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Blue Lines, Greenbelts, and the Effects of Growth Management: The Geographical Effects of Growth Management Policies in Boulder, Colorado

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BLUE LINE, GREENBELTS, AND THE EFFECTS OF GROWTH MANAGEMENT: THE GEOGRAPHICAL EFFECTS OF GROWTH MANAGEMENT POLICIES IN BOULDER, COLORADO

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Abstract

This study evaluates and describes the effects of growth management policies, established by the city of Boulder, Colorado, for the city and the surrounding region. A variety of techniques contribute to this evaluation, including remote sensing analysis of land-use change for the region, mapping of commuter flow patterns, and analysis of the distribution of housing values, housing units, number of jobs, and income values. Growth management policies focus on planning for development to ensure continuous, adjacent growth, while preventing haphazard, leapfrog development. In cases such as Boulder, when planning is implemented unilaterally by a city as opposed to on a regional level, growth tends to be funneled to new locations, thereby perpetuating sprawl and all its negative implications. Boulder has had a long history of employing a variety of policies to manage growth, including a service area boundary as well as a tax to preserve open space that results in a greenbelt that defines the extent of the city. The result has been the formation of a sharp edge between the urban and rural landscape, with increased commuters from the surrounding area, a mismatch between jobs and housing, and a worker earning/housing cost mismatch for Boulder. This has funneled growth to the surrounding area, as documented by steady increases in the built environment.

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1 Introduction

1.1 Background of Urban Growth in the United States

Since the end of World War II, growth in the United States has been associated with sprawling development patterns creating suburban America with significant implications for open space, public services and overall livability of urban areas (Jackson, 1985; Garreau, 1991; Muller, 2004 ; Fishman, 2005). Sprawling development patterns have resulted in the loss of open space, farmland, and natural ecosystems and are detrimental to regional biodiversity as well as the sustainability of the city in terms of local agriculture, ecosystem services, and wildlife corridors among other potential impacts (Talen & Brody, 2005). In the United States, more people now live in suburbia than in the combined inner city and rural areas (Hayden, 2009). Suburbs are the outlying areas of the city dominated by low density subdivision housing patterns (Palen, 2002). It is not just land and natural ecosystems that are affected by sprawling growth patterns; there are also socio-economic and infrastructure downfalls associated with sprawling development patterns. For example, public transit is less accessible in suburban areas, and infrastructure such as roads, water, and sewage treatment has to extend outward and is very costly both to install and maintain. High-density urban growth allows for easier access to public services and minimizes the infrastructure cost associated with sprawling expansion (Pollock, 1998; Ding, Knaap, & Hopkins, 1999).

Smart growth encompasses a variety of growth management policies that focus on a holistic approach to urban development originating in the 1980s and 1990s. Components of smart growth may include urban growth boundaries (UGBs) and transit oriented development (TOD). The purpose of these types of growth policies is to dynamically plan for growth in a way that preserves land while also promoting high-density growth, accessibility to public services, and livability of cities. These policies attempt to mitigate the negative effects of sprawling growth on surrounding land, as well as to improve the social environment of the city, by reducing commuting times, decreasing infrastructure costs, and increasing accessibility to public services (Pollock, 1998; Ding et al., 1999; Palen, 2002).

The implementation and structure of growth management policies can vary based on political structure and location (Daniels, 2000; Bae & Jun, 2003; Marin, 2007). In some cases, policies are very rigid and do not allow for additional growth (Pollock, 1998; Bae & Jun, 2003; Jackson, 2005). In other cases, policies are dynamic and allow adjustments for projected growth. Additionally, the form of government can greatly affect the flexibility or rigidity of the policy. For example, the regional government for the Portland, OR, Metropolitan Region has implemented a dynamic urban growth boundary allowing for changes to the boundary to accommodate projected growth for the entire region (Gillham, 2009). In contrast, Boulder, Colorado, has unilaterally implemented strict growth policies for only the city with the unintended result that growth is forced to relocate elsewhere, as the economy of Boulder continues to grow. Portland's UGB is based on the urban service district concept similar to the city of

Boulder's service area boundary, which restricts the extent of water and sewage services and limits growth (Gillham, 2009). The purpose of the current study is to assess the effects of growth policies established by the city of Boulder, both on the city itself and on the surrounding area.

1.2 Historical Overview of Boulder's Growth Planning

Boulder is situated approximately 30 miles northwest of Denver against the foothills of the Rocky Mountains seen in Figure 1. Home to the University of Colorado - Boulder, it has the feel of typical college town America. In addition to the university, it houses a number of research and development institutes as well as both public and private think tank type organizations. A number of these organizations work in conjunction with the university. Residence of the city have significant access to open space and outdoor activities including mountain biking, rock climbing, hiking and trail running; Boulder's open space program also attributes to its desirability. Boulder colloquially has been referred to as "the people's republic of Boulder" or "25 square miles surrounded by reality." Boulder has an aura that is homogenous with a liberal, leftist, outdoorsy hippie feel to it creating the Boulder utopia.

Figure 1. Colorado with Boulder Region (outlined with gray box)
(*source:* http://www.newmapworld.org/colorado-map/)

There is no statewide policy in Colorado requiring cities to implement growth management policies; however, Boulder has implemented a variety of policies to limit growth, including establishing a greenbelt, a blue line amendment implementing a service area concept, and implementing a tax to preserve open space (Pollock, 1998; de Raismes III, Hoyt, Pollock, Gordon, & Gehr, 2000; Jackson, 2005). In this work "Boulder" refers to the City of Boulder, while "Boulder County" refers to the County of Boulder. The policies implemented by Boulder were in response to concerns of significant population growth and the subsequent effects of sprawl stemming in the 1950s, prior to the new urbanism and smart growth movements of the 1980s and 1990s. The policies implemented by the city are rigid in nature and have significantly affected the regional landscape and the socio-economic fabric of the city.

In 1910, Fredrick Law Olmsted, Jr. advocated for the protection of the foothills that border Boulder's western edge. It was not until post World War II that the city realized what the booming growth period meant for the region. Reaction to the post war growth period resulted in Boulder's implementation of a service area boundary for water service in 1959 through the Blue Line Amendment. The Blue Line Amendment placed an elevation limit on water services in order to limit growth into the foothills and the spatial extent of the city. The Blue Line amendment was eventually revised to include sewage service (de Raismes III et al., 2000).

In the early stages of planning Boulder acknowledged population growth was inevitable, but wanted to control both the rate and location of growth. In the early sixties, Boulder proposed a plan for the service area concept referred to as the "Spokes of the

Wheel" in order to manage where growth occurred. It was proposed that both residential and commercial growth would occur to the north along the Diagonal Highway, to the east along Arapahoe Ave, and to the south on South Broadway. The only spoke that was ever started was the one to the North. The spokes of the wheel plan was squashed by voters in 1965. The city ended up annexing the non-residential portion of the North spoke and the residential portion remains as part of Gunbarrel today (de Raismes III et al., 2000).

There is no perfect way to plan, and Boulder's plan was an evolving process. The plan received a wake up when Robinson vs. the City of Boulder Decision was handed down in 1976, which essentially allowed for subdivision development in Gunbarrel and forced Boulder to formulate a comprehensive plan for growth. The comprehensive plan defined eligibility for city water, which were properties developed before 1977. Additionally, it also made it feasible for the city to obtain most of the land surrounding the city and designate it as open space (de Raismes III et al., 2000). This created the greenbelt that surrounds the city today, which can be seen in Appendix A. "Unlike many cities that have either sprawled into the countryside or facilitated leapfrog development, Boulder has created a sharp edge between urban and rural" (de Raismes III et al., 2000, p. 8).

Boulder has worked in conjunction with Boulder County in its quest for protecting open space in the county, not just for recreational purposes, but also to protect natural prairie grasslands, migratory corridors, riparian zones, and natural stream flow, among other motivations. Boulder's open space initiatives have been aided by a city sales tax to support the purchasing of open space, initiated in 1967; the motivation to preserve open space stemmed from the Mountain Parks Program, initiated in 1898 by the city, to preserve the Flatirons (de Raismes III et al., 2000). On multiple occasions, the city has worked in conjunction with the county to buy areas in the county and designate them as open space. This process has kept certain development projects from coming to fruition or at least away from the city. For example, Boulder's open space has forced the I-470 Beltway to connect to Highway 36 seven miles southeast of Boulder in Broomfield. Boulder's open space program also prevented the town of Superior from acquiring additional land for expansion. Superior had annexed a 1,700 acre parcel in 1987, which resulted in the significant development along McCaslin Boulevard. Further development of Superior was prevented by Boulder and Boulder County through the acquisition of the 496 acre parcel of Eldorado Mountain and Conda quarry as well as the condemning of the 475 acre Flatiron Vista parcel. The last major acquisition of land by the city and county was in 1999, a 1,500 acre area that spans both Boulder and Jefferson county (de Raismes III et al., 2000).

1.3 Research Questions

Boulder's planning strategies have been evolving and shaping the landscape since post-World War II. The few writings on Boulder describe the planning policies and some of the effects of the policies such as *Growth Management In Boulder, Colorado: A Case Study* (de Raismes III et al., 2000), but few studies quantify those effects and link them to the surrounding landscape. Additionally, much of the planning research looks at only one aspect at a time, for example, either commuting patterns or housing values. This project looks at a variety of aspects – commuting, housing values, income values, housing job mismatch, and land-use changes in an attempt to provide quantification and description of how urban growth policies influence these facets. Census data were available for 1970 to 2000 and so this is the time period used for the study.

Unfortunately, it is difficult to clearly identify causality, i.e. to separate effects of growth policies from the cause and effect relationships that normal population growth or market forces can have on housing values or new development to name a few. The purpose of this study is not to determine causality; rather the goal is to describe the changes and attributes of the region that have potentially been affected by growth policies, in addition to normal population growth and market force effects. Boulder has had significant influence on land-use planning throughout the county because of its unique efforts to preserve open space (de Raismes III et al., 2000).

The goal of this research is to describe the spatial patterns of commuting, housing values, income distribution, housing-job mismatch and land-use changes in Boulder and its surrounding hinterland between 1970 and 2000. This research was guided by the following research questions:

1. Are growth management policies established by the city of Boulder encouraging livable, affordable communities in the city of Boulder and the surrounding region?

    a. How have commuting patterns changed between 1970 and 2000?

    b. How has the balance between jobs and housing changed between 1970 and 2000?

    c. How have housing values and income values changed between 1970 and 2000?

2. Are growth boundary policies established by the city of Boulder effective in promoting compact, adjacent growth, and preserving agriculture and natural open space?

    a. How has the fractional mean of impervious surface cover changed between 1984 and 2002?

1.4 Study Area

The study area for this project has been defined as the "hinterland" of Boulder. A hinterland differs from a field of influence. A field of influence is the furthest spatial extent in which a city has influence; in contrast, a hinterland is limited to the areas around the city with the most influence (Taaffe, Gauthier, & O'Kelly, 1996). Both the hinterland and field of influence can be defined by a variety of aspects. In some cases Boulder's area of influence has been defined by the extent of its open space acquisitions, which extend outside of Boulder County (de Raismes III et al., 2000). For this study the hinterland was defined by the percent of commuters by labor force for areas surrounding the city of Boulder. Commuters are those persons who work in Boulder and live either in Boulder or outside Boulder. "Labor force" is defined as the combination of both employed workers and unemployed workers that are actively looking for work that live in a specified geographical area, in this case within a defined municipality (BEA, 2004; SOCDS, 2005). The total labor force count is reported as the number of people for an individual city or town. A minimal commuter exchange threshold of 15 to 25 percent of commuters entering a county is used to join counties to metropolitan statistical areas as defined by the United States Office of Management and Budget. For this study a threshold of 15 percent was employed to define the Boulder hinterland (OMB, 2000). A ratio of total commuters to Boulder by total labor force was calculated for each municipality and converted to a percent.

Based on this criterion, the city of Boulder's hinterland comprises the cities and towns of Boulder, Erie, Gunbarrel, Lafayette, Longmont, Louisville, Niwot, and Superior displayed in Figure 2. Also included in the land-use change assessments were Broomfield and Dacono; they were both on the cusp of fifteen percent with approximately 14 percent of their labor force commuting to Boulder. This defines the study area for this research.

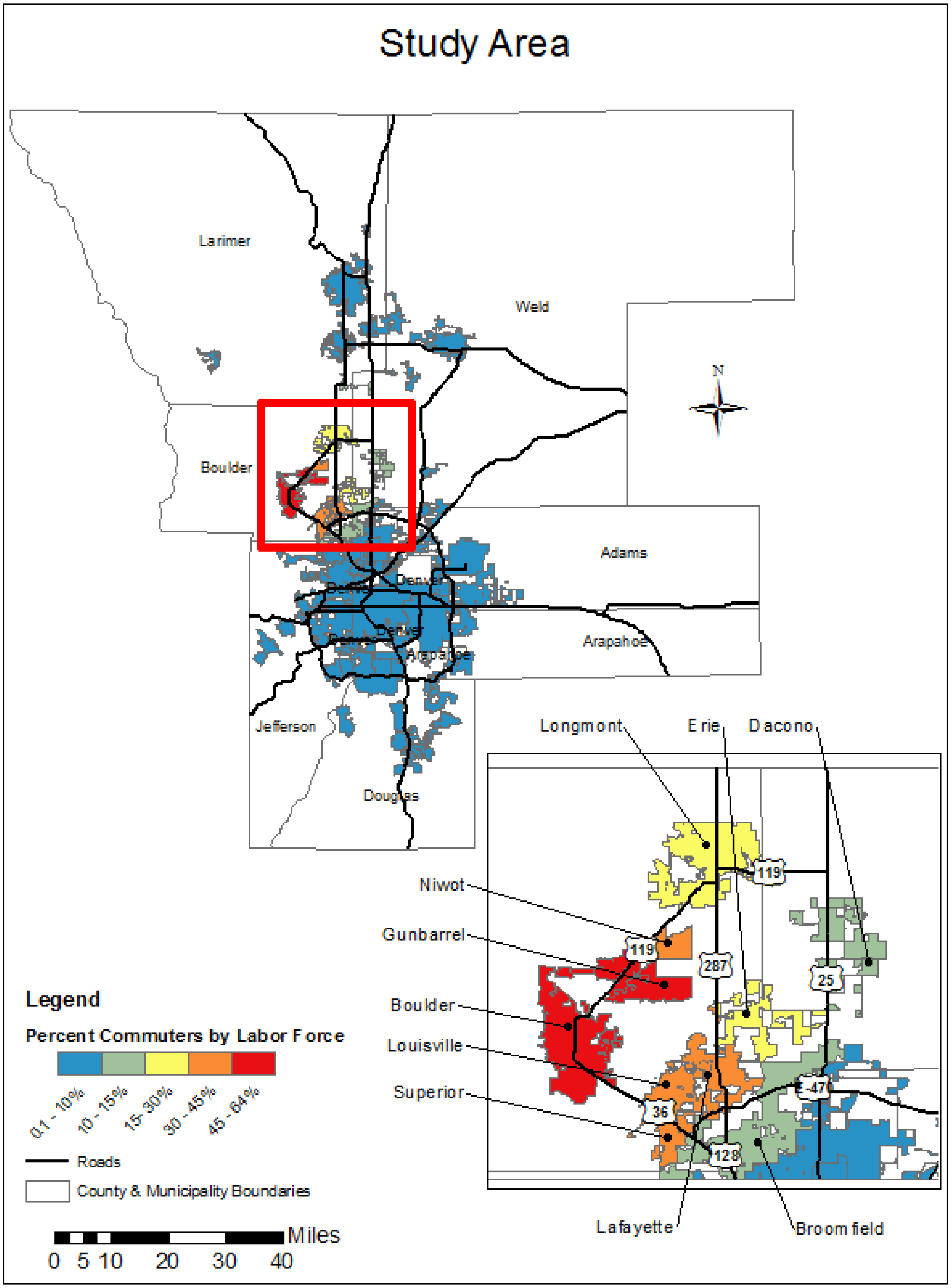

Figure 2. Study Area: Percent of Commuters by Labor Force (*source:* SOCDS, 2005; CTPP, 2000)

