Apr 1st, 8:00 AM

LANDSAT Applications in Georgia: A Successful Example of Technology Transfer between NASA and State Government

Bruce Q. Rado
Georgia Department of Natural Resources, Environmental Protection Division, Resource Assessment Program

Lawrie E. Jordan
Georgia Institute of Technology, Engineering Experiment Station

Follow this and additional works at: https://commons.erau.edu/space-congress-proceedings

EMBRY-RIDDLE
Aeronautical University™
SCHOLARLY COMMONS

LANDSAT APPLICATIONS IN GEORGIA:
A SUCCESSFUL EXAMPLE OF
TECHNOLOGY TRANSFER BETWEEN
NASA AND STATE GOVERNMENT

Bruce Q. Rado
Georgia Department of Natural Resources
Environmental Protection Division
Resource Assessment Program

Lawrie E. Jordan, III
Georgia Institute of Technology
Engineering Experiment Station

ABSTRACT

Over the past several years the State of Georgia has been using Landsat data to assist state and federal program managers in their decision-making efforts. The Georgia effort has been staffed by the Environmental Protection Division, Department of Natural Resources which has served to coordinate efforts between the Corps of Engineers, Soil Conservation Service, Georgia Forestry Commission, Department of Community Affairs, Game and Fish Division, and several local governments.

This paper will deal with the technical and administrative steps which have led to an operational Landsat effort in Georgia. These steps will include technology transfer from NASA to State agencies, the merging of technology with existing state programs, and the role of the Department of Natural Resources and the Georgia Institute of Technology.

REPORT

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.

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 several basic issues which should be addressed regarding future vegetation (landcover) mapping efforts. Several of these issues are listed below:

1) Is a 50-100+ acre minimum mapping unit sufficiently detailed to address the array of questions posed to a state natural resource agency?

2) Are the newest available aerial photographs, usually two to six years old, adequate as a data source or must a state incur the cost of flying aerial photographs?

3) How can a state effectively update manually-created maps without incurring the entire cost of the initial effort?

4) How can statistical information be efficiently derived by watershed and/or county boundaries from the manually-drawn maps?

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 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 tape (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 all of the island sand 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 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 group was able to identify all 75 pre-selected ground truth training samples. Also, additional training samples were selected from the Landsat 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 was 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. Phase I was completed with cooperation from ERL. Several Landsat-derived products were produced, including the processing of two Landsat scenes (see Figure 1), 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 was 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 (see Figure 2). 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.

The next several pages will evaluate the Phase I demonstration products by category as they relate to the specific project proposals. Topics to be covered in this evaluation include: descriptions of the products, the classification scheme, pros and cons of products generated, and multi-temporal considerations for future processing. Although the results presented for the Phase I demonstration effort represent a specific geographical area (Georgia) with unique management and data requirements, conclusions have been presented which should be of interest to states which are considering the use of Landsat digital data.

There are five graphic products as output of Phase I. They are:

1) 1:250,000 scale (approximately) of north Georgia scene (100 x 100 nautical miles) acquired 21 April, 1975.

2) 1" = 1 mile product of Environmental Protection Division Water Quality Management Units (WQMU) 1419, 1420, and 1421 (around Allatoona Lake).

3) 1" = 1 mile scale product of Hall County integrating manually collected land-use data in the urban area with satellite collected landcover data in the rural area.

4) 1:250,000 scale (approximately) of coastal Georgia scene (100 x 100 nautical miles) acquired 23 August, 1975.

5) 1" = 1 mile scale product of Environmental Protection Division WQMUs 0610, 0611 (Altamaha River sound).

The 1:250,000 products were produced on a color film recorder and printed on 30" x 40" print paper. The 1" = 1 mile products are electronic enlargements of specific sections of the 1:250,000 products that were output by a printer-plotter in black and white and then converted to color via the "chromalin" process and finally printed. The 1" = 1 mile products are "geo-referenced" and are at a specific scale. The tick-marks on the 1" = 1 mile products are 10,000 meters apart at· scale. The 1:250,000 products are geometrically corrected, that is, they are proportionally correct horizontally and vertically, and they approximate a 1:250,000 scale.

Tabular products include statistical summaries for each of the

1" = 1 mile products of percentages of each cover category, aggregated by Water Quality Management Unit (WQMU). Evaluations of the training samples (uniformity, standard deviations, and other factors) are included later in this evaluation.

Several of the project applications describe the process used to obtain these products. The process is briefly re-stated as follows:

1) Selection of several site-specific training samples, using high and low-altitude photography and other data sources, to geographically locate examples of each of the necessary landcover categories.

