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REMOTE SENSING ANALYSIS OF URBAN EXPANSION IN BIRMINGHAM, ALABAMA: 1988-2004

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1. INTRODUCTION

The population of the United States now exceeds 300 million citizens (U.S. Census Bureau, 2006), and approximately 75 percent of the U.S. population is classified as urban (Kaplan, 2004). Predictions for future growth estimate the U.S. population increasing by another 100 million over the next 50 years, with around 80 percent of that growth taking place in the country's metropolitan areas (Carlson and Dierwechter, 2007). Alabama, although often thought of as a very rural state, also has most of its citizens residing in urban or suburban areas (Klein, 1993).

In the realm of urban studies, urban sprawl is a topic of growing interest and is seen as having negative affects on society as a whole (Torrens, 2006). Concerns have been raised about the expansion of urban space across the rural landscape in a manner that seems to be haphazard and uncontrolled, with arbitrarily placed developments consuming greenfield space at a rate twice that of actual population growth (Sultana and Weber, 2007; Carlson and Dierwechter, 2007). Urban expansion can lead to problems, such as "traffic congestion, environmental contamination, income and racial segregation of neighborhoods, the mismatch between jobs and housing, local fiscal disparities, conversion of farmland to urban uses, and civic alienation, among other maladies" (Galster *et al*., 2001, 683).

Urban growth is often called "urban sprawl," a term that has come to define a multitude of conditions concerning the urban periphery (Galster *et al.*, 2001). Varying definitions of urban sprawl may include rapid and unorganized building-up of largely undeveloped land, growth outside a predetermined distance from the city center, the consumption of forest and agricultural lands by low density suburban residential and commercial development, and development displaying non-contiguous growth (El Nasser and Overberg, 2001; Transportation Research Board, 2002; Yang and Lo, 2002; Mundia and Aniya, 2004). Hayden (2004, 7) defines urban sprawl as "unregulated growth expressed as careless new use of land and other resources as well as abandonment of older built areas."

O'Sullivan (2007) states that land is a normal good, meaning that an increase in the amount of wealth a person accumulates leads to a desire to purchase more land. In addition, he cites that the low cost of travel allows individuals of moderate income to own larger portions of less expensive land surrounding the city and commute to work and social functions, creating an environment of low-density settlement. Public policies such as the insurance of mortgages to home buyers by the Federal Housing Administration, federal income tax deductions for home mortgages, federal tax deductions for new commercial real estate, and the federal government's subsidizing highway construction made the surrounding rural landscape more accessible and appealing to residents seeking to flee the aging urban centers (Jackson, 1985; Hayden, 2004). Such policies, along with the advent of the automobile, led to the decentralization of employment and population. By 2001, 80 percent of the population and 78 percent of total employment within U.S. metropolitan areas were located beyond 3 miles from the city-center, with the median distance for both being 8 miles and 7 miles respectively. With further decline and decay of the center-city, push factors such as the perception of high crime rates, poverty, low quality schools, and high taxes become more prevalent, driving more affluent urban citizens to leave and seek new opportunities on the fringe of the urban landscape (Jackson, 1985; O'Sullivan, 2007).

One method used to analyze the spatial aspects of the expansion of urban development is remote sensing. Since the launch of Landsat 1, the first "land sensing satellite," in the summer of 1972 the Landsat Program has archived imagery nearly twice per month for public use at a moderate spatial resolution (Saunders et al., 2003). The USGS currently maintains and collects data from Landsat 5 and Landsat 7. These data are collected frequently and are cost-effective (Ryznar and Wagner, 2001). However, cloud cover can limit the number of scenes that are useful in any given year, especially in the humid climate of the southeastern U.S. Remotely sensed data integrated into a geographic information system (GIS) enables the monitoring of urban growth in ways that are not possible using traditional methods of using census data (Sultana and Marzen, 2004). This study analyzes the spatial component of urban expansion through the tracking of built-up areas in the Birmingham metropolitan area using remote sensing and change detection techniques. Two cloud-free Landsat 5 Thematic Mapper (TM) images with near-anniversary dates in 1988 and 2004 are used. With this method, we gain a new prospective of the spatial make-up of urban expansion.