2 Literature Review

2.1 Historical Overview

The concept of sustainability dates back to the writings of George Perkins Marsh in 1874. Marsh spoke to the issues and effects associated with deforestation on the ecology of a region and offered warnings concerning the human effect on nature, including land and resource degradation. Marsh postulated "…the great question, whether man is of material nature or above her" (Marsh, 1874, p. 644). In the mid-twentieth century, Carl Sauer (1956, p. 66) suggested that "renewable resources are not being renewed." Although both men were speaking to the loss and destruction of natural resources, urban development and sustainability depend on these very resources that are being lost and degraded. Urban areas are not isolated entities; they are dependent on the constant flow of materials into and out of the city. These materials no longer come from the immediate hinterland, as many goods are imported into the urban center from all over the globe.

Urban morphology in the United States has greatly changed since the close of World War II. Cities experienced a mass exodus of residents, enabled by the changes in lending policies by the Federal Housing Administration and the Veterans Administration loan programs making housing affordable to a larger portion of the population (Palen, 2002). In conjunction with changes to the federally funded loan programs, housing construction, which had ceased for nearly two decades, became rampant through Fordist production of subdivisions, resulting in the sprawling suburban growth that defines the United States today (Jackson, 1985; Palen, 2002; Muller, 2004 ; Fishman, 2005). The 1956 Highway Act resulted in the necessity of cars for commuting (Muller, 2004), and the federal government underwrote construction for five million new homes (Jackson, 1985).

The decentralization of metropolitan areas marked the beginning of sprawling development patterns in the United States (Palen, 2002; Fishman, 2005). Environmental impacts of development, such as pollution and loss of natural landscapes, became evident during the 1960s via profound events such as the burning of the Cuyahoga River (Daniels, 2009). Polluted waterways, loss of farmland, forest, natural ecosystems, and wildlife were addressed through subsequent federal legislation including the Clean Water Act (1972), the Wilderness Act (1964), the Endangered Species Act (1972), to name a few (Daniels, 2009). Planning policies that established growth limits were initially utilized as a means to protect agricultural land, forestland, and environmentally sensitive ecosystems, but have evolved into holistic plans to develop livable cities (Daniels, 2000; Talen & Brody, 2005; Daniels, 2009).

Since the 1980s many metropolitan areas have experienced a shift towards more regional development moving away from viewing the city and nature as separate entities, but instead as interdependent (Talen & Brody, 2005). UGBs promote the connection between city and nature by focusing on both the internal and external land use. UGB are a twofold management policy, managing the urban growth within the boundary and natural resource land, including agricultural and forest land, outside the boundary (Ding et al., 1999; Abbott & Margheim, 2008). The design of UGBs often allows for the protection of natural and working agrarian landscapes around the city, reinforcing the concept that cities are linked to their natural landscapes. Large metropolitan areas are often seen as a contrast to the ideals of environmental conservation, but they could be seen as a solution to mitigating urban heat island effect, air pollution, storm water runoff, to name a few through maintaining and promoting green corridors and protecting existing farmland, forest, and open space. In fact, through appropriate planning policies that maintain human-nature linkages and protect regional biodiversity, cities themselves can positively contribute to the mitigation of urban environmental problems (Collins et al., 2000; Talen & Brody, 2005).

Until the mid-twentieth century, city planning focused on walkabilty and mass transit. As advances were made in transit technology, street cars contributed to the expansion of cities as well as movement out of the city by the more affluent into bedroom communities. This was later supported by the emergence of the automobile and highway system, resulting in white flight, the mass migration of affluent, predominantly white people out of the city and into the suburbs (Palen, 2002). American subrubs lost the walkablity that was found in cities. Beginning in the 1980s, planning in the United States took on a new face with new urbanism and smart growth working to create more liveable and walkable communities within suburbs and cities, which had become dominated by the automobile. New urbanism focuses on building communities that integrate all aspects of a person’s daily life into the community, designing communities where people live, work, and play (Palen, 2002). Smart growth encompasses a variety of planning policies including UGB and TOD, but also focuses on creating livable cities.

Smarth growth is an umbrella for a variety of growth management strategies with the intent of planning for growth while limiting sprawl (Palen, 2002; Ye, Mandpe, & Meyer, 2005). Smart growth focuses on an integrative community approach that includes planning, transportation, economic development, housing, community development, and natural resource preservation. Smart growth planning aims to be comprehensive in nature in order to promote increased density and generate economies of scale for benifits such as public transit, schools, and emergency services (Ye et al., 2005). In planning for high density, smart growth also places emphasis on design and provides a variety of housing options for all income levels, leading to more diverse neighborhoods. The promotion of higher density housing allows for urban areas to increase their density without significantly altering the landscape, thus preventing or limiting sprawl (SGN, 2002). The goal of smart growth transportation is to plan urban areas so that there are a variety of integrated transportation options to promote connectivity within the community, including walking, biking, public transit, and automobiles (Ye et al., 2005).

UGBs were an outcome of the growth control movement of the 1960s and 1970s in response to sprawl and the pressures on the carrying capacity of the local environment (Marin, 2007). For example, “metropolitan counties house 80 percent of the nation’s population, but also produce one fourth of the nation’s food” (Daniels, 2000, p. 262). As urban areas continue to expand outward, the loss of agriculutual land becomes ineveitable, subsequently decreasing the nation’s domestic food supply (Daniels, 2000).

UGB are a two-part strategy that targets planning, zoning, and management both inside and outside the growth boundary (Ding et al., 1999). Essentially, UGBs manage the urban and rural land use and the transition between with the goal "to promote compact and contiguous development patterns that can be efficiently served by public services and to preserve or protect open space, agricultural land, and environmentally sensitive areas (Ding et al., 1999, p. 53)." Commonly, the boundary allows for internal growth to support population increases over the next 20 years, at which point the boundary can be re-evaluated to ensure effectiveness (Ding et al., 1999).

Land-use outside the boundary is often managed through zoning and protection strategies. The preservation of this land is critical, since it has been taken over by sprawling development in many areas. Nevertheless, of equal importance is the implementation of higher density growth inside the boundary, which helps to limit the spatial extent of infrastructure. High-density growth allows for increased access to public services, including water, sewage, and public transit (Nelson & Moore, 1993, 1996; Ding et al., 1999; Abbott & Margheim, 2008).

2.2 Portland, Oregon

The state of Oregon has been a pioneer in land-use planning and urban growth containment policies (Marin, 2007; Abbott & Margheim, 2008). As a result, the Portland region is one of the most researched examples of an UGB and has been both idealized and criticized (Kline & Alig, 1999; Brueckner, 2000; Jun, 2004; Marin, 2007; Abbott & Margheim, 2008). The Oregon state legislature required urban growth management in response to the rapid population growth experienced in the 1950s and 1960s. The state of

Oregon's 1973 Land Conservation and Development Act required that cities produce a comprehensive land-use plan; consequently, cities must establish urban growth boundaries to restrict urban growth, while also zoning land outside of the growth boundary as exclusive farm use, forest use, or exception areas (Kline & Alig, 1999). Oregon's land-use policy program focuses on three goals regarding the land outside the UGB: first, there should be an orderly and efficient transistion between rural and urban land uses; second, agriculture lands should be protected; and third, forestland should be protected (Kline & Alig, 1999). The combination of the compact contiguous development and the protection of farmland and open space promotes the sustainable development of cities.

Portland is highlighted in the literature as a city that has benefited from UGB implementation, though previous studies have evaluated the UGB to be both effective as well as ineffective in managing growth (Jun, 2004). Jun (2004) conducted an analysis of commuting flow patterns that suggested that the UGB for the city of Portland has been ineffective in terms of controlling sprawl, minimizing car usage, and promoting public transit. These outcomes were strongly influenced by the growth in Clark County, Washington, which did not establish an UGB until 1995, but is part of Portland's Metropolitan Statistical Area (Jun, 2004), illustrating the necessity of a regional approach to establish and regulate UGBs.

Sprawling patterns of development consume vast swaths of land that were formerly farmland. Loss of farmland has occurred at an extremely high rate in the US, estimated at a rate of 3,000 acres per year in 1980, as urban areas continue to extend outward, the loss of agricultural land becomes inevitable, subsequently decreasing the nation's domestic food supply (Daniels, 2000). It is more profitable to sell off farmland for development—land values, as a result, become unaffordable to farmers. Additionally, the development of land as commercial or residential increases the tax base and promotes economic growth. The state of Oregon has recognized this and in response has implemented statewide land-use policies that require management of agrarian lands through exclusive farm use districts (EFU). These districts are found in the protected land outside the growth boundary. There is also zoning within the UGB for farming (Marin, 2007).

Land values of EFU districts have been found to vary depending on accessibility to Portland's UGB. Parcels that are accessible to urban areas have higher values than those parcels that are inaccessible. Farms within the actually UGB carried a value almost three times greater than farms in EFU districts (Marin, 2007). The value of farmland is always lower than the value of developable land making it harder to limit the sale of farm land for development and, thereby, making it more crucial to protect farmland through planning.

In addition to farmland, open space and natural ecosystems are protected through Oregon's planning policies. Analysis of data collected by the U.S. Department of Agriculture (USDA) Forest Service through the Forest Inventory and Analysis Program has shown that open space and natural ecosystems that are converted to developed land tend to be within the Portland's UGB (Kline & Alig, 1999), implying that the boundary has effectively promoted infill. However it remains uncertain as to whether UGBs will be successful in reducing development on all available land (Kline & Alig, 1999).

2.3 Other Examples

Lancaster County, Pennsylvania, has implemented urban growth boundary policies at a county level in order to protect agricultural lands. Lancaster has a rich history of agriculture, supported by the Amish and Mennonite populations. During the 1980s, agricultural land was lost at a rate of 3,000 acres per year to urban development (Daniels, 2000). To counteract this unprecedented land-use change, the county implemented planning policies in order to protect agrarian land uses. As of 1993, twenty growth boundaries had been established around cities and villages within the county as a means of protecting farm land (Daniels, 2000). Furthermore, high land values make it difficult for new farmers to buy land and for exisiting farmers to acquire additional acreage; these issues are being addressed through easements, zoning, and protection policies (Daniels, 2000).

Finally, greenbelts have been used as a growth management policy. A greenbelt is essentially a designated protected area encircling a city. Seoul, South Korea, has had a long established greenbelt policy. Seoul's greenbelt has been very rigid in nature while coinciding with rapid population growth. The combination has adversely affected spatial matches of housing locations and job locations, because the greenbelt interferes with contiguous growth and results in leapfrog-style growth that accelerates sprawl. Additionally, the rigidity of the policy has created a spatial mismatch of housing and jobs for the people of Seoul resulting in increased commuting (Bae & Jun, 2003).

Portland's UGB seems to be a dominant focus of the literature for smart growth and UGB policies, but there are many cities that have implemented policies to manage growth. Some cities have implemented policies that have been more effective than others, although continued research is necessary in order to determine how effective urban growth boundaries are in containing growth and protecting farmland, forest, open space and ecosystems and generating livable and socio-economically diverse cities.

2.4 Boulder, Colorado

Unlike Oregon, the state of Colorado has not implemented statewide planning policies; instead planning is relegated to cities and counties (Pollock, 1998). Since 1990, Colorado has experienced unprecedented population growth, especially in the Front Range urban corridor (along Interstate 25 (I-25) from Pueblo, Colorado, to Cheyenne, Wyoming) and, in particular, in the Denver Front Range region seen in Figure 1 (including Adams, Arapaho, Boulder, Denver, Douglas, El Paso, Jefferson, Larimer, and Weld Counties) (Census, 2000). The 1990s saw a shift in population distribution throughout the United States, in which regions of the South and West experienced increases in population growth and the Midwest and Northeast experienced loss in terms of national distribution (Perry & Mackun, 2001).

Denver is the second largest city in the Rocky Mountain west, after Phoenix, Arizona. In the Denver Front Range region, Douglas County led in population growth during the 1990 decade with an increase of 191 percent (Census, 2000). During the 1990's, growth in most counties ranged between 20.2 percent and 37.3 percent per decade (Census, 2000). Denver County had the lowest increase at 18.6 percent per decade

(Census, 2000). Boulder County found itself in the middle at 29.3 percent per decade (Census, 2000). Within Boulder County, the city of Boulder experienced a growth rate of 18.9 percent per decade between 1990 and 2000 exceeding the national average of 13.2 percent per decade (Census, 2010). However, the city of Boulder had the lowest decadal growth rate in Boulder County, being surpassed by Longmont at 37.9 percent, Louisville at 53.2 percent, and Lafayette at 59.9 percent (Census, 2005). The Denver Front Range is anticipating growth of over 700,000 over the next two decades, making growth policy dialogue critical for the region (Sheehan, 1998).

