Appendix B

The Use of Landsat Data in State Information Systems

Computers have revolutionized the way States manage statistical, demographic, and natural resource data. Because they are acquired in digital form, data from the Landsat system have been particularly appropriate for inclusion in broad-based information s,stems. Early research efforts were directed primarily to producing land cover maps from Landsat digital data. These land cover maps were generally used as the single source for resource management analysis.

Geographic Information Systems in State Government

The Landsat system has the promise of providing up-to-date, low-priced, land cover data. In the **IWO'S,** many States and universities, with assistance from the National Aeronautics and Space Administration **(NASA), began to purchase specialized hardware that could support NASA's software for Landsat data proc**essing.

With the publishing of Ian McHarg's book *Design With Nature,* [1] State and local governments began applying multiple data sources and multiple disciplinary approaches to resource analysis. McHarg advocated the use of hand-drawn overlays depicting a particular element (as defined by a particular specialist) affecting the suitability of area for a particular use. This overlay system, McHarg recognized, would eventually be computer-assisted. Shortly after, Carl Steinitz and his associates (Harvard Graduate School of Design) began to develop an automated "geographic information system" (GIS) to manipulate data geographically referenced to a position on the Earth's surface. Steinitz and his associates developed the first widely accepted geographic information systems software —IMGRID. Data elements used in IMGRID software are the data equivalent of the picture element of Landsat data (pixel): * attributes could be assigned to grid positions (X, Y coordinates) or cells, with each cell representing specific areas of the surface. Because both Landsat processing systems and IMGRID use computerized digital storage and manipulation techniques, it is possible to link the two systems by computer to perform rapid analysis.

In particular, it is possible to present to the user multiple solutions to a resource management question based on values specified by the user. GIS technology blossomed in the late 1970's; these GIS software packages were made available to the States at little or no cost .

Several small companies started up which used the same technology, but modified the software to suit particular markets—primarily energy development. A few private firms added Landsat data-processing software to their systems, but most relied on users to obtain their own Landsat data. The applicability of Landsat data to resource management is now clear: many States accepted the startup expense associated with processing Landsat data because they were to obtain final products that could assist in managing their limited resources.

Currently, about 19 States have developed geographic information systems (table B-l). Not all of these systems have direct Landsat data-processing capability, but most do utilize Landsat data in some form. These geographic information systems are, for the most part, less than 3 years old; they were developed in response to pressures for increased efficiency and the recognized need to develop an information network among State agencies. Texas and Minnesota have systems which have been in existence for more than 10 years.

State agencies have approached the development of State systems in two ways. The first, and less successful, scheme has been to spend millions of dollars on hardware, software, and staff. The aim was to establish a very large, technically sophisticated system to serve all users for digital data, satellite data proc-

Table B-1 .—State Landsat Data Users With Geographic Information Systems

Alabama	**Montana**
Alaska	**Nebraska**
Arizona	**New** Jersey
Florida	North Carolina
Iowa	New Mexico
Kentucky	Ohio
Louisiana	South Carolina
Maryland	Texas
Minnesota	Virginia
Mississippi	

SOURCE This listing is not comprehensive and does not Include reference to the several universities which support State systems

[1] Ian McHarg, *Design With Nature* (Garden City, N.Y Natural History Press, 1969)

* Each pixel covers an area on the ground of about 1.2 acres

essing, resource management, and analysis. Because they are costly and unwieldly, these systems produced both users and strong opponents within State governments; about half have fallen into disuse and currently are not operational or are severely underutilized.

The second approach has been one of a very measured growth, with systems acquisition and staff development based totally on user demand for projects which could utilize Landsat and GIS technologies. The systems that have evolved from the second approach, while smaller and much less sophisticated, are the most stable and are beginning to grow larger as demand for them increases.