2) Entering the training samples into the computer system to determine the training samples' uniformity.

3) Selection of additional training samples if necessary to insure accuracy.

4) Run training samples through system, producing graphic and tabular output (aggregated by geographical areas such as a WQMU).

5) Distribute results for field-verification and accuracy.

6) Send results to applications groups to test for concurrency/approval.

7) Make iterative adjustments as needed by application groups.

8) Turn over final product to application groups (graphic and tabular).

In the course of the effort, it was found that a sufficient number of acceptable training samples had been collected, thus eliminating the need to perform step 3. An initial set of products showed that some further adjustments were necessary. This mostly concerned the statistics of certain categories as well as some refinement in the color scheme to improve legibility.

The aggregated classification schemes used for Phase I products are as follows:

Mountains

1. Water
2. Coniferous Forest
3. Deciduous Forest
4. Cultivated Areas
5. Pasture, Other Grasses
6. Exposed Soil
7. Rock Outcrops, Quarries
8. High Density Urban
9. Low Density Urban
10. Shadowed Areas, Uncategorized

Coast

1. Water
2. Spartina
3. Juncus
4. Mixed Brackish and Fresh Marsh, Shrubs
5. Beach, Spoil, and Sand Bars
6. Sparsely Vegetated or Barren Land
7. Bottomland Hardwood Forest
8. Oak-Dominated Forest
9. Pine Forest
10. Corn
11. Other Crops
12. Pasture, Other Grasses
13. High Density Urban
14. Low Denisty Urban
15. Clouds, Cloud Shadows, Uncategorized

Discussion of the classification schemes used for Phase I products should focus on three major considerations involved when the desired categories for display were chosen:

1) Given one set (scene) of satellite tapes each for the mountains and coastal areas, what would be the most effective aggregation of categories identified in the project applications against the issues identified?

2) What would be the optimum categories to display given a graphic (color) limitation of approximately 15 colors?

3) What were the multi-temporal effects involved with training samples collected in July for satellite tapes dated April and August versus the classification scheme?

The aggregation of various training sample classes (i.e. slash pine, loblolly pine, and longleaf pine) into one category (coniferous forest) involved the statistical evaluation of each training sample for uniformity first within itself, that is, was it homogeneous or "pure" as a sample, and second, how similar it was to the other classes. If samples were statistically very similar, their "signatures" could not be separated and therefore they were aggregated and printed out as one category.

The aggregations chosen were primarily a function of statistical evaluations. In terms of color scheme considerations, the actual number of colors displayed (e.g. 15 for the coast) is somewhat excessive for graphic clarity. Although the detail is included on a 1.1 acre basis, one cannot easily see the spatial distribution of 15 different colors, each a small area, on a map. An optimum number would probably be closer to 10 classes, depending on the nature of the features displayed. An alternative approach would be to print out thematic maps, that is, to retain the same categories but print aggregations of them on more than one map. For example, the 15 level map of the coast could be

reprinted as three maps with 5 categories (colors) on each map. These maps could be output as color transparencies so that when overlaid, the composite would be identical to the original 15 level map. Another alternative is to keep the same number of classes (15) or even increase the number to illustrate all signatures which could be separated, but to select a smaller geographic area. Put another way, for the total scene (100 nm x 100 nm) there may be 15 or greater distinct classes, but a given sub-area of the scene such as a county or WQMU may only have 7 or 8 classes. Separate maps could be produced showing the respective classes for each sub-area of the scene.

The specific management applications would obviously be a major factor in choosing the final graphic format. This is a flexibility associated with Phase II which was necessarily compromised in Phase I to be one product for several applications.

The multi-temporal effects in terms of time of satellite passover vs. time of sample collection was a factor in the final output, though it did not present a major problem. The group of personnel involved was fortunate to have several knowledgeable field investigators who were aware of both existing and previous landcover conditions. This information was carefully recorded on the respective ground-truth forms and proved very valuable. However, the multi-temporal effect in terms of the time of year (April and August tapes) versus several of the cover categories desired did have a greater impact on the output results, and this is discussed in following sections of this report in greater detail.

For a cursory evaluation, the Environmental Protection Division of the Department of Natural Resources determined a preliminary list of landcover classifications of interest to the Non-Point Source Pollution Program as follows:

1) High-density urban (high percentage impervious cover)

2) Low-density urban (low percentage impervious cover)

3) Bare ground — exposed soil, exposed rock, spoil, sand (beach or spoil)

4) Agriculture production lands — row crops

5) Pasture or grasslands

6) Forested areas (entire) — deciduous, coniferous, mixed (natural)

7) Production forests (current) ("planted")

8) Salt-water marshes (spartina and juncus groups) freshwater marshes, sloughs, river swamps (cypress gum and bottomland hardwoods)

9) Surface water — ponds, lakes, and rivers

10) Unclassified (none of the above)

The desired product furnished for this work program is a graphic and tabular output of the landcover classifications listed above. The spatial (graphic) data is aggregated into representative WQMUs, with tabular (statistical) data for

each WQMU, giving the number of acres and percentage of each cover type found in a WQMU.

