EDITORS' INTRODUCTION TO:
P.G. RISSER AND L.R. IVERSON
Geographic Information Systems and Natural Resource Issues at the State Level

Previous chapters in this section have discussed new ways to obtain data about the environment, but the question remains, once one has the data, how does one use it? With the vast quantities of information becoming available about our global environment, especially through remote sensing, the problem is a major one. Ironically, we may think we know little about our global environment, but in fact in some ways we have much more data than we can use. Two important steps in the utilization of data are discussed in the next two chapters. One step is technical: the use of advanced computer techniques for the processing of spatial data. These are known as "geographic information systems," which have been mentioned but not elaborated on in several of the previous chapters. The other step is political and societal: developing the programs by which people collect data in a consistent form and agree to share and use it. The next two chapters illustrate these steps, but they do so at different spatial scales. The first chapter, by Drs. Risser and Iverson, deals with the application of the geographic information system to the state of Illinois in the United States, a spatial scale relevant to many nations, and many environmental problems that have a cumulative impact. In this chapter, we see that an efficient and unusual state organization, the Illinois Natural History Survey, has the social and political mechanisms to collect and use data; the new development is the implementation of a geographic information system.

Dr. Risser and Dr. Iverson worked on the development of the Geographic Information System at the Illinois Natural History Survey, where Dr. Risser was director and Dr. Iverson was a staff member. Now Vice President for Research at the University of New Mexico, Dr. Risser has been president of the Ecological Society of America; his research has focused on grasslands of North America.

15 GEOGRAPHIC INFORMATION SYSTEMS AND NATURAL RESOURCE ISSUES AT THE STATE LEVEL

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INTRODUCTION

The state of Illinois has an area of about 146,500 sq km and a population of approximately 11.5 million. Although deciduous and pine forests are found in the southern portion and along rivers and streams, most of the land area was originally tall grass prairie that has been converted to such agricultural crops as corn, soybeans, orchards, and pastures. In certain regions, especially near Chicago, east St. Louis, and Peoria, substantial commercial and industrial development exists. Much of the state is underlain by coal, and significant localized petroleum reserves have been identified. Thus, the state is populous, with a complicated commercial-industrial system superimposed on a matrix of largely human-altered ecosystems. Under these circumstances, it is not surprising that severe pressures have been placed on the natural resources of the state and that decisions about the utilization and conservation of these resources always involve diverse points of view.

To facilitate the understanding of the state's natural resources and to assist in providing a rational framework for making decisions, the Illinois Natural History Survey has led the development of a statewide geographic information system (GIS). This system has been developed in concert with the Illinois Department of Energy and Natural Resources, which includes the following divisions: State Geological Survey, State Water Survey, Illinois State Museum, and the Office of Energy and Environmental Affairs. These organizations in combination acquire, archive, and make available a broad array of data sets and bring a high level of expertise to the complex issues of natural resources in the state. This chapter focuses on the biological aspects of this system, describing data sets and specific applications. Information about the hardware and software is given at the end of the chapter.[1]

DATA BASES

The data bases upon which these systems operate are designed to meet the needs of different types of users. As an operating principle, files of general data are shared among all system users; more specific or sensitive data sets are available to fewer users. There are essentially four components that make up the data base: 1) a statewide map data base; 2) a more detailed map data base for parts of the state underlain by coal; 3) site-specific data bases developed for special purposes or projects; and 4) a relational data base consisting of tabular data. Since all map data bases use the same projection and coordinate bases, appropriate files can be combined. Similarly, since tabular data files use the same codes as map data files, the two types of data can be manipulated as coherent files.[2]

The statewide map file consists of about 85 parameters that have been mapped and coordinates digitized (i.e., transferred into computer-compatible form) at the scale of 1 : 500,000 with a minimum polygon resolution of 2.6 sq km. The data for these files originated primarily from published maps at scales of 1 : 250,000 or 1 : 500,000. In all cases, these data files were checked by experts, usually on the basis of experience rather than by detailed interpretation of other sources of data or through additional collection of field data. These statewide maps include topics such as:

