

URBAN GROWTH MONITORING OF BIRMINGHAM, AL
USING LANDSAT MSS AND TM IMAGERY

By

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A THESIS

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ABSTRACT

Monitoring urban growth and change in land-use/land-cover in metropolitan areas is of critical interest in the twenty-first century. It is of utmost importance to those who study urban and metropolitan dynamics and to individuals who are in resource management. This research is focused on monitoring urban spatial growth or urbanization and land-use/land-cover changes in the Birmingham, Alabama, Metropolitan Area. This research will analyze urban growth and land-use/land-cover change over a thirty-four period from 1974 to 2008. This research takes place in the counties of Jefferson and Shelby, which is the core of the Birmingham, Alabama, Metropolitan Area. Landsat images from four years, one for each decade in the thirty-four year period, which were also very close to anniversary dates, were obtained to monitor the urban growth and land-use/land-cover change. GIS and remote sensing methods were utilized to achieve the research goal. The results reveal that over the thirty-four period there was a steady decline in forests, agricultural lands, and green space and an expansion of urban and residential land-use/land-cover in the metropolitan area. The majority of the growth was low density urban and residential along the Interstate 459, United States Highway 280, and the United States Highway 31 (south of the City of Birmingham) corridors. These areas create “fingers” branching out from the older urban areas in Birmingham. The expansion of residential areas was quite dispersed. This is a major indicator of urban sprawl. It is expected that the urban population and land-use/land-cover changes will continue farther into the twenty-first century. It is obvious from the field that the area is experiencing urban sprawl. The reason that this research

is important is because it quantitatively measures the expansion of urban sprawl over thirty-four year period. It is important to know where urbanization has occurred and how much has occurred. Implications of this research is that it could be used in the Birmingham, AL, Metropolitan Area to determine what areas are growing, predict where growth will occur next, and how much growth will occur in the future. The methodology of this research could be utilized in Birmingham or other areas to monitor urban growth.

DEDICATION

To my parents and sister and in memory of my grandparents.

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CONTENTS

ABSTRACT	ii
DEDICATION	iv
ACKNOWLEDGEMENTS	v
LIST OF TABLES	viii
LIST OF FIGURES	viii
1. INTRODUCTION	1
1.1. Introduction	1
1.2. General Background	2
1.3. Research Question.....	10
1.4. Objectives.....	10
2. BACKGROUND AND LITERATURE REVIEW	11
2.1. Historical Growth of Birmingham	11
2.2. Urban Sprawl in the United States	12
2.3. In-Fill Development vs. Urban Sprawl	13
2.4. Remote Sensing Techniques Utilized to Detect Urban Sprawl.....	13
3. METHODOLOGY	17
3.1. Introduction	17
3.2. Study Area.....	18
3.3. Data Acquisition and Collection	18
3.3.1. Satellite Images.....	18

3.3.2. Reference and Collateral Data.....	21
3.3.3 In-Situ Data Collection/Fieldwork	22
3.4. Data Processing.....	22
3.4.1. Image Preprocessing.....	22
3.4.2. Image Classification Scheme.....	29
3.4.3. Supervised Classification	32
3.4.4 Accuracy Assessment.....	38
3.4.5 Change Detection	41
4. RESULTS AND DISCUSSION.....	43
4.1. Analysis of Supervised Classification.....	43
4.2. Analysis of Change Detection.....	47
4.3. Analysis of the Urban Land-use/Land-cover	55
4.4. Analysis of Urban Change Detection.....	65
4.5 Physiographical Aspects	75
4.6 Population Trends	76
4.7 Possibility of In-Fill Development to Manage Urban Sprawl.....	85
5. CONCLUSIONS.....	88
BIBLIOGRAPHY.....	93

LIST OF TABLES

4.1 Land-Use/Land-Cover Statistics for the Birmingham Metropolitan Area: 1974-2008	45
4.2 Metropolitan Area Land-Use/Land-Cover Changes: 1974-1988	53
4.3 Metropolitan Area Land-Use/Land-Cover Changes: 1988-1998	53
4.4 Metropolitan Area Land-Use/Land-Cover Changes: 1998-2008	54
4.5 Metropolitan Area Land-Use/Land-Cover Changes: 1974-2008	54
4.6 Land-Use/Land-Cover Statistics for the Birmingham Urban Area: 1974-2008	63
4.7 Urban Area Land-Use/Land-Cover Changes: 1974-1988	71
4.8 Urban Area Land-Use/Land-Cover Changes: 1988-1998	71
4.9 Urban Area Land-Use/Land-Cover Changes: 1998-2008	72
4.10 Urban Area Land-Use/Land-Cover Changes: 1974-2008	72

LIST OF FIGURES

1.1 Urban Commerical Growth Along Interstate 459.....	7
1.2 Residential Growth Near Lake Purdy, AL Near the U.S. Highway 280 Corridor	7
1.3 Residential Growth in Chelsea, AL Along U.S Highway 280 in Rural Area.....	8
1.4 Commerical Growth Along U.S. Highway 280 in Birmingham	8
1.5 Commerical Growth Along U.S. Highway 280 in Birmingham	9
1.6 Commerical Growth Along U.S. Highway 280 in Birmingham	9
3.1 Birmingham, AL, Metropolitan Area Basemap.....	20
3.2 Landsat MSS Image 1974.....	25
3.3 Landsat TM Image 1988.....	26
3.4 Landsat TM Image 1998.....	27
3.5 Landsat TM Image 2008.....	28
3.6 USGS Classification System	30
3.7 USGS Classification System	31
3.8 Supervised Classification 1974.....	34
3.9 Supervised Classification 1988.....	35
3.10 Supervised Classification 1998.....	36
3.11 Supervised Classification 2008.....	37
3.12 In-Situ Data Collection	40
3.13 Change Detection with Erdas Imagine Spatial Modeler.....	42
4.1 Comparison of Supervised Classifications	44

4.2 Land-Use/Land-Cover Statistics.....	45
4.3 Land-Use/Land-Cover Statistics.....	45
4.4 Metropolitan Land-Use/Land-Cover Changes: 1974-1988	49
4.5 Metropolitan Land-Use/Land-Cover Changes: 1988-1998	50
4.6 Metropolitan Land-Use/Land-Cover Changes: 1998-2008	51
4.7 Metropolitan Land-Use/Land-Cover Changes: 1974-2008	52
4.8 Birmingham, AL Metropolitan Area Basemap.....	57
4.9 City Limits in Birmingham, AL, Metro Area.....	58
4.10 Supervised Classification of Urban Areas 1974	59
4.11 Supervised Classification of Urban Areas 1988	60
4.12 Supervised Classification of Urban Areas 1998	61
4.13 Supervised Classification of Urban Areas 2008	62
4.14 Land-Use/Land-Cover Statistics.....	63
4.15 Land-Use/Land-Cover Statistics.....	63
4.16 Urban Land-Use/Land-Cover Changes: 1974-1988	67
4.17 Urban Land-Use/Land-Cover Changes: 1988-1998	68
4.18 Urban Land-Use/Land-Cover Changes: 1998-2008	69
4.19 Urban Land-Use/Land-Cover Changes: 1974-2008	70
4.20 Physiographic Analysis.....	73
4.21 Major Corridors	74
4.22 Metropolitan Growth Corridors	79

4.23 Metropolitan Growth Corridors	80
4.24 Traffic Counts	81
4.25 Population Trends	82
4.26 Population and Land-Use/Land-Cover	83
4.27 Possible Areas of Urban Sprawl	84
4.28 In-Fill Development.....	86

CHAPTER 1

INTRODUCTION

1.1. Introduction

This research is about urban growth monitoring using Landsat MSS and TM imagery of the Birmingham, Alabama, Metropolitan Area. This research seeks to support the conclusions of past research that the Birmingham, Alabama, Metropolitan Area is experiencing mass urbanization and urban sprawl, a concept that we will expound upon in the following sections. In addition, this research seeks to expand upon those conclusions by monitoring urban expansion over a four decade period—1974 to 2008. The early to mid 1970s is the earliest that Landsat MSS data is available. This research will thus follow urbanization in the Birmingham, Alabama, Metropolitan Area from one of the earliest possible dates to one of the latest dates available—2008.

This research seeks too quantitatively measure the expansion of urbanization in the Birmingham, AL, Metropolitan Area over a thirty-four year study period. It seeks to measure the amount of increase in square kilometers of urbanization, chart where urbanization has occurred, when it occurred, and what caused it to occur. There are many factors that could have caused urbanization to occur in particular locations—socioeconomic factors, physiographic factors, and the construction of new highway corridors could all be catalysts. In addition, it seeks to seek and propose solutions to urban sprawl. This research will use a methodology based partly on

Geographic Information Systems (GIS) and remote sensing to measure the changes in urbanization over time.

Global population expansion and migration to urban areas is of great concern in the 21st Century. Population and economic growth demands are advancing into previously rural areas causing chaotic and messy development of rural areas and damaging the viability of the inner cities. This is known as urban sprawl (Daniels 1999). Urban sprawl has been defined as “dispersed and inefficient urban growth” (Hasse and Lathrop 2003). This increasing urban population and the land use and land cover changes that result from urbanization have greatly disrupted the organization and role of ecosystems (Yu and Ng 2006). This problem is significant. Urban sprawl is a problem in many American cities. Urban sprawl is more and more recognized as an occurrence with extensive harmful effects on society (Torrens 2006).

1.2. General Background

The expansion of urban growth and intensity of population increases in metropolitan areas remains one of the major modes of change felt throughout the world (Yang 2002). There is an area between the open countryside and urban areas, which is a very large area that is expanding and undergoing changes. This is where urban sprawl is occurring. Economic activities and population are forcefully advancing outward from suburbs resulting in disorganized development of previously rural areas. Land use can no longer be considered at the scale of a local town or a city; a regional focus must be adopted to land use and growth management because of the interaction of several counties in a metropolitan area. These areas are where the United States’ most bitter conflicts over development of open lands and population growth are occurring. It has been suggested that improved growth management regulations and

codes are vital to prevent chaotic development that makes an inefficient use of land that diverts public funds and private investment away from existing municipalities, making these newly developed areas expensive to service (Daniels 1999). With the energy problems of today, utilizing the space within cities is vital for the future (Wilson 1981).

This commercial and residential pattern sprawling out among agricultural and forested areas did not happen instantaneously. It has been happening for over one hundred years. In the 19th Century, these areas were small compared to today, sparsely populated, and bordered cities that were small compared to today's cities. As these cities expanded, people migrated into these areas and established these areas as residential suburbs. Once a suburb was created, rural areas outside of the particular suburb became part of the suburb's sphere of influence. Thus, these rural areas became part of the areas becoming influenced by urban sprawl. Population growth continued and these areas became part of new suburban and urban expansion. With this expansion, new rural areas became more and more urbanized under the influence of new suburbs (Daniels 1999).

The urban sprawl of today came into its own in the latter part of the 20th Century. It was triggered by the spectacular growth of suburbs and the beginning of spread-out metropolitan areas. The main reason of why suburbs expanded and grew so quickly relative to cities was the emergence of the automobile as an affordable means of transportation. Vast automobile ownership created a demand for more and larger roads. Automobiles along with more roads enabled a much larger freedom of mobility over a much larger landscape. This created a much more spread-out pattern of settlement at a much lower population density in previously rural areas. People also wanted to get away from cities that were crowded and had less than sanitary

living conditions in some cases. Also living expenses were cheaper in suburbs than in the central cities.

From 1977 to 1997, the largest cities of the thirty-nine highest populated metropolitan areas gained less than 1 million residents; the population of the suburbs increased by 30 million. Additionally, areas around these suburbs gained 20 million people residing in over seven hundred counties that have been included in metropolitan regions since the latter half of the 20th Century. As these suburbs became larger, more rural land was developed or was put under development pressure. Understanding the expansion of suburbs is vital to understanding the origin of sprawling areas and the future of these areas (Daniels 1999).

Urban sprawl does not advance social and national goals of affordable housing, energy efficiency, economic competitiveness, or environmental quality. Urban sprawl also puts limits on public transportation. The reason is that in areas experiencing urban sprawl, there are multiple municipal local governments and many times these different entities are not cooperative in coordination of public transportation across municipal limits. Thus, in many instances the only way to travel from municipality to municipality is to drive an automobile. Federal government policies have contributed heavily to sprawl as well (Daniels 1999). Other harmful effects of urban sprawl include the destruction of forests, loss of farmland, skyrocketing transportation and infrastructure expenses, increased pollution from automobiles, loss of natural wildlife habitat, and water pollution from septic and sewer systems.

The growth in the use of the automobile gave people greater freedom in mobility and made urban sprawl possible. The construction and growth of suburbs along with the construction of the Interstate Highway System made tens of thousands of hectares of previously

rural land accessible. These rural areas attracted people from urban areas because of socioeconomic, political, and high crime in large cities. With the automobile and the Interstate Highway System it was possible to live in a suburb or rural area and commute into the city for work every day. This gave rise to suburban employment centers outside of the central business district in the inner city as businesses moved outward from the central city as well (Daniels 1999). It is the hypothesis of this research that this also holds true in the Birmingham, Alabama, Metropolitan Area.

It has proven difficult to create and implement solutions to curb urban sprawl. These are the results of an expanding population and economy. It is expected that the tests of managing sprawl will become more intense and difficult (Daniels 1999). Urban sprawl occurs in Alabama. The Birmingham metro area is an example where all negative impacts mentioned above have been experienced. The purpose of this research is to use remote sensing and GIS to identify the expansion of sprawl, predict where it might expand to next, and propose ways of responsibly managing it.

Today, it is vital to monitor growth in metropolitan and urban areas. An excellent way to monitor and analyze this growth is through GIS and remote sensing methods. By obtaining satellite images over a period of time, a remote sensing method can be developed or advanced upon to analyze the land cover and land use temporal and spatial changes over time. It can be used, for example, to determine how much agricultural, forested, and open land has been converted into urban land uses over a period of time (Yang 2002). Once land cover data has been extracted, census data integrated into a geographic information system can be used to further analyze the demographic characteristics of the changes that are occurring and have

occurred (Lo and Yang 2002). Figures 1.1 to 1.6 show examples of urbanization and urban sprawl in the study area.



Figure 1.1 Urban Commercial Growth Along Interstate 459.



Figure 1.2 Residential Growth in Lake Purdy near the U.S. Highway 280 corridor.



Figure 1.3 Residential Growth in Chelsea along U.S. Highway 280 in a predominately rural area.



Figure 1.4 Commercial Growth along U.S. Highway 280 in Birmingham.



Figure 1.5 Commercial Growth along U.S. Highway 280 in Birmingham.



Figure 1.6 Commercial Growth along U.S. Highway 280 in Birmingham.

1.3. Research Question

What this study seeks to find is where urbanization and land-use/land-cover change is occurring and how much change is occurring. During the last 34 years (1974 to 2008), during which decade did the most changes occur and why? Where did these changes occur and why? This research is based on two facts which are supported in the literature. The first fact is that the Birmingham, Alabama, Metropolitan Area is experiencing the phenomenon known as urban sprawl. The second fact is that geographic information systems and remote sensing can be a valuable tool to utilize in order to identify, quantify, and document the expansion of urban sprawl over a time period. Therefore, the urban growth will be monitored using geographic information systems and remote sensing to document any occurring urban sprawl.

1.4. Objectives

The research summarized in the thesis is based on the remote sensing process. The remote sensing process consists of four steps: statement of the problem, data collection, data-to-information conversion, and information presentation (Jensen, et al. 2005). This research is designed to follow this process.

The specific objectives were as follows:

1. To determine if the Birmingham, Alabama, Metropolitan Area is experiencing the phenomenon of urban sprawl.
2. To study land-use/land-cover changes over time to determine the expansion of urban areas and where urban sprawl is occurring.
3. To display the effectiveness of geographic information systems and remote sensing as useful tools to document urban land cover/land use changes over time.
4. Upon successful completion of this research, for it to contribute to the knowledge of urban sprawl patterns, and to help urban and metropolitan areas such as the Birmingham, Alabama, Metropolitan Area manage growth and urban sprawl using better methods.

CHAPTER 2

BACKGROUND AND LITERATURE REVIEW

2.1. Historical Growth of Birmingham

After the Civil War, industry came to north and central Alabama in the form of mines and mills producing coal and iron. Alabama, having superior resources to neighboring Tennessee, Mississippi, and Georgia, became the South's base for coal and iron production. Birmingham was at the epicenter of this. Coal deposits were prominent in the Warrior, Coosa, and Cahaba River valleys. By 1865 there were sixteen blast furnaces in present day Birmingham. By 1871, the city blocks and lots of what would become Birmingham had been laid out because of this boom in steel and coal. This expansion lasted throughout the 19th and early 20th Centuries. By 1950, activity in Alabama was increasingly centered in urban areas. Birmingham was the twenty-seventh largest city in the United States, trailing only New Orleans and Atlanta in the southeast. Since 1900, the population of Birmingham has quadrupled. Later in the 20th Century, Birmingham experienced growth resulting from the banking and medical industries, much of it attributed to the University of Alabama in Birmingham (UAB) (Rogers, et al. 1994). Multiple cities have also emerged in the metro area such as Hoover, Pelham, Mountain Brook, etc., competing with Birmingham for land and population.

2.2. Urban Sprawl in the United States

Many scholarly journal articles and books have been written on urban sprawl, its causes, and how such techniques as geographic information systems can be used to control it. The amount of developed land in the United States increased dramatically by 14.2 million hectares between the years 1982 and 2003. This expansion is expected to continue for the foreseeable future. One of the largest areas where this is occurring is in the South Central region of the United States (White, et al. 2009). The Birmingham metro area is located in this region. When people talk about land that is being lost to sprawl, they generally discuss farmland. Forests are overlooked many times. In some areas such as New Jersey, urban sprawl has resulted not only in loss of farmland, but significant deforestation as well (MacDonald 2005). Urban sprawl has had an impact on the forests of Rhode Island. Landsat images and remote sensing were used to determine the amount of forest land in Rhode Island between the years of 1985 to 1999 that had been urbanized. The loss of forest land also reduces the flora and fauna habitats in the area (Novak and Wang 2004). Even though this study took place in Rhode Island, the same principle applies in this study's research area.

Some ways exist to manage and curb urban sprawl. A way to curb and manage sprawl is through buying development rights to farmland, forests, and open space. Purchasing development rights means that the purchasing agency compensates the landowner for the profit lost from not using the property in exchange for strict restrictions on what the property owner can do with the land, thus limiting what the property can be used for (Daniels 2001). Another negative impact of urban sprawl is the longer time it takes for people to commute to their places of work (Sultana and Weber 2007).

2.3. In-Fill Development vs. Urban Sprawl

Encouraging in-fill development, which is developing land between the cities and sprawling areas, is another way to manage and curb sprawl (Daniels 2001). To a certain extent, in-fill development could control urban sprawl which has led to the increasing costs of utilities and other public services and has increased the consumption of energy. In the energy crisis of today, energy efficiency is very important. In-Fill development offers an efficient utilization and development of urban areas within cities, instead of the outward expansion of urban sprawl. Birmingham is an excellent area to examine these landuse issues. The most common type of vacant land within cities or urban areas is remnant parcels that are fragments of land left over after development. This is the most common type in Birmingham. In 1981 there were around 10,670 acres of vacant land that lie within the city limits of Birmingham. This vacant land could have accommodated over 160,000 people. This represented approximately 63 percent of the residential population living in areas of urban sprawl. If this population lived within Birmingham, the energy savings with a decrease in sprawl would have increased dramatically (Wilson 1981). These observations were made in 1981 during another energy crisis. The same holds true today.

2.4. Remote Sensing Techniques Utilized to Detect Urban Sprawl

Urban to suburban population shifts were being analyzed in the mid 1970s. The shifts in technology, economics, and the ease of travel are factors for urban expansion (Carnahan, et al. 1974). It is possible to use a cockriging method to determine population density based on a surface fraction derived from satellite images (Wu and Murray 2005). Empirical evidence has shown that people are attracted to areas that provide a clean environment, cultural amenities, and

have good weather. Many times this results in development along ecologically sensitive areas. It is necessary to determine the spatial distribution of environmental features to prevent ecological damage from happening. It is essential to determine how the environment affects residential development and urban sprawl (Wu 2001). Population growth and advancing technology have led to mass urbanization. To understand this occurrence, one must understand urban processes and patterns thoroughly. To understand urban sprawl, specific temporal and spatial information on a particular urban area is a necessity. Land use patterns and population distributions must be understood. An aid to understanding these characteristics is the use of satellite imagery. Satellite images can be utilized to understand the evolution and expansion of urban areas over time (Liu and Zhou 2007). These strategies are exactly what this research seeks to accomplish. Urban sprawl is also common on and around coastal areas. Metrics have been developed based on correlation to determine sprawl patterns that are unique to other environments (Crawford 2007). Although the Birmingham metro area is not a coastal area, some of these metrics could be adjusted and adopted for the Birmingham area. Landscape level metrics have been used to determine the amount and effects of urbanization in Tucson, Arizona, and Anchorage, Alaska, as well (DiBari 2007; Markon 2003). It is possible to examine the relationship between US Census data and land cover data to determine areas of urban sprawl more clearly (Radeloff, et al. 2000). In the Cairo, Egypt, metro area (which is much larger than the Birmingham metro area), for example, urbanization is occurring on desert land and land that was formerly farmland along the Nile Delta. It was discovered that population per unit area of a developed area can be a good indicator of urbanization (Yin, et al. 2005).

Having accurate change detection data of land features is vital for understanding connections and interactions between physical and human phenomena to better understand the

world and to better manage resources. Satellite images and remote sensing data derived from these images are the main source of change detection data and information. Modern techniques of change detection are artificial neural networks, spectral mixture analysis, and the combination of remotely sensed and geographic information systems data have become common techniques for change detection. All of these techniques have their own strengths and weaknesses (Lu, et al. 2004). Using the integrated remote sensing/geographic information systems classification model, the trajectory of land use/cover change will determine the trajectory of urban expansion (Liu and Zhou 2005). There are also techniques being developed for the classification of multi-temporal images (Bruzzone, et al. 2004). Traditional spectral based classification methods are sometimes considered unproductive in classifying urban land use and land-cover features from high resolution satellite images. To accurately classify these urban areas texture analysis in the pixels should be analyzed. The idea of lacunarity estimation methods can be used in texture analysis to classify urban areas (Myint and Lam 2005)

Based on growth, there have been four city types identified: “low-growth cities with modest rates of infilling; high-growth cities with rapid, fragmented development; expansive-growth cities with extensive dispersion at low population densities; and frantic-growth cities with extraordinary land conversion rates at high population densities” (Schneider and Woodcock 2008). Within the last few decades, urban areas have exploded in population. NASA has created a world urbanization map. Urban sprawl has become interesting to scientists (Ness 2004). Urban sprawl can also be referred to as “exurbia,” and there have been many studies done on it and many satellite images taken (Sutton, et al. 2006). To better assist with classification of the urban areas in an image, census data may be used to better determine populated areas (Aubrecht, et al. 2008). Remote sensing and GIS offer the best way to manage

urbanization (Yang 2005). Studies of urban sprawl similar to this study have taken place in the southeast in such places as Pensacola, Florida (Yang and Liu 2005).

Unsupervised classifications have been successful in detecting urban sprawl (Liao, et al. 2008). Another method of classifying urban sprawl is a merger of remotely sensed images, landscape metrics, and gradient analysis. This method is used to compare both the temporal and spatial characteristics of urban sprawl. This method was employed in Guangzhou, China (Yu and Ng 2006). Sprawl has caused congestion, environmental damage, and the loss of open space. The Dempster-Shafer Theory offers another method of mapping sprawl (Lein 2003). The ability to effectively manage urbanization presents many challenges. Remote sensing can be used to provide solutions to the management of urban sprawl (Ward, et al. 2000). It is also possible to use classification and geographically weighted regression to identify sprawl (Jensen, et al. 2005).

No literature was found about urban land-use classifications and change detections in the Birmingham metro area. Papers have been written about urban sprawl, In-Fill development, and commuting patterns in the metro area. Most notably these are the Sultana and Wilson papers mentioned previously. It is the goal of this study to adapt the techniques reviewed to create a change detection over time showing the expansion of urban sprawl in the Birmingham metro area.

CHAPTER 3

METHODOLOGY

3.1. Introduction

The Birmingham, AL, area is an area that has been growing since the end of the Civil War. This original growth was caused by the presence of coal and iron ore in the area. Now, the Birmingham, AL, metropolitan area is undergoing rapid urbanization. This study believes that this is an excellent area to study the expansion of urban sprawl and methods to responsibly manage urbanization. This area fits the criteria for an area that is experiencing urban sprawl. These reasons are why that the Birmingham, Alabama, Metropolitan Area was selected as a case study. There have been similar studies, but none exactly like this one, throughout the southeastern United States and around the country. Birmingham was also selected as a case study because of its close proximity to the University of Alabama, this made it less difficult to go the study area and collect in-situ data. The reason that this time period was chosen—1974 to 2008 was to get the oldest and newest Landsat satellite possible. This strategy allowed the most comprehensive change detection possible.

The *Remote Sensing Process* is utilized in this research. The remote sensing process consists of four steps—Statement of the Problem, Data Collection, Data-to-Information Conversion, and Information Presentation. The first step of the *Remote Sensing Process*, the statement of the problem, consists of three steps—formulate hypothesis, select appropriate logic, and select appropriate model. The second step, being data collection, consists of three steps—*In*

Situ Measurements, Collateral Data, and Remote Sensing. The third step, being Data-to-Information Conversion, consists of three steps—Analog (Visual) Image Processing, Digital Image Processing, and Hypothesis Testing. The fourth and final step, being Information Presentation, consists of five steps—Image Metadata, Accuracy Assessment, Analog and Digital, Statistics, and Graphs (Jensen 2007).

3.2. Study Area

This study will look at Jefferson and Shelby counties. They are the core of the Birmingham, Alabama, Metropolitan Area. The Birmingham metro area is located in central Alabama (Figure 3.1). The total land area of Jefferson County is 2,882 square kilometers. The total land area of Shelby County is 2,058 square kilometers. Thus, the study area has a total land area of 4,940 square kilometers. The estimated 2008 population of Jefferson County is 659,503, while the population of Shelby County is 187,784. The total population of the two county area is 847,287. The population of Alabama is approximately 4,661,900. Approximately 18.2 % of Alabama's total population lives in this two county area as of 2008 (Alabama QuickFacts from the US Census Bureau 2008).

