COMPUTER APPLICATIONS IN LANDUSE MAPPING AND THE MINNESOTA LAND MANAGEMENT INFORMATION SYSTEM

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The concept of rational use of land resources is not new, but the general public's awareness of the limited nature of our land resources and the urgent need for optimal utilization of them are phenomena of this decade. Today, most planners, officials, and the public share this awareness. In order to manage land resources effectively and plan for the future, it is essential that we begin to comprehend the land utilization of the past and present. To achieve this, we are in need of a vast amount of information on land resources and related socio-economic variables. When one is dealing with a large are, such as a major region or country, automation becomes necessary for carrying out the tasks of information collection, analysis, and updating. Accordingly, the State of Minnesota has established an automated land information system to facilitate the work of resource management and planning.

The Minnesota Land Management Information System Study, MLMIS, is being developed under the auspices of the Minnesota State Planning Agency and the University of Minnesota Center for Urban and Regional Affairs. The system is primarily a result of the four earlier studies which began in 1966: (1) a study on lakeshore development of a small area in central Minnesota, the Brainerd area in Crow Wing County (Orning, 1967); (2) an expansion of the Brainerd study, the Minnesota Lake Shore Development Study (Borchert, et al., 1970a and 1970b); (3) a report on state land holdings (Minnesota State Planning Agency, 1968); and (4) the state land use mapping project (MLMIS, 1971). During the undertaking of these studies, it became apparent that a statewide data system was essential to these types of investigations and a rational use of land resources. Therefore, the MLMIS aims at providing extensive information to officials, planners, and researchers in decision-making and policy formulation concerning Minnesota land and water. The study works toward establishing a statewide data base for land related information, i.e., landuse, land ownership, land value, land characteristics, and government landuse controls.

In the following, this paper will discuss the system design and current developments of MLMIS. These include the topics of basic data unit, the geocoding system, major information sources, data structure, procedures of data input, procedure of data retrieval, display and analysis of land information, and finally data updating and potential information source. It should be noted at this point that the MLMIS does not claim superiority in hardware or software design. The system has been funded modestly by the state, and thus far has only employed a handful of personnel trained in systems management. But it is progressing rapidly and, more importantly, it has been producing valuable results such as landuse maps and research reports on land resources and utilization. In addition it has provided data and consultation to a number of state agencies and private firms.

The Basic Data Unit

The choice of a basic data collection unit is crucial to an information system. In Minnesota, it was determined as a result of much use and examination of land records that the basic unit for a statewide coverage should be the forty-acre parcel, the smallest consistent unit in the U. S. land survey system. This system was employed to survey most lands in the central and western United States. The first order reference axes in the system are the 32 pairs of locally defined principal meridians and base lines (parallels). The second order references are tiers of townships and ranges (Figs. 1 & 2). A township, which is defined by a pair of township lines and ranges, is a 36-mile square. Within a township, there are 36 sections (one-mile square), and in each section, 16 forty-acre parcels.

There are nearly 1.4 million of these forty-acre parcels or data cells in Minnesota. Most blocks of land, whether in public or private ownership, have the edges of forty-acre parcels as boundary lines. The parcel divisions are reflected in agricultural areas as field lines, in forested areas as timber cutting boundaries, and in cities as major streets. In fact, in cities, major commercial developments often occur on section corners of the U. S. land survey. These lines and cells describe the manner in which people have divided and shaped the landscape of Minnesota. The pattern is quite evident when the state is viewed from the air (Fig. 3). The forty-acre parcel is important in other ways. This parcel is recorded on many governmental records for Minnesota at the county, regional, state, and federal levels. The cell structure also lends itself to computer mapping which is necessary in analyzing large volumes of data over extensive areas.

It may be argued that the forty-acre parcel is not a good choice for the basic data unit. The U. S. land survey system is based on locally defined reference axes, and therefore does not have global applications. With this respect, a better choice would be the Universal Transverse Mercator System (UTM). The UTM is well defined on large scale topographic maps. From the geographic point of view, however, the forty-acre parcel is an excellent choice because it is closely associated with the land utilization and settlement patterns of Minnesota. However, the UTM system has been used to record the southwest corner of every township in the state.

The MLMIS is designed to serve mainly planning and studies at the state, regional, and county levels. It is not intended to be a municipal or urban information system, and it is not effective in small-scale investigations, such as those needing information on sewer lines and city streets. Special care, however, is being taken to assure that data collected below the level of forty-acre units can be aggregated and incorporated into MLMIS. Generally, these data are maintained for municipal or county subdivisions. One such example is an urban study employing 10-acre data cells (Robinette, 1971).