Biology
- Natural Divisions of the State
- Ecoregions
- Potential Natural Vegetation
- Pre–European Settlement Vegetation
- Soil Associations
- Land Use/Land Cover

Geology
- Bedrock Geology
- Quaternary Geology

Glacial Boundaries
Thickness of Loess
Coal Reserves
Hydrology
Stream Low Flows
River Mileages
High Groundwater Yield Areas
Sediment Survey Stations
Stream Channelization and Canalization
Administrative Units
Various Political Subdivisions
Dedicated Natural Areas
Soil and Water Conservation Districts
Surface and Underground Mines
Electric Utility Service Areas
Infrastructure and Special Features
Existing Roads and Railroads
Oil and Gas Pipelines
Airports and Air Navigation Facilities
Electricity Transmission Lines
Incorporated Settlements

These general data sets are used for regional analyses that do not require information mapped at a scale of finer resolution.

The first fully integrated geographic information system, the Canadian Geographic Information System (CGIS) developed in the early 1960s, was designed to provide information on marginal agricultural lands and lands suitable for agricultural production in Canada.

The state of Illinois geographic information system was originally developed to satisfy a similar purpose, the needs of the Illinois Lands Unsuitable for Mining Program. Under this program, petitions can be submitted to the Illinois Department of Mines and Minerals requesting that specific parcels of land be designated as unsuitable for some or all types of mining. A number of mandatory and discretionary criteria are invoked in this decision-making process. To assist in these decisions, the federal government requires that a data base be constructed to assist those who wish to submit petitions and to help those who will evaluate those petitions.

Because of the emphasis on coal resources, a coal-area data base has been developed. This map file incorporates most of the parameters included in the statewide map file but is mapped at the scale of 1 : 40,000 with a minimum polygon resolution of 1 hectare. Further, the data have been interpreted thoroughly, often with comparisons among several sources of information. Production of an integrated terrain unit map, for example, involves reconciling on the same map such sources as aerial photographs, soils maps, vegetation, and geological substrate. Integrated terrain unit maps have been constructed for relatively few areas, and the coal-area data base has been completed for eighty 12-minute U.S. Geological Survey topographic quadrangle maps.

The site-specific map data base consists of a large number of maps developed for specific purposes. All files employ a common coordinate and projection system to permit integration whenever appropriate. Examples of these files include habitat for deer and pheasant populations, erosion rates within watersheds, and streams likely to be vulnerable to acid deposition.

Many tabular data sets are also included in the system, and these files are linked through the coordinate system to the map files. Investigators can, on the one hand, merely manipulate the tabular data files; on the other hand, they can use the information in the tabular files as attribute information with the map files. For example, investigators can manipulate the tabular data and then plot the results, or they can select tabular data and manipulate it on the basis of the cartographic coordinates in the map file.

A typical tabular data set is the Illinois Plant Information Network (ILPIN), a file on the 3,300 plants that occur in Illinois. Entries for each species include: taxonomic information; life history characteristics; habitat requirements; geographic distribution; and information concerning how individual species respond to management and environmental insults. ILPIN allows rapid summarization of plant attributes by any number of selected criteria. For example, it is possible to identify in a matter of minutes which species grow in Cook County in bogs that have red flowers that bloom in June. It also allows generation of potential species lists for persons investigating any particular natural community, county, or natural division.

A data set entitled the Illinois Fish and Wildlife Information System (IFWIS) contains parallel information about the animals found in Illinois. Data sets such as these require an enormous amount of original field work, considerable biological expertise and judgment, and careful attention to ensure that the information represented by the data set is current and accurate. Thus, developing and maintaining such a data base should be undertaken only by a staff with scientific and technical expertise in the plants and animals of the region and in the hardware and software systems being employed.