3.3. Data Acquisition and Collection

3.3.1. Satellite Images

The remotely sensed data used for this study are Landsat Multispectral Scanner (MSS) and Landsat Thematic Mapper (TM) imagery. The Landsat MSS was the first generation of Landsat and had a spatial resolution of 79x79 m for bands 4 through 7. The Landsat TM is a technologically advanced sensor integrating multiple radiometric, spectral, and geometric

enhancements from its predecessors. It can acquire data in seven bands of the spectrum—visible spectrum (blue, green, red), near-IR, mid-IR, and thermal. The wavelength location and range of the TM bands have been enhanced from its predecessors, improving the spectral differentiability of surface features of Earth (Lillesand, et al. 2004). It has a spatial resolution of 30x30 m. For urban land cover classifications with Landsat TM, the most useful bands are visible, near-infrared, middle-infrared, and panchromatic (Jensen 2007).

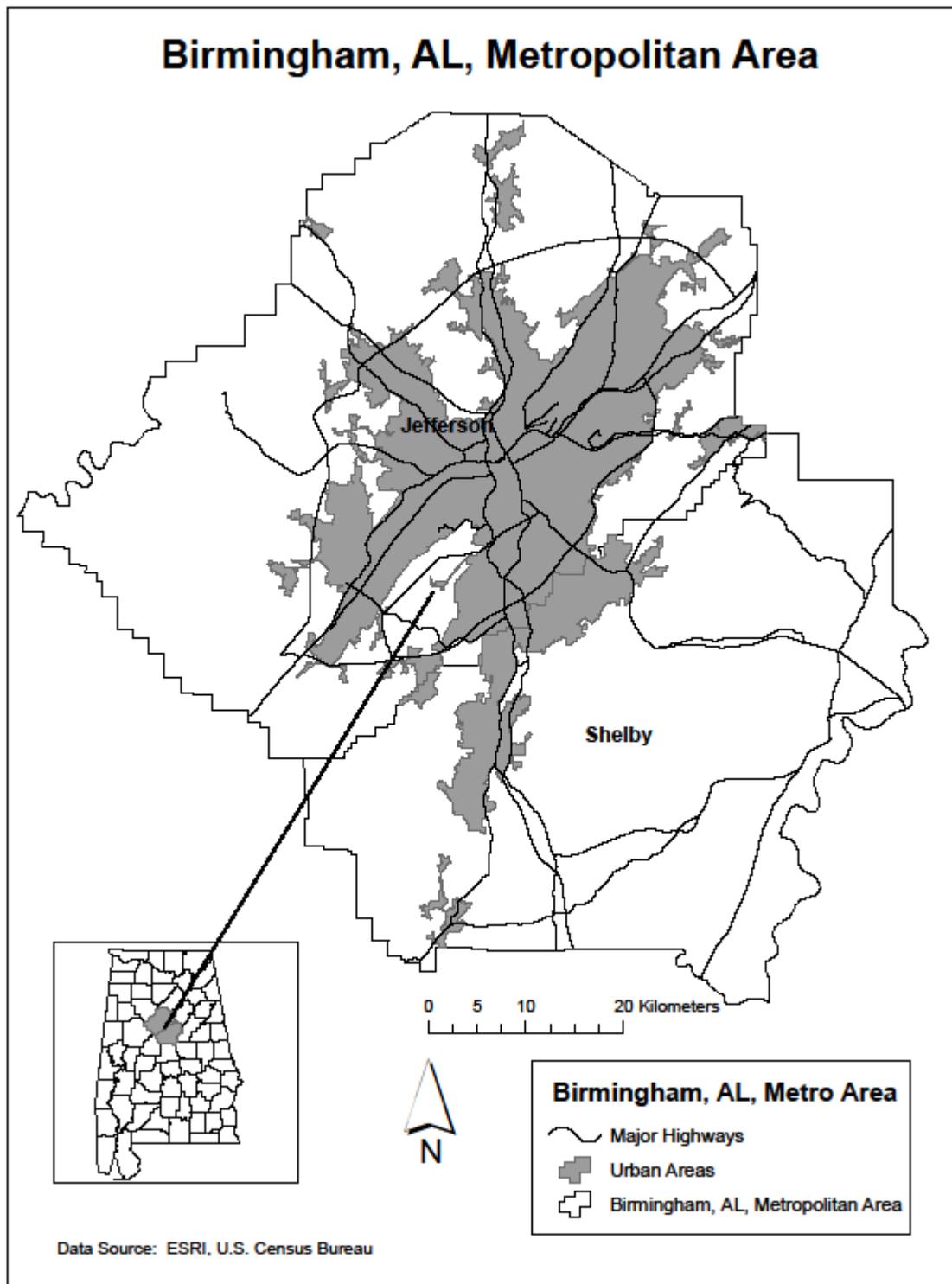


Figure 3.1 Basic map showing location of study area within Alabama and location of urban areas within metropolitan area.

This study spans a four decade time period—1970s, 1980s, 1990s, and 2000s. For the 1970s a Landsat MSS image from October 7, 1974 was obtained. For the 1980s Landsat TM images from October 12, 1988 and October 6, 1989 were obtained because of the lack of data covering the study area in its entirety; this will be elaborated on later. For the 1990s, a Landsat TM image from October 15, 1998 was obtained. For the 2000s a Landsat TM image from October 19, 2008 was obtained. Temporal resolution is a large issue in finding the correct satellite imagery. Data should be obtained from a system that acquires data at the same time of day, being that all of the data is from Landsat that is not an issue. Images with corresponding anniversary dates, which are dates over time which correspond with season, month, and preferably week should be obtained. Many times this is not possible because of the times that the sensor system passes over the particular area. Another problem is weather; when there is a thunderstorm, it is impossible to classify an urban area in the image. Many times anniversary dates are impossible, and the logical alternative would be to find images of the area in the same month or season (Jensen 2007). This study was successful in finding satellite data very close to anniversary dates. All data was obtained from the USGS Global Visualization Viewer (GLOVIS).

3.3.2. Reference and Collateral Data

It is important to obtain reference and collateral data to supplement the remote sensing data. This data is of value and importance in the remote sensing process. It is ideal that this data be GIS compatible (Jensen 2007). Reference data was obtained from the United States Department of Transportation, United States Census Bureau, Geolytics, and the United States Geological Survey. Data from the United States Department of Transportation was obtained from the National Transportation Atlas Databases 2008 (NTAD). This data included highway,

waterway, and county boundary data. Reference data obtained from the United States Census Bureau included urban area TIGER data. Data was obtained from Geolytics with 2008 population per census tract estimations. This data was used to analyze the population per census tract in high density and low density urban areas and to see if high population and population density per census tract exists in these areas. A surface was created from the population data. Digital elevation models (DEMs) were obtained from the USGS to analyze the elevation of the urban areas and the slopes that they are built on. Traffic counts were obtained from the Alabama Department of Transportation (ALDOT) to analyze the traffic patterns in the urban areas to see if they correspond with highly traveled sections of major highways.

3.3.3 In Situ Data Collection/Fieldwork

Data collected directly from the field is known as *in situ* data (Jensen 2007). For this research, some data was collected from the field. Digital photographs were taken in the field of each land-use/land-cover class. Global Positioning Systems (GPS) points were taken in the photograph location. These points were overlaid compared with the 2008 supervised classification image to determine if the GPS points and photographs corresponded with the supervised classification image. This is called “ground truthing.” The goal is to see if the GPS coordinates and digital photographs correspond correctly with the land-use/land-cover classes.

3.4. Data Processing

3.4.1. Image Preprocessing

As discussed earlier, all images were obtained from GLOVIS. When they were obtained, they were in the WGS UTM Zone 16 N projection. Once they were obtained, they were converted to UTM Zone 16 N. The next step was to overlay the county boundaries and major

highways shapefile over the image to see if geometric rectification was required. The only image that required geometric rectification was the October 7, 1974 Landsat MSS image. The last three images were already rectified, so they did not require any further rectification. Many older images have not been georectified. The method chosen to georectify the 1974 image was *Image-to-Image Registration*. “*Image-to-image registration* is the translation and rotation alignment process by which two images of like geometry and of the same geographic area are positioned coincident with respect to one another so that corresponding elements of the same ground area appear in the same place on the registered images” (Jensen 2007). The reason this method was utilized is because the Landsat MSS imagery is 30 years older than the highway data that was being utilized, so there have been changes. County boundary data would have been of little use because it would be impossible to determine county boundaries from an image that was based on a survey.

Another difficulty with georectification based on roads is the lower spatial resolution of Landsat MSS imagery compared to the later Landsat TM imager. That being said, *Image-to-image registration* was the best option. The 1974 image was georectified based on the October 19, 2008 image. Before the 1974 image was georectified, the original 1974 image had a subset taken from it of a smaller area, including all of the study area, in order to have less of the image to work with. A total of 450 ground control points had to be taken based on the 2008 image to properly georectify the 1974 image. A ground control point is “a location on the surface of the Earth (e.g., a road intersection) that can be identified on the imagery and located accurately on a map” (Jensen 2007). After the 1974 image was rectified, it was resampled to 30x30 m spatial resolution to correspond to the other three images. Being that the images were of a larger area than just the study area, the next step was to subset out the needed area. The method to subset

the study area out of the image is to take the county boundaries layer and convert it to an *area of interest (AOI)* and then subset out the study area. So, the new image is just of Jefferson and Shelby counties. There was not an image available of weather, suitable dates, and time of year for the late 1980s. So, images from October 12, 1988 and October 6, 1989 had to be obtained. Being that only a small area of southwestern Jefferson County was required to make the 1988 image complete, a very small area of the 1989 image was extracted via subset for a mosaic to have a complete image for the decade of the 1980s. “*Mosaicking* is the process of combining multiple images into a single seamless composite image” (Jensen 2007). The seam line generation method was based on the most nadir seam line. When doing a mosaic, it is important to do color corrections because the two images will not perfectly correspond with colors, even if they are in the same area and same band combination(s). So, it is important to use color balancing and histogram matching to make the color of the two images being mosaicked corresponding. After the mosaic was successful, the final image was extracted via subset from the mosaicked image. To view these images, see Figures 3.2-3.5.

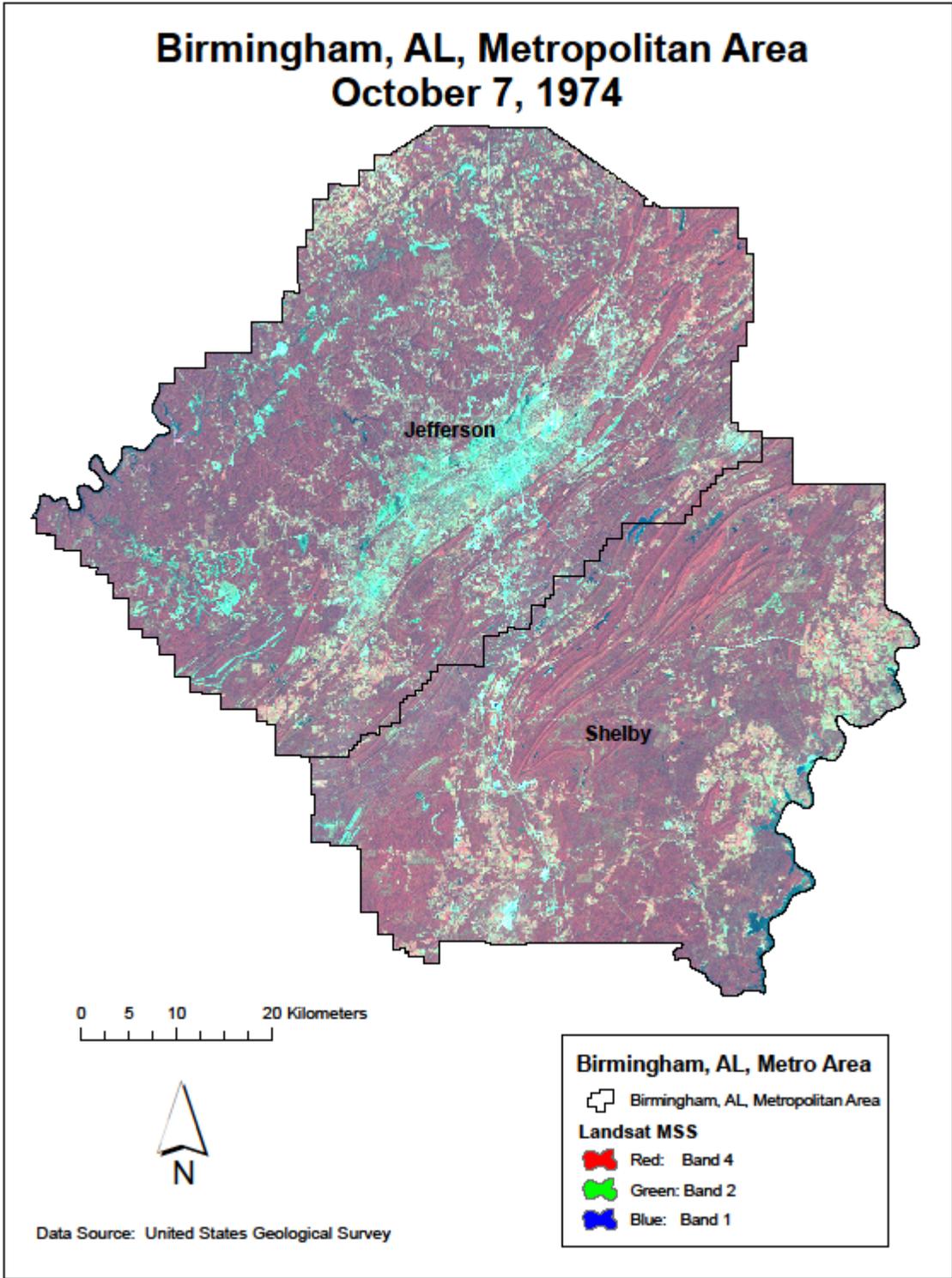
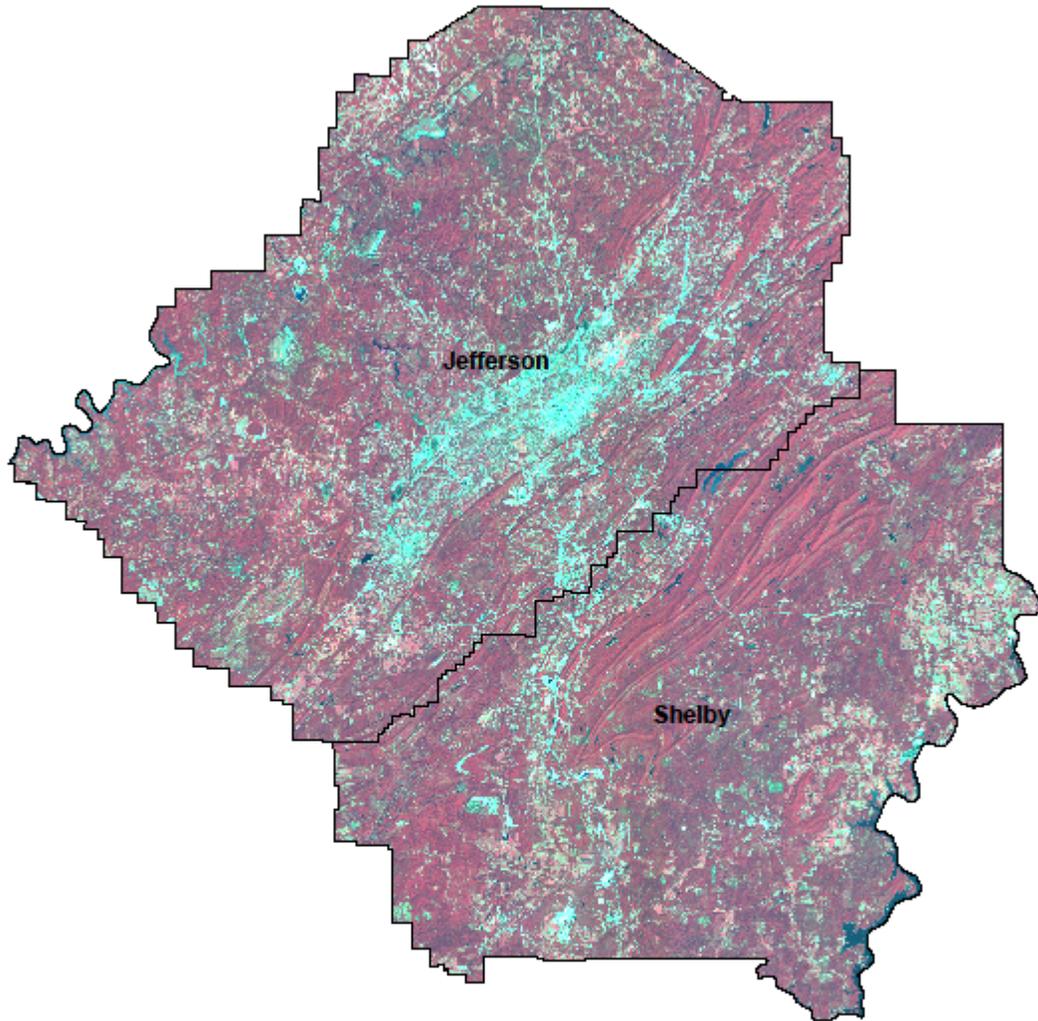


Figure 3.2 Landsat MSS image of the study area—October 7, 1974.

Birmingham, AL, Metropolitan Area October 12, 1988/October 6, 1989



0 5 10 20 Kilometers



Data Source: United States Geological Survey

Birmingham, AL, Metro Area

□ Birmingham, AL, Metropolitan Area

Landsat TM

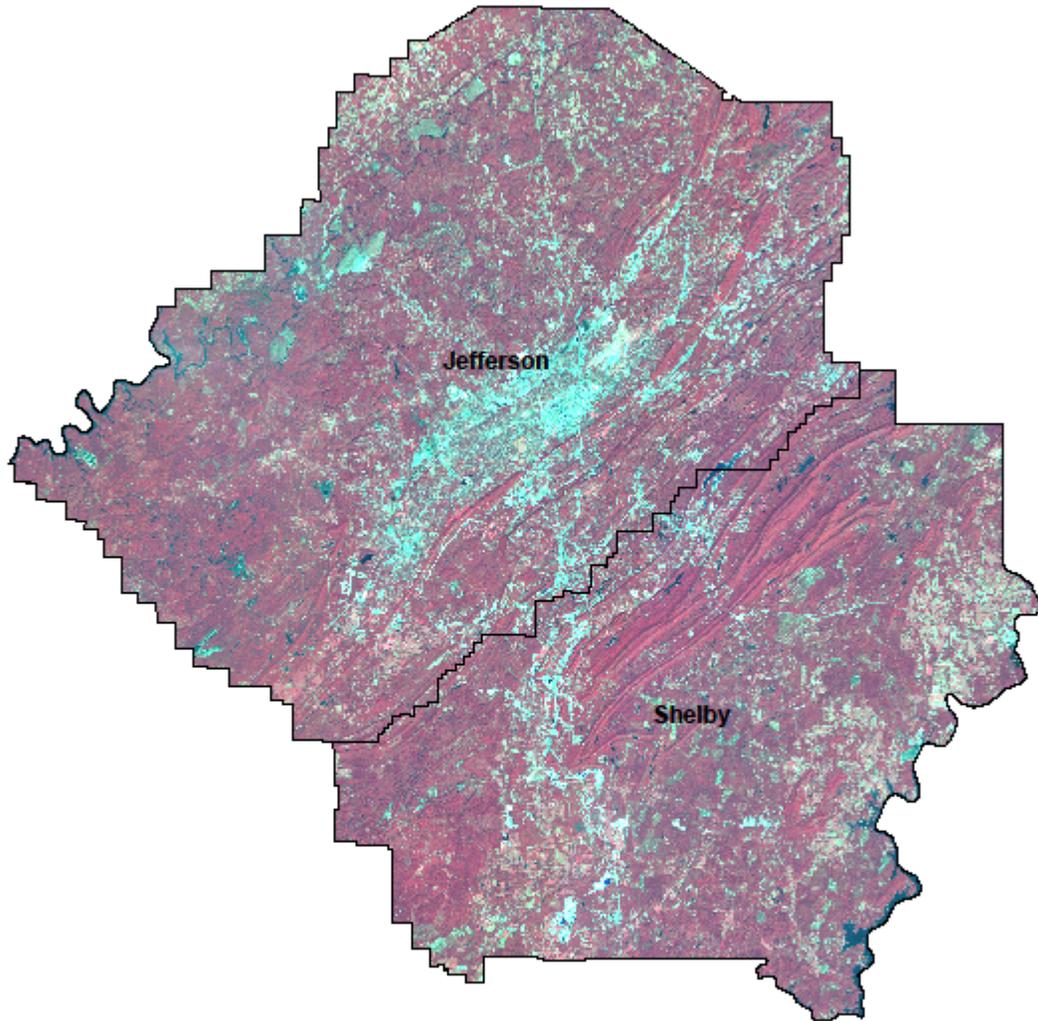
Red: Band 4

Green: Band 3

Blue: Band 2

Figure 3.3 Landsat TM image of the study area—October 12, 1988/October 6, 1989.

Birmingham, AL, Metropolitan Area October 15, 1998



0 5 10 20 Kilometers



Data Source: United States Geological Survey

Birmingham, AL, Metro Area

☐ Birmingham, AL, Metropolitan Area

Landsat TM

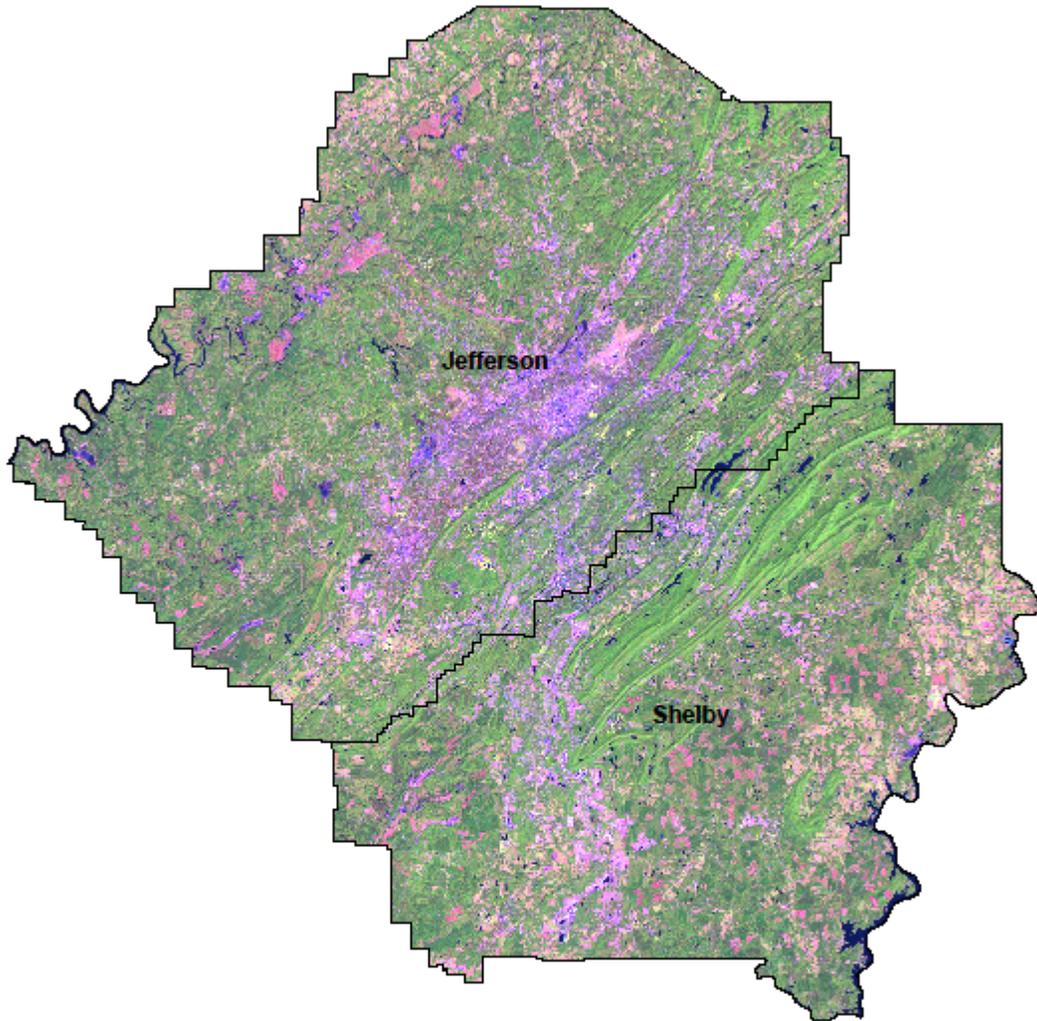
Red: Band 4

Green: Band 3

Blue: Band 2

Figure 3.4 Landsat TM image of the study area—October 15, 1998.

Birmingham, AL, Metropolitan Area October 19, 2008



0 5 10 20 Kilometers



Data Source: United States Geological Survey

Birmingham, AL, Metro Area

-  Birmingham, AL, Metropolitan Area

Landsat TM

-  Red: Band 5
-  Green: Band 4
-  Blue: Band 3

Figure 3.5 Landsat TM image of the study area—October 19, 2008.

3.4.2. Image Classification Scheme

The classification scheme is based on the U.S. Geological Survey (USGS) *Land-use/Land-Cover Classification System for Use with Remote Sensor Data* and the U.S. Geological Survey (USGS) *Land-use/Land-Cover Classification System for Use with Remote Sensor Data* modified for the National Land Cover Dataset. This classification is mainly a resource-based land-cover classification system. It is based upon 30 m Landsat TM data. The first classification includes nine main classes and thirty-seven classes overall. The second classification system includes nine main classes and twenty-two classes overall. For a diagram of classification systems, see Figures 3.6 and 3.7. For this research, a total of six land-cover/land-use classes were used—Barren, High Density Urban/Built-up Land, Low Density Urban/Residential, Water, Forest, and Light Vegetation/Agriculture (Jensen 2007). *Barren* consists of areas that are less than 20% light vegetation cover. They are generally in transition to a new land-use/land-cover. They include quarries, barren agricultural fields, barren rock, sand, and clear-cut areas. *High Density Urban/Built-up* land use consists of areas that are around 80-100% building materials. It is mainly industrial and commercial structures with large transportation facilities and large open roofs. It is located mainly in city cores and has a low amount of residential areas. *Low Density Urban/Residential* consists of areas that are around 50-80% building materials. This class is located in all classes of residential developments, local roads, etc. This class consists of up to 20% vegetation cover. *Water* consists of all areas that are covered in water—streams, reservoirs, rivers, and lakes. *Forest* consists of all areas that are 90-100 covered in forests of all types. *Agriculture/Light Vegetation* consists of areas with large percentages of herbaceous vegetation, grasses, light crops, pastures, municipal parks, and golf courses (Yang 2002). In order to run an

accurate change detection, each of the four images must have the same land-cover/land-use classes in the same order.

