The feasibility of using a geographic information system to monitor change in a portion of the rural-urban fringe in Omaha, Nebraska

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THE FEASIBILITY OF USING A
GEOGRAPHIC INFORMATION SYSTEM
TO MONITOR CHANGE
IN A PORTION OF THE
RURAL-URBAN FRINGE IN OMAHA, NEBRASKA

A Thesis
Presented to the

Department of Geography/Geology
and the
Faculty of the Graduate College
University of Nebraska

In Partial Fulfillment
of the Requirements for the Degree

Master of Arts

University of Nebraska at Omaha

by

John Ross
Thesis Acceptance

Accepted for the faculty of the Graduate College, University of Nebraska, in partial fulfillment of the requirements for the degree Master of Arts, University of Nebraska at Omaha.

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Date Dec. 4, 1984
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CHAPTER I
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 GIS to monitor changes for a portion of the rural-urban fringe of western Omaha (Figure 1).
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. A case in point is the City of Omaha which has not produced a land-use map since 1973.

The concept of change detection was a key element in the formulation of the Land Use Change Geographic Information System (LUCGIS) created for this thesis 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.
GEOGRAPHIC INFORMATION SYSTEMS

For the last twenty years, there has been a movement to develop automated tools for efficient storage, analysis, and presentation of spatial data. These efforts have been implemented for a variety of uses: land-use analysis, urban planning, environmental planning, natural resource exploration, zoning, census statistics, natural resource management, transportation, coastal studies, construction facility management, taxation and ownership monitoring, spatial analysis, and military purposes, among others. In the future, GIS systems will be more widespread as the computer industry evolves and as the GIS software becomes distributed at a reasonable cost.

Graphics, and more specifically maps, have historically been a structure for most disciplines concerned with spatial analysis. Maps have provided us with a medium for record keeping, conceiving of ideas, analyzing concepts, predicting the future, developing decisions about geography, and communicating spatial concepts to others (Dangermond, 1982, p. 2). Computerizing maps as part of a geographic information system should enable increases in the amount, speed, and accuracy of information gained from the analysis of maps. Other advantages of using automated geographic system technology compared to manual techniques include the following:

1) Data are maintained in a physically compact format (i.e., the magnetic tape).
2) Data can be maintained and extracted at a lower cost per unit of data handled.

3) Data can be retrieved with much greater speed.

4) Various computerized tools allow for a variety of types of manipulation including map measurement, map overlay, transformation, graphic design, and data base manipulations.

5) Graphic and non-graphic (i.e., attribute information) can be merged and manipulated simultaneously in a "related" manner.

6) Rapid and repeated analytic testing of conceptual models about geography can be performed (i.e., land suitability/capability). This facilitates the evaluation of both scientific and policy criteria over large areas in short periods of time.

7) Change analysis can be efficiently performed for two or more different time periods.

8) Interactive graphic design and automated drafting tools can be applied to cartographic design and production.
9) Certain forms of analysis can be performed cost effectively that simply could not be done efficiently if performed manually (i.e., digital terrain analysis, calculations such as slope aspect, sun intensity, watershed, overlay analysis of multiple sets of complex polygon map sheets, etc.). (Dangermond, 1982, pp. 5-6)

Typical GIS software packages include a variety of standard options: windowing, edge matching, geometric correction, projection change, statistical analysis, and overlaying. Programs developed specifically for this project include, overlaying, acreage statistics, updating, and several display routines. These programs combined with software supplied by Spatial Data Systems and a locally developed digitizing program, comprise the LUCGIS.

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. Representing point entities, of course, pose few major problems since they may be represented as single
pairs of coordinates. However, the representation of line and area boundary-information is somewhat more complex (Marble, 1983, p. 925). 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). An example of this type of output is produced by a program called SYMAP (Figure 2) developed at Harvard University’s Laboratory for Computer Graphics and Spatial Analysis during the mid-to-late 1960's.

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 (Peuquet, 1979, p. 133). 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
FIGURE 2

Example of SYMAP
displaying land-use change for the rural-urban fringe.

LAND-USE CHANGE IN THE RURAL-URBAN FRINGE

The rural-urban fringe has been of considerable interest to urban geographers. These areas have developed as the result of decentralizing processes which began to affect American cities in the 1860's. Railways were among the first decentralizers and equalizers of urban rents and housing values (Woodward and Woodward, 1865, p. 12) with settlement occurring around railway stations. Later, inter-urban electric streetcar lines had an even greater impact because streetcars made many more stops. The greatest impact on rural areas came about because of the automobile. Development radiated outward from the city like spokes of a wheel. Over time, residential, commercial, and industrial land uses began to fill in the area between those routes.

