

Using a Geographic Information System (GIS) and Aerial Imagery to Create a Land Cover Classification Dataset to Analyze Land Cover Change in the Urbanizing City of Shakopee, Minnesota

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Abstract

This study focused on land cover change as a result of urban development. The city of Shakopee, Minnesota experienced rapid population growth over the past twenty years and was chosen for the study area. Through the use of aerial imagery and a geographic information system (GIS), land cover classification layers were delineated via photo interpretation. Land cover classifications were created for the years 2003 and 2015 to analyze overall acreage change within each class as well as to determine change between individual land cover classes.

Introduction

Urban growth, commonly known as urban sprawl, is urban environments such as residential or commercial properties expanding into rural areas or undeveloped land (Yuan, Sawaya, Loeffelholz, and Bauer, 2005). Squires (2002) suggests there may be certain economic benefits of urban growth, but those benefits are weighed against impacts such as ecosystem degradation, water and air pollution, greater energy usage, and loss of farm or agricultural land.

Historically, much of this urban change resulted from the transformation of cropland and forested areas on the outer edge of a metropolitan area (Yuan, 2007). These transformations change the physical landscape as well as the ecosystem functionality of areas such as agriculture, wetlands, rangeland, and forested areas (Vitousek, 1994).

The examination of these land cover changes are of interest to regional land managers and policy makers who wish to make the best decisions possible to balance both the benefits and cost of urban development (Yuan *et al.*, 2005). Rawat and Kumar (2015) also state the importance of land use/cover data for planning and future decision making regarding land use purposes to fit the needs of the population.

Study Area

The city of Shakopee is located in Scott County, Minnesota and is part of the Twin Cities Metropolitan Area. Figure 1 represents the study area. The population of Shakopee has risen dramatically over the last few decades. The United States Census (2003) estimated a population of 11,739 and 20,569 for the years of 1990 and 2000, respectively. The Metropolitan

Council (2015) estimated the population of Shakopee to be 37,076 in 2010 and forecasted the population of Shakopee to be 43,900 by 2020. As a result of current population growth, the number of urban households is also rising. There were an estimated 12,772 households in 2010 and that amount is expected to rise to 15,400 by 2020 (Metropolitan Council, 2015).

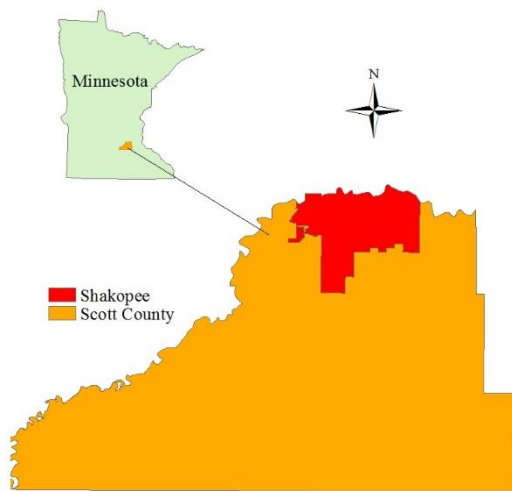


Figure 1. The study area of Shakopee, MN.

Project Definition

There were multiple objectives for this project. The first objective was to delineate land cover layers for 2003 and 2015 for the entire city of Shakopee utilizing aerial imagery. The second objective was to analyze land cover change over time for the city of Shakopee. Specifically, the change in acres between each unique land cover classification was analyzed.

Methodology

Data Preparation

Imagery Acquisition

Imagery for this project was obtained

through the National Agriculture Imagery Program (NAIP) and was used to create land cover datasets through on-screen digitizing. NAIP started in 2003 and is provided by the United States Department of Agriculture's (USDA) Farm Service Agency (FSA). NAIP compressed county mosaics (CCM) are available for free download through the USDA GeoSpatial Data Gateway in a .sid format and spatially referenced in the Universal Transverse Mercator (UTM) coordinate system, North American Datum of 1983 (NAD 1983) (USDA FSA, 2016).

NAIP imagery is obtained via film cameras and digital sensors during the growing season throughout the United States and has a spatial resolution of one meter (USDA FSA, 2016). The ready availability of the imagery, spatial resolution, and temporal availability of the imagery were the reasons why NAIP imagery was chosen for this study area.

Geodatabase Creation

A file geodatabase, along with two folders, were created to store project data. A file geodatabase was created, housing two feature datasets. One feature dataset was for a generalized land cover approach, and one was for a more detailed land cover approach. Each feature dataset contained one polygon feature class for 2003 and one polygon feature class for 2015. One folder stored the NAIP imagery for both years that were analyzed. Another folder stored shapefiles used as collateral data for delineation as well as map layouts. These shapefiles were downloaded from the Minnesota GeoSpatial Commons and included roads, historic wetlands, current wetlands, and municipal boundaries. All of the data used for this analysis were projected in the NAD 1983 UTM Zone 15N coordinate system.

Land Cover Classification System

As decision makers examine changes in land cover, it is essential to have a standardized system for land cover classification (Anderson, Hardy, Roach, and Witmer, 1976). Anderson *et al.* (1976) suggests it is important to manage areas of agricultural and environmental concern, as well as large development sites. Anderson *et al.* (1976) developed a land cover classification system that included four levels of detail. Level I was the most generalized and level IV was the most specific. Level I and level II were used as the basis of this analysis (Figure 2).

Anderson *et al.* (1976) stated there will never be a flawless classification system as different users have different needs.

Modification of Land Cover Classification System

Not all of the Anderson *et al.* (1976) land cover classes were present within the study area. An adaption of the land cover classification system was used for this analysis (Table 1). A visual representation of each land cover class is presented in Appendix A.

Level I and Level II Classification

First, a level II land cover classification was delineated for 2003 using the 2003 NAIP imagery. Second, a level II land cover classification was delineated for 2015 using the 2015 NAIP imagery. The 2003 level II land cover classification feature polygon class was duplicated and used as a basis for 2015 delineation. Where land cover changed from 2003, splitting and merging polygons, along with changing attribute values, were performed as needed.

