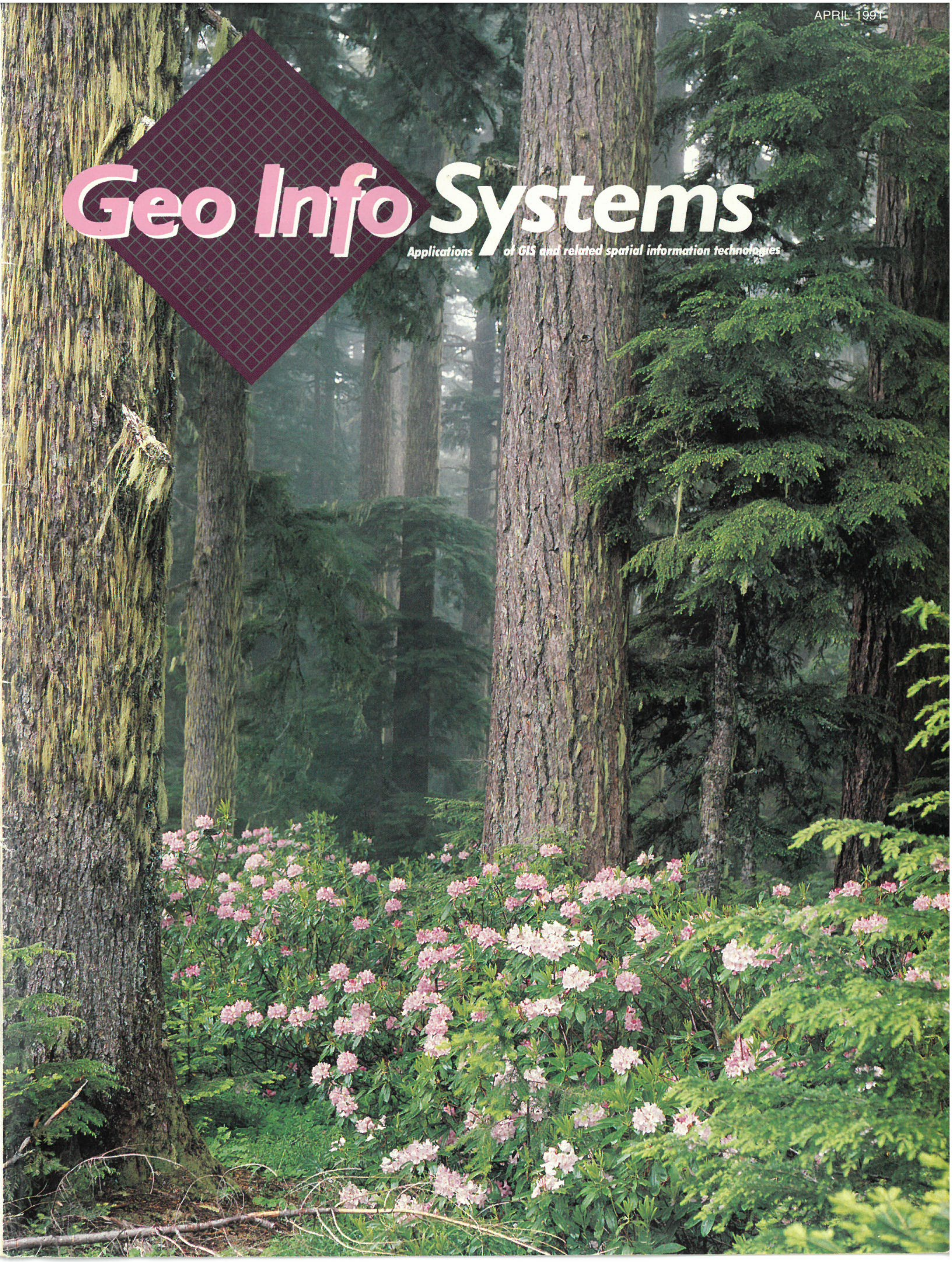
VOLUME 1 NUMBER 4

APRIL 1991

Geo Info Systems

Applications of GIS and related spatial information technologies



Geo Info Systems

APRIL 1991

Measuring Real Benefits of GIS/LIS in Wisconsin

Puneet Kishor
University of Wisconsin–Madison

Cooperation among organizations and agencies and a long-term commitment from decision makers to develop and maintain data bases is essential to the viability of a geographic and land information system (GIS/LIS). Cooperation and commitment, in turn, are fostered by an appreciation of the full range of benefits the technology produces. This article presents a method for measuring GIS/LIS benefits that was used in a multiagency natural resources project in Dane County, Wisconsin.

