypress/Tupelo	648
Mixed Pine/Hardwood	3,604
Pine	3,965
Hardwood	19,028
Brush	249
Agriculture	583
Sand	174
Water/Marsh	1,272
Inert Materials	400
Unclassified	1,653
TOTAL	32,842

type within each data base cell, and comparing this result with the Landsat derived vegetation/land cover information read into the data base. Ordinarily, a field verification would be made for all data base cells for which the two sources of information were in disagreement as to predominant land cover/vegetation type. However, because the Pascagoula Heritage demonstration area is relatively inaccessible and contains large areas of swamp forest, field verification would have required the use of helicopters and boats which was not possible with the resources allocated to this project. Consequently, a second photo-interpretation, using large scale (1:20,000) color infrared photography, was made for the data base cells for which the small scale photo-interpretation was in disagreement with the computer implemented land cover classification with Landsat data. The results showed that there was agreement between the photo-interpretation and the Landsat derived classification for 82% of the data base cells. The hardwood forest, which was predominant in the area, had the highest frequency of agreement (94%); whereas most disagreement occurred in situations where the photo-interpreter categorized a data base cell as mixed pine/hardwood forest and the computer implemented classification showed the same cell as being hardwood forest. The criteria for this distinction was that if 75% or more of the area encompassed by the data base cell was not either pine or hardwood it would be categorized as mixed pine/hardwood. In order to determine whether or not the problem may have been one of applying criteria, eight data base cell areas for which this type of disagreement occured that were accessible by roads on the periphery of the demonstration area were checked in the field. The field verification showed that all of these areas were borderline cases with the actual percentage of surface covered by crowns of hardwood trees being very close to 75%. However, this type of disagreement had only a minor effect on rating whitetail deer habitat because, as shown in Table 13 and explained latter in this section, the outcome can only change the accumulated weight for a given data base cell by 2 (bottomland hardwood is given a weight of 8, and mixed pine-hardwood is given a weight of 6 as a forest overstory variable) on a relative scale of 0 to 36.

The final step in the data processing flow of this application demonstration (Activity H in Figure 3) was to use one of the application 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 factors that were considered to be important to whitetail deer habitat assessment, and to take account of the manner in which these factors combined for each data base cell (39.5 acres) so that the value of each cell as deer habitat could be assessed and aggregated for the entire demonstration area.

The first step in developing the computer program was to select the factors that would be included, and to determine the source of information from which the factor would be derived if other than Landsat digital data. Three criteria were specified for this purpose:

(1) The significance of the factor to whitetail deer habitat

assessment had to be understood well enough that it could be quantified (i.e., as a factor in carrying capacity or as a relative weight);

(2) If derived from other Landsat digital data, there had to be an existing source (i.e., a map) from which the factor in question could be digitized for input to the data base, and,

(3) If derived from other than Landsat digital data, the factor had to be important enough to whitetail deer habitat assessment that its inclusion justified the cost of digitizing.

With these criteria in mind, a selection of factors and source information was made by Mississippi Game and Fish personnel meeting in a workshop setting with ERL perosnnel.

Some factors that were initially thought to be pertinent were eliminated by the criteria for the selection of factors. For example, it was thought that the high audio level at the fringes or urban and densely populated rural areas would degrade those areas as deer habitat; however, there was no substantial information available as a basis for quantifying this factor. It was also thought that prolonged inundation was a pertinent factor because inundated areas are essentially removed from use by deer while inundated. The original idea was to include this factor as derived and digitized from a combination of available hurricane flood maps and 15 min. series contour maps; however, information derived by this method was found to be too gross to justify digitizing. Subsequently, it was decided that it would be better to take account of this variable indirectly through its known relation to overstory vegetation and soil.

The factors that were selected for inclusion in the data base and, subsequently, in the computer program developed for whitetail deer habitat assessment were as follows:

(1) Forest overstory species or species association,

(2) The interspersion of various land cover and vegetation types,

(3) Understory species and abundance, and,

(4) Forest overstory crown closure (density).

Information on the forest overstory species or species association was to be derived directly from Landsat acquired MSS data through the classification techniques previously described in this report. Information on the interspersion of land cover and vegetation types was to be determined from the Landsat derived land cover/vegetation classification, after it was brought into the data base, through use of a separate computer program that determined the number of land cover/vegetation types in the data base cells immediately adjacent to each individual data base cell. Information on the understory species and abundance was to be inferred from known relationships to soils, aspect, and elevation parameters. The soils information was to be digitized from county soils maps produced by the USDA Soil Conservation Service. The topographic factors (aspect and elevation) were to be digitized from contour maps produced by the U. S. Geological Survey. However, because of the flat nature of the terrain within the area subsequently selected for the demonstration addressed in this report, topographic parameters were not digitized for this demonstration.

The crown closure factor relates to the amount of illumination that passes through the forest overstory as it influences the presence and abundance of species in the understory. At the time that this project was planned, it was known that the crown closure of the forest overstory trees could be accurately categorized through photo interpretation. However, since no studies had been made to determine the best crown closure categories for whitetail deer habitat assessment, a research effort was launched to make this determination for the Mississippi coastal plain forests. A field tally of browse species frequencies was made for three to five 100 meter by 100 meter plots within various crown closure conditions established within $\pm$ 5% through photo-interpretation of large scale color infrared photography. Analysis of the resulting field tally showed that there was no substantial difference in the browse species present and their frequency in the crown closure categories between 10% and 25%. For the most part, the understory in crown closures up to 25% was predominantly grass with very few important browse species. However, the number of important browse species and the frequency of plants for each species increased significantly at 25% crown closure. It was the opinion of the ERL investigators that this happened because nearly all important browse species are intolerant (do not grow in full sunlight) and that the shade afforded by a 25% crown closure is a crucial point that allows these important species to out-compete grasses and less important tolerant species. Further analysis revealed that there was significant decline in the presence and abundance of important browse species at the 40% and 65% breaks in crown closure after which there was no significant change. The results of this analysis led the investigators to recommend crown closure categories of 0-25%, 25%-40%, 40%-65%, and 65%-100% as being most meaningful to whitetail deer habitat in Mississippi coastal plains forests.