- | Classification Level | |
|--|--|
| 1. Water | |
| 1.1. Open Water | |
| 1.2. Perennial Ice/Snow | |
| 2. Developed | |
| 2.1. Low-Intensity Residential | |
| 2.2. High-Intensity Residential | |
| 2.3. Commercial/Industrial/Transportation | |
| 3. Barren | |
| 3.1. Bare Rock/Sand/Clay | |
| 3.2. Quarries/Strip Mines/Gravel Pits | |
| 3.3. Transitional | |
| 4. Forested Upland | |
| 4.1. Deciduous Forest | |
| 4.2. Evergreen Forest | |
| 4.3. Mixed Forest | |
| 5. Shrubland | |
| 5.1. Shrubland | |
| 6. Non-Natural Woody | |
| 6.1. Orchards/Vineyards, Other | |
| 7. Herbaceous Upland Natural/Seminatural Vegetation | |
| 7.1. Grasslands/Herbaceous | |
| 8. Herbaceous Planted/Cultivated | |
| 8.1. Pasture/Hay | |
| 8.2. Row Crops | |
| 8.3. Small Grains | |
| 8.4. Fallow | |
| 8.5. Urban/Recreation | |
| 8.6. Grasses | |
| 9. Wetland | |
| 9.1. Woody Wetlands | |
| 9.2. Emergent Herbaceous Wetlands | |

Figure 3.6 U.S. Geological Survey Land-Use/Land-Cover Classification System for Use with Remote Sensor Data modified for the National Land Cover Dataset and NOAA Coastal Change Analysis Program (Jensen 2007).

Classification Level	
1. Urban or Built-up Land	
1.1. Residential	
1.2. Commercial and Services	
1.3. Industrial	
1.4. Transportation, Communications, and Utilities	
1.5. Industrial and Commercial Complexes	
1.6. Mixed Urban or Built-Up	
1.7. Other Urban or Built-Up Land	
2. Agricultural Land	
2.1. Cropland and Pasture	
2.2. Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas	
2.3. Confined Feeding Operations	
2.4. Other Agricultural Land	
3. Rangeland	
3.1. Herbaceous Rangeland	
3.2. Shrub-Brushland Rangeland	
3.3. Mixed Rangeland	
4. Forest Land	
4.1. Deciduous Forest Land	
4.2. Evergreen Forest Land	
4.3. Mixed Forest Land	
5. Water	
5.1. Streams and Canals	
5.2. Lakes	
5.3. Reservoirs	
5.4. Bays and Estuaries	
6. Wetland	
6.1. Forested Wetland	
6.2. Nonforested Wetland	
7. Barren land	
7.1. Dry Salt Flats	
7.2. Beaches	
7.3. Sandy Areas Other Than Beaches	
7.4. Bare Exposed Rock	
7.5. Strip Mines, Quarries, and Gravel Pits	
7.6. Transitional Areas	
7.7. Mixed Barren Land	
8. Tundra	
8.1. Shrub and Brush Tundra	
8.2. Herbaceous Tundra	
8.3. Bare Ground Tundra	
8.4. Wet Tundra	
8.5. Mixed Tundra	
9. Perennial Snow or Ice	
9.1. Perennial Snowfields	
9.2. Glaciers	

Figure 3.7 U.S. Geological Survey *Land-Use/Land-Cover Classification System for Use with Remote Sensor Data* (Jensen 2007)

3.4.3. Supervised Classification

The classification scheme used for this research is the supervised classification scheme. All four images underwent a supervised classification. Using the supervised classification method, the location and identity of a number of land-use/land-cover types (e.g. water, forest, residential) are recognized via a mixture of fieldwork, map analysis, individual experience, and digital image and aerial photograph interpretation. Specific sites are located on the remotely sensed data that characterize uniform samples of particular land-use/land-cover types. These areas are known as “training sites,” because the spectral attributes of these areas are utilized to sequence the classification algorithm for the goal of creating a land-use/land-cover map of the entire remotely sensed image. The band combinations utilized were 4, 3, 2 (Near-Infrared, Red, and Green) and 5, 4, 3 (Mid-Infrared, Near-Infrared, and Red). The 4, 3, 2 combination is very useful for identifying urban, residential, and forested areas. The 5, 4, 3 combination is very useful for identifying barren and areas of light vegetation and agriculture. Both combinations are equal in their ability to detect water. Once the image has been classified to the satisfaction of the user, the next step is to select the appropriate image classification logic. For this research the parametric rule selected was maximum likelihood. Maximum likelihood and other parametric methods assume remote sensing data and knowledge of normally distributed data about the types of the fundamental class density functions. The nonparametric rule selected was parallelepiped. Parallelepiped and other nonparametric methods may be used with remotely sensed data that do not have a normal distribution and has no assumption that the types of fundamental densities are known (Jensen 2007). Once an image has undergone a supervised classification and the new supervised classification image has been created, this image must then be recoded. The recoding process eliminates all of the classes that do not have any value, thus leaving only the desired

land-use/land-cover classes once the supervised classification has been ran. The recoding process also puts all land-use/land-cover classes in the same order, thus enabling a change detection. It is of primary importance for each supervised classification image to have its land-use/land-cover classes in the same order, because if not, the results of the change detection will be flawed. Figures 3.8-3.11 display the results of the supervised classification/recoding process. Even though in these figures the land-use/land-cover classes are in different orders, this is because they are displayed by their unique values rather than their internal colormap. The display has no bearing on the change detection.

Birmingham, AL, Metropolitan Area October 7, 1974

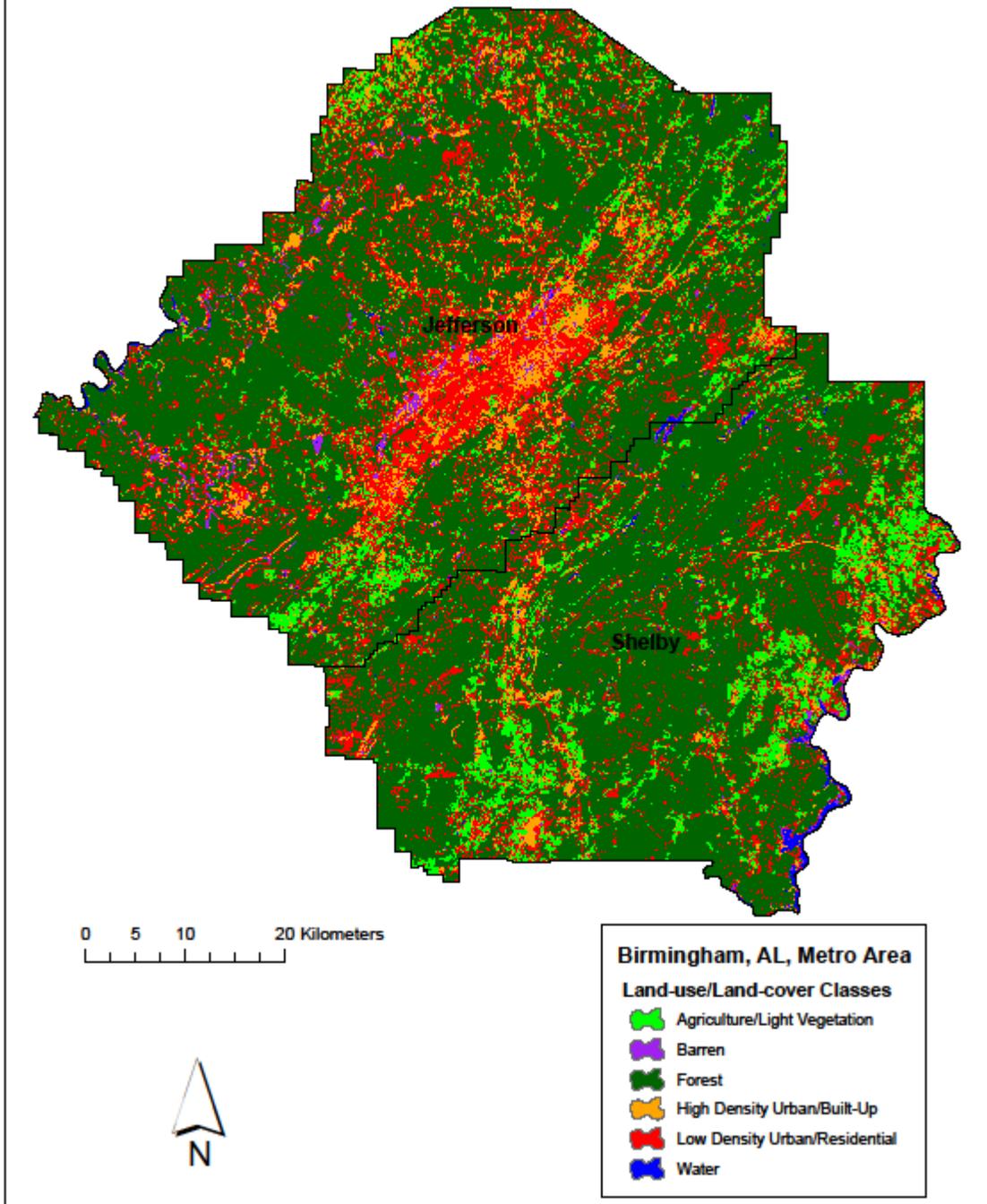


Figure 3.8 Supervised classification of study area—October 7, 1974.

**Birmingham, AL, Metropolitan Area
October 12, 1988/October 6, 1989**

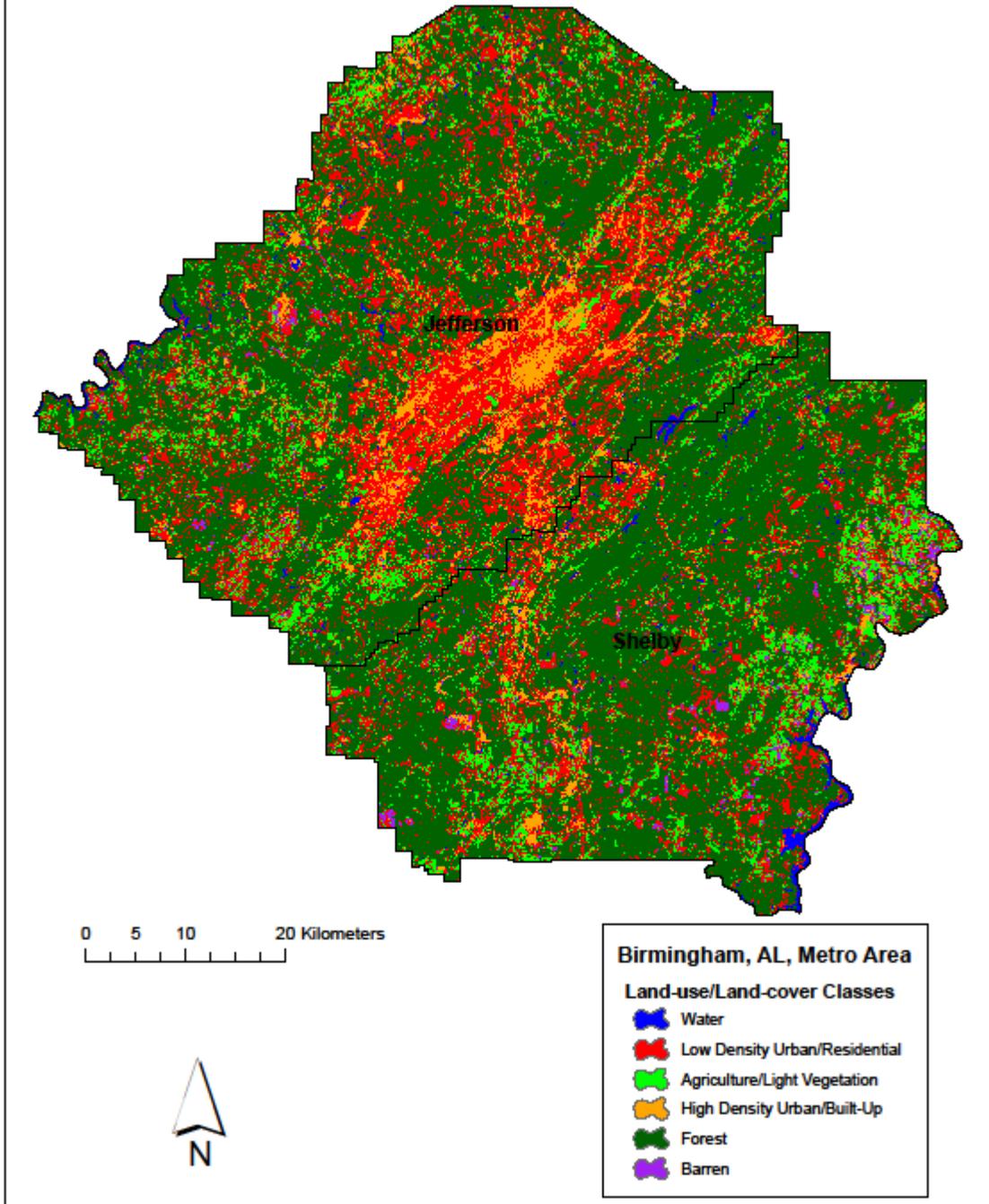


Figure 3.9 Supervised classification of the study area—October 12, 1988/October 6, 1989.

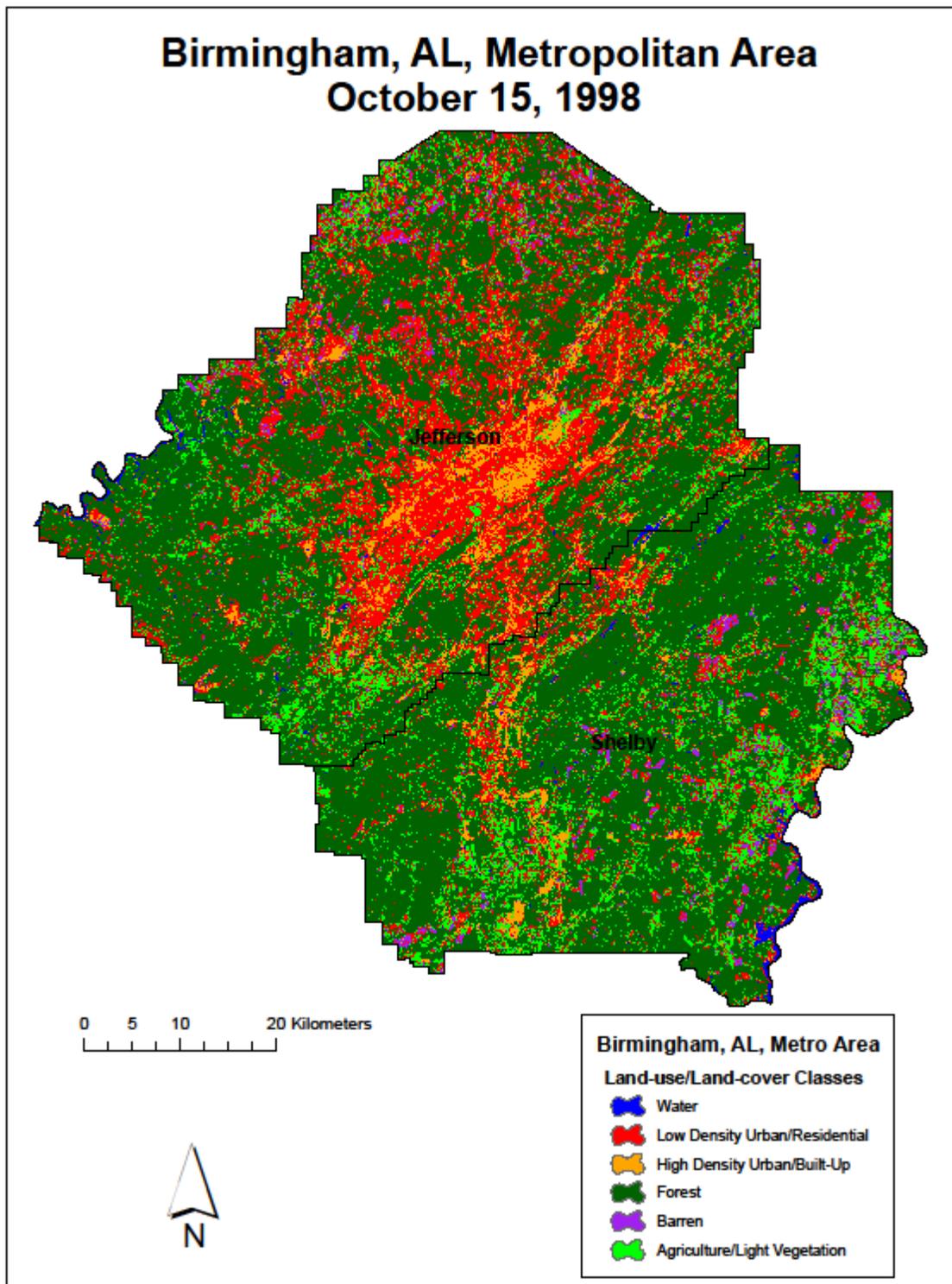


Figure 3.10 Supervised classification of the study area—October 15, 1998.

Birmingham, AL, Metropolitan Area October 19, 2008

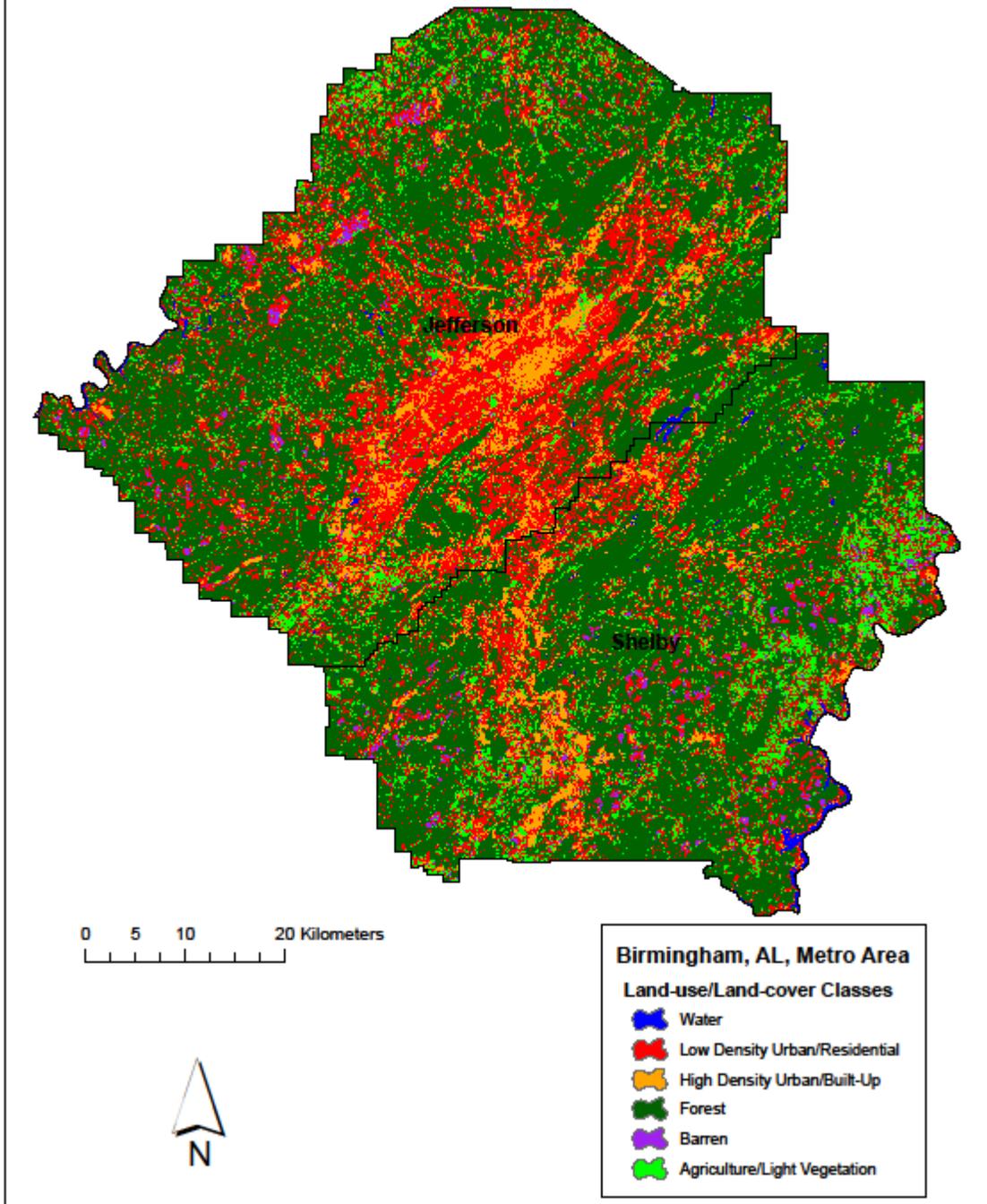


Figure 3.11 Supervised classification of the study area—October 19, 2008.

3.4.4 Accuracy Assessment

Information taken from remotely sensed data is becoming very important. This information is generally in the form of statistics of thematic maps. It is vital that this information is accurate because important decisions will be made using this data. It is an unavoidable fact that this data contains error, and it should be minimized as much as possible. An accuracy assessment informs the user how much confidence they should have in the thematic information they are looking at. An accuracy assessment makes information derived from remotely sensed data credible (Jensen 2007).

The accuracy assessment sampling method chose for this research was the *stratified random sampling*. This method is preferred because a set minimum number of samples are taken from each land-use/land-cover category after a supervised classification/recoded thematic map has been created. There are two steps to stratified random sampling. First of all, using a supervised or unsupervised classification method (analyst's choice), the image is classified into different land-use/land-cover classes which are based on what is found based on information found in the thematic map derived from remote sensing. Then random samples are allocated throughout the stratum. The main advantage of stratified random sampling is that all land-use/land-cover classes, no matter their spatial size in proportion to the study area, will have a minimum number of samples allocated for accuracy and error evaluation. It is very difficult to locate adequate samples for classes that only take up a small amount of the study area without stratification (Jensen 2007).

The supervised classification of each image consisted of six classes. Using the *stratified random sampling* a total of 258 random points were created for each image with a minimum of

forty-three points per land-use/land-cover class. Once the points were created for each image, the accuracy assessment was initiated. Because of the limited availability of ground truthing data, the accuracy of these images is limited. The overall accuracy of the 1974 image was 75.97%. The overall Kappa Statistics were 0.7116. The *Kappa* statistic is a “discrete multivariate technique of used in accuracy assessment.” Kappa analysis produces the K^2 statistic, which approximates the Kappa. The Kappa statistic measures the accuracy or harmony connecting the classification map from remotely sensed data, and the reference data specified the chance agreement and the major diagonal, which is specified by the column and row totals (Jensen 2007). The overall classification accuracy of the 1988/1989 image is 80.62%. The Overall Kappa Statistics were 0.7674. The overall classification accuracy of the 1998 image is 78.29%. The Overall Kappa Statistics were 0.7395. The overall classification accuracy of the 2008 image is 87.21%, the highest accuracy of the four. The Overall Kappa Statistics were 0.8465.

In situ data collection is helpful in an accuracy assessment. Once an image has been classified and an accuracy assessment ran, it is useful to go out into the field and collect digital photographic images and GPS coordinates of each land-use/land-cover class in the field. If GPS points and photographs correspond with the land-use/land-cover classes, it further solidifies the supervised classification and accuracy assessment. This was done for this research. Images and GPS coordinates were taken for each land-use/land cover class in the study area. This in situ data collection was successful in that the photographs and the GPS coordinates matched correctly with the supervised classification. This further legitimized the supervised classification and accuracy assessment. This was done with the October 19, 2008 data. See Figure 3.12 for a demonstration of this.

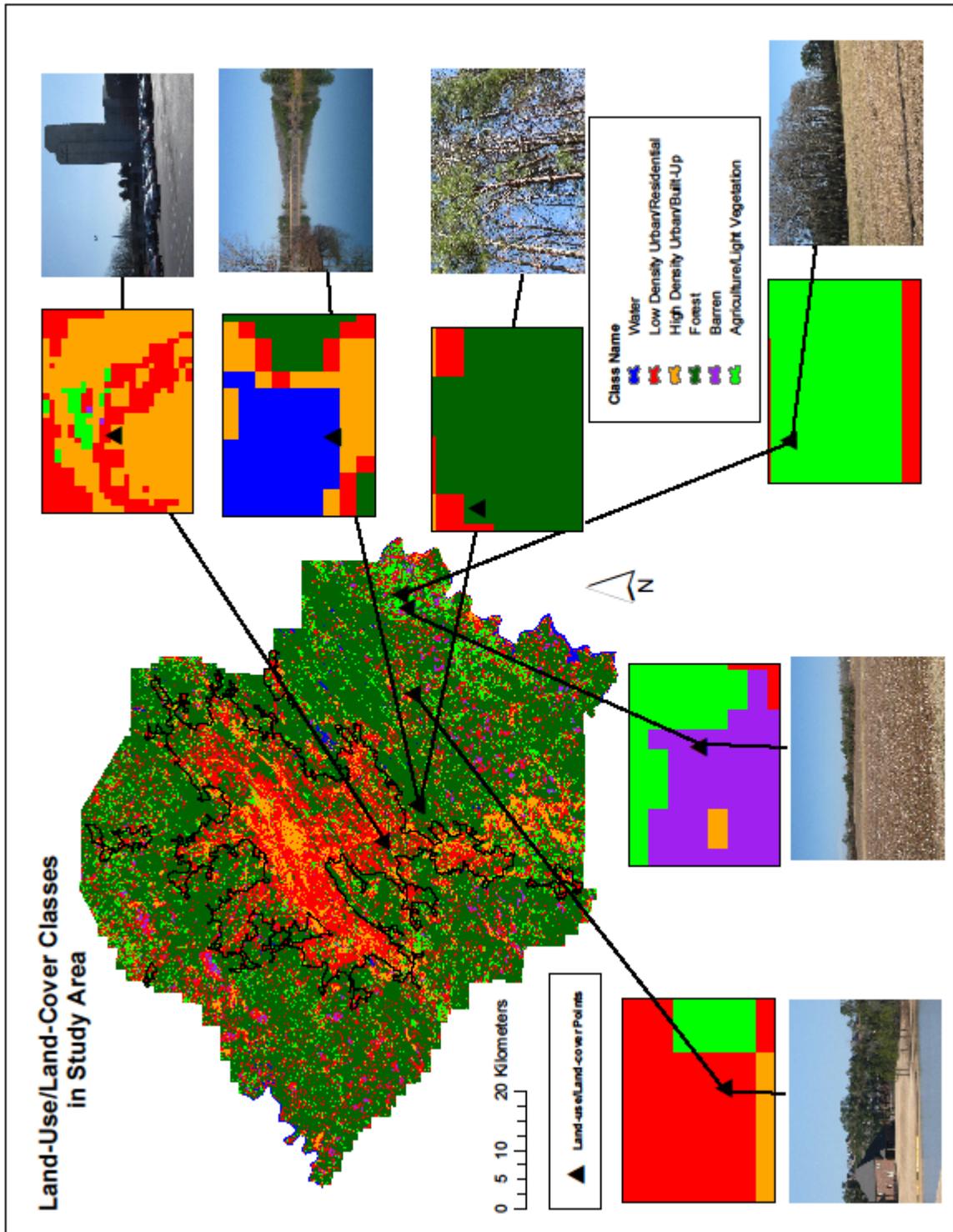


Figure 3.12 In-situ data collection in the study area.