2. STUDY AREA

According to the Birmingham Regional Chamber of Commerce (2006), there are seven counties that fall within the Birmingham-Hoover Metropolitan Area. These counties include Bibb, Blount, Chilton, Jefferson, St Clair, Shelby and Walker Counties, which were home to 1,079,089 people in 2004. Jefferson County, of which Birmingham is the county seat, and Shelby County, the site of the most explosive suburban growth, are the areas of interest for this study (Figure 1). These two counties are the most highly populated and densely settled of the seven. Several major transportation arteries are located throughout the study area. These highways include Interstates 65, 59, 20, and 459, as well as U.S. Highways 280 and 31.

The metropolitan area of Birmingham, Alabama is no exception to the trend affecting other metropolitan areas across the U.S., which are experiencing a continuous decline of the center-city. Between 1990 and 2005, the inner city of Birmingham lost almost 35,000 residents, or 13 percent of its total population (U.S. Census Bureau, 2006). The Birmingham metropolitan area also experienced substantial expansion of suburban areas into the surrounding rural landscape. Evidence of this expansion is noticeable when observing census data for the communities and counties surrounding the city center or driving along roadways in the Birmingham suburbs in the middle of an increasingly crowded rush hour as shown in Figure 2.

FIGURE 1
JEFFERSON AND SHELBY COUNTIES, ALABAMA

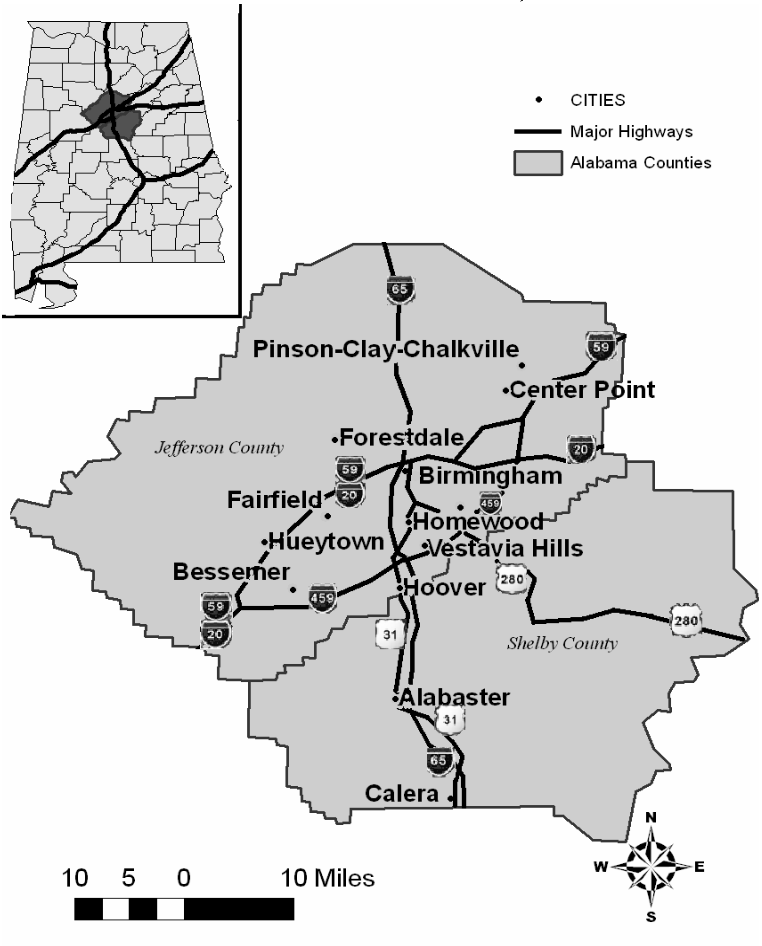


FIGURE 2
LOOKING SOUTH ALONG U.S. HIGHWAY 280 DURING A TYPICAL RUSH HOUR

According to the U.S. Census Bureau, the population in Jefferson and Shelby Counties increased 10.4 percent between 1990 and 2005. Of the two counties, the most rapid growth in that 15-year period took place in Shelby County, which experienced a population increase of about 73 percent (Table 1). Evidence of the growing impacts of this rapid growth is presented by Sultana and Weber (2007), who used census data to map areas of sprawl in Jefferson and Shelby Counties in a study of commuting times in the Birmingham metropolitan area. Their study found that commuting times in the region averaged well over 30 minutes.