Although previous work had shown that it was possible to derive forest crown closure classes from Landsat data, there was no existing information as to the accuracy with which this could be done for these specific crown closure categories. However, although an effort was instigated to make this determination, the outcome was not crucial for the demonstration area addressed in this report because it was determined through photo-interpretation that 98% of the forest (744 of the 758 data base cells corresponding to the forested area) fell in the "65% to 100%" crown closure category. Consequently, it was decided to use the photo-interpreted crown closure information that had been input to the data base.

The original idea for developing the computer program for whitetail deer habitat assessment was that the value of each data base cell (39.5 acre area) was to be quantified in terms of potential carrying capacity expressed in "animal units per unit area". This would have required the establishment of such a value for all conceivable combinations of factors. For example, one possible combination may have been dense, oak-hickory forest with a button bush - swamp privet understory (as inferred from soils, aspect, and elevation) with no other land cover types adjacent, for which the potential carrying capacity may have been established at 11 acres per deer (3.6 deer per data base cell). After an exhaustive literature search, it was determined that, although information on carrying capacity existed for many of the possible combinations of factors in Mississippi, such information did not exist for the majority of possible combinations. Consequently, it was decided that, even though it would be desirable to incorporate carrying capacities into future refinements of the computer program, the program used for habitat assessment for this demonstration project would be written to accept an input of weights established for each variable. Subsequently, a literature review along with two summers of field work was oriented to determining the appropriate weights for each factor (variable). The variables and corresponding weights as used for this study are shown in Table 13.

The weights for the forest overstory type relate to the importance of both the foliage of tree species in the particular forest type within reach of deer, and the mast (e.g., acorns) that falls to the ground. The weights for the understory relate to both presence and abundance of species not found in the overstory as inferred from known relationships to soils, aspect, and elevation. It can be noted, by examining Table 13, that the understory variables carry twice the weight of the overstory variables. Although not shown as a variable in Table 13, the effects of inundation are implicit in both overstory and understory weights. For example, a cypress-tupelo swamp forest overstory would be given the lowest overstory weight and a soil with characteristics conducive to inundation would receive a low

TABLE 13

WHITETAIL DEER HABITAT ASSESSMENT
VARIABLES AND WEIGHTS

	Weight
<u>Overstory</u>	
Excellent	8
Good	6
Fair	4
Poor	2
<u>Understory</u> (inferred from soils, aspect, elev., etc.)	
Excellent	16
Good	12
Fair	8
Poor	4
None	0
<u>Crown Closure</u>	
10% - 25%	0
25% - 40%	2
40% - 65%	1
65% - 100 %	0
<u>Land Cover Interspersion</u>	
Forest/Brush	0
Forest/Brush + 1 other	3
Forest/Brush + 2 others	9
Forest/Brush + 3 or more others	12

weight (0 to 4) in respect to the understory variable; thereby, indirectly accounting for the effects of inundation on deer habitat.

The crown closure factor is treated separately because it can be categorized with remotely sensed data. However, in effect, the weight given to this factor is a bonus to the weight given to the understory because it relates to the presence and abundance of browse species in the understory as influenced by the filtering effect that the overstory tree crowns have on the sunlight reaching the understory. The weights for the crown closure categories were established by using the 65% to 100% category as a standard (weight of 0), and determining the weights for the other crown closure categories through a relative assessment of the abundance and importance of browse species shown in the field tallies made (as previously explained) for plots within each crown closure category.

The rationale for the weights established for the various land cover interspersion categories is that the value of the habitat is enhanced if, within the normal range of a whitetail deer (generally considered to be within ½ to 1½ miles of the spot at which it was born (ref. 16)), there is a wide variety of food sources, other than those found in a forested environ, available at different times throughout the year. The actual weights derived from this demonstration were based on the importance of the winter cover crops, agricultural crops, and pasture grasses found in or adjacent to the demonstration area.

It should be noted that, even though an effort was made to make the weights used for this demonstration as realistic as possible, the weights are furnished to the computer program as card input; and, therefore, can be changed by merely substituting a new card should future field studies furnish a basis for changing the weights.

After the weighting system as shown in Table 13 was developed, a weight was assigned to each of the actual forest overstory vegetation types as derived from Landsat data for the demonstration area on the basis of the types importance as whitetail deer habitat. Through an analysis of field tallies of understory browse species by soil type combined with information in available literature treating the relationship between soil characteristics and vegetation, weights were assigned to each soil type shown on the county soils maps encompassing the demonstration area. The weights assigned to the forest overstory vegetation types, and to the soil types in respect to the importance of the understory vegetation with which each soil type correlates are shown in Table 14. Again, the reader should note, that even though the weights shown in Table 14 were used for this demonstration, the weights are furnished to the computer program as card input; and, therefore, can be changed by merely substituting a new card should future field studies furnish a basis for changing the weights assigned.

The computer program developed for whitetail deer habitat assessment outputs information in several formats. Table 15 shows a combined occurrences summary for all data base cells within the Pascagoula Heritage demonstration area. For example, Table 15 shows that within the entire demonstration area, there were 372

TABLE 14

Weights Assigned To Forest Overstory Vegetation Types And To Soil Types Found In The Demonstration Area

Forest Overstory Type	Weight
Bottomland Hardwood	8
Mixed Pine - Hardwood	6
Pine	4
Cypress - Tupelo	2
Tupelo	2
Soil Type	
Alaga loamy sand, terrace	8
Alluvial land	4
Atmore fine sandy loam	4
Basin fine sandy loam	8
Cahaba fine sandy loam	12
Dunbar loam	16
Leaf - Lenoir Association	4
Lenoir silt loam	12
McLaurin fine sandy loam	12
Rains loam, dark surface	8
Rumford sandy loam	4
Susquehanna - Benndale complex	16
Swamp soils	0