Several factors influence the relative accuracy of the results obtained to date. The following is a discussion by cover-category of results as they were evaluated by field investigation.

1. High density urban (HDU) and
2. Low density urban (LDU):

   In the coastal scene, most high density urban (high impervious cover) areas were properly located, even though the primary months for locating urban land use are December through early March (leaf-down situations). The definition of low density urban was such that reflectance qualities were similar to sand-spoil areas, causing some confusion. This is apparently because most LDU areas have unpaved streets (sand or shells) and little vegetation cover. High density areas have a better recognition rate because of the more unique reflectance of concentrated areas.

3. Bare ground:

   The cover classifications produced for this category were:

   Mountain Scene

   A. Exposed soil
   B. Rock outcrops, quarries

   Coast Scene

   A. Beach, spoil, sand bars
   B. Sparsely vegetated or barren land

   In the coast scene, large areas of spoil and beach areas were identified correctly. However, the particular tape used (23 August, 1975) happened to be near high-tide, thus showing all beaches or sand bars for which training samples were collected. The best solution to this in the future would be to pick a tape at low-tide. Sparsely vegetated or barren land may not be adequately separated from beach, spoil, and sand bars in areas where the two categories exist in close proximity. In this mountain scene, large rock outcrops (e.g. Stone Mountain) and active quarries appear reasonably well-defined. Some of the sanitary landfill sites also appear to be coming out as cultivated which is probably a function of landfills being turned over frequently with bulldozers. This situation could more likely be remedied by more tightly defining the term "cultivated".

4. Agriculture production lands — row crops:

The tapes used were 21 April (mountain scene) and 23 August (coastal scene). As has been mentioned earlier, a compromise situation developed for using one or two tapes (and therefore dates) against several applications, which under optimum conditions would have required several different times of year. Field investigators have identified late June as being best for determining tobacco, corn, and millet in the coastal scene, and July in the mountain scene for most agriculture. In the coast, optimum times for pasture are July-August and for Peanuts and Soybeans, mid-August is the optimum time.

In the coast, Glynn and McIntosh County figures for corn are closely related to the Soil Conservation Service figures. In the pasture category, some tobacco fields (harvested with weeds and grass present) and recently planted pine areas are being picked up as pasture. This relates back to what was on the ground in 1975 vs. samples collected in 1976, plus time of year consideration. In the mountains (April) there were some similar problems with multi-temporal considerations. Hall County appears to have some acreage which is cultivated showing up as pasture/grass. Better correlation between crop calendars and satellite pass-over should greatly increase the accuracy of results in these categories.

5. Pasture or Grasslands:

   There were favorable results in determining the category pasture/other grasses in the mountains. As previously stated, the pasture category on the coast had some other elements mixed in which could be better differentiated using correlations with crop calendars.

6. Forested areas and
7. Production forests:

   Categories used were:

   Mountains

   1. Coniferous forest
   2. Deciduous forest

   Coast

   1. Bottomland hardwood forest
   2. Oak dominated forest
   3. Pine forest

Relatively high accuracy levels were obtained in the mountains for the coniferous and deciduous forest categories, even though the optimum time of year was identified as mid-winter to differentiate between

coniferous and deciduous forest. Some interest was expressed in showing a category for mixed forest. Software routines will be available shortly from ERL to delimit mixed forest categories.

Results of forested categories on the coastal tape were certainly acceptable but less favorable than the mountain scene due primarily to the August date. Flying a small plane over the area processed showed that in August, even at altitudes of a few thousand feet (versus 500 mile altitude of satellite) it was difficult to distinguish pines from hardwoods. Statistical evaluations of samples used for "production forest" (planted pine stands) indicated that silvicultural areas could be separated, however, a graphic constraint of 15 colors had been reached and therefore planted and natural pine stands were grouped together. For more accurate results a winter tape (when water conditions are high, deciduous trees are leaf-down and wooded swamps would be more visible) would be desirable.

8. Marsh categories:

Marsh classifications used in the coast were:

+ Spartina marsh
+ Juncus marsh
+ Mixed brackish and fresh marsh, shrubs.

There were no classifications in the mountains for freshwater wetlands.

