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GEORGIA'S OPERATIONAL LANDSAT PROCESSING SYSTEM

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I. INTRODUCTION

The State of Georgia and the Georgia Institute of Technology have created an exemplary relationship in the formation of a cohesive group for the analysis of Landsat data, its application to real world problems, and its inclusion in applications using geographic data base techniques. This group has evolved over a period of four to five years and lists as its accomplishments several successful demonstration projects using Landsat data, an operational Landsat classification of the entire State of Georgia using 60 classes, the integration of Landsat data into several geographic data bases for use in operational short and long range planning, and the development of those data bases. Funds for performing these projects have come from a variety of state, federal, and local governmental agencies. The state of Georgia has immediate access to an Earth Resources Digital Analysis system designed and assembled by Georgia Tech for dedicated computer analysis of Landsat and other geographically oriented data.

II. BACKGROUND

This section will deal primarily with the use of digital satellite data for natural resource management programs. The program currently employing Landsat digital data in Georgia is called the Resource Assessment Program.

Within Georgia it should be noted that the Resource Assessment Program's use of Landsat digital data is only one element within state government using remote sensing products. Also, within the Department of Natural Resources, there are other divisions

performing remote sensing. These other divisions include the Environmental Protection Division (EPD) Geologic Branch's use of Landsat and photographic images for interpretation of geologic features and the Water Quality branch's use of classified Landsat products to aid in detecting sources of non-point pollution. The Georgia Department of Transportation has complete aerial photography capabilities and is beginning to explore satellite techniques for highway corridor analysis.

The Resource Assessment Program is comprised of three major components. The first component is the Resource Index of Georgia and in published form delineates the natural resource data available in Georgia. The publication includes various information relating to natural resources in the state as published by federal agencies, state agencies, local governments and the university system. The second component is a resource inventory of soils and vegetation (landcover) information. This information has been collected and manually mapped at 1" = 1 mile for each county in Georgia. The third element, Resource Research, has been the process of exploring ways to better obtain information which may be useful for natural resource decisions. The latter element not only involves the use of Landsat classified products but also the integration of all Natural Resource Data using computerized spatial resource data bases.

Historically, remote sensing data has been provided by employing the use of aircraft to obtain photography. Often this information is analyzed and manually interpreted to delineate those areas of particular interest. It was this process of manual photographic interpretation which was used to map

vegetation (landcover) (at a minimum map unit of 50-100+ acres) for each of Georgia's 159 counties. Although the vegetation (landcover) maps have been useful and a void was filled at a particular period of time, there are questions about whether the accuracy (50-100 acre mapping units) is sufficient, and what the cost of updating the maps will be.

What emerged from the evaluation of the manual mapping efforts was a desire to begin analyzing the possible use of computerized digital data for natural resource management programs. An initial effort was launched in 1974 between the Department of Natural Resources and Georgia Tech to perform a digital landcover classification of the Atlanta area. A supervised approach was employed to determine landcover whereby aerial photographs were used to verify unclassified Landsat data as displayed on gray level "brightness maps". Once a determination was made identifying the most probable landcover category from the unclassified data, a classification of each 1.1 acre cell was performed.

The result of the classification was a 10 category gray level map which was manually colored for graphic display purposes. This exercise began to demonstrate that Landsat digital data, incorporated with a training sample approach, could be employed to produce landcover information at a detailed minimum map unit (1.1 acre) and possibly at more affordable costs than our present techniques.

Following this initial experience using Landsat digital data, Georgia and several other southern states were invited to participate in a three-day workshop at the Earth Resources Laboratory (ERL) of NASA. The purpose of the workshop was to become more familiar with automatic classification techniques as they relate to future natural resource information systems.

Aside from the three days of lectures which the group received, the opportunity was also offered to process one Landsat type (approximately 100 miles x 25 nautical miles) provided the ground support and Landsat computer-compatible tape could be acquired.