Level I		Level II	
1	Urban or Built-up Land	11	Residential.
		12	Commercial and Services.
		13	Industrial.
		14	Transportation, Communi- cations, and Utilities.
		15	Industrial and Commercial Complexes.
		16	Mixed Urban or Built-up Land.
		17	Other Urban or Built-up Land.
2	Agricultural Land	21	Cropland and Pasture.
		22	Orchards, Groves, Vine- yards, Nurseries, and Ornamental Horticultural Areas.
		23	Confined Feeding Opera- tions.
		24	Other Agricultural Land.
3	Rangeland	31	Herbaceous Rangeland.
		32	Shrub and Brush Range- land.
		33	Mixed Rangeland.
4	Forest Land	41	Deciduous Forest Land.
		42	Evergreen Forest Land.
		43	Mixed Forest Land.
5	Water	51	Streams and Canals.
		52	Lakes.
		53	Reservoirs.
		54	Bays and Estuaries.
6	Wetland	61	Forested Wetland.
		62	Nonforested Wetland.
7	Barren Land	71	Dry Salt Flats.
		72	Beaches.
		73	Sandy Areas other than Beaches.
		74	Bare Exposed Rock.
		75	Strip Mines, Quarries, and Gravel Pits.
		76	Transitional Areas.
		77	Mixed Barren Land.
8	Tundra	81	Shrub and Brush Tundra.
		82	Herbaceous Tundra.
		83	Bare Ground Tundra.
		84	Wet Tundra.
		85	Mixed Tundra.
9	Perennial Snow or Ice	91	Perennial Snowfields.
		92	Glaciers.

Figure 2. Level I and Level II land cover classification system proposed by Anderson *et al.* (1976).

Level I land cover classifications were derived from the level II land cover classifications. Level II land cover classes were merged into their respective level I category classes. The field calculator was used to attribute polygons with their level I land cover classification. A map for level I land cover classification for 2003 and 2015 are presented in Appendix B and Appendix C, respectively. A map for level II land cover classification for 2003 and 2015 are presented in Appendix D and Appendix E, respectively.

Table 1. Land cover classification system used for analysis.

Level I	Level II	Description
1. Urban	11. Residential 12. Commercial/Services 13. Industrial 14. Transportation 15. Built Up 16. Other	Housing developments ranging from high density to low density Areas used for the sale of goods and services such as businesses and shopping districts Areas used primarily for manufacturing Roads at county level and greater using the route_system field from the roads layer provided by Minnesota Department of Transportation (MnDOT) Areas of roadside development along with single houses or farmsteads Open areas within an urban setting such as golf courses, parks, and undeveloped land
2. Agricultural	21. Cropland/Pasture	Areas predominantly used for farming or grazing
3. Rangeland	31. Herbaceous 32. Shrub/Brush	Areas of natural grassland or prairie Areas of natural shrub or brush
4. Forest	41. Deciduous	Areas of forest dominated by trees that lose their leaves each year
5. Water	51. River 52. Pond 53. Lake	Natural areas of flowing water Small and shallow bodies of water Large bodies of water exceeding 50 acres
6. Wetland	61. Forested Wetland 62. Nonforested Wetland	Wetlands dominated by tree species Wetlands dominated by vegetation
7. Barren	71. Transitional	Areas of bare soil or filling used for construction

Spatial Analysis

Acreage Calculation

The shape area field for all polygon feature classes measured in sq. meters. An acreage field was added and area was converted from sq. meters to acres using Esri's ArcGIS Field Calculator as follows:

$$[\text{Shape_Area}] * .00024711$$

Summary statistics were able to show the total amount of acreage each land cover classification contained for level I and level II. Amount of acreage, along with percent change, were calculated for both years.

Changes Between Each Unique Land Cover Classification

Amount of change between each unique land cover classification, in acres, was also

calculated. This was accomplished using the Union tool and Dissolve tool within Esri's ArcToolbox. First, the Union tool was run to create overlapping features from both polygon feature datasets. Second, the Dissolve tool was run to 'merge' like attributes using the "class" field for both years. This process was done for both level I and level II land cover classifications. The attribute tables were then imported to Microsoft Excel for analysis.

Mapping Consistency

Mapping Scale and Minimum Mapping Unit (MMU)

Land cover classifications were delineated on-screen at a scale of 1:5,000. The MMU consisted of one acre.

Quality Control

Quality of photo interpretation was supported through several years of work experience mapping National Wetland Inventory (NWI) data and various land cover projects. A review of all land cover classifications was also reviewed by a professional aerial photo interpreter with GeoSpatial Services of Saint Mary's University of Minnesota. Data was checked for MMU, same adjacent attributes, sliver polygons, nulls, and ghost polygons. Updates were subsequently made based on subject matter expert review.

Results

Level I Classification

The acreage for each land cover class was calculated for level I classifications, along with the percentage of change from 2003 to 2015 (Table 2). Changes, in acres, were also calculated between each unique level I land cover classification. Five of the most predominant changes are shown in Table 3. A spatial representation of these changes is found in Figure 3. A full table of unique level I land cover classification changes is presented in Appendix F.

Table 2. The amount, in acres, of each level I land cover classification and percent change between 2003 and 2015.

Class	2003 Acreage	2015 Acreage	Percent Change
Urban	8741.48	10455.33	19.61%
Wetland	2178.39	2265.73	4.01%
Water	1161.62	1187.88	2.26%
Forest	1535.72	1433.29	-6.67%
Agricultural	3885.58	2947.11	-24.15%
Rangeland	933.86	389.10	-58.33%
Barren	409.30	167.51	-59.07%
Total	18845.9	18845.9	0.00%

From 2003 to 2015, urban land cover had the greatest increase (19.61%). Wetland areas and open water also

increased 4.01% and 2.26%, respectively. Barren land had a 59.07% decrease. Rangeland, agricultural land, and forest land also saw decreases of 58.33%, 24.15%, and 6.67%, respectively.

Table 3. The five highest level I land cover classification changes, in acres, between unique classes.