The Geocoding System

The locational content of data in Minnesota consists of the following hierarchies: the state, county, township, section, and parcel. The geocoding system in MLMIS contains the identification codes for all these elements. In addition, it encodes the minor civil divisions (MCD) which are the administrative subdivisions comprised of townships, incorporated places, and other areas. The MCD and the county identification are adopted from the U. S. Bureau of the Census; therefore, the MLMIS is linked to the coding system of the U. S. censuses. The centroids of the MCD are recorded in latitudes and longitudes, correct to the nearest 10 seconds. The ability to locate a forty-acre parcel by a point reference to spherical coordinates, however, has yet to be perfected. In the future, one point of each parcel may be identified in latitude and longitude. At present, each forty-acre parcel is uniquely defined by a serial number of fourteen characters, and parcel data may be displayed on township maps to be discussed later (Fig. 2 and Table 1).

In the U. S. land survey system, some townships are not precisely thirty-six square miles. In these irregularly shaped townships, some sections contain more than sixteen parcels per section, and these "extra" parcels are identified by a special code. Approximately ten percent of the townships needed some adjustments.

Major Information Sources

There are four major data sources for MLMIS: (1) various levels of governments, county, state, and federal; (2) the U. S. Bureau of the Census; (3) the University of Minnesota excluding MLMIS; and (4) the MLMIS itself. The Bureau of the Census is listed independently because of its obvious importance. The census data may be used directly by the MLMIS, since the system has adopted the census areal codes, as indicated previously. In contrast, data and records provided by other governmental agencies may be used only after some reorganization of data elements.

Nevertheless, a major purpose of the MLMIS is to make optimal use of land information concerning the State of Minnesota. By building an automatic geocoding and transferring system, the MLMIS attempts to systematize a broad range of data now collected routinely and maintained separately by various government agencies in their licensing and managing functions. Currently, these data can be used only by their collectors, and are not readily available for general use. Most of these data have not been collected or encoded in any compatible manner. In the future, MLMIS may also develop standardized methods of data collection to improve the quality and to facilitate data input to MLMIS.

Various departments of the University of Minnesota have contributed information and their research findings to MLMIS. For example, the Department of Soils has provided information on soil types. Finally, the MLMIS through the Center for Urban and Regional Affairs has collected the bulk of the data now contained in the system.

At present, the main body of data content of the MLMIS is the complete coverage (of 1.4 million cells) of state landuse types and water orientation. In the United States, other data systems comparable to the MLMIS are described by Swanson and Denenberg (Swanson, 1969, Denenberg, et al.). However, neither has this large a number of data cells. Information on water orientation was obtained from aerial photographs and the county highway maps issued by the state Highway Department. It contains seven types of orientations denoting wherever a forty-acre parcel adjoined a lake, stream, or ditch. Information on landuse was interpreted from aerial photographs. A nine-category classification was established so that the interpreters could determine the landuse types from the photographs with a minimum consultation of other data sources (Orning and Maki, 1972, Appendix C). The nine categories are: forested, water, marsh, cultivated, pasture and open, urban residential, urban non-residential or mixed residential, extractive, and lastly, transportation. The dominant landuse was identified for each forty-acre parcel from the photographs which were read stereoscopically by a three-man team, two interpreters and one map recorder. Double interpretation facilitated accuracy. The basic unit of interpretation was a township within which section lines were followed. Each regular section was divided into sixteen forty-acre parcels based on field lines, timber cut edges, as well as a transparent reference grid. It was assumed that these parcels cover all surface area, including water bodies. Despite the clearly defined landuse categories there were many cases in which it was difficult to determine from the photographs the dominant landuse. These problems were resolved by field checking.

MLMIS Data Structure

The data are presently maintained on twelve machine readable magnetic tapes; with one exception, each tape contains one development region defined by the State of Minnesota. Development Region 3 is on two tapes. A development region contains one to eleven contiguous counties. All tapes are maintained on the CDC 6600 computer system under the 7000 MODIFY/SCOPE OPL format with 556 BPI. Each of the eighty-seven counties in the state is contained in a separate file on the tape corresponding to its development region. The county field consists of records for each forty-acre parcel or government lot.

Each unique record of a parcel has the following four components: a 14-character identification key, minor civil division (MCD) number, longitude and latitude of the MCD centroid, and seven types of data. These data types are landuse, water orientation, federal land ownership, relative ownership (full or partial of the parcel, federal ownership only), geomorphic region, state land class, and soils. The last three types are completed for only a small number of counties.

A brief description on the hardware situation of the MLMIS is in order, since the hardware affects the designs of data structure and input/output procedures. The MLMIS has been a very economical system with respect to equipment purchasing (Table 2). Except for the last item, these machines are the property of the University Computer Center. The Image Analyzer was funded by several sources.