Puneet Kishor *is with the Land Information and Computer Graphics Facility, University of Wisconsin–Madison. He is also a PhD candidate in Land Resources, Institute for Environmental Studies at the university.*

As geographic and land information systems (GIS/LISs) proliferate, so do attempts to conduct cost–benefit analyses to justify investment in such systems. Traditional cost–benefit analyses usually focus on a project's tangible and quantifiable aspects. Yet experience shows that nonquantifiable aspects often are just as important as quantifiable aspects in determining the success of GIS/LIS applications. Emphasis on intangible aspects is particularly important in evaluating GIS/LIS applications because such applications are usually in the realm of public service, where less tangible "quality of life" issues are being addressed.

The long-term nature of GIS/LIS applications poses another problem: setting up the systems involves high up-front costs but benefits accrue over a long period of time. This situation creates pressure to justify the high setup costs. Additionally, a clear picture of the benefits that accrue from both immediate and long-term application of the technology is often lacking. Because cooperation with other organizations and agencies and long-term commitment from decision makers to develop and maintain data bases are essential for the viability of a GIS/LIS approach, it is important to find ways to measure and show those less-quantifiable benefits that are realized more slowly.

Benefits from the application of any technology can be classified in two general categories: the technological benefits — that is, the tools and techniques afforded by the technology; and the actual program benefits that are based on what the technology helps an organization to accomplish — such as meeting agency mandates and serving clients.

The confusion between the technological and the program benefits is compounded by the pressure to justify high initial costs. This pressure results in a misplaced emphasis on benchmarks, software and hardware specifications, and functional capabilities of the GIS, while the needs the system was envisioned to fill are neglected.

For example, if the program's objective is to determine a county's highly erodible lands, the GIS's worth could be measured by the extent to which it helps the county conservationist's office do that at an affordable cost. Fancy GIS capabilities such as sorting and indexing data, retrieving data quickly, and performing mathematical and spatial analyses are really not what the county conservationist is after. Those capabilities are just the technological benefits that contribute to completing the actual task at hand. The important distinction between technological benefits and program benefits is emphasized in this article using the example of a multiagency project recently carried out in Wisconsin.

INTRODUCTION TO CONSOIL

Conservation of Natural Resources through Sharing of Information Layers (CONSOIL) was a multiagency venture in Dane County, Wisconsin, that involved federal, state, and local government agencies and various departments of the University of Wisconsin–Madison. The project was initiated in 1987 by a memorandum of understanding signed by the project's cooperators; the project's goal was to improve various resource conservation programs' delivery of services. The project addressed several programs included in the 1985 Food Security Act, particularly conserva-

CONSOIL Project Cooperators

Dane County, Wisconsin
Division of Systems and Data Processing
Department of Land Records and Regulation
Land Conservation Committee

U.S. Department of Agriculture
Soil Conservation Service
Agricultural Stabilization and Conservation Service

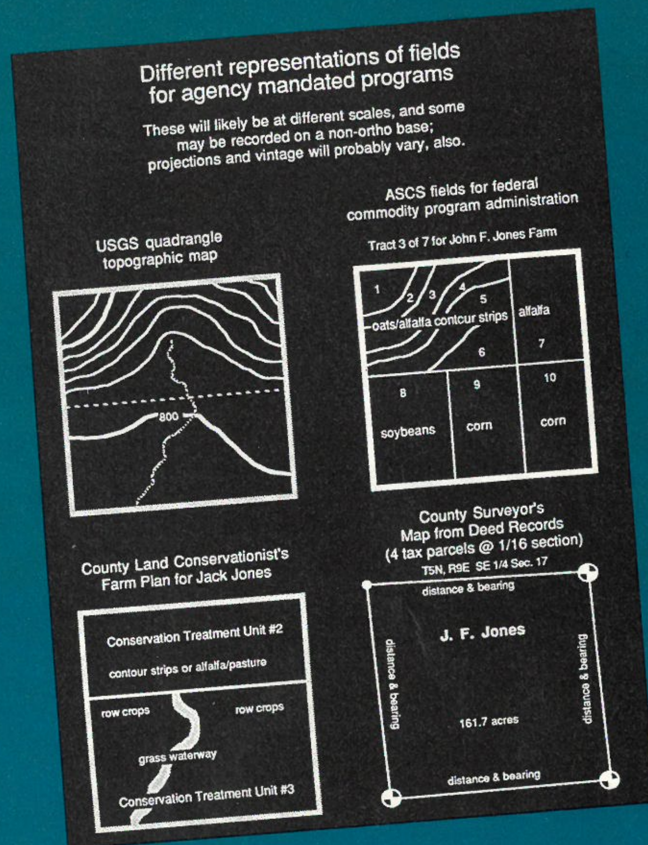
U.S. Department of the Interior
U.S. Geological Survey, Water Resources Division