C2

TABLE 15

COMBINED OCCURRENCES SUMMARY

FOR WHITETAIL DEER HABITAT VARIABLES

LAND COVER	SOIL	CROWN CLOSURE 20-40%	CROWN CLOSURE 40-65%	CROWN CLOSURE 65-100%
Bottomland Hardwood				
	Swamp	0	2	14
	Alaga Loamy Sand	0	0	8
	Atmore Fine Sandy Loam	0	0	1
	Basin Fine Sandy Loam	0	0	3
	Leaf-Lenoir Assoc.	0	3	372
	Lenoir Silt Loam	0	0	3
	Susquehanna-Benndale	0	0	2
	Alluvial Land	0	0	308
Mixed Pine/Hardwood				
	Rains Loam	0	0	0
	Leaf-Lenoir Assoc.	0	0	4
	Alluvial Land	0	0	9
Pine				
	Swamp	0	5	5
	Dunbar Loam	0	0	2
	Rains Loam	0	2	1
	Leaf-Lenoir Assoc.	0	0	6
	Lenoir Silt Loam	0	0	1
	Alluvial Land	0	0	3
Tupelo				
	Swamp	0	1	3
	Alaga Loamy Sand	1	0	0
	Leaf-Lenoir Assoc.	0	0	2
	Alluvial Land	0	0	3
Cypress-Tupelo				
	Swamp	0	0	2
	Leaf-Lenoir Assoc.	0	0	2
	Alluvial Land	0	0	2

data base cells (about 14,700 acres) with dense (65% to 100% crown closure), bottomland hardwood forest with Leaf-Lenoir Association soils. It is also interesting to note the correlation between overstory vegetation and soils shown in Table 15. For example, of the 389 data base cells with Leaf-Lenoir soils, 375 coincide with bottomland hardwood forest. For reasons explained previously, a carrying capacity factor was not readily available for use in the computer program for whitetail deer habitat assessment. However, as these factors become known through field studies, they can easily be applied to the information shown in Table 14 to arrive at a total potential carrying capacity for the Pascagoula Heritage area. In this sense, it would be most efficient to generate information as shown in Table 14 as a basis for such field studies. As seen in Table 14, 680 data base cells (372 + 308), encompassing 89% of the area, relate to dense, bottomland hardwood on Leaf-Lenoir and Alluvial land soils. Consequently, with such information, field studies would be oriented to dense, bottomland forests on these two soils and directed at the specific areas shown to have this combination on a map generated from the data base tapes so as to determine potential carrying capacity for 89% of the area in a rapid manner.

An example of the second type of output is shown in Figure 15. The number shown for a particular row and column is the accumulated weights of all variables for the particular data base cell to which that row and column relates. The diagram in Figure 16 enables one to put the individual pages of the line printer output into geographic perspective. For instance, the output included in

FIGURE 15 - ACCUMULATED WEIGHTS OF WHITETAIL DEER HABITAT VARIABLES FOR INDIVIDUAL DATA BASE CELLS

ROWS	COLUMNS 301 - 315														
2499	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2501	0	0	0	0	0	0	0	0	0	12	12	12	8	15	0
2502	0	0	0	0	0	0	0	0	0	0	12	12	12	0	0
2503	0	0	0	0	0	0	0	0	0	0	12	12	15	0	0
2504	0	0	0	0	0	0	12	12	0	12	12	12	0	0	0
2505	0	0	0	0	0	0	12	12	12	12	12	12	0	0	0
2506	0	0	0	15	0	12	12	12	12	12	12	12	0	0	0
2507	0	0	0	0	15	12	12	12	0	0	0	0	0	0	0
2508	0	13	0	12	12	12	12	12	0	0	0	0	0	0	0
2509	0	0	12	12	12	12	16	16	10	12	0	0	0	0	0
2510	0	0	12	12	12	12	16	12	16	12	0	0	0	0	0
2511	0	0	12	12	12	12	12	16	12	12	0	0	0	0	0
2512	0	0	12	12	12	12	12	16	0	0	0	0	0	0	0
2513	0	0	12	12	12	12	12	12	0	0	0	0	0	0	0
2514	0	0	0	12	12	12	12	12	0	0	0	0	0	0	0
2515	0	0	0	0	0	12	12	12	0	0	0	0	0	0	0
2516	0	0	0	0	0	12	12	12	23	0	0	0	0	0	0
2517	0	0	0	13	0	12	12	12	15	0	0	0	0	0	0
2518	0	0	0	0	0	12	12	12	12	0	0	0	0	0	0
2519	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0
2520	0	0	0	0	0	0	0	0	0	12	12	0	0	0	0
2521	0	0	0	0	0	0	0	0	15	12	12	0	0	0	0
2522	0	0	0	0	0	0	0	0	0	12	12	0	0	0	0
2523	0	0	0	0	0	27	15	15	15	12	15	0	0	0	0
2524	0	0	0	0	0	0	24	12	12	12	0	0	0	0	0
2525	0	0	0	0	0	0	0	12	12	12	0	0	0	0	0
2526	0	0	0	0	0	0	0	12	12	12	15	0	0	0	0
2527	0	0	0	0	0	0	0	12	0	12	12	12	12	0	0
2528	0	0	0	0	0	0	0	15	15	12	12	12	12	0	0
2529	0	0	0	0	0	0	0	0	15	12	12	12	12	0	0