TABLE 1
POPULATION BY COUNTY

	2005	2000	1990
Jefferson County	657,229	662,047	651,525
Shelby County	171,465	143,293	99,358

Source: U.S. Census Bureau, 2005 Population Estimates, Census 2000, 1990 Census

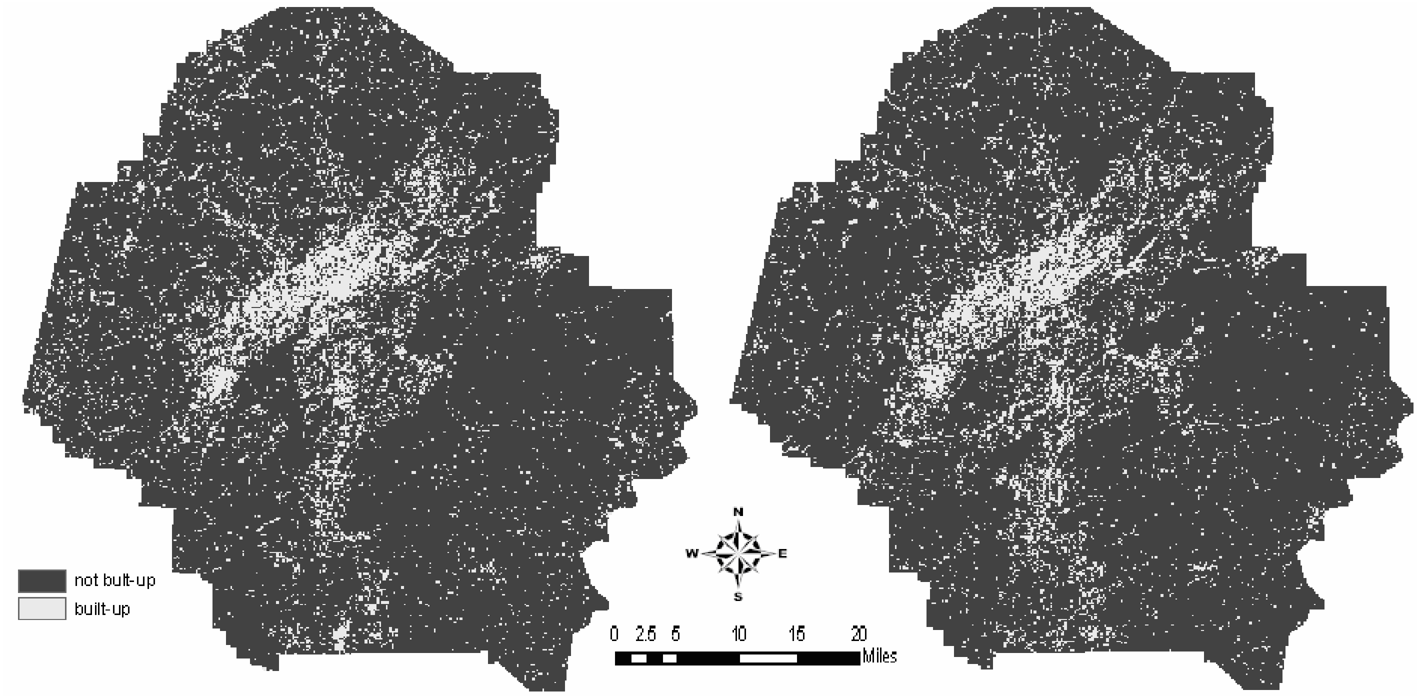
Sultana and Weber's (2007) study examined population growth by census tract, which is very useful for many applications. But for studies that evaluate environmental factors such as how sprawl might affect water quality or reduce the amount of land for agricultural purposes, remote sensing methods that track the physical changes in the landscape might be more useful. Satellite imagery provides a synoptic view of the physical landscape of the area of interest, which can show the actual amount of agriculture and forested land that has been converted to urban built-up areas over time. The goal of this project was to use remote sensing and change detection methods to identify and analyze the expansion of built-up areas in the Birmingham metropolitan area of Jefferson and Shelby Counties.