The Procedures of Data Input

The procedure of data input to MLMIS employed before 1973 was a traditional one. It contains the following steps. For each forty-acre parcel, land information was coded on maps (scale 1:24,000), locational and land information was recorded on mark sense cards, the card information was read, checked, and finally transferred onto tapes. This procedure is cumbersome.

Lately, a new method of data input has been developed called the CRT data entry system, which would eventually improve and expand the MLMIS operations. The CRT (cathode ray tube) is connected to the University's main computer CDC 6600 via a CDC 3200 (Fig. 4). At the CDC 3200, programs and data are stored on disk pack and are available for the work on CRT. At this experimental stage, only one county, Itasca, is programmed into the CRT data entry system. This system consists of two files, locational directory and data files. Data of forty-acre parcels may be called to be shown on CRT for an area one-half of a township at a time (Fig. 5). This areal coverage on screen is limited by the CRT (CDC 211) capacity which allows 50 characters horizontally and 20 vertically. However, it does provide a comfortable view on the CRT screen. Each parcel is designated by a two-digit code, thus spatially it forms a small square, resembling the "map image" of a parcel on a township map. Subroutines are available for displaying either the data as stored on the computer tapes or a map with coded symbols for one-half of a township. Entering new data, correcting, and updating information can be performed easily, and the results of these operations are viewed immediately on the screen. Hard copies of the final records are produced by the line printer through an instruction from the CRT.

The CRT input procedure is most effective with graphic source materials such as maps and photographs, but it is by no means limited to such usage. In many ways it is superior to the previously employed input method. If the source materials are of comparable scales to the screen imagery, they may be used directly for data input. The results of data entry may be checked immediately by viewing the spatial patterns on the original materials and that on the screen. If only one class of data exists within a township, such as forested land, the data entry may be completed by a single request call on CRT. If it has a predominant class, this may be entered first for the entire township. Then other classes may be input in areas where the data fall under these classes. No punch cards or transient tapes are necessary in this system, for input goes directly to the CDC 3200 disk pack. Lastly, the entire operation is much less dreary, and therefore it moves along faster and with fewer chances for error. Currently, the CRT data entry system is being implemented, and for Itasca County, a dozen new types of data such as county zoning, school districts are entered for each forty-acre parcel.

Procedure of Data Retrieval

At present MLMIS does not have a user oriented program for expedient retrieval of data from the system. This remains to be a weak point in the system. Data are stored on tapes by state development regions and by counties. In order to obtain data on forty-acre parcels of several townships in different counties, for example, a special program would have to be written to search for, first the requested counties, and then the townships, etc. A simple request of data would cost approximately $8.20 at the Minnesota computer system, not including the time for program writing and submission. However, the situation will be improved greatly in the near future. The University Computer Center has purchased a data retrieval package, System 2000. In the future, MLMIS will attempt to employ this system for its data retrieval.

Display and Analysis of Land Information

Computer mapping is the primary mode of data display for

MLMIS. Line printer, Calcomp plotter, and CRT have been utilized for cartographic work. These devices are particularly useful for the large amounts of data analyzed and for displaying land information in a spatial context. Needless to say, statistical programs are also available for data analysis and tabulation.

A MINNMAP program produces maps based on data of forty-acre parcels (Fig. 6). The most substantial contribution of the MLMIS to date in data analysis and mapping is the statewide landuse map at 1:500,000. It is a multi-colored map, thus it cannot be reproduced for this publication. Based on its dominant landuse, each forty-acre parcel is classified into one of the nine categories: forested, cultivated, water, marsh, pasture and open, urban residential, urban non-residential or mixed residential, extractive, and lastly, transportation. The map is a product of sequential use of a computer printer and photographic process. By employing the program MINNMAP, the line printer produced a grey-tone township map for each of the primary colors (red, yellow, and blue). The township maps were then pasted into blocks of six townships, and these blocks were aligned and photographically reduced (Fig. 7). A plate was made for each of the colors required for printing the resultant map. This map, which contains 1.4 million data cells, would have been a difficult task if conventional cartographic procedures were used. But the reproduction method just described was also tedious. As a result other mapping methods are being developed.

Recently, experimentation has moved into the application of the Calcomp plotter to data display. With the plotter a large area such as a county, region, or even the entire state can be mapped in a single computer submission. This eliminates the need for pasting printer outputs of small areas (Figs. 8 & 9). On a state or county map, each plotted symbol represents one forty-acre cell. Different numerals, symbols, and/or colors are employed in differentiating symbol classes.