Urban sprawl is a more modern term for this outward growth evident in the rural-urban fringe. It is defined as the continuous expansion that goes on around the average city with a belt of land always in the process of conversion from rural to urban land use (Murphy, 1966, p. 449). According to Harvey and Clark (1965), sprawl occurs in three main forms:

Low density continuous development in the rural-urban fringe is the lowest order of sprawl and is considered by
many the least offensive. Ribbon-development sprawl is made up of segments, compact within themselves but extending axially along travel routes and leaving interstices undeveloped. A third type of sprawl is leap-frog development. It consists of discontinuous though compact patches of urban uses in an essentially rural matrix.

From the viewpoint of land developers, the economic advantage of going beyond the zone of high land values, high taxes, and restrictive zoning and subdivision regulations are basic causes of urban sprawl (Loundsberry, 1981, p. 48). Movement to these rural-urban fringe areas was attractive to those who desired larger residential lot sizes and more open space. Following the arrival of single family residents, the need for commercial activities, parks, and schools also developed. Industry located in some fringe areas, but Loundsberry notes that desirable sites for specific types of industry and recreational developments have been overrun by residential and commercial land uses before their values became known (Loundsberry, 1981, p. 48).

Other Land-Use Comparisons In The Rural-Urban Fringe

Another urban-fringe problem, resulting because of the effects of urban sprawl, is the loss of prime agricultural farmland to urban uses. Land that is level, well drained, and accessible to transportation lends itself to efficient crop production, but these
characteristics make it equally well suited to urban development. A United States Department of Agriculture study revealed that nearly 17 million acres of farmland were converted to urban and built-up areas during the 1967-1975 period (Healy, 1979, p. 18). Very few believe that we are in immediate danger of damaging agricultural production because of this process. However, agriculture can offer urban areas important open space which is now disappearing. The loss of agricultural land in the urban fringe area will be analyzed using the LUCGIS.

Of the 17 million acres of agricultural land that has gone into urban uses during 1967-1975, as noted by the United States Department of Agriculture, about 60 percent was in the three most fertile soil capability classes. The LUCGIS land-use classification includes information on agriculture and soils, so it was possible to conduct a similar study in the Omaha rural-urban fringe area.

The analysis of land use in comparison to soils in rural-urban fringe areas can show some other interesting problems. The Soil Conservation Service issues soil surveys by county. These surveys contain various tables displaying different characteristics of soil series. One such table includes engineering interpretations, which lists the soil series and its relation to several urban uses such as degree of limitation for: dwellings with basements, sanitary landfills, sewage lagoons, and others. The LUCGIS makes it possible to compare the soils map with a land-use map to find out if there
are incompatible uses or to locate potential sites for urban uses.

The portion of Omaha that serves as the study area for this project includes a small stream, Big Papillion Creek. Most often, urbanization increases the magnitude and frequency of floods. There are several reasons for increased flooding in urban areas: 1) increases of impervious surfaces on the flood plain and within the drainage basin, 2) straightening of the stream channel, and 3) subdividing into building sites enables runoff to reach the stream more quickly. These processes can be observed in this study area. Of principle concern is the encroachment of urban land uses onto the flood plain of the Big Papillion.

PURPOSE OF THIS THESIS

The focus of this thesis is in the creation of a geographic information system and the examination of its usefulness for detecting land-use change on the rural-urban fringe. In doing so, decisions concerning the most advantageous methods for handling data will be discussed. The rural-urban fringe land-use analysis will center on how the land use in this study area has changed, how land use on the flood plain has changed, and how land use can be analyzed in conjunction with soils information. The effectiveness of the GIS will be judged by the amount, speed, and accuracy of information (maps and areal calculations) generated by the system.
ORGANIZATION OF THIS THESIS

This thesis is roughly organized according to the specific questions involved. Chapter 2 will discuss the method used to create the Land Use Change Geographic Information System. Chapter 3 concerns the analysis of both the LUCGIS and selected land-use information generated by the system. Chapter 4 examines possible improvements to the LUCGIS and presents the conclusion of this research project.
CHAPTER II
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. To implement these steps, decisions concerning mapping of overlays, difficulty in programming, and method of encoding the data had to be made.

