# The Potential for Geographic Information Systems in Agricultural Economics

1989

Proceedings of a symposium at the annual meeting of the
American Agricultural Economics Association

AAEA 1989

7183

Geography, Economic

July 30–August 2

Louisiana State University
Baton Rouge, Louisiana

#7318

# Abstract

The Potential for Geographic Information Systems in Agricultural Economics. Edward Reinsel, Organizer (Economic Research Service, USDA); Gene Wunderlich, Moderator (Economic Research Service, USDA); David Moyer (National Geodetic Survey); Robert Marx (Bureau of the Census, USDC); and Jane Luzar (Louisiana State University)

Geographic Information Systems (GIS) are a means of acquiring, storing, retrieving, and analyzing natural resource, socio-economic, and other data. Although such systems offer great flexibility in handling complex geographically oriented information, they have been used relatively little by our profession. This symposium explored concepts underlying GIS's and identified several systems of significant potential interest to agricultural economists. The objective was to provide an understanding of GIS's and thus allow informed decisions by members of the profession concerning adoption of this technology. Moyer introduced general concepts of GIS, noted use by various government agencies and discussed forms of output, including maps, tables, and graphs. Marx described and offered suggestions on accessing and using TIGER--the Census Bureau's new geographic support system. Luzar considered the practical issue of adoption and application of GIS's to analysis of rural problems, including electronic transfer of large data bases, potential products, and hardware and software needs.

# The Potential for Geographic Information System in Agricultural Economics

Organizer: **Edward I. Reinsel**, USDA/ERS

# APPLYING GEOGRAPHIC INFORMATION SYSTEMS TO ANALYSES OF RURAL ECONOMIC PROBLEMS

Opening remarks by
Gene Wunderlich, Moderator

If there is a quality or condition that describes almost all of modern life, it is change. Our daily and professional lives undergo constant, and ever-more rapid change. The increased tempo of change is in part the result of technological and knowledge innovations. This symposium, for example, is a result of technological extensions of the computer, digital cartography, and global positioning systems.

The element of constancy in this environment of change is place. A geographic location is permanent.

It is this element of constancy that provides researchers a means for linking analytical variables. Agricultural and resource economists, particularly, will find spatial identifiers a natural way to combine variables relevant to their models.

Place can be a dependent variable as we predict the location of crop production, a preferred place of investment, or a likely source of pollution. Place can be an independent variable to predict output, cost, or revenue. Place can be simply a non-explanatory identifier for linking two or more operative variables.

The American Agricultural Economics Association has been concerned for at least two decades with the quality, quantity, and accessibility of data for research, management and policy making. For at least that long, and more, a number of organizations and institutions have been involved with the design of georeferenced, automated, data systems.

Much of the early conceptual and organizational work on geographic information systems can be tied to a cooperative project with Robert Cook of the Land Records Improvement Committee of the American Bar Association and the U.S. Department of Agriculture's Economic Research Service, whose interests lay in the statistical, analytical, and managerial potential of georeferenced information systems. Today a wide range of professional and governmental organizations have major programs in the development and implementation of geographic and land information systems. In 1988, under the Federal Lands Exchange Act, PL 100-409, Section 8, the U.S. Department of Interior, with the Departments of Agriculture and Commerce, conducted a one-year overview study of the state of, and needs for, land information. The report from that study reflects the rapidly growing interest in geographic information systems.

The purpose of this symposium is to continue the coordination of data users and data providers so that users get what they need at the lowest cost in time and energy. Information products are not unlike other products in our economy. Information is valuable and it takes resources to create and use it. It is time to rationalize our information system, or at least those parts of the information system relevant to our research.

To initiate our discussion, Dave Moyer will provide an overview of the basic components of a Geographic Information System. Among other things he will introduce the lexicon of GIS, so that we will exchange views with a common vocabulary. Bob Marx will describe one form of GIS and relate it to GIS in general. He is in the role of a producer/creator of a national geo-referenced data system. Jane Luzar is in the role of a user of geo-referenced data systems. She will include the problems of getting technology-driven informations systems to respond to real world needs. The statements by Moyer, Marx, and Luzar provide an excellent backdrop for conversation about the growing field of geographic information development and management.

# WHAT IS A GEOGRAPHIC INFORMATION SYSTEM?

## Definitions, Concepts, and Applications

D. David Moyer

National Geodetic Survey
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

and

Institute for Environmental Studies
University of Wisconsin
Madison, Wisconsin

## I. Introduction

Geographic information systems (GIS) as we know them are a relatively recent innovation. Their development over the past 20 years has paralleled the development of high capacity, low cost computers. Major progress in terms of development and implementation has occurred in the last 5 years, due to a number of factors such as the technological push of hardware and software availability, and due to the demand pull of an increasing need to manipulate and analyze spatial data for a variety of agricultural, environmental, and energy related programs.

The developments of recent years have been so rapid that the vocabulary has sometimes not kept pace with the technology, and therefore some discipline in use of terms may be in order. I will review the origins and present status of concepts now generally accepted by professionals working with GIS. I will also flesh out the concepts with illustrations from GIS development work in Wisconsin.

## II. Definitions

The advent of GIS is a relatively recent phenomenon, fueled by: (1) the need for better, more timely information on which to base decisions about the resources in a spatial context and (2) the availability of affordable computer technology to support the compilation and use of such information.

The demand for information about land and related resources is not new in itself. In fact, the roots of modern GIS and land information systems can be traced back thousands of years. The earliest recorded use of spatially organized land resource records dates from about 3,400 B.C. (Dowson and Sheppard, 1952, p. 2) Egyptian agricultural settlements in the Nile, Tigris, and Euphrates river valleys were regularly subjected to substantial floods. In order to maintain orderly agricultural production and to facilitate the collection of land taxes, the Pharaohs developed rudimentary land record systems, consisting of maps and written records on clay tablets (National Research Council, 1983, p. 5) Both the Greeks and Romans later established elaborate land record systems, primarily for the collection of land taxes.

The first register of rights to land was developed in England about 400 A.D. (Binns, 1953, p. 4) Property was described, and a register was also kept, recording all deeds and mortgages. A second land property record system, the Domesday Book, was completed for England in 1086. The Domesday Book combined both fiscal tax data and census data on land resources into a single system (Dowson and Sheppard, 1952, p. 5) Furthermore, these data were organized into shires (similar to our counties), and within shires, further organized by feudal lords, to facilitate collection of taxes and control by the King. Similar cadastral developments were carried out in France by Louis VI in 1115 and by Napoleon in 1807.

Much of the recent development of GIS grew out of systems developed to manage natural resources, starting 20 to 25 years ago. Early natural resource systems were developed by the Maritime Provinces in eastern Canada (Land Resources Information System (LRIS)), by the State of Minnesota (Minnesota Land Management Information System (MLMIS)), and by the State of New York (Land Use and Natural Resource Inventory (LUNR)), among others. Many of these early systems were built on grid systems and the initial grids used were fairly coarse. For example, a 640 acre grid was used for Minnesota and a 247 acre grid was used for New York. Minnesota has since refined its system by using a 40 acre cell. Later systems were built on land parcels, often using tax parcels as the basic building block for the system. Use of coordinate descriptions for parcels has been facilitated by the adoption of the State Plane Coordinate System (SPCS) by most states. SPCS is adaptable to both the Public Land Survey System (PLSS) in the western states and to the metes and bounds descriptions used in the eastern Colonial states as well.

In general terms, a GIS is a systematic arrangement of data related spatially to the earth. This relationship can be in three dimensions, including those found on the surface of the earth, below the surface (such as mineral rights), and above the earth (such as air rights).

