

EVALUATION OF THE IMPACT OF GOVERNMENT LAND USE POLICIES ON TREE  
CANOPY COVERAGE IN THE ATLANTA METROPOLITAN STATISTICAL AREA

by

ELIZABETH SHORE HILL

(Under the direction of JEFFREY H. DORFMAN)

ABSTRACT

This thesis presents an analysis of the effectiveness of land use policies in reducing the change in the percent of tree canopy covering land in Atlanta Metropolitan Statistical Area during the period from 1991 to 2001. High rates of tree canopy loss in the region during that period have been associated with the region's explosive population growth, and it is expected that certain policies can substantially alleviate the loss of tree canopy.

Two conclusions originated from the findings of this study. First, impervious surface, tree ordinance robustness, quality growth projects, increased existence of land uses that naturally sustain higher tree canopy levels, and emphasis on quality growth and tree canopy protection each aid in reducing the loss of the percent of tree canopy cover county land. Second, urbanization plays a major role in whether or not a county has established land use policies to protect tree canopy coverage.

INDEX WORDS: Atlanta, GIS, GMM, Impervious surface, Land use policy, Tree Canopy, Tree Ordinance, Urbanization,

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B.S., The University of North Carolina at Greensboro, 2005

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment  
of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2007

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May 2007

## ACKNOWLEDGEMENTS

I would like to thank my committee members for their invaluable assistance and support during this research undertaking. Dr. Jeffrey Dorfman has gone far and beyond what was expected of him as a major professor. His guidance in econometrics and steadfast support throughout my time here at the University of Georgia has helped me to realize my abilities and future ambitions as an environmental economist. I feel that Dr. Elizabeth Kramer's insight and technical understanding of the ecological world is matched by few, and it has been an honor to work with someone of such extraordinary caliber. Dr. John Bergstrom has provided me with the gift of understanding and implementing nonmarket valuation techniques, which has unfailingly benefited me in all of my research pursuits to date. I feel lucky to have gained this knowledge from one of the best, especially knowing that I will use these techniques continuously throughout the rest of my career.

I would also like to thank my family for a lifetime of encouragement which has helped me to realize my potential. They are the most kindhearted people I know, and I feel exceptionally fortunate to have been raised in an environment filled with such genuine, interminable love.

I wish to express my gratitude for all of my friends and colleagues, especially Clarissa Long, Katie Dulin, Katie Hanks, Joe Goodenbury, Peter Norris, Josh Gill, Sam Pugh, Matt Armstrong, and Kristy Plattner, all of whom I'm deeply indebted to, for both their extraordinary friendship and some of the greatest memories I could ask for. Finally, I would especially like to thank Andrew Hunt not only for his unwavering support in all of my pursuits, but for sincerely understanding me as a person and making every day with him joyous and fulfilling.

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## CHAPTER I: INTRODUCTION

### Background

Metropolitan Atlanta has begun experiencing the negative effects associated with not sustaining a sufficient level of tree canopy coverage, with approximately 60% of Atlanta's natural tree cover being removed since 1985 (Trees Atlanta, 2006). This trend is troubling, since contiguous areas of tree canopy play a critical role in the environment, providing benefits such as clean water and air, erosion prevention, climate control, and sustained ecological resources and native species habitat. Additionally, tree canopy plays an economic role by increasing housing values, alleviating expenditures related to erosion destruction, decreasing spending on sewer systems, increasing energy efficiency, and reducing medical costs related to health issues, such as asthma, that are associated with environmental degradation (GFC).

One factor that is believed to be contributing to metropolitan Atlanta's loss of tree canopy coverage is the region's explosive population growth, which increased 26.42% from 1970-1980, 31.91% from 1980-1990, and 38.41% from 1990-2000 in the 28-county Atlanta Metropolitan Statistical Area (MSA) (Census Bureau, 2005; RE Center, 2005).<sup>1</sup> With this rapid growth comes an increase in the demand for land, which contributes to sprawl, with a great deal of the land use changing from forest and agricultural to urban uses. This increase in land development has paved the way for massive losses in tree canopy, with the 28-county metropolitan Atlanta region losing

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<sup>1</sup> These statistics are for the 2005 MSA definition for the Atlanta-Sandy Springs-Marietta region for the July 1, 2003 and July 1, 2004 population estimates, which from hereon will be referred to as the Atlanta MSA. Also, decades represented here reflect the April 1 Census data rather than mid-year estimates.

an average 58 acres of tree canopy a day from 1991 to 2001; however, during this time period, impervious surface in the 28-county metropolitan Atlanta region increased by 31.34 acres a day, implying that for each acre of impervious surface created, 1.85 acres of tree canopy was removed (NARSAL). This difference can be attributed to a variety of influences; however, the cost for developers to preserve trees is the most likely explanation.