Wisconsin Department of Natural Resources

Wisconsin Department of Agriculture, Trade, and Consumer Protection

University of Wisconsin
University of Wisconsin–Extension
Wisconsin Geological and Natural History Survey

University of Wisconsin–Madison
College of Agricultural and Life Sciences
Department of Landscape Architecture
College of Engineering
Department of Civil and Environmental Engineering
Institute for Environmental Studies
Environmental Remote Sensing Center
State Cartographer's Office



tion compliance, conservation reserve planning, and wetland protection. It also addressed the Wisconsin state programs for soil erosion control, nonpoint source pollution abatement, and farmland preservation. The work's focus was primarily at the Dane County Field Office. The field office is where the staff of the Dane County Land Conservation Committee (LCC) and the U.S. Department of Agriculture's Soil Conservation Service work together. In Dane County it is the service delivery point for federal, state, and local conservation programs, as well as the commodity programs administered by the USDA Agricultural Stabilization and Conservation Service.

GIS/LIS's ROLE IN CONSOIL

The CONSOIL project explored the use of GIS and related technologies such as satellite-based positioning systems and orthophotography for meeting the mandates of the various programs of the 1985 Food Security Act. The project's cooperators also dealt with a number of organizational changes and institutional arrangements in and among the agencies with the aim of improving the program overall.

The project's agenda was to modernize and manage the information used by participating organizations to carry out their respective county, state, and federal responsibilities for soil and water conservation programs. The spatial information technologies were used to demonstrate the potential for automating routine tasks, as well as to develop new applications and find solutions to problems that were difficult, infeasible, or even impossible to solve using manual means.

THE confusion between the technological and the program benefits is compounded by the pressure to justify high initial cost.

INSTITUTIONAL ISSUES

The CONSOIL project lasted three years and was primarily a demonstration of the advantages of the GIS/LIS approach to information management. The new technology required training of personnel, learning familiarity with a new GIS-specific "lingo," and developing an open-mindedness to trying out new methods. Such organizational changes were necessary to keep pace with the changing work environment as a new technology was assimilated into routine tasks.

Several applications required the use of a variety of data from different sources. To make the best use of the existing resources and to avoid duplication, the participating agencies set up new arrangements and understanding among themselves for sharing data. Such institutional arrangements were essential for implementing and maintaining proper channels of communication among the participating agencies for managing data and for setting policies that would affect the agencies themselves.

To facilitate decision making, representatives from the participating agencies met periodically as a nominal group to discuss the status of various CONSOIL-related tasks, any issues of common concern, and future activities. The periodic meetings were held at various cooperators' facilities to add to the sense of general participation and responsibility. This nominal group approach was carried on right up to the end of the project and was integral to the process of evaluating CONSOIL.

EVALUATION OF CONSOIL

The evaluation of CONSOIL comprised several steps. First, a nominal group meeting was held to brainstorm and identify all possible benefits that GIS and related technologies provided. The costs associated with the GIS/LIS approach were acknowledged, but participants mutually agreed to emphasize the benefits only, because it would be very difficult to identify and allocate all of the costs realistically.

CATEGORIZING *benefits according to efficiency, effectiveness, and equity was done to better understand the societal effects of GIS/LIS.*

Next, a list of GIS-related functions — that is, tools and techniques afforded by the technology — was prepared. This list was divided into three categories: data capture and manipulation, data analysis, and information output. In addition, two institutional conditions were added to the list as categories — "organizational changes" and "institutional arrangements." Those institutional conditions were considered essential for a successful implementation of GIS/LIS.