The city of Boulder has an interesting history of growth policies. Between 1950 and 1970, the city had an increased annual population growth rate between 4 and 6.3 percent, while most of the other cities and towns in Boulder County were experiencing declining growth or annual growth measuring below 2 percent (Census, 2010). Population growth is a key driver in the implementation of growth policies. During the decade of the 1950s, the city of Boulder experienced its highest yearly average growth rate at 6.3 percent. The concern for population growth and its subsequent effects on development resulted in the implementation of a service area concept, which limits the extent to which public services are offered and, essentially, creates a growth boundary in the process. In 1959, a “blue line” amendment was added to the Boulder Charter restricting city water service above 5,750 feet and which was later applied to sewage services (Pollock, 1998). In 1967, Boulder was the first city in the United States to implement a tax to preserve open space as a growth management policy (Pollock, 1998). And in 1970, Boulder defined the geographic extent to which the city could expand onto the plains with the establishment of a 27,000 acre greenbelt (Pollock, 1998). Later refinement of the policies resulted in city water and sewage services being limited to the extent of the established city boundary.

The city of Boulder houses a number of large employers for the region, including the University of Colorado flagship campus, IBM Corporation, Ball Aerospace and Technologies, the National Institute of Standards and Technology (NIST) Boulder Laboratories, the National Oceanic and Atmospheric Administration (NOAA) regional office, the National Center for Atmospheric Research (NCAR), Covidien, Amgen, Boulder Valley School District, Community Hospital Association, City of Boulder Government, and Boulder County Government (Boulder, 2009). With the limits on growth instituted by the city, the potential for a mismatch between available housing units and jobs is high. Employment opportunities are encouraged to grow and locate in Boulder, but additional housing is not planned for in conjunction with increased employment opportunities. In contrast to Oregon's policies, Boulder's boundary has not been defined to accommodate projected growth. The subsequent effects include a spatial mismatch between jobs and housing and an increased number of people having to commute into the city.

Boulder County is a member of the Denver Regional Council of Governments (DRCOG) along with Adams, Arapahoe, Broomfield, Denver, Clear Creek, Douglas, Jefferson, and Gilpin counties. DRCOG is a regional planning commission for the greater Denver Metro Region, initially formed in 1955 as a four county planning and development authority to address growth and planning issues on a regional level.

Currently, DRCOG is working on "Metro Vision 2035", which includes the "Mile High Compact". The Mile High Compact addresses how growth will be managed in the region. DRCOG is not an elected entity, and therefore the growth policies it proposes, including the Mile High Compact, are voluntary agreements that counties and municipalities choose to comply with. Metro Vision 2035 focuses on growth and development, transportation, and the environment and includes expansions to the 2006 defined service area boundary. DRCOG offers a similar regional planning approach as that found in Portland, except that in Portland the planning body is part of the regionally elected government (DRCOG, 2010).

2.5 Expected Outcomes Working Hypotheses

Population growth is a driving factor in the establishment of growth management policies. Unfortunately, the policies established by Boulder have been unilateral and rigid in nature. I hypothesize that the data will show that the urban fabric of Boulder and the urban morphology of the region have been influenced by Boulder's implemented growth policies.

Based on my review of the literature, I expect that the spatial influence of the growth policies to be defined by commuting patterns, with a significant portion of commuters coming in from the surrounding areas. Boulder is a large employment center with stringent growth limits in place since the 1970s; there has been a growing disparity between the number jobs and the number of housing units. Because jobs have surpassed housing units, people are forced to reside outside of Boulder. As a result of the growth boundary established by Boulder, the data should show an increase in the number of commuters to Boulder from outlying areas.

As a result of the mismatch between housing and jobs, housing within the city of Boulder becomes more valuable. Because of growth limiting policies, there is a high demand for housing in Boulder, but there is a limited amount of housing, which forces values to rise. This limits the demographic that can afford to live in Boulder. I hypothesize that the city of Boulder will have higher housing values than the surrounding areas. The same is expected for income distributions, because only families with high income can afford the higher priced homes. As housing values increase and become less affordable, lower income families relocate. The overall hypothesis, therefore, is that the growth boundary policies and growth management policies have had negative impact on the city and the region, including the promotion and development of sprawling subdivisions and decreased livability for the region.

Boulder is contained by a distinct greenbelt, which limits the horizontal extent, and city policies restrict building height limiting the density of development. I expect that there will be some infill in the city, while most growth has been funneled to the surrounding areas in the form of suburban sprawl. Some of the surrounding towns near Boulder, such as Superior, Lafayette, Louisville, and Broomfield, have experienced large increases in population growth, which should be evident both visually and statistically from the analysis.

3 Data & Methods Overview

A variety of methods were employed for this research, including remote sensing, GIS, and statistical analyses. Remote sensing was used to determine land-use changes for the study area, including changes in extent and density of impervious surfaces, as well as loss of land to urban development. Combinations of mapping and graphical techniques were used to assess flow of commuters into Boulder. Statistical analyses were used to analyze both housing values and household income values of Boulder relative to the surrounding area. A descriptive analysis was used to compare the number of housing units with the number of jobs in the city of Boulder. For most analyses comparison of data sets were conducted at the unit of the municipality to assess the relationships between the variables in all cases except for temporal commuter flow data, which were only available at the county level prior to the 2000 census. Municipalities are geographical areas defined by a political boundary with their own elected government; both cities and towns are considered municipalities (Ehrlich, Flexner, Carruth, & Hawkins, 1980).

The municipality data came predominantly from the State of the City Database System (SOCDS) maintained by the United States Department of Housing and Urban Development. SOCDS is a compilation of decennial census data for the 1970, 1980, 1990, and 2000 censuses. Data are available at variable spatial units: individual municipalities, the surrounding suburban area, and the Primary Metropolitan Statistical

Area (PMSA), to name a few. The data incorporate numerous census variables for individual cities by the decadal census. The data set includes place ID, city name, Metropolitan Statistical Area (MSA), PMSA code, whether the city is a central city, the Core Based Statistical Area (CBSA) name, the PMSA name, population, median household income, and median household owner's value, to name a few of the attributes included (SOCDS, 2005).

The remote sensing data were chosen based on image quality and correspondence closest to decennial census resulting in Landsat images from 1984, 1990, 1996 and 2002. The 1984 was the earliest available and best quality image for the area. The smallest unit of analysis is ideal. All data were available at the municipality unit; therefore this unit was chosen for comparison. The census block group unit was used in conjunction with the municipality scale for the remote sensing data, as the smaller block group unit allowed for a more detailed assessment of land-use change. The temporal commuter flow data were not available at the municipality scale; it was only available at the county-level.

Further discussion of data, methods, and results for each small study follows in the subsequent sections. Data sets used for this project are summarized in Table 1.

Table 1. Project Data

Research Question	Topic	Source
a. How have commuting patterns changed between 1970 and 2000?	Commuting Flow Patterns	Census Transportation Planning Products - Place-to-Place Worker Flow Data; Bureau of Economic Analysis temporal county to county flow - Municipality unit used for comparative analysis
b. How have housing values and income values changed between 1970 and 2000?	Housing Values & Income Values	SOCDS - Municipality unit
c. How has the balance between jobs and housing changed between 1970 and 2000?	Number Housing Units Number of jobs	SOCDS -Municipality Unit
d. How has the percent of impervious surface cover changed between 1984 and 2002?	Land-cover Change	Landsat 5 Thematic Mapper (TM) 30-m resolution imagery -Municipality and block group unit

4 Commuter Flow and Identifying Boulder's Hinterland

4.1 Data & Methods

The goal of examining commuter flow data was to identify any existing patterns, and through these patterns define Boulder's hinterland. Commuter flow data are available from Census Transportation Planning Products (CTPP, 2000) and the Bureau of Economic Analysis through the U.S. Department of Commerce (BEA, 2004). For the 2000 census only, the CTPP provides commuter flow data in a multi-scalar format. The data set provides both residence location and work location in variable spatial units. Place-to-place commuter flow data were use for this study in order to have a consistent unit for comparison. Place-to-place commuter flow is by municipalities, resident municipality to work municipality. Temporal analysis between the 1970 to 2000 censuses could only be conducted at a county-to-county unit, available from the Bureau of Economic Analysis (BEA, 2004).

The data were tabulated from the CTPP to determine the number of commuters into Boulder and what municipality they originate from. The data set includes the location of residence and the location of work and provides a count of commuters for each combination of residence locations and work locations. The number of commuters to Boulder was defined by their work location. These data were used in conjunction with Labor Force data from the SOCDS (2005). The number of commuters to

Boulder for an individual municipality was divided by the number of workers in the labor force for the same municipality to create a percent of commuters by labor force to Boulder. This percentage was used to define whether a municipality belongs to Boulder's hinterland. The U.S. Office of Management and Budget advocates a minimum threshold of commuting exchange between counties of 15 to 25 percent in order to join a county to a metropolitan statistical area (OMB, 2000). Here, the study area was delimited by using a threshold of fifteen percent to define Boulder's hinterland (Figure 2).

Further statistical analysis was conducted on the percent of commuters-by-labor-force for each city to determine if there was a spatial association between location and the attribute value of percent commuter-by-labor-force. Spatial autocorrelation and cluster analysis were used to determine if in fact there were spatial associations. Spatial autocorrelation relies on the attributes of spatial objects by measuring the level of similarity between measured attributes within close proximity to each other (Ding & Fotheringham, 1992; McGrew Jr. & Monroe, 2000; ESRI, 2011b). The Moran's I coefficient is used to measure correlation which ranges from -1 to +1, corresponding to negative-dissimilar, positive-similar, zero-randomly dispersed (Ding & Fotheringham, 1992). These values can be converted into a z-score. Spatial autocorrelation was extended with Cluster-and-Outlier analysis in order to visually represent the clustering effect. Employing the Moran's I coefficient. A z-score of +/- 1.96 at a 0.05 significance level was utilized for both spatial autocorrelation and cluster analysis to determine whether or not to reject the null hypothesis which assumes that the Moran's I coefficient will be zero, indicating that the pattern is random (Ding & Fotheringham, 1992; ESRI, 2011a).

Analyzing commuter data through time at the county level was limited because the spatial unit of analysis was so coarse (i.e. county level). Thus, rather than apply statistical tests, descriptive analysis of the commuter count was used to assess changes over time. In addition to raw commuter counts, percents of commuters by employed residents and by total workers were calculated. Employed residents are employed persons residing in a specified geographical boundary, in this case the specified MSA. Total workers equates to the total number of jobs within a specified geographical boundary (SOCDS, 2005). In order to do this the county units were converted to MSA units. MSA data acquired from SOCDS could then be incorporated with the commuter flow data. Designated MSAs encompass the entire county they are located in and for larger Metro areas the MSA may include multiple counties; 1990 MSA standards were employed and included the following MSAs (with counties): Boulder (Boulder County), Denver (Adams, Arapahoe, Denver, Douglas, and Jefferson County), Greeley (Weld County), and Fort-Collins-Loveland (Larimer County). Thus, the commuter data were easily converted by combining the number of commuters to Boulder for the counties included in each MSA (Census, 1996; Winter, 2011). This data set could then be used in conjunction with labor force and worker data sets from SOCDS for each MSA.

The number of commuters to Boulder from each MSA was graphed to illustrate changes over time. Subsequently, percent of commuters by Total Jobs and Total Employed Workers were calculated. The percent commuters by Total Jobs were calculated by dividing the total number of commuter's to the Boulder MSA from a specified MSA. Pie charts and line graphs were used to display this information graphically per decade. The same process was repeated replacing total jobs with total employed workers.

4.2 Results

The purpose of this analysis was to determine if the growth policies have influenced commuting patterns into Boulder. The temporal study of commuter flow patterns was limited by the coarse spatial units of available data. Place-to-Place commuter flow is much more insightful than County-to-County commuter flow; however, the Place-to-Place commuter flow was only available for the 2000 census. It is very difficult to compare a county-level unit to a city-level unit, because a county-level unit includes a number of cities and towns. It would be much more insightful to know between which cities and towns in a county people are commuting. Census 2000 place-to-place commuter flow data were used in conjunction with SOCDS labor force data to define the hinterland for the city of Boulder, and further statistical analysis using spatial autocorrelation and map cluster analysis was applied to the percent of commuters by labor force in order to assess spatial associations between the attribute, percent commuters by labor force, and nearby locations (Ding & Fotheringham, 1992).

Boulder's hinterland was defined by the percent of commuters by labor force. It was found that 63.8 percent of the city of Boulder's labor force commuters originated in the city of Boulder. A threshold of 15 percent was used. Cities and towns along the arterials that enter Boulder, US Route 36 and Highway 119 strongly contribute to

Boulder's work force. The following cities and towns contributed large portions of their labor force (>15%) to Boulder designating them as part of the hinterland: Gunbarrel (54.4%), Niwot (38.4%), Lafayette (33%), Louisville (32.5%), Superior (30.3%), Erie (27.6%), and Longmont (20.6%). On the cusp were Dacono (14%) and Broomfield (13.8%) after which the percents dropped off significantly. These areas can be seen in Figure 2. Commuters from Boulder, Erie, Gunbarrel, Lafayette, Louisville, Longmont, Niwot, and Superior with the destination of Boulder account for 60,225 of the 127,690 total commuters residing and working within Boulder County (CTPP, 2000; BEA, 2004). The 60,225 are commuters originating from a designated municipality in Boulder County; Figure 2 does not include commuters originating from the unincorporated or smaller town areas of Boulder County. Note that closer areas contribute more of their work force than areas further away.