Others have set out to build similar systems. Peter Adeniyi's 1980 study of land-use change in Lagos, Nigeria employed a similar method but was limited by the technology of the 1970's. Instead of using an a coordinate digitizer and later converting to a raster mode, a grid was overlayed onto land-use maps and each grid cell was encoded individually - a time consuming process. The method chosen for LUCGIS cuts time drastically, is more accurate, and produces a final product of higher quality.

PREPARATION OF MAP OVERLAYS

The first set of overlays to be produced were the land-use maps. These overlays were mapped using aerial photography. Several problems arose in the acquisition of appropriate imagery, including the severe distortion of imagery and several incomplete sets of
photographs. Three sets of acceptable imagery were finally obtained: 1) black and white photographs taken in July 1971, 2) color infrared photographs from July 1976, and 3) high altitude color infrared photographs of May 1981.

The land-use maps were prepared with a Bausch and Lomb Zoom Transfer Scope (ZTS). The ZTS allows the scale of the photograph to be adjusted to the scale of the map permitting the conveyance of information from an aerial photograph to the map. This enables the manual alteration of information on the map based on the more recent information from the aerial photograph. The USGS 7.5 minute Quadrangle of Irvington, Nebraska was chosen for the base map. The use of this base map 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. The basic classification system for the Existing Land Use Map of Omaha, Nebraska, May 1973, distributed by the Omaha City Planning Department, was chosen for this project. The five land-use categories from this classification system include: 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.
The choice of a seven-class system was not made arbitrarily. There is no specific optimum number of categories to use in order to minimize confusion between categories. In general, however, a range from four to seven patterns is frequently suggested for mapping purposes (Campbell, 1982, pp. 187-188).

The first land-use map created was the 1971 land-use overlay. Photographic interpretation went slowly at first, because of the difficulty in using other sources of information to verify the photographic interpretation process. Three types of interpretation verification were employed: (1) the Polk City Directory, (2) 1973 Existing Land Use Map, and (3) field observations. The usefulness of Polk's City Directory was limited because it only included the area east of Interstate 680 in the 1971 edition. The Existing Land Use Map was helpful, but it was constructed two years after the time period of this overlay. Field observations can be time consuming and were made only as a last resort. However, if the object on the photograph could not be interpreted or verified by other means, a field observation was made.

After the first land-use overlay was constructed, copies were made using the diazo copying process (an ultraviolet light photographic process). The next two land-use overlays were constructed using the diazo copies which saved time in the map preparation and assured a high degree of coincidence between the maps. The 1976 land-use overlay was constructed in the very same
manner as the 1971 overlay. It should be noted that the Polk City Directory extended past Interstate 680 and proved to be more useful for the 1976 and 1981 overlays. However, for the 1981 overlay, the process of land-use classification relied more heavily on field observations. In all, over fifty sites were checked to insure proper interpretation. The Polk City Directory and the new 1976 land-use overlay were also referenced during the construction of the 1981 overlay.

Road maps of the urban fringe area were also produced from the three sets of aerial photographs. These overlays were constructed in the same manner as the land-use overlays. Diazo prints of the 1971 road map overlay were produced, and the two remaining road maps were constructed on these prints.

The final two overlays to be produced depicted flood plain and soils information. These two overlays were copied directly from existing maps via the Zoom Transfer Scope and scaled to the Irvington, Nebraska 7.5 minute Quadrangle (scale 1:24,000) base map. The flood plain map overlay was taken from the Federal Emergency Management Agency's Flood Insurance Rate Map of October 1980. The information transferred to the overlay was the 100 year flood plain and 500 year flood plain. The soils map overlay was taken from the 1975 Douglas County Soil Survey produced by the Soil Conservation Service (SCS). To produce a discernible soils map, generalization of the SCS soil classes was necessary. Soils generalization was
achieved by combining soils groups with similar characteristics.

DATA ENTRY

Upon completion of the map overlays, the task of entering data into a computer at the Remote Sensing Applications Laboratory was initiated. Choosing the manner for data entry was important for this project, as it is for any project involving computer mapping. Three types of data entry were considered, photo digitizing with a video-digitizer/scanner (ordinarily used for digitizing photographs), arc/node digitizing, and ordinary string or 'spaghetti' digitizing.