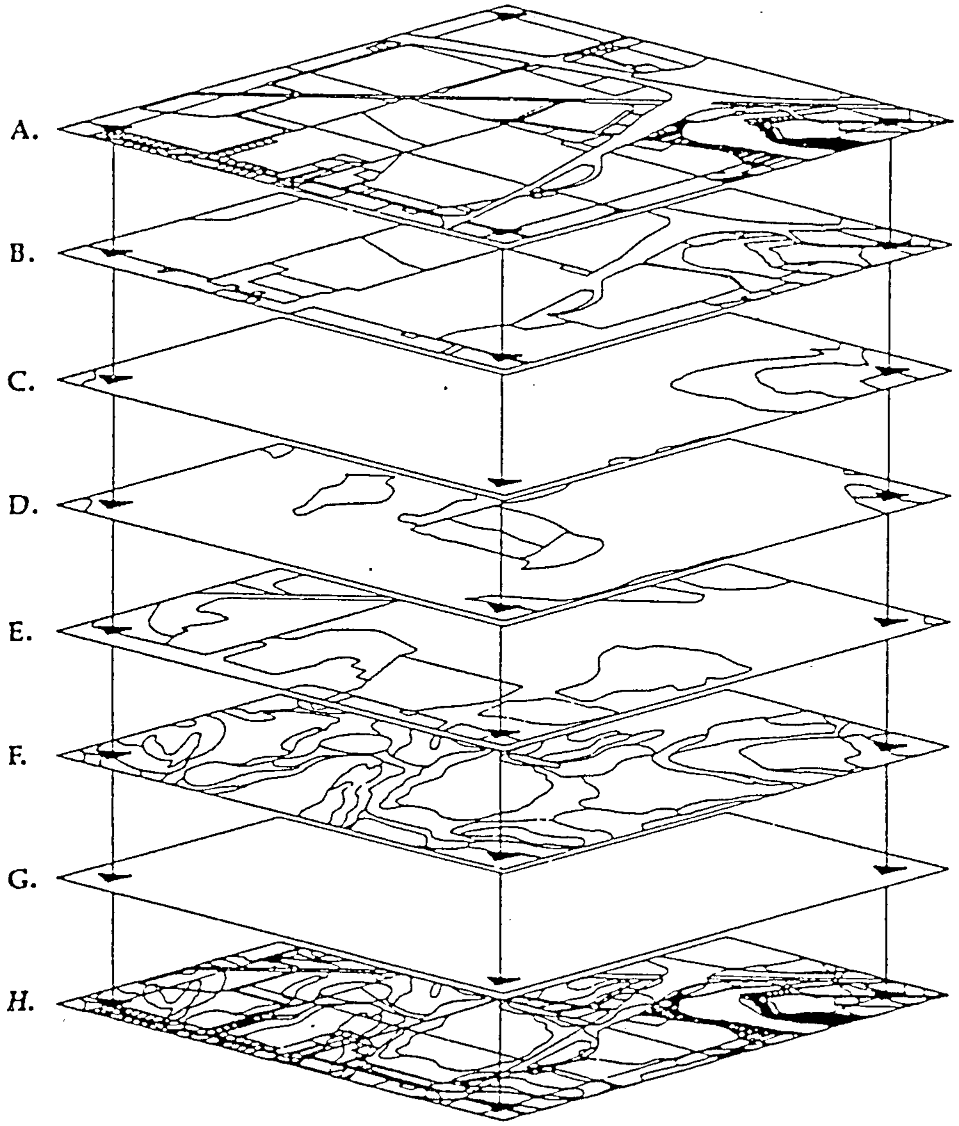
In more specific terms, a GIS is a system of spatially referenced data, including the hardware, software, staff, and institutional support, that can be used to acquire, store, manipulate, analyze, and display spatial data. As Parker has noted, "a GIS is more than just a special kind of information system ... [i]t is a technology." (Parker, 1988, p. 1547) Only when looking at a GIS as technology for handling all matter of spatial data can its true significance become apparent.

Special note should be made of the analysis capability, since this is what distinguishes a GIS from similar systems that can be used for manipulation and display of data, but lack the capability to permit analysis of related data files. Examples of systems without these analytical capabilities include computer aided mapping (CAM) systems and computer aided design (CAD) systems.

A land information system (LIS) is a subset of a GIS. The contents of an LIS is restricted to data about land, whereas a GIS often includes data about people, infrastructure, etc. These latter data, while they can be analyzed and/or displayed in spatial terms, are not specifically about the land itself. LISs are often built to serve multiple uses and therefore are often referred to as multipurpose land information systems.

A third related term that is used fairly frequently in GIS-related literature is multipurpose cadastre (MPC). The more frequent use of this term resulted from the publication of two National Research Council reports on multipurpose cadastre in 1980 and 1983. However, there is clearly resistance to the use of the term multipurpose cadastre and the term multipurpose land information system (MPLIS) now appears to be more widely accepted.

In spite of the resistance to the use of the term multipurpose cadastre, an understanding of the origins of the terms are useful to a fuller grasp of the GIS field. Originally the term cadastre was limited to a record of areas and values for taxation, but cadastre has now evolved to include identification and description of particular pieces of land and the rights in that land. MPC can thus serve as a continuous record of rights and attributes of land parcels. An MPC, as the name implies serves two or more purposes and can relate data about such things as ownership, taxation, environmental resources and other related items. The key to these multiple uses, and the analytical capability noted earlier is the use of a common spatial framework, e.g., the National Geodetic Reference System (NGRS).



# Concept for a Multipurpose Land Information System

**Section 22, T8N, R9E, Town of Westport, Dane County, Wisconsin**

| **Data Layers:** | **Responsible Agency:** |
|---|---|
| A. Parcels | Surveyor, Dane County Land Regulation and Records Department. |
| B. Zoning | Zoning Administrator, Dane County Land Regulation and Records Department. |
| C. Floodplains | Zoning Administrator, Dane County Land Regulation and Records Department. |
| D. Wetlands | Wisconsin Department of Natural Resources. |
| E. Land Cover | Dane County Land Conservation Committee. |
| F. Soils | United States Department of Agriculture, Soil Conservation Service. |
| G. Reference Framework | Public Land Survey System corners with geodetic coordinates. |
| *H. Composite Overlay* | *Layers integrated as needed, example shows parcels, soils and reference framework.* |

**Figure 1.** Concept for a multipurpose land information system

## III. Multipurpose Land Information System Framework

As GIS, LIS, and MPC systems have developed, it is apparent that the differences in definitions among them are blurred, and moreover, will continue to become more blurred in the future. It is likely that the distinctions among spatial data systems will eventually disappear altogether. Therefore, an understanding of the general concepts on which these systems are built is more important than the definitions themselves.

Two projects have been carried out in Wisconsin during the last 6 years to develop and test an MPLIS. These projects are truly interdisciplinary, with a number of University departments, local government departments, and state and Federal agencies all cooperating. These projects, the Dane County Land Records Project and the CONSOIL (Conservation of Natural Resources Through the Sharing of Information Layers), included development of a state-of-the-art MPLIS for Dane County, as well as several statewide "layers" of digital data including wetlands and similar resource data. One of the major results of this developmental work is the MPLIS concept illustrated in Figure 1. Each of the layers in this diagram represents a separate digital file, maintained by a particular office or agency of local, state, or Federal government. The seven layers depicted in this model MPLIS include data from five separate offices in Federal, state, and local governments.

This MPLIS model pulls together much of what we know about GIS, both as to the data they contain, how they are to be maintained, and the structure of the systems themselves. The layers in MPLIS are built on the land survey network (i.e. the National Geodetic Reference System), which provides the foundation for the entire system. That is, the survey control points serve as the "pins" by which we can tie any two or more of these layers together. This ability to register data, i.e., link layers we want to include in our analysis, is the critical part of the system. This structured spatial relationship is what distinguishes a true GIS or MPLIS from simpler spatial data systems like CAD and CAM systems mentioned earlier. MPLIS also has the capability of linking both digital data files (e.g., maps or other digitized information) with tabular data files (e.g., nongraphic files containing attribute data about particular ownership parcels or resource polygons).

Ownership parcels typically are outlined by a series of corners and straight lines that connects them (a square is a simple example of an ownership parcel). Resource polygons are generally much more irregular, with many curving lines and few straight edges. Resource polygons are are exemplified by soils maps that contain many irregular polygons in a wide variety of sizes (areas).

Finally, the list of agencies and offices that cooperated in the Dane County Land Records Project, shown at the bottom of Figure 1, should be noted. Each of these agencies provided the original data that were converted into digital form. Each agency is responsible for preparation of the data before conversion to digital form, for review of the digital product after conversion, and most importantly, for being the custodian of the digital file once it is ready for access by all users of the MPLIS. The MPLIS relies on these distributed data files that are shared by a wide variety of users at all levels of government.

## IV. Applications, Evaluation, and Results

The development and use of GIS are exploding at all levels of government. For instance, a recent inventory of GIS use in the Federal government was conducted by the Federal Interagency Coordinating Committee on Digital Cartography (FICCDC, 1988). Of the 44 Federal organizations that responded to this 1988 survey, 37 indicated they either were using or intend to use a GIS. Further, 12 reported they were already using a GIS in an operational mode, and 31 reported they are using existing data sets from at least one other organization.

Federal expenditures are also increasing at a rapid rate, with fiscal year (FY) 88 GIS expenditures amounting to $50-55 million. FY 89 expenditures are expected to increase by another $10 to $15 million. Within the next 2 to 3 years, GIS expenditures at the Federal level are expected to jump significantly. For instance, the Office of Management and Budget estimates that by 1992, the expenditures in "electronic mapping databases" alone will amount to $200 million annually (Arthur, 1989). This is double the $99 million spent in FY 88, with expenditures for the 1988-92 period to total an estimated $760 million. (These data do <u>not</u> include national security expenditures.)