3.4.5 Change Detection

Many hold that land-use/land-cover change is a major factor in global change. In recent years there have been sizeable efforts going into developing and advancing change detection methods using information derived from remotely sensed data (Jensen 2007). To carry out change detection, a model was utilized to carry out the change detection. To do a change detection, the spatial distribution of land land-use/land-cover classes are extracted to determine the change over time. A total of four change detections were carried out—1974-1988, 1988-1998, 1998-2008, and 1974-2008. The model utilized is shown in Figure 3.13. The model consists of an older image and a new image being input into a function. Once input into the function, the older image is multiplied by ten, then the newer image is added to it. This generates the change detection image. The reason that the older image is multiplied by ten and then the newer image is added to it is because it is a very efficient way to show change detection. For example, in this research the land-use/land-cover class *Forest* is class number *five*, the land-use/land-cover class *High Density Urban/Built-Up* is class *two*. If *Forest* is multiplied by *ten*, that would equal *50*, then *two* for *High Density Urban/Built-Up* is added to it that would equal *52*. This calculation would show the change from *Forest* to *High Density Urban/Built-Up* from the earlier image to the later image. This change detection model creates a thematic map that provides the areas of change and the amount of area that they consist of.

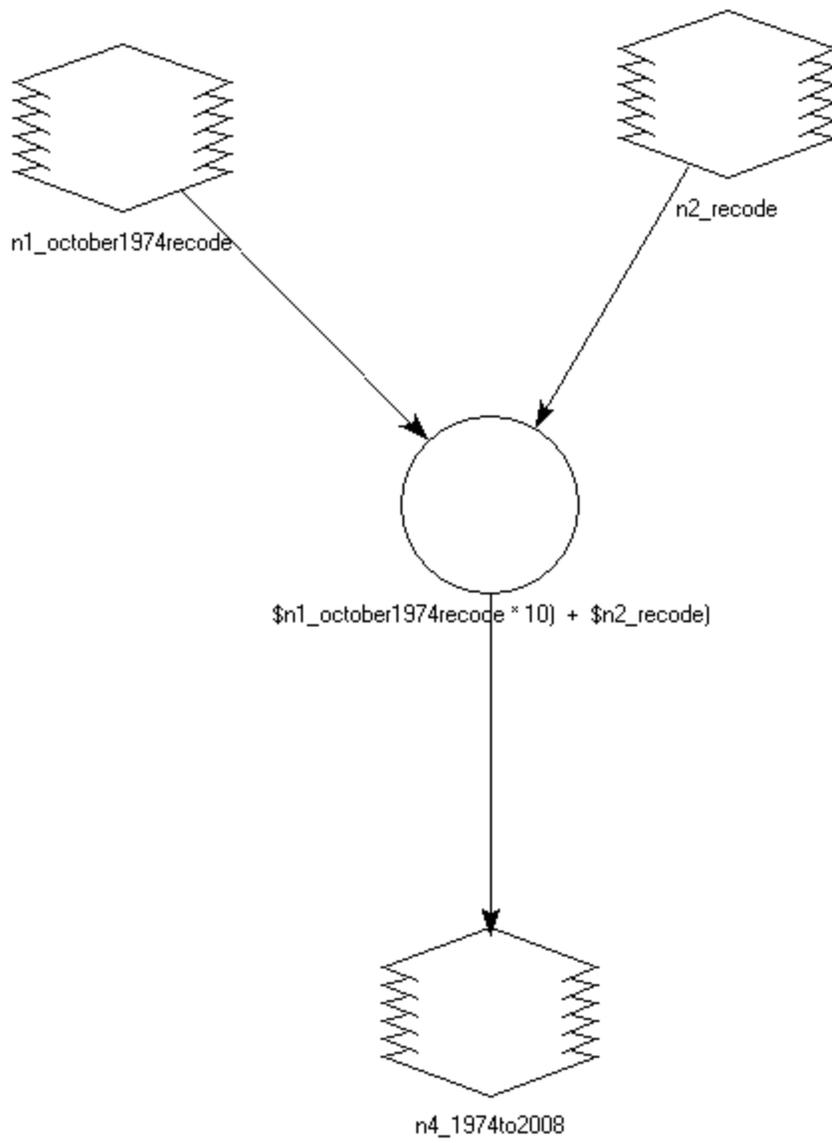


Figure 3.13 Change detection with Erdas Imagine Spatial Modeler.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Analysis of Supervised Classification

Based on Figure 4.1, it is obvious that there has been urban growth in the Birmingham, AL, Metropolitan Area over the 1974-2008 thirty-four year period. High Density Urban/Built-Up and Low Density Urban/Residential have both grown in the four images while Forest has decreased in square kilometers. Based on Table 4.1, an analysis of the 1974 data shows that the total square kilometers of High Density Urban/Built-up was 286.87 or 5.7% of the total land-use/land-cover. The total area of Low Density Urban/Residential was 946.1 square kilometers or 18.8% of the total land-use/land-cover. The total area of Forest was 3257.39 square kilometers or 65.03% of the total land-use/land-cover. The total area of Agriculture/Light Vegetation was 435.2 or 8.7% of the total land-use/land-cover. Barren and Water will not be discussed being that the square kilometers of Barren varied greatly from year to year and Water remained relatively constant. The total Urban/Developed land-use/land-cover (High Density Urban/Built-Up + Low Density Urban/Residential) for 1974 was 1232.98 square kilometers or 24.6% of the total land-use/land-cover. The total area of the Vegetation (Forest + Agriculture/Light Vegetation) was 3692.59 square kilometers or 73.7% of the total land-use/land-cover.

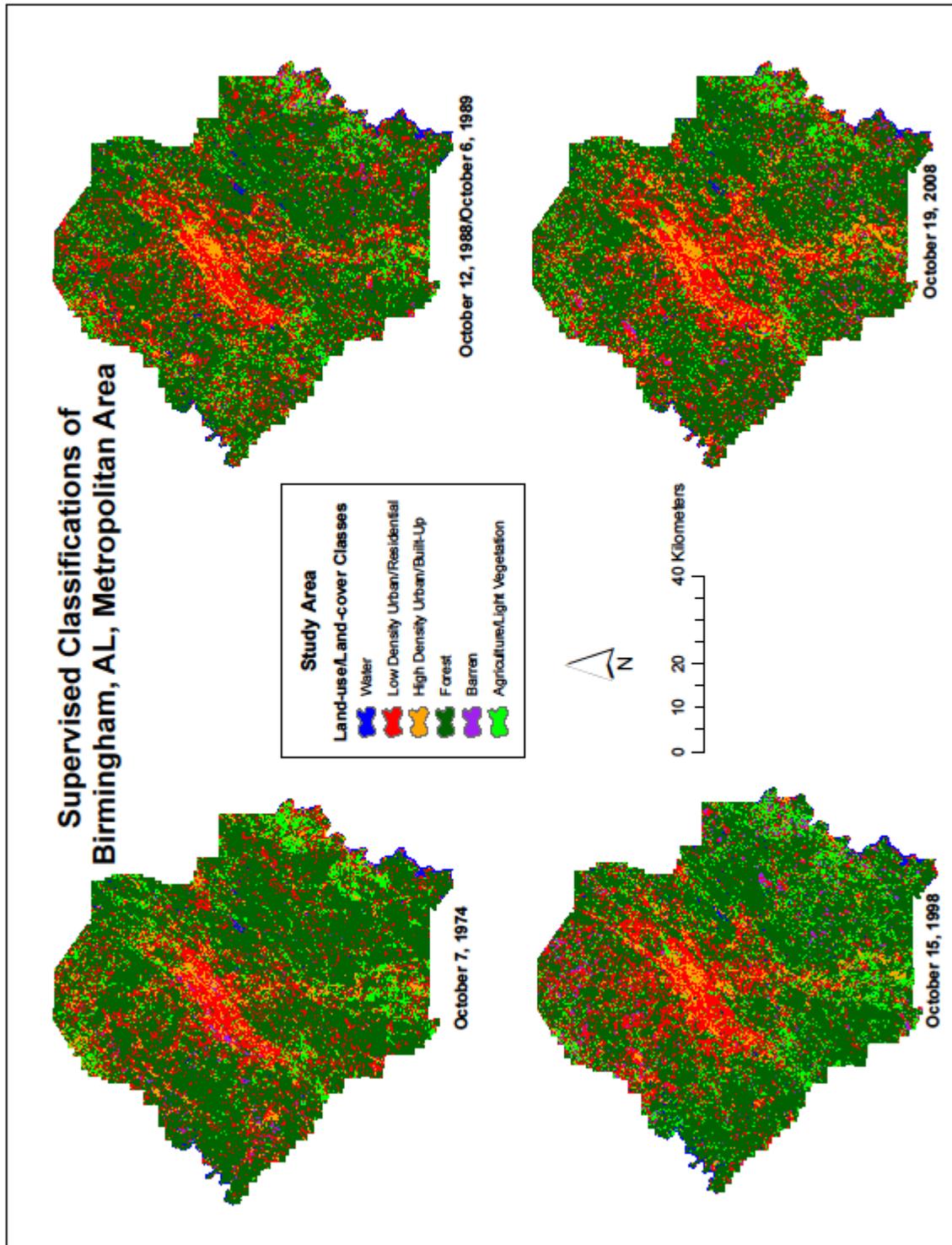


Figure 4.1 Comparison of supervised classifications showing urban and residential growth over time.

Table 4.1

Land-Use/Land-Cover Statistics for the Birmingham, AL Metropolitan Area: 1974-2008

No.	Land-Use/Land-Cover	1974		1988		1998		2008	
		Area (sq km)	%						
1	Barren	51.03545671	1.018895238	66.74580659	1.332532905	121.3795338	2.423156334	77.64836154	1.550105508
2	High Density Urban/Built-Up	286.8696731	5.727197572	250.3088829	4.997240124	209.0998411	4.174357807	343.3521338	6.854388465
3	Low Density Urban/Residential	946.1071167	18.8885159	1159.799266	23.1545735	1047.256512	20.90687097	1185.603317	23.66837105
4	Water	32.31191466	0.645089867	65.2625204	1.302920143	46.2229998	0.922771338	37.8801301	0.756206533
5	Forest	3257.376246	65.03175164	2976.828734	59.43028397	2970.871761	59.30890079	2870.768721	57.30957251
6	Agriculture/Light Vegetation	435.2008821	8.688549783	489.9972605	9.782449359	614.3192798	12.26394276	493.9780723	9.861355931
	In Total	5008.901289	100	5008.94247	100	5009.149928	100	5009.230736	100

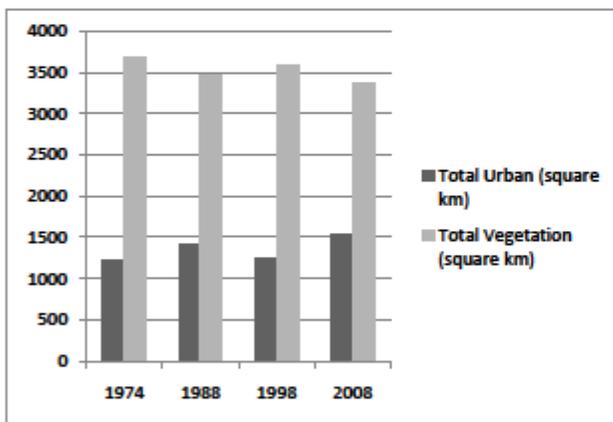


Figure 4.2 Total area of Urban and Vegetation Land-use/Land-cover during time period of study.

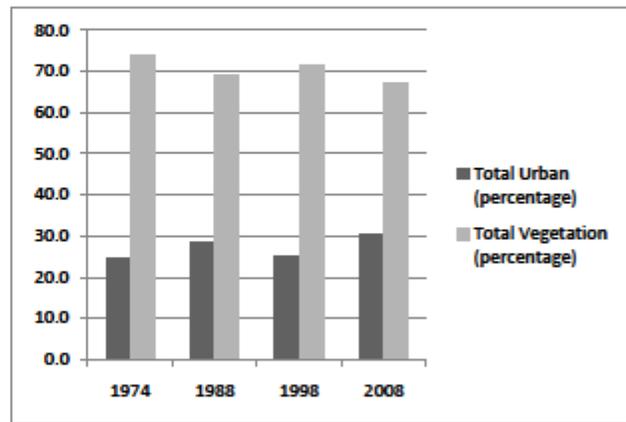


Figure 4.3 Total percentage of Urban and Vegetation Land-use/Land-cover during time period of study.

Based on Table 4.1, an analysis of the 1988 data shows that the total square kilometers of High Density Urban/Built-Up was 250.31 or 4.9% of the total land-use/land-cover. The total area of Low Density Urban/Residential was 1159.8 square kilometers or 23.2% of the total land-use/land-cover. The total area of Forest was 2976.84 square kilometers or 59.4% of the total land-use/land-cover. The total square kilometers of Agriculture/Light Vegetation was 489.99 or 9.38% of the total land-use/land-cover. The total in square kilometers of the Urban/Developed areas was 1410.11 or 28.2% of the total land-use/land-cover. The total area of Vegetation was 3466.84 square kilometers or 69.2% of the total land-use/land-cover.

Based on Table 4.1, an analysis of the 1998 data shows that the total square kilometers of High Density Urban/Built-Up was 209.1 or 4.2% of the total land-use/land-cover. The total area of Low Density Urban/Residential was 1047.26 square kilometers or 20.9% of the total land-use/land-cover. The total square kilometers of Forest was 2970.88 or 59.3% of the total land-use/land-cover. The total area of Agriculture/Light Vegetation was 614.32 square kilometers or 12.3% of the total land-use/land-cover. The total Urban/Developed area was 1256.36 square kilometers or 25.1% of the total land-use/land-cover. The total square kilometers of vegetation was 3585.2 or 71.6% of the total area of land-use/land-cover.

Based on Table 4.1, an analysis of the 2008 data shows that the total square kilometers of High Density Urban/Built-Up was 343.35 or 6.9% of the total land-use/land-cover. The total area of Low Density Urban/Residential was 1185.6 square kilometers or 23.7% of the total land-use/land-cover. The total area of Forest is 2870.78 square kilometers or 57.3% of the total land-use/land-cover. The total area of Agriculture/Light Vegetation is 493.98 square kilometers or 9.9% of the total land-use/land-cover. The total of Urban/Developed area is 1528.96 square

kilometers or 30.5% of land-use/land-cover. The total square kilometers of Vegetation is 3364.76 or 67.2% of the total land-use/land-cover.

It is obvious from Table 4.1 and Figures 4.2 and 4.3 that there was urbanization from 1974 to 1988 and a decrease in land covered primarily in vegetation. However, from 1988 to 1998 land covered primarily in vegetation increased while urban areas decreased. Then from 1998 to 2008, the area primarily covered in vegetation decreased again while the area urban areas increased again. This obviously does not correspond to the hypothesis of continual urban growth over the thirty-four year period. This issue will be examined and explained later on in the analysis of urban land-use/land-cover and analysis of urban change detection.

4.2. Analysis of Change Detection

Based on Figures 4.4-4.7, it is obvious that there has been urban expansion in the Birmingham, AL, Metro Area along the time period of this study. By examining Tables 4.2-4.5, the changes in land-use/land-cover can be examined. By examining Figure 4.2, there was approximately 1232.98 square kilometers of total urban areas in 1974. Table 4.2 shows there was 1356.68 square kilometers of urban areas between 1974 and 1988. Table 4.3 shows there was 1220.25 square kilometers of urban areas between 1988 and 1998. According to Table 4.4, there was 1481.4 square kilometers of urban areas between 1998 and 2008. According to Table 4.5, which is a comprehensive change detection of the thirty-year period from 1974 to 2008, there was a total of 1488.49 square kilometers in urban areas. That corresponds with the 1998 to 2008 change detection (Table 4.4) which had 1481.4 square kilometers of total urban areas. Obviously the same problem and issue is prevalent in this information being that urban areas

grew from 1974 to 1988, it then decreased in 1998, only to grow again in 2008. This issue will be examined in the next section.

Birmingham, AL, Metropolitan Area 1974 to 1988 Change Detection

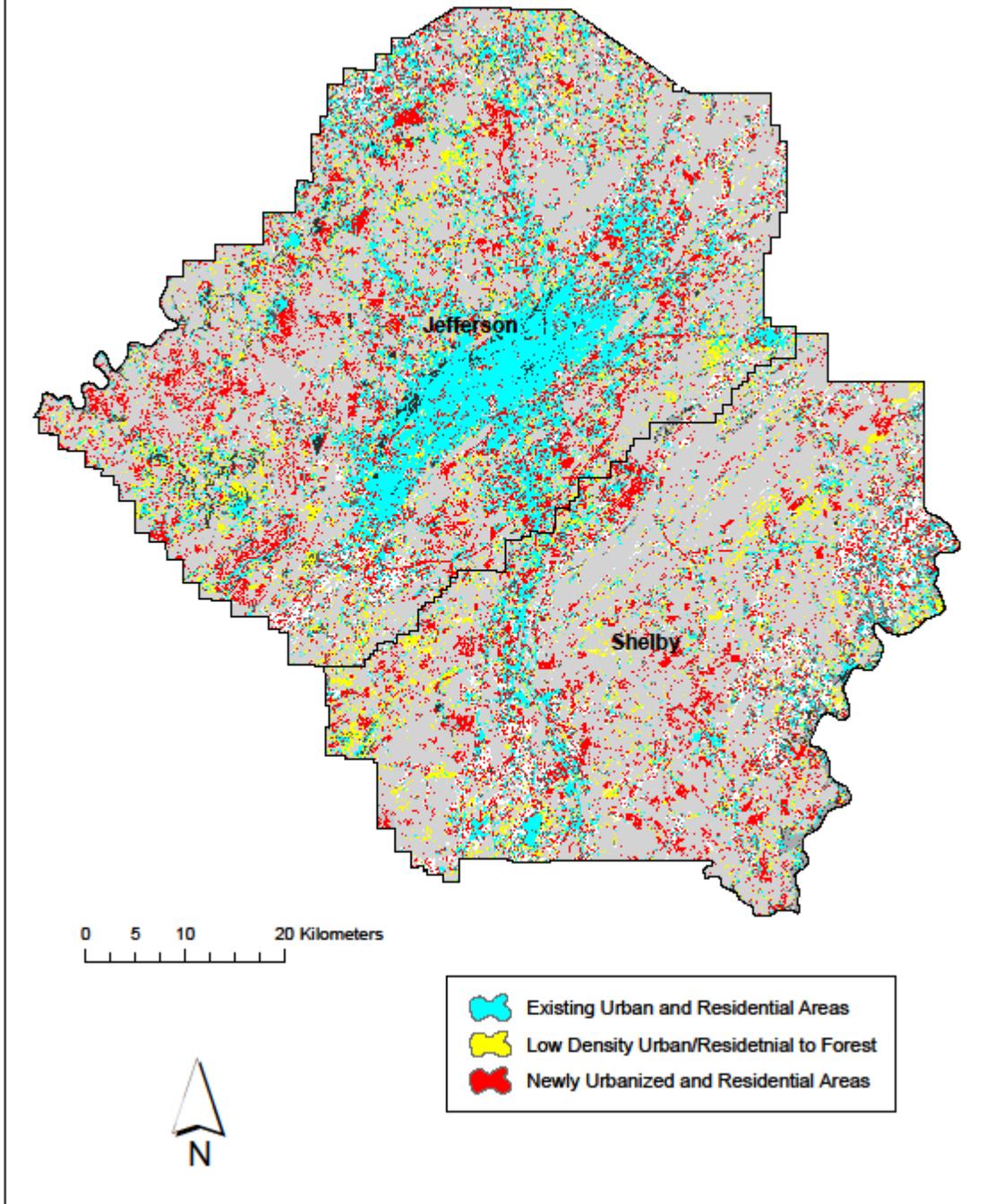


Figure 4.4 Land-use/Land-cover change over a fourteen year period.

Birmingham, AL, Metropolitan Area 1988 to 1998 Change Detection

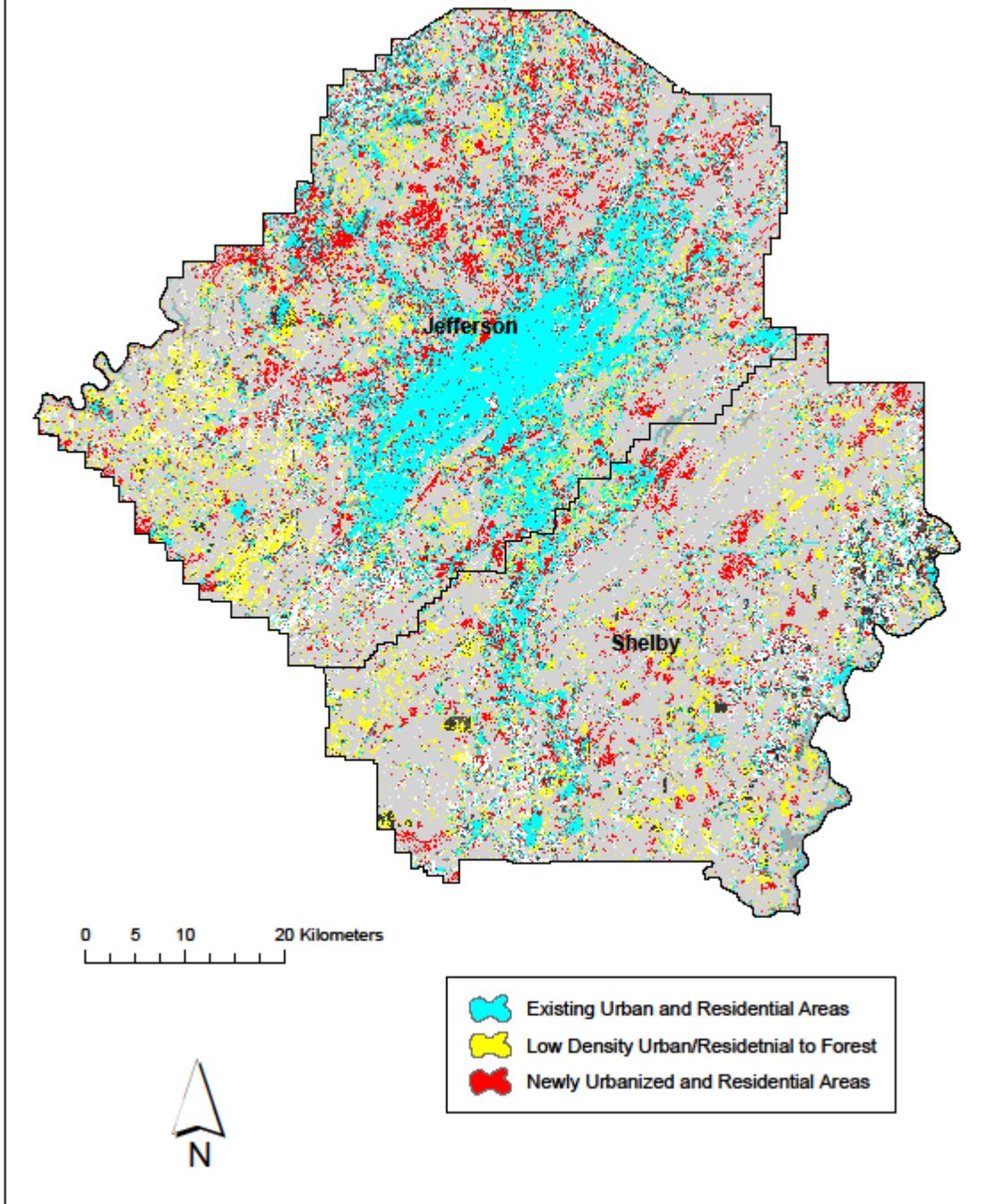


Figure 4.5 Land-use/Land-cover change over a ten year period.

