DETECTING LAND USE CHANGE ON OMAHA'S URBAN FRINGE USING A GEOGRAPHIC INFORMATION SYSTEM

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ABSTRACT

Many urban planners find it difficult to inventory changing land uses. A Land Use Change Geographic Information System (LUCGIS) was created to test the feasibility of using an automated approach for monitoring these types of changes. Polygon outlines were entered in a vector format using an X-Y digitizing table. A vector to raster conversion was employed to make digital maps usable on a raster-oriented color graphics terminal. Utilization of a graphics terminal made it possible to view the map creation and overlaying processes, as well as allowing for manual editing. Raster-oriented programs for map overlay and acreage calculation were written. The value of LUCGIS was found in the precision of the resultant 'change' maps. The computerized method of detecting change appears to be more accurate than most conventional methods. By overlaying these land-use maps, many comparsions of land-use categories were produced in the form of dot-matrix printer maps and acreage calculations.

INTRODUCTION

Geographers and cartographers have long been interested in using new methods that make it possible to investigate and depict different aspects of the physical and human/cultural environment. In recent years, Geographic Information Systems (GIS) have proven to be useful in studying spatial relationships and may be useful in monitoring certain types of change in the environment. A GIS is most often a computerized system designed to store, manipulate, analyze, and display large volumes of spatial data. The various applications of geographic information systems have yet to be explored.

One possible application of the GIS concept is in monitoring the rural-urban fringe. This area is a zone of transition between well recognized urban land use and the area devoted to agriculture (Wehrein, 1942, p.53). As the urbanized area spreads outward, so does this fringe area and, as a consequence, the rural-urban fringe area changes rapidly. It is the purpose of this research project to test the feasibility of using a raster-oriented GIS to monitor changes for a portion of the rural-urban fringe of western Omaha.

The Importance of Change Detection

Land-use change information is very important, especially to urban planners. Multi-temporal change analysis may assist the planner in determining a spatial trend. F. Stuart Chapin saw the need for assembling and summarizing land-use data. He also saw the need for construction of systematic procedures for keeping account of changes (Chapin, 1972, p. 298). Even though this is an important aspect of urban planning, the lack of systematic procedures to update and maintain land-use changes has hindered many planning agencies from keeping accurate up-to-date records.

The concept of change detection was a key element in the formulation of the Land Use Change Geographic Information System (LUCGIS) created for this research project. Before change detection was carried out, the maps created for this project had to be encoded and stored in a computerized map file. Automated change detection involves the comparison of two maps that have been encoded into numbers. In this case, two land-use maps were compared to automatically produce a map which displays the areas where change has occurred. A geographic information system is designed to perform such functions.

GIS Data Handling

A fundamental concern in designing a GIS is the encoding of spatial information. Consideration should be given to purpose for the GIS and those who will be using the information. The two most common techniques for encoding spatial data are vector and raster. Vector format refers to single pairs of digital X-Y coordinates that are connected with lines. The vector algorithms used for overlaying maps are particularly complex and consume a great deal of processing time. The other major type of representation for automated cartographic data is raster format. Grid formats, a form of raster organization, were frequently used in the earliest days of automated spatial data handling before specialized graphic output devices were available, since they lent themselves to line printer output. Each grid cell was translated into a character position on a line printer to produce a simple but crude form of graphic output (Peuquet, 1979, p. 132).

Vector format is used more often because of historical predominance of vector-oriented algorithms, and vector encoding is best adapted to retaining the logical map entities familiar to humans. However, new technology has provided better resolution for raster representation, therefore improving the capabilities to depict map features. With this improved output, raster systems may be favored over vector systems because of faster processing, less complex programs, and more efficient computer storage. Improved raster technology will aid immensely in displaying land-use change for the rural-urban fringe.

CREATION OF LUCGIS

The creation of the Land Use Change Geographic Information System involved two major steps: 1) preparation of the map overlays, and 2) digitization of these overlays. The land-use overlays were mapped from aerial photography using a Bausch and Lomb Zoom Transfer Scope (ZTS). The ZTS allows the scale of the photograph to be adjusted to the scale of a base map permitting the conveyance of information from an aerial photograph to the map. This process assures that the geometric distortion inherent in aerial photography is removed, as well as conforming all of the overlays to the same scale.

In order to map land use, the development of a land-use classification system was essential. Normally, five land-use categories are used by the City of Omaha: single-family residential, commercial, public, industrial, and vacant. Two additional categories were used in the LUCGIS land-use classification system: multi-family residential and agriculture.