Of the Landsat tapes which the group had access to, it was decided to pick a coastal Georgia frame including most of the islands and marshes, while extending inland to include the new I-95, the cities of Savannah and Brunswick,

plus the river swamps and areas of upland vegetation. Then the individual who received the training sample and ground truth instructions was dispatched to meet with coastal scientists and planners to determine categories and areas of interest. Before the previous categories were chosen, an attempt was made to determine the types of data that would be relevant for the various state agencies. It was determined that the following categories of landcover were needed: sand and spoil areas, salt and brackish marsh grasses, grass areas (golf courses and airstrips), different associations of upland vegetation, and different types of urban/impervious activities. The training samples, which numbered approximately 75, were then aggregated until we had five samples, which numbered approximately 75, were then aggregated until we had five samples for each category ranging from a minimum of 16 to 25 acres to a maximum of several hundred acres. The total amount of time for collecting these training samples was approximately two days.

During the three days at the ERL facility, the group received an intensive briefing on how the system operates, the types of equipment and the associated costs, a demonstration of the more scientific method of obtaining samples, and a presentation of the assorted case studies as they pertain to application by different disciplines. The latter proved to be quite beneficial, because we were able to relate to specific issues and see how the automatic classification system was used to assist in the decision-making process.

During the visit, the individual who collected the training samples was given instructions on how to operate the image display system so training samples could be identified from the aerial photographs and then located via the cursor on the Landsat unclassified display. The following day, the statistical information was ready for review and analysis. Each training sample was reviewed for any bi-modal characteristics while the divergence statistics were checked to determine if further training samples were needed and the probable categories which could be separable. Following a review of the statistics, the classifications were grouped and the data were classified using spectral pattern recognition programs. The actual printing of the unclassified display and the classified product to a scale of 1:250,000 (1' = app. 4 miles) was then

performed on the ERL data analysis system.

The classified final product was presented to Georgia personnel the next week and included the following categories: low density urban, high density urban, beach and spoil areas, grass areas, salt water marsh grass, brackish marsh grass, surface water, and upland vegetation.

The results of the ERL Landsat tape and the previous Georgia Tech effort were of sufficient interest to several program managers from the State of Georgia that a formal request for technology transfer assistance was submitted to NASA. NASA agreed to initiate a Research and Technology Operating Plan (RTOP) (now referred to as the Regional Application Program) consisting of two primary objectives.

Phase I: To determine the feasibility of using satellite-derived landcover information for management applications in Georgia, using NASA computers and programs, essentially cost-free to the state. Georgia would be responsible for supplying people, performing project coordination, and most importantly, relating the technology to ongoing management programs.

Phase II: Upon successful completion of Phase I, to transfer the NASA application technology and computer software to Georgia. The state would acquire the necessary processing capabilities and NASA would train Georgia personnel in the techniques of using Landsat data.

Prior to the initial execution of Phase I, an effort was launched within the Department of Natural Resources to survey existing programs and determine which of these programs might require data which Landsat could provide. Once these programs were identified through a formal project proposal process, a review procedure was established whereby Phase I projects would be evaluated for future program use on an operational basis. In Phase I several Landsat-derived products were produced, including the processing of two Landsat scenes each 100 nautical miles by 100 nautical miles, one for coastal Georgia and one for the northern portion of the state. Landcover categories were displayed on the products and determined to be of interest to several state, federal, and sub-state programs. The data were produced in formats specified

by the user ranging from geographically mapped products at various scales to statistical data by water quality management units (watersheds) and county boundaries. As the completion of Phase I approached, it became apparent that Landsat digital processing could provide relatively detailed and accurate data on a repetitive basis covering the entire state. Since many of our programs require statewide data and analysis over time, Landsat's type of coverage and data production becomes essential.

Concurrent with the Phase I demonstration effort, the necessary computer capabilities, including hardware for utilizing the Landsat data, were available at or being acquired by the Georgia Institute of Technology (Georgia Tech). These facilities are discussed in detail in Section IV. Due to the close proximity to the state office buildings and its expertise and equipment capabilities in the area of digital processing, Georgia Tech has assumed responsibility (within the context of the Georgia project) for keeping abreast with the latest techniques in digital processing while providing the interface between the equipment and the state's program criteria as supplied by the Department of Natural Resources.