2003 Class	2015 Class	Acreage
Agricultural	Urban	863.16
Rangeland	Urban	489.49
Barren	Urban	284.97
Forest	Urban	124.67
Agricultural	Wetland	75.82

In 2015, agricultural land lost 22.21% of the original 2003 acreage to urban land. Rangeland, barren land, and forest land also lost 52.42%, 69.62%, and 8.12% to urban land, respectively. Agricultural land lost 1.95% to wetland as well.

Level II Classification

The acreage for each land cover was calculated for level II classifications, along with the percentage of change from 2003 to 2015 (Table 4). Changes, in acres, were also calculated between each unique level II land cover classification. Five of the most predominant changes are shown in Table 5. A spatial representation of these changes is found in Figure 4. A full table of unique level II land cover classification changes is presented in Appendix G.

From 2003 to 2015, urban-residential experienced the most growth at 31.31%. Urban-commercial, water-pond, and urban-industrial experienced growth as well at 29.19%, 19.20%, and 11.54%, respectively. Barren-transitional lost the most land cover (59.07%). Rangeland-herbaceous, agricultural-cropland, and forest-deciduous also lost land cover (58.74%, 24.15%, and 6.67%, respectively).

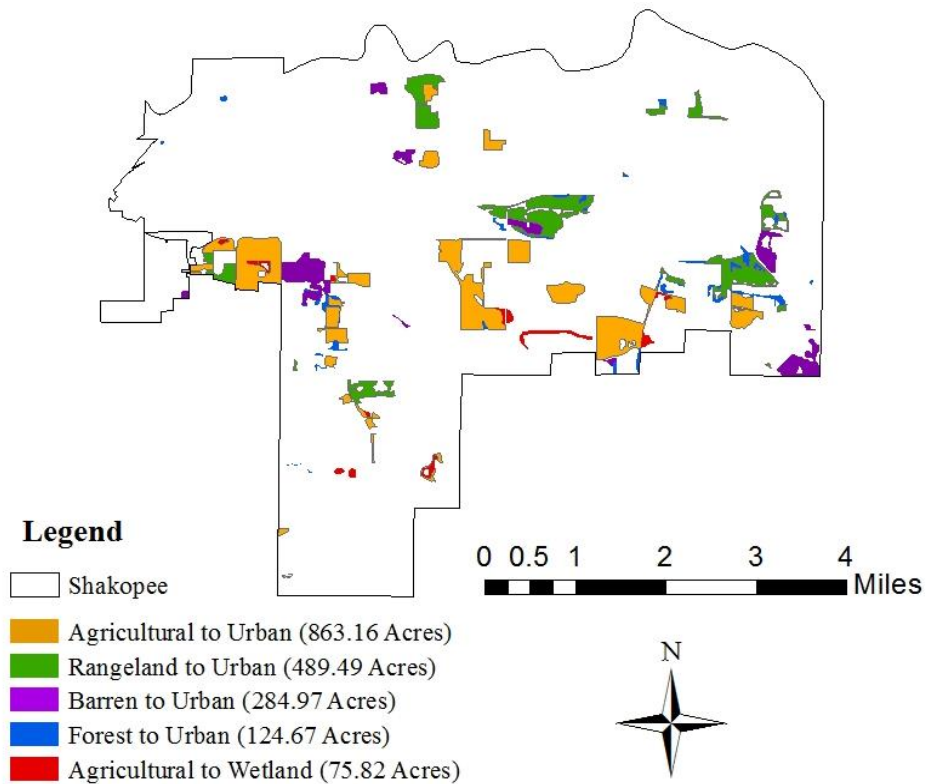


Figure 3. The five most predominant changes for level I classification.

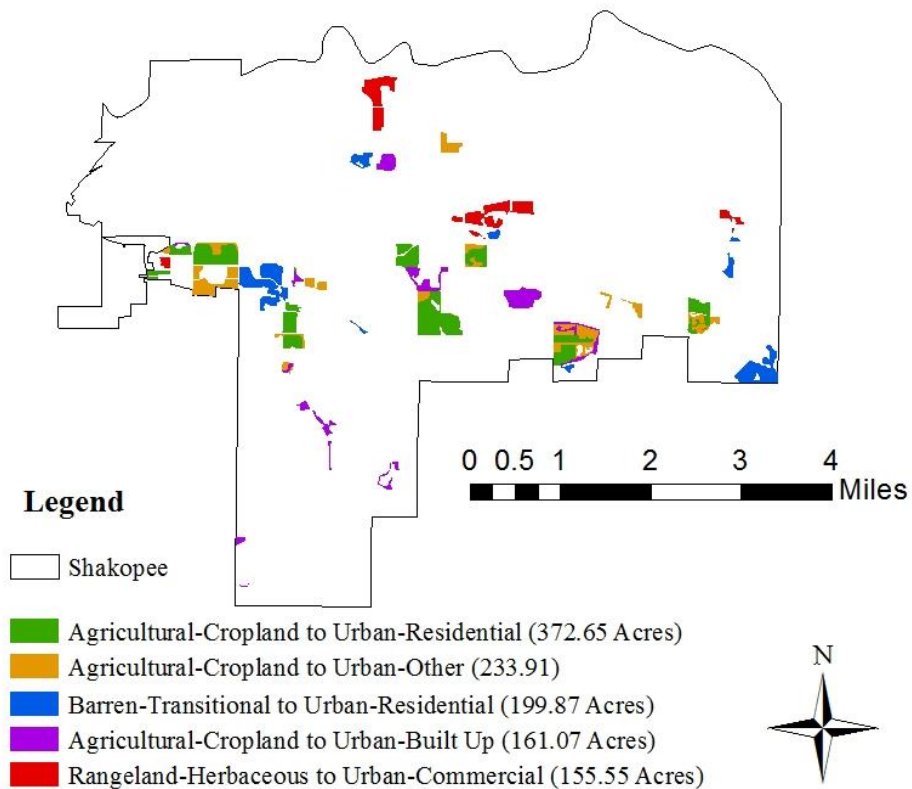


Figure 4. The five most predominant changes in level II classification.