Birmingham, AL, Metropolitan Area 1998 to 2008 Change Detection

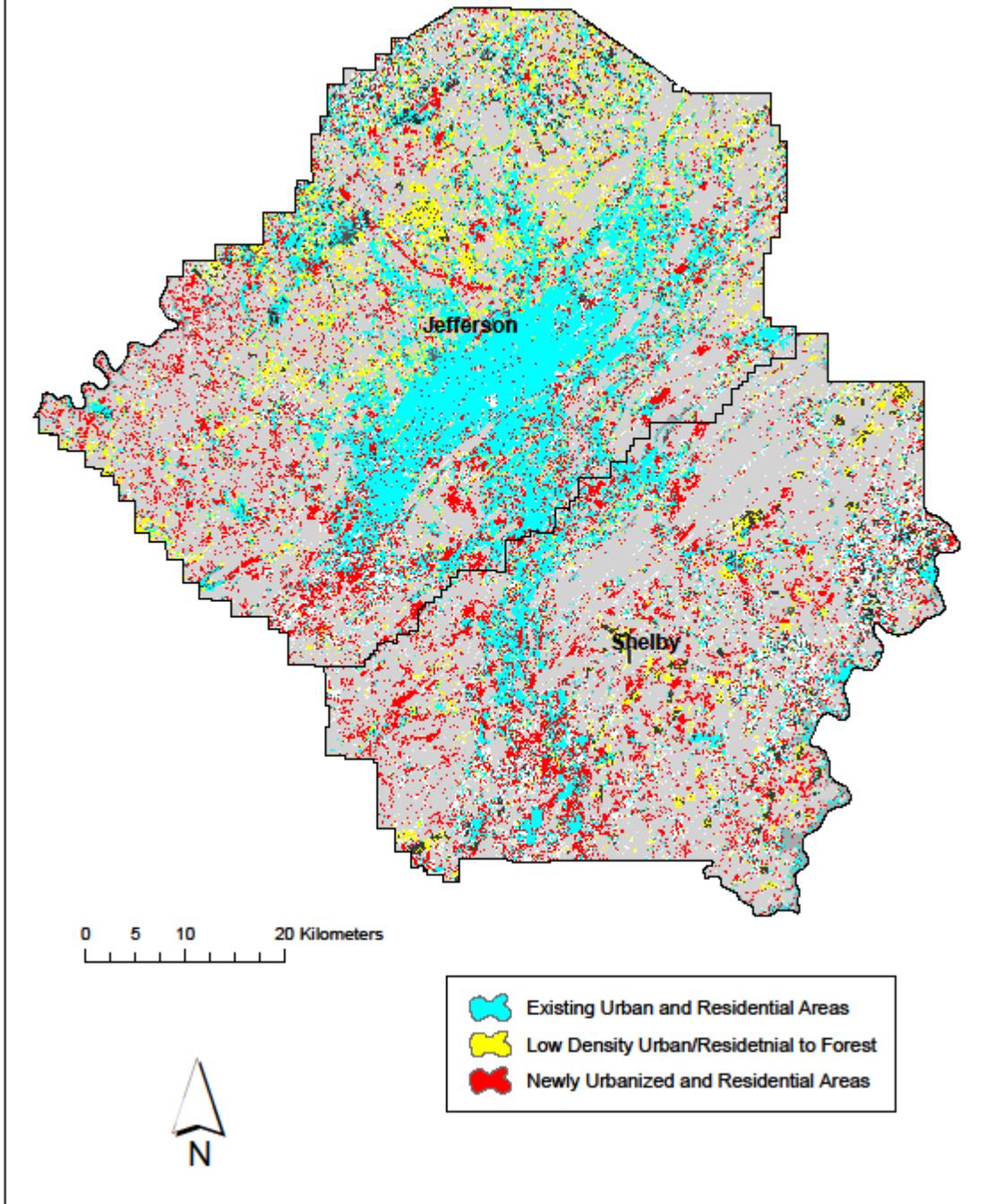


Figure 4.6 Land-use/Land-cover change over a ten year period.

Birmingham, AL, Metropolitan Area 1974 to 2008 Change Detection

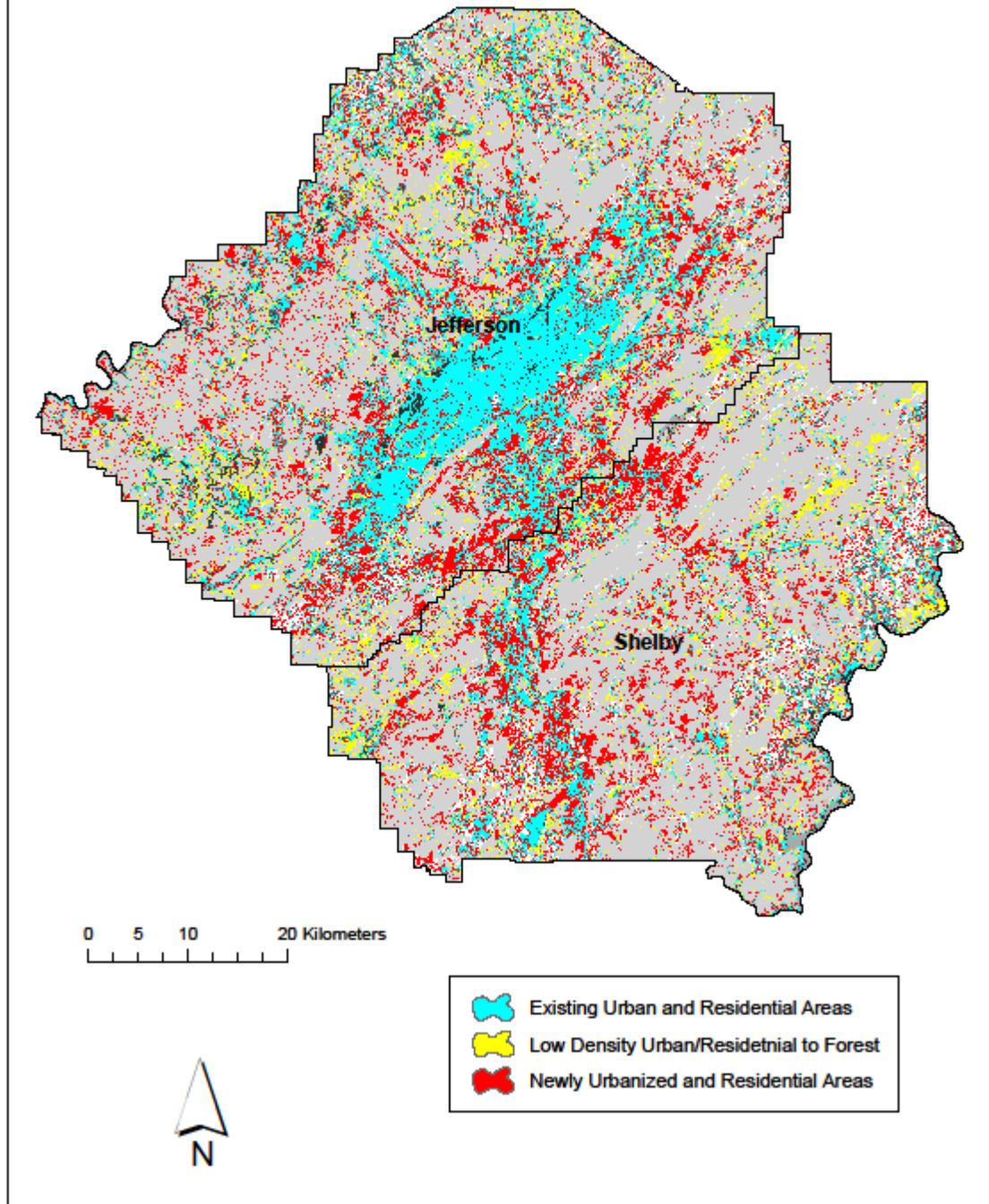


Figure 4.7 Land-use/Land-cover change over a thirty-four year period.

Table 4.2

Metropolitan Area Land-Use/Land-Cover Changes: 1974-1988	
Land-Use/Land-Cover Change	Amount of Change in sq. km.
Forest to High Density Urban/Built-Up	50.67182238
Forest to Low Density Urban/Residential	472.4941209
Agriculture/Light Vegetation to High Density Urban/Built-Up	27.72167874
Agriculture/Light Vegetation to Low Density Urban/Residential	128.6379755
High Density Urban/Built-Up (no change)	97.62312684
Low Density Urban/Residential (no change)	440.5492075
High Density Urban/Built-Up to Low Density Urban/Residential	77.79236487
Low Density Urban/Residential to High Density Urban/Built-Up	61.19105909
*Low Density Urban/Residential to Forest	331.0989
Total Urban	1356.681356

Table 4.3

Metropolitan Area Land-Use/Land-Cover Changes: 1988-1998	
Land-Use/Land-Cover Change	Amount of Change in sq. km.
Forest to High Density Urban/Built-Up	37.16995536
Forest to Low Density Urban/Residential	344.0177607
Agriculture/Light Vegetation to High Density Urban/Built-Up	10.59030598
Agriculture/Light Vegetation to Low Density Urban/Residential	64.01155614
High Density Urban/Built-Up (no change)	113.3873485
Low Density Urban/Residential (no change)	544.8480287
High Density Urban/Built-Up to Low Density Urban/Residential	68.67819672
Low Density Urban/Residential to High Density Urban/Built-up	37.54446764
*Low Density Urban/Residential to Forest	402.5877518
Total Urban	1220.24762

Table 4.4

Metropolitan Area Land-Use/Land-Cover Changes: 1998-2008	
Land-Use/Land-Cover Change	Amount of Change in sq. km.
Forest to High Density Urban/Built-Up	66.92037178
Forest to Low Density Urban/Residential	329.7287963
Agriculture/Light Vegetation to High Density Urban/Built-Up	43.26756437
Agriculture/Light Vegetation to Low Density Urban/Residential	179.8839982
High Density Urban/Built-Up (no change)	143.2007016
Low Density Urban/Residential (no change)	606.2436969
High Density Urban/Built-Up to Low Density Urban/Residential	45.06579311
Low Density Urban/Residential to High Density Urban/Built-Up	67.08872101
*Low Density Urban/Residential to Forest	312.360336
Total Urban	1481.399643

Table 4.5

Metropolitan Area Land-Use/Land-Cover Changes: 1974-2008	
Land-Use/Land-Cover Change	Amount of Change in sq. km.
Forest to High Density Urban/Built-Up	122.858158
Forest to Low Density Urban/Residential	495.0114775
Agriculture/Light Vegetation to High Density Urban/Built-Up	35.98840279
Agriculture/Light Vegetation to Low Density Urban/Residential	147.7070219
High Density Urban/Built-Up (no change)	86.81950943
Low Density Urban/Residential (no change)	417.3247842
High Density Urban/Built-Up to Low Density Urban/Residential	104.6044398
Low Density Urban/Residential to High Density Urban/Built-Up	78.1785321
*Low Density Urban/Residential to Forest	333.28485
Total Urban	1488.492326

Another issue to point out in Figures 4.4-4.7 and Tables 4.2-4.5 is that any time a supervised classification is being utilized in an image that has both residential and forest land-use/land-cover areas, there will be overlapping and fluctuations from image to image. So, there are areas of “grey” or areas that could be considered either forest or low density residential. It is really impossible using Landsat imagery, because of its spatial resolution, to determine the land-use/land-cover in this case many times.

4.3. Analysis of the Urban Land-use/Land-cover

Obviously the amount of urban areas shrinking from 1988 to 1998 is an issue. The study concluded it could only be a few issues causing this. One issue that it could be is that there was some kind of error in the classification of the 1998 image. However, by visually analyzing the images, it is obvious that there was urban growth from 1988 to 1998. For example, Birmingham has long been known for steel production. For steel production, iron ore, coal, and limestone are required. Jefferson and Shelby counties contain all three of these natural resources in abundance. That is the reason that Birmingham rose to be such a major force in the steel industry. In the latter half of the 20th Century, the steel industry in Birmingham declined in vitality (Rogers, et al. 1994). If the steel industry in Birmingham was declining that would mean that there would be less of a need for rock quarries, coal and iron ore mines. Rock quarries and mines have the same spectral signature as urban areas partly because of barren rock corresponding with roads, bridges, overpasses, and sidewalks, and because at these facilities, there are many large buildings that would generate the same spatial spectral signature as buildings in urban areas. Because of this evidence, this research decided to examine this idea to determine if this was the reason for the overall loss in total urban areas.

To determine if this was indeed the cause of the loss in the total square kilometers of urban areas, an urban areas shapefile was obtained from the United States Census Bureau. This file was then used to extract out the areas of Jefferson and Shelby counties that were considered part of the urban area(s). Figure 4.8 displays the urban areas within the two county metropolitan area. To examine this theory, this urban areas boundary was used to extract out the land-use/land-cover for only the areas with its boundaries, Figures 4.10-4.13. From that point, the areas for each land-use/land-cover were recalculated and new change detections were carried out.

So, why use urban areas instead of city limits? The reason is that cities annex areas that are rural or undeveloped for future growth. By examining Figure 4.9, this is obvious. Large areas of Forest and Agriculture/Light Vegetation are within city limits, but these are definitely not urban. Therefore, it makes more sense to use an extent that consists of only urban areas.

Based on Figures 4.10-4.13, the growth of urban areas is obvious once again. Based on Table 4.6, in 1974, the area of High Density Urban/Built-Up was 127.88 square kilometers or 11.9% of the total land-use/land-cover. The total square kilometers of Low Density Urban/Residential was 364.64 or 33.8% of the total land-use/land-cover. The area of Forest was 478.76 square kilometers or 44.4% of the total land-use/land-cover. The area of Agriculture/Light Vegetation was 94.27 square kilometers or 8.7% of the total land-use/land-cover. The total area covered in urban was 479.66 square kilometers or 45.7% of the total land-use/land-cover. The total area covered in vegetation was 573.15 square kilometers or 53.1% of the total land-use/land-cover.

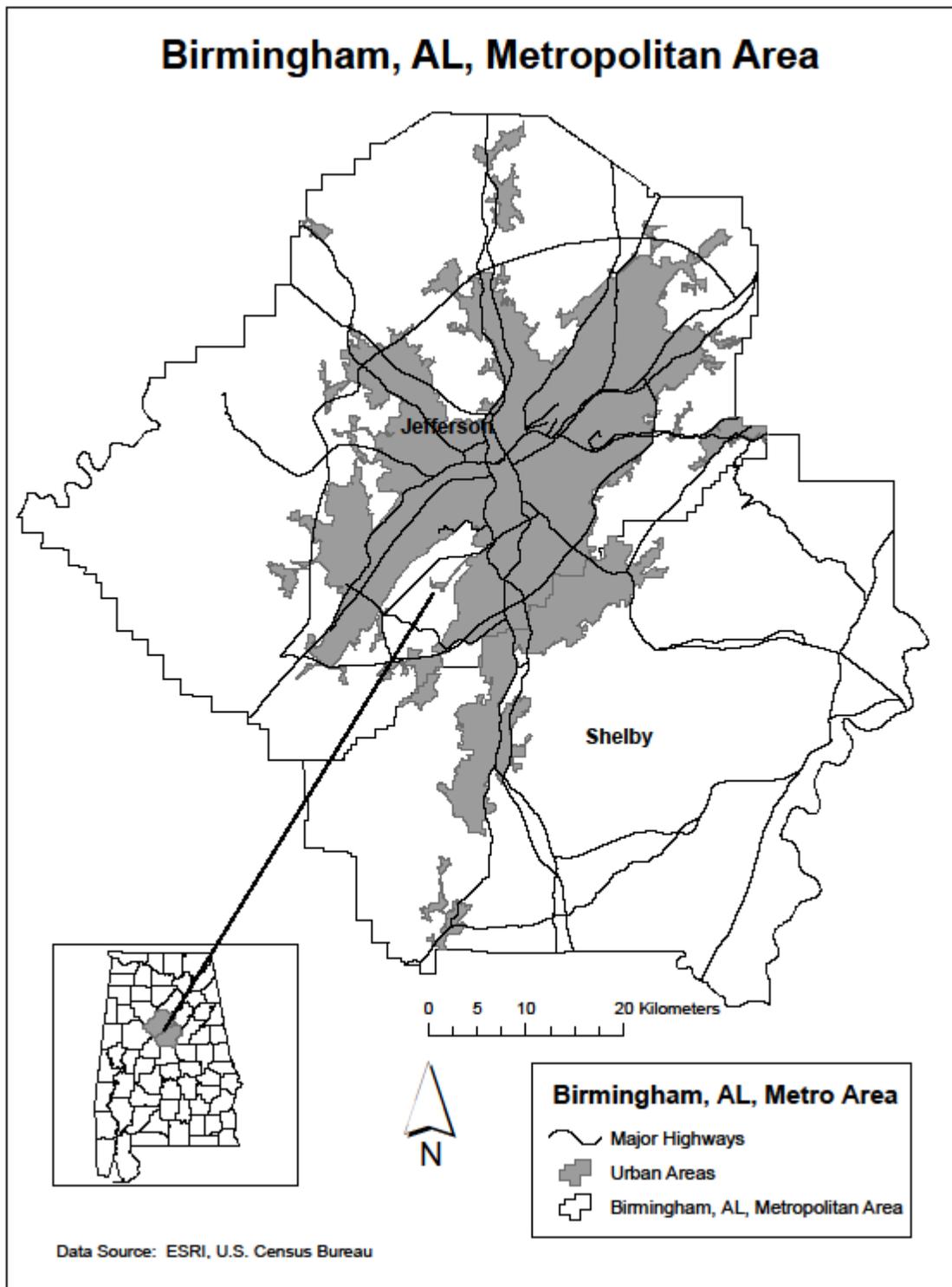


Figure 4.8 Base map of study area showing the urban areas.

Birmingham, AL, Metropolitan Area City Limits

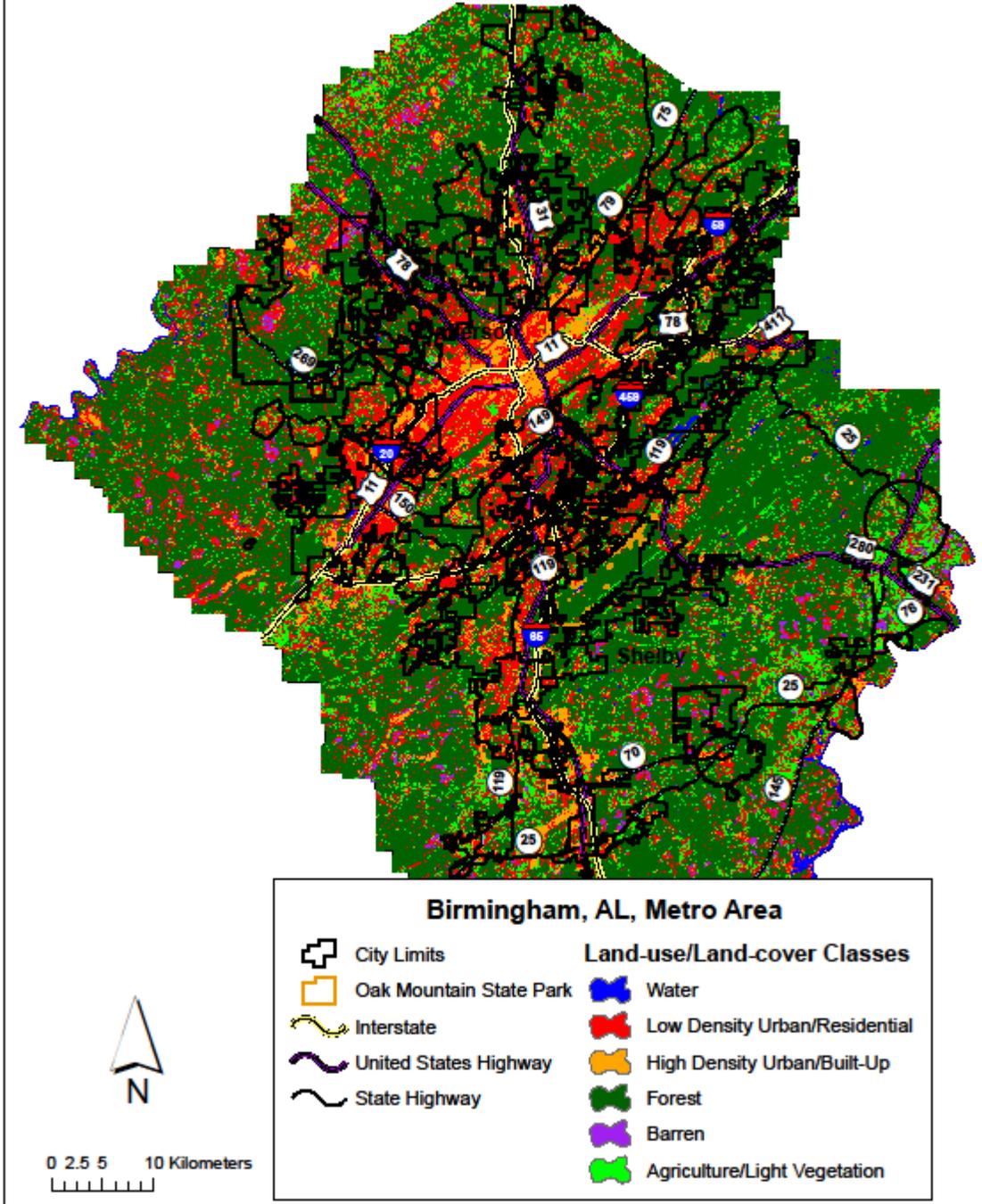


Figure 4.9 City Limits in Birmingham, Alabama, Metropolitan Area.

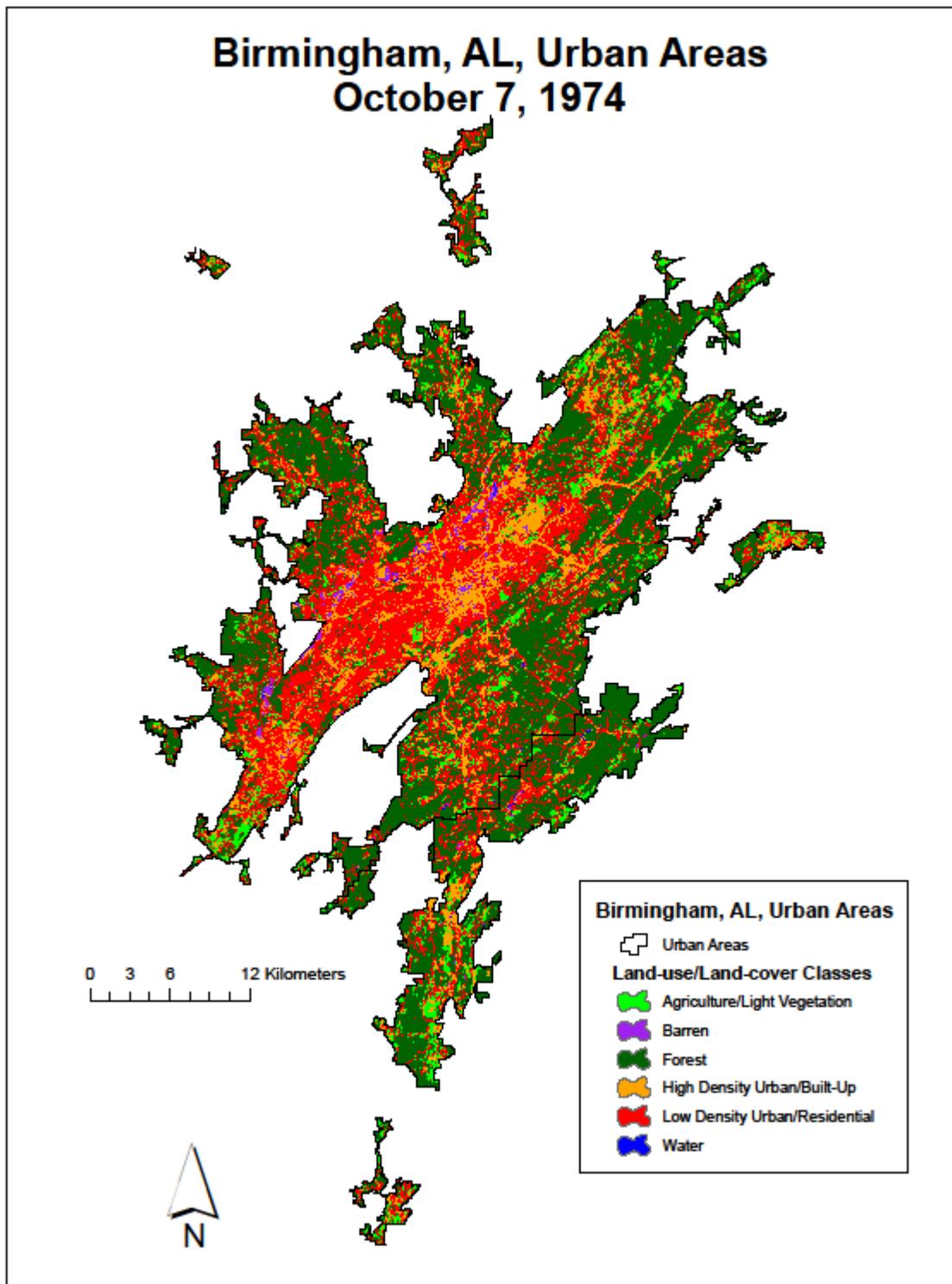


Figure 4.10 Supervised classification of urban areas—October 7, 1974.

Birmingham, AL, Urban Areas October 12, 1988/October 6, 1989

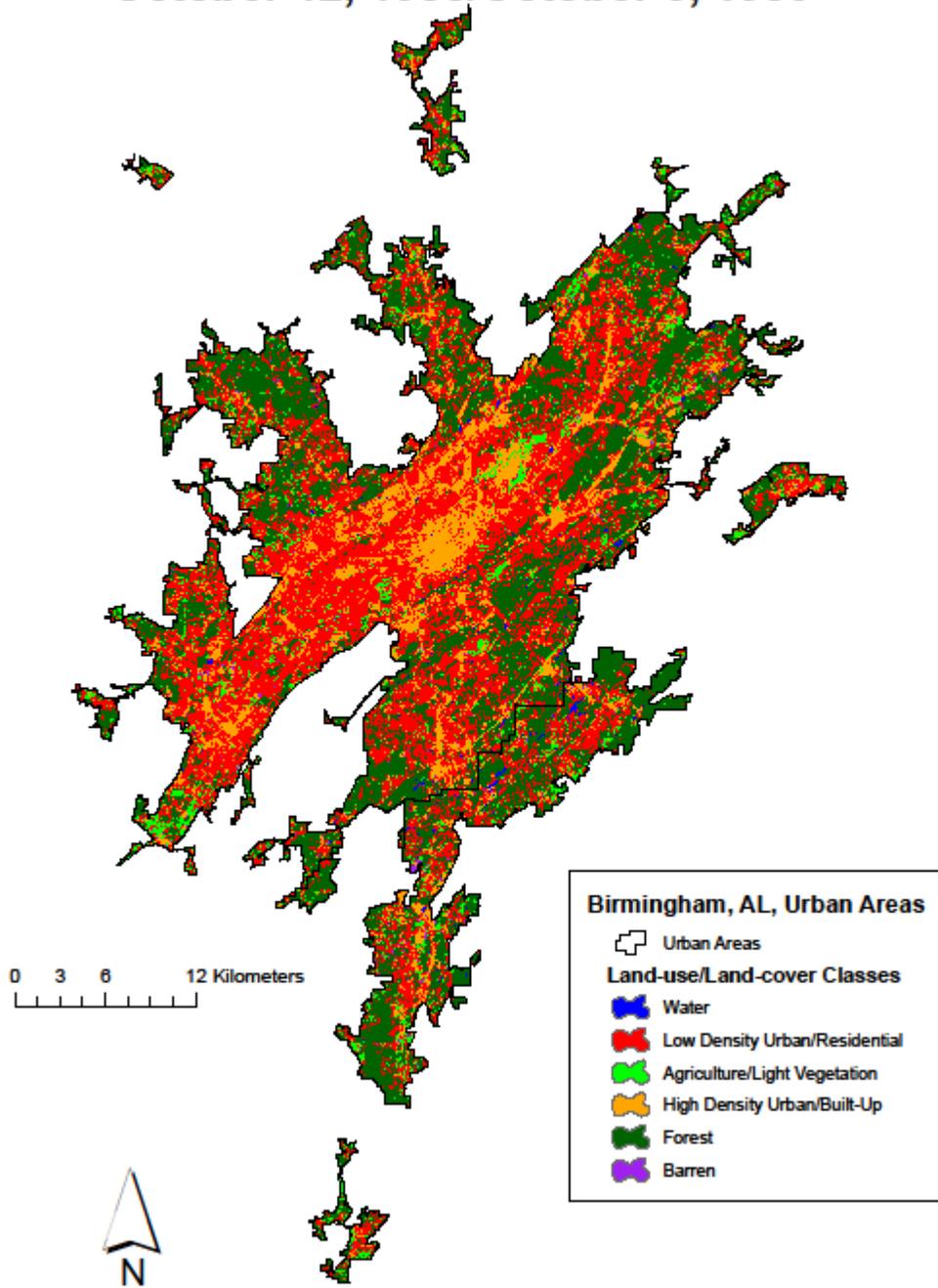


Figure 4.11 Supervised classification of urban areas—October 12, 1988/October 6, 1989.

