

A Change Detection Analysis of Agricultural Land Use from the 1970's to 2001 in Dane County, Wisconsin and the Relationship to Urban Growth.

Travis J. Bare

Department of Resource Analysis, Saint Mary's University of Minnesota, Winona, MN 55987

Keywords: GIS, Urban Growth, ArcGIS, Land Use, Land Cover, Agricultural Land

Abstract

This study explored the application of a geographic information system (GIS) to a land use and land cover (LULC) change detection analysis. Primary concern was given to changes in agricultural and developed land resulting from urban growth, although several land use categories were taken into consideration. Dane County, Wisconsin was the location for the study and the LULC raster data layers spanned three time periods including the 1970's, 1992, and 2001. Objectives included the identification of areas of rapid urban growth and how this directly impacted the availability of agricultural land, and the production of extrapolated values illustrating possible agriculturally impacted areas due to future urban growth.

Introduction

Dane County is located in the south central portion of Wisconsin and is home to the state capital, Madison. According to the Census 2000, Dane County hosted a population of 426,526 and covered a land area of 1,201 square miles. The city of Madison is centrally located in Dane County with a population of 208,054 in 2000. Figure 1 illustrates the study location.

Dane County has historically been one of the fastest growing counties in the Midwest as well as one of the most agriculturally productive counties in Wisconsin. Based on gross agricultural sales, Dane County has generally ranked first in Wisconsin and in the top fifty nationwide (Ventura et al., 2002). Data collected by the College of Agriculture and Life Sciences at the University of Wisconsin-Madison

suggested that 67 percent of all the land in the county was owned and managed by farmers, and the agrarian driven economy provided jobs to 23,739 residents (University of Wisconsin Extension et al., 2004). Economic estimates indicated that agriculture accounted for \$3.19 billion in annual economic activity, contributing \$1.11 billion to the county's total annual income (University of Wisconsin Extension et al., 2004).

Rapid urban growth has occurred in many metropolitan areas around the United States in the past 30 years. In many cases this was characterized as urban sprawl, a term generally referring to scattered and uncontrolled urban development in suburban environments having a negative impact on transportation networks, local resources, and open spaces (Peiser, as cited in Ji et al., 2006). This has typically involved



Figure 1. The study area in southern Wisconsin.

development in rural areas resulting in a low population and housing unit density for these regions. This development has triggered the fragmentation of farms and agricultural land ensuing in the depreciation of an economy traditionally driven by agricultural production and the aesthetic degradation of rural communities (Brabec and Smith, 2002).

This analysis provided evidence of rapid urban growth in many rural areas of Dane County, which were on the fringe of particular urban or suburban centers. Due to the proportionately high percentage of agricultural land that exists in Dane County, there has been concern for the negative impact that urban growth may have had on the largely agrarian driven society. This project evaluated LULC changes that have taken place primarily in the status of agricultural and developed land use types from three time periods: the 1970's, 1992, and 2001. The LULC data for the 1970's dataset was collected from aerial imagery acquired between 1970 and 1985. This differs from the 1992 and 2001 datasets which used data collected during the specified years, accordingly. Consideration was also given to changes that have occurred with regard to other various land use types, which may also have impacted agricultural land.

Methods

Data Acquisition

Several datasets were needed to complete this research. Primary datasets included three raster data layers identifying LULC information for the study area. These datasets were used for the core analysis procedures and illustrated land use information for the 1970's, 1992, and 2001 accordingly.

The 1992 and 2001 datasets were clipped from the National Land Cover Dataset (NLCD) created by the US Geological Survey (USGS) to correspond to the study area. Each raster dataset was produced with a spatial resolution of 30 meters. The 1970's LULC data was acquired from historical LULC information created by the USGS. The three LULC layers utilized are based on the level II classification system described by Anderson et al. (1976).

Other raster datasets utilized included a Wisconsin stewardship raster dataset created under the USGS Gap Analysis program (GAP), and a digital elevation model (DEM) created by the USGS. Both datasets were acquired via the Wisconsin Department of Natural Resources (DNR). The GAP dataset was used to identify land that was owned and operated by various state and federal agencies. The DEM was used to create a hillshade or relief layer enhancing visual acuity for several map outputs.

Various vector datasets were utilized including state and county boundaries, roads, cities, and hydrology. These datasets were used primarily for visual enhancement and clarity rather than analysis. Vector data was acquired from the Wisconsin DNR, Environmental Systems Research

Institute (ESRI), and the National Atlas database.