Between 2003 and 2015, agricultural-cropland lost 9.59% of the original 2003 acreage to urban-residential land. Agricultural-cropland lost 6.02% to urban-other and barren-transitional lost 48.83% to urban-residential. Also, agricultural-cropland lost 4.14% to urban-built up and rangeland herbaceous lost 16.76% to urban-commercial.

Table 4. The amount, in acres, of each level II land cover classification and percent change between 2003 and 2015.

Class	2003 Acreage	2015 Acreage	Percent Change
Urban-Residential	3083.37	4048.71	31.31%
Urban-Commercial	1654.68	2137.66	29.19%
Water-Pond	136.76	163.02	19.20%
Urban-Industrial	398.97	445.02	11.54%
Urban-Transportation	697.84	767.66	10.01%
Rangeland-Shrub/Brush	5.64	6.16	9.19%
Urban-Other	1689.30	1837.10	8.75%
Wetland-Nonforested	1496.66	1583.99	5.84%
Urban-Built Up	1217.32	1219.19	0.15%
Water-Lake	834.50	834.50	0.00%
Water-River	190.36	190.36	0.00%
Wetland-Forested	681.74	681.74	0.00%
Forest-Deciduous	1535.72	1433.29	-6.67%
Agricultural-Cropland	3885.58	2947.11	-24.15%
Rangeland-Herbaceous	928.22	382.94	-58.74%
Barren-Transitional	409.30	167.51	-59.07%
Total	18845.9	18845.9	0.00%

Discussion

Limitations

With any photo interpretation analysis, the decisions made by the interpreter are subject to a degree of speculation. The use of aerial imagery requires more effort and expertise than interpreting a regular map.

Table 5. The five highest level II land cover classification changes, in acres, between unique classes.

2003 Class	2015 Class	Acreage
Agricultural-Cropland	Urban-Residential	372.65
Agricultural-Cropland	Urban-Other	233.91
Barren-Transitional	Urban-Residential	199.87
Agricultural-Cropland	Urban-Built Up	161.07
Rangeland-Herbaceous	Urban-Commercial	155.55

Another limitation was the classification system itself. While this analysis presented a great amount of detail in level II classifications for urban environments, only one subtype was present in the study area for level II categories for agricultural lands, forest lands, and barren lands.

The last limitation of this study consisted of the MMU value of one acre. While one acre is sufficient for a land cover change analysis, smaller areas of land cover classifications less than one acre were forced to be “lumped” into the surrounding dominant land cover classifications.

Conclusion

This study used a GIS and aerial photo interpretation to analyze land cover changes in the city of Shakopee, Minnesota. This analysis showed a considerable change in urban environment. Specifically, residential areas grew substantially. When one type of land cover increases over time, other land cover areas are impacted. These impacts are apparent

in this study as agricultural and forest areas suffered considerable loss due to urban expansion. It is important to track these changes as the city of Shakopee continues to expect urban growth.

Acknowledgements

I would like to express thanks to the staff of Saint Mary's University Department of Resource Analysis including Dr. Dave McConville, Mr. John Ebert, and my project advisor Mrs. Greta Poser for their continued guidance and support throughout this process. I would also like to thank staff members at GeoSpatial Services including Andy Robertson, Jeff Knopf, Kris Knopf, and David Rokus for the invaluable experience I have gained working alongside them. A specific thanks to David Rokus for his involvement in the project and quality assurance assessment.

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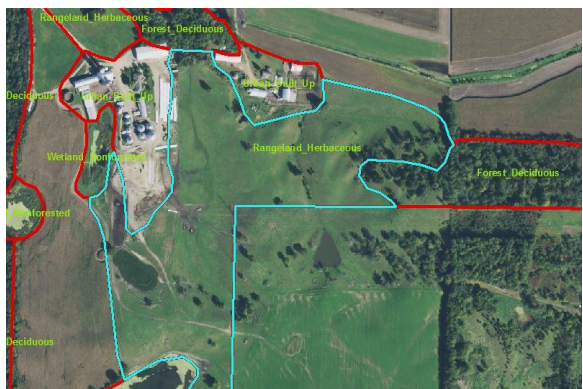
Appendix A. A visual representation of land cover classifications.



Agricultural-Cropland/Pasture



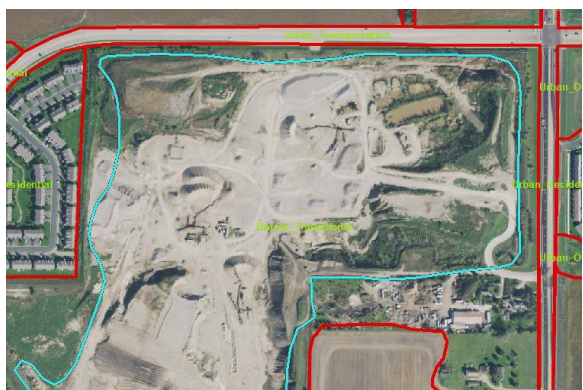
Urban-Built Up



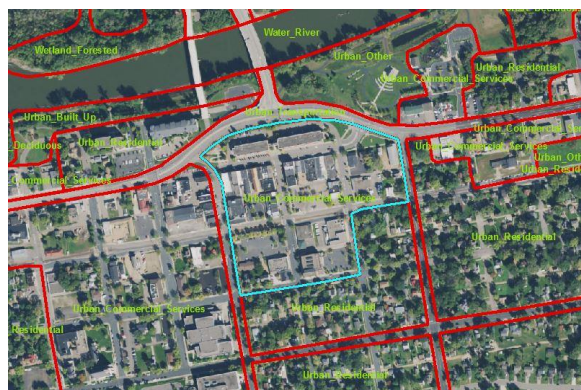
Rangeland-Herbaceous



Forest-Deciduous

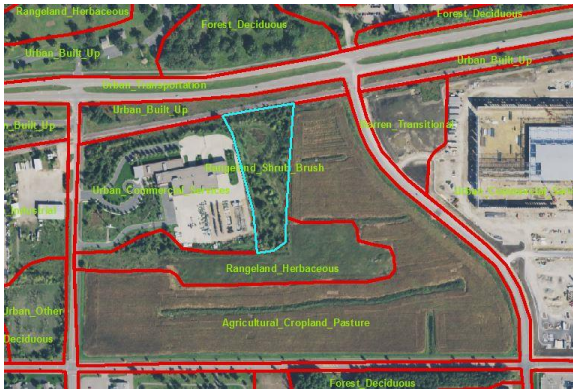


Barren-Transitional



Urban-Commercial

Appendix A (continued). A visual representation of land cover classifications.