Photo digitization was initially considered as the method by which data would be entered into the computer. An optic's scanner or vidicon camera was to be employed which would, in essence, take a picture of a map and convert it into a matrix (640 by 480) of picture elements (pixels) each having a gray tone between 0 (black) and 255 (white). There were several problems associated with photo digitizing. Firstly, the scanner would pick up jagged line widths which meant that the digitized picture would have had to be carefully edited. Secondly, gray-tone shading markers were to be used to create a map of the different land uses. The major difficulty in implementing this digitizing approach was finding a suitable material on which to apply the gray tones. On mylar the marker tended to bead up, and on paper the marker would be absorbed.
more heavily on some portions than on others, thus causing the scanner to pick up different gray values from the same gray-tone marker. The scanner, therefore could only distinguish three or four gray tones out of the eight marker tones on the map. There would also be a problem in the registration of overlays. Maps would have to be placed in the exact same spot during digitization for acceptable accuracy.

The second method considered was the use of a digitizing table to enter X-Y coordinates in an arc/node topologic structure, later to be changed to raster representation. The basic arc/node topological elements of a polygon map, including arcs, nodes, and polygons (Figure 3), are all uniquely identified and cross-referenced to one another (Hallam, 1981, p. 3). The arc/node form of digitizing has several advantages: 1) coincidental arcs of two different maps could be registered, 2) arcs shared by different polygons of the same map would not be duplicated, 3) polygons could be manipulated separately, 4) storage would be efficient, and 5) maps would be easily updated.

There were three important reasons why arc/node data-structure was not implemented for LUCGIS. First, digitizing in an arc/node mode would have taken a long time because each node, arc, and polygon must be entered and given a unique identifier. To do this, arcs and polygons would have had to be numbered on the maps. This would have taken a considerable amount of time since there are so
FIGURE 3

Arc/node Data Structure

Source: Hallam, 1981.
many arcs and polygons on the land-use maps. Second, the software for arc/node digitization was not available. Third, the arc/node method is often used when manipulations are performed using vector graphics. However, these maps would not be used or manipulated until they were changed into raster form. Had the project been directed toward the use of vector graphics instead of raster graphics, an arc/node data-structure would have been used.

The final method of data entry considered, and eventually chosen, was the so-called spaghetti method of data entry. The spaghetti method allows the user to simply record X-Y coordinates during the process of digitization. These X-Y coordinates were later changed to a grid cell representation in the rasterization process. Coordinates were digitized using a Numonics digitizer and a pre-existing digitizing program called NUMON. 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 rasterizing of this information was necessary to use the Eyecom II Image Processor equipped with Spatial Data Systems software and software developed specifically for this project. Rasterization was accomplished by using a pre-existing set
of vector-based subroutines to write the vector information to the raster-based Eyecom terminal. Once the vector information was in the memory of the Eyecom terminal, the maps could then be saved and processed in a raster mode.

DIGITAL MAP CONSTRUCTION

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 digital land-use polygon maps had to be compared to insure that coincidental arcs 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 Eyecom 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 (PAN).

Polygons were then assigned gray tones according to the corresponding land-use category. A seed-polygon fill program called PFLL (Table 1) was used to assign gray tones to polygons. The user is prompted for the desired gray-tone value and then is asked to place the joystick cursor within the polygon. Shading proceeds from the seed-value outward until a boundary is reached. After all polygons were filled, a program that compared the two maps (ALCOMP, a program which was used later in the actual overlay process) was
employed to find any areas on the maps that were still misregistered.

The final process in constructing these computer maps was the addition of map titles, legends, roads, north arrow, and scale. Actual comparisons (change maps) were made using map files without such ancillary information. The lettering was done with two different routines. The title was created by a program called NOTES, which produces a larger, bolder letter. The lettering in the legend was produced by SHSYM, that allows the user to choose the gray-tone value, height, and angle of the letter. The very last element to be added to each map was the road overlay using a program called FLDP2 (Table 1). The road overlay was edited in raster mode to display only major thoroughfares because showing all roads created clutter and obscured the polygon boundaries.