Landsat Data and the Decisionmaking Process in Mississippi

The Mississippi Automated Resource Information System (MARIS) was created by Executive Order 459, signed by Gov. William F. Winter in May 1983. Mississippi had joined with other States in developing a broadly based system for acquiring, storing, analyzing, and disseminating cultural and natural resource data.

Much earlier, in 1970, a group of 10 State agencies had met with NASA officials from the Earth Resources Laboratory located at Bay St. Louis, Miss., to obtain NASA's help in developing statewide land-use maps based on aerial photography. Participants at that meeting agreed that the State would provide interpretation of aerial photography, and that NASA would provide the aircraft from which the aerial photography would be obtained.

NASA supplied 1:120,000 color infrared photos which the Mississippi Research and Development Center enlarged to 1:24,000 and printed in black and white. U.S. Geological Survey quadrangle sheets were used as geographic reference control. These photos were manually interpreted by the R&D center and participating agencies' staff using the Anderson Classification System employing 51 categories of land use. The training and quality control were provided by the R&D center and a Lockheed consultant.

The project produced 1,440 manually interpreted photos (one per township). These became the statewide land-use base map. The mapping project, which was not completed until 1975, ultimately required a combined effort of the 10 sub-State planning and development districts, the University of Southern Mississippi, NASA, and the Mississippi Research and Development Center.

This photographic data base was completed during the peak of the U.S. Department of Housing and Urban Development's (HUD) 701 Planning Program, a program that required each of the State's 10 sub-State planning districts to produce future county land-use maps for their multi-county areas. To assist those districts in developing future land-use plans, HUD suggested that each sub-State planning and development district, using the State mapping project's aerial photography as a base, prepare overlays depicting selected factors that would affect future land-use development. The overlays included 100-year flood plains, prime agricultural lands, dilapidated housing, water and sewer districts, areas of ecological concern, and noise hazards.

The actual use of these hand-drawn overlays met with marginal success. At that same time, the traditional approaches to land-use planning were coming under heavy attack because of the top-down planning philosophy encouraged by the HUD programs. The HUD 701 program had failed to educate decisionmakers in dealing with problems associated with managing the growth they began to face in the late 1960's and early 1970's. When Federal funding of planning activities faded, it appeared that in Mississippi land-use planning would cease to exist. However, the problems associated with growth continued to mount, and the need for land-use planning or, as it began to be called, "resource management, " became obvious even to the most skeptical. If State or local officials were going to make resource allocation decisions, they needed understandable and accurate information on which to base those decisions.

Major advances in the acquisition and manipulation of land-use related information were made during the early **1970's,** Landsat 1 introduced a new and exciting data source. Computerized data management systems, geographic information systems, and Landsat satellite digital data all became readily available to planners and resource managers. The problem no longer was the acquisition and manipulation of data, but how to introduce the user to the land-use management process. The problem now was to generate **a** "defensible process" for regional planning or resource management.2

At this stage, recognizing the advances in data acquisition and management, many States invested hundreds of thousands and even millions of dollars in sophisticated computer equipment which gave them the capability to process these new digital data. Mississippi, however, did not have the capital available to purchase one of these sophisticated data management systems, and, therefore, had simply to observe the progress of other States. Many of these sys-

'Carl Steinitz, *Defensible Processes for Regional Landscape Design* Harvard Graduate School of Design Latis vol 1, No. 1, Washington D C , 1979

terns proved to be as much of a disaster as the old HUD 701 Land Use Planning Program. It appeared that the potential users would not accept and could not deal with sophisticated methods for managing data exhibited in these systems. A few systems failed and were closed down completely, and others were underutilized. The ingredient lacking in most States whose systems had fallen into misuse was a strong user community properly educated in the use and application of these new technologies,

To develop a geographically referenced information system for Mississippi, the system had to be cheap, and it had to produce products that were immediately usable by State agencies in fulfilling their mandated responsibility. In the tradition of Mississippi government, the organization would have to be voluntary. Membership would be only those agencies which could be convinced that they directly benefited from membership. Because legislators of the State of Mississippi sit on the boards of all major State agencies, the legislators must be convinced directly that new systems are beneficial. Representative Wes McIngvale, of Batesville, Miss., was the original advocate of automated systems technologies and information-sharing networks in Mississippi. He wished to see the State central data-processing computer network heavily used by State agencies.