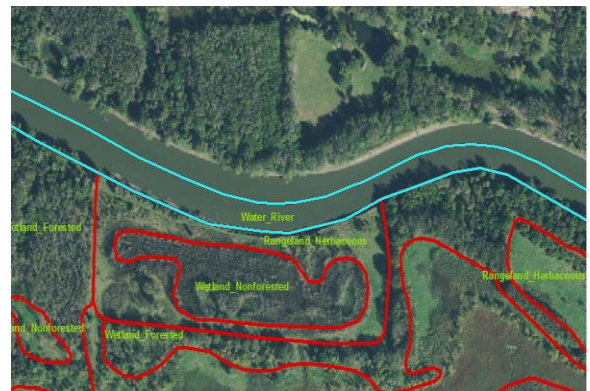
Rangeland-Shrub/Brush



Water-Pond



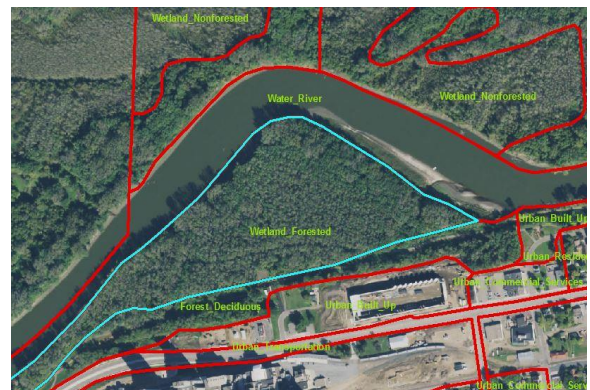
Water-Lake



Water-River



Urban-Industrial



Wetland-Forested

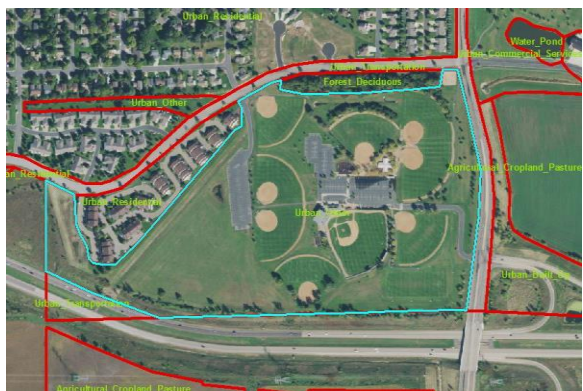
Appendix A (continued). A visual representation of land cover classifications.