Although it is suspected that in many cases developers do not account for the value of trees, the trunk method is generally used among those who do accounting for a tree's market value but not for its nonmarket value (Cullen, 2000). This method leads developers to estimate that on average, removing a tree reduces a house's sales price by \$394. In the eyes of a developer, this cost is likely a small price to pay in relation to the potential costs associated with preserving the tree (Nowak, 2002).<sup>2</sup> Additionally, with increased use of portable sawmills, lumber companies have become more willing to accept small quantities of lumber created during land development (Cassens et. al). This gives developers an opportunity to make up the profits lost on a building's reduced sales price from tree removal. However, in accounting for the total value of trees, studies have found that for each large front yard tree, the sales price of a house increases by a minimum of 0.88% (Anderson and Cordell, 1988).<sup>3</sup> In 2000, the median sales price for a home in the 28-county Metropolitan Atlanta region was approximately \$110,593 (CensusScope, 2000), which implies that for each large tree that remains undisturbed during development, the median sales price would at a minimum increase by \$973. Noting that this estimate does not account for nonmarket values of trees, such as savings from increasing energy efficiency and reduced stormwater runoff, it is clear that economic gains from tree preservation

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<sup>2</sup> Please see Chapter II for a description of the trunk method valuation technique.

<sup>3</sup> Previous studies show this range of values from 0.88% to 7.00% (Anderson and Cordell, 2002; Payne, 1973).

are substantial enough to show that tree preservation may be a viable alternative to current development practices.

However, a significant problem remains in regards to factors that affect tree canopy loss: many relatively rural counties in the Atlanta region are incurring high rates of population growth that they historically have not experienced. This growth is regarded as being a driving factor in the shortage of middle-class housing in the City of Atlanta, where in 1990 only one-fourth of the houses were in the middle-class price range (\$75,000-\$175,000) (Katz et al., 2000). Excess housing demand has led homeowners to settle in neighboring counties where middle-class housing is both available and affordable. Although expanding land development due to population growth is inevitable, many of the urbanizing counties in which this growth is occurring face the same dilemma as metropolitan fringe counties all over the country: the need for growth management where the demand and/or resources to implement such practices previously did not exist (Daniels, 1999). For example, lenient land use policies such as low-density and single-use zoning, lack of impact fees on development, and minimum lot-size requirements are implemented in a number of counties in the Atlanta MSA (Brookings, 2000; Giles, 1980; Heim, 2001). However, the complexity of administration through elected government officials, difficulty in changing administrative structures, and developer's opposition to implementing more stringent standards are all challenges that impede county policy-makers from instituting better conservation land use policies (Olsen, 2000).

#### Purpose of the Study

Difficulties in establishing better conservation practices will remain as the need for such policies increases in the Atlanta MSA. Therefore, in order for policy makers to make the most efficient and effective policy choices, they must be supplied with information concerning both

the benefits of tree canopy and the influence of policies that they can create to preserve it. An abundant amount of studies have examined the benefit of tree canopy; however, to date, few studies have analyzed the influence of policies to preserve it.

Given this need, the central question of this study is: how much benefit does government intervention--through land use policies--have in reducing tree canopy loss throughout the 28-county metropolitan Atlanta area? To answer this, the following research objectives are pursued:

1. Identifying economic, environmental and social factors and values that may affect tree canopy coverage.
2. Examining the changing states of tree canopy cover and urban morphology over time in each county.
3. Evaluating the significance and effectiveness of specific land use policies in regards to preserving tree canopy coverage in each county.
4. Proposing optimal land use policy choices for counties based on the state of their population density, change in percent of tree canopy covering county land area, and other defining characteristics.

The study will be organized into the following sections: Chapter II reviews relevant literature to establish the relationship between prior findings and our research problem. Chapter III provides detailed descriptions of the data and methodology used in this study. Chapter IV summarizes the analysis results of this study, while Chapter V provides a discussion of these results. The final chapter will present conclusions on the results of our study as well as what these results mean for policy-makers in the area.

## CHAPTER II: LITERATURE REVIEW

This section presents an overview of literature related to the topics that are being considered in this study. In fact, although the specific question being asked in this study is unique, other studies have taken on parts of this question independently, incidentally providing the ingredients needed to create a comprehensive and logical recipe for this study's organizational structure. In order to coherently piece together the concepts that are needed for this approach, selected literature will be divided into two sections. First, relevant previous works concerning the value of tree canopy coverage will be summarized. Second, selected studies that have focused on the factors that create variation in tree canopy coverage will be considered.

### Previous Works on the Value of Tree Canopy Coverage

A myriad of studies have examined the environmental effects of tree canopy depletion and the value that tree preservation provides to a community. The trunk formula method (Council of Tree & Landscape Appraisers, 2000) is the most commonly used approach for estimating tree value. The underlying assumption of the method is that inherent benefits of a tree can be recreated by replacing the tree, and therefore, the cost of the tree loss can be depreciated over time as the new tree (hopefully) replaces the old tree (Cullen, 2000).

The trunk method has historically been the most popular method for tree valuation, so much so that a calculator program was created for arborists to use on-site to approximate the

value of trees (Fitzpatrick, 1990). In order to determine the compensatory value of trees, information on the tree's location, species type, trunk area, dieback condition, initial unit cost, and installed cost are considered. Nowak's (2002) compensatory value of urban trees study used the trunk formula, and included a city-specific study on Metropolitan Atlanta. The study found that the median value of a tree was approximately \$394 per unit, while median tree canopy cover created by one tree was valued at \$29.58 per square meter.

Although the trunk formula method is accepted as the most common method for valuing trees, the number it produces can only be considered as a baseline for the value that trees provide. This is because the true comprehensive economic value and the future stream of benefits associated with preserving trees and tree canopy encompasses indirect, but significantly related factors such as increasing housing values, decreasing spending on sewer standards, increasing energy efficiency, and reducing medical costs related to health issues (McPherson, 2007).