**SUMMARY**

The methodology used in the formation of LUCGIS involved preparation of map overlays, data entry, and digital map construction. Creation of the LUCGIS data base used the most time in building this Geographic Information System. At this point, the map overlays were ready to overlay, make comparisons, and calculate areal statistics.
TABLE I

PROGRAMS WRITTEN FOR LUCGIS

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<th>PROGRAM</th>
<th>FUNCTION</th>
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<td>ALCOMP</td>
<td>Contains four different comparison options. Two map files are overlayed to determine which chosen values, that represent land uses, are in the same or different locations. The program was used to produce the land-use change maps and for verification of accurate registration.</td>
</tr>
<tr>
<td>UPDAT</td>
<td>Writes the chosen value of one map file over another. It was used primarily for overlaying the road map, legend, and title onto the change maps.</td>
</tr>
<tr>
<td>FLDP2</td>
<td>Displays all of the values from one map that are in the same position as the chosen value, or values, from another map. It was developed to show land use on the flood plain.</td>
</tr>
<tr>
<td>SAME2</td>
<td>Works very much like FLDP2, but instead of displaying all values in the same position as the value chosen from another map, it displays all values with the exception of the chosen value. For example, if the vacant land value was chosen, the change map would show all land use values that coincide from the other map except for vacant land.</td>
</tr>
<tr>
<td>SHOW</td>
<td>Displays any chosen land use category (pixel value) from a single map.</td>
</tr>
<tr>
<td>CPIX</td>
<td>Changes a pixel value to a desired value throughout the entire file. This enabled map files to be output to the dot-matrix printer.</td>
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<td>CHAN⁴</td>
<td>Changes a range of gray tone values to a single value. It was developed for use with the photodigitizer and gray tone markers, originally intended for the digitizing method.</td>
</tr>
<tr>
<td>CALJR2</td>
<td>Uses several subroutines which enable data entered on the vector-oriented X-Y digitizer, to be written to the raster-oriented color graphics terminal.</td>
</tr>
<tr>
<td>PFLL</td>
<td>A routine which allows polygons to be filled with a gray tone value between 0-255 delimited by a user specified pixel value.</td>
</tr>
<tr>
<td>THESIS</td>
<td>Compares map files to determine the number of pixels that have changed within each category. Output consists of a two-dimensional table of these pixel counts by land-use category.</td>
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</table>
Urban planners often find it difficult to record and analyze changing land uses. The Land Use Change Geographic Information System (LUCGIS) was created to test the feasibility of using an automated approach for these purposes. This chapter will focus on the analysis of both the Land Use Change Geographic Information System and demonstrate the different types of land-use information that may be generated by the system.

**LUCGIS PROGRAMS**

Perhaps 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: 1) a computer and a raster-oriented image processing terminal, with some of the necessary software, were available in the Remote Sensing Applications Laboratory at the University of Nebraska at Omaha; 2) the programs for raster overlaying are not as complicated 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 (Figure 4), the vector method of
FIGURE 4

Raster Overlaying
'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 several raster overlaying programs for LUCGIS. These overlaying programs can be broken down into two categories: 1) programs that were used for overlaying, making comparisons, and producing a map and 2) programs that were used to simply add information onto a map. The program ALCOMP, most important of the overlay programs in LUCGIS, compares two land-use maps to produce the change maps. ALCOMP is also used to detect errors in matching coincidental lines of polygon maps made during the spaghetti digitizing process. The program FLDP2 was developed to compare and overlay the flood plain map with land-use maps. A map is produced that shows all land uses on either the 100 or 500 year flood plain. The program UPDAT is the second type of overlay program which adds information from one map to another. It does not compare maps, but rather allows the chosen values of one map to take presidence over the values on another map. UPDAT enables the roads, title, and legend overlays to be written onto the land-use, flood plain, and soils maps.

LUCGIS also includes the programs needed for map construction. CALJR2 is a program 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 (PFLL) was needed to enter the desired pixel values into each polygon.

Calculation of acreage was an important aspect of LUCGIS. The program THESIS compares two land-use map files and calculates the number of pixels that have changed between the categories of the two maps to output the two-dimensional Table 2. 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.

These programs, along with the other programs listed in Table 1, comprise the map manipulation capabilities of LUCGIS. Several programs available on the image processing system were also used in this project. As many as twelve programs were run on a digital file to produce the desired map.

EXAMPLES OF LAND-USE COMPARISONS

Many land-use comparisons can be displayed and analyzed with LUCGIS. Of these many comparisons, only a few will be investigated to demonstrate the usefulness of this system.
### TABLE II

**LAND USE CHANGE ACREAGES**

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<tr>
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<tr>
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<tr>
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</table>

(Measurement in acres)
Land-use categories consist of single-family residential, multi-family residential, commercial, industrial, public, agricultural, and vacant. The maps produced for this section 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 6) exhibits change in the upper left corner of the map, north of Maple Street and west of I-680, resulting from the growth of two large housing developments. Also seen on this map is the growth of the Regency area, another housing development, east of I-680 and south of Dodge Street. 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 7) has changed greatly since 1971, with almost a 60% increase. Most of the change has occurred north of Maple Street and west of I-680. Of the 133 acres of multi-family residential added between 1971 and 1981, 95 acres are north of Maple Street. Taking advantage of the increased
population, commercial activities followed residential growth into this area (see Figure 8). However, most of the commercial land use is the result of strip development and is located along Dodge Street, with larger shopping centers adjacent to the I-680 interchange.