Two File Geodatabases (FGDB) were created in ArcCatalog 9.3 to store the datasets. One FGDB was used to store a majority of data used in the project. The second FGDB provided storage for the results of the change detection analysis using the raster calculator. All of the datasets were compiled into the FGDB's as standalone features at the geodatabase level. Each dataset was then evaluated to ensure it contained essential metadata. It was desirable that each datasets metadata contained a sufficient amount of information regarding its format and purpose for the analysis. Any supplemental information necessary to fully describe each dataset was then added using ArcCatalog 9.3.

Data Limitations

The 1970's LULC dataset was created on a much more regional status, possibly resulting in more generalized data than the more recent USGS NLCD's. However, it used the same classification scheme. Some of the differentiation between datasets may also be a result of advancements in technology and the enhanced quality of imagery acquisition methods in recent years. Evidence of these accuracy considerations was observed when comparing the 1970's and 1992 LULC datasets with the 2001 dataset. Development of the 2001 dataset involved a higher degree of accuracy, which could be a result of the inclusion of transportation networks. The 1970's and 1992 LULC datasets do not depict the majority of road networks. Instead, they only accounted for some of the major highways and interstates as seen in Figure 2.

Projection

All of the data used for the analysis procedures in this research were projected using the following:

Projected Coordinate System: USA
Contiguous Albers Equal Area Conic
USGS version

Standard Parallel 1: 29.500000

Standard Parallel 2: 45.500000

Central Meridian: -96.000000

Latitude of Origin: 23.000000

False Easting: 0.000000

False Northing: 0.000000

Linear Unit: Meter

Geographic Coordinate System:

GCS North American 1983

Datum: D North American 1983

Ellipsoid: GRS 1980

Semi-major Axis: 6378137.000000

Semi-minor Axis: 6356752.314140

Flattening Ratio: 298.257222

Data Preparation

Identifying the Study Area

The original LULC datasets were created to represent defined regions. The 1970's dataset encompassed the entire northeastern quarter of the United States. The 1992 dataset included only the state of Wisconsin, while the 2001 dataset was divided into an area that included Wisconsin, Michigan, and parts of Illinois and Minnesota. Each dataset was clipped from its original size to represent the study location using the raster 'clip' tool in 'Data Management Tools' within ArcToolbox. The 'clip' tool was selected because of its ability to maintain attribute data integrity and to completely redefine the extent of each dataset.

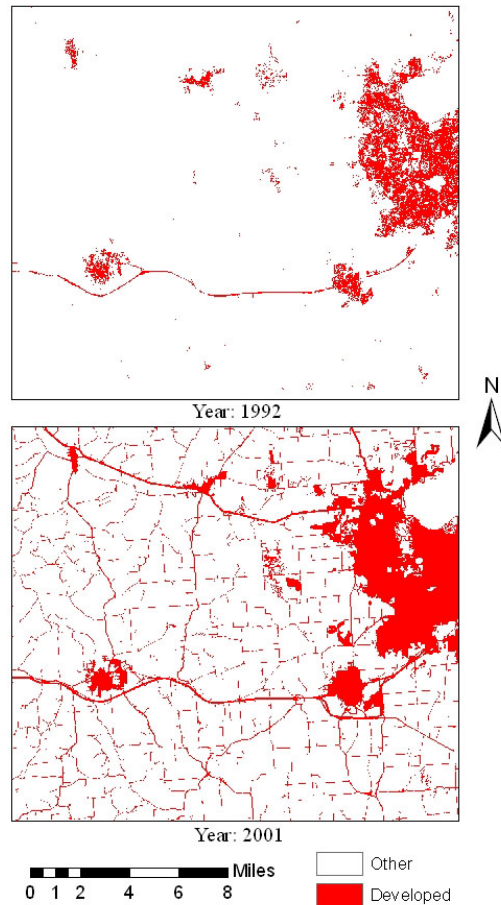


Figure 2. The sparse linear red markings delineate road networks.

LULC Classification

As the need to plan and manage critical areas in the landscape increased due to rapid changes in land use, a greater demand for standardized LULC classification procedures arose. Anderson et al. (1976) described four classification levels to be used with LULC data collected through the means of remote sensing technologies. Level I was the most generalized, while level IV was very specific but difficult to define from ordinary aerial photography. Level II classification was used for the three LULC datasets in this project. This classification method used a two-digit code to define each land use category.