APPLICATIONS

The geographic information system has had numerous applications assisting in the analysis and resolution of a variety of natural resource issues in Illinois. In addition, it is used routinely by the Natural History Survey to study plant and animal populations and the ecosystems of the state. For the purposes of this discussion, however, applications will be considered along a continuum from merely retrieving data from the system and applying it to using the cartographic and tabular data in descriptive and predictive mathematical manipulations. If geographic information systems are to reach their potential in assisting with natural resource issues, the administration, structure, and use of the system must incorporate the most advanced mathematical capabilities as well as the most powerful ecological concepts.

A geographic information system permits the reproduction of digitized maps and maps displaying data contained in the tabular data files. This enormously useful capability has been used consistently to depict the resources of Illinois, especially in the decision-making arena where participants are relatively unaccustomed to reviewing these types of information. In addition, interesting biological conditions of the state have become apparent by manipulating and displaying information. For example, the distribution of known historical locations of state threatened or endangered plants can be plotted along with the locations of protected nature preserves established to preserve natural communities including rare species (Figure 15–1, see color insert).

The overlay and buffering capabilities of the system have been employed in several projects. In one case, the vulnerability to soil erosion for part of Illinois was predicted using the overlay of five GIS layers. The *K* factor (erodibility) for the soils ranged from .23 to .47, with the highest values receiving ten points in an additive model and the lowest erodibility values receiving zero points. Similarly, slope in the area ranged from zero to 35 degrees; the points for these polygons ranged from one to nine points. Fifty-meter buffers were placed around the escarpment faces, and these were given three points. Landforms of various types were treated similarly. With the overlay of these four layers, it was possible to create five classes of vulnerability to erosion if permanent vegetation were removed (Figure 15–2, see color insert). Fortunately, much of the area is under permanent cover; when the vegetation map is added to the combined overlay, a map depicting probable areas currently undergoing erosion can be generated (Figure 15–3, see color insert).

In the same fashion, 14 GIS layers were used to predict suitable habitat locations for endangered plant species for the same area of southwestern Illinois. The ILPIN data base was accessed to find the most common habitat types for endangered species in Jackson County—wetlands, bluffs, and closed deciduous forests. The GIS was invoked to determine all areas under disturbance (i.e., agriculture, urban) or adjacent to disturbance (i.e., buffers around roads, pipelines, railroads, agriculture, and urban). These were scored in the negative direction. The favorable locations were then scored in the positive direction according to their closeness to the desired habitats. The resulting map (Figure 15–4, see color insert) depicts five classes of suitability to provide suitable habitat for endangered plant species.

Siting issues have also been approached by overlaying several environmental parameters and then evaluating the suitability of alternative sites, and several soil and vegetation characteristics have been evaluated by using overlay techniques to determine vegetation vulnerability to air pollutants. As one example, forest productivity for a portion of Illinois was predicted using point, polygons, and tabular data from the GIS and Landsat Thematic Mapper (TM) data coupled with a regression model. The U.S. Forest Service data on the Illinois Continuous Forest Inventory (CFI) plots, collected in 1985, included data pertaining to forest productivity at plot locations scattered throughout the state. Additional 1 hectare resolution data from the coal area data base used for the model included a woodland soil productivity index as derived from the soil layer. Landsat TM was then used in combination with the other data to develop a regression model aimed at predicting forest productivity. The resulting map depicts the variation of deciduous forest productivity classes based on the best regression fit for each 30-by-30-m pixel of northern Pope County, Illinois (Figure 15–5, see color insert). These analyses have obvious implications, not only for increasing our understanding of the ecological systems in Illinois, but also for improving our ability to manage these natural resources.