The first organizational meeting involved only directors representing the four agencies that would most obviously benefit from a new information network. * These agencies also had been exposed to satellite and geographic information systems through past projects. The Mississippi Department of Energy and Transportation agreed to provide staff support and to house any specialized hardware. This group, with assistance from the R&D center staff, prepared a "policy structure" for the system. The term "policy structure" was painstakingly selected to describe an organization which assisted in policy decisions, but did not make policy decisions. A primary mandate was that this organization would not become a new agency or level of bureaucracy. Its purpose would be to reduce the cost of agency operations and assist all members in their legislated functions. It would also serve to educate and inform member agencies about automation. Users of the system would have the ability to play "what if" games based on the iterative capabilities of the computer system and multiple data sources. Two new technologies were to be introduced by the Mississippi Automated Resource Information System (MARIS)—geographic information systems and Landsat satellite data.

*Mississippi Department of Natural Resources, Mississippi Department of Energy and Transportation, Mississippi Research and Development Center, and Mississippi Department of Economic Development.

Using these criteria, a consortium of 19 State agencies was formed. It is directed by a policy committee made up of the agency directors from each of the 19. The MARIS central staff oversees the operation of the specialized computer system which serves MARIS member agencies. This computer is a stand-alone system with software that allows for interpretation of multispectral scanning (MSS) and thematic mapper (TM) satellite data. The software also includes a geographic information system.

MSS and TM data provide a quick and reliable source of historic and current land cover data. When properly geographically referenced, these data can be compared with other data concerning topography, flood hazards, or census. This ability to combine data and compare and analyze their interactions is of great value.

Two major functional divisions make up the MARIS organizations: the MARIS catalog and the MARIS analytical effort. The MARIS catalog is an interactive computerized catalog of natural resource and cultural data. The catalog allows a user with the proper I.D. to query the State central data-processing records and ascertain the locations of reports and data stored in each member agency's files. The catalog can be searched by agency, publication title, or key word. Presently only a description of the document stored within each member agency files is available. However, more detailed information and actual data from the documents will be added next. MARIS can also be called on to aid in analyzing the data available.

User satisfaction is the key to the MARIS operation. MARIS is not funded directly in the State's budget. It depends on voluntary participation and support from its member agencies. If MARIS loses the support of its users, MARIS loses its funding. By supplying user agencies with **data needs, MARIS has begun to build an impressive data base for Mississippi.** The original aerial photography and overlays mentioned earlier have now been digitized and added to the State's geographic information system. New elements include the State's transportation network as classified by the Highway Department's standard classifications, major and minor watersheds as defined by the Soil Conservation Service, Federal and State park lands and preserved areas, water and sewer districts, 412 soil types, major population centers, and various interpretive maps based on these elements. Statewide models of preservation, conservation, and development suitability have been developed. Each model depicts the areas least suitable and most suitable for a specified use. The maps are not future land-use plans. They are presentations of levels of suitability for a particular use, and will serve as a policy tool for those agencies

in State government that deal in development of the State's resourccs.