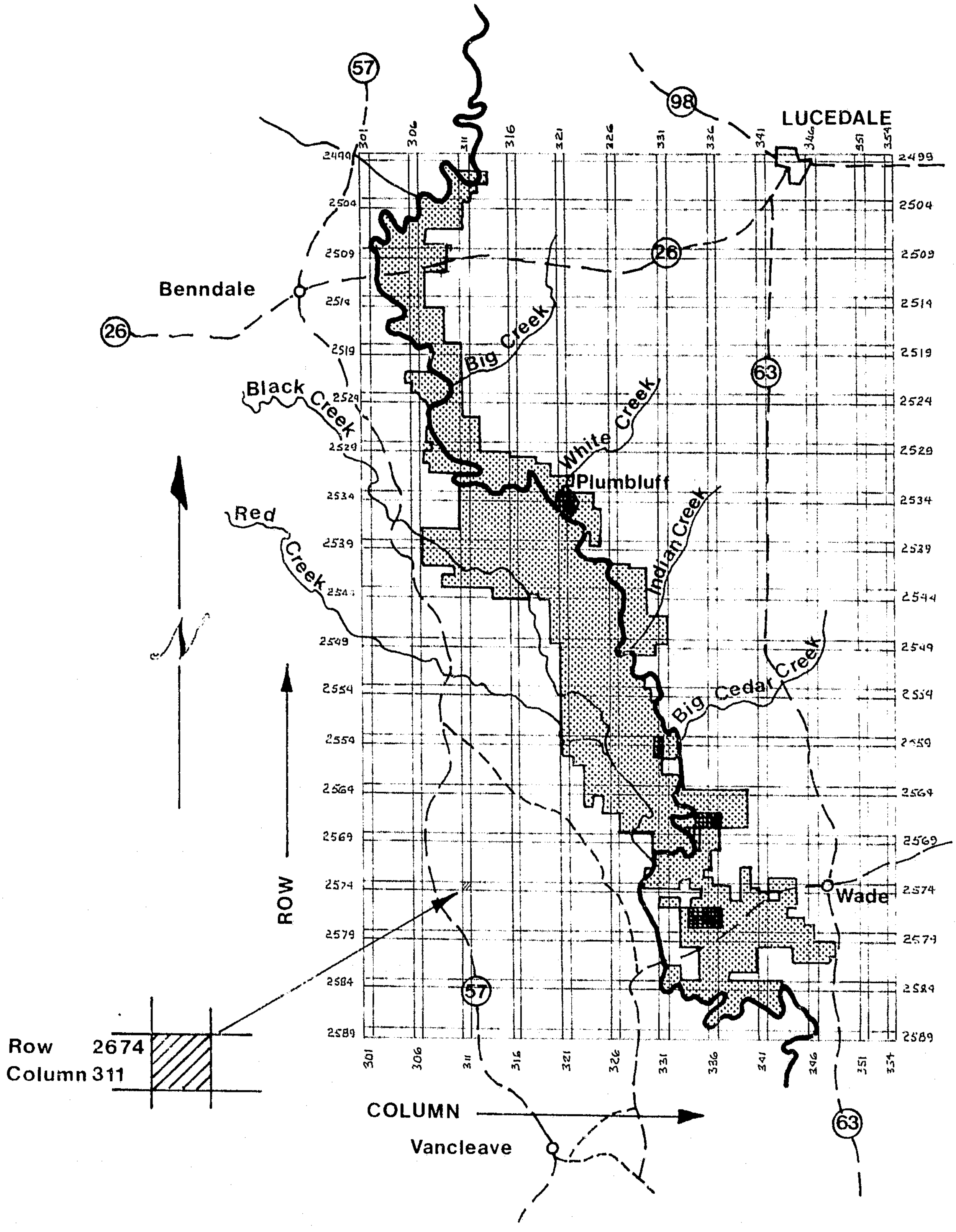


FIGURE 16 Diagram to aid placement of individual line printer sheets in geographic perspective.

Figure 15 coincides with an area in the extreme northern portion of the demonstration area. By using a reference point shown as a (northing, easting) UTM grid coordinate on a data base building input card, the (northing, easting) coordinates can be easily determined for each row and column, which, in turn, would enable one to locate any particular data base cell on a map with UTM grid coordinates. The zeros in Figure 15 relate to the data base cells for which no information was input to the data base because these cells were outside the Pascagoula Heritage demonstration area. Consequently, the interface between zeros and accumulated weights show the approximate boundary of the Pascagoula Heritage demonstration area.

The thid type of output, a summation of acreage corresponding to each rating (accumulated weight) on a relative scale of 2 to 36, is shown in Table 16. In reference to Table 12, it can be seen that the lowest possible rating would be 2, arrived at if a data base cell contained dense, cypress-typelo swamp forest with a soil that carried no weight (e.g., swamp soil) and was not adjacent to any other land cover type. The highest possible rating would be 36, arrived at if a data base cell contained bottomland hardwood with a soil rated as excellent for understory species in a position in which the cells around the rated cell contained 3 or more other land cover types. In the case of this demonstration area, the highest accumulated weight was 27. Table 16 reveals that the rating of 12 corresponded to the largest acreage (25,738 acres). However, the reader should keep in mind that the 2 to 36 scale is relative to forested habitats, and that a rating

TABLE 16

ACREAGE SUMMATION BY WHITETAIL

DEER HABITAT RATING

Rating*	Acreage
27	39.5
26	0.0
25	0.0
24	39.5
23	79.1
22	0.0
21	0.0
20	118.6
19	39.5
18	0.0
17	0.0
16	474.4
15	1,383.8
14	39.5
13	118.6
12	25,738.4
11	158.1
10	474.4
9	118.6
8	988.4
7	39.5
6	316.3
5	158.1
4	158.1
3	39.5
2	237.2
	30,759.1

* Maximum possible accumulated weight is 36, but values from 28 to 36 were not encountered.

of 12 implies a fairly high carrying capacity. In fact, in this particular demonstration area where there was a high incidence of dense bottomland hardwood (with a weight of 8) correlating with Leaf-Lenoir and alluvial soils (each with a weight of 4), the majority of data base cells with an accumulated weight of 12 are likely to reflect this particular combination of variables. The reader may note that the total acreage shown in Table 16 is not the same as that shown in Table 12. This disparity does not indicate a discrepancy but, rather, is related to the manner in which the boundary, as input with UTM grid coordinates, is matched to a 50m X 50m grid in one case and a 400m X 400m grid in the other case. Consequently, the acreage shown in Table 1 which comes from the GEOREF tape with 50m X 50m cells is closer to the actual acreage in the demonstration area.

The final output is the color-coded habitat map for the entire demonstration area as shown in Figure 17. This map is created with the same data base tape information used for Figure 15 but shows the information in a format that permits easier visual analysis. The map was made by film recording information on the data base tape in a manner that the area encompassed by each cell (at the particular scale) was assigned a color that corresponded to a particular range on the 2 to 36 scale. The actual ranges used and the colors assigned to each range are as follows:

POTENTIAL DEER HABITAT IN THE PASCAGOULA HERITAGE AREA

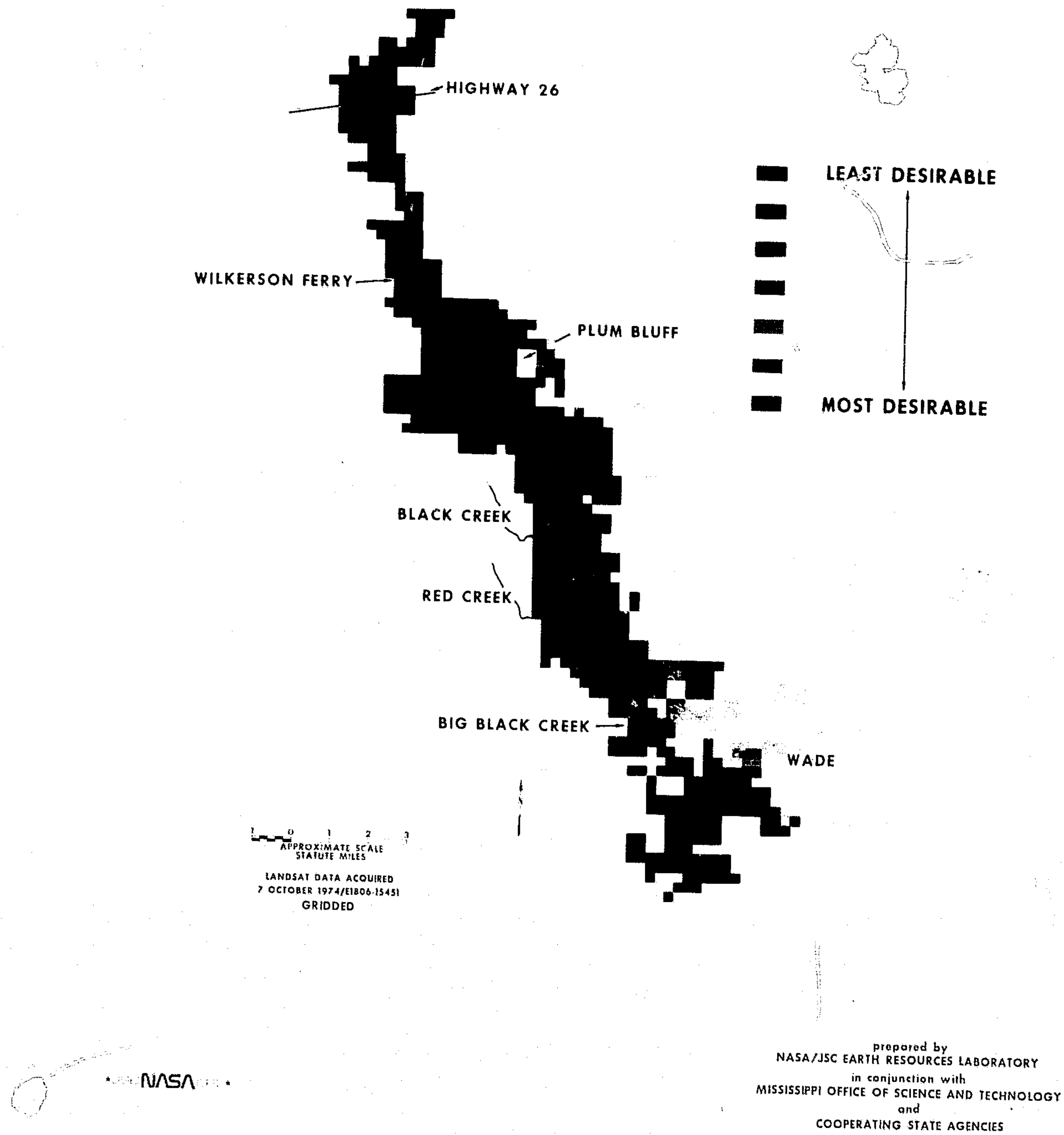


Figure 17.

	Map Color	Accumulated Weight
Outside Area	White	0
Least Desirable	Black	5-7
	Light Blue	8-10
	Green	11-14
	Yellow-Green	15-17
	Yellow	18-20
	Orange	21-26
Most Desirable	Red	27-30
Not Encountered		31-36

A visual analysis of the map reveals that the areas on the least desirable end of the scale appear more frequently in the lower one-third of the demonstration area than in the upper two-thirds, apparently because cypress-tupelo swamp (as shown in Figure 14) is more common in the lower one-third. One can also see that the effects of the land cover interspersion variable raise the habitat rating of those cells on the boundaries of the area because of their apparent proximity to cropland and pasture areas.

The system for whitetail deer habitat assessment as described in this report was demonstrated for an established area of land within which wildlife management will be a prime concern. However, the system described also has utility for processing data for large areas (e.g., an entire state) for the purpose of identifying smaller areas within the total area that have high potential for whitetail deer management. In addressing the latter purpose, the question arises as to whether the information gained by integrating soils and topographic (e.g., aspect, elevation) data with the vegetation/

land cover information justifies the cost of digitizing soils or topographic data from existing source maps. Based on the strong correlation between forest overstory type and soils shown in this demonstration (see Table 15), it is the author's opinion that it would be adequate and cost-effective to base a preliminary selection of areas with high potential for white-tail deer management solely on a vegetation/land cover classification. However, since soils information is necessary for many applications in addition to wildlife habitat assessment, it would be desirable to explore cost-share arrangements between various agencies that could use digitized soils information. Also, it would be desirable to consider the use of elevation and aspect information on tapes available through the National Cartographic Information Center, especially for mountainous areas; which, when combined with vegetation/land cover in a data base, would add a low-cost element of information useful for the preliminary identification of areas with high potential as deer habitat.

The emphasis during this project was to demonstrate a computer implemented information system and assoicated procedures for the assessment of potential whitetail deer habitat. The most attractive feature of the system involves the use of satellite acquired data to derive vegetation/land cover information that has not previously been available to wildlife managers in a timely, cost-effective manner. If the output of the system were to be improved, the greatest potential for improvement lies in the refinement of the application program (Activity H in Figure 3). In the literature review conducted during this project, the authors encountered many field studies in which overstory and understory vegetation was sampled to determine carrying capacity. However, none of these studies included the gathering of soils data in the plots for which vegetation data was gathered, or referenced the location of field plots in a manner that they could be matched with information on soil maps.

In many studies, the forest overstory was categorized as sparse or dense for each field plot but the exact criteria used for this categorization was not specified. A field study was conducted in Mississippi during this project to determine the relationship between crown closure and understory vegetation, and it is the authors' feeling that the results of this study could be extended to all coastal plains forests in Mississippi.

However, if not already performed, similiar studies would have to be conducted for other areas, especially mountainous areas where slope, aspect, and elevation parameters are likely to be significant.

Computer techniques are very efficient for measuring land cover interspersion and/or the length of interface between two or more vegetation/land cover types. However, more information from field studies is needed to quantify these factors in respect to deer habitat.