Spatial autocorrelation was used to determine if there is a spatial relationship between the percent of commuters by labor force and municipality location (McGrew Jr. & Monroe, 2000). Statistical significance was measured with z-scores and p-values indicating whether or not to reject the null hypothesis. The result was significant with a p-value of 0.01, supporting rejecting the null hypothesis, and the positive Moran I coefficient of 0.46 indicated a clustered effect (Ding & Fotheringham, 1992; ESRI, 2011b). Figure 3 shows that at a probability of one percent the null hypothesis can be rejected because the z-score of 9.6 is greater than the critical z-value of 2.58 indicating a clustering effect. Therefore there is positive spatial autocorrelation between the ratio of commuters by labor force and municipality locations. This suggests a strong association between Boulder and the surrounding area, supporting the notion that Boulder has a strong draw on commuters from the surrounding area. This effect drops off as distance to Boulder increases

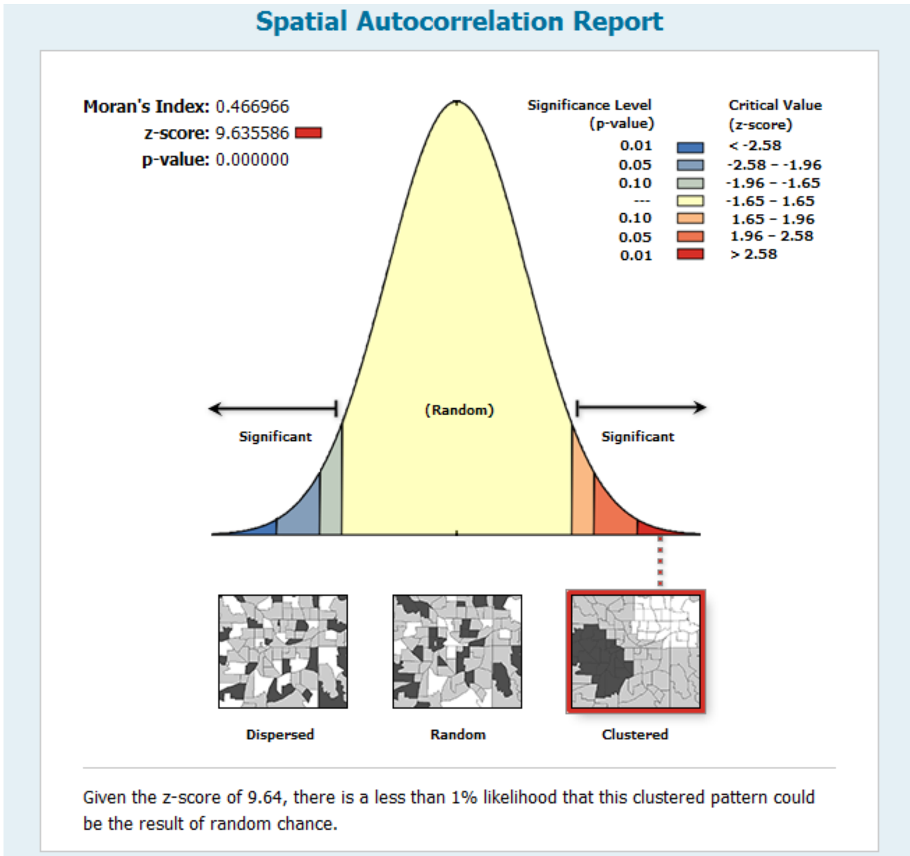

Figure 3. Spatial Autocorrelation Report (*generated by:* ARC GIS *data source:* SOCDS, 2005; CTPP, 2000)

The findings from spatial autocorrelation were visually displayed by employing Cluster and Outlier Analysis. Statistical significance was again tested with z-scores and p-values indicating whether or not to reject the null hypothesis that spatial patterns are random. The significance level of 0.05 was used. Data were classified as HH, high values surrounded by high values, for a statistically significant cluster of high values, which rejects the null hypothesis that the spatial distribution is due to random chance at a five percent significance level. Figure 4 shows the areas found to have high values next to high values creating a clustering effect that is statistically significant: Boulder, Erie, Gunbarrel, Lafayette, Louisville, Niwot, and Superior, indicating that the ratio value of commuters by labor force is of a similar magnitude for these areas based on the Local Moran’s I statistic indicating spatial association (ESRI, 2011a).

Both spatial autocorrelation and Cluster-and-Outlier analysis were necessary in order to map the findings. Spatial autocorrelation provided a statistical output indicating that there is a clustering effect and thus positive spatial autocorrelation, while cluster outlier analysis actually shows where the clustering effect is taking place as seen in Figure 4.

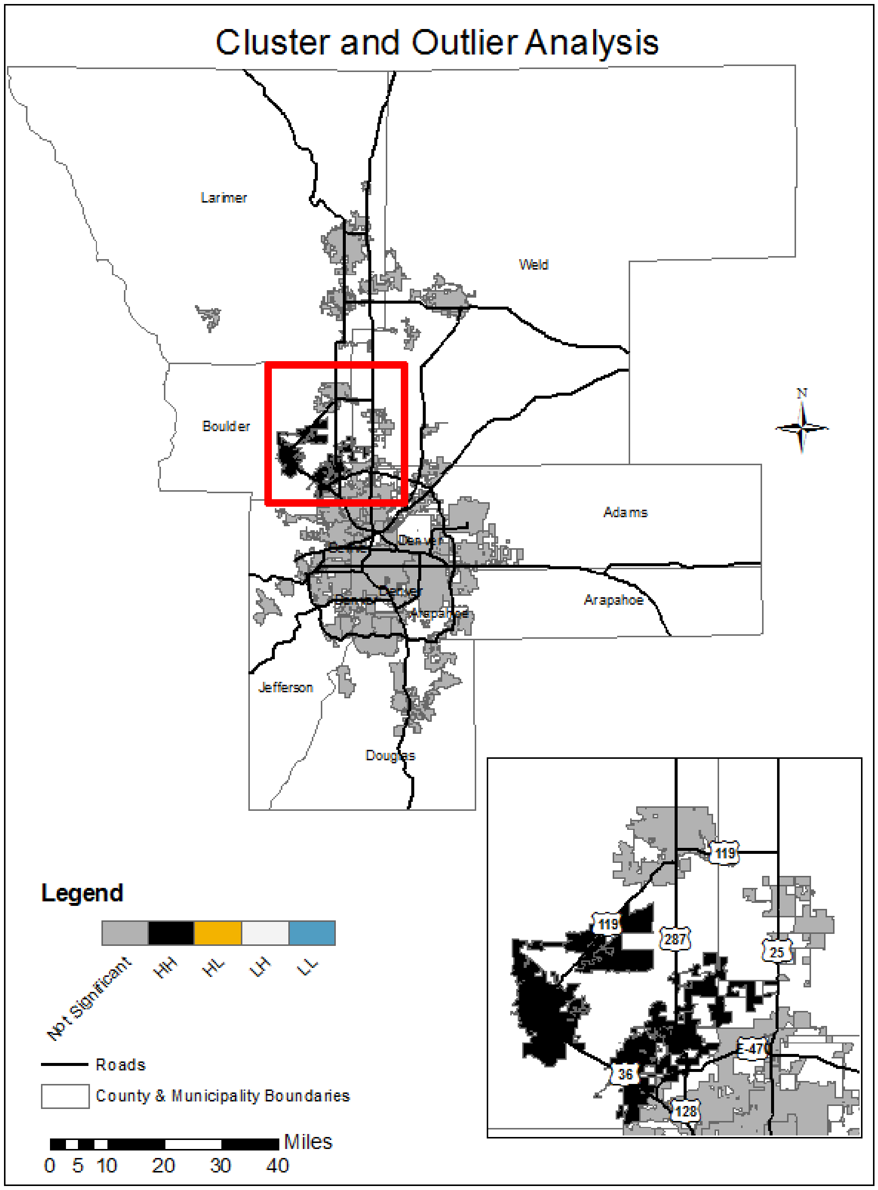

Figure 4. Cluster-and-Outlier Analysis (*generated by*: ARC GIS *data source:* SOCDS, 2005; CTPP, 2000)

Although the temporal analysis for 1970-2000 decennial censuses was limited due to the coarser unit of analysis, it still provided insight to commuting patterns. Comparable to the Place-to-Place data, in which the largest percentage of commuters to Boulder are from surrounding areas in Boulder County, the majority of commuters to Boulder County were found to originate in Boulder County. Figure 5 includes data on commuters to the Boulder MSA from the surrounding MSAs of Denver, Fort-Collins-Loveland, and Greeley from 1970 to 2000. Commuters that remain within Boulder MSA far exceed the number of commuters coming in from other MSAs, because of this the y-axis in Figure 5 was transformed by log10 in order to illustrate trends for all four MSAs on the same plot. The number of commuters within the Boulder MSA, including the city of Boulder, has grown from about 41,000 in 1970 to over 120,000 in 2000, an increase of threefold. The Denver MSA was the second largest contributor, growing from just over 4,000 commuters in 1970 to just over 38,000 commuters in 2000, while the commuter contribution from the Fort-Collins-Loveland and Greeley MSAs have each grown from just around 700 in 1970 to almost 8,000 in 2000 (BEA, 2004). However, these MSAs do not contribute enough commuters to be included as part of Boulder's hinterland. All of the origin MSAs displayed in Figure 5 exhibit striking increases from 1970 to 2000. In the case of Fort-Collins-Loveland and Greeley there is a tenfold increase from 1970 to 2000 in the number of commuters they contribute to the Boulder MSA.

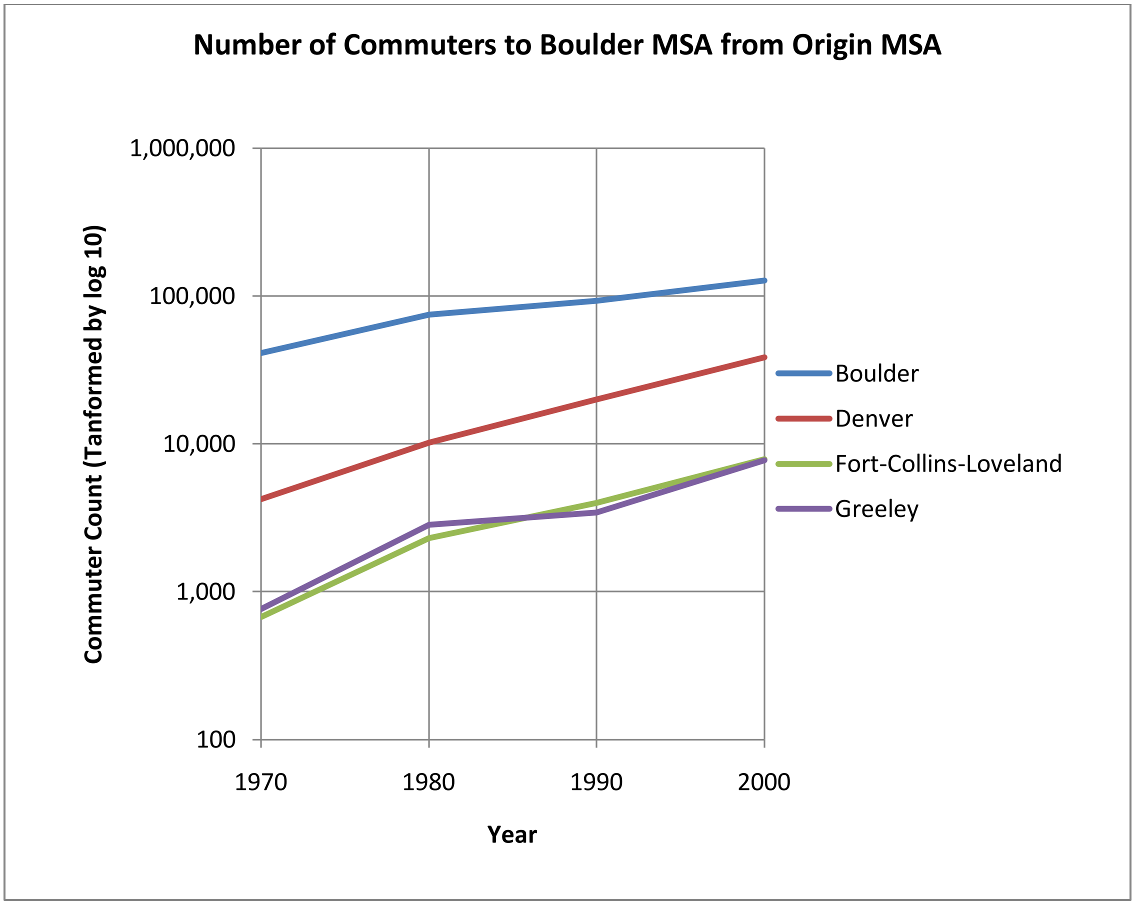

Figure 5. Number of Commuters to Boulder MSA from Origin MSA; y-axis transformed by log 10 (*source:* BEA, 2004)

Commuter numbers for all four MSAs exhibited evident growth between 1970 and 2000; however, the coarse unit of the MSA limits the interpretation of the number of commuters in relation to Boulder. Figure 6 illustrates the percent of total commuters to the Boulder MSA by the origin MSA. The largest percent of total commuters to the Boulder MSA originate in the Boulder MSA; however, the proportion of commuters to Boulder from the surrounding areas has increased from 1970 to 2000. The proportion of commuters to the Boulder MSA originating in the Fort Collins-Loveland and Greeley MSAs has increased substantially, from just around 1.5% to 4.3% for each. The percent of commuters to the Boulder MSA originating in the Denver MSA has more than doubled.

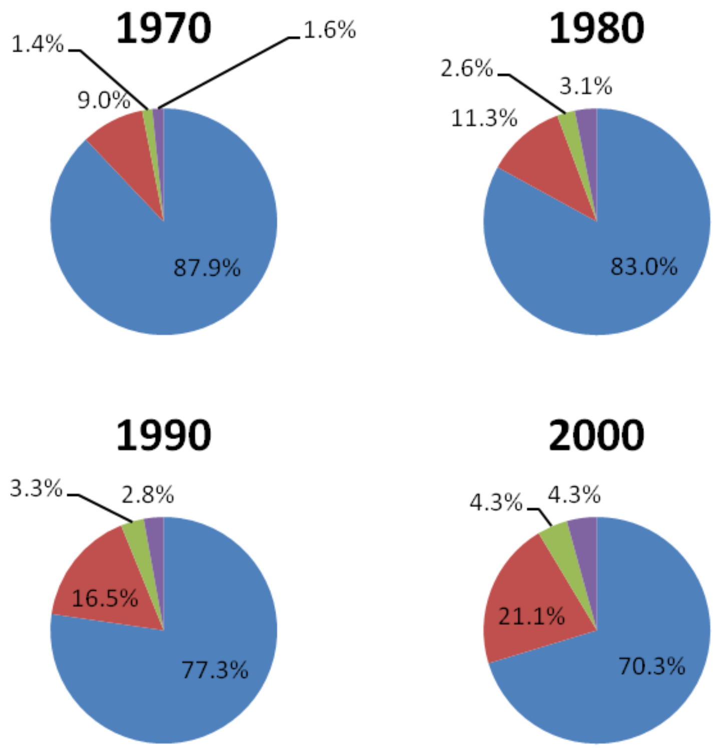

Figure 6. Percentage of Total Commuters to Boulder MSA from Boulder (blue), Denver (red), Fort Collins-Loveland (green), and Greeley (purple) MSAs (*source:* BEA, 2004; SOCDS, 2005)

Boulder draws predominantly from the immediate area surrounding it, as evident in the 2000 place-to-place commuter flow data. The 2000 data support the fact that Boulder houses a large number of jobs for the region with people commuting in from the surrounding communities. The temporal data indicate that the majority of commuters to the Boulder MSA are from within the MSA; with Boulder being a large job hub for the region it could be assumed that many of these commuters in the Boulder MSA commute to Boulder. The following sections will also support the conclusion that commuting from the surrounding area has increased through time as the mismatches between locations of jobs and housing, housing and income values, and changes in impervious surface are explored. Despite Boulder's strict growth policies it has continued to grow as a significant job hub for the Boulder region, while large numbers of commuters are living in the surrounding communities.