To further examine these benefits, the results from a study by American Forests (2001) can be referenced. The study used remote sensing to map the land cover in metro Atlanta for the years 1974, 1986, and 1996. Using American Forests' CITYgreen<sup>®</sup> software, the economic impact due to changes in land cover from tree loss was calculated. The software focuses on factors that have been recognized in other studies as being effected by the quantity of tree canopy, including stormwater runoff, air quality, stored and sequestered carbon, energy use, and avoided carbon (Mansfield, 2005; Galvin, 1999; Dwyer, 1999; Stewart, 2005; McPherson et al., 2005). American Forests estimated that between 1974 and 1996 in the 775,000 acre study area, which centered around the city of Atlanta, average tree cover decreased from 45% to 29%. This decrease affected several ecological services. First, the decrease led to a 33% increase in

stormwater runoff, with estimated costs associated with the increase at \$1.18 billion (\$2/cubic ft. of storage). Second, the loss in tree canopy resulted in approximately \$28 million loss per year associated with pollutants that could have been prevented with adequate canopy coverage. Third, energy costs are estimated to be \$2.8 million higher annually with the loss. Finally, carbon avoided would average at 14,000 tons per year. The study went on to estimate what the benefits associated with increasing the tree canopy coverage from 29% to 40%, which would bring Atlanta into the American Forest's Eastern U.S. recommended average tree canopy coverage of 40%. This change would result in a stormwater runoff decrease of 20% at an annual value of \$1.7 billion. Air pollutants would decrease by 4,054 tons at a value of \$73.4 million per year, and energy savings would be valued at \$2.8 million annually. Annual carbon stored would increase from 8 million tons to 13.3 million tons, and carbon sequestered would increase from 58,000 tons to 104,000 tons annually. Overall, the total savings from maintaining the current 29% tree canopy coverage would total to approximately \$2.36 billion, while savings from increasing tree canopy coverage to 40% are approximately \$4.06 billion.

Several hedonic studies have also been conducted that have aimed to assess the benefits in sales prices of properties with and without trees. By doing so, it is possible to capture many of the nonmarket benefits that are associated with trees, such as wildlife habitat, aesthetic integrity, existence values, and privacy. Anderson and Cordell (1988) found that in Athens, Georgia, each large front-yard tree created a 0.88% increase in the sales price of the house and that housing prices increased 3.5%-4.5% when landscaping incorporated trees. This finding is in line with previous studies by Payne (1973) and Morales (1976) who found that trees increased property values by 7% and 6%, respectively. Anderson and Cordell (1988) also found that if trees were to increase housing price by 5% in 1985, government revenues from property taxes would increase

approximately \$200,000 in Athens, GA. Given that the median percentage of municipal budgets dedicated to tree preservation and care was approximately 0.4%, and with Athens as no exception at 0.46%, which was approximately \$100,000 in 1985, it shows that even without considering the benefits of trees related to ecological services, it is easy to see the exponential benefits that preserving tree canopy can create.

McPherson (2007) undertook an innovative study that used the hedonic method while also accounting for services provided by tree canopy coverage in order to derive tree valuation. Specifically, this tree valuation study accounted for factors such as energy savings, atmospheric carbon dioxide reduction, air quality benefits, stormwater runoff reductions, and aesthetic and other benefits (whose values were captured by examining the changes in housing sales price transactions) as factors that would influence the net present value of a tree over a planning period of 40 years. The study found the projected annual benefits over a 40 year time period from a single tree for aesthetics and other benefits (\$2,025), runoff reduction (\$476), energy savings (\$280), net air quality (\$243), and CO<sub>2</sub> reductions (\$78). With 65% of the total benefit of the tree being realized through aesthetics and other benefits, this finding further supports Anderson's and Cordell's (1988) suggestion that the gains from property taxes from preserving trees can be substantial. However, as pointed out in another study by McPherson et al. (2005), the average annual benefits, setting aside the affect of aesthetics and focusing on the benefits from stormwater, clear air, and energy savings from trees, five cities ranged from \$31 to \$89 per tree, while these cities annually spent an average of \$13-65 on each tree. Given these studies, it should be clear that all community governments should value trees not only for the gains from property tax increases, but also for their value in preventing the incurrence of expenses associated with maintaining the integrity of crucial ecosystem functions.

### Previous Works on Land Use Policies and Practices in Relation to Tree Canopy

As categorized by Heynan and Lindsey (2003), variation in tree canopy coverage can be attributed to four main factors, which include: ecological and geographic factors, urban morphology, socioeconomic factors, and local policy. Although this study is specifically concerned with the effect of land use policy on tree canopy coverage, it is important to explore and account for other factors in order to control for their effect.

In regards to ecological and geographic factors, one of the main concerns is that land development has created changes in the soils, sunlight, and ecoregions that trees are exposed to (Heynan and Linsey, 2003). For example, nourishment lost due to topsoil removal during development and flooding along with tall buildings and other structures in urban areas that may block sunlight to trees both attribute to decreasing life-sustaining inputs that are necessary for maintaining tree and therefore tree canopy. Other urban features such as compacted soils, pollution, and impervious surface stress trees, resulting in an average service life of 10 to 25 years which is far below that of trees growing in the wild (average lifespan > 50 years). Another factor that decreases tree sustainability is lack of species diversity, which is often unregulated by communities, despite its low implementation costs. By maintaining tree diversity through species regulation, trees are more likely to be healthy, withstand disease, and live longer, therefore reducing management and tree replacement costs that are incurred by communities (Galvin, 1999).