Wetland-Nonforested



Urban-Residential

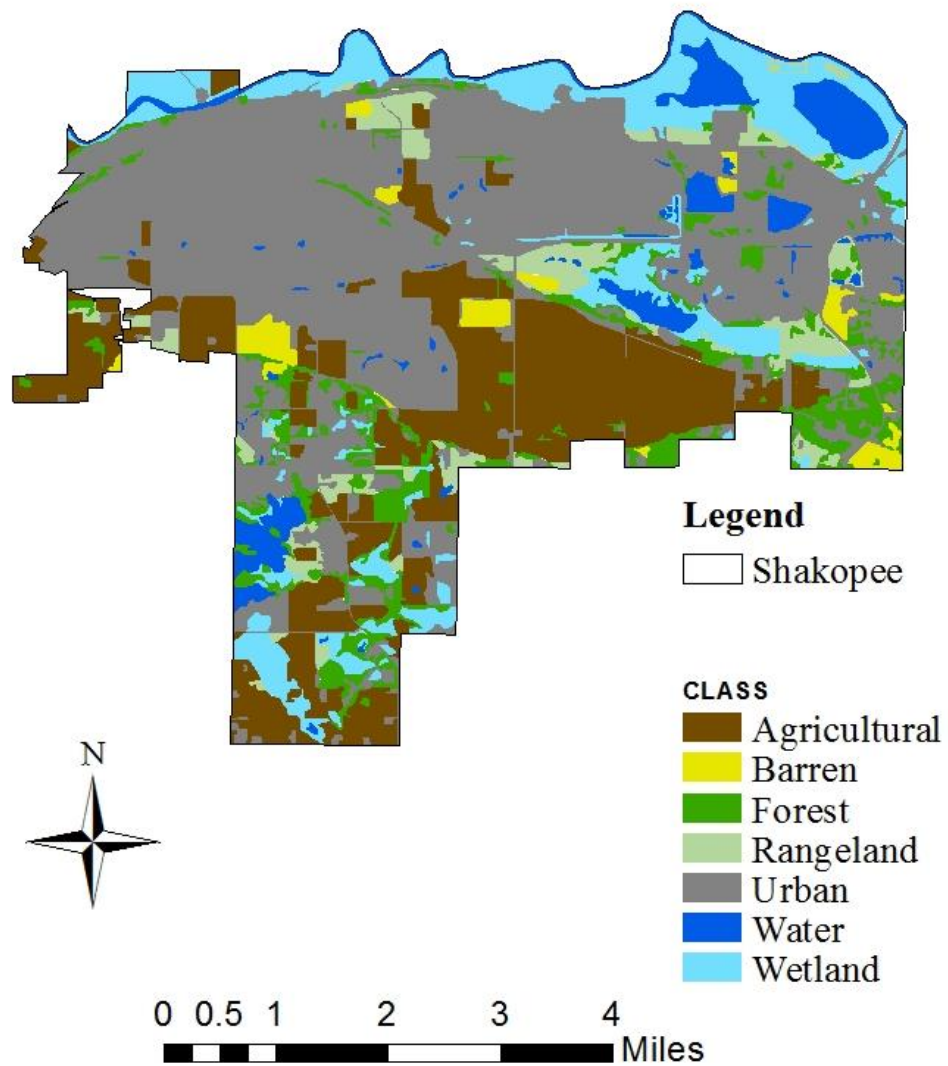


Urban-Other

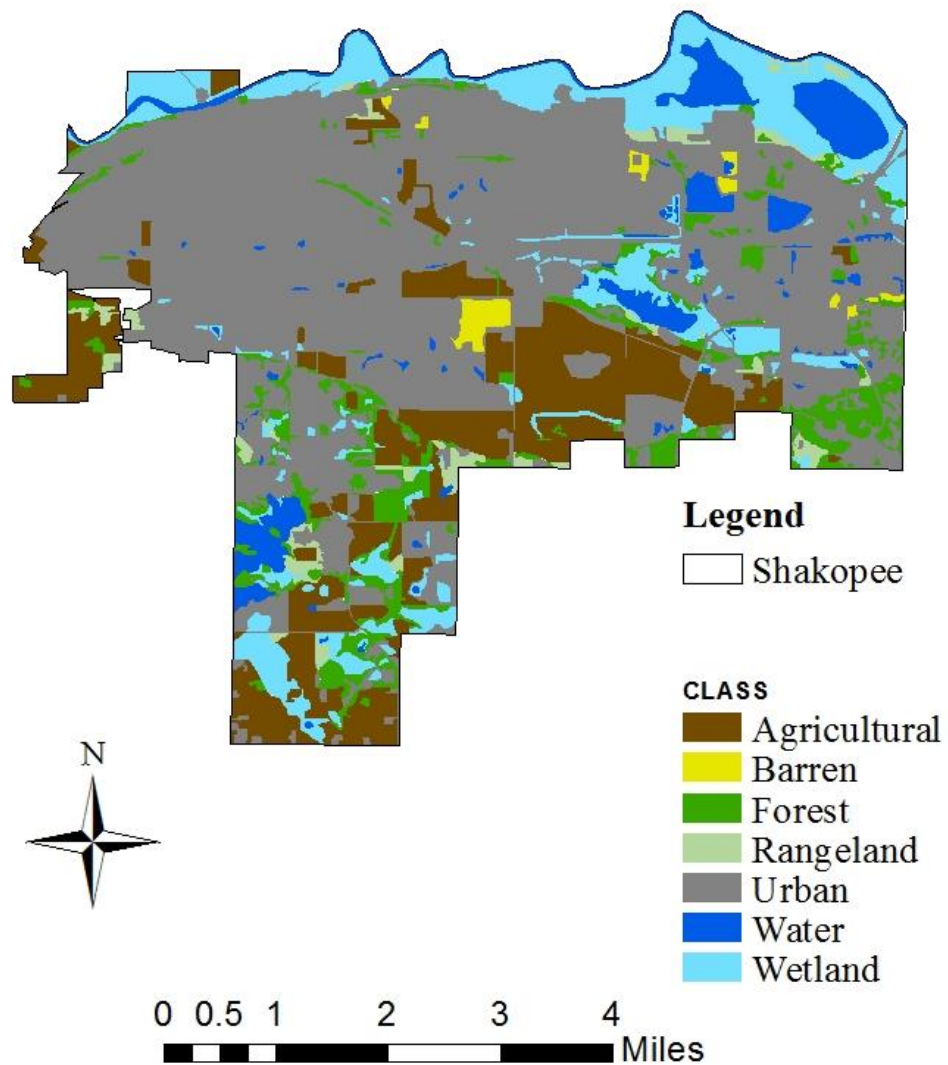


Urban-Transportation

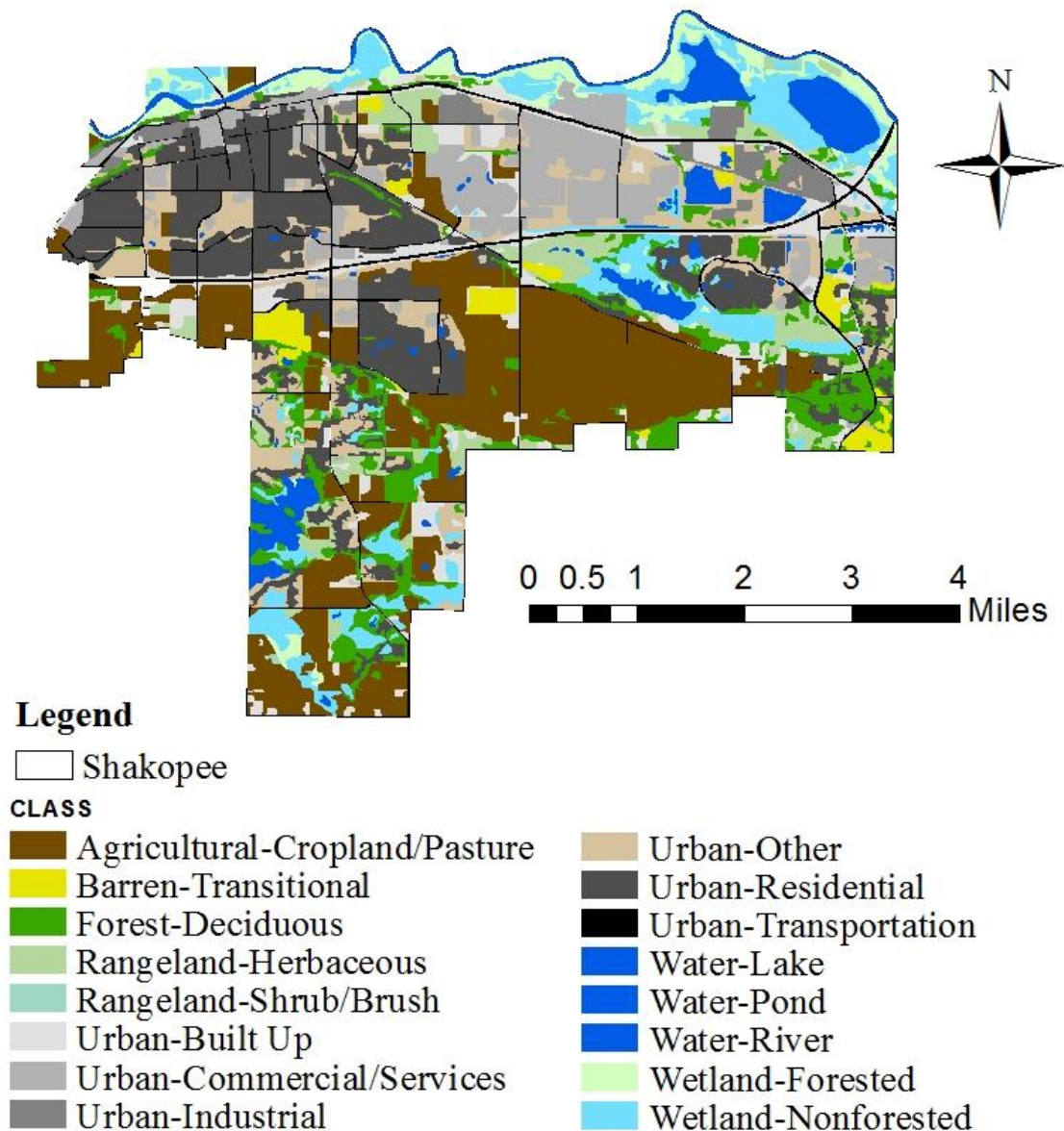
Level I Land Cover Classifications in 2003 for the City of Shakopee, MN