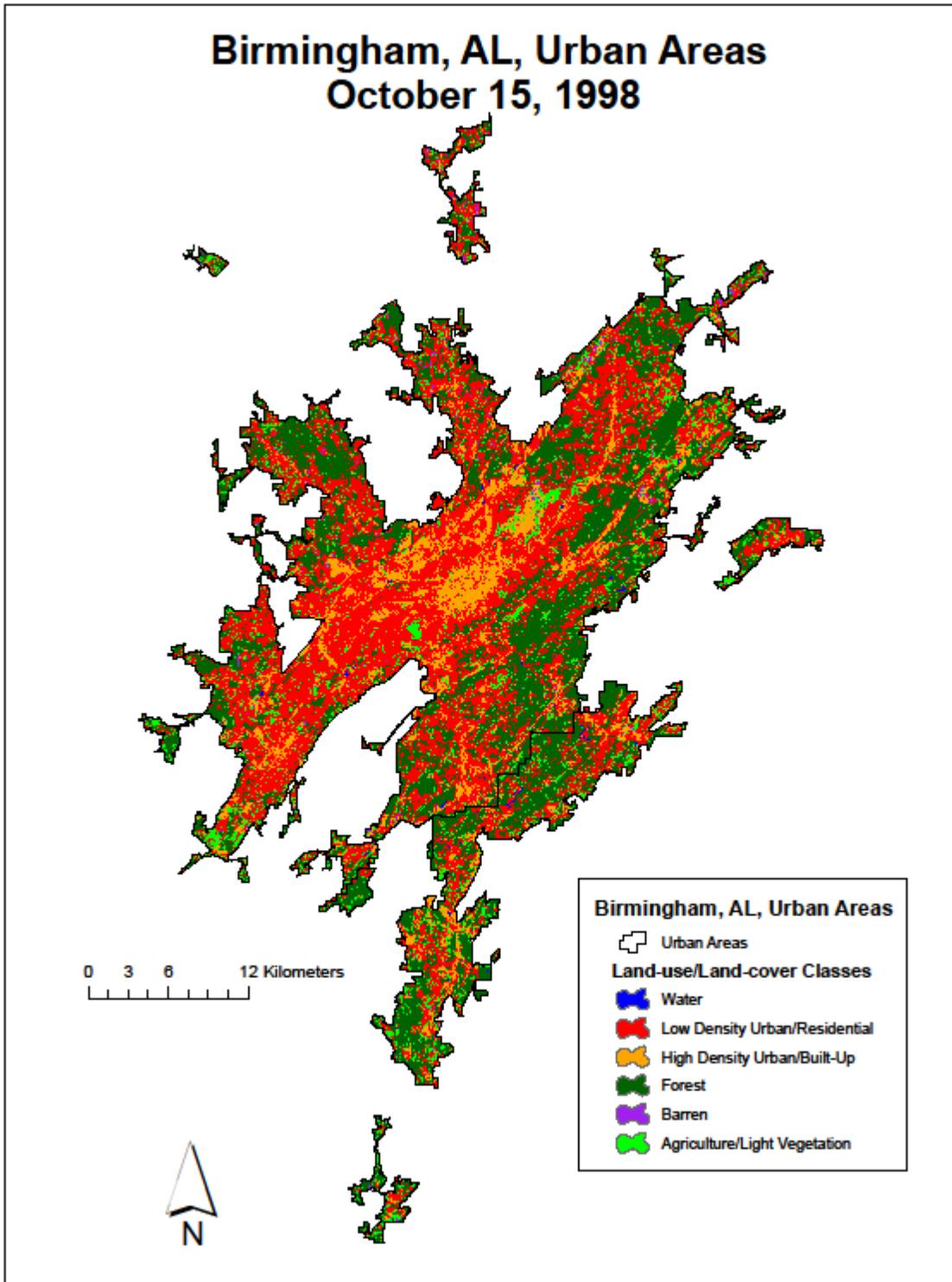


Figure 4.12 Supervised classification of urban areas—October 15, 1998.

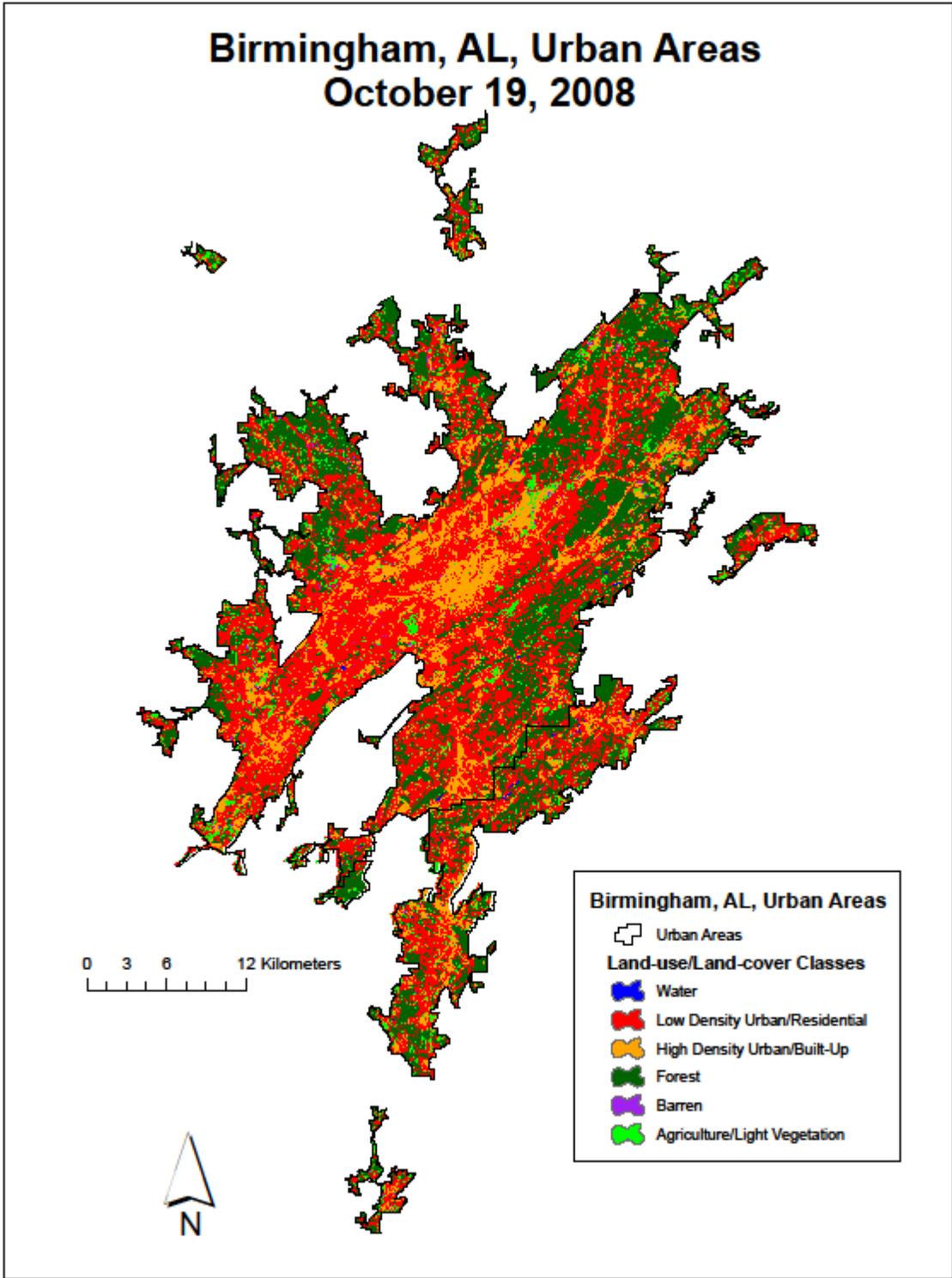


Figure 4.13 Supervised classification of urban areas.

Table 4.6

Land-Use/Land-Cover Statistics for the Birmingham, AL Urban Area: 1974-2008

No.	Land-Use/Land-Cover	1974		1988		1998		2008	
		Area (sq km)	%						
1	Barren	11.95592901	1.108321086	7.314307722	0.678041768	10.67670799	0.989747124	6.83549662	0.633678143
2	High Density Urban/Built-up	127.8801449	11.8545586	136.3077072	12.63582588	115.3702434	10.69499763	154.5668644	14.32897257
3	Low Density Urban/Residential	364.641836	33.80249541	453.3204389	42.02314197	486.4955966	45.09888427	512.1805087	47.48120165
4	Water	1.115101251	0.103370489	4.67459184	0.433338142	1.910701568	0.177124951	1.116901293	0.103541261
5	Forest	478.7644821	44.38172642	401.3808174	37.20830041	353.973675	32.81389989	332.8057022	30.85243266
6	Agriculture/Light Vegetation	94.3848647	8.749528004	75.74213029	7.021351832	110.3039676	10.22534614	71.19618316	6.600173712
	In Total	1078.742358	100	1078.739993	100	1078.730892	100	1078.701656	100

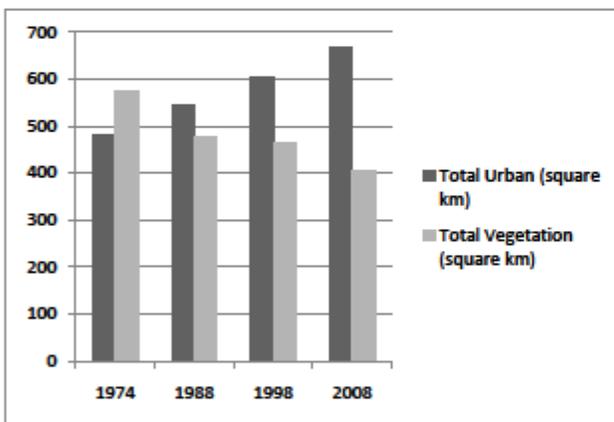


Figure 4.13 Total area of Urban and Vegetation Land-use/Land-cover during time period of study.

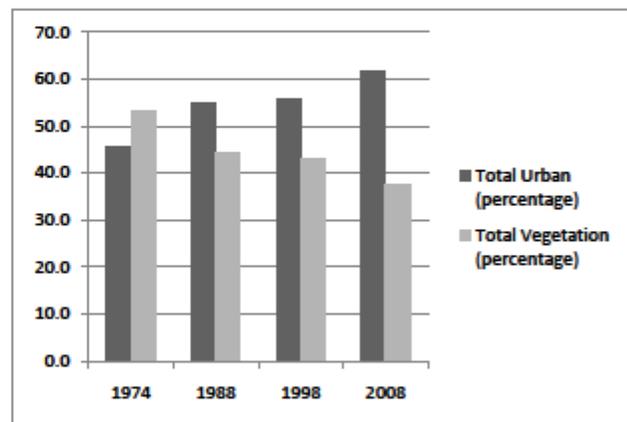


Figure 4.14 Total percentage of Urban and Vegetation Land-use/Land-cover during time period of study.

Based on Table 4.6, which displays data for only the urban areas, in 1988/1989, the area of High Density Urban/Built-Up was 136.3 square kilometers or 12.6% of the total land-use/land-cover. The area of Low Density Urban/Residential was 453.32 square kilometers or 42.02% of the total land-use/land-cover. The area of Forest was 401.38 square kilometers or 37.2% of the total land-use/land-cover. The total area of Agriculture/Light Vegetation was 75.74 square kilometers or 7.02% of the total land-use/land-cover. The total area with a primary urban land cover was 543.01 square kilometers or 54.7% of the total land-use/land-cover. The total area that was primarily covered in vegetation was 477.12 square kilometers or 44.2% of the total land-use/land cover.

Based on Table 4.6, in 1998, the area of High Density Urban/Built-Up was 115.37 square kilometers or 10.7% of the total land-use/land-cover. The area of Low Density Urban/Residential was 486.49 square kilometers or 45.1% of the total land-use/land-cover. The total area of Forest was 353.97 square kilometers or 32.8% of the total land-use/land-cover. The total area of Agriculture/Light Vegetation was 110.3 square kilometers or 10.2% of the total land-use/land cover. The total area with a primary urban land cover is 601.86 square kilometers or 55.8% of the total land-use/land-cover. The total area primarily covered in vegetation was 464.27 square kilometers or 43.04% of the total land-use/land-cover.

Based on Table 4.6, in 2008, the area of High Density Urban/Built-Up was 154.56 square kilometers or 14.3% of the total land-use/land-cover. The area of Low Density Urban/Residential was 512.18 square kilometers or 47.5% of the total land-use/land-cover. The area of Forest was 332.72 square kilometers or 30.9% of the total land-use/land-cover. The area of Agriculture/Light Vegetation was 71.19 square kilometers or 6.6% of the total land-use/land-cover. The total area with a primary urban land cover is 666.75 square kilometers or 61.8% of

the total land-use/land-cover. The total area with a primary vegetation cover is 404.003 square kilometers or 37.5% of the total land-use/land-cover.

Based on Figure 4.14, the growth of the total square kilometers of urban areas is obvious from 1974 to 2008. In 1974, there was more land covered in vegetation than there were urban areas. By 1988, urbanization had increased and had overtaken vegetation for the majority of the total land-use/land-cover square kilometers. This trend continued through 2008. By examining Figure 4.14, which shows the percentage of total urban and vegetation, the same trends are obvious. Based on Figures 4.10-4.15 and Table 4.6, the idea that urbanization expanded in the urban areas seems to be confirmed, while built up areas outside of the urban area seem to have declined. By examining the change detection images, this idea will be further expanded upon.

4.4. Analysis of Urban Change Detection

Based on Figures 4.16-4.19, it is obvious that there has been urbanization in the Birmingham, AL, urban areas along the time period of this study. By examining Tables 4.7-4.10, changes in land-use/land-cover can be observed. By examining Figure 4.13, there was approximately 492.52 square kilometers of total urban areas in 1974. By examining Table 4.7, there was 578.83 square kilometers of urban areas between 1974 and 1988. By examining Table 4.8 there was 595.03 square kilometers of urban areas between 1988 and 1998. By examining Table 4.4, there was 659.83 square kilometers of urban areas between 1998 and 2008. By examining Table 4.10, which is a comprehensive change detection of the thirty-year period from 1974 to 2008, there were a total of 655.67 square kilometers of urbanized areas. That corresponds with the 1998 to 2008 change detection (Table 4.9) which had 659.83 square kilometers of total urban areas. It appears that the issue was that urbanization expanded in the

urban areas, while built-up areas decreased farther away from the urban areas. Another issue to point out in Figures 4.16-4.19 and Tables 4.7-4.10 is that anytime a supervised classification is being utilized in an image that has both residential and forest land-use/land-cover areas, there will be overlapping and fluctuations from image to image. So there are areas of “grey” or areas that could be considered either forest or low density urban/residential. It is really impossible using Landsat imagery, because of its spatial resolution, to determine the land-use/land-cover in this case many times. This is obviously a limitation of the study.

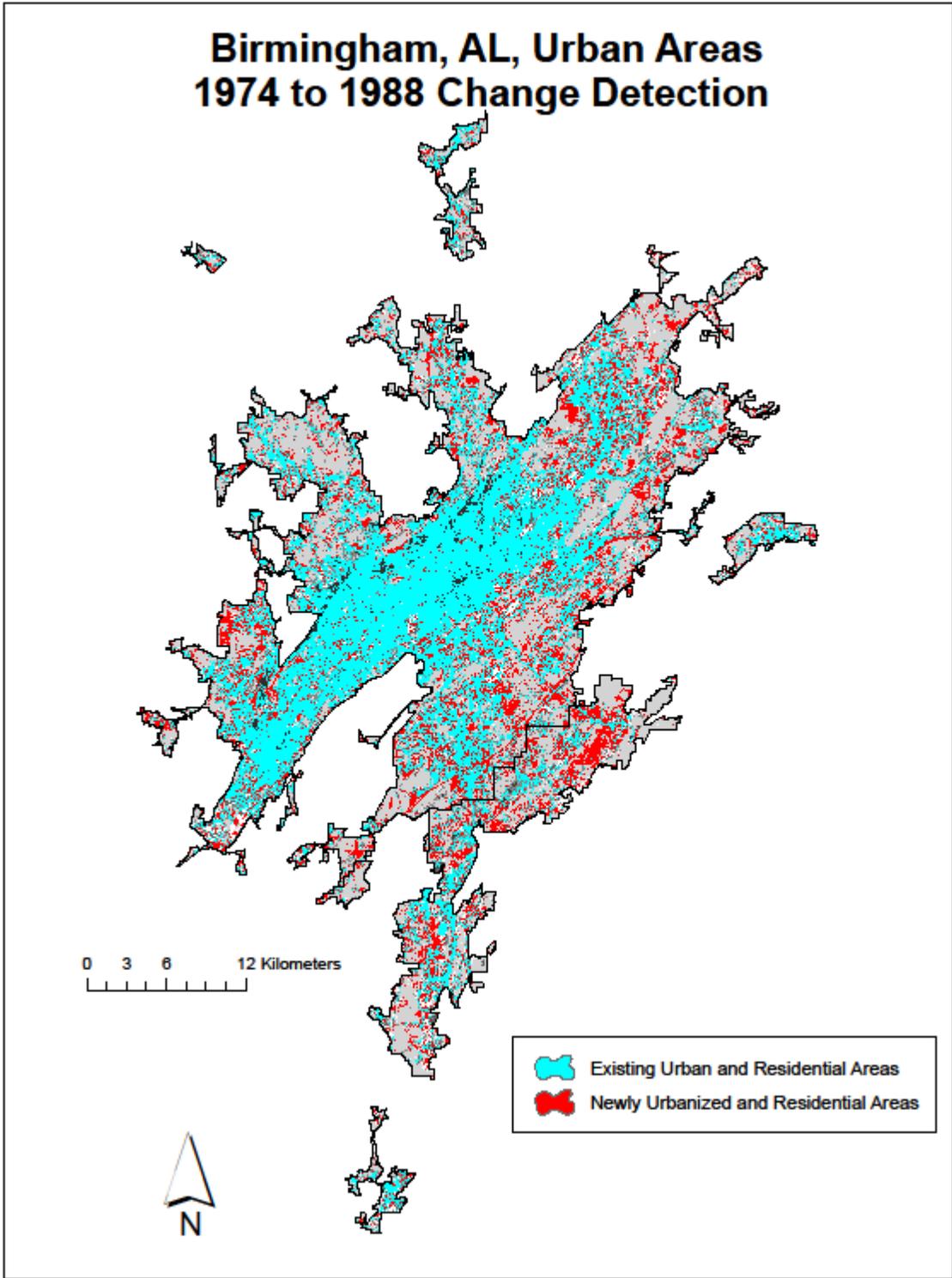


Figure 4.16 Land-use/Land-cover change over a fourteen year period.

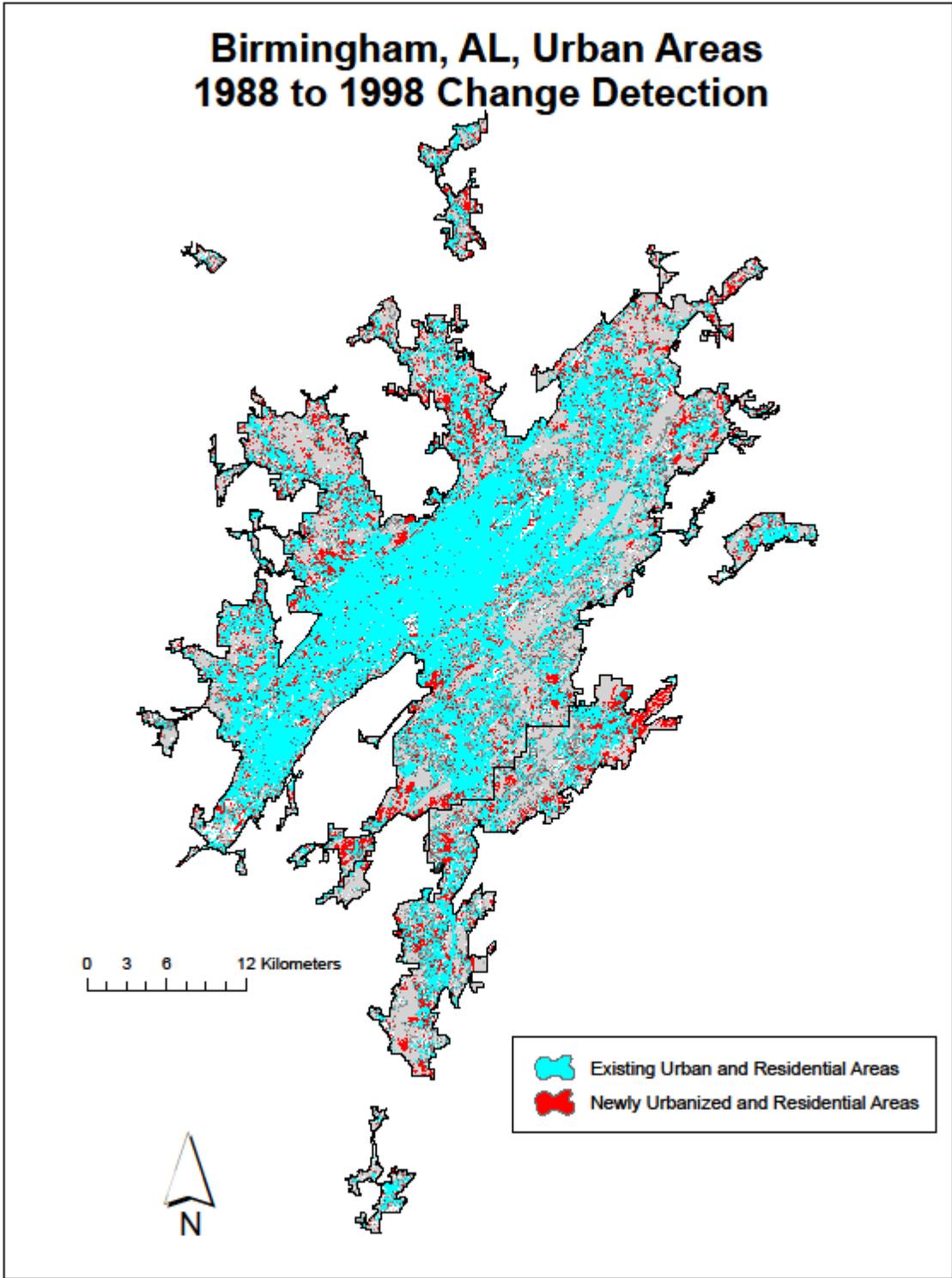


Figure 4.17 Land-use/Land-cover change over a ten year period.

Birmingham, AL, Urban Areas 1988 to 1998 Change Detection

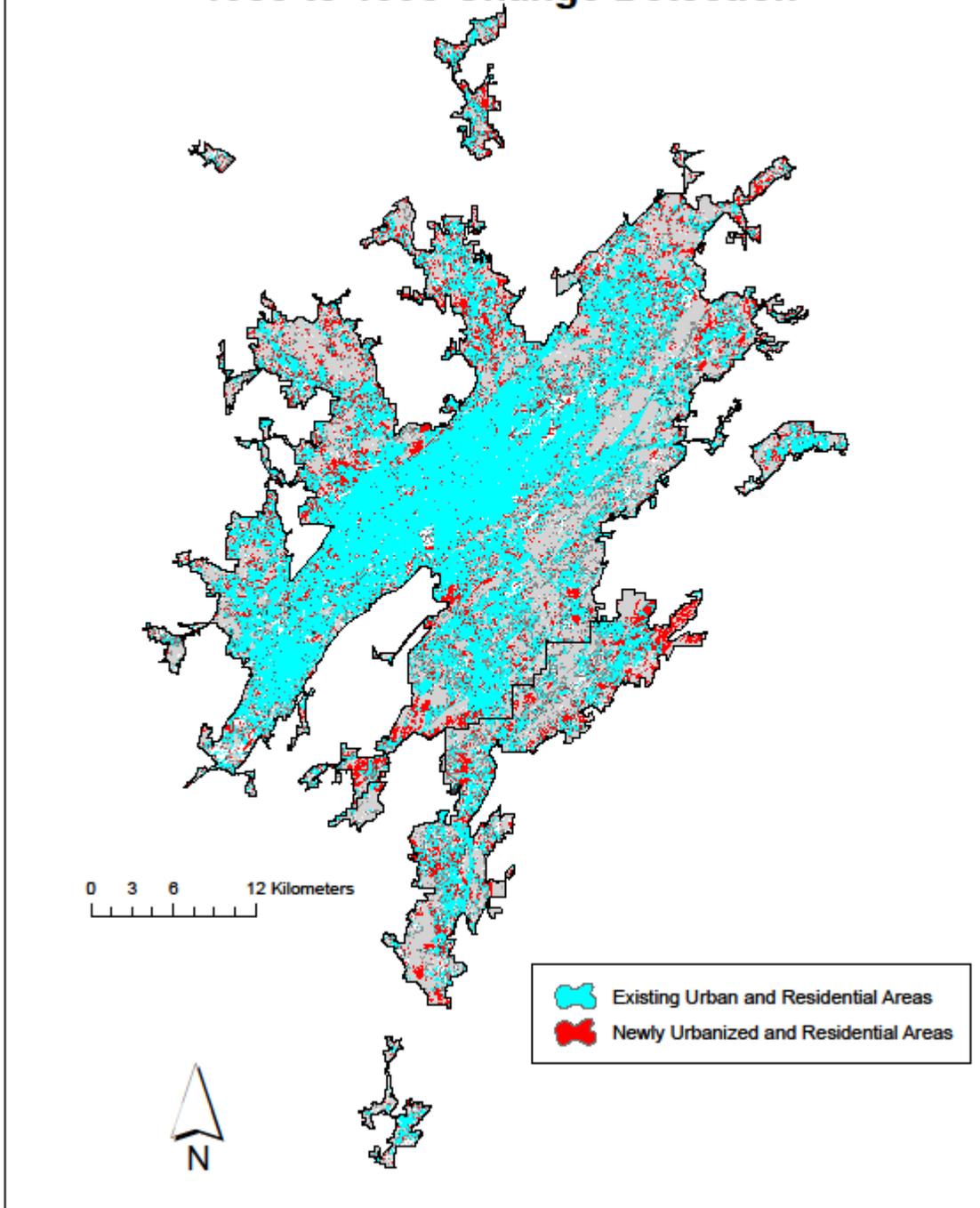


Figure 4.18 Land-use/Land-cover change over a ten year period.