Current applications of the geographic information system emphasize the combination of spatial-tabular data sets with simulation models.[3] This approach retains the power of the geographic information system, but adds the specificity of mechanistically describing how natural resource entities or processes operate in the field. For example, the data system includes a large data base on the distribution of forest types in Illinois as well as descriptive data about forest stands, including species composition, stem sizes, and site quality. These data are now being coupled with a simulation model that projects forest growth and the economic returns that can be expected with alternative timber management techniques. In another example, simulation models of the population dynamics of agricultural insect pests have been developed that combine life history characteristics of the insects with climatic data and crop conditions. Coupling these models within the context of a geographic information system allows us to predict how various areas of the state will be affected by agricultural pests, thus increasing the likelihood the most appropriate management strategies will be recommended. The precision of these predictions enhances the efficacy of insect pest management treatments while reducing the hazards to the environment from needless applications of chemicals.

SUMMARY

Geographic information systems are powerful tools for addressing natural resource issues. Illinois is a diverse state with many natural resources and constant pressure to develop and utilize them. Only with the assistance of an organized data base that can be manipulated is it possible for the state to make wise decisions about these natural resources. Experience has shown, however, that biological data require considerable expertise, both when the data are collected and when the results are interpreted. Therefore, a geographic information system that focuses on natural resource issues can only be developed and used in conjunction with biological scientists.

Currently, most geographic information systems used for evaluating natural resource topics employ a number of powerful capabilities, including map overlays, buffering displays, and algebraic calculations. Future applications will combine the spatial and tabular data with simulation models that capture the mechanistic behavior of biological populations and ecological processes. The incorporation of these mechanisms will reinforce the requirement that the data system and the scientists operate in tandem; it will also enhance the predictive and prescriptive capabilities of the geographic information system at the state level.

NOTES

[1] The hardware system is located at the Illinois Natural History Survey and consists of linked Prime 750 and 9955 minicomputers with 24-mb main memory, two tape drives, 80 ports, and 3300-mg disk storage on six disk drives. A complete graphics workstation is located at each of the five divisions of the Department of Energy and Natural Resources.

Each consists of a digitizer and graphics terminal: three workstations have 86-cm drum plotters. In addition, approximately 40 graphics or alphanumeric terminals are connected to the system. Access to remote stations is provided by hard-wired connections, through a coax cable on the University of Illinois campus, through dial-up ports, or through dedicated telephone lines connected to multiplexers and high-speed modems.

Although a number of software packages are available on the system, ARC/INFO is the primary package for managing spatial and tabular data. ARC (marketed by Environmental Systems Research Institute [ESRI] in Redlands, California) is a series of geographic information processing routines for encoding, manipulating, and displaying spatial data (i.e., data that can be categorized into points, lines, or polygons, and that are stored in x, y coordinate form). Analytic capabilities include algebraic manipulations, overlays, and buffering. INFO (Marketed by Henco Software in Waltham, Massachusetts) is a relational data base management package. A major advantage of the ARC/INFO system is its capability for combining spatial and tabular data. Recently we have acquired the ERDAS software (marketed by Erdas, Inc., of Atlanta, Georgia), which provides image processing and raster GIS processing. This system has been integrated into the ARC/INFO software so that vector GIS files can be integrated with ERDAS for further processing. Other major software packages available to state of Illinois personnel include GRID, GRID/TOPO, TEXT, Minitab, ELAS, EMHASP, IGL, PRIMOS, Surface II, TERMS, FORTRAN 77, NETWORK, and MIDASPLUS.

[2] C.G. Treworgy, 1984. "Design and Development of a Geograhic Information System for Illinois." Proceedings of Pecora IX, Spatial Information Technologies for Remote Sensing Today and Tomorrow, Silver Springs, Maryland, pp. 29–32.

[3] P.G. Risser and C.G. Treworgy, 1986. "Overview of Ecological Data Management," in *Research Data Management, and the Ecological Sciences*, W.K. Michner (ed.), University of South Carolina Press, Columbia, pp. 9–22.