As these data suggest, several Federal agencies are putting major resources into LIS/GIS development. For example, the Forest Service in the U.S. Department of Agriculture is moving forward with a plan to implement an agency-wide GIS in 1991. As managers of nearly 200 million acres of public land, 103,000 miles of trails, 340,000 miles of roads, and 348 wilderness areas, the Forest Service has massive files of spatial data to manage. These files are used by 30,000 employees in approximately 800 offices located throughout the United States and its territories (Hartgraves, 1989, p. 1). The Forest Service has already invested $125 million in information technology to improve the quality of data and make them more accessible to managers throughout the agency. Current plans are to award a major GIS contract in 1991 to further enhance existing capabilities. This contract will require the expenditure of an additional $113 million in FY 88-92 (Arthur, 1989).

The Department of the Interior, the other major Federal land management agency, is developing its own GIS program of similar scope and magnitude. FY 88-92 expenditures by the Bureau of Land Management (BLM) on the Automated Land and Minerals Records System (ALMRS) will total $97 million (Arthur, 1989). A second Interior program, to develop a National Digital Cartographic Data Base, will require expenditures of $228 million in the 5-year 1988-92 time period. Development of the data base is a cooperative effort supported by BLM and the U.S. Geological Survey (USGS).

A second cooperative GIS project in which USGS is currently involved is the development of the 1990 Census Support Systems with the U.S. Department of Commerce. Much of the $177 million expenditure in the FY 88-92 time period is related to building a system for the 1990 Census. The Topologically Integrated Geographic Encoding and Referencing (TIGER) system was described by Robert Marx in a paper presented at the Symposium on The Potential for Geographic Information Systems in Agricultural Economics (Marx, 1989).

The major Federal GIS development efforts noted above are focused to a large extent on GIS data bases. Data bases are an important aspect of GIS development, and one that requires the bulk of GIS costs. Data base development typically makes up 75 percent or more of total GIS costs. However, in terms of long run implications for widespread use of GIS, some of the more exciting activities involve cooperative efforts among the Federal, state, and local governments to develop GISs.

Several Federal agencies have on-going programs that provide funding and technical assistance to states and counties to facilitate GIS/LIS development. For example, the National Geodetic Survey (NGS) provides technical assistance, through a system of state advisors, to state and local agencies. The NGS state advisors, currently in 25 states, are Federal employees, with states providing partial reimbursement to NGS for their services. NGS is also supporting a series of pilot projects by providing funding and direct services to state and local governments engaged in the development of an MPLIS. The national headquarters office of NGS also provides technical assistance to these pilot projects on an as-needed basis.

As a result of these pilot projects, many state and local agencies have made major strides in developing GIS/LIS. Also, NGS is sharing the results of the lessons learned in several ways, including support for a newsletter that provides a method to distribute information about the pilot projects. Hopefully, the sharing of pilot project results will result in time savings and prevent "newcomers" from making the same mistakes that others have made earlier.

BLM also works with local and state governments, providing funding and technical assistance to facilitate the development and use of LIS. (LIS is used here specifically to distinguish the parcel-based systems to which BLM is devoting attention and resources.) BLM has provided the leadership for efforts to develop digital Public Land Survey System data bases to support LIS in New Mexico. Work on analysis of the cadastral and related layers in the State of Washington has also been supported by BLM (Moyer, 1989).

One additional noteworthy activity at the Federal level that is providing coordination and assistance regarding GIS/LIS is the work of the Federal Geodetic Control Committee (FGCC). FGCC consists of representatives from 11 Federal departments and agencies with geodetic and related land survey system activities and interests. One of the many current FGCC projects is the preparation of "The Multipurpose Land Information System Guidebook". The purpose of the Guidebook is to aid government agencies, particularly at the local and state levels, in the development of modern, automated LIS (Moyer, 1989, p. 9).

The assistance programs of Federal agencies are proving valuable to state and local government in developing GIS/LIS, and to the Federal agencies themselves as specific data sets can be shared more rapidly and more effectively. Also, some of the cooperative GIS/LIS work has produced systems that have already proven to be valuable in the development and evaluation of government programs and policies at the Federal and state levels.

For example, some of our recent work at the University of Wisconsin involves evaluating the impact of soil conservation provisions of the 1985 Farm Security Act (FSA). This capability was the result of earlier work on the development of a prototype GIS/LIS for Dane County, Wisconsin.

## V. The Wisconsin Project

The prototype system grew out of the Dane County Land Records Project (DCLRP), a 4-year effort involving local, state, Federal, and private interests. The initial agreement in 1983 involved Dane County, the University of Wisconsin, Soil Conservation Service, and the Wisconsin Department of Natural Resources. Other agencies became involved as the project progressed. The goal of DCLRP was to demonstrate the utility of an MPLIS for managing local land records and for integrating these records for land planning (Niemann, et. al., 1987).

The basic operating concept for DCLRP included two primary components. First, the agency having the legal mandate to collect and store a particular set of spatial information should be responsible for maintaining its individual data layers in a digital form. Second, a mathematical reference framework should provide the linkage between layers (Chrisman, et al., 1984). (See Figure 1.) In DCLRP, all seven layers of data shown in Figure 1 were compiled in automated form for three PLSS townships.

DCLRP also investigated the latest technologies available to capture and manage the layered data, including geopositioning technologies (such as the Global Positioning System), data scanning, and remote sensing (Niemann, et al., 1987). The project demonstrated that use of the technologies was feasible and identified a number of major institutional issues that must be considered.

In 1984, while DCLRP was underway, the State of Wisconsin implemented Administrative Rule 160, calling for erosion control plans to be completed for 54 of Wisconsin's 72 counties by 1987. The mandate required not only that an erosion control plan be developed for each county, but also that the plan be sufficiently detailed to identify individual ownership parcels where erosion standards were not being met (Wisconsin Administrative Rules, Ag160.05(4b), 1984). This meant that in order to comply with the mandate, it was necessary to spatially integrate soil survey data and land ownership data. Because of earlier work on DCLRP, Dane County chose to complete the necessary data layers for the entire county and use its MPLIS to develop the county erosion control plan (Chrisman et al., 1986).

While the erosion planning process was underway, Wisconsin passed additional legislation requiring that in order to be eligible for income tax credits under the State's Farmland Preservation Program, landowners had to be in compliance with erosion control standards and zoned so as to ensure that their land would remain in agriculture. These cross-compliance requirements meant that additional data be linked in the LIS. This also proved to be only the first of several cross-compliance provisions developed by state and Federal lawmakers.

The 1985 Food Security Act (FSA) passed by Congress contained additional cross-compliance provisions. FSA moved to further restrict the tillage of marginal farmland, included "Sodbuster" provisions to address highly erodible lands, and a "Swampbuster" provision to address the drainage of wetlands. These provisions required that conservation districts integrate resource information on soils with information on owners and land users who received <u>any</u> Federal farm program benefits. Because the data integration required by FSA was similar to the earlier Wisconsin requirements, DCLRP provided an ideal base to demonstrate that a MPLIS could respond to these requirements efficiently and equitably.

While Congress was preparing the 1985 Food Security Act, one of the Congressional staffers involved saw a demonstration of the Dane County Land Information System. He recognized the potential of the land information system in assisting the development, evaluation, and implementation of such policies. We hope to continue to refine the Dane County System with additional 1990 Farm Bill analyses.

Because of our success at implementing and evaluating agricultural policy, we are currently discussing further funding to support additional work involving the 1990 Farm Bill. It is gratifying to see the recognition by Congress of the potential uses of MPLIS in the policy arena. The impact at the local and state levels is equally important.

One key result in the Dane County erosion control planning process was the ready acceptance of the plan. One of the major reasons for acceptance was the feeling by farm owners that the plan was equitable, because the automated MPLIS had helped assure that everyone would be treated fairly.

A second key result was the increased efficiency that was realized in the Dane County Land Conservation Committee (LCC) office, that is responsible for developing the plans, getting them implemented, and monitoring compliance. For instance, the Dane County Erosion Control Plan (DCECP), developed in an automated mode, was comparable in cost to other counties that used manual techniques (Moyer, 1988). The DCECP experience demonstrated that automated systems were not too costly for county government to consider. Also, the productivity of LCC jumped dramatically when the automated system was adopted for its on-going planning functions in the office. The number of farm plans per employee increased five-fold, and total plans developed in Dane County amounted to 20 percent of all plans developed in the state.

Third, the Dane County LIS has been successfully used to demonstrate to farm operators the economic feasibility of alternative approaches to farm management. For example, comparisons were made among several cropping patterns and several management techniques. The results, based on analyses using the "layered" model, demonstrated to farm operators the economic feasibility of using practices that reduced soil erosion, yet still provided net income levels similar to those received when using earlier, more erosive techniques.

The Wisconsin experience demonstrates that Geographic Information Systems are an important new technology that have many important uses in agriculture and rural resource management. We have only begun to tap the potential of these systems, but the implications for providing better information, more efficiently, in a more timely fashion to decisionmakers are clear. Additional work, ranging from assistance in Federal farm policy development and evaluation, to monitoring the quality of ground water, is already underway in Wisconsin. I invite you to consider how you can incorporate the concept of MPLIS into the many aspects of your work that would benefit from this major improvement in the handling of spatial data.