5 Housing and Income Value

5.1 Data & Methods

The objective of this analysis is to determine if the housing and income values for Boulder are statistically higher than the corresponding values for Boulder County, the Front Range, and the state of Colorado. Housing values and household income values were obtained from SOCDS for the decennial censuses (1970, 1980, 1990, and 2000) at the municipality-level unit. Household income is defined as the total income of all those living in the same household. Household owner's value represents the owner's estimate of the property value (SOCDS, 2005). In this data set, the dollar values were reported for their respective census year (i.e., 1970 census = 1970 dollars); subsequently, all dollar values were converted to 2010-dollar values using the Bureau of Labor Statistics CPI (Consumer Price Index) Inflation Calculator. Table 2 indicates the inflation rate for each census.

Table 2. Inflation Rate (*source:* SOCDS, 2005; BEA 2004)

Census	Inflation Rate for 2010 Dollar conversion
1970	562%
1980	264.63%
1990	166.837%
2000	126.63%

Since the data are for individual cities, the data set includes all places that were designated as cities for their respective census. Therefore, there are more cities in the 2000 census than in the 1970 census. For each census date, all data for the state of

Colorado was utilized to generate random samples representing the state for analysis. Additionally, cities that fall within a designated MSA were assigned to their appropriate MSA. The MSAs were employed to produce random samples of the Colorado Front Range region, which included all cities in the following MSAs: Boulder, Colorado Springs, Denver-Aurora, Fort Collins-Loveland, Greeley, and Pueblo. In addition, the Boulder region was composed of all cities within the Boulder MSA, which corresponds to Boulder County.

Housing value and household income are both reported as median values and, as a result, nonparametric statistical tests were used. Nonparametric tests do not require an understanding of the population parameters and can be applied to test for difference of medians between independent samples. Additionally, there are fewer limiting assumptions about the nature of the distribution of the population for nonparametric tests in contrast to the parametric counterparts (McGrew Jr. & Monroe, 2000). Nonparametric, one-sample hypothesis tests (also known as sign tests) were used to test the null hypothesis that there is no difference between Boulder's income or housing values compared to the county, the Front Range, or the state. The second null hypothesis tested was that Boulder does not have higher income or housing values than the county, the Front Range, or the state.

For the state and Front Range, there were enough cities to randomly sample. This was conducted as an iterative process. Twenty housing values were randomly sampled for the state and the Front Range. This was repeated using income values. The process was repeated multiple times to ensure that any observed statistical significance were robust. Once the random sample was extracted each datum was assigned a (+) or a (–) designating whether the value was above or below the value for the city of Boulder. The values for the city of Boulder are listed below in Table 3.

Table 3. City of Boulder Income and Housing Values (adjusted to 2010 Dollar Values) (*source:* SOCDS, 2005)

Census	**Median Household Income ($)**	**Median Housing Value ($)**
1970	24,037	131,278
1980	44,310	228,905
1990	49,062	204,375
2000	56,658	385,842

Minus signs were tallied and divided by the sample size to provide the proportion, needed to calculate the z-statistic, which was compared to the critical value (α=0.05) to determine whether or not to reject the null hypothesis. A total of 86 sign tests were conducted all following the same process. The state and Front Range housing values were sampled five times for each decade. Only one sample of housing values was conducted at the county level utilizing all values per census excluding 1970 due to lack of data. The same sampling schema was used for income values.

5.2 Results

The city of Boulder had higher housing values than the state, the Front Range and the county. For all 43 samples, the null hypothesis was rejected at the five percent significance level, indicating a robust finding that Boulder’s housing values are different and higher in comparison to the state of Colorado, the Colorado Front Range, and the rest of Boulder County. The results for the median household income were not as clear-cut, and whether Boulder was different from the state, the Front Range and the county was variable: sometimes Boulder income was statistically different and sometimes it was not.

Boulder's median household income was not higher than the Front Range or the county. Additionally, in 1970 and 2000, Boulder's household income was not higher than the state; however, in 1990 it was found to be higher than the state for all five samples. Lastly, for the 1980 state samples there was variability among the samples.

The results of the hypothesis testing indicate that Boulder has higher median housing values than the state of Colorado, the Front Range, and the county. Although parametric hypothesis testing is more sensitive than the nonparametric counterpart used here, the fact that the null hypothesis was rejected supports the statistical significance with higher confidence, because it is actually harder to reject the null hypothesis in a nonparametric hypothesis test (Burt, Barber, & Rigby, 2009). Household income values for Boulder were not found to be statistically different than the state, the Front Range, or the county; therefore, whether income values have been influenced by Boulder's growth management policies remains inconclusive.

The distributions of median household income for the state, the Front Range and the Boulder region are shown in Figures 7a-c; Boulder's income value is designated by the red line, illustrating where Boulder's income value lies in relation to the distribution of all the values for the state, the Front Range, and the county per decade. All years for both the state and Front Range distributions appear to have a positive skew with the number of outliers increasing after 1970. After 1970, Boulder's median income values lie closer to the mean of the medians for both the state and the Front Range. Compared to the other municipalities in Boulder County, the city is just below the mean of the medians.

This relationship is the opposite of the median housing values, which were found to be higher than the region, the Front Range, and the state.

Boulder's has very high housing values in comparison to the income values. As a result of Boulder's strict growth policies limits on building permits have been enforced, resulting in limits on available housing, and this could be one of the major forces influencing housing values. Additionally, Boulder's median household incomes could be influenced by the large population of college students who live within city limits. Lastly, the desirability to live in Boulder may result in people willing to spend a larger portion of their income on housing, while cutting back in other areas.

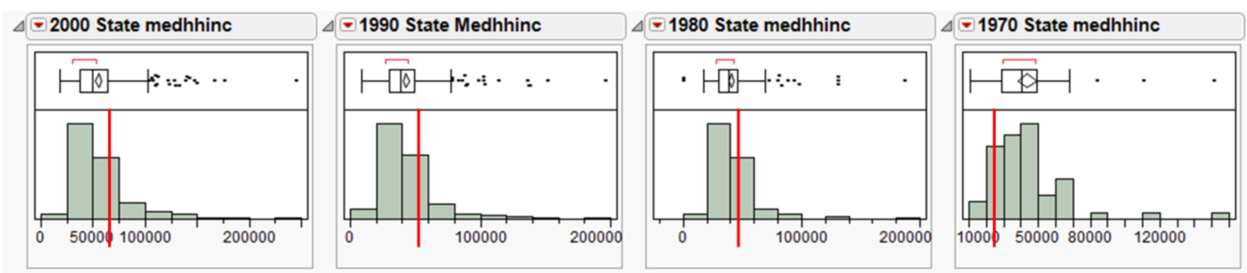

Figure 7a. Median Household Income Distribution for the State of Colorado (The red line indicates the median household income for the city of Boulder) (*source:* SOCDS, 2005)

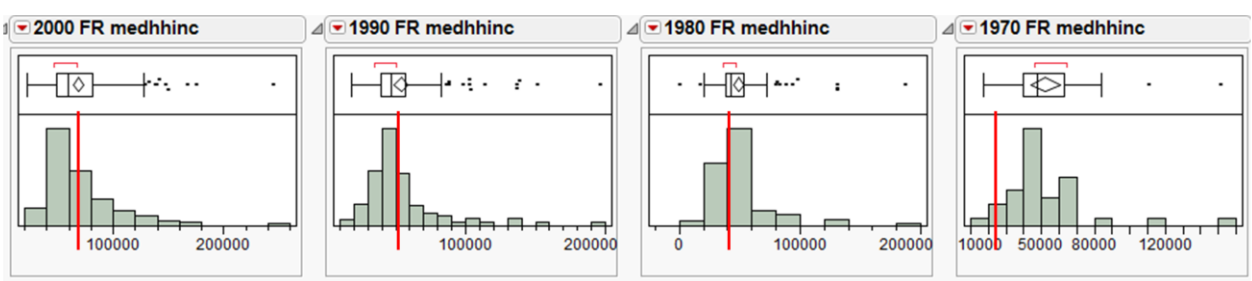

Figure 7b. Median Household Income Distribution for the Colorado Front Range (The red line indicates the median household income for the city of Boulder) (*source:* SOCDS, 2005)

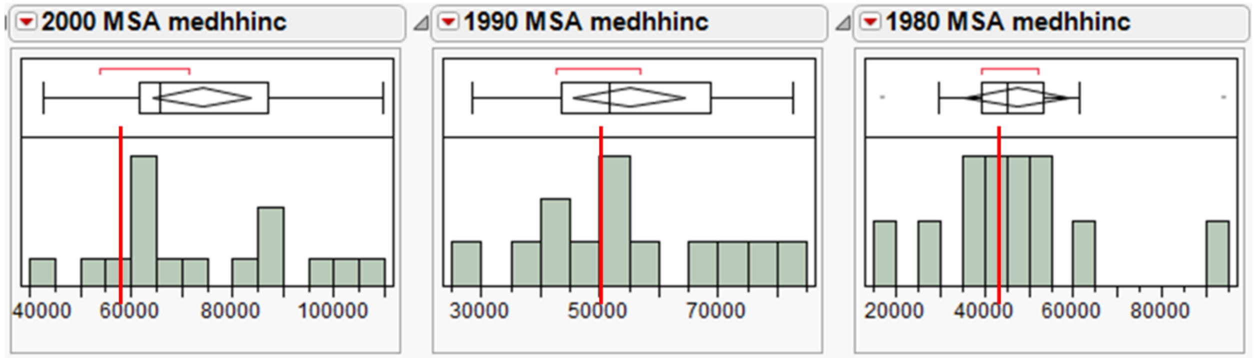

Figure 7c. Median Household Income Distribution for Boulder County (The red line indicates the median household income for the city of Boulder) (*source:* SOCDS, 2005)

6 Housing Job Balance Assessment

6.1 Data & Methods

The goal of this analysis was to determine if there is a mismatch between jobs and housing, and more specifically if Boulder's workforce exceeds its available housing. The relationship between jobs and housing was also explored for municipalities that compose Boulder's hinterland. Jobs were represented by the total number of workers for each municipality (SOCDS, 2005). These data were only available for 1980, 1990, and 2000 for the hinterland cities. Housing counts included both owned and rented units, where a unit refers to homes, apartments, mobile homes, and a group of rooms or a single room that is occupied as separate living quarters (Census, 2009). All data were obtained from SOCDS. The data were normalized by dividing the number of jobs by housing units in order to better interpret the balance between jobs and housing. Previous studies have suggested that a range of 0.75 to 1.25 represents a balance between jobs and housing in the 1970s, however, with the shift from one worker households to two or more worker households, a ratio of 1.5 is considered to be balanced (Cervero, 1989). If the ratio of jobs to housing exceeds this value, there is a mismatch between jobs and housing, indicating insufficient housing for the workforce.

6.2 Results

Table 4 presents the relationship of jobs and housing for Boulder and the municipalities in its hinterland, while Figure 8 illustrates that for Boulder, jobs have been on the rise while housing has been slow to follow, resulting in a disparity between available jobs and available housing. Figure 8 shows the changes in the number of jobs and housing for each of the municipalities in the study area for each time period. The y-axis represents the raw count of houses and jobs and is adjusted for each plot. The normalized data of jobs per household indicates that Boulder surpassed the suggested threshold of 1.5 in 1980, and by 1990 and 2000, the ratio was well above the balanced threshold (Cervero, 1989). One reason for the imbalance may be that Boulder is a job hub for Boulder County (SOCDS, 2005). All other cities in Boulder's hinterland exhibit a closer balance of jobs and housing, or in a number of cases, a housing surplus compared to jobs, essentially balancing the higher number of jobs found in Boulder with the higher number of housing units found in the surrounding areas.

Table 4. Hinterland Job Housing Balance (*source:* SOCDS, 2005)

	Total Housing Units			**Total Jobs**			**Jobs per Housing Unit**		
City Name	1980	1990	2000	1980	1990	2000	1980	1990	2000
Boulder	30213	36162	40473	51959	73650	90720	1.7	2.0	2.2
Broomfield	7232	9116	14267		13992	20090		1.5	1.4
Dacono	860	963	1132			335			0.3
Erie	489	513	2280			945			0.4
Gunbarrel	1975	3962	4207		612	895		0.2	0.2
Lafayette	3699	5775	9096		2856	5570		0.5	0.6
Longmont	16341	20420	27319	15102	20762	32875	0.9	1.0	1.2
Louisville	2264	4778	7360		4405	12285		0.9	1.7
Niwot		1141	1540		690	1965		0.6	1.3
Superior	92	119	3681			1210			0.3

The mismatch found in Boulder has been growing over time, while Broomfield (1.4), Longmont (1.2), Niwot (1.3) have an adequate number of housing units to accommodate the number of jobs available in those locations. While the Louisville jobs per housing value (1.7) falls just over the threshold, the municipality experienced a significant jump in the number of jobs between 1990 and 2000, while the number housing units lagged slightly behind. The other end of the spectrum includes Dacono (0.3), Erie (0.4), Gunbarrel (0.2), Lafayette (0.6), and Superior (0.3) all of which fall well below the threshold of 1.5 indicating a reverse mismatch with abundant housing and minimal jobs, as seen in Figure 8.