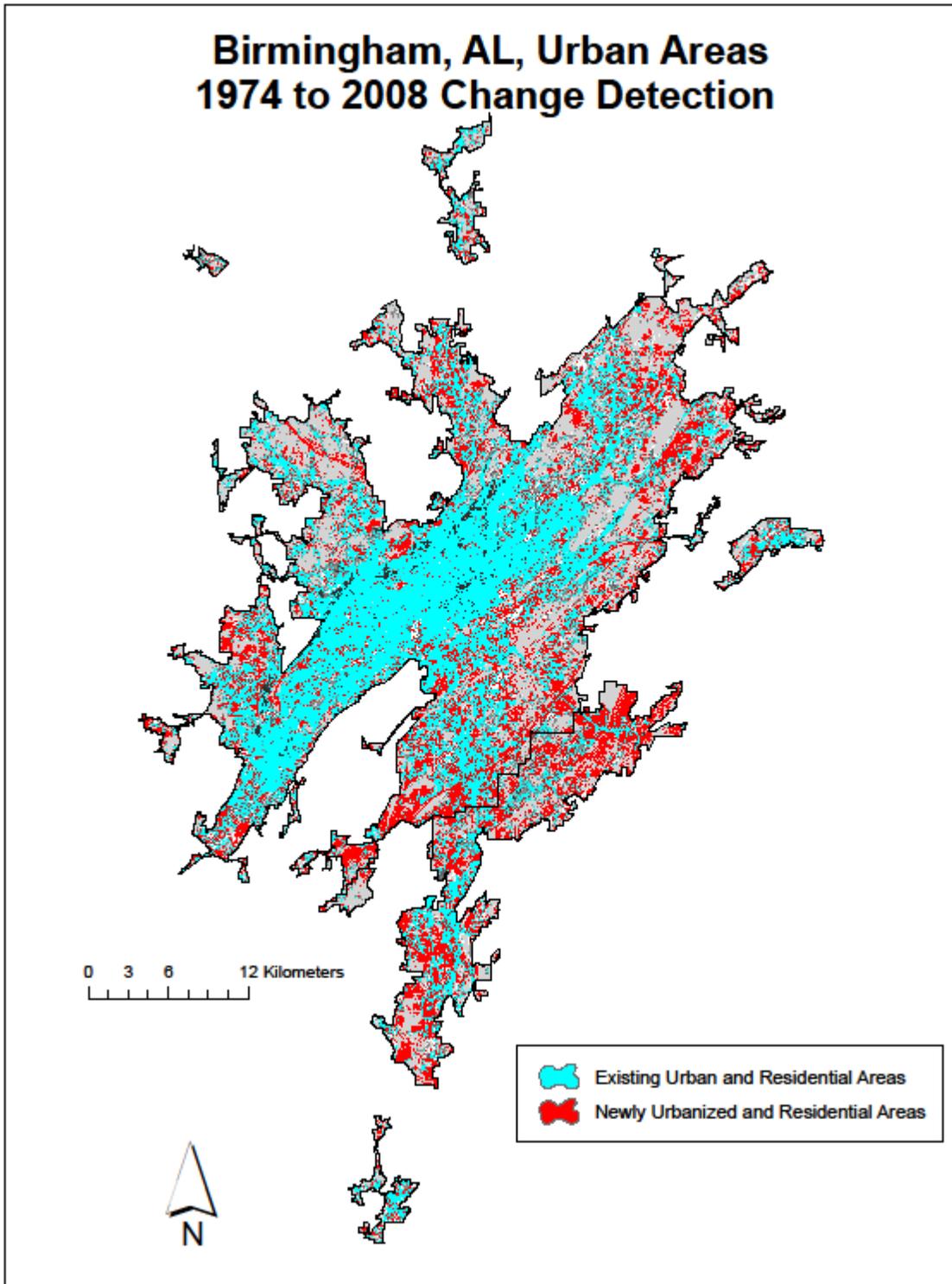


Figure 4.19 Land-use/Land-cover change over a thirty-four year period.

Table 4.7**Urban Area Land-Use/Land-Cover Changes: 1974-1988**

Land-Use/Land-Cover Change	Amount of Change in sq. km.
Forest to High Density Urban/Built-Up	19.93770257
Forest to Low Density Urban/Residential	114.7085014
Agriculture/Light Vegetation to High Density Urban/Built-Up	8.357399533
Agriculture/Light Vegetation to Low Density Urban/Residential	42.22794314
High Density Urban/Built-Up (no change)	62.91909915
Low Density Urban/Residential (no change)	244.197029
High Density Urban/Built-Up to Low Density Urban/Residential	48.25070149
Low Density Urban/Residential to High Density Urban/Built-Up	38.23107349
Total Urban	578.8294497

Table 4.8**Urban Area Land-Use/Land-Cover Changes: 1988-1998**

Land-Use/Land-Cover Change	Amount of Change in sq. km.
Forest to High Density Urban/Built-Up	13.26149022
Forest to Low Density Urban/Residential	87.30901719
Agriculture/Light Vegetation to High Density Urban/Built-Up	3.806997623
Agriculture/Light Vegetation to Low Density Urban/Residential	18.89461076
High Density Urban/Built-Up (no change)	78.78070434
Low Density Urban/Residential (no change)	332.5881432
High Density Urban/Built-Up to Low Density Urban/Residential	42.60867139
Low Density Urban/Residential to High Density Urban/Built-Up	17.78039787
Total Urban	595.0300326

Table 4.9

Urban Area Land-Use/Land-Cover Changes:	
Land-Use/Land-Cover Change	Amount of Change in sq. km.
Forest to High Density Urban/Built-Up	13.99321366
Forest to Low Density Urban/Residential	65.76756808
Agriculture/Light Vegetation to High Density Urban/Built-Up	11.59830346
Agriculture/Light Vegetation to Low Density Urban/Residential	47.13389862
High Density Urban/Built-Up (no change)	89.49341316
Low Density Urban/Residential (no change)	374.1315525
High Density Urban/Built-Up to Low Density Urban/Residential	21.90060276
Low Density Urban/Residential to High Density Urban/Built-Up	35.81461458
Total Urban	659.8331668

Table 4.10

Urban Area Land-Use/Land-Cover Changes:	
Land-Use/Land-Cover Change	Amount of Change in sq. km.
Forest to High Density Urban/Built-Up	36.35281411
Forest to Low Density Urban/Residential	160.0307033
Agriculture/Light Vegetation to High Density Urban/Built-Up	11.42819304
Agriculture/Light Vegetation to Low Density Urban/Residential	49.50529173
High Density Urban/Built-Up (no change)	55.69743531
Low Density Urban/Residential (no change)	241.4907504
High Density Urban/Built-Up to Low Density Urban/Residential	56.77642435
Low Density Urban/Residential to High Density Urban/Built-Up	44.3942092
Total Urban	655.6758215

Birmingham, AL, Metropolitan Area Physiographical Attributes

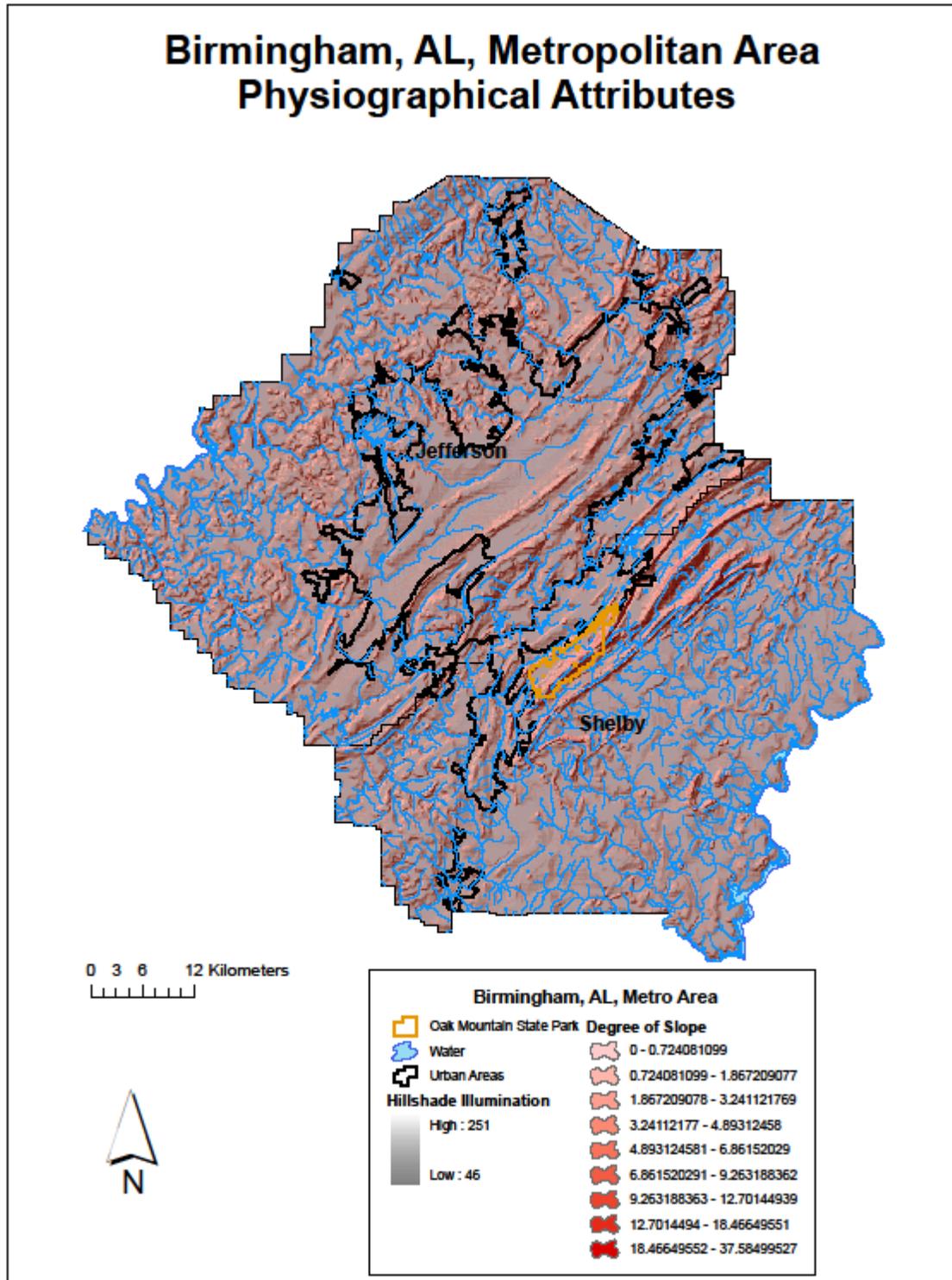


Figure 4.20 Physiographic analysis of the study area.

Birmingham, AL, Metropolitan Area Major Highways

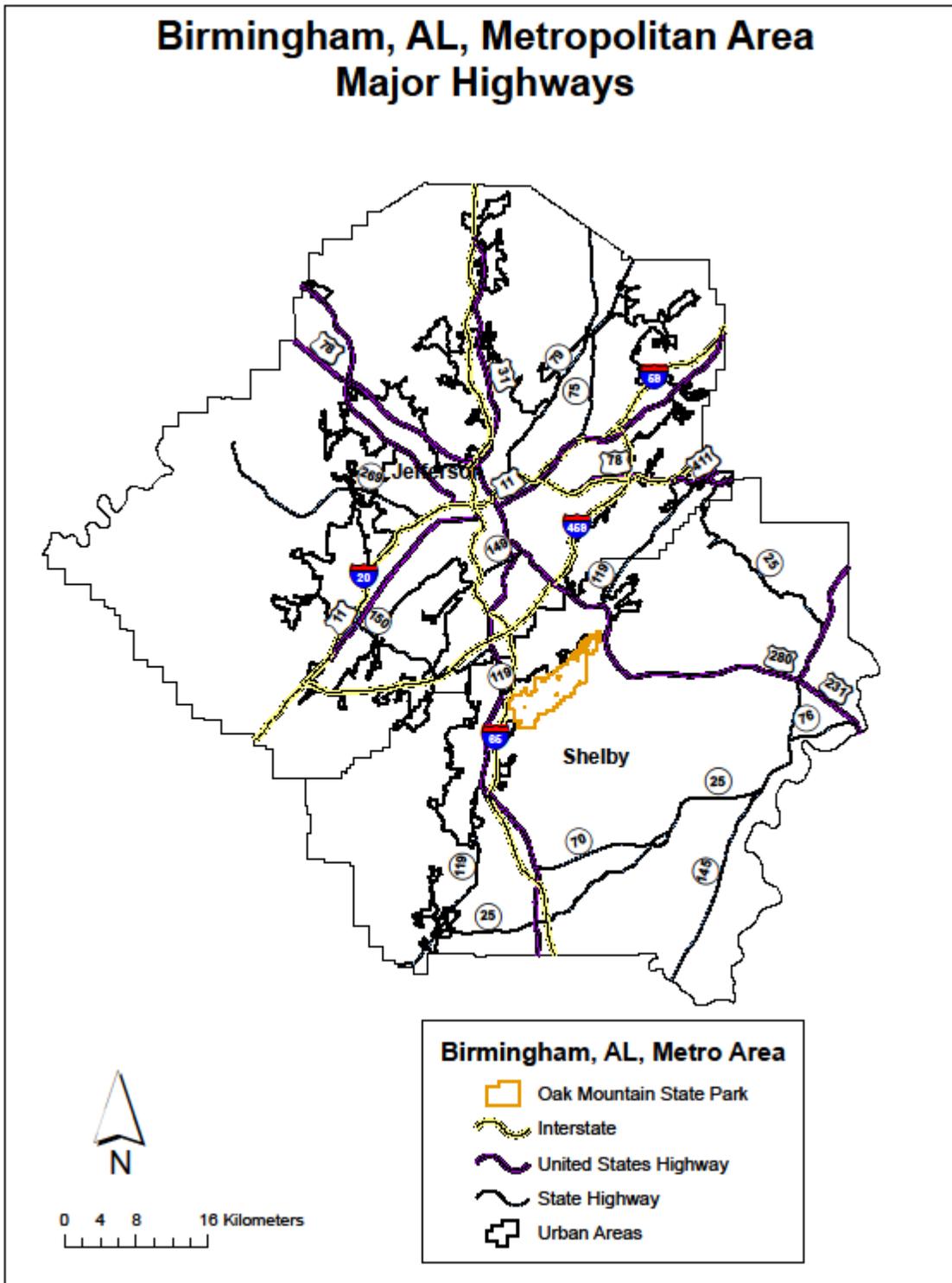


Figure 4.21 Distribution of major highways in the study area.

4.5 Physiographical Aspects

There are obviously physiographical aspects that have caused the Birmingham, AL, urban areas to be located where they are. To begin with, the area started growing in the 19th Century and experienced growth on into the 20th Century because of the steel industry. It was rich in iron ore, limestone, and coal which was the original source of growth and expansion in the area. Since then, the Birmingham Metro Area has expanded for other reasons. There has been expansion in the healthcare, banking, energy industries, etc. for example. (Rogers, et al. 2004). With this expansion, there has been an expansion in the residential areas in the area, while the old mines and quarries have decreased in number. This section will examine the physical attributes that have an effect on where urbanization occurs.

By analyzing Figure 4.20, the urban area is displayed over a hillshade illumination, which is made transparent over slope data of the Birmingham, AL, Metropolitan Area which also shows the extent of the urban area. The streams in the study area are also shown in Figure 4.20. It is obvious from Figure 4.20 that the urban area takes up a large portion of the two county area. According to Table 4.1, in 2008, the Birmingham metro was approximately 30.5% urban. It is also very centrally located in the two county area. By examining Figure 4.21, although it is not a map of physical attributes, it should be mentioned here as a first indicator of why growth has occurred where it has. By observing the major highways, especially the Interstates and United States Highways, it is obvious that the urban area has created “fingers” extending along the length of these major highways. This will be discussed in more detail later. Back to Figure 4.20, one prominent physiographical attribute that stands out about the location of the urban area is that it is located in the part of the two county area that has the least amount of streams. The reason for this is perhaps it is much easier to develop areas that are not constrained by many

streams. Plus, well watered areas are more suitable for agriculture, which is found outside of the urban area. Another obvious physiographical constraint is that of mountainous areas. By analyzing Figure 4.20, there are some areas of high elevation in the study area. The area covered by the urban area is somewhat flat except for a few areas. But the urban area straddles a very mountains area on its southwestern border. This is obviously a constraint to urbanization. It is logical to develop areas of flatter terrain than those that are mountainous, which is obviously the case for Birmingham. Another constraint, which might be considered both physiographical and perhaps cultural, is that of Oak Mountain State Park. It is primarily a forested area with lakes. It is clearly a barrier to urbanization. It is a barrier to urbanization because it is a protected area.

4.6 Population Trends

Based on Figure 4.22, the urban areas are concentrated around the major highway corridors such as Interstates 20, 59, 65, and 459; United States Highways 11, 31, and 78; and State highways such as 119. The major cities and towns tend to be located near these corridors as well; this obviously corresponds to the urban areas. Logically, businesses are going to locate near to these major corridors because they offer the most business opportunities. Therefore, a large population can be expected to be found in these areas. By examining Figure 4.23, the areas where urbanization has expanded can be seen. This is a version of the change detection from 1974 to 2008 examined earlier. The areas in cyan represent the urban extent as of 1974; the areas in red represent the urban expansion since 1974 up until 2008. By examining this map, it can be seen that most of the urban areas in 1974 existed around the Interstate 20/59 corridor and the United States Highway 11 and 78 corridors. Urban areas also existed around the Interstate 65 and United States Highway 31 corridors which parallel and intersect each other, but the

amount of urban areas along this corridor was a smaller amount than the previously mentioned ones. Since that time, Interstate 459 has been completed. It was completed in 1984. It bypasses the older Birmingham urban area going from Interstate 20/59 near Bessemer in the south and connecting at Interstate 59 near Trussville in the north. It is almost 53.1 kilometers in length. Since Interstate 459's completion, there has been much urban growth along this new bypass corridor. Important cities in the Birmingham, Alabama, Metropolitan Area on or near this corridor are Bessemer, Hoover, Vestavia Hills, Lake Purdy, Mountain Brook, Cahaba Heights and Trussville. Another corridor of growth since 1974 has been along United States Highway 280. United States Highway 280 exists in the eastern part of the Birmingham, AL, Metropolitan Area going from Birmingham southward on into Shelby County. Important cities on or near United States Highway 280 include Homewood, Vestavia Hills, Cahaba Heights, Lake Purdy, Inverness, Meadowbrook, and Chelsea. Growth along this corridor extends from Birmingham to Chelsea. This corridor, unlike Interstate 459 which is entirely located in what the United States Census Bureau considers the Birmingham, AL, Urban Area, extends out from it. In fact new urban growth along this corridor extends out of what is considered the Birmingham urban area all the way to Chelsea. This area and corridor can be considered a formerly rural area that is experiencing urban sprawl. The Interstate 459 corridor can also be considered an area that has experienced urban sprawl being that the area was sparsely developed before the construction of the interstate bypass. State Highway 119 that runs near United States Highway 280 can also be considered an urbanizing area for the same reasons as that of United States Highway 280. A third area that has experienced sizeable urbanization is the Interstate 65 and United States Highway 31 corridors south of Birmingham. Most of this growth has occurred in Shelby County in such cities and towns as Helena, Pelham, Alabaster, Saginaw, and Calera. This area extends

southward from the older urban areas of Birmingham. These areas are suburbs of Birmingham, which is why they are experiencing growth.

A major indicator of highly populated and urban areas is that of highway traffic counts. Traffic counts are measured in “Average Annual Daily Traffic” or “AADT.” Based on Figure 4.24, the largest traffic counts are in the Birmingham urban area and in the areas classified as either “High Density Urban/Built-up” or “Low Density Urban/Residential.” As the distance increases from the core of the urban area, the traffic counts gradually decrease. Figure 4.25 compares a map of the estimated population per census tract for 2008 with the estimated population density per census tract for 2008. From the estimated population per census tract for 2008, some of the larger census tracts outside of the urban area have larger populations than the smaller census tracts in the urban area. However, these smaller census tracts in the urban area have much larger traffic counts. The smaller census tracts in the urban areas have a much higher population density than the larger tracts outside of the urban area to go along with the much higher traffic counts. High population density and high traffic counts are good indicators of an urban area. Continuing the discussion on population density per census tract, another indicator of urbanization is to compare population density to the areas that are classified as urban or residential on a map. By examining Figure 4.26, the areas of high population density correspond to the areas that have an urban land-use/land-cover classification. Obviously there is a correlation between major corridors, high traffic counts, high population density, etc., leading to urban areas and urban expansion. Figure 4.27 shows the areas of potential urban sprawl at a larger scale.

Birmingham, AL, Metropolitan Area Metropolitan Growth Corridors 2008

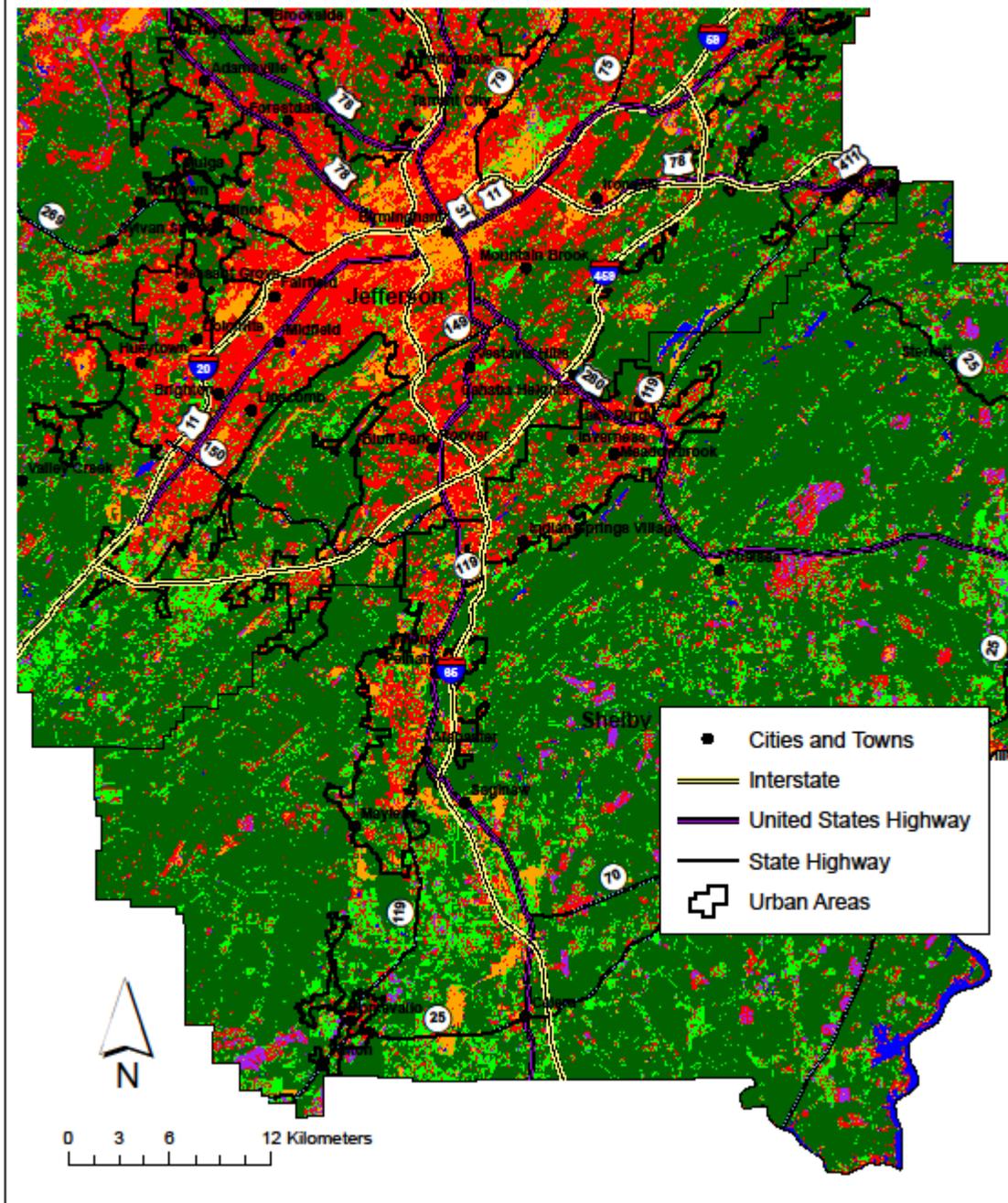


Figure 4.22 Location of growth corridors in the study area.