Ecoregions are also affected by human development, since the functions of these lands, specifically forested regions in the case of Atlanta, are modified in development (Heynan and Lindsey, 2003). In regards to geographic factors, areas with a topography characterized by steep slopes, which are often undesirable for developers to build on due to structural risks and higher

construction costs, may see higher percentages of tree canopy than areas with less steep topography (Ambrose, 1994). Some communities even regulate construction on steep slopes, therefore allowing for these areas to remain as open space where forest growth can occur. The same idea applies to areas that have higher densities of riparian corridors, where construction may be limited in floodplains, therefore allowing for more forested area to exist. In fact, communities that have a relatively high percentage of land with a slope steepness of greater than 15% or dense stream networks have greater tree preservation than in areas of flatter slopes and less dense stream network (Heynan and Lindsey, 2003).

Urban morphology, which can primarily be described by development patterns, local land use, and population density can have considerable effects on tree canopy coverage. In a study by Dwyer (1999) a categorical framework was incorporated into a study assessing the benefits of tree canopy, including a categorical variable for land-use categories that was based on the Anderson Land Use Classification System (Anderson et al., 1976). These categories included density of single-family residential (high density lot size < .25 acres, medium density .25-.20 acres, low density > .80 acres), multiple-family residential, mobile home, commercial, institutional, parks, cemeteries, golf courses, undeveloped/conservancy, agriculture, roads, and water. The same criteria used in assigning value to each of these land-use categories is used by a popular local government decision-making program created by CITYgreen (American Forests, 2002), which also delineates tree coverage into five categories for each land-use category, including very light (0-5%), light (6-20%), medium (21-40%), heavy (41-60%), and covered (> 60%). This is useful since different land uses often experience different degrees of development. For example, development patterns can have a huge effect on tree canopy coverage, with 1-2 family homes (31.4%), vacant land (44.5%), and parkland (47.6%) having the highest mean

percent tree canopy coverage in urban areas, while land uses such as industrial (19.9%), and commercial (7.2%) are much lower. It can be inferred from this data that urban communities with a higher percentage of residential, vacant, or parkland will have higher levels of tree canopy coverage (Nowak et. al, 1996). This finding is reflected in American Forests abovementioned goal standards for U.S. cities, which encourages cities to strive for 40% average, but also has differing average percentage requirements for differing land uses, such as downtown and industrial area (15%), urban residential and light commercial areas (25%), and suburban areas (50%) (American Forests).

Another important development factor is that of population density. Past studies have recognized that a negative relationship between population density and tree canopy coverage exists (Heynan and Lindsey, 2003; Nowak et al., 1996; Dwyer, 2000). Furthermore, considering that 80% of the U.S. population lives within urban areas, accounting for 24.5% of the area in the country, reason to be concerned over the effect of losing urban tree canopy exist, given that  $\frac{1}{4}$  of the tree cover in the U.S is located within urban areas (Nowak et al. 1996, Dwyer 2000). In regards to the effects that development has on tree canopy patterns, Jim (1989) examined the association between land use and urban tree-canopy features, including coverage, shape, connectivity, and contiguity in Hong-Kong. The study found that urban areas that experience high-density development were at greater environmental risk in comparison to areas of lower-density development. It also found that despite the percentage of parkland and preservation areas, the only influential factor that alleviates environmental degradation related to the loss of tree canopy is contingent canopy that is continuously connected to other areas of high density canopy (rather than disjointed clusters of isolated canopy).

It is irrefutable that particular land use policies used by local governments may have an effect on tree canopy coverage. Comprehensive plans, zoning ordinances, tree ordinances, subdivision regulations, and participation in tree programs are all instruments that can be used to help protect trees, and therefore improve tree canopy coverage (Heynan and Linsey, 2003).

One of the largest problems that metropolitan cities face is the lack of a comprehensive development plan that includes zoning, development, and regulation clauses that are stringent enough to keep the land development growth at a comparable level to the population growth. For example, over the 30 year period from 1960-1990, 10 of the largest cities in Pennsylvania saw a population growth of 12%, while developed land increased by over 80% (Arendt, 2004). However, a different scenario has unfolded in Atlanta where from 1980-2000 the population growth rate in the Atlanta MSA region increased by 83%, however, developed land use increased 81% from 1982-1997 (NCCE, 2003; DCA, 2006). This nearly one-to-one ratio suggests that on an aggregate scale, the 28 counties in the Atlanta MSA region have made an attempt to control sprawl in relation to places like Arendt's study area. However, on an individual scale, it is suspected that this ratio of population to developed land use will highly differ depending on the county being observed.