III. STATEWIDE LANDSAT PROCESSING

In the process of entering into Phase II of the NASA/ERL transfer of technology project, it became obvious that several local, state, and federal agencies were already convinced as to the application of Landsat data to their particular problems. In fact, these agencies requested an effort to classify Landsat data over the entire state of Georgia. Much of the computer software for Landsat processing already existed at Georgia Tech, and several software packages were transferred from NASA/ERL to the Georgia Tech computers during Phase I and the early days of Phase II. Because of the extreme interest shown by the different agencies, an effort by the Georgia Department of Natural Resources was made to define the ground rules for participation in the project and a method for aggregating funds from the different agencies into a single fund that would finance the Landsat analysis. The total cost for the Landsat analysis itself was approximately \$80,000 or approximately \$1.35 per square mile. The results of the Landsat classifications were aggregated by county (159 counties) and by sub watershed (198 sub watersheds). Color images of each county and watershed were generated as well as color images for each separate scene.

Fourteen scenes are totally or partially contained in Georgia. Extensive ground truth and a supervised classification scheme were used in the classification of each scene. Normally fifty to sixty classes were developed from training field signatures and these were aggregated to fifteen classes for color display of the results.

The successful effort in Phase II is a good example of how state, federal, and sub-state regional agencies in Georgia are working together with a common data source for specific management applications. The Department of Natural Resources, EPD has been coordinating a statewide Landsat digital processing effort which was recently completed. The role of DNR in this project has been to establish a structure for joint participation in the effort, the development of product criteria vis-a-vis legislative requirements of the participating agencies, initiating a cost-sharing plan to insure affordable products with a minimum duplication of effort, development of a statewide landcover classification scheme, and to provide data for natural resource management programs as an extension of our technical assistance role.

The following are some of the federal, state, and local agencies which have been part of Phase II operations:

The Environmental Protection Division of the Department of Natural Resources -

1. Water Protection Branch: For Section 208 and 303e of PL 92-500, regarding non-point source pollution and water quality plans for river basins.
2. Land Protection Branch: For the Georgia Solid Waste Management Act, regarding location of potential sites for solid waste disposal.

Soil Conservation Service of the U. S. Department of Agriculture -

For the Conservation Needs Inventory, regarding the extent and areas of change in specific types of agriculture, the location of potential areas of gross erosion, and the resulting effects on water quality.

U.S. Army Corps of Engineers -

For Section 404 of PL 92-500 re-

garding dredge and fill permits, including location of wetlands and spoil areas.

Game and Fish Division of the Department of Natural Resources -

For a Wood Duck Habitat Study under the Pittman-Robertson Act.

These agencies expressed their genuine desire to use the Landsat data by furnishing substantial field support and cost-sharing in the products. The Department of Natural Resources' and Georgia Tech staff trained over 50 people from federal, state, and sub-state regional agencies in the techniques of "ground-truth" activities, which is the process of correlating the Landsat data to actual ground conditions.

It is expected that future uses by programs that are being identified emphasize interactive applications such as the land cover data used by SCS in their Conservation Needs Inventory and by the Environmental Protection Division in their continuing water quality planning process.

IV. SYSTEM DESIGN

Georgia Tech initially worked with the State of Georgia and NASA personnel in developing the design criteria for an earth resources analysis system. Underlying all the criteria was a need for a workable processing system at a modest cost. The specific criteria were:

1. System should be able to process Landsat data in a "reasonable" amount of time.
2. System should have a refreshed color display capability that would allow the compositing of three Landsat channels into a simulated color infrared image (for training field selection).
3. System should have at least black and white hardcopy capability.
4. System should have at least two tape drives.
5. System should be as compatible as possible with other minicomputer systems at Georgia Tech.

A study of existing total systems for earth resources processing was then undertaken. All of the systems investigated proved to be either too costly or insufficient in capability for our needs. Since Georgia Tech is constantly in the process of building one-of-a-kind computer systems for its clients, we decided to investigate the costs associated with the design and integration of an earth

resources processing system composed of commercially available components.

To provide compatibility with existing minicomputer hardware at Georgia Tech, the system design was based on a Data General 16 bit minicomputer with 32,000 words of core memory. Fortran IV was the standard language to be used. Once this decision had been made, a criteria was developed for the subsequent components to be compatible with Data General machines. In general, this constraint was not much of a problem. The medium for program, system, and some data storage was selected to be dual 2.5 megabyte cartridge disks. The philosophy in using this type of medium was that in processing a large number of different areas throughout Georgia, many signatures files would be created unique to a particular region. Having these on separate disks would avoid the confusion of trying to classify one Landsat scene with signatures from another scene. Two nine track tape drives were selected that would handle 10 1/2 inch reels of magnetic tape at a density of 800 or 1600 bits per inch.