Vacant (Figure 9) and agricultural (Figure 10) land uses have experienced losses in acreage. These acres have gone into such uses as, single-family residential, multi-family residential, commercial, public, and industrial. Since 1971, 488 acres were taken out of vacant use and in 1981 only 207 acres were added to this category. The result is a net loss of 281 acres of vacant land between 1971 and 1981. Between 1971 and 1981 agricultural land decreased by nearly 50% (685 acres). A large portion of these agricultural losses went into vacant use by 1981 (Figure 11). In fact, 203 of the 207 acres added to vacant land use between 1971 and 1981 were classified as agriculture in 1971. The change from agricultural land use to vacant land use resulted from one (or any combination) of the following reasons: 1) vacant land may be held for land speculation, 2) land was cleared for development but no buildings were evident, and 3) misinterpretation because of the difficulty in delineating between agricultural land use and vacant land from aerial photographs in some instances.

Table 2 also shows land-use comparisons from one year to another. It was obtained by numerically comparing two map files and
OMAHA URBAN FRINGE

LAND USE CHANGE

1971-1981

VACANT

1981

1971 & 1981

1971

1 MILE

← N
OMAHA URBAN FRINGE

LAND USE CHANGE

AGRICULTURAL 1971 TO VACANT 1981

1  MILES

FIGURE 11
counting the number of pixels that have changed from one category to another. Much of the acreage statistical information was measured directly from land-use change maps using a pre-existing program. The program THESIS (see Table 2) provides as 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.

RURAL TO URBAN ANALYSIS

As mentioned earlier, the problem of rural land being swallowed up by urban uses is a topic that has concerned geographers and urban planners in the recent past. 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. As result of the broad nature of this classification system, one might argue that some parcels of land could be misclassified. For example, in the rural-urban fringe area it is nearly impossible to determine whether a parcel of vacant land is rural or urban. The reasoning behind using vacant land as a rural type is that in 1971 much more of the study area was used in agriculture and the vacant
parcels were very large, which would indicate that in the not-too-distant past much of this vacant land was agricultural.

The 1971-1981 Rural to Urban Land Use Change Map (Figure 12) 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 north of Maple Street and west of I-680. 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, to the east of I-680 and south to Dodge Street, very little rural to urban activity has taken place. The reason for the lack of change here is that much of this area was already classified as urbanized area as seen on the 1971 Land Use Map (Figure 13).

SOILS/LAND USE ANALYSIS

When growth occurs in rural-urban fringe areas, prime agricultural land often goes into urban uses and this area is no exception. As noted in Chapter 1, prime agricultural land has very fertile soil. The two best soils for agriculture in this study area, the Monona series and the Marshall series, were compared to the land-use maps of 1971 and 1981. The acreages show that 31% of these two soils were used for agriculture in 1971 but dropped to 11.8% in 1981. The intensive urban uses (i.e. industrial, public, commercial, single-family residential, and multi-family residential)
gained 630 acres (24.5% increase) of Monona and Marshall soils during the same period.

The consequences of these prime agricultural soils being developed for urban uses may not be a pressing issue for Omaha since good agricultural land is relatively plentiful. However, one must wonder about the effects this could have for the future. It is easy to convert from agricultural uses to urban uses, but the reverse is not true.

Soils information from the Soil Conservation Service (SCS) Engineering Uses of Soils Table has benefited planning agencies, town and city managers, land developers, contractors, and farmers. Among properties of soils important in engineering and for this GIS are permeability, strength, compaction characteristics, soil drainage condition, shrink-swell potential, grain size, plasticity, and soil reaction. The engineering-soils tables reflect the results of engineering laboratory tests on soil samples, estimations of soil properties significant in engineering, and interpretations for various uses (Soil Conservation Service, Douglas County Soil Survey, p. 54). The information from these tables represented on soils maps is not meant to be the deciding factor in determining a site for a particular use, however, it is a good way to begin a preliminary search for potential sites.