Birmingham, AL, Metropolitan Area Metropolitan Growth Corridors 2008

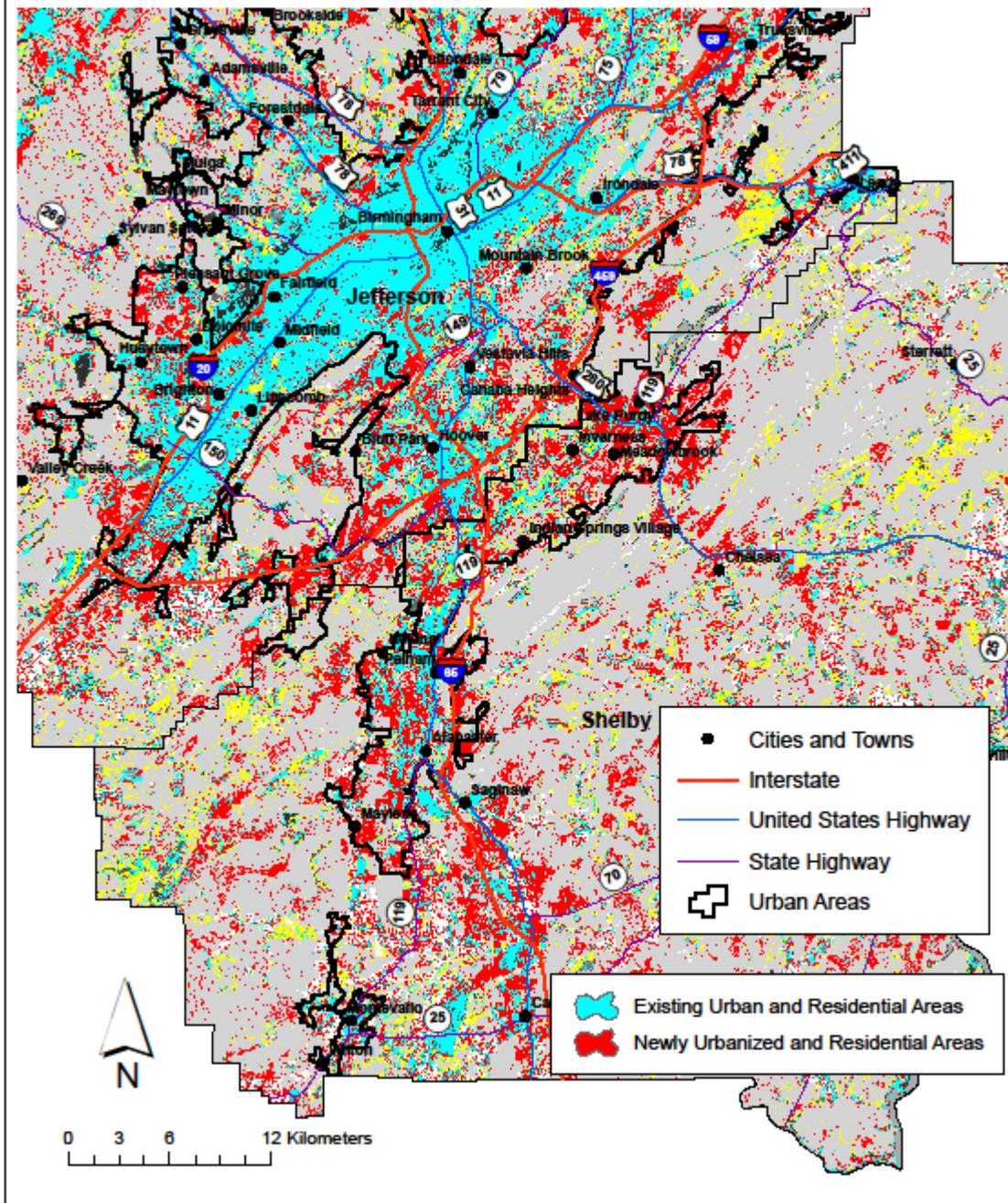


Figure 4.23 Location of growth corridors in study area.

Birmingham, AL, Metropolitan Area Traffic Counts Along Major Corridors

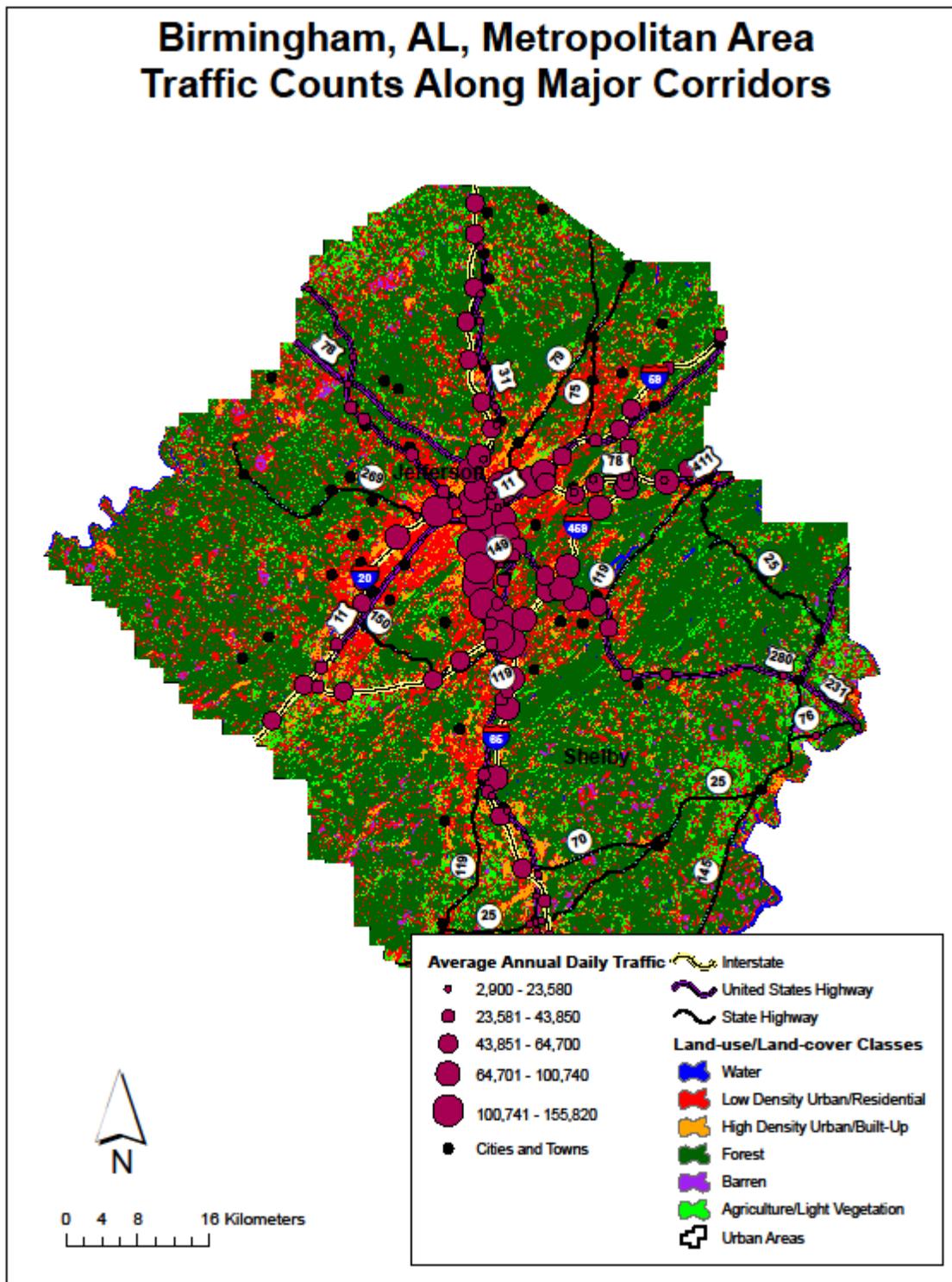


Figure 4.24 Traffic counts are a major indicator of urbanization.

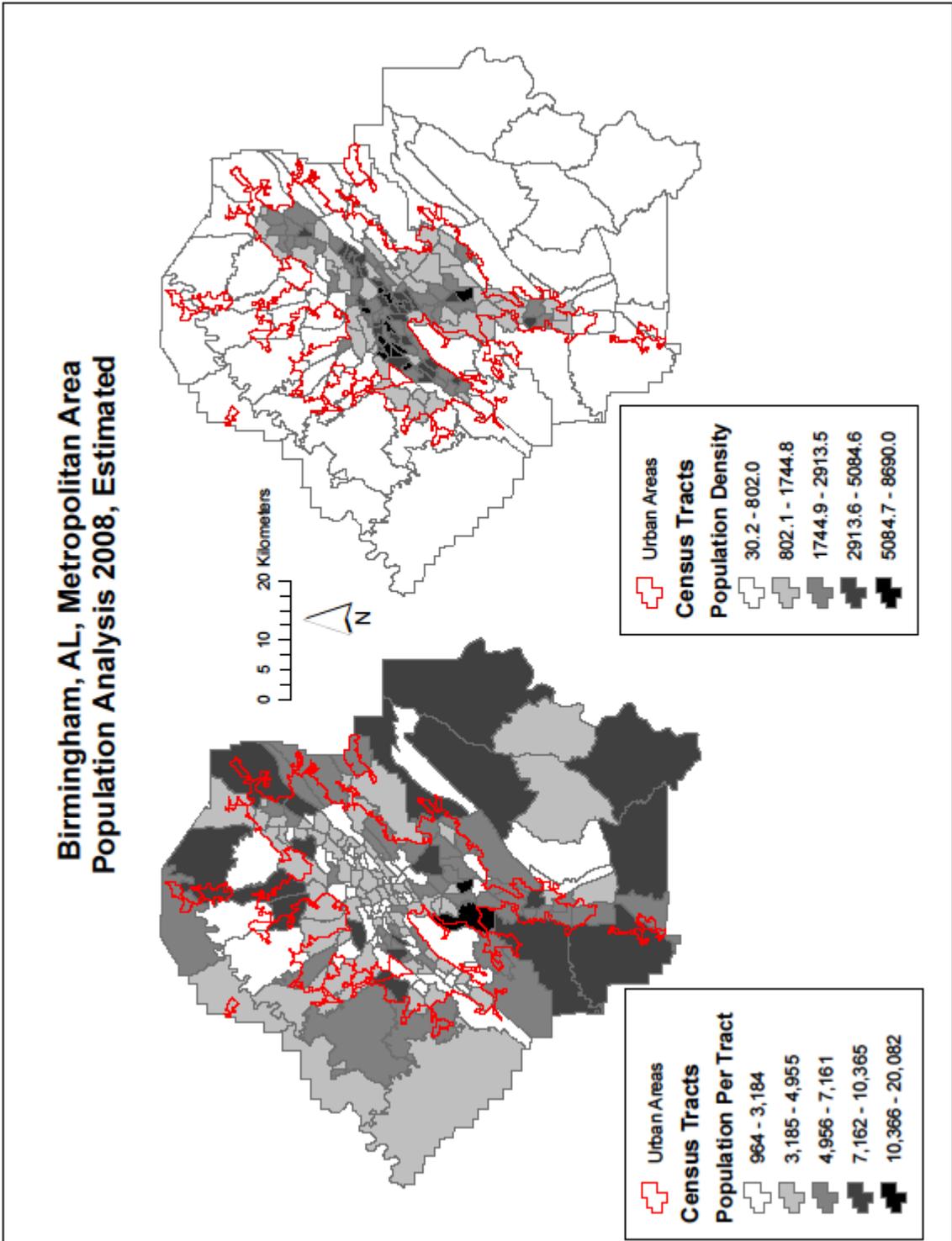


Figure 4.25 Population and Population Density in 2008.

Birmingham, AL, Metropolitan Area Areas of Urban Sprawl 1974 to 2008

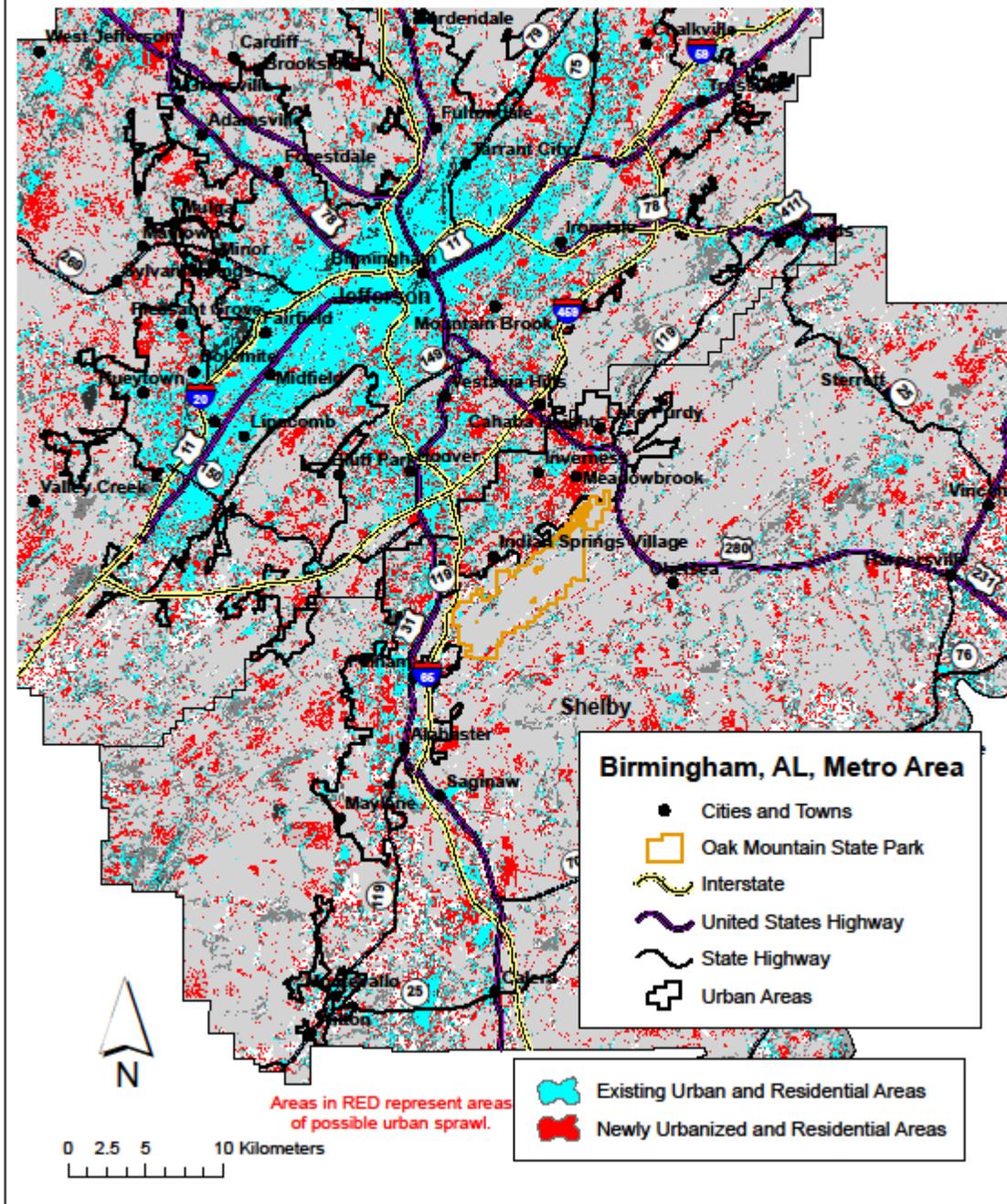


Figure 4.27 Areas of urban sprawl.

4.7 Possibility of In-fill Development to Manage Urban Sprawl

Encouraging in-fill development, which is developing land between the cities and sprawling areas, is another way to manage and curb sprawl (Daniels 2001). It is thought that in-fill development could control urban sprawl which has led to the increasing costs of utilities and other public services and has increased the consumption of energy. In-fill development offers an efficient utilization and development of urban areas within cities, instead of the outward expansion of urban sprawl. Birmingham has proven in this study to be an excellent area to examine these land-use issues. The most common type of vacant land within cities or urban areas is remnant parcels that are fragments of land leftover after development. This is the most common type in Birmingham. In 1981 there were around 43.25 square kilometers of vacant land that lie within the city limits of Birmingham. This vacant land could have accommodated over 160,000 people. This represented approximately 63 percent of the residential population living in areas of urban sprawl. If this population lived within Birmingham, the energy savings with a decrease in sprawl would have increased dramatically (Wilson 1981). These observations were made in 1981 during the energy crisis. The same holds true today.

It is impossible to determine an exact square kilometers of the land that could be utilized for In-Fill development. The reason is that it would take ground-truthing to gather an “inventory” of all of the vacant land that could possibly be utilized for in-fill development, which would require resources that this research does not have. It is impossible to determine based on just a satellite image. It would take ground-truthing, zoning maps, cadastral maps, and information from property owners. However, this study can suggest areas that could possibly be used for in-fill development.

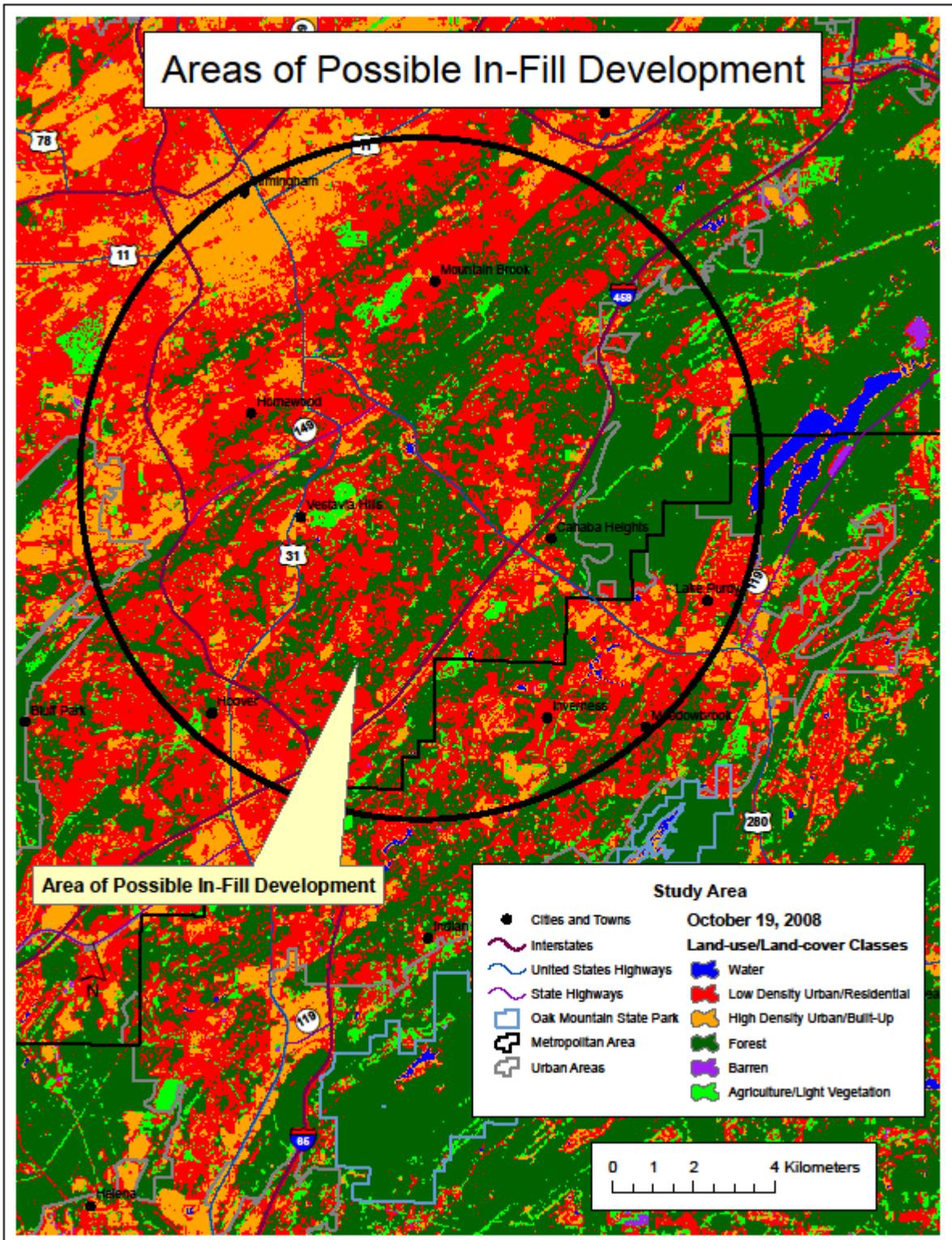


Figure 4.28 Areas perhaps suitable for In-fill Development.

As mentioned earlier, in-fill development is developing undeveloped land between cities instead of developing land further outside of current urban and suburban boundaries, and sprawling areas. Most of the land that could be used for in-fill development is undeveloped fragments of previously undeveloped land that has been developed. By examining Figure 4.28, there are obviously undeveloped areas of “Forest” and “Agriculture/Light Vegetation” in the area in the black circle. Municipalities included in this area include Hoover, Homewood, Vestavia Hills, Inverness, Mountain Brook, Lake Purdy, Cahaba Heights, Meadowbrook, and Birmingham. This area is in the Birmingham urban area. It can be seen that there are many areas that could perhaps be used for in-fill development between the older urban areas to the northwest and the sprawling areas in the central-southeastern portion of the circle. Obviously, these areas seem suitable for in-fill development based on the criteria, but more work would have to be done to determine which areas are suitable. GIS and Remote Sensing obviously can be used to locate areas for in-fill development, however.

CHAPTER 5

CONCLUSIONS

Urban sprawl is a problem in cities throughout the world. It has caused negative impacts in environments and degraded the quality of life for both humans and nature. It is vital to achieve and maintain an understanding of urban and metropolitan patterns. This requires the proficient utilization of methodologies and technologies to monitor expansion and changes in land-use/land-cover in an accurate manner. By utilizing satellite images and remote sensing, it is possible to monitor temporal patterns of growth over a set period of time or the time period of data availability. With remote sensing, it is possible to see patterns in urbanization and predict future patterns and where it might expand to next. Remote sensing gives you a “snapshot” of an area at a given point in time. Remote sensing helps in making it possible to responsibly manage growth.

Urban sprawl can be caused by many factors. One cause is multiple and intersecting authorities and governments. This is obviously an issue in the study area because there are many municipalities surrounding the city of Birmingham. The lack of a regional, city or county vision can be another cause of urban sprawl. Further investigation would be required to determine the extent of the vision in the study area. Rapid population growth can be another cause for sprawl. The area is obviously growing. The expansion of random new development can be another cause of urban sprawl. By doing fieldwork in the study area and analyzing the data, it is obvious that the study area has scattered new development. A lack of adequate planning resources and

dated zoning techniques can be a cause of urban sprawl as well, but this study is unsure of the impact that this has had on the study area (Daniels 1999).

There are many growth management techniques that could possibly limit urban sprawl. This study will examine five. One technique is “Joint planning and joint zoning ordinances for regional planning.” This technique promotes cooperation between cities and counties for growth management. This allows better control over the sites of new development. It also results in a more efficient allocation of utilities—water, electricity, gas, etc. A problem with this technique is that it takes joint cooperation between cities and counties, and that is sometimes difficult. Another technique is “Purchasing of development rights.” This can be a stronger and longer protection for farmland and forestland than zoning. It provides compensation to landowners to maintain their property as forestland or farmland. This maintains resources, it is voluntary, and property remains privately owned. But this technique can be expensive and can potentially just create “islands” of preserved land. Another technique is “Preferential property taxation.” This technique promotes owners of forestland and farmland to keep their land as that land-use. It also promotes the maintaining of historical areas. It promotes keeping land open. It provides financial support of farmers and owners of forestland. However, this technique can be taken advantage of by land speculators. The rules for this technique are often lax, and it can be expensive to maintain. A “Land conversion tax” is another technique. This technique can restrain the development of farmland and forestland and at the same time create revenue for the preservation of these lands. It slows the growth rate. However, revenue is only raised when development occurs. The tax might be high enough to discourage rapid growth. Finally, “Environmental impact assessments” is another technique. This technique analyzes the effects that development will have on water, land resources and air. It assesses alternative sites for

possible development. It identifies problems and potential problems before a project is started so that it can be altered or moved to ensure that the environment is protected, but this can make land development more expensive and can be used as a holdup tactic by some groups (Daniels 1999).

Urban growth boundaries are another possible solution for urban sprawl. An urban growth boundary consists of adequate land and public services to support the expansion of a municipality for two decades. If an urban boundary is properly located and enforced, it can create more efficient land development that is less expensive and cheaper to maintain. This reduces sprawl by not allowing urban public services from expanding into rural areas outside of the urban growth boundaries. Urban growth boundaries also encourage In-Fill development.

This study has used the Birmingham, Alabama, Metropolitan Area as a case study. It has led to some conclusions. First of all, this study has shown that remote sensing and satellite images are incredibly useful for mapping urban change and urban boundaries over time. This confirms work from previous studies, but also I believe that it extends them because this study could find no evidence that a study exactly like this had been carried out in the Birmingham area. The methodology utilized in this study to map land-use/land-cover from satellite images and mapping the changes over time was derived from an understanding of the remote sensor, image interpretation skills, and skills in image extraction methods. Several precautionary methods were taken to ensure the quality and accuracy of the results derived from the satellite data. The MSS data from 1974 was spatially and spectrally enhanced to correspond with the TM data from later dates. A supervised classification approach was utilized in which random training samples were taken from each image. After that an accuracy assessment was performed in order to ensure the accuracy of the classified images.

This study has examined the changes and evolution of the Birmingham, Alabama, Metropolitan area and its growth over time as the largest metropolitan area in Alabama. The growth of urban and residential areas is seen to clearly expand and grow from 1974 to 2008, a thirty-four year period. The spread of “Low Density Urban/Residential” had a dispersed spatial pattern, a major indicator of urban sprawl. This is a characteristic of suburbanization. Both urban and residential areas expanded primarily southward from the Birmingham urban area in 1974. The main corridors of this expansion were on Interstate 459, United States Highway 280, and the Interstate 65/United States Highway 31 corridor south of the city of Birmingham. These findings correspond with traffic and population data that are also indicators of urban expansion.

This study has established a case study focused on Birmingham, AL. This research has proven that much forest and farmland has been urbanized from 1974 to 2008. In 1974, the area now considered the Birmingham, AL, urban area consisted of more land with forest and agriculture/light vegetation land-use/land-cover than that of urban and residential. By 1988, the tables had turned largely because of the completion of Interstate 459. This expansion continued in 1998 and 2008. Most of the growth in urban and residential areas has been at the expense of forest land, which has seen a dramatic drop in total land-use/land-cover square mileage since 1974. These results and conclusions can be useful to those who study, research, and seek a better understanding of urbanization and land-use/land-cover techniques. Many other metropolitan areas in the United States and the world face similar issues. The methodologies and conclusions utilized and put forth could be of benefit for studies in other metropolitan areas and in Birmingham as well. This study could be used to help predict future sprawl. Growth trends could be analyzed from images in consecutive decades to analyze the growth patterns of urban sprawl. That along with socioeconomic and population data could be used to forecast future

growth. Methods and conclusions from this study can be utilized to strive for a more responsible way to manage urban growth in the future. This research methodology could be applied in other cities as well to study their urban expansion and growth patterns.

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