Table 1 illustrates the 37 level II categories characterized by Anderson et al. (1976). Using the Anderson classification scheme as a foundation, all three LULC datasets were divided into 21 different land use categories predetermined by the USGS.

The LULC datasets were reclassified using Spatial Analyst in ArcGIS 9.3. Each dataset was reclassified according to the level I classification system, which subcategorized the 37 level II categories into only nine classes. Table 2 describes the nine level I classes. The datasets contained some variations regarding classification values, reflected in Tables 3, 4, and 5. This illustrated how each dataset was reclassified from its original level II categories into level I categories.

A description of each level I category used in this project can be observed in Table 6. The descriptions summarized the level II categories from which the NLCD was established. Full descriptions of each level I and level II land use categories can be viewed via the USGS website.

Data Analysis

The land use change detection analysis involved the use of the three LULC raster datasets and the GAP dataset. The objective for the analysis was to identify areas in Dane County where temporal changes occurred in LULC during the study interval. Primary concern was given to changes that took place on agricultural land due to urban growth. However, some changes that took place involved other land cover types and were worth noting as they occasionally had the potential to effect agricultural land in a significant way. The results were in numerical and spatial formats.

Table 1. Level II LULC categories based on Anderson et al. (1976).

Class Name	Class Code
Residential	11
Commercial & Services	12
Industrial	13
Transportation, Communications, & Utilities	14
Industrial & Commercial Complexes	15
Mixed Urban or Built-up Land	16
Other Urban or Built-up Land	17
Cropland & Pasture	21
Orchards, Groves, Vineyards, Nurseries, & Ornamental Horticulture	22
Confined Feeding Operations	23
Other Agricultural Land	24
Herbaceous Rangeland	31
Shrub & Brush Rangeland	32
Mixed Rangeland	33
Deciduous Forest Land	41
Evergreen Forest Land	42
Mixed Forest Land	43
Streams & Canals	51
Lakes	52
Reservoirs	53
Bays & Estuaries	54
Forested Wetland	61
Nonforested Wetland	62
Dry Salt Flats.	71
Beaches	72
Sandy Areas other than Beaches	73
Bare Exposed Rock	74
Strip Mines Quarries, & Gravel Pits	75
Transitional Areas	76
Mixed Barren Land	77
Shrub & Brush Tundra	81
Herbaceous Tundra	82
Bare Ground Tundra	83
Wet Tundra	84
Mixed Tundra	85
Perennial Snowfields	91
Glaciers	92

Table 2. Level I LULC categories based on Anderson et al. (1976).

Class Name	Class Code
Urban or Built-up Land	1
Agricultural Land	2
Rangeland	3
Forest Land	4
Water	5
Wetland	6
Barren Land	7
Tundra	8
Perennial Snow or Ice	9

Area Calculations

The area of each land use type was determined to enable the observation of numerical changes that occurred during the study period. The use of raster data allowed for efficient calculations of the land use data. Using the “count” field in the attribute table for each dataset, which represented the number of cells in a particular raster, the surface area was calculated for each land use category. All LULC raster’s were created using 30

* 30 meter cells, and therefore could be converted into consistent area measurements. The acre was selected as

Table 3. Reclassified land use values for the late 1970’s LULC dataset.

Original Class (Abbrev.)	Old Value	New Class	New Value
Residential	11	Developed	1
Commercial/Services	12	Developed	1
Industrial	13	Developed	1
Trans./Comm./Utilities	14	Developed	1
Mixed Urban/Built-up	16	Developed	1
Other Urban/Built-up	17	Developed	1
Cropland/Pasture	21	Agricultural	2
Confined Feeding	23	Agricultural	2
Other Agriculture	24	Agricultural	2
Deciduous Forest	41	Forest Land	4
Evergreen Forest	42	Forest Land	4
Mixed Forest	43	Forest Land	4
Streams/Canals	51	Water	5
Lakes	52	Water	5
Reservoirs	53	Water	5
Forested Wetland	61	Wetland	6
Non-forested Wetland	62	Wetland	6
Sandy - Not Beaches	73	Barren Land	7
Mines/Quarries/Pits	75	Barren Land	7
Transitional Areas	76	Barren Land	7

Table 4. Reclassified land use values for the 1992 LULC dataset.