The previously mentioned study by Nowak et al. (1996) showed that higher tree canopy should exist in communities with higher percentages of residential, vacant, and park land. However, in regards to residential land, simply increasing the amount of land zoned as residential does not guarantee that tree canopy will be preserved if development methods are used that don't preserve trees. One tool to prevent these practices is the use of conservation subdivisions, which are characterized by 40-70% of a given piece of land being protected from development. This conservation method has gained popularity in recent years, likely due to their

ease and low cost of implementation. In preserving this land, tree canopy is also preserved, therefore not only combining the principles of landscape architecture with zoning ordinances, but also, if done correctly, allowing for cities like Atlanta to continue to develop, without incurring nearly the amount of damage that is done with clearcutting practices (Arendt, 2004). However, there are challenges that impede the success of conservation subdivisions. For example, many developers see this innovative method as a financial risk, even though conservation subdivisions were seen to carry a price premium ranging from 12% to 16% per acre over regular subdivisions. Another issue is that many communities have outdated zoning and development laws that prevent the possibility of conservation subdivisions being created (Mohamed, 2006). Finally, one of the most concerning problems is the design that is used in conservation subdivisions. For example, many developers clearcut the percentage of land that can be developed, and leave a block of conserved land untouched. This method has been shown to bring in little to no housing price premium in comparison to regular developments, and provides less ecological benefit than by using a more randomized development pattern (Goodenbery, 2006). 

Communities may also implement tree ordinances, which can be designed to incorporate a variety of requirements and regulations in regards to sustaining trees. At a minimum, however, most tree ordinances establish a community tree board, regular tree upkeep and maintenance, tree inventory, and rules regarding the preservation of a certain number and type of trees during development. More sophisticated ordinances have provisions such as requirements for private property care, established penalties and fines for violations, regulation of disease and abatement, and educational requirements and programs (Elmendorf et al., 2003).

A multitude of studies have examined the relationship between tree ordinances and their effect on trees. Trieman (2004) conducted a study on 602 Missouri communities that attempted

to capture the knowledge and strategies that were taken by local officials in regards to adopting and managing tree ordinances. Among its many conclusions, the study found that in the areas surveyed, many communities are reactive in caring for trees, do not have a sufficient budget, and often do not employ tree specialists. This is an issue considering that tree management, employee training and education, and financial assistance are crucial for the operation of successful tree protection policies (ODF, 2004). Other studies have been conducted concerning tree ordinance effectiveness. These include: Green and Howe (1998) who researched funding, tree management, education and public awareness in smaller communities; Ricard (1994) who studied municipal needs for tree programs, officials' opinions concerning public tree value, support for community tree programs, and the need for technical assistance; Clark and Matheny's (1998) survey study on policies and practices that influenced municipal tree programs; and Allen (1995) studied municipal employees' opinions and attitudes towards urban forestry policies and programs. The studies illustrate that issues are present for not only the existence and components of tree ordinances, but in the management, enforcement, and support of the ordinances by communities.

Two studies of particular importance were conducted by Elmendorf et al. (2003) and Schroeder et al, (2003). Both took a comprehensive approach to surveying municipalities by combining questions concerning municipal employee attitudes and factual information that influenced the well-being of trees in both large and small communities. Elmendorf attempted to determine what trends in urban forestry practices, programs, and sustainability influence tree numbers and their prosperity. The study concluded that although ordinances do provide indirect influence, the factors that influence tree density and health are the levels of enforcement and management implemented by municipalities and communities. Specifically, time, energy, knowledge, support, politics, and municipal cooperation are correlated with ordinance success.

Schroeder used a similar approach and concluded that inadequate tree policies exist in smaller communities which lack the knowledge, support, and funding to implement protective practices, in comparison to larger communities which are more likely to have educated tree care specialists, better tree care services, existing and well-specified tree ordinances, and a superior chance at receiving state and federal grants for tree protection.

Given the conclusions of these tree ordinance studies, it is useful to consider the recommendation by Clarke et al. (1997) who outlined three key goals that need to be met in order to sustain urban forest. These goals include maintaining healthy trees and forest resources, upholding community wide support, and establishing and successfully implementing a comprehensive management approach. Although these goals are broad, they provide a solid foundation that communities can create in order to prevent and/or fix problems that may exist in their tree ordinances. Furthermore, despite the number of problems associated with tree ordinances, communities that implement them have significantly increased over the past 15 years (ODF, 2004), which gives reason to believe that communities are beginning to appreciate and respond to the benefits and need for sustaining tree and tree canopy.

In addition to tree ordinances, some communities may choose to participate in programs that support tree protection through external aid. This aid often comes in the form of grants from groups that have a vested interest in the well-being of trees, such as tree protection and conservation commissions or utility companies. In Georgia, a variety of such tree commissions exist, most notably the Georgia Forestry Commission, who awarded approximately \$280,000 in grants to communities who would use the money to protect or better their trees (GFC, 2007). In Iowa, a major utility company established a tree-planting program called Trees Forever in 1990, which gave communities the opportunity to match dollar for dollar on tree

preservation activities, given that each community established a person responsible for facilitating the desired plan. It was found that during the first five years of Trees Forever's existence (1990-1995), the number of trees in surveyed Iowa communities increased 300% (Vitosh and Thompson, 2000).