The Mississippi Automated Resource Information System is unique among Southern States. It uses a state-of-the-art computer system and an active political systern which provides support and guidance. The future of the system will depend on its ability to pro-f duce products usable to the consortium members. Cost, the aspect of MARIS most vulnerable to transfer of the Landsat system, is a major concern to member agencies. The MARIS central staff and the specialized computer system which they manage represent a major investment by the State Miississippi,

Projects in Mississippi Using Landsat Data

Nuclear Waste Storage Disposal Studies

A ste in Perry County, Miss., has been selected as one of the prime sites for potential development of a nuclear waste storage disposal site. The unique salt dome geology of the area possesses many attributes which appear desirable for such a facility. Mississippi has acquired Landsat data of the area surrounding the potential site and will classify these data to produce land cover maps of the area. Landsat data were found to be suitable in this study because the study area was predominantly rural in character, and high-qua lit}' I.andsat data were readily available. The land cover maps will be merged with other elements stored in the state's geographic information system to assess the impact of the development of the facility and to assist in developing a management plan for the area. Other peripheral studies will include transportation access studies concentrating on nuclear waste transportation safety .

Delta Ground Water Studies

Although the Mississippi Delta has traditionally been the land of cotton, two new crops rice and catfish –-have made substantial gains in recent years. Rice area has increased to over 300,000 acres, and catfish farming is currently estimated to consume 60,000 acres of delta and. Because these new industries are heavy water users, ground water depletion is now a problem in the delta, The Mississippi Department of Natural Resource\ and several Federal agencies were asked to investigate ground water use and to assess future alternatives to manage the water resources of this most critical area.

With the assistance of NASA's Earth Resources Laboratory and a private consultant, Mississippi acquired and classified four 1981 scenes (two dates --]uly and September) of Landsat data of the Mississippi Delta. The product was a map of rice and catfish operations. These data were then merged into the State geographic informnation system. The spatial allocation of these operations affects ground water quantity availablc for irrigation. The allocation is also dependent on soil characteristics; clay soils make better field and pond bottoms than do more porous soils. The occurrcnce of existing rice and catfish operations can be expected to be consistent with the' occurrence of clay soils and depletion of ground water.

An analysis is now being prepared which matches future rice and catfish operations to suitable soils in order to determine existing ground water availability. These data will be combined to produce spatial models of the area's agricultural and aquacultural potentials and their effects on ground water availability. Without Landsat satellite data, this study would have been more expensive* and could not have been based on multitemporal coverage of the entire delta region.

Statewide Land Cover Update

The State has acquired Landsat satellite data coverage for the entire State, which will be used to produce a statewide land cover element in the existing geographic information system. This will be the first statewide land cover classification since 1 1975, when aerial photography was used.

Land cover information acquired from the Landsat satel lite has many advantages over traditionallly acquired data when merged with at statewide geographic information system. They are consistent in format and resolution, are digital, and are therefore machine-processable; the same classification methodologies can be applied to all elements of the complete data set.

The level of detail acquired from Landsat data cannot match that of aerial photography. Therefore, the Landsat data will be grouped into approximately 12 to 15 classes instead of the **51** classes used in the photographic survey. However, the cost of the **1975** photo project was approximately $450,000. The cost of the Landsat project will be less than $75,000, which will be allocated over several projects, The 1983 cost of repeating the original photographic project would be over Si million

*A cost comparison of Landsat data versus aerial photography was prepared as a first step in the data source selection. Although exact figures are no longer available, photography and the required manual photo interpretation would have added between $40,000 and $50,000 to this $42,000 project.

The Pacific Northwest Project: A Regional Resource Inventory Demonstration

In 1975, the Pacific Northwest Regional Commission, with support from NASA and the U.S. Geological Survey, initiated the Land Resources Inventory project for the application of Landsat data to resource problems on a regional basis. The project helped introduce new land-monitoring techniques and was a major Commission activity until its termination in 1980.

The primary objective of the Pacific Northwest project was to provide to a wide variety of natural resource planning and management agencies in Idaho, Oregon, and Washington, an opportunity to extract, apply, and evaluate information derived from Landsat multispectral data and other collateral sources. The results of the project were assessed by the users according to demonstrated utility and cost; these results formed an input to future monitoring and planning.