Original Class (Abbrev.)	Old Value	New Class	New Value
Open Water	11	Water	1
Low Int. Residential	21	Developed	2
High Int. Residential	22	Developed	2
Comm./Indust./Trans.	23	Developed	2
Bare Rock/Sand/Clay	31	Barren Land	3
Quarries/Mines/Pits	32	Barren Land	3
Deciduous Forest	41	Forest Land	4
Evergreen Forest	42	Forest Land	4
Mixed Forest	43	Forest Land	4
Orchards/Vineyards	61	Non-nat. Woody	6
Grasslands/Herb.	71	Herb. Upland	7
Pasture/Hay	81	Agricultural	8
Row Crops	82	Agricultural	8
Small Grains	83	Agricultural	8
Urban/Rec. Grasses	85	Agricultural	8
Woody Wetlands	91	Wetland	9
Emerg. Herb. Wetlands	92	Wetland	9

Table 5. Reclassified land use values for the 2001 LULC dataset.

Original Class (Abbrev.)	Old Value	New Class	New Value
Open Water	11	Water	1
Developed, Open Space	21	Developed	2
Developed, Low Intensity	22	Developed	2
Developed, Medium Int.	23	Developed	2
Developed, High Intensity	24	Developed	2
Barren Land	31	Barren Land	3
Deciduous Forest	41	Forest Land	4
Evergreen Forest	42	Forest Land	4
Mixed Forest	43	Forest Land	4
Shrub/Scrub	52	Shrubland	5
Herbaceous	71	Herb. Upland	7
Hay/Pasture	81	Agricultural	8
Cultivated Crops	82	Agricultural	8
Woody Wetlands	90	Wetland	9
Emergent Herb. Wetlands	95	Wetland	9

Table 6. NLCD class descriptions (Adapted from U.S. Geological Survey, 1999).

Class	Description of Classes
Water	Areas of open water, generally with less than 25 percent or greater cover of water (per pixel).
Developed	Areas characterized by high percentage of constructed materials including low/high density residential, commercial, industrial, and transportation.
Barren Land	Areas characterized by bare rock, gravel, sand, silt, clay, with minimal "green" vegetation present. Includes quarries, mines, pits, and transitional areas.
Forest Land	Areas characterized by tree cover. Includes areas with deciduous, evergreen, and/or mixed forest types.
Non-Natural Woody	Areas dominated by non-natural woody vegetation. Includes orchards, vineyards, etc. Can be difficult to differentiate between natural & non-natural.
Shrubland	Areas characterized by natural or semi-natural woody vegetation. Includes evergreen and deciduous species of true shrubs and young trees.
Herbaceous Upland	Upland areas characterized by natural or semi-natural herbaceous vegetation. Includes areas dominated by upland grasses and forbs
Agricultural	Areas characterized by vegetation managed for the production of food, feed, or fiber. Includes pasture, hay, row crops, small grains, fallow, & recreational land.
Wetland	Areas where the soil or substrate is periodically saturated with or covered with water. Includes woody and emergent herbaceous wetland areas.

the unit of measure to represent the data due to its common use as a unit of measurement for surface area throughout the United States.

With the understanding that one square meter equals 0.000247 acres, the conversion used to transfer each dataset from square meters to acres was as follows:

“count” (number of grid cells per category) * .222394 (amount of acres per every 30 * 30 meter cell).

Tables 7, 8, and 9 reveal the results of these calculations for each LULC category and each temporal period.

The results indicated several LULC changes, some of which were substantial. To help clarify some of the results, Figure 3 illustrates the changes that occurred in the four largest LULC categories for each of the three datasets; developed, agricultural, forest land, and wetland. The most substantial changes

took place in the developed and agricultural categories.

Between the 1970's and 1992, agricultural land area decreased by 3.67 percent. Over the course of the following nine years from 1992 to 2001 the decline rose to 17.05 percent. This resulted in an annual loss rate of 1.89 percent for this time period.

While agricultural land area decreased, developed land increased overall. However, between the 1970's and 1992 the results were unexpected. According to the datasets, developed land experienced a decline of 18.06 percent. This may be a result of accuracy concerns regarding the 1970's dataset. Conversely, from 1992 to 2001 developed land increased by 163.97 percent, an annual rate of 18.22 percent.