To demonstrate this capability, the Engineering Interpretations
Table was consulted for soil series limitations for sewage lagoons to determine where they would best be located. The table includes one of three responses (slight limitation, moderate limitation severe limitation) for each soil concerning its degree and kind of limitation for sewage lagoons. Each response is modified with a short explanation. The soil best suited for sewage lagoons is the Marshall series, the only series with just a slight limitation for construction of sewage lagoons. Figure 14 illustrates the portions of the study area with only a slight limitation for sewage lagoon sites. It should be noted that although there is a slight limitation according to this type of soil, other factors influenced the location of a sewage lagoon in an area of moderate limitation.

FLOOD PLAIN ANALYSIS

Since the study area includes a stream, Big Papillion Creek, analysis of urban encroachment was implemented. A flood insurance rate map from the Federal Emergency Management Agency showing the 100 and 500 year flood plains was digitized to overlay with land-use maps. Maps were constructed displaying land-use information from 1971 (Figure 15) and 1981 (Figure 16). Acreages were then derived from these maps. Important changes included decreases in Agriculture by 32.7% and Vacant land by 20.9%. Urban type uses: commercial, single-family residential, and multi-family residential increased from 1.9% to 7.4%. Even though these combined urban uses increased nearly three and one half times the actual acreage is very
small.

The public land increases from 76 acres in 1971 to 196 in 1981 were due to the addition of golf courses and parkland. The increase in public land is evidence of a conscious effort to preserve open space on the flood plain, even at the cost of agricultural and vacant lands. Although agriculture and vacant lands are considered compatible uses on the flood plain there can be problems, such as, agricultural runoff which can contribute to the polluting of streams.

SUMMARY

The Land Use Change Geographic Information System enables change maps to be produced by overlaying two maps. The most interesting changes in this rural-urban fringe study area, between 1971 and 1981, dealt with the increase in residential land use, the decreases from agricultural land use and vacant land, and the increase in public land added to the flood plain. These changes can be seen in either map form or through tabular acreage calculations.
FIGURE 15

OMAHA URBAN FRINGE

1971 FLOOD PLAIN LAND USE

100 YEAR FLOOD

SINGLE-FAMILY RES
MULTI-FAMILY RES
COMMERCIAL
INDUSTRIAL
PUBLIC
AGRICULTURAL
VACANT

Source: FEMA, 1980.
CHAPTER IV
CONCLUSION

The major objective of this project was the creation and evaluation of a geographic information system designed specifically for detecting change in a rural-urban fringe area. This objective was sought through the development of several programs to assist urban planners and geographers in land-use change analysis. The information gained from the use of LUCGIS will be useful to those interested in land-use change for the rural-urban fringe. Hopefully, the system will lead to further analysis or for a more ambitious project for the entire city of Omaha.

The programs written for LUCGIS were the key to the success of this system. These programs also improved the general mapping, overlaying, and area calculation capabilities of the Eyecom Image Processing system. Probably the most favorable aspect of the LUCGIS programs is the ease with which these raster-oriented programs can be altered to assist in other projects.

IMPORTANCE OF RASTER APPROACH

Another concern of this project was testing the feasibility of the raster approach for spatial data encoding. 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, as stated in Chapter 2, 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.

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 graphics 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.
IMPROVING UPON LUCGIS

The LUCGIS system was designed primarily for the multi-temporal analysis of land use. While designing the system, attention was given to the way that updates and improvements could be made. It was intended from the beginning that this project was a precursor to a much larger GIS that would encompass the entire city of Omaha. By mapping overlapping segments, roughly the same size as maps produced for LUCGIS, a composite land-use map of Omaha could be made.

To develop a system for the city of Omaha, it would be advisable to break down the LUCGIS land-use classification system into many more categories. It would be possible to use a classification system with up to 256 categories on the Eyecom Image Processor. In all probability, it would not be necessary to use all of these gray-tone values. Omaha City Planning’s Major Land Use Code calls for 9 major land uses which could be divided into 49 sub-uses, which could further be divided into 80 more uses. The overlaying program ALCOMP could be altered to compare ranges of values instead of single values. This would allow all sub-uses from one general category to be compared to the subuses of that same category from another year.

Although LUCGIS was developed to study land-use change, an Omaha GIS might allow the addition of other types of overlays, with land use as one component. Overlays could be used with land use, as
were the soils and 1980 flood plain overlays in LUCGIS. These overlays might include such information as census tracts, tax maps, neighborhoods, and land ownership.