The use of Landsat data for public purposes is most effective when user needs in a given region are aggregated and the data can be applied to solving a variety of problems. The Pacific Northwest depends on its forests and irrigated crop lands as well as expanding urban areas around Puget Sound and inland; collectively, these present a range of informational mapping and monitoring needs. The project focused on the contribution to be made by satellite multispectral data modeled to the peculiarities of the region's vegetation, soils, and terrain.

The Pacific Northwest encompasses two major and contrasting ecoregions. Each is typified by a combination of climate, soils, and topography radically different from the other. They are sharply separated by the crest of the Cascades. The western or coastal portion of Washington and Oregon is classified as the Humid Temperate Domain. It contains the Pacific Forest and the Columbia Forest provinces. To the east and south lies the Dry Domain, an area of net water deficiency. This section is further subdivided into the Palouse Grassland, the Intermountain Sagebrush, and the Rocky Mountain Forest provinces.

The areas covered are extensive; for example, the Palouse Grassland covers 12,400 square miles and is an important wheat producer. The Willamette-Puget Forest covers 13,000 square miles and is a major supplier of forest products.

Under the aegis of the Pacific Northwest Commission, some 50 State agencies studied the economics of using Landsat data in a variety of applications. They undertook projects covering the major concerns over forest inventory, wildlife habitat, land cover, irrigated land inventory, urban areas, toxic weed occurrence, rangeland resources, reservoir volume, and surface mining.

A report prepared by the Commission lists examples of significant results attained on a State-by-State basis.

Idaho

- **Idaho Department of Water Resources. —Surveys of 36 million acres of agricultural land were accomplished at a cost of $41,646, compared with a cost of $65,800 by conventional means.**
- In a 4-million-acre area along the Snake River, yearly increases in irrigated land were recorded and crop types identified. A multistage statistical analysis incorporating Landsat data was developed and integrated into the activities of the Idaho Department of Natural Resources.

Oregon

- Oregon Fish and Wildlife reported a cost savings of 43 percent using Landsat for habitat inventory.
- **Oregon Water Resources Department.—By** interstate compact, the extent of irrigated farmland along the Klamath River Basin is reported. The department developed a system depending in part on Landsat data for monitoring irrigation.
- **Oregon Department of Agriculture.** —Landsat digital data were used to identify areas of a noxious weed, the Tansey Ragwort. Infestations of the weed cause $3 million to $8 million a year in direct losses of livestock.
- **The Department of Transportation,** along with other agencies, used Landsat data to determine the type and percentage of land cover. They produced statistical summaries as an aid to zoning and pollution control. The department adopted the method for continuing use.

Washington

- **Washington Department of Natural Resources.—** An estimated cost saving of 48 percent was achieved in a forest inventory covering over 13 million acres.
- A timber volume inventory was conducted in western Washington involving analysis of data from 20 million acres. The resulting information was used in State productivity studies and the technique was adopted and expanded by the Washington Department of Natural Resources.
- Central Puget Sound, a multiagency organization, incorporated Landsat data into urban planning in an 8,000-square-mile area. It used the results in transportation planning and water and air quality

studies. A new computerized data base was prepared and put into use by the city of Tacoma.

Governor Straub of Oregon, State cochairman of the three-state project, concluded in a letter to the Administrator of NASA that Landsat has provided a new, more effective and less costly source of management data. He emphasized that the involvement of a "critical mass" of individual agency participants is prerequisite to proving the overall value of Landsat data on a State regional basis. He further stated that "the acquisition of equipment and changeover to a new data base can bean expensive proposition" and that "the most critical element is continuity of data. Without assurance of continuity, States cannot accept the risks of utilizing Landsat data as a primary too] ."[3]

In a letter to the Chairman, Office of Science and Technology Policy (OSTP) of the White House, the chairman of the Pacific Northwest project's Technology Transfer Task Force commented on remote-sensing capabilities demonstrated in the Pacific Northwest. He said that much of the information derived is being used for remote areas where data were previously unavailable. The letter noted the uniqueness of the Landsat system to provide frequent coverage which " . . . establishes a historical record of the changes and transit ions." He pointed out that from fiscal year 1975 through fiscal year 1979, roughly $6.5 million was committed by participating agencies— Federal, State, and local. As a result of the success of the initial 3-year demonstration, a follow-on Landsat applications pro--gram was approved which provided for- a larger share of funding by local participants. The States began the purchase of software as well as arranging access to major hardware systems for the exploitation of the data on a continuing basis.