3. METHODS

For this project, two cloud-free Landsat 5 TM images of Jefferson and Shelby Counties were analyzed using change detection procedures. The TM device aboard Landsat 5 is a scanning radiometer collecting data in seven spectral bands including those for visible light, near infrared (NIR), and thermal infrared (USGS, 2006). A band combination of red and green visible light along with NIR, called a false color composite, allows for delineation of urban and vegetated areas. For the change detection aspect of the project, the images selected span nearly two decades. The imagery used includes near-anniversary images, the first acquired on Oct. 13, 1988 and the second on Nov. 10, 2004, both of which were previously georegistered to the UTM coordinate system. In the Birmingham area, the majority of leaves usually remain on the trees until late November or December. Jefferson and Shelby counties were then extracted from the full Landsat TM scenes (path 20, row 37). The Landsat imagery used for this study was obtained from AlabamaView, an online geospatial data portal for the state of Alabama (www.alabamaview.org). The imagery are pre-processed to correct for geometric and radiometric errors and calibrated to percent reflectance. However, to obtain a better spatial match between the imagery the 1988 image was re-registered to the 2004 image with an RMS less than 1.0.

The two images were examined in tandem to monitor the expansion of the urban area over the 16-year period. Both images were classified using an ISODATA unsupervised classification procedure. The Landsat images were initially classified into 100 classes, each of which was designated as either built-up or not built-up (Figure 3). Having only two classes aided in reducing error and complexity. Urban impervious surfaces such as buildings, highways, parking lots, and 'treeless' portions of residential neighborhoods were included in the built-up classification, while vegetated areas, water, and agricultural or bare land was classified as not built-up. The false color composite, which consists of the electromagnetic band combination of

FIGURE 3
LAND COVER OF JEFFERSON AND SHELBY COUNTIES



4-3-2, was examined for each year to determine the category for each class. The accuracy of the classified images was assessed by plotting 30 random points on each of the two-class images and using the Landsat imagery as the reference. The results of this assessment showed a 97 percent accuracy rate for the 1988 classified image and 93 percent for the 2004 image. Next, the two images were recoded, creating a binary image for each year showing the land cover as having either a built-up or not built-up classification.

Once recoded, a post-classification matrix process was used to produce a final map merging and comparing the two recoded images, allowing for analysis of from-and-to land cover changes over the 16-year period (Figure 4). It is from this final output that quantitative measurements of land cover change can be calculated.

4. RESULTS OF CHANGE DETECTION ANALYSIS

The results display a substantial amount urban change (Table 2, Figure 4). Most of the expansion took place to the south and east of Birmingham. As expected, the majority of this growth took place within corridors only a few miles wide along the major highways in the metropolitan area. Considerable change can be seen along the Interstate 65 corridor from the city of Hoover, just south of inner-city Birmingham, to the city of Calera near the southern border of Shelby County. A large portion of the development in this corridor is accessed along U.S. Highway 31, which snakes its way back and forth across the more rapid and free-flowing traffic artery Interstate 65.

TABLE 2
ANALYSIS RESULTS BY CLASS

Classes	Area (Square Miles)	% of Total Landscape
Built-up (unchanged)	104	6
Built-up to not built-up	117	6
Not built-up (unchanged)	1471	81
Not built-up to built-up	135	7
Total	1827	100

Another area experiencing explosive growth is the U.S. Highway 280 corridor. Rapid residential and commercial development is taking place from the Mountain Brook/Interstate 459 area, across and into the multiple valleys of Double Oak Mountain, to the city of Chelsea. One major problem with such growth along this corridor is that U.S. Highway 280 is not a limited access expressway. Rather, it is a four- to six-lane two-way thoroughfare with traffic lights and turn lanes, contributing to congestion during rush hour (Figure 2). Other sections of the metropolitan area experiencing substantial growth include the Interstate 459 corridor, which contains the Galleria and Summit shopping centers and adjacent developments, the Liberty Park office complex and neighborhood, and the Trussville area near the Interstate 459/Interstate 59 junction, which just opened the new Pinnacle shopping center. The cities and major highways listed here are labeled in Figure 1.

The results also indicate that a portion of the metropolitan area returned from a developed state to undeveloped. However, field work in the area and aerial photography revealed that most of the space that falls in this category is actually occupied by low-density residential neighborhoods, as seen in Figure 5. A probable explanation for this result is the maturation of vegetation in low-density residential areas over the 16-year period studied, which were newly cleared areas in 1988.