In addition to local incentive-based programs, a nationally recognized organization called Tree City USA (TCUSA) has been noted for its success in community participation. Although communities that are recognized in TCUSA are eligible for financial assistance that they could not otherwise apply for, a huge incentive for community participation is the publicity and public image that is generated. In order to be designated as a Tree City, communities must complete four requirements. First, the community must establish a tree ordinance that puts into writing the community's forestry work plan, which ideally would establish planting, maintenance, and removal guidelines. Second, a tree board or department must be established, consisting of a commission of volunteer citizens who manage and develop the community's tree ordinance, with at least one of those persons being legally responsible for the care and management of trees in the area. Third, a community forestry program with a \$2 per capita annual budget must be established, to be used for regular maintenance, tree species diversity, removal, and regulation. Finally, the city must create a proclamation and observance for Arbor Day (NADF, 2007).

Galvin and Bleil (2004) studied the relationship between tree canopy quantity and the implementation of TCUSA. They found that communities that used the program had significantly lower percentage of tree canopy coverage (25.98%) versus non-TCUSA communities (34.55%). These results may indicate that communities that use voluntary programs such as TCUSA are often those that have less tree canopy coverage due to development. Additionally, it is possible that areas with greater tree canopy coverage are less affluent, and may

not be able to afford the costs to implement the program. Green et al.'s (1998) study provides further support to this lack of funding, finding that smaller communities have more trouble than larger communities in regards to obtaining grant money. With respects to tree funds like TCUSA, Treiman (2005) found that larger communities (population > 50,000) were more likely to support increasing taxes to support a tree fund, while smaller communities showed a much smaller willingness to pay. Additionally, survey recipients often were unaware of whether or not their city was involved with TCUSA. These results indicate that by increasing educational and informational sources and programming, the percentage of communities involved in TCUSA could increase, as public support is a crucial factor in improving and preserving tree sustaining policies, especially in small communities.

Heynen and Lindsey's (2003) study of the effect on tree canopy density due to five characteristic factors, which includes ecological and land use policy factors, unexpectedly found that policies that were designed to protect trees did not significantly influence tree canopy coverage. Instead, education and income were highly correlated with the amount of tree canopy density. Given this finding, attention should be placed on possible socioeconomic and demographic factors that may influence tree canopy cover.

Dickerson's et al. (2001) study of influential community characteristics on municipal tree ordinances found that communities with higher levels of education and mean income were more likely to have tree ordinance and protection provisions enacted versus less educated and poorer communities. Significant community characteristics variables include level of education, mean annual per-capita income, average price of home, unemployment rate, poverty level, single head of household, and total population. Mixed results were found concerning gender, race, and age. Dickerson concluded that larger communities with wealthier and better-educated residents had

more tree ordinance provisions, economic resources to maintain tree personnel, and violation penalties. Smaller communities with poorer and less-educated residents tended to depend on tree boards, not tree ordinances, with a specific focus on creating provisions that promoted aesthetic quality and safety.

Wall et al. (2006) took a similar approach to Dickerson's (2006) study, and attempted to identify factors that affect state participation in urban and community forestry programs in the United States. Variables that were found to provide explanation in participation included the state's percent of working population, income level, percent of forested land, dominant political affiliation, state government expenditures on education, and participation in urban and community forestry programs. Given that policy makers use a strategy that pursues maximizing marginal returns, improvements in participation rates should aim at not only increasing the number of states that participate in programs, but should also put an emphasis on increasing participation in states with higher rates of middle-age people, heavily forested land, "blue states" (political affiliation leans toward the Democratic party), and states that have a large percentage of their expenditures allocated to education.

The fact that education and income are significant in both of these studies is of no surprise, since willingness to pay is correlated with income, and income is related to a consumer's level of education (Massey, 1993). It should be probable that, given this relationship, and the outcomes of the previously reviewed hedonic studies that concluded that trees add value to houses, people with higher education--and therefore income--will be more likely to live on a property with dense tree canopy (Heynan and Lindsey, 2003).

These studies provide supporting evidence that environmental and economic consequences are created through the loss of tree canopy, and that in order to account for the

negative externality created by tree canopy depletion, it is necessary for government intervention to take place. Evidence presented from these studies will be used during both the collection of the data used in the study at hand and the hypothesis about the effects, signs, and significance of factors that are suspected to influence tree canopy cover.

## CHAPTER III: DATA AND METHODOLOGY

### Study Area

This analysis will use data for the 28-county Metropolitan Statistical Area (MSA) defined for metropolitan Atlanta, Georgia. A MSA is defined by the United States Office of Management and Budget (OMB) as “a core area containing a substantial population nucleus, together with adjacent communities having a high degree of economic and social integration with that core” which has at least one urbanized area of 50,000 or more persons, with each county within the MSA having 10,000 or more inhabitants (U.S. Census, 2005). In addition to the MSA region, seven other metropolitan Atlanta regions exist, which range from a seven- county Workforce Development Area to the 29-county Atlanta County Planning Area (CPA) (ARC, 2005). Although this study aims to examine the maximum amount of counties possible, the 28-county MSA region is used rather than the CPA region (the MSA region excludes Hall county) in order to conserve the use of certain data that was only available for the MSA regions.