Other overlays that might also be used in an Omaha GIS include geology, slope, drainage, zoning, utilities, and historical areas. When using these overlays it is often necessary to record information about these areas through the use of a relational data base. For example, if an overlay of historical areas were to be added to the system, the relational data base could include tabular and textual information about the type of area, when it was discovered, facilities available at the area, and historical significance. The value of these data bases rests with the greater amount of specific information about these areas that can be recorded. This type of approach is very useful to all types of planners.

Taking into consideration that this system would use a large data base (as compared to LUCGIS) the method of data entry and data storage would have to be more efficient. Digitizing the maps for the Omaha GIS should probably be accomplished using an arc/node method. This approach would assure proper registration between coincidental arcs, so the manual correction of misregistered lines with a 'paintbrush' program would not be necessary. During arc/node digitizing, the user could specify the gray-tone value needed for each polygon and enter it into the data file to avoid using a
time-consuming polygon fill routine. Although the arc/node method requires more time than the spaghetti method for data entry (as discussed in Chapter 2), there would be a net savings of time by reducing the number of programs that have to be run to produce a map.

Storage of raster data for a larger data base could also be improved in comparison to LUCGIS. All pixel values are presently recorded as single elements of a data file. The data file is made up of 640 columns by 480 rows, totaling 307,200 data elements. To prevent from recording so many values, a run-length encoding conversion program could be written. Data can be stored by recording the number of successive values and the value itself all across each row, as opposed to recording every value (Figure 17). Utilization of this run-length encoding storage technique could reduce storage costs by over fifty percent.

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 map comparison or producing hand drawn comparison maps.
FIGURE 17
RUN-LENGTH ENCODING

CONVENTIONAL RASTER ENCODING

RUN-LENGTH ENCODING
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 database maps digitized, it is only a matter of maintaining the system. For example, if LUCGIS is to be useful in monitoring land-use change in this rural-urban fringe area, another map should be produced and digitized in 1986 for comparison with the 1971, 1976, and 1981 land-use maps.

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 three land-use maps, many comparisons of land-use categories were produced in the form of dot-matrix printer maps and acreage calculations.

The value of this research project to geography rests in the
demonstration of the usefulness of a technique that enables geographers to analyze spatial changes in a temporal context. The Land Use Change Geographic Information System demonstrates the effectiveness of a GIS to monitor change, as well as the ability of technologically advanced tools to assist in the pursuit of geographical study.
APPENDIX A

Land Uses Found In The Study Area

Industrial: substations, maintenance garages, bottling plant, warehousing

Public: parks, sewage treatment, golf courses, schools, churches, raquetball courts

Commercial: offices, banks, restaurants, fast foods, grocery, convenience stores, auto sales, gas stations, hotels, motels, shopping malls, drive-ins

Single-family residential: single family houses, trailer houses

Multi-family residential: apartments, duplexes, apartment recreation areas

Agricultural: croplands, fallow lands

Vacant: transportation, lands not in other uses
## APPENDIX B

### Land-Use Acreage Table

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Total Study Area Acreage = 4303

### Flood Plain Land-Use Table

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Total Flood Plain Acreage = 720

(Measurement in acres)
Soils Map (1975): used for overlaying with land-use maps to derive acreage calculation comparisons of soils to land use and for displaying the Marshall series soils in Figure 14.
OMAHA URBAN FRINGE

1975

SOILS MAP

WATER
STEINRAUER
GIBBON
GULLIED LAND
KENNEBEC
MONONA
MARSHALL
JUDSON
ROUGH LAND (LOESS)
LUTON

1 MILES

Source: SCS, 1975.
Appendix D

Land Use Map (1981): used in the comparisons of land-use categories to the 1971 Land Use Map in Figure 13 to produce land-use change maps.
Appendix E

Land Use Map (1976): comparisons with the 1976 Land Use Map to either the 1971 or 1981 Land Use Maps can also be made. Examples are seen in Appendices F and G.
Appendix F

Single-family Residential Land Use Change Map (1971-1976): because of the nature of growth in Omaha and the improved transportation in, and leading to, the study area, it was thought that most growth in single-family residential land use occurred between 1971 and 1976. However, in comparing the 1971-1976 single-family residential change map to the 1976-1981 single-family residential change map (Appendix G) it is evident that change occurred at roughly the same rate.
Appendix G

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