FIGURE 4
1988-2004 LAND COVER CHANGE ANALYSIS

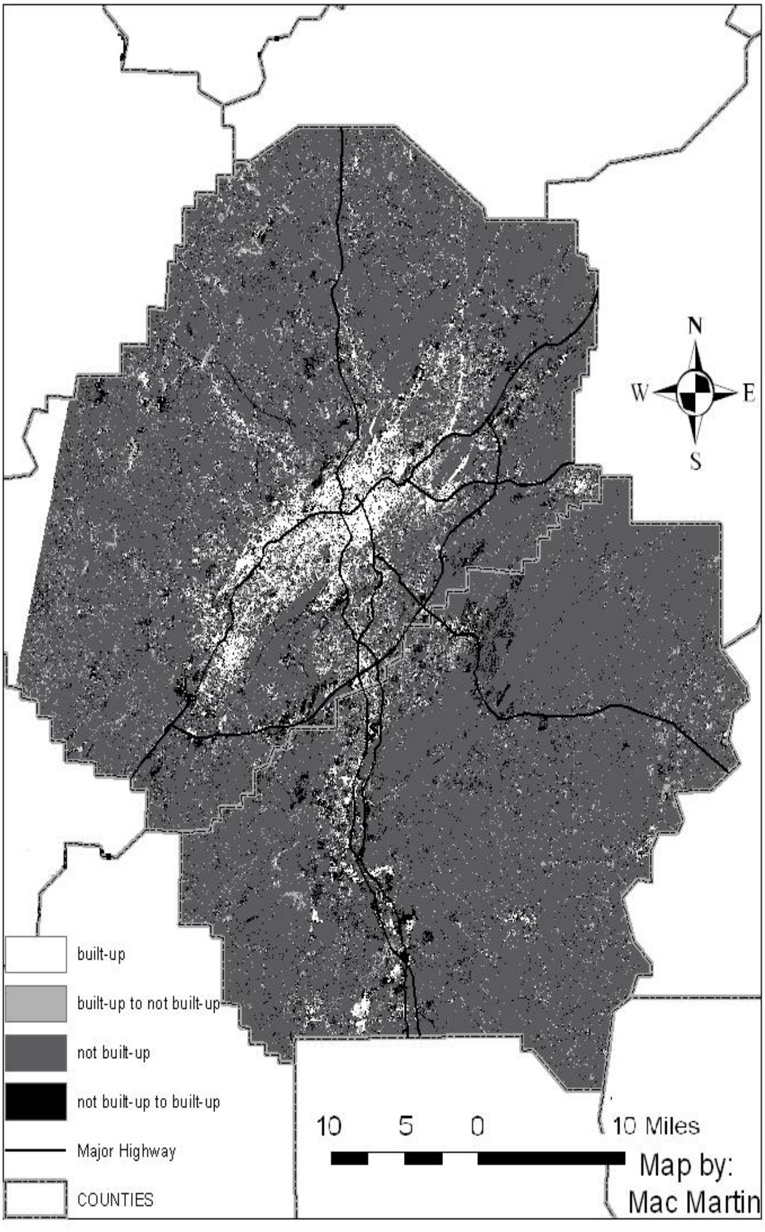


FIGURE 5
LOW-DENSITY NEIGHBORHOODS ADJACENT TO HIGHWAY 280

Source: Europa Technologies and Google Earth, 2006

5. SUMMARY

This study was conducted to better understand the trends of development and expansion of the Birmingham metropolitan area. Having a better grasp of such trends can enable planners and city officials to make more informed decisions. Maps that show growth at the landscape scale over several decades can be an asset in communicating the need for regional planning. A post-classification comparison of Landsat TM imagery was used to detect urban expansion in Jefferson and Shelby Counties, which are the most populous and densely settled counties in the Birmingham-Hoover Metropolitan Area. A false color composite band combination was most effective in verifying the unsupervised classification and determining what was built-up and what was largely vegetated or undeveloped.

The results show that there is extensive urban expansion taking place, especially to the south and east of the center city along the major highways. Studies using remote sensing and change detection techniques may aid in finding the proper balance between the preservation of Alabama's rich natural heritage and the economic development needed to ensure a better quality of life for generations of Alabamians to come. However, for a more complete analysis, future studies should include further field work and perhaps more detailed classes of land cover. In addition, more extensive use of other remote sensing datasets, such as aerial photography, could prove to be useful.

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