Relatively high accuracies were obtained for the spartina category, and approximately the same for juncus, mixed brackish, and freshwater shrubs. It is anticipated that juncus may be more accurate since the color on the graph display is difficult to distinguish from spartina. The mixed brackish, etc. class may need some revision, possibly having too many categories combined.

9. Surface Water:

Excellent results were achieved for the surface water (impoundment) classification.

10. Uncategorized:

Cover categories not falling within the definitions of the above groupings were printed out as uncategorized ("unclassified"). In the mountain scene, the major areas in this class are parts of Allatoona Lake (adjacent to and fed by streams crossing areas under construction of I-75) and parts of Lake Lanier. Cursory field checks indicate siltation from erosion as probable cause. In the coastal scene, areas of vegetation die-back (dead trees covered with

spanish moss) and holding ponds for pulp mills are appearing as uncategorized. This was anticipated since training samples were not performed for these categories.

As was noted in the previous evaluation section, a major consideration involved in processing satellite data is tape selection for the time of year which yields the greatest contrast among the classes which are of interest. Since spectral reflectances of cover categories such as crops, deciduous vegetation, marsh types, etc. change throughout the year, it is important to know when the optimum times are for determining spectral signatures that will separate the respective categories. It was an obvious compromise in the Phase I products illustrated to attempt to show nearly all categories for each application using only one time of year (April or August). As such, certain categories were separable and others were not. However, some categories such as coniferous/deciduous were shown as being reasonably separable in April (mountains) and were not well separated in August (coast), implying that given other times of year, further categories using a combination of times of year could be differentiated with greater accuracies. The flexibility in Phase II to perform such operations should greatly enhance the ability to fulfill specific user needs. The following list, prepared by project field investigators for the various applications, identified the optimum time of year for identifying certain cover categories desired:

Mountains

1. Game and Fish Division
   Wetlands, distinct forest types, watershed drainages—winter (December, January, Marsh)

2. Soil Conservation Service —
   Agriculture — July (need four seasons)

3. Area Planning and Development Commissions —
   Forest separation — winter

Coast

1. Game and Fish Division —
   Salt marsh, brackish marsh, cypress gum — bottomland hardwood — late February or early March

2. Soil Conservation Service —
   Cropland — tobacco, corn, millet — late June; peanuts, soybeans — mid-August; pasture — July or August

3. Coastal Area Planning and Development Commission —
   Urban high and low density — late December through early March

4. Marshlands Protection —

Tidal wetlands — late summer

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). Due to the close proximity to the State office buildings and its expertise 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.

The current 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 (DNR) 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 (see Figure 3), 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 are a 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. The computer-compatible Landsat data allows us to summarize the acreage of various landcover conditions within a watershed that may be related to agricultural, silvicultural, construction, or mining elements of potential non-point source pollution. From this summary and supplemental information, we can develop a comparative ranking of the potential of watersheds within the state to emit non-point source pollution, followed by formulation of best management practices to mitigate the effects of non-point source pollution.

2. Land Protection Branch: For the Georgia Solid Waste Management Act, regarding location of potential sites for solid waste disposal. We can use the Landsat data in conjunction with other information (e.g. soils and hydrology) to determine areas which may be suitable for landfill sites in advance of sending personnel into the field to investigate. Some of the conditions that the Landsat can detect are related to criteria on distance from surface water, wetland conditions, and existing development.

Soil Conservation Service (SCS) 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. Specific land cover conditions which are derived from Landsat include location of pasture, bare ground, and crops. The Landsat information allows land cover trend identification, which should facilitate more effective allocation of field personnel. Also, the vegetation cover and water relationships (e.g. wetland conditions) identified by Landsat are useful for environmental assessment in water resources projects.

U.S. Army Corps of Engineers —

For Section 404 of PL 92-500 regarding dredge and fill permits, including location of wetlands and spoil areas. In order for the Corps of Engineers to effectively implement program, they first need to be aware of where the wetlands exist. Landsat data provides this information. Also, the repetitive nature of Landsat allows monitoring of changing conditions over time.

Game and Fish Division of the Department of Natural Resources —

For a Wood Duck Habitat Study under the Pittman-Robertson Act. Landsat is well-suited for determining different types of vegetation. This is valuable information for our wildlife biologists in studying habitat areas.

These agencies have 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' staff has trained over 50 people from federal, state, and sub-state regional agencies in the techniques of "ground-truth" activities, which is the process of validating the Landsat data to actual ground conditions.

The challenge to the existing program during Phase II is to provide a quality of information and support that warrants continuing use of Landsat data. It is expected that future uses by programs that are being identified emphasize iterative 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.