Substantial changes in forest land and wetland took place during the study interval as well. Both land cover types experienced an overall increase in land area. From the 1970's to 1992 forest

land experienced an increase of 58.48 percent. Between 1992 and 2001 this increase declined to 9.38 percent. Wetlands experienced a decrease of 40.94 percent between the 1970's and 1992, but exhibited an increase of 179.94 percent from 1992 to 2001. This resulted in 13,509 more wetland acres in the 2001 dataset than in the 1970's dataset.

Figures 4, 5, and 6 illustrate the spatial LULC changes that took place during the period of study. An evaluation of the developed areas, shown in red, reveals minimal visual change from the 1970's to 1992. However, from 1992 to 2001 the developed area increased greatly. Not only did the primary metropolitan center increase in density extensively, but many of the outlying communities also experienced significant visual expansion. Figures 4, 5, 6 also illustrate a gradual increase in forest land during the study interval.

Unavailable Land

One issue in calculating appropriate area measurements involved accounting for land that is unavailable for agricultural or development purposes. In this analysis a GAP dataset was used to determine which parcels of land were classified as national, state, or local park lands. The LULC datasets did not take these parcels into consideration. For example, an area classified as agricultural land in 1992 may actually have been land that was unavailable for agricultural use due to its land stewardship classification. However, it was assigned as agricultural land due to the type of land cover. Identifying these areas allowed for alternative area calculations for each land use class. Any area that fell within a GAP region was

subtracted from the total available land use category. Tables 7, 8, and 9 reflect these calculations in the 'acres – GAP' column.

Change Detection Analysis

Spatial analysis of the LULC raster datasets was accomplished primarily with the use of the raster calculator, accessed through the ArcGIS Spatial Analyst extension. The raster calculator evaluated cell values between selected raster layers using map algebra statements. The objective was to produce numerical and spatial results for an LULC change detection analysis. The analysis involved an evaluation of the LULC changes that took place during the study period with regard to agriculturally classified land.

Table 7. 1970's conversion to acres.

Classes	1970's Acres	Acres - GAP	Percent
Water	22463.35		2.83%
Developed	47037.22	46777.24	5.94%
Barren Land	3627.69	3609.23	0.46%
Forest Land	62711.99	59028.04	7.91%
Agricultural	635934.09	622872.00	80.25%
Wetland	20679.75	14199.19	2.61%

Table 8. 1992 conversion to acres.

Classes	1992 Acres	Acres - GAP	Percent
Water	23646.04		2.98%
Developed	38540.44	38438.80	4.86%
Barren Land	170.80	169.24	0.02%
Forest Land	99386.99	94258.81	12.54%
Non-natural Woody	5.12	4.67	0.00%
Herbaceous Upland	5924.80	5740.88	0.75%
Agricultural	612568.26	597911.38	77.30%
Wetland	12212.99	8905.77	1.54%

Table 9. 2001 conversion to acres.

Classes	2001 Acres	Acres - GAP	Percent
Water	25507.70		3.22%
Developed	101735.25	100878.14	12.84%
Barren Land	431.89	431.89	0.05%
Forest Land	108710.64	103608.25	13.72%
Shrubland	8105.37	7809.59	1.02%
Herbaceous Upland	5663.04	5479.12	0.71%
Agricultural	508112.25	498359.16	64.12%
Wetland	34189.30	30882.08	4.31%

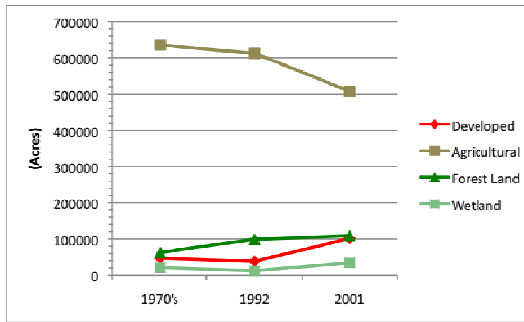


Figure 3. LULC temporal changes within the four largest LULC categories for Dane County.

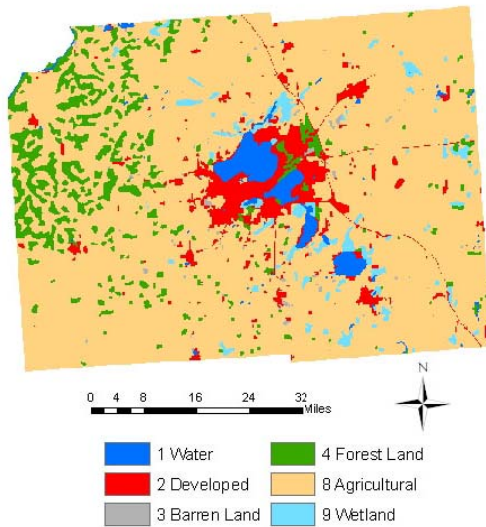


Figure 4. 1970's LULC datasets.