# REFERENCES

Arthur, Jack, 1989, Results of OMB's Electronic Mapping Data Base Survey, in proceedings of National Conference on GIS, Charting the Future of the Federal Government, Vienna, VA, March.

Binns, Sir Bernard O., 1953, Cadastral Surveys and Records of Rights in Land, FAO Agricultural Series No. 18, Food and Agricultural Organization of the Untied Nations, Rome, Italy.

Chrisman, N.R., D.F. Mezera, D.D. Moyer, B.J. Niemann, Jr., A.P. Vonderohe, 1984, Modernization of Routine Land Records in Dane County, Wisconsin: Implications to Rural Landscape Assessment and Planning, URISA Professional Paper 84-1, Washington, D.C. 44 pp.

Chrisman, N.R., D.F. Mezera, D.D. Moyer, B.J. Niemann, Jr., J.G. Sullivan, A.P. Vonderohe, 1986, Soil Erosion Planning in Wisconsin: Order of Magnitude Implications of Integrating New Technologies, 1986 URISA Proceedings, Volume I, pp. 117-129.

Dowson, Sir Ernest and V.L.O. Sheppard, 1952, Land Registration, Colonial Research Publication No. 13, Her Majesty's Stationary Office, London.

Federal Interagency Coordinating Committee on Digital Cartography, 1988, A Summary of GIS Activities in the Federal Government, Reports Working Group, August, 45 pp.

Hartgraves, Charles R., 1989, The Forest Service Future Information Environment, in proceedings of National Conference on GIS, Charting the Future of the Federal Government, Vienna, VA, March.

Marx, Robert, 1989, Applications of the Census Bureau's 'TIGER' Files in a Geographic Information System, paper delivered to the Symposium on The Potential for Geographic Information Systems in Agricultural Economics, Baton Rogue, LA, August.

Moyer, D. David, 1989, The Role of URISA as An Association in Geographic Information Systems, in proceedings of National Conference on GIS, Charting the Future of the Federal Government, Vienna, VA, March.

Moyer, D.D., B.J. Niemann, Jr., R.F. Gurda, S.J. Ventura, 1988, Comparing the Costs: Manual Versus Automated Procedures for Handling Land Records, in Technical Papers of 1988 ACSM Annual Convention, Volume 5, GIS, St. Louis, pp. 198-206.

National Research Council, 1983, Procedures and Standards for a Multipurpose Cadastre, National Academy Press, Washington, D.C.

Niemann, B.J., Jr., J.G. Sullivan, S.J. Ventura, N.R. Chrisman, A.P. Vonderohe, D.F. Mezera, D.D. Moyer, 1987, Results of the Dane County Land Record Project, Photogrammetric Engineering and Remote Sensing, Volume 53, No. 10, October, pp. 1371-78.

Parker, H. Dennison, 1988, The Unique Qualities of a Geographic Information System: A Commentary, in Photogrammetric Engineering and Remote Sensing, Volume 54, No. 11, November, pp. 1547-49.

Wisconsin Administrative Rules, 1984, Chapter Ag 160, Soil Erosion Control Program.

# THE CENSUS BUREAU'S TOPOLOGICALLY INTERGRATED GEOGRAPHIC ENCODING AND REFERENCE SYSTEM

## Putting People in your GIS

Robert Marx

Geography Division
Bureau of the Census
Washington, D.C.

## Putting People in Your GIS

It's very appropriate that I should have the opportunity to deliver this talk at this location -- the campus of LSU and its famous Tigers.

A figure famous to geographers, Gilbert M. Grosvenor, President and Chairman of the illustrious National Geographic Society, frequently says, "If you don't know where you are, you're nowhere." In GIS, we can start to find the answer.

While it's nice to know where you are, it's even nicer to have some idea of where you are going. Many years ago Cervantes, the creator of that crazy but occasionally profound dreamer Don Quixote, recognized the value and intrigue of maps by exclaiming that "...in a map, one could journey over all the universe, without the expense and fatigue of traveling, without suffering the inconveniences of heat, cold, hunger, and thirst."

Even in his wildest dreams, old Don Quixote could not have conceived of the maps people are creating these days. Using computerized mapping and geographic information system techniques, we can travel from the vastness of outer space, toward the earth, seeing more and more detail, travelling through the familiar range of small-scale maps and larger-scale maps to the other end of the map scale continuum, where humans constantly strive for greater and greater detail, which demands greater and greater accuracy in observation and measurement.

And that brings me to the subject of geographic information systems (GIS). What does this have to do with GIS, you ask? And what does GIS have to do with the American Agricultural Economics Association? Well, that depends on your definition of a GIS.

The debate goes on endlessly. Some argue that the only "true" GIS is a system that processes overlays of information; others contend that a GIS must include natural resources data. Still others argue endlessly about the level of accuracy one needs in the coordinates of the features and data polygon boundaries, and I'm sure you are aware of the enormous amounts of energy people are expending these days to study the physical conditions that surround us under the rubric of "global change." Using a GIS certainly will help in these studies.

I believe that GIS technology can help you. It is in this context that I want to suggest another definition -- perhaps a bit more generic: "A GIS is a computer system that helps us discover relationships between and among sets of data that we could not see or understand before." In this broader context, I believe all the preceding views of a GIS are missing one important ingredient -- people!

People inhabit almost every part of the earth. They either affect what is going on or are affected by what is going on. This is even more stunning when you stop to realize that in the next 50 years, the earth's population will double. This growth likely will continue the dramatic shift from rural settlement to urban settlement -- the urban population of the world likely will triple in the same 50 years. Certainly these shifts are having...and will continue to have...a dramatic affect on the agricultural production and consumer demand situations. As a result, I suggest that people must be a "layer" in your thinking about GIS.

"People" information traditionally has not been in a form that computers could process conveniently in a GIS context. On the natural resources side of the aisle, we have satellite imagery and, as Carl Sagan would say, its "billions and billions" of pixels. I'd like to extend the notion of pixels to the context of people in a GIS and coin a new term -- censels.

The way in which the Census Bureau collects and tabulates data is by "polygon" -- just like those people collecting and studying soils or land use/land cover information. More importantly, in creating "people polygons," the Census Bureau routinely uses the same earth surface features most people want -- and include -- in their GIS: streets, roads, streams, railroads, governmental unit boundaries, and so forth. And this leads me to a discussion about tigers!

People normally visualize a tiger as a large, yellow, cat-like animal with black stripes. The TIGER to which I refer is an altogether different creature. It is an acronym we at the Census Bureau created to refer to our new computerized geographic support system; the Topologically Integrated Geographic Encoding and Referencing System. The TIGER System is not a GIS, per se. It is a very valuable source of information that can form one important component of a GIS. Let me explain.

The Geography Division, one component of the Census Bureau, developed the TIGER System in response to a major goal the agency set in 1981: to automate the full range of cartographic and geographic support processes in time to serve the data collection, tabulation, and dissemination needs of the 1990 decennial census -- the bicentennial census of the United States.

The charge included having the first geographic products from the TIGER System ready when the preparatory field activities for the 1990 census began in early 1988. This gave the Geography Division:

- Six short years to design, develop, test, and implement a computer data base like none in existence before: a data base that would handle both the cartographic and geographic tasks for which we are responsible.

- Six short years to identify, procure, install, and learn to use the graphic work stations, computer-driven plotters, and new host minicomputers required to build and use the TIGER data base.

- Six short years to build a computer file containing every known street and road in the United States, the name of each, and the range of address numbers located along each section of every street in the 345 largest urban areas of the United States.

- Six short years to include all the railroads in the United States and the names of their operating companies, along with all significant hydrographic features and their associated names.

To create an automated map base of this magnitude, the Census Bureau entered into a major cooperative agreement with the U.S. Geological Survey -- our Nation's map maker. Under the terms of the agreement, the USGS used its automated scanning equipment and sophisticated computer processing techniques to convert the roads, rivers, lakes, railroads, and so forth on its conventional maps for the lower-48 states into computer files.

In this era of limited resources, especially for those of us in public service positions, such sharing is critical. This process provided a fully sufficient cartographic base for taking a census -- even at the city block level. I suggest that TIGER -- the derived cousin of the USGS files -- will provide a fully adequate base for most agricultural planning applications. But I digress...

The Census Bureau followed the production steps of the cooperative project with the vertical integration of the separate USGS data layers and the update of the street network in these files with new streets, street names, and address ranges, using source materials collected from city, county, and state governments. We followed this with the horizontal integration and edge matching of the adjacent enhanced USGS files with the updated GBF/DIME-Files prepared for earlier censuses -- to form county-based files rather than quadrangles, the format in which the information came from the USGS.