Table 1 lists the five categories of GIS-related functions and institutional conditions in detail. The list is not comprehensive, but it covers the CONSOIL participant's overall experience with GIS/LIS. Categories 4 and 5 are particularly incomplete, reflecting the need to think through and incorporate concerns about organizational changes and institutional arrangements into the system in more detail in the future.

Table 1. List of GIS/LIS-related functions and work conditions

1. Data capture and manipulation
- 1.1 easy data capture through digitizing or scanning
- 1.2 data quality checks such as completeness and logical consistency possible
- 1.3 compact storage and flexibility because of digital nature of data
- 1.4 data transformation from one coordinate system to another possible
- 1.5 data conversion from one scale to another possible
- 1.6 difficult projections possible
- 1.7 increased coding and classification efficiency
- 1.8 possible to update the data base easily
- 1.9 increased positional accuracy due to Global Positioning System
- 1.10 increased positional accuracy due to orthophoto quarter quadrangles

2. Data analysis
- 2.1 full relational data management capabilities
  - 2.1.1 sorting and indexing
  - 2.1.2 selectively retrieving data with Boolean logic
  - 2.1.3 full spreadsheet analysis capabilities
  - 2.1.4 attribute merging by combining two or more data base files
  - 2.1.5 programming to automate performance of tedious operations
- 2.2 spatial data manipulation and analysis
  - 2.2.1 buffering points, lines, and polygons
  - 2.2.2 combining two or more maps to create new maps
  - 2.2.3 easy measurement of occurrences, distances, and areas possible
- 2.3 data conversion for viewing–analysis purposes — that is, contours to TIN
- 2.4 modeling
- 2.5 performing "what if . . .?" analyses

3. Information output
- 3.1 immediate graphics display
- 3.2 customized hard-copy maps made quickly at varying scales
- 3.3 tabular display of attributes
- 3.4 customized reports of attributes generated quickly and easily

4. Organizational changes
- 4.1 encouraging use of new methods
- 4.2 hiring new, trained staff
- 4.3 training current staff
- 4.4 commitment of upper-level management and elected officials

5. Institutional arrangements
- 5.1 data sharing (multiple access of shared data by participating agencies)
- 5.2 data custodianship
- 5.3 ongoing meetings for reporting and planning
- 5.4 memoranda of understanding and cooperative agreements

The next step was to assign the five categories to the CONSOIL program activities that they affected. This process was accomplished primarily by reviewing published papers and departmental reports, as well as by interviewing people from the participating agencies. The purpose was to determine which GIS functions or institutional conditions were responsible for any benefits that a participating agency might have accrued.

The benefits were then categorized by type along a continuum having tangible and measurable "economics" at one end and a more intangible and difficult-to-measure "social" benefit at the other end. As a result, all possible benefits were coalesced under

- efficiency, an overall measure of accomplishing tasks faster;
- effectiveness, an increased capacity to perform tasks previously impossible or infeasible; and

• equity, a measure of fairness and uniform treatment as perceived by the affected public.

This categorization was done to aid understanding of the societal effects of GIS/LIS.

The evaluation process resulted in a three-part relationship among the technological benefits, organizational changes, and institutional conditions; CONSOIL program benefits; and the continuum of efficiency, effectiveness, and equity. To summarize, GIS and related technologies were applied to various CONSOIL program activities in hopes of providing capabilities and fostering institutional conditions that would help execute both day-to-day and new tasks in a more efficient, effective, and equitable manner.

FINDINGS

Applying GIS/LIS benefited primary CONSOIL program activities such as the determination of "highly erodible lands"; Farmland Preservation Certification and the Food Security Act's Conservation Planning; processing soils data for the Dane County Soil Erosion Control Plan down to the level of individual farms, farm conservation plan maintenance, and revisions; and conservation tillage.

As an example, the effect of GIS/LIS techniques on the determination of highly erodible lands is illustrated in Table 2. The specific functions or institutional conditions directly responsible for realizing the particular benefit are listed in the first column. The second column lists the particular CONSOIL program benefit. The last three columns indicate whether the benefit was manifested as increased efficiency, overall effectiveness, or equity as perceived by the program's clients.

The district conservationist at the field extension office routinely assesses, among other things, the erodibility of farmland. (The photograph on the opening page of this article illustrates the assessment process.) The Universal Soil Loss Equation factors for rainfall, slope, slope length, erodibility, and the tolerable soil loss are used to calculate the soil erosion index. This index is the basis for determining highly erodible lands. Under the 1985 Food Security Act, those areas are subject to conservation provisions.