Data Entry

Upon completion of the map overlays, the task of entering data into a computer at the Remote Sensing Applications Laboratory was initiated. The method of data entry chosen for this project was the ordinary string method, also referred to as the spaghetti method of data entry. The spaghetti method allows the user to simply record X-Y coordinates during the process of digitization. The digitized polygons were later changed to a grid cell representation in the rasterization process. The best aspect of using the spagetti method was the time saved during the digitization process. All land-use maps were digitized within one week's time. The biggest problem with this type of digitizing was the inability to exactly register lines, which became evident when map files were overlayed.

After the land-use maps were digitized, a vector to raster conversion was implemented. The conversion of this information was necessary to use an image processor equipped with raster-oriented software. Rasterization was accomplished by using a pre-existing set of vector-based subroutines to write the vector information to the image processing color graphics terminal. Once the vector information was in the memory of the color graphics terminal, the maps could then be saved and processed in a raster mode.

After the rasterization process, it was necessary to perform a number of cosmetic and semi-automated steps to produce the gray-tone images that would be used in the land-use change analysis. Before polygons could be shaded, the rasterized land-use polygon maps had to be compared to insure that coincidental lines matched exactly, pixel by pixel. To do this, each of the digital land-use polygon overlays was entered into one of the three picture planes on the image processing terminal. In positions where pixels were out of place compared to other overlays, the correct pixel was entered and the out-of-place pixels were erased using a 'paintbrush' program.

Polygons were then assigned gray tones according to the corresponding land-use category. A seed-polygon fill program was used to assign one of the 256 gray tones available on the image processor to each polygon. After all polygons were filled, a program that compared the two maps (this program was used later in the actual overlay process) was employed to find any areas on the maps that were still misregistered. Upon completion of these digital land-use maps, analysis was implemented.

ANALYSIS OF GIS AND LAND USE

The best feature of LUCGIS is the ability to easily overlay maps. In this process, two polygon map files which are expressed in raster format, are compared pixel-by-pixel to produce a change map. The raster method for overlaying was chosen because the programs for raster overlaying are not as complex as programs used in the vector domain. Whereas raster overlaying involves the comparison of one cell to another resulting in the output of another value, the vector method of 'point-in-polygon' compares the lines of both polygons, notes the intersections, and then compares the X-Y locations within that area. The vector overlaying method is therefore more complicated and requires much more processing time.

It was necessary to develop three raster overlaying programs for LUCGIS. The first overlaying program was written for comparison of two land-use maps to determine which chosen value (representing a land use) was in the same or different locations. This was used for the production of the land-use change maps and verification of accurate registration. The second program was developed for the rural to urban land-use map. It compares two land-use maps and displays all values from one map that are in the same position as the chosen value of the other map. The final overlaying program produced for LUCGIS writes all chosen values from one map over another. It was used primarily for overlaying the road map, legend, title, scale, and north arrow onto the change maps.

LUCGIS also includes the programs needed for map construction. A program was written which uses several subroutines to manipulate the vector formatted data entered from an X-Y digitizing table so digital polygon maps can be displayed on the raster-oriented color graphics terminal. To construct the gray-tone maps, a polygon fill program was developed to enter the desired pixel values into each polygon.

Calculation of acreage was an important aspect of LUCGIS. A program was needed that compares two land-use map files and calculates the number of pixels that have changed between the categories of two maps to output a two-dimensional table (see Table 1). The pixels were then multiplied by a factor of .03 which represents the area (in acres) covered by each pixel. Pixel counts from pre-existing programs were used on single maps and multiplied by this factor to determine acreage.

Examples of Land-Use Comparisons

The maps produced for this project display land-use change between 1971 and 1981. These multi-temporal change maps show the land-use category as it exists in three possible time frames: 1) 1971, the land-use changed to another category before 1981, 2) 1971 and 1981, the land-use was the same in both years, or 3) 1981, the land-use was changed from another category since 1971.

Because of the nature of the rural-urban fringe, the growth of single-family residential was particularly evident. The Single-Family Residential Land Use Change Map (Figure 1) exhibits change in the upper left corner of the map, resulting from the growth of two large housing developments. Another housing development is seen in the lower left corner of the map. The remainder of the single-family residential added to the study area between 1971 and 1981 is the result of filling in the 1971 residential areas and of smaller developments.