- In addition to building an up-to-date feature base for the whole U.S., we had six short years to enter and verify the boundaries, names, and numeric codes for all the geographic areas used by the Census Bureau to tabulate the results of both the 1980 and 1990 censuses -- which also provides the more limited set used for the agriculture censuses.

I am delighted to report that this development task is complete; the overall goal, nearly met. I'm telling you all this background of the TIGER System because the TIGER data base structure provides a bold new approach in automated cartographic and geographic files. It adapts the theories of topology, graph theory, and associated fields of mathematics to provide a disciplined, mathematical description of the geographic structure of the United States. (See Figure 1)

At the base of this structure, and linking all other components together, is the spatial or geometric framework. The spatial information in the TIGER data base includes the coordinate locations of all known street intersections -- and the points at which streets cross rivers, railroads, and other mapped features -- roughly 28 million points. It also includes the information that shows which of those points are connected by the 40 million lines that define the transportation and hydrography network of the United States and which sets of those lines enclose the 12 million polygons that comprise the TIGER data base.

The TIGER data base is much more than points, lines, and areas, however. The majority of the TIGER data base structure is composed of the attributes describing the various components of the spatial structure. It is this specific set of attributes that make the TIGER data base useful for the Census Bureau; and it is this set of attributes that will put people into GISs. Let me describe these attributes briefly.

First, the feature attributes. This information includes street names and river names along with address ranges and ZIP codes. It also includes landmarks -- named areas such as major parks and military bases -- plus named apartment and office buildings that are important as alternate ways to address mail; for example, the Empire State Building in New York City or the Premier Tower here in Baton Rouge.

Most importantly, the attributes in the TIGER data base include all the geographic entities for which the Census Bureau tabulates the data it collects. We have included both the 1980 census set of areas and the 1990 census set. (See Figure 2) These geographic entities are the "censels" I discussed earlier. Each censel has a string of data associated with it in Census Bureau data files -- just like a pixel in a satellite transmission. There are nearly 3,300 censels that we call counties -- but that's pretty coarse resolution for people characteristics.

There are over 39,000 units of local government subdividing those 3,300 counties -- townships and cities and villages. They provide more than a 10-fold increase in the number of censels, but still offer fairly coarse resolution. On the plus side, demographic data are available for all of these governmental units and economic data are available for many of them.

To zoom in closer, there are over 65,000 census tracts for the 1990 census -- a big increase over the 1980 census because these areas (and their cousins -- the block numbering areas) cover the entire

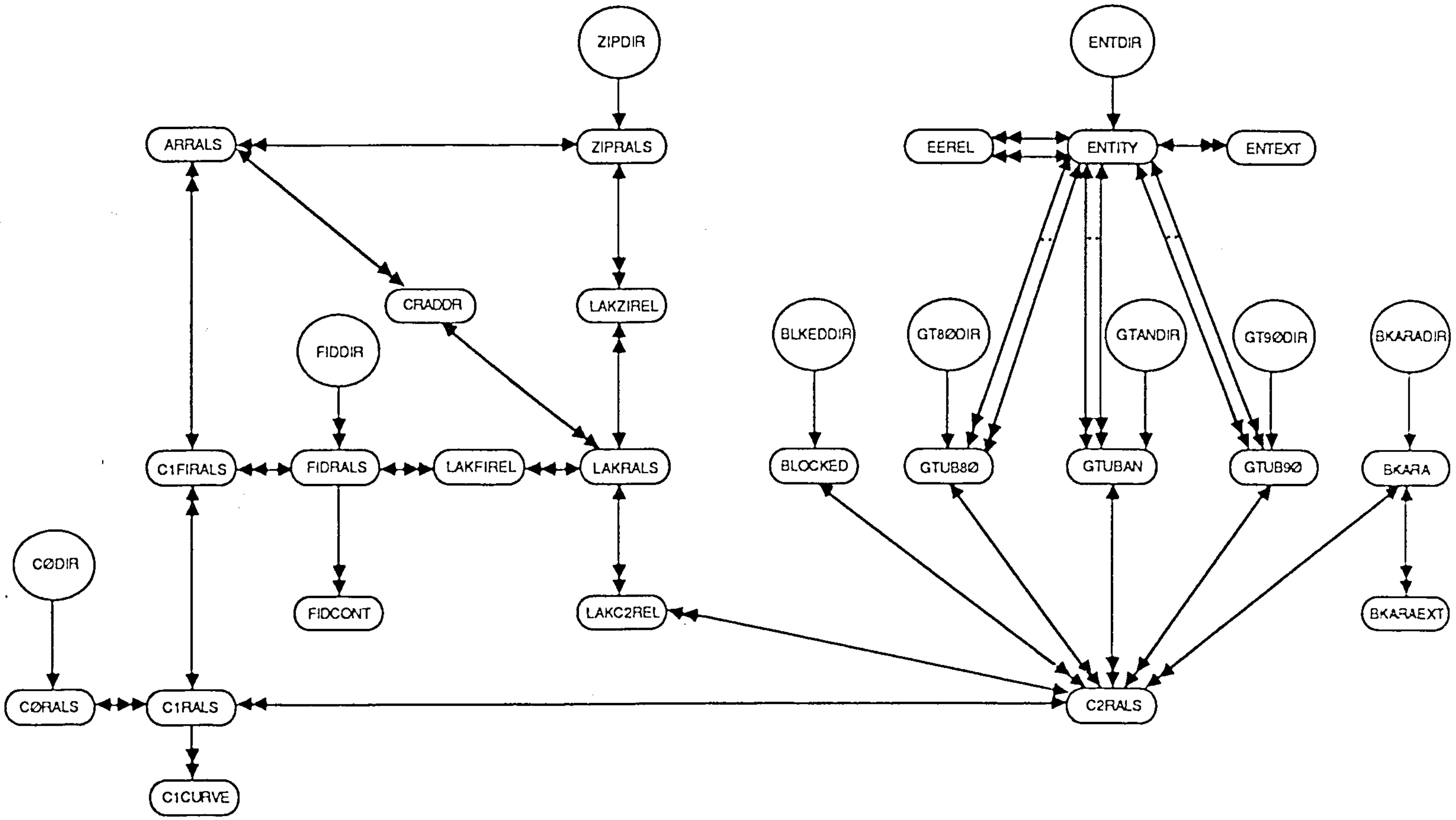


Figure 1: TIGER Data Base Structure

**KEY TO SYMBOLS:**

▭ RANDOM ACCESS LOGICAL SUBFILE ○ BALANCED-TREE DIRECTORY

——▶ ONE-TO-ONE RELATIONSHIP ——▶▶ ONE-TO-MANY RELATIONSHIP

◀——▶▶ ONE-TO-MANY RELATIONSHIP WITH MEMBER POINTING BACK TO ITS OWNER

•• PARALLEL MULTIPLE LINKAGES

**KEY TO SUBFILE ABBREVIATIONS:**

ARRALS - ADDRESS RANGES
BKARA - 1990 BLOCK/ADDRESS REGISTER AREA (ARA)
BKARADIR - 1990 BLOCK/ARA DIRECTORY
BKARAEXT - 1990 BLOCK/ARA EXTENSION
BLKEDDIR - 1980 BLOCK/ENUMERATION DISTRICT DIRECTORY
BLOCKED - 1980 BLOCK/ENUMERATION DISTRICT
C0DIR - 0-CELL DIRECTORY
C0RALS - 0-CELL
C1CURVE - 1-CELL CURVATURE
C1FIRALS - 1-CELL/FEATURE IDENTIFIER RELATIONSHIP

**KEY TO SUBFILE ABBREVIATIONS (CONTINUED):**

C1RALS - 1-CELL
C2RALS - 2-CELL
CRADDR - CROSS-REFERENCE ADDRESS
EEREL - ENTITY TO ENTITY RELATIONSHIP
ENTDIR - GEOGRAPHIC ENTITIES DIRECTORY
ENTEXT - GEOGRAPHIC ENTITIES EXTENSIONS
ENTITY - GEOGRAPHIC ENTITIES
FIDCONT - FEATURE NAME CONTINUATION
FIDDIR - FEATURE IDENTIFIER DIRECTORY
FIDRALS - FEATURE IDENTIFIER
GT80DIR - 1980 GEOGRAPHIC TABULATION UNIT BASE DIRECTORY
GT90DIR - 1990 GEOGRAPHIC TABULATION UNIT BASE DIRECTORY
GTANDIR - 1990 ANCILLARY GEOGRAPHIC TABULATION UNIT BASE DIRECTORY
GTUB80 - 1980 GEOGRAPHIC TABULATION UNIT BASE
GTUB90 - 1990 GEOGRAPHIC TABULATION UNIT BASE
GTUBAN - 1990 ANCILLARY GEOGRAPHIC TABULATION UNIT BASE
LAKC2REL - LANDMARK, AREA, KEY GEOGRAPHIC LOCATION/2-CELL RELATIONSHIP
LAKFIREL - LANDMARK, AREA, KEY GEOGRAPHIC LOCATION/FEATURE IDENTIFIER RELATIONSHIP
LAKRALS - LANDMARKS, AREAS, KEY GEOGRAPHIC LOCATIONS
LAKZIREL - LANDMARK, AREA, KEY GEOGRAPHIC LOCATION/5-DIGIT ZIP CODE RELATIONSHIP
ZIPDIR - ZIP CODE DIRECTORY
ZIPRALS - ZIP CODE

United States. These census tracts and BNAs are subdivided into over 200,000 block groups that further segment the governmental units for purposes of data presentation. At this level, a GIS user has access to the full range of decennial census responses -- 100 percent and sample.