In summary, the use of Landsat digital data and computer implemented techniques offers the wildlife manager a powerful tool that can be used at the present time. However, the degree of improvement will be dependent on additional field research on whitetail deer habitat that is conducted in a framework that assumes the use of remotely sensed data integrated with other pertinent data that can be digitized from existing sources (e.g., soil maps).

Some additional improvements could be made through the use of predictive models that utilize vegetation/land cover information derived from Landsat acquired MSS data. This demonstration did not determine actual habitat as could have resulted from prescribed burning or other past land management practices. It would, of course, be possible to create a data base in the manner described in this report; and, subsequently, feed data base information into a model designed to predict the possible effect of various levels or types of management practices oriented at improving the deer habitat.

Site Selection

The phrase "site selection" is used to refer to the use of Landsat derived land cover information to locate potential sites for any of a number of purposes (e.g., an industrial site, an airport, a campground, etc.). However, for the purpose of demonstrating the procedures and results of one site selection application during the course of this project, it was decided to demonstrate the selection of potential campground sites. The area selected for this demonstration encompassed about 30,000 acres located within the Pascagoula River drainage in Jackson and George counties. The area had recently been acquired by the State, and named the Pascagoula Heritage Area.

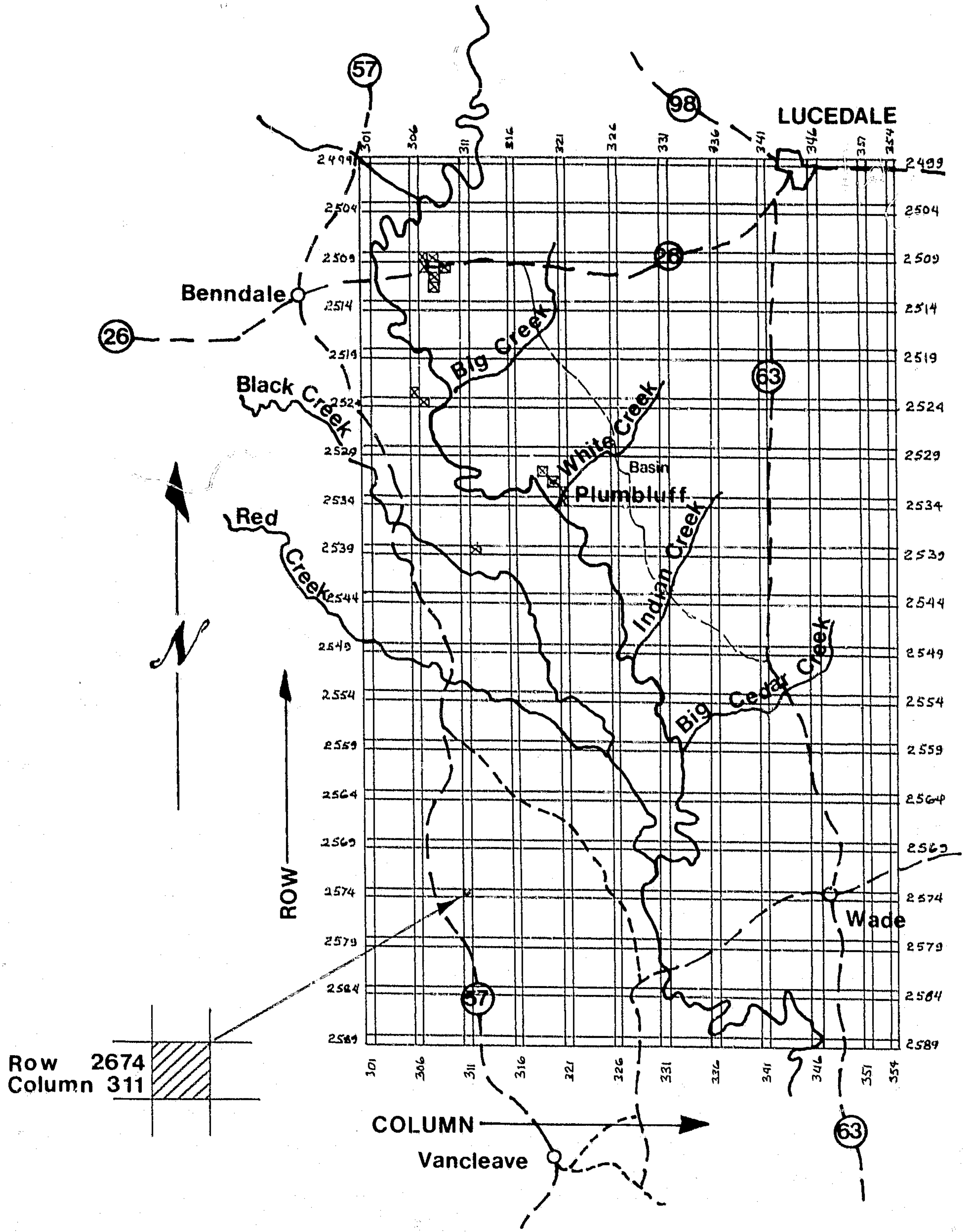
The first step was to establish the factors pertinent to campground site selection. Vegetation is a factor because campgrounds are usually selected to emphasize a particular natural setting and/or activity associated with that natural setting. In the case of a forested area, it is usually desirable to maintain a degree of tree shade. Therefore, the crown coverage (% of the surface covered with tree crowns) is a factor. Soil is a factor because it is desirable to have a soil that is well-drained, is not a type (e.g., clay) that is bothersome to campers when wet, and is not easily compacted when subjected to use by campground users. Accessibility is a factor not only in respect to the distance that a campground user would have to travel from first class roads, but also with respect to the cost of any roads that may have to be built. Consequently, when "accessibility" is digitized, (Activity G, Figure 3) each data base cell would be categorized with respect to its distance from various types of roads (e.g., 0 to 10 miles from a primary highway, 3 to 5 from an all-weather, gravel road, etc.). Of the various topographic features, "slope" is a factor because it would not be desirable to have a campground located on too great an incline; "aspect" would be a factor in steep, mountainous terrain because north aspects would receive less direct sunlight than other aspects; and elevation would be a factor as it relates to temperature and snow accumulation at higher elevations. In summary then, five pertinent factors were identified: (1) vegetation types, (2) crown coverage, if forested, (3) soil type, (4) accessibility, and (5) topographic factors.