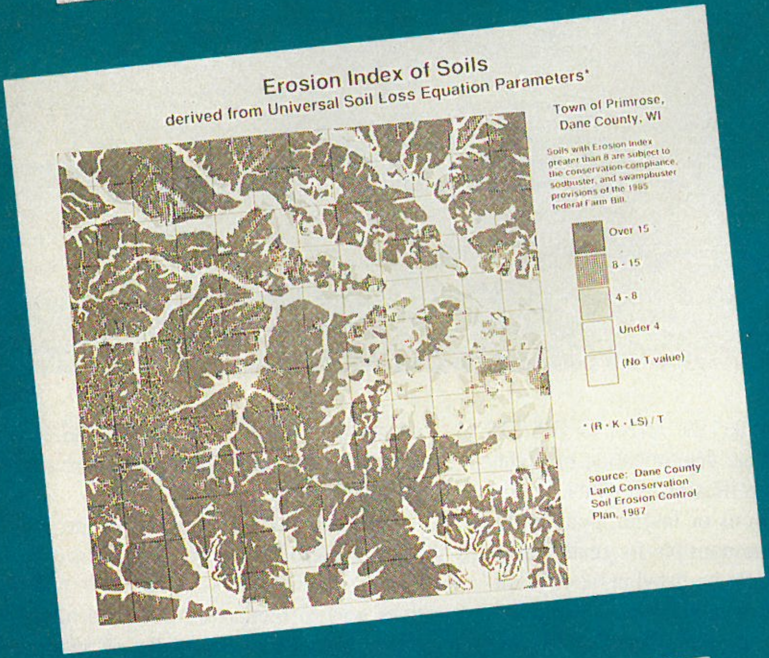
Before CONSOIL, most of the data about soil erodibility were maintained in a manual form. One of CONSOIL's objectives was to modernize that information and automate the process for determining highly erodible lands.

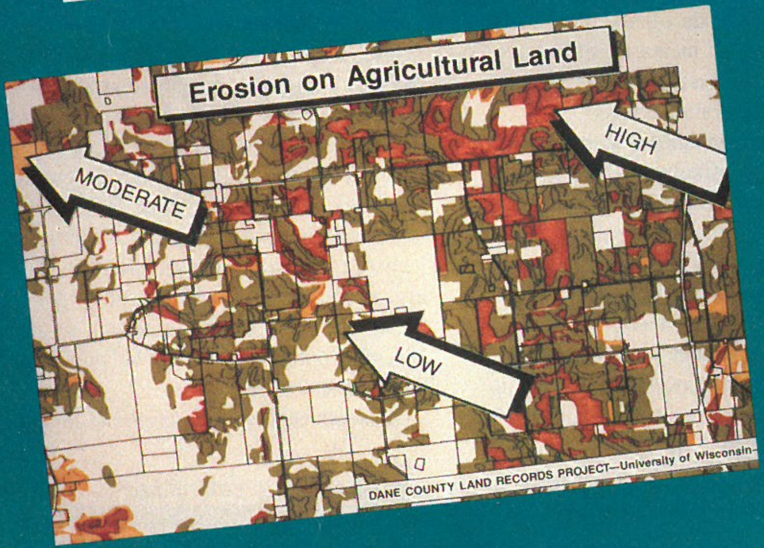
Examples of manual and automated data formats are shown in the illustration on page 50. Clearly, manually collected and maintained data limited the district conservationist's ability to determine highly erodible lands at the field office. In contrast, automated data were not only available selectively and in customized formats, they also were easier to update, made it possible to track the attributes related to soil loss more quickly, and permitted quick calculations and analyses.