Data Updating and Potential Information Source

The CRT data entry system provides a means of data editing and updating, as discussed earlier. Since land utilization changes through time, information sources and methods for data updating are of utmost importance to a data system like the MLMIS. One potential information source which is being investigated is satellite imagery. Via a grant to the State Planning Agency from NASA, the MLMIS is examining the applications of satellite imagery to Minnesota landuse mapping (Brown, et al., 1973). Earth Resources Technology Satellite (ERT-1) provides the imagery in the form of bulk MSS 70 mm positive transparencies, projected for interpretation of individual bands or color combined. Slides are made of these color combined scenes and projected for interpretation at scales ranging from 1:30,000 to 1:250,000. Nine-inch bulk positive and negative transparencies are being analyzed by density level slicing with an Interpretation System VP-8 image analyzer.

Imagery is evaluated as a potential source for supplying up-to-date information on landuse. It is hoped that the resolution will enable the expansion of the classification scheme currently in use. Thus far, research has shown good results with regard to urban and extractive land uses. In urban places with populations of 7,000 or more, for example, areas of different urban functions can be detected, making possible a refinement of the two-class urban landuse types now employed. In mining areas, a great deal of area measurement and extractive feature classification can be carried out with sufficient accuracy. Research on these and other landuse types are still in progress. In addition, preliminary studies on density of artificial surfaces in the Twin Cities indicate that with some ground truth it will be possible to collect data on impermeability by one-mile cells, and to map the degree of impermeability in the urban area. Moreover, a model for urban run off may be developed based on the data on impermeability and storm sewer networks (Brown, et al., 1973).

MLMIS is an ongoing study; thus far most efforts have been placed in areas of data collection, improvements of input and output procedures, mapping programs, etc. Some progress, however, has been made in data analysis, model formulation, and prediction. Indeed, much of the value of MLMIS has been in the accomplishment of research which meets current needs in land management and planning. A list of major publications is included in this paper. More recent studies include land for development in northern Minnesota (Rusch, et al., 1972), recreational resource study on lakes in the St. Paul area (Wietecki and Orning, 1973), legal controls in relation to landuse (Gilbert, 1973), and the Rapid Analysis Fiscal Tool or RAFT (MLMIS and CURA, 1972). The potential impact of RAFT should be noted. It is a group of computer programs designed to create and manipulate a data base which is to serve as a means of analyzing current laws and proposed alternative policies on state taxation. When it is completed, it will contain a data base relevant to the formulation of fiscal laws and policies, and will be equipped with a package of fiscal models capable of evaluating present and proposed changes to tax laws.

In conclusion, the creation of the MLMIS has been made possible by the promotion of long-term cooperation and coordination among researchers, planners, and public officials. It has been as much a political exercise as it has been an information system study. Active interdisciplinary cooperation in data collection and utilization within the University community has taken place. MLMIS staff has worked closely with government agencies to standardize data collection and storage techniques. There has been a sharing of personnel between the University and governmental agencies. Many times this resulted in permanent state employment. In addition, there are regular meetings between University faculty and users (or potential users) from state agencies. Working with these officials has proved to be a fruitful experience. Now the MLMIS personnel is more knowledgeable in the types of information needed and the types of questions asked of the information. Therefore the contents of the MLMIS and computer access systems can be better designed to meet specific user requests. The ultimate goal of the MLMIS, of course, is not simply one of data accumulation. Rather, its goal is to provide pertinent information, and, in turn, to improve the quality of public and private decisions affecting the environment.

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Information requests should be directed to Mr. G. W. Orning, director of MLMIS or Dr. K. Kozar, Systems Director.

TABLE 1--CHARACTERS OF PARCEL IDENTIFICATION

Type of Location	Number of Characters	Example
County	2	31
Township	3	055
Range	3	262
Section	2	36
Quarter-Quarter Section (forty-acre parcel)	2	31
Government Lot*	2	09

* All parcels which are not exactly forty acres were originally surveyed in size by the government and called government lots. Ownership is not implied.

TABLE 2--A LIST OF HARDWARE EMPLOYED IN THE MLMIS

CDC 6600 COMPUTER

65 k words, extended core storage, 841 disk drives, eight seven track tape drives

CDC 3200 COMPUTER

32 k words, 854 disk drives, three seven track tape drives, CRT controller

CDC 211, CRT (CATHODE RAY TUBE)

Alpha-numerical model with 50 characters horizontally and 20 vertically

CALCOMP PLOTTER 563

Drum with 11" and 32" paper

INTERPRETATION SYSTEMS VP-8 IMAGE ANALYZER

(for analyzing ERTS-1 imagery)