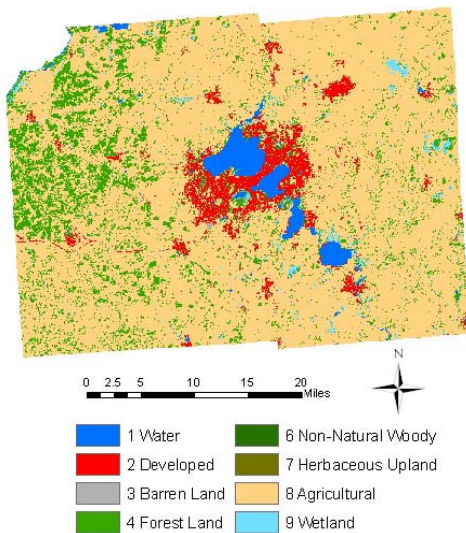


Figure 5. 1992 LULC datasets

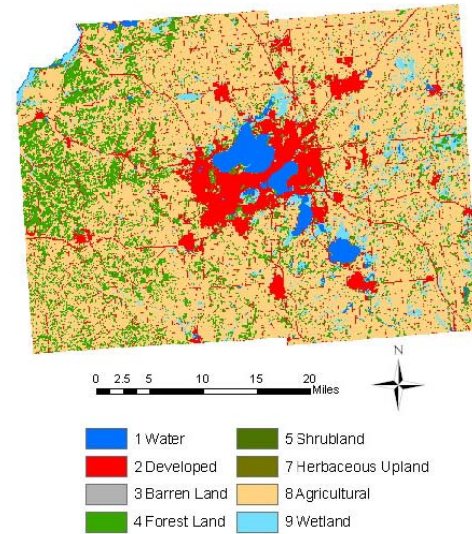


Figure 6. 2001 LULC datasets.

Changes were evaluated for three intervals using each dataset. The intervals included the following: 1970's to 1992, 1992 to 2001, and 1970's to 2001. The primary LULC categories that apparently had the greatest impact on agricultural land were developed, forest land, and wetland. These three categories encompassed 89 to 90 percent of all the LULC categories excluding agriculture. For each dataset, map algebra statements were used to produce an output defining the land that was once classified as agricultural in an older dataset, but was classified as one of the primary LULC categories in a more recent dataset. A sample of the condition statement syntax used to create an output showing land that was agricultural (value = 8) in 1992 and was classified as developed (value = 2) in 2001 is as follows:

Output = con(Agricultural == 8 and
Developed == 2, 1, 0)

Each interval also included an analysis of land that was agricultural in the older

dataset, but was classified as anything different in a more recent dataset.

The majority of agricultural land use change that took place involved developed land. However, a large amount of agricultural land also transitioned into forest land or wetland. Numerical results are represented in Tables 10, 11, and 12. The results indicate a greater amount of change taking place during the 1992 to 2001 interval than what was observed during the 1970's to 1992 interval. Figures 7, 8, and 9 illustrate the spatial changes that occurred during the intervals.

Extrapolations

The analysis included the construction of potential LULC conditions for specified future periods, based on historical growth patterns. Utilizing the 'Forecast' function in Microsoft Excel, future acreage values were calculated based on a linear model. The results are dependent on the previous growth or loss rates for the range of data. The dates selected for the extrapolations were 2020, 2030, and 2040.

The 1992 and 2001 LULC datasets were created using imagery acquired during a specific year. As a result these definitive years could be used to extrapolate the values for a later time period. However, the 1970's LULC dataset was produced using aerial photography collected from 1970 to 1985. The variables for the 'Forecast' function required definitive values. Therefore, the date 1978 was used to represent an average time period for the dataset.

For purposes of this analysis, only the developed and agricultural land use categories were taken into

Table 10. The amount of acres that changed from agricultural land to the respective LULC class during the interval of the 1970's to 1992.

Class	Agricultural Acres Changed
Developed	9836.26
Forest Land	50072.68
Wetland	4661.60
All Categories	69299.97

Table 11. The amount of acres that changed from agricultural land to the respective LULC class during the interval of 1992 to 2001.