A twenty inch printer/plotter was selected to provide the black and white hardcopy capability for the system. The resolution of the printer/plotter was 160 dots per inch. A line printer was not necessary for the system since the printer/plotter performed that function also.

The color display capability was met by the acquisition of a commercially available color video interactive display system. The system provided a 512 by 512 by 8 bits resolution image on a 25 inch professional color monitor. The color infrared capability was provided by a selectable mode whereby the system was converted into a three image 256 x 256 x 8 bits system with four graphics planes. In this system data from three of the four Landsat channels can be directly mapped into the red, blue and green color guns at 8 bit resolution. The system also included a user defined function memory by which each of the Landsat images could be independently scaled in a linear, piecewise linear, or nonlinear process. A pseudo color memory was also provided to allow the mapping of gray scales on either a 512 by 512 image or a 256 by 256 image in 64 colors which are user selectable from a palet of 4096 colors.

The total hardware cost of the earth resources system was approximately

\$80,000. Approximately \$10,000 was expended for systems integration manpower. The cost for the interactive color display and refresh memory was about one third of the total cost of the system. While this system was designed and procured in 1976, it is our feeling that a state government with university or other technical assistance could put a similar system together today for the same total cost. By sacrificing the quality of the color display hardware costs might be lowered by \$15,000 to \$20,000. A recent Georgia Tech study gives block diagram designs for systems ranging from \$30,000 to \$160,000 depending on the monetary constraints and required sophistication.

During the Phase II segment of the technology transfer program, the system was upgraded by adding floating point hardware and an optimizing Fortran compiler. The resultant system performs a maximum likelihood classification for 60 classes of a full scene of Landsat data in approximately thirty hours.

The basic Fortran modules available on this system include:

1. Maximum likelihood classification
2. Sequential clustering (Al Wylie ASTEP-NASA/JSC)
3. Training Field Selection
 - a. Color infrared image
 - b. Cursor training field selection
 - c. Histograms
 - d. 2 channel ellipse plots
 - e. Haze filtering (Pat Chavez USGS/Flagstaff)
 - f. MTF filtering (Pat Chavez USGS/Flagstaff)
 - g. Alarm (one class linear classifier)
 - h. Ground control point location (GCP)
4. Destriping (radiometric correction) (Ronnie Pierson NASA/ERL)
5. Polygon extraction (counties, watersheds)
6. GCP derived transformation matrix computation
7. Super G rectification of classified data (Marsalis Grahame NASA/ERL)
8. Full rectification of raw or classified data using bilinear or nearest neighbor resampling.
9. Joining mechanism for extracting polygons not contained in a single scene.
10. Change detection in Landsat data from two time periods
11. NIMGRID - Minicomputer extended version of Harvard IMGRID Geographic Data Base program. (David Sinton - Harvard Graduate School of Landscape

Architecture)

V. COMPUTERIZED DATA BASE ANALYSIS

In order to achieve maximum utilization of Landsat derived data, it is necessary to combine it with other data, such as soils, land use, topography and geology. To do this effectively and efficiently, all of the data must be compatible at equivalent scales and must be stored in a format that allows easy access and flexible manipulation. Given these requirements, it is reasonable to explore the use of current computer technology for these purposes.

Until recently, manipulation of natural resource data by computer has had fairly limited application for most resource management programs. Part of this problem has been in the geographic or "spatial" nature of most of these programs, and part of the problem has been the requirement for specialized training in computer languages in order to use the machines. In the past few years, however, improvements have been made in these areas, allowing for both mapped (geographic) computer output, and for direct access to the machine by resource program managers who have not had extensive training in computer programming. These improvements are generally in the form of a "packaged" set of computer programs that can be used on one or more types of computers, and operate through a simplified set of programming commands. The packaged systems that appear to have potential for use in Georgia are called IMGRID, CONGRID, and NIMGRID. IMGRID and CONGRID are designed for the large computer environment and are basically batch oriented programs. NIMGRID on the other hand is an extensive modification of IMGRID that is designed to operate with intensive user interaction on a minicomputer. Unlike the IMGRID and CONGRID systems, NIMGRID is designed to operate in a raster line by line mode and the data base size that can be analyzed at any one time is dependent only on disk size, not program array size. The NIMGRID program makes extensive use of computer overlay structure to minimize the size of the program in core.