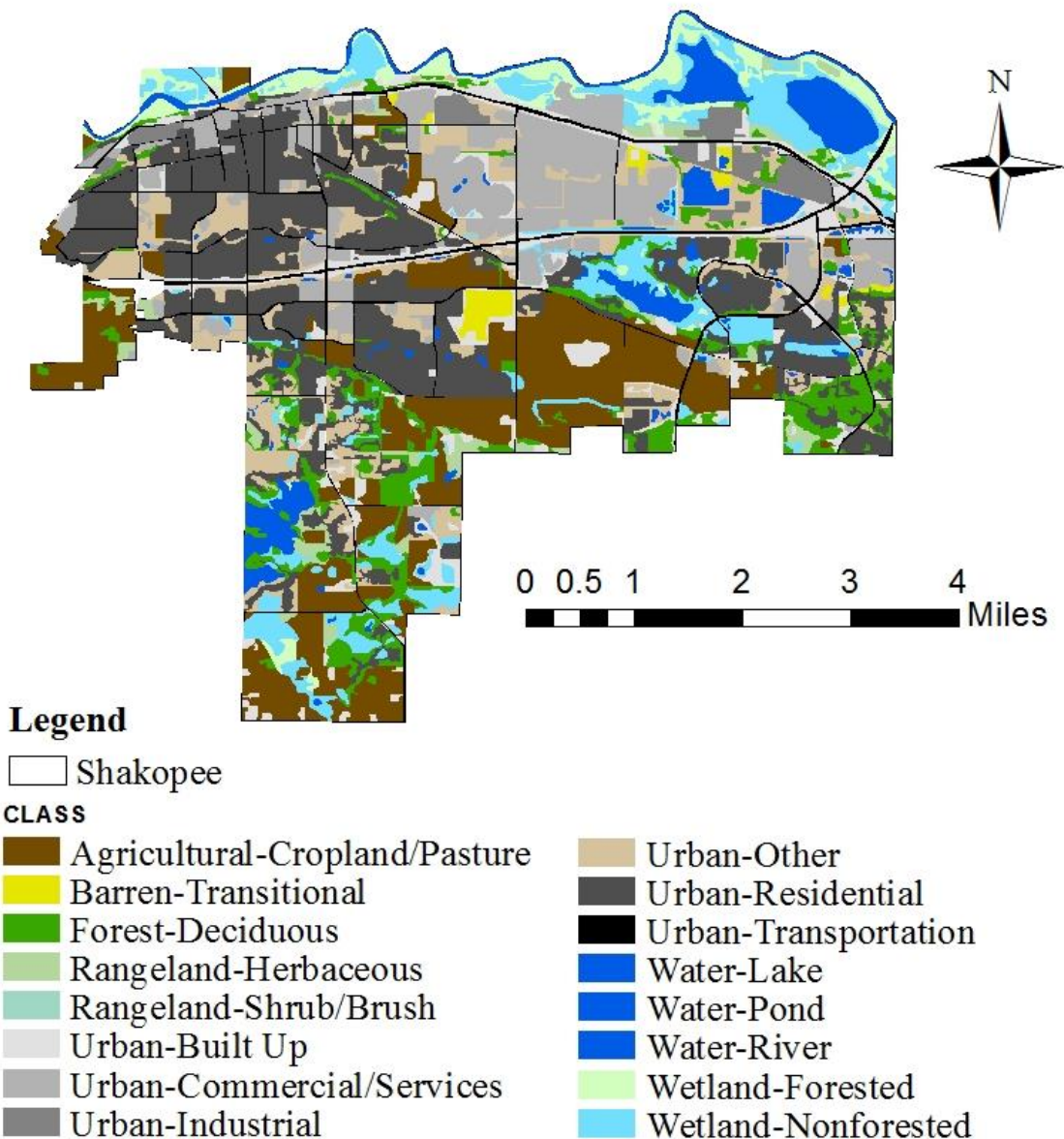
Level I Land Cover Classifications in 2015 for the City of Shakopee, MN



Level II Land Cover Classifications in 2003 for the City of Shakopee, MN



Level II Land Cover Classifications in 2015 for the City of Shakopee, MN



Appendix F. Change between each unique level I land cover code from 2003 to 2015.