Class	Agricultural Acres Changed
Developed	59380.75
Forest Land	37986.90
Wetland	20590.79
All Categories	131867.19

Table 12. The amount of acres that changed from agricultural land to the respective LULC class during the interval of the 1970's to 2001.

Class	Agricultural Acres Changed
Developed	57572.25
Forest Land	64738.23
Wetland	19406.77
All Categories	156825.80

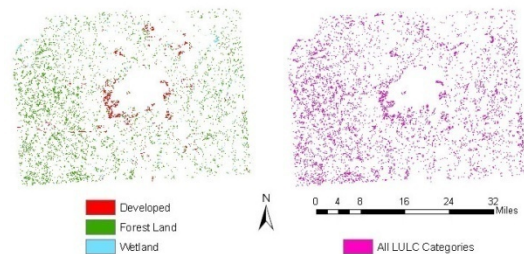


Figure 7. Designates spatially where agricultural land became another class during the interval of the 1970's to 1992.

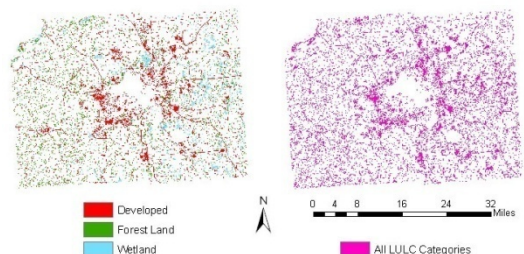


Figure 8. Designates spatially where agricultural land became another class during the interval of 1992 to 2001.

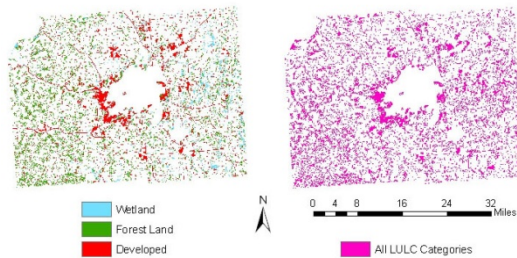


Figure 9. Designates spatially where agricultural land became another class during the interval of the 1970's to 2001.

consideration for the extrapolations. These categories experienced the majority of change and encompassed the largest portion of LULC in Dane County. The numerical results were based on the assumption that the LULC categories continued to follow a similar growth or loss rate respective to the historical rate of change. Table 13 defines the total number of acres for developed and agricultural land that resulted from a continuation of historical and current rates of change. Figure 10 reflects how the percent of land in Dane County could rapidly transition from being largely agricultural to developed land. This analysis did not take into consideration the changes that might have taken place with regard to other land use classes, which may have affected this rate of change.

Several variables could have played a role in the rate of growth or loss of land use classes. The former calculations did not take these variables into consideration, as it would have required a great deal of resources to accurately represent the extrapolations while considering potential variables. One assumption not accounted for in this analysis included limitations due to the carrying capacity for the various municipal and county infrastructures. An additional assumption involved several land cover or environmental factors which could have limited urban

growth or agricultural use. Some of these factors may have included terrain, slope, soils, and land cover such as wetland or preserved areas that might limit use.

Considerations

LULC changes that took place in Dane County, WI from the 1970's to 2001 could be a result of several factors. Some of these factors may involve legislative regulations or land values. The objective of this research does not involve an evaluation of the effectiveness or legitimacy of any of the following variables. Rather, the research provides a description of possible factors that may contribute to some of the LULC transformations that have taken place.

Conservation Programs

Federal and state governments have implemented a variety of regulations related to conservation practices. Some of the conservation programs that may have influenced LULC changes included Conservation Reserve (CRP), Wetlands Reserve (WRP), Grassland Reserve, and the Farm Bill. Many of these programs involved the restoration, preservation, and protection of various land cover types. This may have prevented the application of these land use types for human development, whether agricultural or urban in nature. Some of these programs may or may not have been established early enough to be reflected in the results of this analysis. However, an increase in many of these programs could have potentially resulted in the expansion of wetland and forest areas or a limitation of urban or agricultural development into these

Table 13. Extrapolated acreage values for agricultural and developed land.