Finally, there are between 7 and 9 million census blocks -- people polygons -- for which we will tabulate the 100 percent data from the 1990 census. As with the census tracts, this represents a huge increase over the 1980 census when block-level data were available primarily for the urban cores of metropolitan statistical areas. These "millions and millions" of blocks provide a very fine-grained censal resolution to the demographic data sets available from the Census Bureau.

The TIGER System links the Census Bureau's geographic areas directly with this network of features, and thus, to many other data sets available in a local GIS. The codes used to identify the Census Bureau's geographic areas provide the capability for a computer to link with, and perform analyses on, the data sets that flow from the decennial, economic, and agriculture censuses, and from the Census Bureau's sample surveys.

In earlier days, we thought about such uses in terms of thematic maps and struggled to get the computer to help us with limited data sets. For a GIS user now days the problem is not a lack of data in machine-readable format nor a lack of computer hardware on which to process those data. Quite the opposite -- asking for an item of Census Bureau data can be likened to trying to take a sip of water from a fire hydrant!

In a GIS environment, one can examine other geographically distributed data sets -- soil categories, hazardous wastes, water quality, land use/land cover, and so forth -- in the context of the governments responsible for managing an area, and in the context of the characteristics of the people who occupy the land, their farms, their business, and their industrial activity. The feature and landmark attributes discussed earlier provide an additional linkage mechanism to local data sets.

Knowledge of these landmarks may be a critical piece of information in understanding other component information in a GIS, such as explaining why housing units in the center of a city have incomplete plumbing -- because they are student housing near the university where the students share these facilities.

The TIGER data base, the demographic, economic and agricultural statistics available from the Census Bureau, the geographically referenced information maintained by state and local governments, and the analytical power available to study the interrelationships of

### POLITICAL AREAS

- United States
- States & State Equivalents ( 57 )
  - States ( 50 )
  - District of Columbia (1)
  - Outlying Areas ( 6 )
- Counties, Parishes, & Other County Equivalents ( 3,231 )
- Minor Civil Divisions — MCD ( 30,491 )
- Incorporated Places ( 19,176 )
- American Indian Reservations ( 275 )
  - Indian Subreservation Areas ( 228 )
- Alaska Native Villages ( 209 )
- Congressional Districts — CD ( 435 )
- Election Precincts ( 36,361 ) [In 23 participating States]
- School Districts (16,075)
- Neighborhoods (28,381 )
- ZIP Codes ( ≅ 37,000 )

### STATISTICAL AREAS

- Regions ( 4 )
- Divisions ( 9 )
- Standard Consolidated Statistical Areas — SCSA ( 17 )
- Standard Metropolitan Statistical Areas — SMSA ( 323 )
- Urbanized Areas — UA ( 373 )
- Census County Divisions — CCD ( 5,512 )
- Unorganized Territories ( 274 )
- Census Designated Places — CDP ( 3,733 )
- Census Tracts ( 43,383 )
- Block Numbering Areas — BNA ( 3,404 )
- Enumeration Districts — ED ( 102,235 )
- Block Groups — BG ( 156,163 )
  - ( Tabulated parts —( 197,957 )
- Blocks ( 2,473,679 )
  - ( Tabulated parts — 2,545,416 )
- Traffic Analysis Zones (≅160,000)

Figure 2: 1980 Census Geographic Areas

these data sets using the GIS technology now available in the private sector to merge and manipulate these massive and diverse data sets, make better understanding a very real possibility.

Meetings such as this promote the exchange of ideas that will lead, ultimately, to much more powerful and productive systems. The TIGER data base is available now. Many of the GIS vendors already have interfaces prepared to read the TIGER/Line files -- the first public version of TIGER -- into their GIS. Many of the other vendors have development of such interfaces underway. For more information on the TIGER/Line files contact the staff at the address and telephone number shown below.

State and Regional Programs Staff
Data User Services Division
Bureau of the Census
Washington, D.C. 20233

(301) 763-1580

## Reference Materials

Boudriault, G., *Topology in the TIGER File*, **Proceedings: Eighth International Symposium on Computer Assisted Cartography**, pp. 258-263, 1987

Broome, F. R., Beard, C., and Martinez, A., *Automated Map Inset Determination*, **Proceedings: Eighth International Symposium on Computer Assisted Cartography**, pp. 466-470, 1987

Callahan, G. M. and Marx, R. W., *The 1:100,000-Scale Data Base: Implications for GIS in Illinois*, **Illinois Mapnotes**, Issue Nos. 10/11, pp. 6-8,1988

Fairchild, D., *The Display of Boundary Information: A Challenge in Map Design in an Automated Production System*, **Proceedings: Eighth International Symposium on Computer Assisted Cartography**, pp. 456-465, 1987

Kinnear, C., *The TIGER Structure*, **Proceedings: Eighth International Symposium on Computer Assisted Cartography**, pp. 249-257, 1987

LaMacchia, R. A., Tomasi, S. G., and Piepenburg, S. K., *The TIGER File: Proposed Products*, paper distributed at the National Conference of State Legislatures, November 1987

Martinez, A., *Application of Expert Rules in Automated Cartography*, paper presented at the 10th Annual Applied Geography Conference, October 1987*

Marx, R. W., *Computer Mapping and the Census Bureau: The Future and You*, paper presented at the AM/FM International Eastern Regional Conference, Williamsburg, Virginia, May 1986 *

Marx, R. W., *LIS/GIS Activities of the United States Census Bureau*, paper presented at an information exchange sponsored by the United States Embassy, Bonn, Federal Republic of Germany, November 1988

Marx, R. W., *The TIGER File Supports Census Bureau Tests*, **Illinois Mapnotes**, Issue No. 9, pp. 2-5, Winter 1987

Marx, R. W., *The TIGER System: Automating the Geographic Structure of the United States Census*, **Government Publications Review**, Vol. 13, pp. 181-201, 1986

Marx, R. W., *The TIGER System: Six Years to Success*, presented at the 13th International Conference of the International Cartographic Association, Morelia, Mexico, October 1987

Marx, R. W., *TIGER: An Automated Cartographic/Geographic Data Base,* **Illinois Mapnotes**, Issue No. 6, pp. 1-2, Spring 1985

Marx, R. W. and Saalfeld, A. J., *Programs for Assuring Map Quality at the Bureau of the Census*, **Proceedings of the 4th Annual Research Conference**, pp. 239-259, 1988

McDowell, T., Meixler, D., Rosenson, P., and Davis, B., *Maintenance of Geographic Structure Files at the Bureau of the Census*, **Proceedings: Eighth International Symposium on Computer Assisted Cartography**, pp. 264-269, 1987

McKenzie, B. Y. and LaMacchia, R. A., *The U.S. Geological Survey-U.S. Bureau of the Census Cooperative Digital Mapping Project: A Unique Success Story*, paper presented at the Fall Meeting of the American Congress on Surveying and Mapping, Reno, Nevada, October 1987

Meixler, D. and Saalfeld, A. J., *Polygonization and Topological Editing at the Bureau of the Census*, **Proceedings: Eighth International Symposium on Computer Assisted Cartography**, pp. 731-737, 1987

Sobel, J., *Principal Components of the Census Bureau's TIGER File*, **Research in Contemporary and Applied Geography: A Discussion Series**, Vol. X, No. 3, pp. 1-16, 1986

Trainor, T. F., *Attribute Coding Scheme: Identification of Features in the U.S. Census Bureau's TIGER System*, **Proceedings: AUTO CARTO London 86**, Vol. 1, pp. 117-126, September 1986

U.S. Bureau of the Census, *TIGER Tales*, Washington, DC 20233 *

U.S. Geological Survey, *1:100,000-Scale Digital Cartographic Data Base For Federal Requirements*, **Year Book, Fiscal Year 1984**, Reston, Virginia 22092

Wanie, T. L., *Estimating Production Parameters For Large-Volume Automated Mapping on a Raster Plotter*, **Proceedings: Eighth International Symposium on Computer Assisted Cartography**, pp 270-277, 1987

White, M. A., *Technical Requirements and Standards for a Multipurpose Geographic Data System*, **The American Cartographer**, 11, 1, pp. 15-26, 1984

* A package of all unpublished papers is available for $5 from Customer Services, Data User Services Division, Bureau of the Census, Washington, DC 20233, (301) 763-4100.

# APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS TO ANALYSIS OF RURAL ECONOMIC PROBLEMS

E. Jane Luzar

Department of Agricultural Economics and Agribusiness
Lousiana, State University
Baton Rogue, Louisana

# APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS TO ANALYSIS OF RURAL ECONOMIC PROBLEMS*

E. Jane Luzar**

## INTRODUCTION

The application of Geographic Information Systems (GIS) technology to the analysis of rural economic problems is still a relatively new occurrence. Limited familiarity with and access to GIS hardware and software as well as uncertainty regarding "economic" applicability of this form of spatial analysis has undoubtedly contributed to past rates of adoption. However, as the micro-computer revolution has continued to offer increasingly powerful computing at the desktop environment, economic researchers have found GIS more accessible. GIS software designed for the micro-computer has now reached similar levels of accessibility, heightening interest among researchers.

This part of the symposium is designed to familiarize applied economists with some of these developments both in terms of software and hardware, and some potential applications. Throughout this discussion,[1] the Louisiana Agricultural Decision Support System (LADSS) housed within four academic departments and coordinated by the Computer Aided Design and Geographic Information Systems Research Laboratory (CADGIS) at Louisiana State University will serve as a

---

*Paper presented at the Symposium "The Potential for Geographic Information Systems in Agricultural Economics" held during the annual meeting of the American Agricultural Economics Association, July 1989, Baton Rouge, Louisiana.

**Assistant Professor, Department of Agricultural Economics & Agribusiness, Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center.

[1] The AAEA Symposium discussion reported here was supported by a slide show designed to accentuate the graphic potential of GIS applications. In the absence of these slides, more than is preferred is left to the imagination of the reader.

vehicle for demonstrating some of the GIS software and hardware currently available for analysis of rural economic problems.

This discussion will first identify some of the computer hardware used in GIS analysis, ranging from the personal computer to a VAX level system. Industry standard software will be reviewed in the context of some analysis conducted and underway through the CADGIS Lab and LADSS. The discussion concludes with some comments about the future of GIS research in application to rural economic problems.

## The LADSS and CADGIS Lab at LSU

The CADGIS Research Laboratory at Louisiana State University is operated jointly by the Department of Geography, the College of Design, and the College of Agriculture. It supports the instruction and research of faculty and students in mapping, architecture, engineering, and agricultural applications. Its mapping applications encompass computer cartography, geographic information systems, and remote sensing.

The CADGIS lab has a wide complement of hardware associated with its DEC VAX mini-computers, Intergraph workstations, and IBM micro-computers. The CADGIS Lab has an Intergraph system with three central processing units: two Intergraph 730's and one Intergraph 250. The system operates with 16 Megabytes of memory and 1 Gigabyte of disk storage. CADGIS and LADSS operate with one Interview 220 workstation (providing a larger than usual digitizing surface) and a number of Interact 220 Workstations. The Interacts and Interview Workstations have 16 Megabytes of memory and 150 Megabytes of storage.

The addition of Intergraph Interact 220 workstations has added a valuable facet to the CADGIS Lab's processing capabilities. The Interacts can either work as stand-alone units or as processors of data provided by the Microvax II. Unix is the operating system used by the workstations. By using a process called File Management Utilities (FMU), data can be transferred from Unix to DOS and vice versa. The workstations then become interfaces between the two different operating systems.

The Cadgis Lab serves as the central depository for data bases and computer programs. Satellite programs or remote stations are linked to one another and this central depository through a campus-wide fiber optics network. For example, the Department of Agricultural Economics, as a cooperator in LADSS, houses an Intergraph Interact 220 Workstation that is linked via eithernet to 386 micro-computers in individual researcher's offices and the VAX in the CADGIS Lab.

Software for these machines include Intergraph mapping products, ERDAS software for remotely sensed data, other mapping packages such as Atlas Graphics, and other statistical analysis packages. The Department of Agricultural Economics and Agribusiness has recently purchased Intergraph's newest GIS package, MicroStation GIS, to run on its Intergraph Interact 220 Workstation. This package utilizes a relational database, Oracle, for its informational storage. Oracle is widely recognized as the industry standard for relational databases and can be purchased to run on most micro-computers, mini-computers, workstations, and mainframes. SAS has also been added to the workstations, creating a more familiar statistical interface for some Agricultural Economists.

The CADGIS lab also utilizes Earth Resources Data Analysis Systems (ERDAS), a raster analysis package. ERDAS was developed as a tool to collect and analyze data using image processing and computer mapping techniques. ERDAS software was originally conceived as a microcomputer-based systems, but was later adapted to the VAX/VMS system. The CADGIS lab currently utilizes both versions. ERDAS software may be separated into two distinct components, Image Processing and GIS.

Classification of remotely sensed spectral information is the primary function of the Image Processing software. In this context, remotely sensed refers to data collected by high altitude aircraft or satellites such as Landsat or Spot. The GIS element utilizes such operations as overlay, matrix, and proximity while performing analysis of grided polygon data.

The CADGIS Lab's experience goes beyond application of software and hardware as many of the staff members have programming experience in several different computer languages. Customer service libraries from both Intergraph and ERDAS allow the importing and exporting of data from the applications and embed routines within our own FORTRAN programs. An example of such a program is the Intergraph-to-ERDAS (IE) program. Written in the CADGIS Lab, this program allows a user to transfer a grid file generated by the DTM or GDU packages from Intergraph to a file that can be displayed and analyzed by ERDAS programs.

LADSS and the CADGIS Lab also utilize the information and equipment of the Department of Geography and Anthropology at LSU. The Department has a long history of involvement in teaching and research in the fields of air photo interpretation and remote sensing. It also has such image interpretation equipment as light tables, mirror stereoscopes, optical enlargers, and photogrammetric equipment for measuring parallax, distance, areas, and volumes. The Department of Geography and Anthropology also maintains and staffs the Cartographic Information Center (CIC) with a collection of 500,000 maps and over 60,000 aerial photographs. Color and color infrared aerial photographs of Louisiana collected by NASA in the 1970's are stored in the Department's new Remote Sensing Laboratory.

## Data Bases

The CADGIS Lab also has the capability of creating and storing digital data for graphic and nongraphic databases from nondigital sources. Currently, the maps and databases are the products of the staff and students of the client academic units that support the CADGIS lab. A list of data bases currently available to the CADGIS Lab are shown in Tables 1 and 2. As the central GIS facility for the newly formed Louisiana Coastal GIS (LCGIS) network, the CADGIS lab will not only provide storage and indexing for selected coastal databases, but will also provide translators for the different data formats used by LCGIS members, including faculty from the Department of Agricultural Economics & Agribusiness. Translators will be necessary since there are approximately over 80 current users of spatial data from the public and private sectors in south Louisiana concerned with evaluating coastal data.

Data sets are collected from a wide range of sources, including old maps. Existing maps are often digitized through an effective use of student labor. The resulting maps are known as vector maps. Data sets are also collected from other sources such as satellites or high altitude photography, yielding data sets known as raster files.

A number of statewide data sets of interest to the College of Agriculture are being collected in the CADGIS Lab by researchers involved in LADSS. Data bases currently include landuse, soil associations, Louisiana Department of Environmental Quality water management districts, water basins, water quality sample well sites, Department of Natural Resources wildlife habitats, agricultural crop and commodity parish level time series records, and geologic formations. These state level data bases are being combined into a geo-referenced Louisiana Atlas. As all of these Louisiana Atlas data sets are geo-referenced, they all can be compared using some form of x-y coordinate system.