The 8,376 square mile Atlanta MSA region accounts for 14% of the area in Georgia (57,906 square miles), and as of 2005, 4,917,717 inhabitants resided in the Atlanta MSA region, accounting for 54.20% of the state’s population (9,072,576 inhabitants) (U.S. Census, 2005). This metropolitan region grew around the city of Atlanta, located in Fulton County (and partly in DeKalb County), which lies in northwest Georgia and is the state’s capitol city. The favorable geography of the region set the stage for Atlanta’s role as a prominent railroad center during the mid-1800s. This spurred economic development that has been the catalyst for the region’s

extraordinarily high population growth, which has exponentially increased since 1970 from 1,840,280 to 4,917,717 in 2005 in the 28-county metropolitan area (RE Center, 2005).

Reiterating that the population projection in 2030 for the 20-county Atlanta alone is estimated at six million, it can be inferred that the area's rate of population growth will likely continue (ARC, 2006).

The high population growth rate in Atlanta is just one reason that this region is an ideal area for this study. Additionally, nearly all of the counties in the Atlanta MSA region lay within the Piedmont Uplands, with similar physiographic characteristics such as gently rolling hills, isolated mountains, presence of rivers and ravines, and mixed deciduous forests, which are predominated by oak-hickory-pine forests (Holder et al., 1986; GWW, 2000).<sup>4</sup> Furthermore, the Piedmont region is geologically characterized by the predominance of red clay soil and granite deposits (UGA). Figure 7 in Appendix A presents a map of the physiographic regions in Georgia (U.S. DOC, 2005; Fenneman et al., 1946). The physiographic consistency throughout the counties is useful to this study since, as noted by Heynan and Lindsey (2003), ecological and geological factors both directly and indirectly influence tree canopy sources, such as vegetation and population habitability, respectively. This characteristic of the Atlanta MSA region will aid in identifying land use policies that effect tree canopy coverage, since the effect from heterogeneous physiographic regions on tree canopy is minimized.

### Data

The dependent variable used in this study was the change in percent of land within the county covered in tree canopy from 1991 to 2001 (*canopy*). This data was provided by the

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<sup>4</sup> Bartow and Paulding County partially lie in the Tennessee physiographic region, and Dawson partially lies in the Southern region.

Natural Resources Spatial Analysis Laboratory (NARSAL) at the University of Georgia's Institute of Ecology. NARSAL developed this unique dataset for the southeast region of the United States through calibrating one square meter pixel infrared aerial photos and 30 square meter pixel Landsat satellite imagery for the years 1991, 2001, and 2005.<sup>5</sup> This temporal data set includes information on each pixel's percent tree canopy coverage, therefore making it possible to assess the changes in tree canopy coverage over the past 15 years due to different factors related to growth and land use policies. In regards to error associated with the tree canopy data, the root mean square error (RMSE) is approximately .75-.85 for each model, which represents the overall accuracy of the map. Specifically, it measures the discrepancy between coordinate values in a reconstructed image relative to the original image (Lo et al, 2002). Figure 8 in Appendix A shows the time lapse of change for tree canopy in the Atlanta MSA region from 1991 to 2005 (NARSAL).

The change in impervious surface from 1991 to 2001 (*IS*) for each of the counties in the Atlanta MSA is considered to be a primary factor influencing tree canopy change. This is because impervious surface accounts for several types of land use, including parking lots, rooftops, roads, sidewalks, and other areas that are characterized by compacted materials such as concrete, asphalt and brick that water cannot pass through and trees cannot grow on (Lu, et al., 2006). Data for this variable was derived from the same dataset as our dependent variable, percent change in tree canopy from 1991 to 2001. Given that these two variables were collected at the same time, on the same 30m<sup>2</sup> pixel scales, and with the same collection methods, no additional discrepancies in positional accuracy are created by this spatial data (Lo, 2002).

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<sup>5</sup> Data for 2005 was unused due to a lack of available and reliable explanatory variables.

A weighted index of tree canopy given 2001 land use types (*landuse*) was used to illustrate the nature of the development pattern in each of the Atlanta MSA counties.<sup>6</sup> As noted by Nowak et al. (1996), due to inherent differences between land use types, variation in tree canopy coverage is expected to exist for differing land use categories. In order to weight each of the land use types by the expected percent tree canopy, tree canopy goals set forth by American Forests were used. Their research indicates that communities east of the Mississippi should attempt to attain (or sustain) an overall tree canopy coverage of 40%, achieved for most communities through 15% coverage in downtown and industrial areas (light coverage), 25% in urban residential and commercial areas (medium coverage), and 50% in suburban residential areas (heavy coverage) (AF). These coverage goals offer a rough approximation of the development patterns that are associated with specific land use types, therefore making it possible to designate expected percent tree canopy weights to land use types considered in this study. Specifically, tree canopy coverage weights were 50% in residential lots and small plots (less than twenty-five acres), 25% in commercial, 15% in industrial and utilities, and 100% in undeveloped/sparsely developed land which includes agriculture, forestry, large residential lots (greater than five acres), and vacant land. The sum of the weighted land types was divided through by the total acreage in each county, resulting in a value for each county ranging from zero to one. Mathematically, the *landuse* variable was:

$$Landuse = \frac{industrial(0.15) + commercial(0.25) + residential(0.5) + other(1.0)}{totalcountyacres}$$

This value provided an estimate of the degree of difficulty counties face in regards to sustaining their existing tree canopy coverage, with values closer to one representing counties

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<sup>6</sup> Data for 1991 was unavailable.

that should have less trouble sustaining tree canopy, given that a large majority of their land is undeveloped/sparsely developed land.