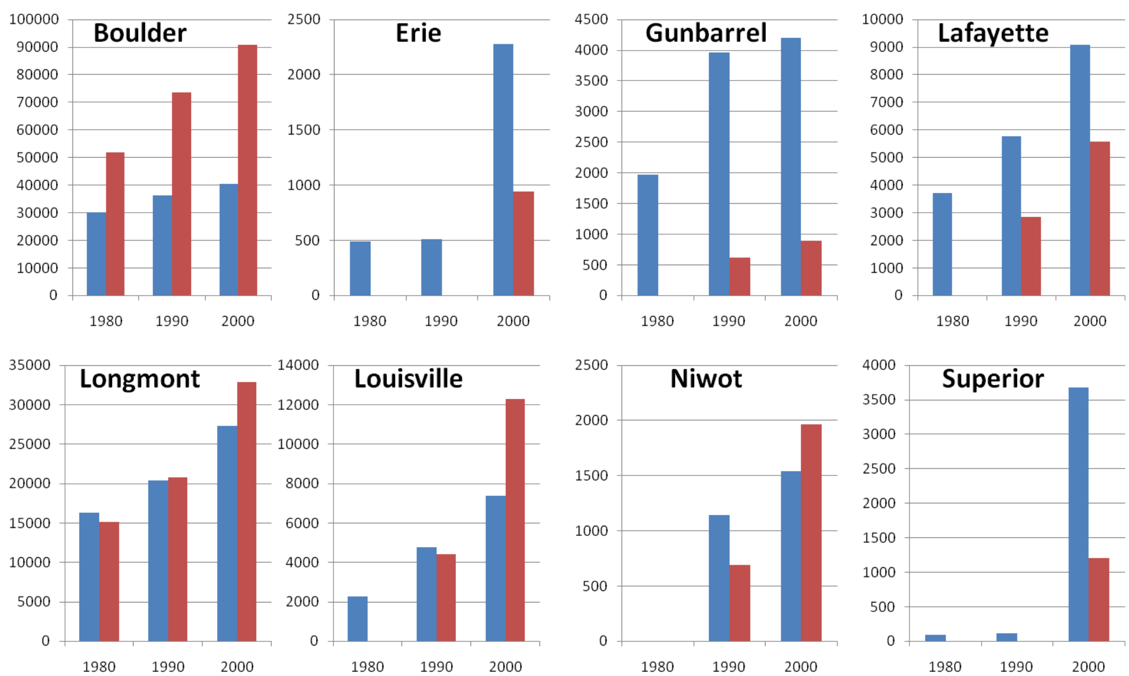

Figure 8. Housing Job Mismatch: Total Housing Units (blue) & Total Jobs (red) (the y-axis represents the raw count and is adjusted for each graph while the x-axis corresponds to the year.) (*source:* SOCDS, 2005)

The data show a mismatch between jobs and housing for Boulder with significantly more jobs then housing; while in some of the surrounding areas the opposite effect has ensued. Places like Erie, Gunbarrel, Lafayette, and Superior have significantly more housing units available than there are jobs. This implies that many of the surrounding areas act as bedroom communities for the job hub that Boulder has created.

7 Remote Sensing & Changes in Extent of Impervious Surface

7.1 Data & Methods

While it may not be possible to directly link all anthropogenic changes in the landscape to Boulder's growth policies, the policies established by Boulder have more than likely played a significant role in shaping the landscape in the region today. The goal of this analysis is to determine the spatial influence of growth policies on the extent and density of development based on changes in impervious surface cover. Impervious surfaces are structural components of the landscape through which water cannot penetrate, including buildings and paved surface areas. Because urban landscapes are heterogeneous in nature, the goal was to quantify impervious surface changes in the area. Through the use of Multiple Endmember Spectral Mixture Analysis (MESMA) and zonal statistics, the changes in impervious surface were quantified for both census block groups and municipality units.

Landsat TM 5 images were used to determine the spatial patterns of urban growth and/or sprawl in the city of Boulder and in the surrounding region. Landsat TM imagery has moderate spatial resolution with 30-meter pixels. Images were obtained for the same month for the following years: 1984, 1990, 1996 and 2002. Each image contained zero cloud coverage. The extent of analysis included the Boulder region, as defined in Section 1.4, including all the area in between municipality boundaries. Initial processing of the images involved mosaicking the two scenes for each year (33/32 & 33/33) and resizing the image to create the study area. Relative atmospheric correction was conducted through empirical line intercalibration. The 1984 image was chosen as the baseline year, and all other images were atmospherically intercalibrated to that image.

MESMA allows for quantification of temporal changes in vegetation, impervious surface, non-photosynthetic vegetation (NPV), and soil. MESMA is an extension of Spectral Mixture Analysis (SMA), which is an image processing method that accounts for mixed pixels (Roberts, Batista, Pereira, Waller, & Nelson, 1998; Roberts, Gardner, Ustin, Scheer, & Green, 1998; Powell & Roberts, 2010). Pixels very rarely are composed of only one component, and in the case of urban landscapes, which are heterogeneous in nature; most pixels are combinations of pure spectral components (endmembers). While SMA forces every pixel to be modeled with the same two, three, or four endmembers, MESMA allows for each pixel to be modeled using different combinations and numbers endmembers (Powell & Roberts, 2010).

Endmembers were chosen based on the heterogeneity of urban landscapes, which are characterized by impervious surface, green vegetation, NPV and soil, but are defined predominantly by the impervious fraction. The goal of endmember selection was to model urban areas well, while modeling non-urban areas was not a high priority. All four images were consulted for endmember selection to ensure that the endmember was the same in all images; meaning that a green vegetation endmember in the 1984 image also has to be green vegetation in the other three images. Careful consideration was given to the selection of NPV and soil, especially for the 2002 image which corresponded to a severe drought year. Inspection of the spectral distribution graphs for endmembers was used to guarantee that the endmember was the same in all images.

Each pixel was modeled as a combination of four endmembers. The endmembers included green vegetation with 3 possible endmembers, a combination NPV and soil with 5 possible endmembers, impervious surface with 10 possible endmembers, and a water endmember as shade. This generated 150 possible models tested for each pixel. Minimum and maximum constraints for non-shade fractions were placed on the model, -0.05 and 1.05 respectively. Additionally, a maximum shade constraint of 0.80 was imposed on the model. Because of the heterogeneous nature of urban areas, it was critical to model urban areas well, which is why there were 10 possible endmembers to represent impervious surfaces.

The output of MESMA is a set of images in which each pixel is characterized by fractions of the input endmembers. Fractions were shade normalized, because these values provide a better characterization of the composition of each pixel. Urban areas contain shade from buildings and trees, but shade is not a tangible object and shifts throughout the day. The amount of change in impervious surface was calculated by subtracting the older image from the newer image, i.e. 1990 image minus 1984 image, to obtain the amount of change per pixel in impervious fractions. The new calculated image was used in conjunction with zonal statistics to aggregate the amount of change in impervious surface cover by municipality and by unincorporated county spatial units so that the data could be directly compared to the other data sets (Rashed, Weeks, Stow, & Fugate, 2005; Rashed, 2008). The municipality unit was somewhat coarse for determining specific areas of change, so the data were also aggregated by census block group units in order to determine more specific areas of change. A mean fractional value was calculated for each block group or municipality area. Those mean fractions were converted to a percent cover. This same process was then repeated for the single band, green vegetation image in order to compare the changes in vegetation through time.

7.2 Results

The MESMA images modeled impervious surfaces well; however, the 2002 image was collected during a severe drought year and natural cover types did not model as well in that image. Based on visual comparison of the MESMA fraction images, change was visible along the two main arterials entering Boulder. Along Highway 36, previously natural landscape was converted to subdivisions in Superior, Louisville, and Lafayette. Leaving Boulder to the northeast on Highway 119, similar changes occurred as natural landscape was converted to subdivisions. Additionally, there are small areas of infill development visible within Boulder.

Change in impervious surface cover was quantified at the municipality-level and block group-level; Figure 9 illustrates the change between 1984 and 1990, 1990 and 1996, and 1996 and 2002. The small scale of block groups reveals more precisely where change is occurring. The fractional values at the municipality level become truncated, since zonal statistics calculates a mean within each boundary, and there are many pixels with low fractions within each municipality. The percent change for Figures 9 and 10 represents the difference in fractional cover between the two dates. The majority of change for impervious surface cover was found to occur between 1990 and 1996, with some change occurring between 1984 and 1990, and almost no change between 1996 and 2002. Superior exhibited moderate (between 0.11 and 0.20) fractional increases in impervious surface cover between 1984 and 1990 and again between 1990 and 1996, while one block group experienced very high (between 0.41 and 0.50) fractional increases in impervious surface cover between 1990 and 1996. Superior's potential for additional growth was ended by Boulder's acquisition of surrounding parcels for open space.

Changes in impervious cover between 1984 and 1990 were found in a number of block groups in Boulder, Gunbarrel, Niwot, Lafayette, Longmont, Louisville and Broomfield. Most of the block groups that exhibited changes averaged moderate (between 0.11 and 0.20) fractional increases in impervious surface cover. Broomfield also displayed moderate (between 0.21 and 0.30) fractional increases in impervious surface cover in some block groups. The region continued to grow between 1990 and 1996 with moderate (between 0.11 and 0.20) fractional increases in impervious surface cover for numerous block groups throughout the regions. Those block groups were found in Boulder, Broomfield, Erie, Gunbarrel, Lafayette, Longmont, Louisville, and Niwot. Lafayette and Louisville also had block groups that experienced moderate (between 0.21 and 0.30) fractional increase in impervious surface cover, while Broomfield and Longmont had block groups that experienced high (between 0.31 and 0.40) fractional increases in impervious surface cover.

Growth in impervious cover means that other cover types are decreasing as natural landscapes are replaced with subdivisions and big box stores. However, as subdivisions age there is also potential for green vegetation cover to increase as a result of tree maturation and, therefore, potential for an increase in the green vegetation fraction. For that reason, in conjunction with examining impervious cover change, it was important to also look at changes in green vegetation cover seen in Figure 10. In many instances block groups that experienced an increase in impervious surface simultaneously experienced a decrease in green vegetation between 1984 and 1990 as well as 1990 and 1996. Because 2002 was a drought year, it was expected that changes in green vegetation between 1996 and 2002 would be minimal, however with almost no changes in impervious between 1996 and 2002, increases in green vegetation were visible in Boulder, Longmont, Superior, Gunbarrel and Broomfield. As developments age, trees mature, and as trees mature their canopy expands increasing the green vegetation fraction for the pixel often with a corresponding decrease in the impervious fraction because it is obscured by the canopy. Most of the increase in green vegetation occurred in subdivisions, which were still being watered despite the drought.

The areas surrounding Boulder have experienced increases of impervious surface cover that can be linked to the increases in commuting patterns and the housing job mismatches in the region. Further dialogue concerning the relationship between commuting patterns, impervious surface increases, housing job mismatches and the housing and income values occur in the discussion section to follow.

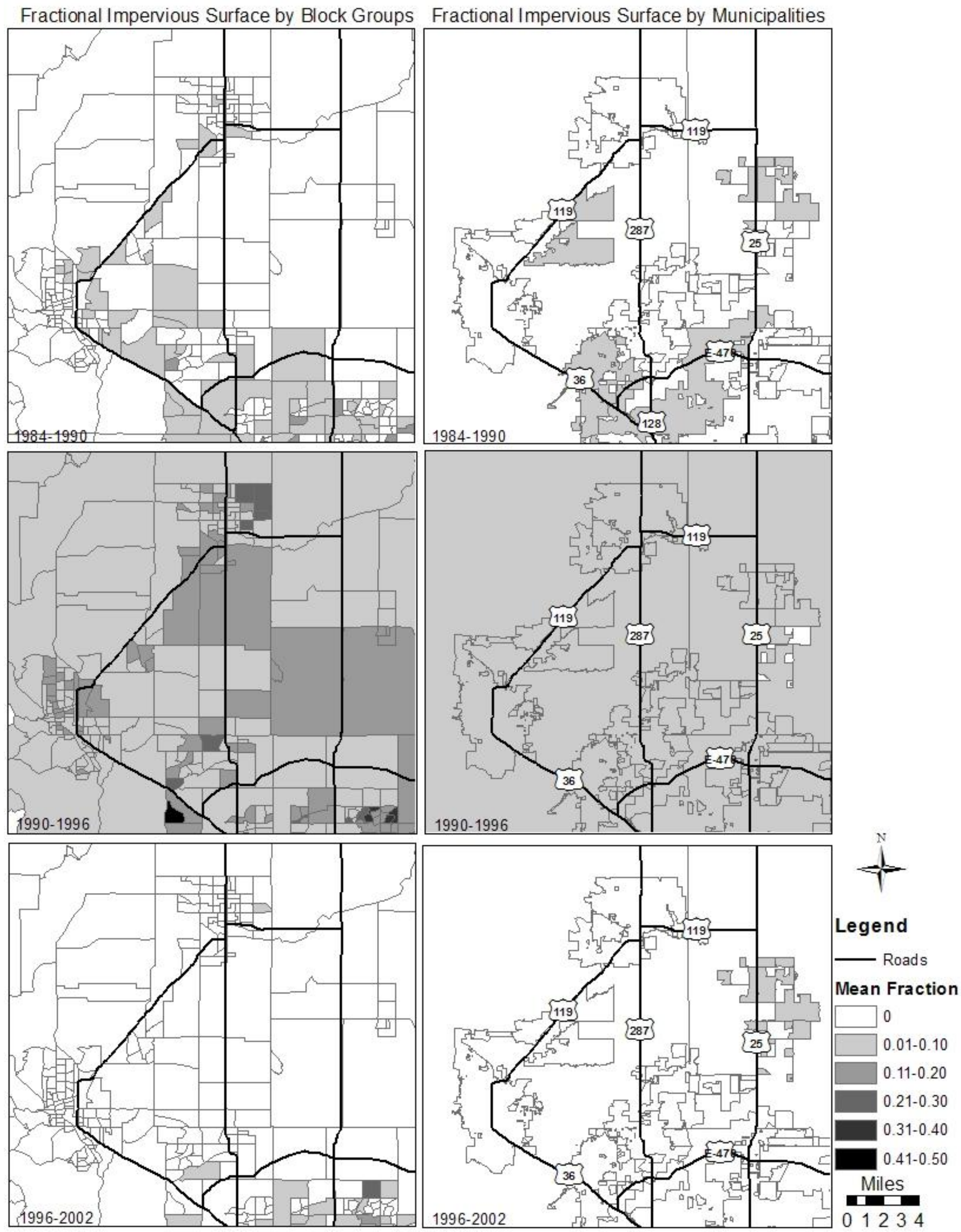

Figure 9. Temporal Changes in Mean Fractional Impervious Surface Cover (*based on MESMA analysis of Landsat imagery*)