Multi-family residential (Figure 2) has changed greatly since 1971, with almost a 60% increase. Most of the change has occurred in the upper left corner of the map. Of the 133 acres of multi-family residential added between 1971 and 1981, 95 acres are located here. Taking advantage of the increased population, commercial activities followed residential growth into this area (see Figure 3). However,

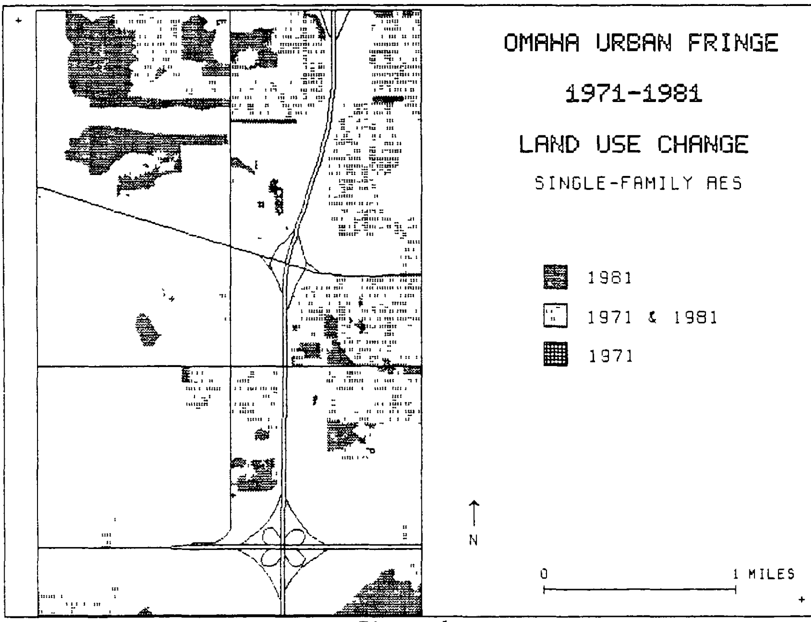

Figure 1

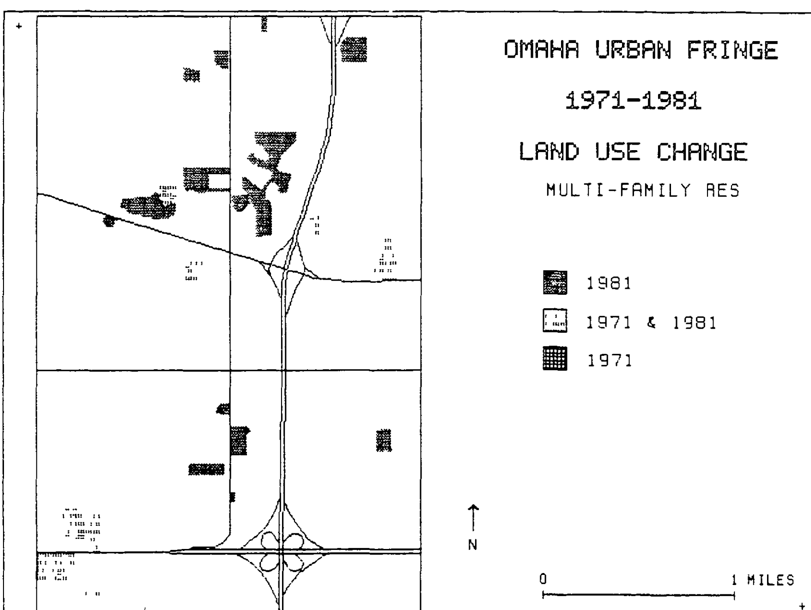

Figure 2

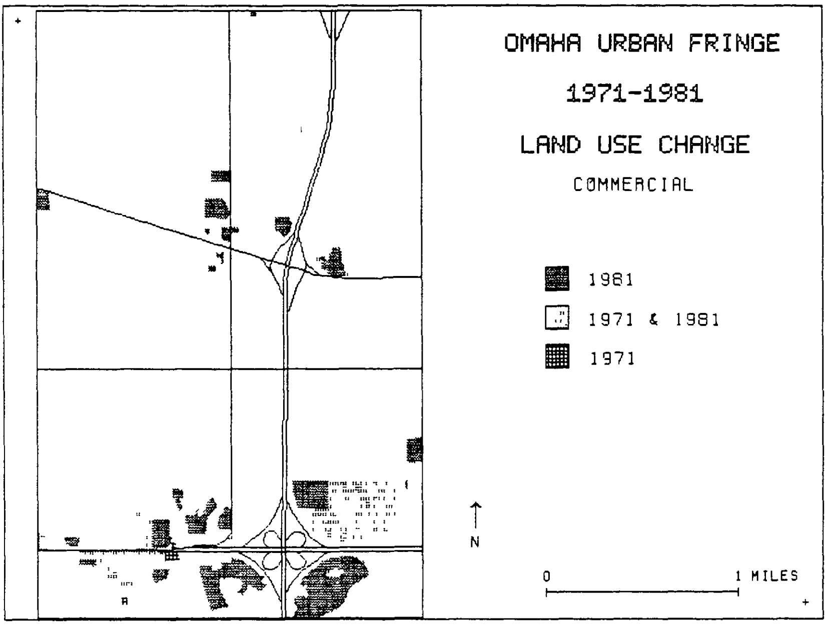

Figure 3

most of the commercial land use is the result of strip development and is located near the intersection of two major roads.

Table 1 also shows land-use comparisons from one year to another. As stated earlier, it was obtained by numerically comparing two map files and counting the number of pixels that have changed from one category to another. This table provides a quick yet efficient way to obtain all acreage comparisons between two maps without having to produce all of the land-use change maps. The table is also very useful when acreage measurements are preferred.

TABLE 1

LAND USE CHANGE ACREAGES

1971 Land Use (Changed to) 1981 Land Use

	IND	PUB	COM	SRES	MRES	AG	VAC
IND	---	0	0	0	0	0	0
PUB	0	---	2	0	0	0	2
COM	0	1	---	0	0	0	0
SRES	0	1	1	---	2	0	1
MRES	0	0	0	0	---	0	0
AG	1	177	55	145	103	---	204
VAC	1	106	117	232	28	4	---

Rural to Urban Analysis

One problem that has been studied by urban planners in the recent past is the changing of rural land uses to urban uses. To show rural to urban change by overlaying land-use maps, the LUCGIS classification scheme had to be divided into rural uses and urban uses. Production of the 1971-1981 Rural to Urban Land-Use Change Map involved comparing rural uses of the 1971 land-use map to the urban uses of the 1981 land-use map. To construct this map, vacant land and agriculture were chosen as the rural uses, and single-family residential, multi-family residential, commercial, industrial, and public were chosen for the urban uses.

The 1971-1981 Rural to Urban Land-Use Change Map (Figure 4) identifies land that has changed from rural uses to urban uses in this ten year span. The area with the greatest amount of change to urban uses is evident in the upper left corner of the map. Urbanization resulted primarily from completion of two large single-family residential housing developments, the construction of a golf course, and the addition of several apartment complexes. Conversely, on the right side of the map, very little rural to urban activity has taken place. The reason for the lack of change is that much of this area was already classified as urbanized area as seen on the 1971 Land-Use Map (Figure 5).