## TABLE 1. Vector Mapping Data Available in the LSU CADGIS Lab: 1989

Airports of Louisiana with database
Aquifer Formations in Northern Louisiana (in progress)
Baton Rouge Downtown Building Map
Census Data for selected parts of Louisiana
Coastline Map of United States Gulf Coast
Climatic data (daily) from 13 state-wide collection points
Commodity Production Database by parish and farming region
Dairy Farm Inventory, Tangipahoa Parish
DEQ Water Segments Map with database
Digital Line Graphs (DLG) for southern half of Louisiana
- Hydrology
- Transportation

DOTD Parish Highway Map of Louisiana(*)
DOTD State Highway Map of Louisiana (*)
East Baton Rouge Parish Maps
- BREC Parks with BREC code numbers
- Council Districts
- Parish Schools with database
- Existing Bikeways
- Floodplains
- Gulf South Utilities Servitudes
- Interstate Highways
- Landmarks and Landmark Codes
- Manmade Water Features
- Natural Water Features
- Railroads
- Secondary Roads
- Tertiary Roads

Geographic Name File for Louisiana (source: U.S.G.S. 1:24000 maps)
Geologic Map of Louisiana (underway)
Landuse of Louisiana based on 1978 data
Louisiana Geological Survey (LGS) Seismic Tracklines Database
Louisiana State University Map
Marine Debris Map (underway)
Micro World Data Bank - world map
Natural Vegetation Map of Louisiana with database
Offshore Lease Block Maps, La. Gulf Coast
Parish Boundary Map of Louisiana

TABLE 1. Vector Mapping Data Available in the LSU CADGIS Lab: 1989 (continued)

---

Shoreline Map of Louisiana Gulf Coast, updated
Public Boat Launches for Louisiana (underway)
Railroad Map of Louisiana with database
Pipeline/Pipeline Support Facilities Map
Salt domes of Louisiana with database
Shoreline Change Map of Louisiana Gulf Coast (underway)

Soil Associations Map of Louisiana with database
Soil Conservation Service Coastal Marsh Inventory
  - Jefferson Parish
  - Cameron Parish
Tiger Files for East Baton Rouge and Jefferson Parishes
Water Quality Study for North-Central Louisiana
Zip Codes for Louisiana
Watershed Map of Louisiana (proposed)
1956 and 1978 U.S. Fish and Wildlife Service National Wetlands - Inventory (NWI) Habitat Type Maps (selected 1983) with database

(*) Restricted access

---

### TABLE 2. Landsat and Raster Images Available in the LSU Cadgis Lab: 1989

Detailed Soils Map of Louisiana (underway)
Digitial Elevation Model (DEM) of lower Amite River Valley
MSS scene of central Louisiana Gulf Coast
MSS scene of the Industrial Corridor
MSS scene of New Orleans and the Florida Parishes
MSS scene of Toledo Bend and Red River area
NHAP of Baton Rouge, La., 1978
NHAP of Livingston Parish, La., 1978
NHAP of lower St. Tammany Parish, La., 1986
NHAP of Crosby Arboretum, Picayune, MS., 1988
Soils Association Map, 250 meter grid
TM scene Barataria and Terrebonne Bays, 1988
TM scene Lake Charles, La., 1988

Definitions:
NHAP - National High Altitude Photography
MSS - Multi Spectral Scanner (LANDSAT 4 data)
TM - Thematic Mapper (LANDSAT 5 data)

This allows researchers to compare two different maps such as landuse and soil associations and produce resultant maps that are geographically correct.

Digitized data sets are also generated from U.S. Geological Survey (U.S.G.S.) 7.5 minute quad sheets. Data layers include roads, Interstates, water bodies, hydrology, political boundaries, and miscellaneous features such as servitudes. Many of these same layers can now be purchased as digitial line graphs (DLG) from the U.S.G.S.

The major categories of landuse as defined by the U.S. Geological Service, 1978 data have also been added to the Louisiana Atlas. Approximately 75 categories of land use are designated by the U.S.G.S.. Researchers from a number of agriculture departments anticipate working with this data in the future comparing land use with other geo-referenced information in the Louisiana Atlas such as water quality. This may be especially helpful in analysis of non-point source pollution.

## Some GIS Applications

All of the regional Experiment Stations of the Louisiana Agricultural Experiment Station are geo-referenced on a data series. Climatic data is being collected daily by sensors at each of these 17 branch Experiment Stations for a research project in the Department of Agricultural Engineering, a cooperator in LADSS. Statewide climatic data collections are made monthly and the information is then added to the database that is geo-referenced to the mapping system.

The Department of Agricultural Engineering has also developed GIS applications for a water quality study for potential irrigation sources. As some plants are more sensitive to salt than others, care must be taken when planning to use groundwater for irrigation. This project involved analyzing geo-referenced well log records for sodium absorption ratios (SAR) and electroconductivity values supplied by the Louisiana Geological Survey (LGS), Each well had a unique identifier, lat-lon location, date, depth of well, and SAR and electroconductivity value. The U.S. Department of Agriculture has previously arranged these two values in a matrix of values that ranged from low sar/low conductivity to very high sar/very high conductivity, creating a 16 value salinity hazard chart.

The combined values were used to created integer values ranging from one to 16, one being low sar/low conductivity. These values were then placed in a map file and contoured. Farmers or produce growers can now identify areas that have water suitable for irrigation and also learn at what depth wells must be drilled, allowing some basic cost considerations.

This same GIS method will be used by the Department of Agricultural Economics & Agribusiness in a water quality study in Louisiana's rice production region which has a growing salt water intrusion problem. Using LGS well water data from 4,470 geo-referenced wells in this region, researchers will determine some of the influences of irrigation for rice and aquaculture on salt water intrusion in the underlying aquifer. Based on this analysis, water management schemes that incorporate site specific water use information will be proposed to minimize saltwater intrusion. In a parallel study, farmers' attitudes toward general environmental quality issues and specific water quality issues will be obtained using the L.G.S well sites as a sampling basis.

The Department of Experimental Statistics in the College of Agriculture, also a cooperator in LADSS, recently completed a statistical analysis of factors affecting the number of deer kills in a state forest in Georgia. The original food stuffs compartment information was digitized from a 7.5 minute map provided by the Wildlife Management Office of Georgia. Results from the original SAS statistical analysis were fed into a Digitial Terrain Model (DTM) representing deer kills. What normally would have been a statistical analysis was enhanced with graphical output such as grid forms and digital terrain maps. Since this study was referenced to a mapping system, future studies will build on these results.

A local development project conducted through the CADGIS Lab used data that was digitized for a 3,000 acre development site in Texas. In this study, criteria for development were established along lines of local zoning maps and with a preset goal of "preserving the integrity of the environment". Slope, water quality management zones, and vegetative cover were initially overlayed. Analysis maps were then generated using several different software packages. For example, vegetation zones were digitized on the Intergraph and then displayed using the ERDAS raster based package. Different maps were then combined and analyzed using ERDAS showing development limitations based on criteria such as slope, soil type, and vegetative cover.

Data series of traditional interest to rural development research is also available on the Louisiana Atlas. For example, infrastructure such as all of the airports of Louisiana are referenced on the Atlas. Each airport is located by its lat-lon coordinate. A database is attached to each airport site including information such as nearest city, parish, runway length, runway surface, etc. In many rural development scenarios, transportation can be a primary component. This has already been useful in discussions of siting specialized agricultural processing facilities such as aquaculture that may require air service with refrigeration facilities.

The Department of Agricultural Economics is currently involved in a definitional study of Louisiana's coastal marsh. Using data collected by the U.S. Soil Conservation Service (SCS) in Louisiana as a 22 parish Coastal Marsh

Inventory that complements the National Natural Resources Inventory (NRI), established criteria are being used to delineate various regions of the coastal marsh. The original 7.5 minute SCS quad sheets were used as the base maps for this data set. Intergraph's World Mapping Software (WMS) was used a generate grids that reflected the projection of the quad sheets. The points were then copied to the WMS files. The individual sheets that comprise each parish were then merged into one large file. The merged marsh file is geo-referenced, so the other 21 parishes surveyed by the SCS can be added. This unique data set can also be geo-referenced to the NRI.

A SAS database that contains 186 possible attributes including water management systems, erosion conditions, vegetation, salinity, land use and some historical information is attached to each file. As statistical analysis is conducted, it can be represented graphically. In turn, graphical overlays can be outputted in numeric form for merger as part of the statistical analysis.

One component of a study in the Agricultural Economics & Agribusiness Department is exploring the economic potential of leasing private forest land for hunting rights. Information was collected via mailed questionnaires to hunters leasing land in selected areas of Louisiana. Information relating to hunting on public lands (Wildlife Management Areas, National Forests) was also collected. This survey information in a traditional SAS analytical framework will then be attached according to the zip code location of respondents. It is anticipated that this information will be used in conjunction with both hedonic and travel cost analysis.

Another GIS project underway in the Agricultural Economics & Agribusiness Department involves analysis of production diversification in Louisiana. This project will eventually link our traditional parish level production data series with other data bases in the Louisiana Atlas and potentially be our most comprehensive data base.

## Conclusions

GIS potentially offers economic researchers the ability to truly incorporate spatial, geographical dimensions in their research. GIS also offers unprecedented means of displaying this contribution. At LSU in the Department of Agricultural Economics & Agribusiness, some researchers are especially committed to developing the analytical contributions of GIS in both traditional and non-traditional economic theoretical frameworks. In the areas of graduate education, efforts are underway to identify a GIS specialization for our Master's degree program and Ph.D. program.

Future research areas targeted for GIS applications include natural resource management, rural revitalization, land information, marketing, and sectoral analysis. As efforts are made to tap the analytical potential of GIS for spatial economic analysis, undoubtedly further applications will be made. The challenge remains for applied economists to move GIS past its initial use as a visual depiction of research results into a role as a true analytical tool.