Dane County Land Conservation Commit-

Table 2. An example of how CONSOIL program benefits are determined

GIS/LIS related functions and institutional conditions	CONSOIL program activity	Benefit type: efficiency	effectiveness	equity
1.1, 1.4, 2.1, 2.2.2, 3	Determination of highly erodible lands	✓		✓





Examples of manual and automated data are shown (top and middle). GIS/LIS techniques (bottom) have helped Dane County reduce its staff time by a ratio of more than 5:1.

tee's process for determining highly erodible lands showed a reduction in staff time of 5:1 or greater using GIS/LIS techniques rather than manual data assimilation and analysis techniques. That figure was generated by comparing the staff time spent on determining highly erodible lands in Dane County, where the process was automated, to staff time in Chippewa County, where the process was manual. In Chippewa County, the average time spent on manual determination of highly erodible lands for a single farm tract ranged from 30 minutes to 1 hour, depending on the size of the farm and the number of fields. The Dane County Land Conservation Committee was able to process a single farm tract in 0.1 hours — that is, in about 6 minutes — using automated methods.

THE process for determining highly erodible lands showed a reduction in staff time of 5:1 or greater using GIS/LIS.

The computer time spent overlaying soils and farm ownership information as part of the assessment process in Dane County is included in the time estimate for the automated method. It took approximately 30 minutes to overlay one township's digital farm tracts and soils information. A township has 120 tracts, which means that 4 tracts were overlaid per minute. Thus, the significant improvement in staff efficiency in Dane County is the direct result of farm tract and soils information existing in digital format.

Although computerization resulted in increased efficiency, this particular program activity is a routine procedure that was performed prior to automation. Effectiveness — the increased capacity to perform tasks previously impossible or infeasible — was not changed by the automation of data because the task already was defined and routinely carried out. Computerization did result, however, in an increased perception by farmers of the fairness of the process, because the computer performed the same procedure on every farmer's land without subjectivity. Thus, effectiveness is not checked off in Table 2, but equity is.

CONCLUSIONS

It must be emphasized that the path to modernizing records through automation has not been easy. It has been particularly difficult to realize the institutional conditions necessary for deriving maximum benefits from a GIS/LIS approach. Even though individual agencies were able to automate their respective data bases and adopt improved work procedures, the lack of institutional arrangements prevented information sharing with other agencies on a routine basis. Data were shared within the scope of well-defined tasks and for the purposes of demonstrating a concept. On average, however, data sharing was not integrated into the administrative responsibilities of the agencies. The agencies lacked initiative to set up and comply with common data standards, or to set up mechanisms that would ensure data custodianship and data sharing.

The CONSOIL project reinforced the importance of the social–institutional components of GIS/LIS as an addition to its technical component. Our conviction was strengthened that, in the transfer and implementation of GIS/LIS, it is usually easier to overcome technical difficulties than it is to overcome organizational or institutional inertia.

Individual agencies can acquire computer systems, automate their data bases, and attempt to modernize and improve their work procedures. In automating and modernizing land records and other information necessary for public policy formulation and environmental resources management, however, responsibilities often cross organizational and institutional boundaries.

Agencies must collaborate, cooperate, and share authority and responsibility if they want to maximize benefits. Unwilling or sluggish cooperation may result from entrenched bureaucracy, narrow organizational vision, limited leadership, or turf battles. To develop the necessary cooperation between agencies and a long-term commitment from decision makers, GIS/LIS project leaders must be able to demonstrate the full range of benefits that the technology's implementation produces. An approach like the one presented in this article can create a framework for presenting the real benefits of automating land records and management.

IT is important to find ways to measure and show the technology's less-quantifiable benefits that are realized more slowly.

Distinction of the real benefits from the technological benefits was helpful in revealing the institutional and political components of GIS/LIS implementation. Once again, it was apparent that viable implementation of the technology should not be confused with the technology itself, and that institutional and political support and leadership are essential for its success.

RECOMMENDATIONS

Without concerted leadership from those responsible for managing agricultural programs at the federal, state, and local government levels, the long-term potential and overall societal benefit of GIS/LIS technology will be minimized, even though the technology's deployment and use are inevitable.

Given the increased demands for manipulating and analyzing data from diverse sources to meet the mandates of future agricultural conservation programs such as the 1990 Food Security Act, the need for farsighted leadership is of prime importance. Such leadership can come from the top, as well as from the local government level. Now is the time to involve elected officials from Congress, the state legislature, and county government to assist us in charting a more effective institutional path toward adopting GIS/LIS technology.

ACKNOWLEDGMENTS

I would like to recognize the valuable contribution of all the participants in the CONSOIL venture. In particular, I am grateful to Bernard J. Niemann, Jr., D. David Moyer, Stephen J. Ventura, and Peter Thum at the Land Information and Computer Graphics Facility at the University of Wisconsin–Madison. ■