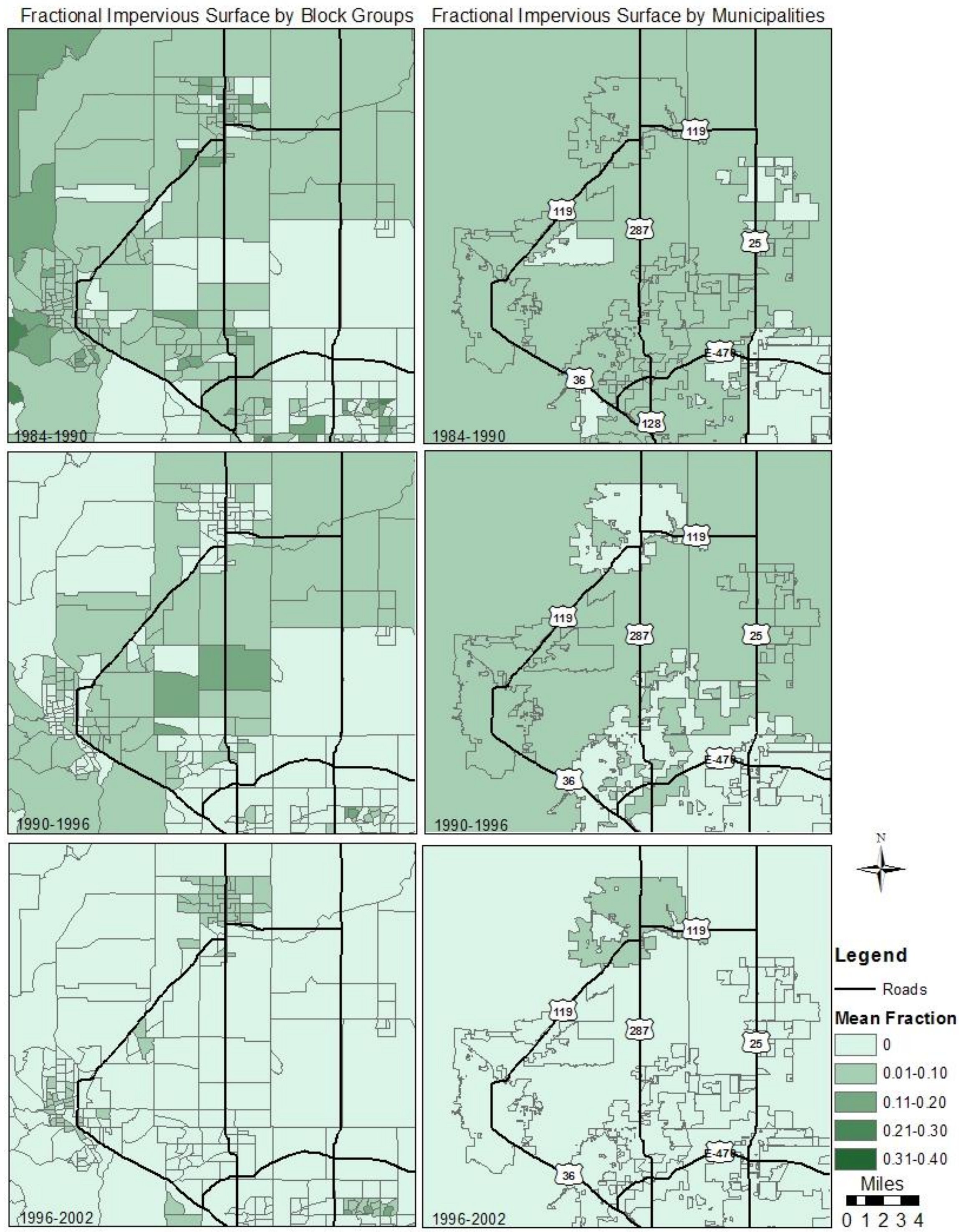

Figure 10. Temporal Change of Mean Fractional Green Vegetation Cover (*based on MESMA analysis of Landsat imagery*)

7.3 Accuracy Assessment

Accuracy assessment for the fraction analysis was conducted on the 2002 image utilizing a 2005 National Agriculture Imagery Program (NAIP) aerial photograph at one meter resolution as the reference image. The reference image was overlain with a ten-by-ten meter grid, each grid cell assigned to its majority cover (impervious surface, green vegetation, NPV, soil) to generate fractional area, covering an area equivalent to 3-by-3 Landsat pixels. Reference and Modeled fractions were graphed for impervious, green vegetation, and NPV plus soil as seen in Figure 11. The plots indicate that impervious surfaces tended to be under-modeled, while NPV and soil tended to be over-modeled. Pearson's r was 0.867 for impervious, 0.829 for green vegetation, and 0.850 for NPV and soil.

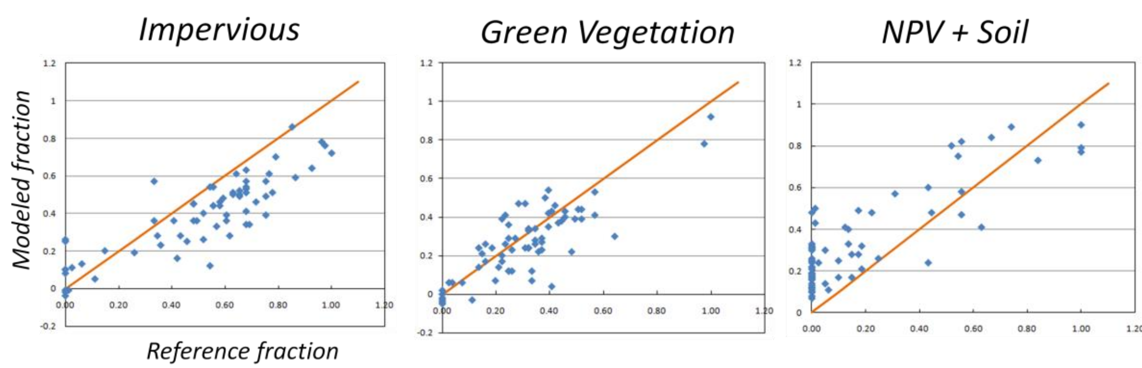

Figure 11. Accuracy Assessment: Modeled versus Reference Fractions

MESMA models are based on individual pixels being composed of two or more endmember fractions. Modeling urban areas which have a heterogeneous composition can result in confusion among the fractions. In some cases, certain endmembers are over-modeled or under-modeled. In many cases, the model will force the pixel to be modeled by a portion of each endmember, meaning that if the pixel is predominantly green vegetation and impervious, a small fraction of NPV would be modeled as well as the shade fraction, generating a four endmember model for the pixel. The plots in Figure 11 indicate the green vegetation is not easily confused with other materials, but impervious is likely being confused with either a NPV or soil.

8 Discussion

The analyses included in this study found a number of spatial associations and statistical results that relate to previous studies in the literature. Working hypotheses initially posed included the following: Boulder was expected to have increased commuting from the surrounding area over time; Boulder was expected to have higher income and housing values relative to the surrounding area, as more jobs then available housing were also expected for Boulder; it was expected that increases in impervious surface cover would mostly occur in the areas surrounding Boulder, while Boulder would experience some infill but no changes in spatial extent. It was anticipated that these working hypotheses could be evaluated through analyses of temporal data sets. Additionally, while the impact of Boulder's growth policies relative to other variables remains an outstanding question, the combination of results from this study with findings from previous studies provide evidence that both the city of Boulder and the surrounding area has been affected and shaped by Boulder's policies.

The growth management policies established by Boulder have been unilateral and rigid in nature, similar to the greenbelt policy found in Seoul, Korea (Bae & Jun, 2003). Boulder's open space program and established greenbelt have played a strong role in both defining the extent of Boulder and creating a sharp edge between the urban and rural landscape, but have also relocated and constrained growth elsewhere in the region.

Regional growth policies can potentially promote the link between "the urban environments and transportation behavior" (Levine, 1998, p. 133) while also encouraging planning approaches that support spatial matches of "affordable housing and decentralized job sites" (Levine, 1998, p. 133); all of which were examined here. The Boulder MSA has experienced increases in number of commuters both from within the MSA and from surrounding MSAs between 1970 and 2000. Additionally, the place-to-place commuter flow data for 2000 showed that substantial portions of the labor force from the surrounding communities commute to Boulder. Additionally, a statistically significant spatial association was found among commuters to Boulder in the surrounding area. Parallels between the findings here and in Portland can be noted. Jun's (2004) study on Portland found that growth was diverted to Clark County, Washington, which is not part of Portland's UGB policy purview, both in the form of housing development and increases in commuters to Portland.

Increases in commuting to Boulder in conjunction with the high housing values and a spatial mismatch between jobs and housing that were found in this study, are important in linking the changes to the growth policies. Cervero (1989) notes a number of forces that influence housing job mismatches: fiscal and exclusionary zoning, growth moratoria, worker earning/housing cost mismatches, two wage-earner households, and job turnover. Additionally, the restrictions on the number of housing and development permits issued each year for the city of Boulder as part of the growth management strategy could be contributing to a number of these factors as well (de Raismes III et al., 2000).

The limits on building permits in conjunction with the greenbelt and service area boundary limit the spatial extent of Boulder's built environment, creating a limited potential for housing growth within the city limits. Although some infill has occurred, at some point in the future Boulder will reach its limit, essentially creating a limited housing market for Boulder. In a very basic sense, as supply decreases or is limited, as in the case of Boulder, demand increases and forces housing values higher (Daly & Farley, 2004).

Analyses of housing values and income values found that Boulder's housing values were higher than the Boulder region, the Front Range, and the state. In contrast, income values were not found to be higher than the region, the Front Range, or the state; in fact, for the region, income values fell below the mean of the medians for 1980, 1990, and 2000, creating a worker earning/housing cost mismatch. This earning/housing cost mismatch and the growth moratoria imposed by Boulder also explain the mismatch between housing and jobs in Boulder, with jobs far exceeding housing. Boulder's greenbelt policy was established in 1970; by 1980, jobs already exceeded housing; by 1990 the numbers of jobs were more than double the number of housing units, and 2000 jobs were still more than double. Housing has been unable to keep up with the number of jobs likely a result of Boulder's policies. Additionally, the opposite has ensued for many of the surrounding towns: Gunbarrel, Erie, Dacono, Lafayette, and Superior, in which housing outnumbers jobs. This pattern indicates that housing has been force elsewhere, similar to the effects found by Jun (2004) in the Portland study. In addition, Bae and Jun (2003) found similar patterns in their study of Seoul, South Korea's greenbelt policy; they found that the rigidity of the growth policy resulted in people decentralizing faster than jobs, creating a mismatch between jobs and housing. More housing found outside the greenbelt, while the jobs were still located within the greenbelt (Bae & Jun, 2003).

These findings are further supported by the analysis of impervious surface change. Many of the areas along Highway 36 and 119 have experienced exceptionally high population growth rates in comparison to Boulder, and subsequently significant increases in impervious surface have occurred. New growth was visible in all four MESMA images. Superior led the structural growth, while also experiencing a huge spike in population growth between 1990 and 2000. Most of the increases in impervious cover occur between 1984 and 1996, with little to no growth between 1996 and 2002. The growth in the areas surrounding Boulder exceeded the growth within Boulder, which is likely an effect of rigid greenbelt policies that result in leapfrog development patterns.

Much of the growth that has occurred since 1970 has been in the clusters around Boulder along the arterials. The developments have commonly been in the form of subdivisions and box store development; the basis of this conclusion is both from the patterns found in the images and the visible development driving along Highway 36. Subdivisions are not a high density form of housing and are one of the many components of sprawling developments. Building density is not measured directly by MESMA; however Boulder limits buildings to a height corresponding to mature tree canopy (55 ft), in order to protect the scenic vistas of the Flatirons to the west of the city in the foot hills (de Raismes III et al., 2000). This eliminates the possibility of high density compact adjacent growth within the city. Boulder has a population density of 3,716 people per square mile (SOCDS, 2005; Boulder, 2009); by comparison Manhattan has a population density of 21,739 people per square mile (Owen, 2004).

Boulder's policies have defined growth not just within the city of Boulder through the service area boundary, but also in the surrounding region through the open space program, which now extends as far south as northern Jefferson County. There are a number of geographic spatial relationships occurring between Boulder and the surrounding region. The job housing relationship influences commuting patterns, while open space policies and service area boundaries have influenced land-use change. Superior is a prime example of the influence Boulder's policies has had on the surrounding area, as Superior's growth has been largely dictated by Boulder's policies. Superior's annexation of the 1,700 acre Rock Creek parcel in 1987 led to substantial growth between then and 1996, visible in the land-use change results. Future growth was blocked by Boulder's purchase of almost 1,000 acres worth of land for the open space program (de Raismes III et al., 2000). This has left Superior with three times as many housing units as jobs, which forces residents to commute to job hubs like Boulder; conversely workers in Boulder are relocated do to high housing values and limited availability of housing in Boulder.

Lastly, these associations are supported by Tobler's law that "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970, p. 236). Boulder directly influences its hinterland, which is evident by the housing jobs mismatch, higher housing values in Boulder, and the resulting commuting patterns that compensate for the numerical and cost mismatches for the area. While the service area boundary and greenbelt have limited the extent of the city, the open space program has shaped the surrounding landscape, and both force growth to the hinterland while also in some cases limiting it. Boulder's policies to limit growth have not just shaped the city, but also the surrounding landscape.

9 Conclusion

Finally, I would like to revisit the two over arching questions of this research. First - Are growth management policies established by the city of Boulder encouraging livable, affordable communities in the city of Boulder and the surrounding region? My assessment is that it is and is not. It could be argued that the growth policies are creating livability within the city of Boulder; however for the surrounding region, the spatial mismatches that are occurring force people that work in Boulder to live elsewhere and commute, which limits the livability of the surrounding areas. Second, are growth boundary policies established by the city of Boulder effective in promoting compact, adjacent growth, and preserving agriculture and natural open space? Again, my assessment would be both “yes” and “no”. Boulder’s open space program has managed to protect a significant amount of open space for the city and surrounding region. Nevertheless, growth has occurred in the region and that growth has been forced into the surrounding communities. The density of Boulder’s growth is limited by the building height limit, and the restricted number of building permits issued.

Growth is inevitable, and as the Boulder Region as well as the greater Denver Front Range Region, continue to grow, managing growth for the region is critical. Planning for “urban environments and transportation behavior” and for “spatial matches between affordable housing and decentralized job sites” involves regional approaches to planning in order to link these pairings (Levine, 1998, p. 133). DRCOG may be the regional authority necessary to make these linkages on a regional level; however, planning authority still lies in the hands of individual counties and municipalities.

This study, illustrates that Boulder has been quite effective in implementing growth policies while simultaneously acquiring large swaths of open space in the region. Their policies are at the municipality level and are not implemented at the regional level; however, the effects of the policies surpass the city limits. As the region continues to grow, people will continue to be forced to the outskirts of the city of Boulder and eventually to the outskirts of Boulder County, only to place increasing pressures and congestion on roadways.