Following several years of experience with remote-sensing systems, the Commission stated, "It is our strong belief that the Federal Governrment should continue to be responsible for Landsat research and development as well as Land sat data at the Federal level. The burden of analysis belongs at the State and local level with the agencies and communities that will apply the data in their planning and management decision-making process. "[4]

In the course of about 5 years, project leaders made a number of management decisions. Partly in view of the unknown or unresolved future of the Landsat series, the States determined that rather than set up a single regional data center, each would be responsible for its *own* data handling and processing schemes. Considerable Landsat data are now stored in various computer banks in the region. However, the abolition of the Commission in 1980 removed a key coordinating body. Although many of the original participants continue to exchange data and to interact with one another through professional meetings and on a collegial basis, an essential part of the cooperative program now is absent. Nevertheless, as a direct result of the demonstration project, the States involved have acquired the improved capability to perform digital analysis and manipulation of Landsat and other georeferenced data on State computers. This operational capability, to greater or lesser degree, continues to be employed as funds and availability of data permit.

[3] letter from (Governor Straub of Oregon State cochairman of the three State project, to NASA Administration 1979

[4] letter from W allac t H edrick to OS T 1' May 5 1 978

Effects of Private Ownership on Use of Landsat Data

At a conference on natural resource inventory methods held in Corvallis, Oreg., in August 1983, three of the leading participants in the Pacific Northwest project were asked to react to the proposed transfer of Landsat to private ownership. They expressed the following concerns:

- Cost. —The profit incentive may raise costs to levels unacceptable to State managers.
- **Data Continuity.–** If the I.andsat program should not prove sufficiently profitable, it might become only seasonally active or be abandoned altogether.
- **Uncertainy.** —The private sector is not accountable to the users in the sense that public agencies are; therefore, there could be a relaxation of qualit y control and service.
- **Monopoly. -** Private sector monopoly could mean less incentive to improve service and keep costs down.
- **Prioritization.** —Data availability may become restricted and preference shown to those parties who can afford to pay the highest prices to receive data or to reserve time of limited transmission and /or processing capabilities.
- **Data Archive. –A** private sector operator may choose only to collect, process, and store those data that have been requested and paid for. Therefore, data of less productive, remote areas may go uncovered and historic data for many regions may become unavailable or nonretrievable.
- Support Photography,—The private sector operator would not be motivated to provide ancillary support to Landsat projects by such things as U-2 underflights and ground checking.
- **Data Processing.** —The private sector might not choose to put in the time and dollars necessary for cleaning up and processing the data as is cur-

rently done. Alternatively, the operator might not do it as well or might charge extra.

- **Data Inquiry.** —The present free search and inquiry service, considered a public service, might become unavailable or available only at a price.
- **Data Restriction.** —The distribution of data may no longer be on a nondiscriminatory basis, but instead may either be made available to the first party to order or subjected to a price bidding where the part y that can pay the most will reserve data and processing time.
- Landsat Data Users Notes. —The Government publication describing Landsat activities may stop .
- **Research.** —Many research and application demonstration projects now occurring at government and other public facilities may stop or else only continue with a charge for the findings. Research might not be conducted with complete objectivity if the end is to support market development.
- Technology **Feedback.** —-Linkages with university and other research facilities are beneficial for learning new technological approaches and require free give-and-take and feedback. Such an arrangement might not be possible for a private operator.