Year	Agricultural Acres	Developed Acres
1978	635934.09	47037.22
1992	612568.26	38540.44
2001	508112.25	101735.25
2020	430685.26	125299.05
2030	378487.64	146488.30
2040	326290.03	167677.54

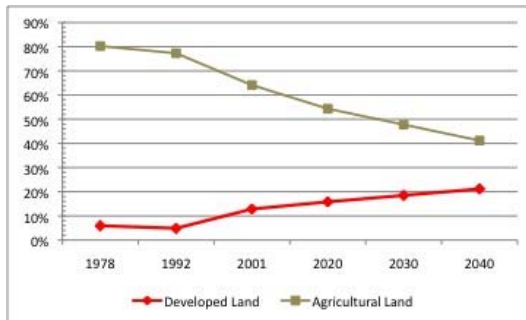


Figure 10. Illustrates the extrapolated pattern of growth or loss for agricultural and developed land use categories.

regions. As described in this analysis, forest land and wetland areas experienced gradual growth during the study interval. This may have reflected an increase in conservation programs established prior to the beginning of the study period.

Land Values

Land values were another factor to be considered as part of this analysis. As urban development progressed into rural areas, economic land values tended to increase substantially causing the conversion of agricultural land to non-agricultural land (Bastian et al., 2002). As the spatial analysis illustrated, the majority of observed change in developed land was an expansion of current urban areas, or fringe development, rather than new development occurring in distant rural locations.

Paul Musser is the assessor for the Town and City of Middleton, City of Verona, and several townships and municipalities on the western fringe of the Madison metropolitan area. Musser (2008) suggested that land values increased rapidly during the 1990's, although there has been a gradual increase since 1982 when he became an assessor in this area of Dane County. According to Musser, agricultural land values on the fringe in 1982 were approximately \$10,000/acre, and increased to roughly \$100,000/acre in 2001 or thereabouts. The increase in agricultural land values in Dane County may have encouraged the sale of agricultural land to be used for other purposes, and could be reflected in the decline of agricultural land in this region.

Results

Despite the difficulties encountered during the development of this project, primarily in the areas of data acquisition and production, geographic information systems provided an accurate and highly functional platform for an LULC change detection analysis. As Dane County's agriculturally based society has declined and the metropolitan and suburban areas have expanded, local governments and agricultural land owners have been in greater need of resources to help manage this dynamic environment. The visual and numerical findings provided a resource capable of increasing the awareness of residents and land use planners to the rapid land use changes that have recently taken place in Dane County. Geographic information systems produced information that could be useful not only to professionals, but to the community as a whole.

Acknowledgments

I would like to express my sincerest gratitude to all those who helped in making this project a success. First, I would like to thank Dr. David McConville, Mr. John Ebert, and Mr. Patrick Thorsell for the commitment that they made to ensure a tremendous experience at Saint Mary's University. I would like to thank all of my classmates at Saint Mary's for the roles that they played in making this a memorable experience. I would like to thank my parents for always encouraging me. Finally, I would like to thank my wife for her patience and for the sacrifices she has made throughout this process.

References

- Anderson, J. R., Hardy, E. E., Roach, J. T., and Witmer, R. E. 1976. A land use and land cover classification system for use with remote sensor data. Washington: U.S. Government Printing Office.
- Bastian, C., McLeod, D., Germino, M., Reiners, W., and Blasko, B. 2002. Environmental amenities and agricultural land values: a hedonic model using geographic information systems data. *Ecological Economics*, 40(3), 337.
- Brabec, E., and Smith, C. 2002. Agricultural land fragmentation: the spatial effects of three land protection strategies in the eastern United States. *Landscape and Urban Planning*, 58, 255-268.
- Ji, W., Ma, J., Twibell, R., and Underhill, K. 2006. Characterizing urban sprawl using multi-stage remote sensing images and landscape metrics. *Computers, Environment & Urban Systems*, 30(6), 861-879. \
- Musser, P. November 6, 2008. Personal Communication. Assessor for the City of Middleton, Wisconsin.
- University of Wisconsin-Extension, Cooperative Extension, Wisconsin Farm Bureau Federation, and Wisconsin Milk Marketing Board. 2004. *Dane County agriculture: Value and economic impact* [Brochure]. Madison, WI.
- U.S. Geological Survey. 1999. Wisconsin land cover dataset. Sioux Falls: U.S. Geological Survey.
- Ventura, S. J., Niemann, B. J. Jr., Sutphin, T. L., and Chenoweth R. E. 2002. *GIS-enhanced land-use planning. In community participation and geographic information systems*. W.J. Craig, T.M. Harris, & D. Weiner (eds). New York: Taylor and Francis. pp. 113-124.