I. Project Title

Detecting Urban Change with Satellite Imagery: Applications for Growth Management in Springfield, Missouri.

II. Lead Investigator

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III. Research Goals / Objectives

A long-term growth analysis was conducted for the city of Springfield, Missouri utilizing satellite based remote sensor data and digital image processing. A historic look at urban growth using remote sensing will allow planners and the public to visualize the expansion occurring in and around the city. The purpose of this investigation will be to assess the usefulness of broad scale satellite data for detecting urban change in the Springfield metropolitan area. This study will use a multi-tiered strategy where NALC Landsat MSS triplicate data sets and Landsat ETM+ data will provide a long-term data set for change analysis. Four change detection methodologies will be analyzed, including post classification comparison, univariate image differencing, differencing of the NDVI, and PCA, and the results of these procedures discussed. It is believed that broad scale digital remote sensing data and image processing can be used for timely and accurate analysis of regional urban and suburban growth. Also, it is expected that different change detection techniques will produce varying results, which could ultimately lead to different planning and management procedures by policy makers. It is hoped that an assessment, such as this, will assist in developing growth management policies and aid in determining environmental priority areas due to urban change.

IV. Summary of Research Activities

Four change detection procedures were performed for various combinations of time sequences. The change detection procedures included post-classification comparison, univariate image differencing, image differencing of the NDVI, and PCA. The time sequences analyzed for each procedure included 1972 to 1984, 1984 to 1992, 1992 to 1999, 1972 to 1999, 1972 to 1992, and 1984 to 1999.

Georectified Landsat MSS data for the years 1972, 1984, and 1992 are used to help detect urban change. The MSS data was purchased by the Institute for the Development of Commercial Remote Sensing Technologies (ICREST) through the NALC project. The fundamental NALC data set is a Landsat MSS triplicate that is comprised of three dates of coregistered imagery that provide complete coverage for the area corresponding to the Landsat WRS-2 path/row tile.

Table 1. Scene Aquistion Dates for Path 25/Row 34

Scene #	Date
1	4-Oct-72
2	18-Sep-84
3	24-Sep-92

The original data were geocoded (geometrically corrected and geographically referenced to a map base) to generate images in a UTM projection with a resampled pixel size of 60 meters by 60 meters. The scenes were later subsetted to the study area of interest. The upper left and lower right coordinates for the subsetted images are 441840.00 E, 4144800.00 N and 496620.00 E, 4102260.00 N, respectively. The subsetted images for each year contain Greene County, along with an approximately 3-kilometer buffer around the county. The analysis for this project was performed on a Windows NT system and it utilizes ENVI (Environment for Visualizing Images) digital image processing software produced by Research Systems, Inc. We will discuss only the two most common of the four classification techniques in the next section.

Cross-classification is a pairwise technique used for change detection. This technique has been the most common technique applied in the analysis of urban growth and change detection (Eastman et al. 1995). The methodology includes post-classification comparison. This involves the application of either an unsupervised or supervised classification procedure to each image date. These two maps are then compared on a pixel-by-pixel basis using a change detection matrix. Cross-classification or post-classification comparison has been shown to be beneficial in urban change analysis (Ehlers et al., 1990; Pathan et al., 1993). It has also been a difficult procedure to use because it often inflates estimates of the numbers of pixels that have experienced change (Martin, 1989). Overestimation occurs when there is error present in the individual date classification maps. Therefore, it is imperative that the individual classification maps used in the post-classification comparison technique be as accurate as possible.

Vegetation Index Differencing has been used successfully for detecting change (Sohl, 1999). Yuan and Elvidge (1998) were able to show great results using Normalized Difference Vegetation Index (NDVI) differencing on NALC data in the Washington, D.C. area. This study has utilized NDVI differencing to detect urban change. The NDVI formula was used to compute the index for each of the dates:

NDVI = (MSS Band 4 – MSS Band2) / (MSS Band 4 + MSS Band 2)

After NDVIs were calculated for each year, the difference from the years was performed for each pair:

1972 NDVI – 1984 NDVI, 1984 NDVI – 1992 NDVI, 1972 NDVI – 1992 NDVI

It was visually possible to detect the change that had taken place between the dates, especially around the city of Springfield. Brighter pixels around the city indicate a change from healthy vegetation to less healthy vegetation or no vegetation. Statistical analysis has yet to be performed on these NDVI differenced images to quantitatively determine the amount of change that has taken place in the study area.