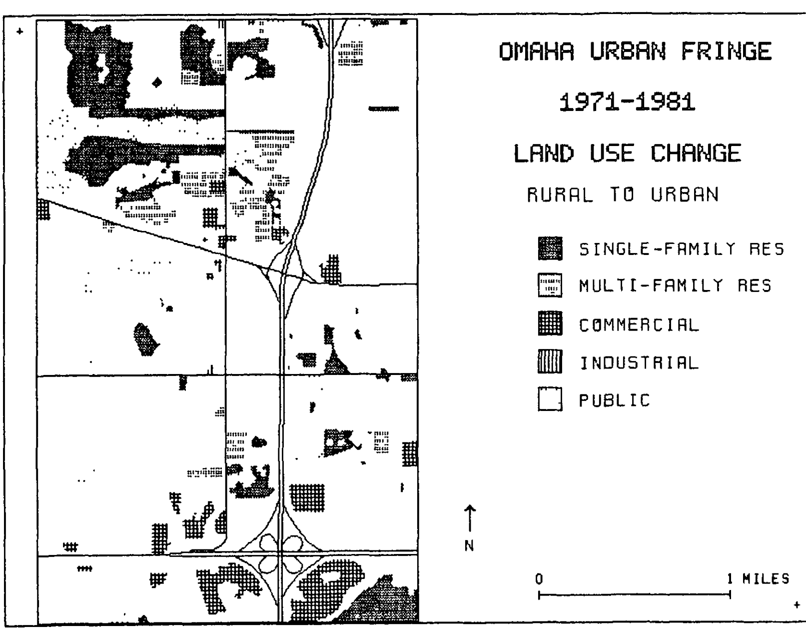

Figure 4

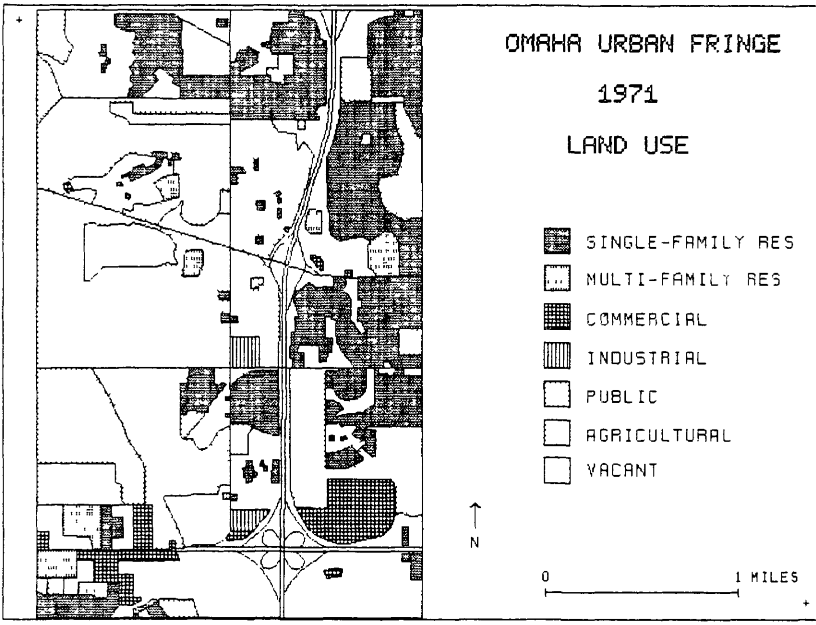

Figure 5

CONCLUSION

Importance of the Raster Approach

A major concern of this project was testing the feasibility of the raster approach for analysis of land-use change. Economy of data storage, minimization of computer time needed for processing, and ease and flexibility in using the data are all increasing concerns as computer utilization increases in cartography (Peuquet, 1979, p. 130). These concerns might be more easily dealt with through raster processing. First, the time it takes to process even a moderate amount of vector-oriented information is much greater than the processing of raster data because of the complex nature of these vector programs. Second, because these vector programs are complex, adding to or altering programs on a vector-oriented system is more difficult than raster programming. Finally, when encoding vast amounts of data, efficient storage is necessary. Data in a raster format can be stored more efficiently than vector data.

The raster method appears to have been a good choice for this particular project. Overall, the raster approach for overlaying polygons to detect change presents a viable alternative to vector manipulation. The only step in this project that might be changed is the way in which data was encoded. The spaghetti method saves time initially, but too much time was spent in the semi-automated registration of the rasterized polygon maps. An arc/node method of data entry would have been preferred, but at the time this project was initiated very little software was available on the system.

With rapid advancements in computer hardware, a raster-oriented geographic information system should be even more valuable to cartographers, geographers, environmentalists, developers, business interests, the military, and others. In the last ten years or so, improvements in such important aspects of raster graphics as data entry devices, the resolution of graphic terminals, and development of the dot-matrix printer, among others have brought great potential to raster technology. It also has brought remote sensing and cartography closer together because of similar computing needs. In fact, LUCGIS was constructed on an image processing system which are most often designed for remote sensing applications. The future may see closer ties between the two disciplines.

Advantages of a Land Use Change GIS

There appear to be several advantages in using an automated Geographic Information System to monitor land-use change:

1) It seems that the resultant change maps would tend to be more precise in detecting change than older methods of visual map comparison or producing hand drawn comparison maps.

2) Data can be stored in a physically compact format such as magnetic tape or disk.

3) Data can be retrieved with much greater speed.

4) Accurate acreage statistics can be accumulated and analyzed.

5) Many comparisons can be extracted from two maps in the form of change maps of acreage calculations.

Most importantly, LUCGIS helps in accounting for land-use change very accurately. Because it took so much time for cartographers to draft these change maps, urban planners seldom used this kind of information. After a system has been created and data base maps digitized, it is only a matter of maintaining the system.

The effectiveness of LUCGIS was found in the precision of the resultant change maps. The computerized method of detecting change appears to have an advantage in speed of map production and accuracy over conventional methods. From the two land-use maps, many comparisons of land-use categories were produced in the form of dot-matrix printer maps and acreage calculations.

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