Among the takeaway points from this study are that growth is inevitable, and although Boulder may limit growth for the city and some of the areas in Boulder County, it ultimately is forced elsewhere creating spatial mismatches that increase commuting time and numbers. It would behoove not just Boulder, but the entire region to work toward more integrative approaches that are not just voluntary agreements through DRCOG, but actual planning strategies employed by all counties and municipalities. This would help to ensure more livable communities, managing spatial matches between jobs and housing, limiting commuting, while simultaneously protecting and providing access to open space for the region.

10 References

Abbott, C., & Margheim, J. (2008). Imagining Portland's Urban Growth Boundary: Planning Regulation as Cultural Icon. *Journal of the American Planning Association, 74*(2), 196-208.

Bae, C. H. C., & Jun, M. J. (2003). Counterfactual planning - What if there had been no greenbelt in Seoul? *Journal of Planning Education and Research, 22*(4), 374-383.

BEA. (2004). Bureau of Economic Analysis Retrieved 5/23/10, from http://www.bea.gov/regional/reis/jtw/default.cfm

Boulder. (2009). Community Data Report. Retrieved 5/23/10, from http://www.bouldercolorado.gov/files/PDS/2009_community_data_report.pdf

Brueckner, J. K. (2000). Urban sprawl: Diagnosis and remedies. *International Regional Science Review, 23*(2), 160-171.

Burt, J. E., Barber, G. M., & Rigby, D. L. (2009). *Elementary Statistics for Geographers*. New York: The Guilford Press.

Census. (1996). Metropolitan Areas: Concept, Components, and Poluation. Retrieved 4/29/11, from http://www.census.gov/prod/2/gen/96statab/app2.pdf

Census. (2000). 2000 United States Census. Retrieved February 27, 2010, from http://www.census.gov/popest/cities/SUB-EST2008-4.html

Census. (2005). Trends Report. Retrieved 5/23/10, from http://www.bouldercolorado.gov/files/PDS/planning%20and%20zoning/Trends_Report.pdf

Census. (2009). American Community Survey Subject Definitions. Retrieved 5/23/10, from http://www.census.gov/acs/www/Downloads/data_documentation/SubjectDefinitions/2009_ACSSubjectDefinitions.pdf

Census. (2010). Boulder County Population 1940-2000. Retrieved 5/22/10, from http://www.bouldercounty.org/lu/demographics/boulder_pop.htm

Cervero, R. (1989). Jobs-Housing Balancing and Regional Mobility. *Journal of the American Planning Association, 55*(2), 136-150.

Collins, J., Kinzig, A., Grimm, N. B., Fagan, W. F., Hope, D., Wu, J., et al. (2000). THe New Urban Ecology. *American Scientist, 88*(5), 416-425.

CTPP. (2000). Census Transportation Planning Products. Retrieved 4/23/10, from http://www.fhwa.dot.gov/ctpp/

Daly, H. E., & Farley, J. (2004). *Ecological Economics Principles and Applications*. Washington: Island Press.

Daniels, T. (2000). Integrated working landscape protection: The case of Lancaster County, Pennsylvania. *Society & Natural Resources, 13*(3), 261-271.

Daniels, T. L. (2009). A Trail Across Time American Environmental Planning From City Beautiful to Sustainability. *Journal of the American Planning Association*, 178-192.

de Raismes III, J. N., Hoyt, H. L., Pollock, P. L., Gordon, J. P., & Gehr, D. J. (2000). Growth Management In Boulder, Colorado: A Case Study. Retrieved 10/15/10, from http://www.bouldercolorado.gov/files/City%20Attorney/Documents/Miscellaneous%20Docs%20of%20Interest/x-bgmcs1.jbn.pdf

Ding, C. R., Knaap, G. J., & Hopkins, L. D. (1999). Managing urban growth with urban growth boundaries: A theoretical analysis. *Journal of Urban Economics, 46*(1), 53-68.

Ding, Y., & Fotheringham, A. S. (1992). The integration of spatial analysis and gis. *Computers, Environment and Urban Systems, 16*(1), 3-19.

DRCOG. (2010). About DRCOG. Retrieved October 17, 2010, from http://drcog.org/index.cfm?page=AboutDRCOG

Ehrlich, E., Flexner, S. B., Carruth, G., & Hawkins, J. M. (Eds.). (1980) Oxford American Dictionary. New York: Avon Books.

ESRI. (2011a). Cluster and Outlier Analysis (Anselin Local Moran's I) (Spatial Statistics). Retrieved 3/20/11, from http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//005p0000000z000000.htm

ESRI. (2011b). Spatial Autocorrelation (Global Moran's I) (Spatial Statistics). Retrieved 3/20/11, from http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//005p0000000n000000.htm

Fishman, R. (2005). The Fifth Migration. *Journal of the American Planning Association, 71*(4), 357-366.

Garreau, J. (1991). *Edge City: Life on the New Frontier*. New York: Doubleday.

Gillham, O. (2009). Regionalism from The Limitless City: A Primer on the Urban Sprawl Debate (2002). In E. L. Birch (Ed.), *The Urban and Regional Planning Reader*. London: Routledge.

Hayden, D. (2009). The Shapes of Suburbia from Building Suburbia: Green Fields and Urban Growth, 1820-2000 (2003). In E. L. Birch (Ed.), *The Urban and Regional Planning Reader*. London: Routledge.

Jackson, K. J. (2005). The Need for Regional Management of Growth: Boulder, Colorado, as a Case Study. *Urban Lawyer, 37*(2), 299-322.

Jackson, K. T. (1985). *Crabgrass Frontier: The Suburbanization of the United States*. New York: Oxford University Press.

Jun, M. J. (2004). The Effects of Portland's Urban Growth Boundary on Urban Development Patterns and Commuting. *Urban Studies, 41*(7), 1333-1348.

Kline, J. D., & Alig, R. J. (1999). Does land use planning slow the conversion of forest and farm lands? *Growth and Change, 30*(1), 3-22.

Levine, J. (1998). Rethinking Accessibility and Jobs-Housing Balance. *Journal of the American Planning Association, 64*(2), 133-149.

Marin, M. C. (2007). Impacts of urban growth boundary versus exclusive farm use zoning on agricultural land uses. *Urban Affairs Review, 43*(2), 199-220.

Marsh, G. P. (1874). *The Earth as Modified by Human Action*. New York: Scribner, Armstrong & Co.

McGrew Jr., J. C., & Monroe, C. B. (2000). *An Introduction to Statistical Problem Solving in Geography*. Long Grove, Illinois: Waveland Press.
Muller, P. (2004). Transportation and Urban Form: Stages in the Spatial Evolution of the American Metropolis. In S. Hanson & G. Giuliano (Eds.), *The Geography of Urban Transportation* (3rd ed.). New York: Guilford Press.
Nelson, A. C., & Moore, T. (1993). Assessing Urban Growth Management. *Land Use Policy, October*, 293-302.
Nelson, A. C., & Moore, T. (1996). Assessing Growth Managment Policy Implementation. *Land Use Policy*, *13*(4), 241-259.
OMB. (2000). Federal Register. *Standards for Defining Metropolitan and Micropolitan Statistical Areas* Retrieved 4/1/11, from http://www.census.gov/population/www/metroareas/files/00-32997.pdf
Owen, D. (2004, October 18). Green Manhattan. *The New Yorker*.
Palen, J. J. (2002). *The Urban World* (6th ed.). New York: McGraw-Hill.
Perry, M. J., & Mackun, P. J. (2001). Population Change and Distribution 1990-2000 Census 2000 Brief. Retrieved May 9, 2010, from http://www.census.gov/prod/2001pubs/c2kbr01-2.pdf
Pollock, P. (1998). Controlling Sprawl in Boulder: Benefits and Pitfalls. *Land Lines, 10*(1).
Powell, R. L., & Roberts, D. A. (2010). Characterizing Urban Land-Cover Change in Rondônia, Brazil: 1985 to 2000. *Journal of Latin American Geography, 9*(3), 183-211.
Rashed, T. (2008). Remote sensing of within-class change in urban neighborhood structures. *Computers Environment and Urban Systems*, *32*(5), 343-354.
Rashed, T., Weeks, J. R., Stow, D., & Fugate, D. (2005). Measuring temporal compositions of urban morphology through spectral mixture analysis: toward a soft approach to change analysis in crowded cities. *International Journal of Remote Sensing*, *26*(4), 699-718.
Roberts, D. A., Batista, G. T., Pereira, J. L. G., Waller, E. K., & Nelson, B. W. (1998). Change Identification Using Multitemporal Spectral Mixture Analysis: Applications in Eastern Amazonia. In R. S. Lunetta & C. D. Elvidge (Eds.), *Remote Sensing Change Detection: Environmental Methods and Applications* (pp. 137-161). Chelsea, MI: Ann Arbor Press.
Roberts, D. A., Gardner, R. C., Ustin, S., Scheer, G., & Green, R. O. (1998). Mapping Chaparral in the Santa Monica Mountains Using Multiple Endmember Spectral Mixture Models. *Remote Sensing of Environment, 65*, 267-279.
Sauer, C. O. (1956). The Agency of Man on the Earth *Man's Role in Changing the Face of the Earth* (pp. 49-69). Chicago: University of Chicago Press.
SGN. (2002). Smart Growth Network - Getting to Smart Growth: 100 policies for implementation. Retrieved 5/21, 2010, from http://www.smartgrowth.org/pdf/gettosg.pdf

Sheehan, R. (1998). Revenue sharing and urban growth agreements in the Denver area. (Colorado)(includes related article on economic development in Boulder, CO). *Government Finance Review, v14*(n2), p25(26).

SOCDS. (2005). State of the City Data System (SOCDS) Census Data. Retrieved 5/21, 2010, from http://socds.huduser.org/Census/Census_java.html

Taaffe, E. J., Gauthier, H. L., & O'Kelly, M. E. (1996). *Geography of Transport*. Saddle River, NJ: Prentice Hall.

Talen, E., & Brody, J. (2005). Human v. Natue Duality in Metropolitan Planning. *Urban Geography, 26*(8), 684-706.

Tobler, W. R. (1970). A Computer Movie Simulating Urban Growth in the Detroit Region. *Economic Geography, 46*, 234-240.

Winter, J. (2011). Changes to the Denver Metropolitan Statistical Area. Retrieved 4/28/11, from http://www.coloradoworkforce.com/LMI/CES/Denver%20MSA%20Changes.pdf

Ye, L., Mandpe, S., & Meyer, P. B. (2005). What is "smart growth?" - Really? *Journal of Planning Literature, 19*(3), 301-315.

Appendix A

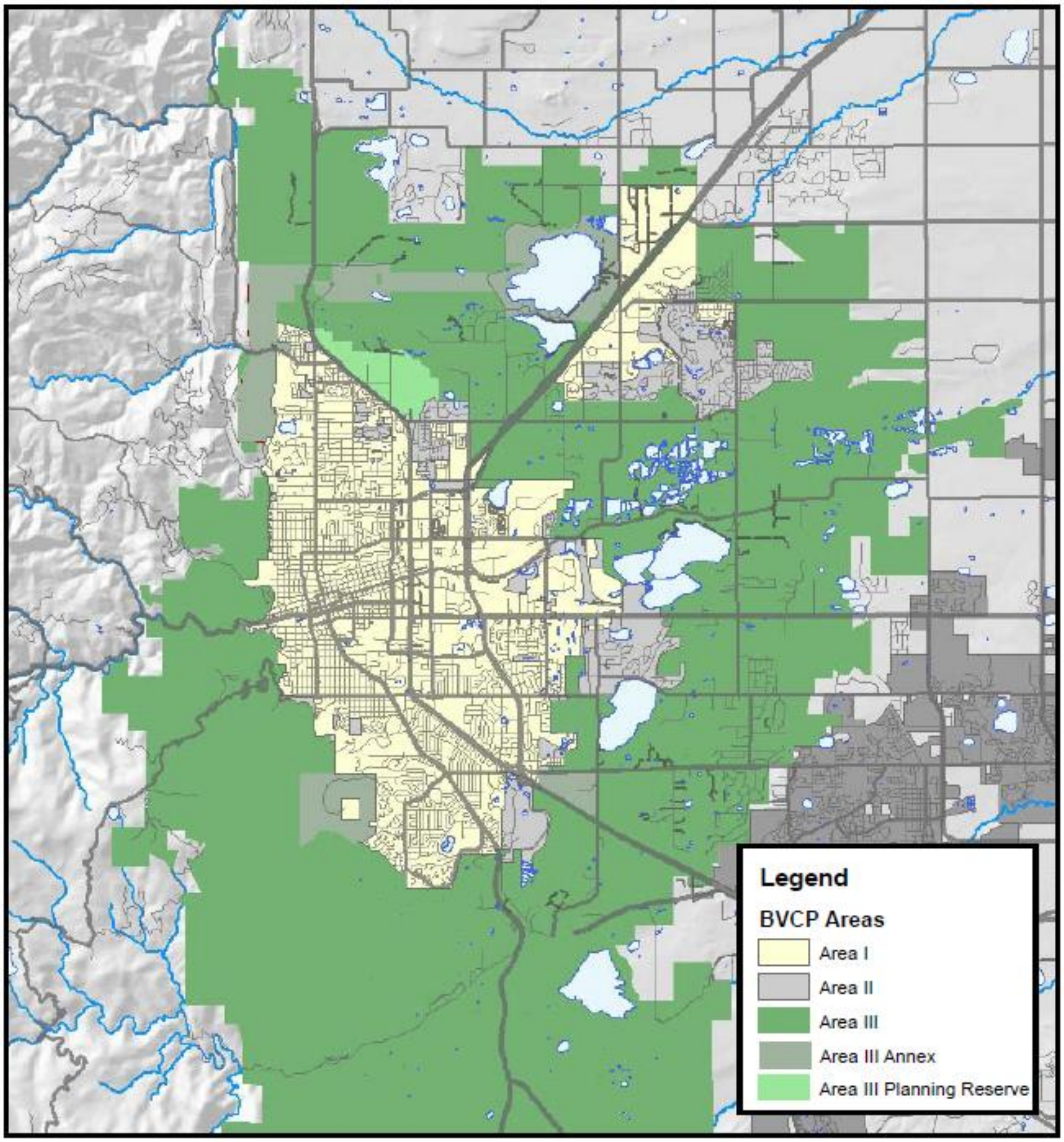

Figure A1. Boulder Land Use Plan – Area 3 Open Space Greenbelt (*source:* Boulder 2009)