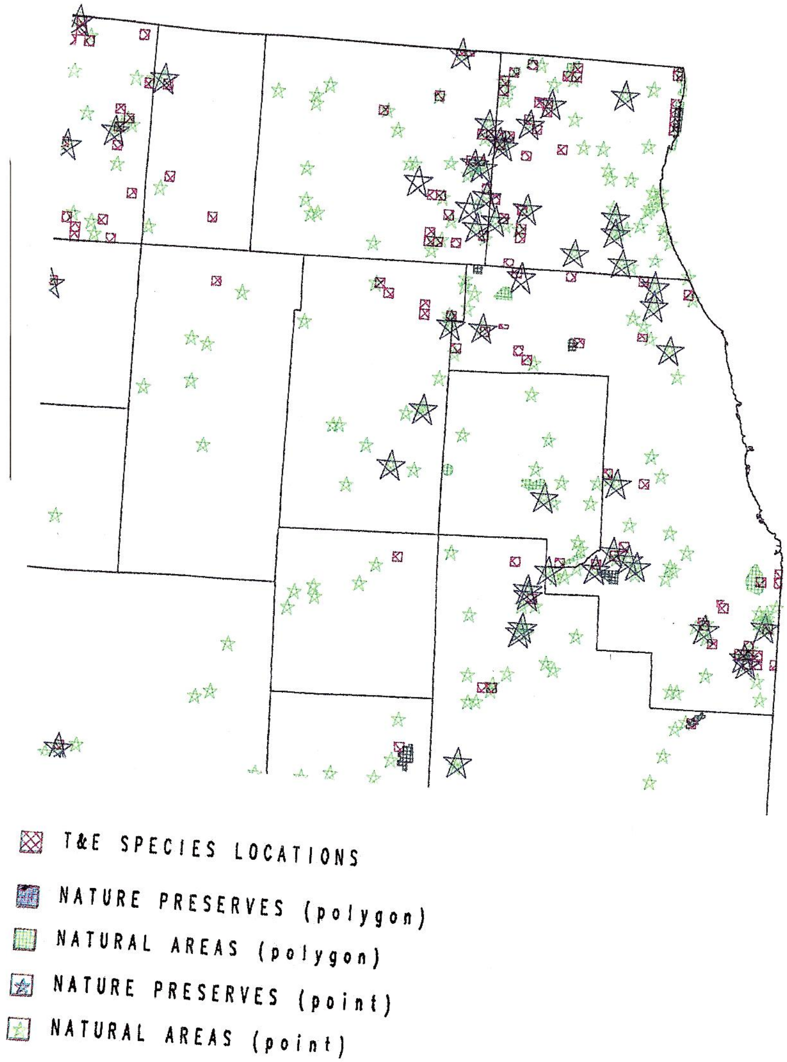

FIGURE 15–1 Spatial relationship between locations of northeastern Illinois threatened and endangered plant species and Nature Preserves or Natural Areas. Polygons are areas greater than 300 acres in size and points are smaller areas.

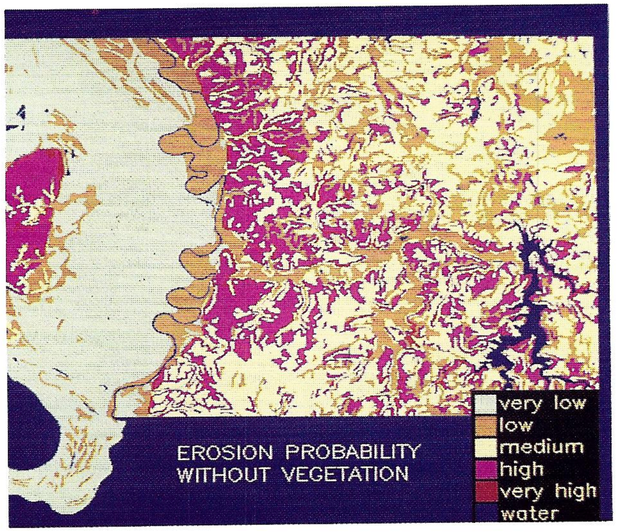

FIGURE 15–2 Probability for excessive erosion in southwest Jackson County, Illinois, if the region were devegetated.