V. Conclusions

All across the United States, the problem of unmanageable urban growth is of great concern to politicians, citizens, and environmentalists. Many states have already taken or begun to take steps to halt expansion and prevent further degradation to agricultural and forested land covers surrounding metropolitan areas (i.e. Oregon and Maryland). Missouri is one of the few states in the Midwest and across the country that is doing little to combat unmanageable urban expansion (Lambrecht, 1999). The time has come for the state to step up and take notice to the problems associated with unlimited growth. It is believed that satellite remote sensing data can play a key role in making the public and policy makers aware of the problems associated with unmanageable urban growth.

The main goal of this research was to test the effectiveness of remote sensing data from satellite based sensor systems to track meaningful urban growth, especially at the urban-rural fringe. This research was implemented with two statements in mind. First, that digital remote sensing data and image processing could be used for timely and accurate analysis of regional urban and suburban growth. Second, that different change detection techniques would produce varying results, ultimately leading to different planning and management procedures by policy makers in urban areas based on the results of the techniques.

Four separate dates of imagery were used in the analysis and four different change detection procedures were tested (post-classification comparison, univariate image differencing, differencing of the NDVI, and PCA). All four procedures were successful in detecting urban change for the Springfield, Missouri study area. The timeliness and accurateness of the procedures are of some concern. Overall, the timeliness of univariate image differencing, NDVI differencing, and PCA were acceptable. Of these three procedures, univariate image differencing was very efficient in producing results. This was in large part due to the few steps that needed to be taken in order to perform univariate image differencing. Post-classification comparison, the most common technique used in urban change detection, was by far the most time consuming procedure of the four tested.

Accuracy of the four change detection methods was not as encouraging as expected. The post-classification procedure produced the poorest results of any of the procedures, even though only five land cover classes were used. The reasons for its inaccuracy may be due to the acquisition times of the imagery as well as the physical conditions that were taking place when some of the data was collected. Another reason for the inaccuracies may have been due to the differences in time between the collection of the satellite data with that of the aerial photographs that were used to collect the sample points. The aerial photographs for the most part were off by one or two years and the seasons varied from the late summer and early fall acquisition times of the satellite data. The other three change detection procedures produced more accurate results. However, these accuracies were made based on some assumptions about the spectral responses due to the land cover changes found in the aerial photographs. Overall, it was felt that univariate image differencing, NDVI differencing, and PCA were rather reliable as well as easier to implement.

The four change detection procedures did produce varying results. The post-classification procedure displayed urban land change as high as fifteen percent. The other three change detection procedures all exhibited urban land change at relatively the same percentages (anywhere from two to four percent) depending on what time sequence. Whether or not these varied results would have an effect on any management or policy decisions made by the policy makers is too hard to determine.

Based on the change detection procedures analyzed, it was determined that univariate image differencing was the easiest procedure to calculate, and also the most accurate when considering the amount of agreement it achieved. Differencing of the NDVI and PCA displayed similar amounts of accuracy as univariate image differencing. These two procedures could be implemented and used in a regional or local planning office, as well, although not as easily as the univariate image differencing technique. Although the post-classification technique was beneficial because of its ability to provide 'from' 'to' information regarding land cover change, it was the most difficult and time consuming of the four procedures and it was also the least accurate of any of the change detection procedures. The poor accuracy of the post-classification technique limited its reliability to accurately describe land cover changes.

Because of the varied results from the different procedures, one of the future areas of research should focus on the combination of methodologies when analyzing urban change because of the complexity of urban environments. Also, a standardized method to compare and contrast various change detection methodologies and their results is imperative in order to help understand the differences between the techniques. Heterogeneous urban areas make it difficult for any one change detection method to be free from errors. It may be necessary to perform different change detection procedures or a combination of procedures to receive the best results. It could be possible to capture all the necessary change with various methodologies. A combination of change detection procedures, rather than just one procedure, could help to form some policy and management decisions at the local level regarding urban growth.

Further research needs to continue to utilize satellite imagery and digital image processing in urban environments for applications such as change detection. Different types of imagery and methodologies need to be tested. Higher resolution imagery, such as IKONOS (1m), should be utilized in the analysis of urban change detection. The opportunity exists for future development of improved methodologies for change detection, especially with the development of higher resolution satellite sensors.