Two projects have been completed using the above computer programs. As an internal project, the Georgia Department of Natural Resources gathered some 20 hand encoded variables including topography, slope, land use, flood plains, geology, soils, transportation, and historical and archaeological site loca-

tion. The data were gathered for the area based on an approximately 10 acre grid. The data were organized on a USGS quadrangle basis with cells defined as equal latitude and longitude increments. Two projects which utilized this data base and the modeling capabilities of the computer programs were the Solid Waste Management Program (allocation) and the Water Protection Branch (evaluation of non point source pollution problems). During the first project, land use and vegetation were hand encoded, but Georgia Tech was concurrently perfecting its geographic rectification capabilities so that Landsat data could be used as an element of the data base.

After seeing preliminary results of the internal project, the Savannah District of the U. S. Army Corps of Engineers asked the Georgia Department of Natural Resources and Georgia Tech to prepare a digital geographic data base surrounding one of the Corps of Engineers maintained reservoirs in the State of Georgia. A study area was defined and data were gathered on a four acre grid defined in latitude and longitude. Variables were gathered manually as those of the internal project, but in this case Landsat land-cover data were integrated into the data base.

During the course of both projects, extensive use was made of both the State of Georgia general purpose computers and the earth resources analysis system at Georgia Tech. The capabilities of color display, interactive editing of data, and interactive modeling were used to great advantage in both studies.

In addition to the above applications, polygon to grid and polygon overlay analysis techniques are being investigated as a means of efficiently integrating digitizer input into the data base.

VI. FUTURE PLANS

Areas in which the State of Georgia and Georgia Tech plan to concentrate on in the near future involve both Landsat data and geographic data base technology.

1. The legislature of the State of Georgia has allocated money toward the applications of Landsat and geographic data base techniques to agricultural problems in Georgia.
2. A study is emerging in which a surface water inventory will be accomplished statewide in support of the impounded water survey.
3. Further work will be done with the

3. Environmental Protection Branch in developing data base models for non point source pollution and locating potential soil erosion areas using Landsat data.
4. An extensive geographic data base for southwest Georgia will be developed for agricultural purposes.
5. Work will be done on automatic location of irrigated land in the agricultural regions of south Georgia.
6. Change detection algorithms will be further developed and applied in urban as well as rural settings.
7. Habitat studies will be emphasized as an application of Landsat data to biological problems. (Location of black indigo snake habitat in Georgia and Alabama.)
8. Interaction with other states on Landsat and data base related projects will be encouraged.
9. Further development of three dimensional modeling techniques for coal reserve calculations using drill hole data, DMA topicon data, and Landsat data.

N. L. Faust has been with the Georgia Tech Engineering Experiment Station since 1973. He is now a Senior Research Scientist in charge of Landsat Digital Analysis and Geographic Data bases. Before coming to EES, Mr. Faust worked for NASA/JSC as a physicist where he developed computer analysis techniques for spacecraft trajectory optimization and for the analysis of Multispectral Scanner Data. He received his BS in Physics from Georgia Tech in 1969 and a MS in Geophysics from Georgia Tech in 1975.

Lawrie Jordan has been an Assistant Research Scientist with Georgia Tech EES since 1977. Activities have included coordination of the state-wide Landsat classification project in Georgia, as well as developing data base analysis techniques. Previously, Mr. Jordan was a resource planner with the Georgia Department of Natural Resources. He received his Bachelor of Landscape Architecture degree with honors from the University of Georgia in 1973, and a Master of Landscape Architecture Degree in 1975 from the Harvard Graduate School of Design.

Senior Resource Planner with the Georgia Department of Natural Resources (NDR). He received his Bachelor of Landscape Architecture Degree from the University of Georgia in 1971 and a Master of Landscape Architecture degree from the Harvard Graduate School of Design in 1973. Activities at DNR include management of on-going data base projects for several areas in the State, remote sensing coordination for Landsat projects, training seminars for state program managers, and river basin planning for non-point source pollution programs.