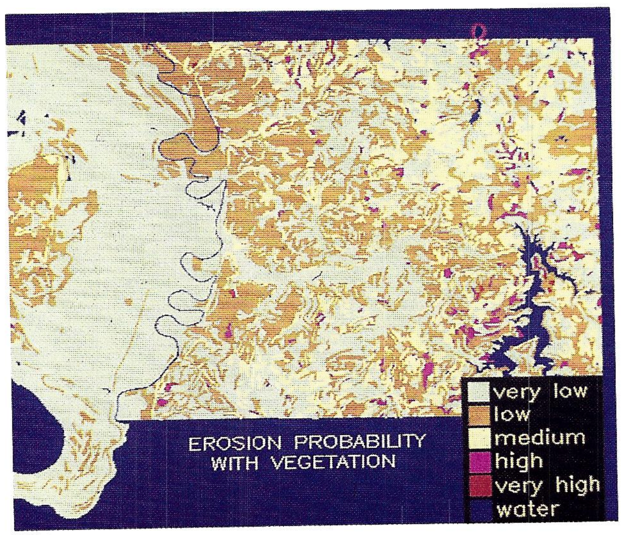

FIGURE 15–3 Probability for excessive erosion in southwest Jackson County, Illinois, with current land use/vegetation patterns.

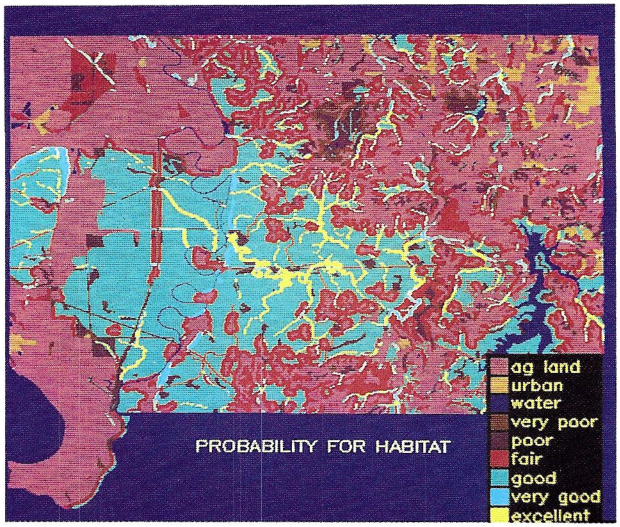

FIGURE 15–4 Probability for good quality endangered plant species habitat in southwest Jackson County, Illinois.

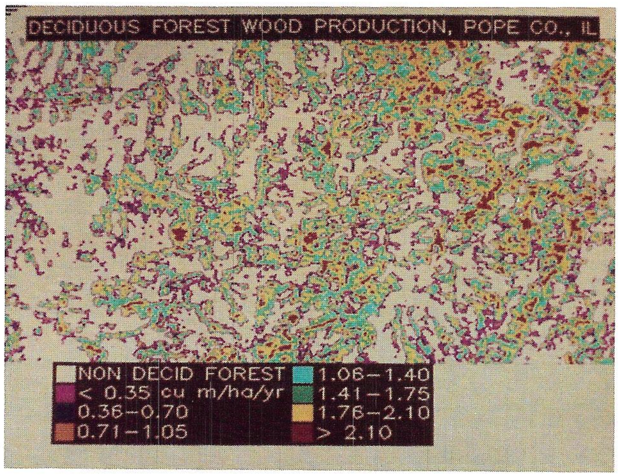

FIGURE 15–5 Estimates of mean annual increment (MAI) in Pope County, Illinois, based on Landsat TM and soils data.

CHANGING THE GLOBAL ENVIRONMENT
Perspectives on Human Involvement

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