A data base (Activity F, Figure 3) containing information on vegetation types, crown coverage, and soils had already been built for this demonstration area for the purpose explained in the previous section. The vegetation information for this data base was derived from Landsat scene E1806-15451 acquired October 7, 1974; and the soils information had been digitized from USDA-SCS county soils maps for Jackson and George counties. Because this particular demonstration area was situated on a flat, coastal plain without any significant topographic variation, the need to address topographic factors for this area was ruled out. Also, because this particular demonstration area had very few established roads, it was decided not to digitize "accessibility". Although accessibility must be considered, it was thought that it would be most cost effective to make a selection of potential campground sites on the basis of vegetation type, crown coverage, and soil type, and, then, plot the selected sites on a map to allow a visual comparison of location of these sites with the few established roads.

Although any combination of factors could have been specified as selection criteria for potential campground sites, it was decided to illustrate the procedure by specifying that the potential campground site should be (1) in bottomland hardwood forest, (2) in the 70% to 100% crown coverage category (other categories in the data base were 10% to 40% and 40% to 70%), and (3) on a soil that was well-drained, not clay, and not easily compacted. The characteristics of the various soil units encountered on the soil maps of the demonstration area were reviewed, and three soil units that met these criteria were identified. They were the Alaga loamy sand, the Basin fine sandy loam, and the Susquehanna-Benndale complex.

A computer program was written to examine the information that had been digitized for each data base cell and to locate those cells that met a combination of specified criteria. This computer program was run (Activity G, Figure 3) using the input criteria previously mentioned which resulted in location of 13 of the 770 data base cells (39.5 acre acres) that met the specified combination of criteria for potential campground sites. The line printer output lists the 13 cells by their data base row number and column number. The approximate geographic location of each of these 13 data base cells is shown with an X on Figure 18 which can also be used to relate to the established roads in and adjacent to the demonstration area. For field evaluation purposes, the data base row and column numbers shown on the line printer output can be converted to UTM coordinates (northing, easting) so that the locations of the selected potential campground sites could be accurately plotted on large scale maps. In respect to accessibility, it should be noted that two of the potential sites are near Highway 26 between Benndale and Lucedale, and four others are not too distant from the same highway. The seven others are all fairly distant from existing first class roads.

It is thought that a first iteration selection of potential campground sites conducted through the computer implemented techniques described in this paper would substantially reduce the costs of campground site selection through the reduction of



Scale = 1:250,000

FIGURE 18 Geographic location of 13 Data Base Cells (shaded) that met the specified criteria for potential campground sites.

field work. As evidenced by the results of this demonstration, 757 data base cells (39.5 acre areas) were eliminated leaving only 13 of the total 770 for field inspection.

V. PRODUCT ADEQUACY, CLASSIFICATION ACCURACY, AND COST EFFICIENCY

Product Adequacy

As mentioned previously in this report, one reason for conducting specific application demonstrations as part of this project was to get feedback from state-level users. It was anticipated that such feedback would serve as a basis for making technical improvements to data processing procedures, and would be a means of establishing user preferences for product formats. Such feedback came from both discussion at the times that state personnel were briefed on the results of the various application demonstrations, and through written product evaluations that were returned to the project managers by mail. The responses fell into two general categories: (1) those responses relating to map products, and (2) those responses relating to statistical information.

Map Products

During the course of this project, maps showing land cover/vegetation were produced at five different scales ranging from a small scale (1:250,000) to a large scale (1:24,000). Responses at the briefings and on the written evaluations indicated a wide range of preferences. Some participants stated that they had no need for maps, and were only interested in statistical information. They considered the most desirable characteristic of Landsat MSS data to be its digital form permitting the generation of statistical information without the need to digitize land cover/vegetation information from a map base. The majority of participants stated that maps were desirable but that small-scale maps (1:125,000 to

1:250,000) were adequate provided that statistical tabulations showing acreage and/or percentage of land cover by category within land units (e.g., counties, major watersheds) were furnished with the maps. Participants who were field personnel did prefer to have large-scale (1:24,000 to 1:63,360) maps; however, there was no consensus as to the type of map. A few preferred color-coded maps, whereas most were satisfied with black and white. Some preferred a series of thematic maps (each showing only one to three land cover/vegetation categories), whereas others preferred composite maps. Of those that preferred color-coded maps, either small-scale or large-scale, there was little agreement as to choice of colors. Some had no preference stating that any colors were adequate as long as they were easy to distinguish from one another. Others preferred that specific colors be assigned to specific land cover/vegetation categories, but these preferrences were not always the same.

In summary, there was no consensus as to map products in respect to scale, type of map, or color/pattern assignments. However, two conclusions could be drawn from the responses: (1) that even though all users do not require maps, there are a sufficient number that do to justify the inclusion of map-making output devices in a natural resource inventory and information system, and (2) that in order to satisfy the variety of users found in state agencies, the map-making part of the system should be as flexible as possible in respect to various options in scale, map type, and color/pattern assignments. In respect to the second conclusion, it should be noted that such flexibility is inherent in the system used during this project.

Statistical Output Products

User participants in the briefings on applications demonstration products found the general formats of the various statistical tabulations to be satisfactory, except that they preferred to eliminate the use of codes whenever possible. For example, they preferred that township designations, e.g., Twp.5N Rge.6W, be printed out rather than given a three-digit code.

When the briefing participants were questioned about their preferences for the "gridded" versus the "non-gridded" data base building options, they expressed a preference for the "non-gridded" option referenced to the public land survey system. Their reasons for this preference were: (1) that agency personnel were already familiar with the public land survey system, (2) that the public land survey system could be easily related to locations on the ground, and (3) the public land survey system was related to ownership which, in turn, was related to land use. However, it was realized that the advantages of the "non-gridded" option were less significant if the data base cell size was smaller than the 40 acre data base cell used for the application demonstrations.

When taking account of data handling factors and the accuracy of ancillary data, most briefing participants found the 40 acre data base cell used for the application demonstrations to be adequate, but some thought that it would be desirable to reduce the cell size to 10 acres for applications conducted in the hill country of Mississippi. Their reason was that, in hill country with broken terrain and considerable topographic variation, there were many crop and pasture areas of less than 40 acres in size.