Attempting this study with imagery from a different season and closer anniversary dates may be another area for future study. This study utilized satellite data that was collected in the late summer and early fall due to data availability. Unfortunately, this time of year has a very high amount of leaf cover which affects the delineation of urban areas. Also, dynamic changes were taking place in these scenes due to the seasons. The anniversary dates were within eighteen days of one another, but for change detection these dates were probably not close enough, especially for the time of the year that the data was acquired. Late winter or early spring imagery would allow for the delineation of urban areas to be less troublesome because the tree cover would be less of a factor. Anniversary dates of one week or less would be more appropriate because less error would be introduced due to less variability in dates.

Finally, a study like this needs to be implemented into a planning department at a local or regional level to see if it is a feasible option for governments to use this type of data to assist in growth management policies. This study suggests the use of multidate satellite imagery as a way to identify patterns and characteristics of urban growth at a broad scale. These identified broad scale areas of change would then be seen as a primary focus for more detailed change detection and mapping with aerial photography or some other higher resolution data source. It would be imperative that a detailed time and cost analysis be performed comparing the satellite imagery methodologies to the aerial photography methodologies.

This thesis incorporated remote sensing, image processing, and GIS in the assessment and analysis of urban change in the Springfield, Missouri metropolitan area. It evaluated the applicability of these techniques for managing future growth within an expanding metropolitan area. Furthermore, it tested four separate change detection techniques (post-classification comparison, univariate image differencing, differencing of the NDVI, and PCA). The results of the change detection procedures were then analyzed and compared based on their applicability to the urban planning process.

A historic look at growth through remote sensing and GIS could allow planners and the public to visualize the expansion occurring in and around Springfield. Such an assessment could allow for determining environmental ‘priority areas’ due to urban growth and assist in developing growth policies. While this thesis did not seek to predict or plan for future urban growth, it aimed at building a foundation, based on the methodologies and results described, for such an application to take place in the metropolitan areas for the state of Missouri.

The key geographic focus of ICREST is structured around developing applications that use remote sensing technologies for solving urban planning and growth management issues. By showing local governments, like Springfield, the usefulness of satellite imagery, a relationship can be created between local governments and commercial remote sensing products. The inexpensive cost of imagery (such as the NALC data @ $15 per triplicate) can help to bridge the gap between local governments and commercial remote sensing data. Inexpensive imagery affords local governments the opportunity to experiment with applications dealing with digital satellite imagery. Simple change detection procedures such as univariate image differencing can assist local governments in determining environmental priority areas due to urban expansion, especially for growth management policies. It is hoped that this study will be a significant step in developing a relationship between metropolitan areas of Missouri and digital satellite imagery.

VI. Presentations / Publications

2000. "Long-term growth visualization and change detection for urban planning applications:a Springfield MO urbanized watershed," *Proceedings of the IEEE International Geophysical & Remote Sensing Society Annual Conference*, 3 pp. (with Daniel J. Daugherty & James M. Dunajcik)

2000. "Long-term growth visualization and change detection for urban planning applications:a Springfield MO urbanized watershed," IEEE International Geophysical & Remote Sensing Society Annual Conference, Honolulu, HI. July 23-28, 2000. (James D. Hipple, Daniel J. Daugherty & James M. Dunajcik)

2000. "The use of multidate satellite imagery for the analysis of urban change: Applications for growth management in Springfield, Missouri," Seventh Biennial MidAmerica GIS Symposium, Osage Beach, Missouri. Poster. May 2000. . Poster. (J. Dunajcik (student), J. D. Hipple, and D. J. Daugherty)

1999. "The use of multidate satellite imagery for the analysis of urban growth: Applications for growth management in Springfield, MO." Pecora 14/Land Satellite Information in the Next Decade III Conference. Denver, CO. December 6-10, 1999. (James M. Dunajcik (student), James D. Hipple, and Fred May)

James Dunajcik – (graduated August 2000)
Thesis title: *The use of multidate satellite imagery for urban growth analysis: Department of Geography: University of Missouri-Columbia.*

VII. Students Supported

Dunajcik, James – Graduate Research Assistant

VIII. Subject Inventions

No inventions or other intellectual property was developed with support from this grant.

IX. Selected References

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