2003 Class	2015 Class	Acreage
Urban	Urban	8679.38
Agricultural	Agricultural	2874.42
Wetland	Wetland	2153.91
Forest	Forest	1407.95
Water	Water	1150.15
Agricultural	Urban	863.16
Rangeland	Urban	489.49
Rangeland	Rangeland	340.83
Barren	Urban	284.97
Forest	Urban	124.67
Barren	Barren	106.30
Agricultural	Wetland	75.82
Rangeland	Agricultural	59.19
Agricultural	Barren	34.28
Urban	Rangeland	20.93
Urban	Barren	20.42
Agricultural	Rangeland	20.09
Agricultural	Water	17.82
Rangeland	Forest	14.96
Rangeland	Wetland	13.86
Urban	Agricultural	13.50
Wetland	Urban	11.71
Barren	Wetland	10.77
Rangeland	Water	10.73
Wetland	Water	9.19
Water	Wetland	7.79
Barren	Rangeland	7.26
Urban	Forest	6.79
Rangeland	Barren	4.79
Wetland	Forest	3.58
Forest	Wetland	3.11
Water	Urban	1.96
Water	Barren	1.72
Urban	Wetland	0.47

Appendix G. Change between each unique level II land cover code from 2003 to 2015.

2003 Class	2015 Class	Acreage
Urban_Residential	Urban_Residential	3077.70
Agricultural_Cropland_Pasture	Agricultural_Cropland_Pasture	2874.42
Urban_Commercial_Services	Urban_Commercial_Services	1652.06
Wetland_Nonforested	Wetland_Nonforested	1472.17
Urban_Other	Urban_Other	1409.15
Forest_Deciduous	Forest_Deciduous	1407.95
Urban_Built_Up	Urban_Built_Up	909.81
Water_Lake	Water_Lake	834.50
Urban_Transportation	Urban_Transportation	695.33
Wetland_Forested	Wetland_Forested	681.74
Urban_Industrial	Urban_Industrial	398.97
Agricultural_Cropland_Pasture	Urban_Residential	372.65
Rangeland_Herbaceous	Rangeland_Herbaceous	338.23
Agricultural_Cropland_Pasture	Urban_Other	233.91
Barren_Transitional	Urban_Residential	199.87
Water_River	Water_River	190.36
Agricultural_Cropland_Pasture	Urban_Built_Up	161.07
Rangeland_Herbaceous	Urban_Commercial_Services	155.55
Rangeland_Herbaceous	Urban_Residential	147.96
Urban_Other	Urban_Commercial_Services	137.21
Water_Pond	Water_Pond	125.29
Urban_Built_Up	Urban_Residential	121.68
Barren_Transitional	Barren_Transitional	106.30
Rangeland_Herbaceous	Urban_Other	104.36
Agricultural_Cropland_Pasture	Wetland_Nonforested	75.82
Urban_Built_Up	Urban_Commercial_Services	75.10
Forest_Deciduous	Urban_Residential	71.04
Agricultural_Cropland_Pasture	Urban_Commercial_Services	62.85
Rangeland_Herbaceous	Agricultural_Cropland_Pasture	59.19
Rangeland_Herbaceous	Urban_Built_Up	58.45
Urban_Other	Urban_Residential	57.54
Urban_Other	Urban_Built_Up	51.83
Barren_Transitional	Urban_Commercial_Services	47.35
Urban_Built_Up	Urban_Other	46.52
Agricultural_Cropland_Pasture	Barren_Transitional	34.28
Agricultural_Cropland_Pasture	Urban_Transportation	32.68
Barren_Transitional	Urban_Other	25.05
Urban_Built_Up	Urban_Industrial	21.55
Urban_Built_Up	Rangeland_Herbaceous	20.93
Agricultural_Cropland_Pasture	Rangeland_Herbaceous	20.09
Agricultural_Cropland_Pasture	Water_Pond	17.82

Appendix G (continued). Change between each unique level II land cover code from 2003 to 2015.

Urban_Other	Barren_Transitional	15.54
Forest_Deciduous	Urban_Other	15.48
Forest_Deciduous	Urban_Built_Up	14.72
Rangeland_Herbaceous	Wetland_Nonforested	13.86
Rangeland_Herbaceous	Urban_Transportation	12.04
Forest_Deciduous	Urban_Transportation	11.17
Rangeland_Herbaceous	Urban_Industrial	11.13
Barren_Transitional	Wetland_Nonforested	10.77
Rangeland_Herbaceous	Water_Pond	10.73
Rangeland_Herbaceous	Forest_Deciduous	9.32
Wetland_Nonforested	Water_Pond	9.19
Urban_Other	Urban_Industrial	8.29
Barren_Transitional	Urban_Built_Up	7.99
Water_Pond	Wetland_Nonforested	7.79
Urban_Other	Agricultural_Cropland_Pasture	7.54
Forest_Deciduous	Urban_Commercial_Services	7.18
Urban_Built_Up	Agricultural_Cropland_Pasture	5.96
Wetland_Nonforested	Urban_Transportation	5.90
Urban_Built_Up	Urban_Transportation	5.84
Wetland_Nonforested	Urban_Built_Up	5.80
Urban_Residential	Urban_Built_Up	5.66
Rangeland_Shrub_Brush	Forest_Deciduous	5.64
Forest_Deciduous	Urban_Industrial	5.08
Urban_Built_Up	Forest_Deciduous	5.06
Urban_Built_Up	Barren_Transitional	4.88
Rangeland_Herbaceous	Barren_Transitional	4.79
Barren_Transitional	Urban_Transportation	4.70
Barren_Transitional	Rangeland_Herbaceous	3.69
Wetland_Nonforested	Forest_Deciduous	3.58
Barren_Transitional	Rangeland_Shrub_Brush	3.56
Forest_Deciduous	Wetland_Nonforested	3.11
Urban_Commercial_Services	Urban_Other	2.62
Rangeland_Herbaceous	Rangeland_Shrub_Brush	2.59
Urban_Transportation	Urban_Built_Up	2.51
Urban_Other	Forest_Deciduous	1.73
Water_Pond	Barren_Transitional	1.72
Water_Pond	Urban_Built_Up	1.33
Urban_Other	Wetland_Nonforested	0.47
Water_Pond	Urban_Commercial_Services	0.36
Water_Pond	Urban_Residential	0.27