The only criticism of technical procedures used in the application demonstrations concerned the equation used in the erosion hazard application. In this sense, the participants who offered an opinion stated a preference for the Universal Soil Loss equation over the Modified Musgrave's equation. Although the Modified Musgrave's equation was an accepted means of calculating soil erosion losses at the start of this project, better results through recent experimentation with the Universal Soil Loss equation had caused preferences to change. As discussed on pages 76 and 77 of this report, changing to the Universal Soil Loss equation only requires modification of a fairly simple computer program used in the last step in the application demonstration (Activity H, Figure 3).

Classification Accuracy

The method and results of verifying the land cover/vegetation classification accuracy for each of the indivudal Landsat data sets processed during this project was discussed in Section IV of this report. These results are shown in summary form in Table 17. As implied by the captions in Table 17, accuracy is influenced by many factors among which are the kind and number of land cover types, the seasons during which the Landsat MSS data was acquired, and the number of Landsat frames included in the data set. However, so as to integrate these various factors, a weighted-average calculation was made which yielded an overall composite accuracy of 85%.

The reader should note that, because of the schedule for

TABLE 17 - ACCURACY SUMMARY FOR LANDSAT-DERIVED LAND COVER INFORMATION IN MISSISSIPPI

Predominant Land Cover Type	Season	Number of Landsat Frames	Number of Land Cover Types	Number of Cover Types Used In Accuracy Check	Number of Points Checked	Percent Correct
Agricultural	Summer	1	11	5	2156	87
Natural Vegetation	Fall	2	10	9	770	82
Ag./Forest (broken terrain)	Winter	2	10	9	345	81
Mixed	Winter	2	8	8	1373	83

Weighted Average: 85

this project and/or the applications selected, no Landsat data acquired during the spring season was included. However, spring data usually yields the highest accuracy for "general cropland" and a higher composite accuracy than does data from other seasons. This is because, during the spring, nearly all cropland is in some stage of soil preparation and devoid of vegetation, thereby, causing little or no confusion between crops and natural vegetation. As mentioned in Section IV of this report, a significant degradation of accuracy came about through confusion between "mixed pine-hardwood" forest signatures and hardwood or pine forest signatures. Efforts are currently underway to derive a "mixed pine-hardwood" forest category through merging seasonal classifications or through distribution relationship analysis techniques rather than through signature development, and preliminary results have shown substantial improvements in accuracy.

When questioned about specific accuracy requirements, there was no concensus among the briefing participants. Some participants stated that accuracy figures were only meaningful when examined in conjunction with cost and time-response factors. However, briefing participants did agree that a 80% composite accuracy was a reasonable goal. By this standard, it was concluded that the accuracies attained in the various land cover classifications produced during this project were adequate.

Cost Efficiency

The project plan called for an assessment of cost efficiency to be made by comparing the cost of producing Landsat derived land cover/vegetation maps and statistics with the cost of producing land cover/vegetation maps and statistics by other methods used by state agencies. After discussions with the various state agencies, it became apparent that the only active mapping project in the state, other than sporadic efforts during which accurate cost records were not kept, was being conducted by the Mississippi Research and Development Center. This project involved the photointerpretation of existing 1:120,000 scale, color infrared aerial photography to show delineations of land cover/vegetation categories on a photo image at a scale of 1:24,000 formated to show one township per map sheet. Each map is accompanied by a tabulation of acreage for each land cover category by section. The accuracy, based on less than 4% sampling, was determined to be 87% at level III, (51 categories), 95% at level II (11 categories), and 97% at level I (6 categories). The cost of producing these maps and acreage statistics as calculated after 1,120 townships had been completed was $312.10 per map sheet or $8.67 per square mile. It should be noted, however, that this calculation was based on the use of existing aerial photography, and would be significantly higher had it been necessary to acquire new aerial photography.

Based on the use of the state-owned IBM 370 Model 155 computer and ERL image display devices, Mississippi Office of Science and Technology personnel made the following estimate of annual operating cost for deriving land cover/vegetation maps and statistics from twenty sets of Landsat data:

Salaries, fringe benefits, and travel	$95,500

Landsat CCT's (20 sets)	4,000
Computer time	30,000
Equipment maintenance	4,000
Misl. supplies	3,500
TOTAL OPERATING COST	$137,000

This effort would allow two complete land cover/vegetation classifications of the state to be produced so as to encompass 103,218 square miles. The projected cost per square mile for this activity would be $1.33 ($137,000 ÷ 103,218 square miles).

A comparison of operating costs per square mile between the two methods indicates a cost efficiency ratio of 1 to 6.5 ($8.67 ÷ $1.33) in favor of deriving land cover/vegetation maps and statistics from Landsat data. However, it should be noted that, at the point at which the land cover/vegetation maps and statistics can be derived from GEOREF tapes (see Figure 3), the information is in digital form. In the case of photo-interpreted land cover/vegetation delineations on maps, a significant additional cost must be incurred to digitize the mapped information for input to a computerized data base.

Although additional cost analysis was not planned for this project, a cost study was conducted for a similar Landsat data processing system being used in Georgia (ref. 19). This study concluded that the Landsat system had a net present value (1977 dollars) of $9.5 million (using a discount rate of 7%) with upper and lower bounds computed at $12.5 million and $6.5 million, respectively, over the timeframe 1977 through 1985. Also, an equal-cost comparison was made of an alternate method using aerial photo-interpretation. The result showed that providing land cover information on a quarterly basis using Landsat data is no more costly than providing the same data products every 21 months through use of high altitude aerial photography.

VI. CONCLUDING COMMENTS

One of the main considerations during the development and demonstration of the natural resource inventory system addressed in this report was to test the hardware/software system and associated procedures needed to utilize Landsat digital data and other digitized data (e.g., soils) to address specific applications. One of the main advantages, both cost-wise and time-wise, of the system used in this project involves the use of Landsat-acquired digital data for the land cover information component; thereby, eliminating the need to digitize such dynamic information from a map or aerial photo base.

It is thought that the utility and the cost of information as derived from Landsat data for the various applications demonstated in this project justify the operational use of data generated by the Landsat satellites, currently furnishing data (Landsat II launched in January, 1975 and Landsat III launched in March 1978). However, additional cost reductions are likely to be forthcoming in the near future when rectified raw data is provided to the user. In addition, the thermal data from Landsat III and the increased spectral and spatial resolution of the Landsat D thematic mapper tentatively programmed for launch in 1981 hold the potential for improvements in both classification accuracy and the types of information that can be derived from Landsat digital data.

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