Information on the percent change in population (*pop*), average household income (*income*), average median age (*age*), average percent of the population that has attained a college degree or greater (*college*), and the average percent of the population inside urbanized areas from 1990 and 2000 (*urbpop*) were collected since they may be factors that indirectly influence the percent change in tree canopy. Data for these variables was collected from the decennial 1990 and 2000 U.S. Census Bureau long-forms.

Another factor recognized in this study is whether or not counties have demonstrated an effort to promote quality growth in their community (*ex*). In order to account for this, data on the number of exemplary local planning and quality growth projects was collected from data offered on the Georgia Department of Community Affairs' (DCA) Georgia Quality Growth Partnership (GQGP) website. The purpose of this partnership is to aid local governments in successfully achieving quality growth through electronically sharing information on practices and successful implementation of quality growth approaches in their community. Quality growth data provided by the GQGP, which appeared to influence tree canopy coverage, included the following policies:

1. Infill development: Addresses design, density, and location of new development projects through reusing existing buildings and vacant land in an effort to decrease development on undeveloped land. Infill development is often recognized for its aid in reducing both urban sprawl and impervious surface, which may aid in protecting existing tree canopy.
2. Cluster Development: An attempt to increase greenspace and openspace by protecting land during development through the use of compact building location designs and mixed-use development patterns.

3. Conservation subdivision ordinance: As previously described in Chapter II, this quality growth tool sets aside and permanently protects undeveloped land during residential development, often through the use of innovative building location and design.
4. Mandatory conservation subdivision ordinance (rural cluster development): A combination of cluster development and a conservation subdivision ordinance, where developers are allowed to cluster housing while protecting a set aside amount of land. In order to make this cost effective, developers are allowed to build houses on smaller lots.
5. Creative design for higher density: Use of heavy landscaping in order to beautify areas that have high-density development.
6. Riparian buffers: Requirement that land along the banks of streams and rivers is exempt from development in order to protect water quality through vegetative buffering. A 25 foot buffer is required on all streams and rivers in Georgia, as set forth by the Erosion and Sediment Control Act; however, communities may choose to enforce more stringent buffer requirements (up to 150 ft) (GGA, 1975).
7. Land Trusts: Nonprofit organizations that have the right to protect undisturbed lands from new development.
8. Park Creation and Financing: Aids in the creation, improvement, and maintenance of parks, greenway, greenspace and open space.
9. Heat Island Mitigation: In order to compensate for the loss of trees during development, this tool is used to increase the use of roofing materials, porous pavements, and tree plantings, which may help to counteract the effects of the heat island effect.

In order to account for all of these practices, a composite index was created in which each clause was assigned a score of one for each exemplary example listed and zero otherwise.

Although only nine different types of exemplary quality growth examples were recognized, many counties have a score greater than nine on this index since communities could have more than one exemplary quality growth example.

Secondary data on each county's policies were problematic to collect, and often were out of date or unavailable. In order to collect this pertinent data, the need arose to directly question county policy-makers concerning tree ordinances and their specific clauses. To do this, a survey was created for this study that was administered to knowledgeable persons within Atlanta MSA counties and cities.<sup>7</sup> The design and implementation of this survey followed Dillman's Total Design Method (1978) and Tailored Design Method (2007) in order to maximize both the reliability of results and response rates gained through our internet survey. In September, 2006, the online survey was administered to all of the counties within the study area, not only to collect data on tree ordinances and their clauses, but also to gain knowledge concerning other variables that had the potential to be significant factors in relation to the effect of land use policies on tree canopy coverage. Prospective respondents were contacted via e-mail, using contact information collected through public sources and a database managed by the Georgia Forestry Commission. Recipients included arborists, urban planners, decision-makers, and other qualified recipients who potentially held a significant amount of knowledge in respects to planning and tree management in their community. If a recipient agreed to complete the internet survey, they were directed from the e-mail invitation to the survey website. The participant then received instructions that guided them to the community that they wished to evaluate. This process utilized a community hierarchy, beginning with the MSA region, from which the user could narrow down to a specific county, and if chosen, an incorporated city that they wished to evaluate. This portion of the survey was created using Dreamweaver version 8.0, a web-development tool created by Macromedia; however, the actual survey that participants completed-- which was linked to the website created by Dreamweaver-- was created using an

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<sup>7</sup> Due to incongruity in the availability of data for cities within the MSA region, city results will be set aside for use in a future study.

internet survey design program known as Survey Monkey. In the initial e-mail invitation, recipients were also given the option to complete a survey upon request through postal mail. Those who opted to do so were sent return mailing envelopes with prepaid postage.

Upon completing the survey, each participant received a thank you note for their time and a reminder that they were still eligible to complete surveys for other communities if they wished to do so. A follow-up reminder e-mail was sent to nonrespondents two weeks later, and a second and final reminder e-mail was sent four weeks after the initial invitation. A copy of the survey, along with screenshots of the website used to administer it, can be found in Appendix B.

The questions asked in the survey were primarily created using findings from previous studies that suggested what policy and management factors may influence a community's percent change in tree canopy. Specifically, questions to account for a county's tree ordinance and its clauses, management, communication efforts, zoning, development regulations, and inhibitors to maintaining tree canopy were of main interest to this study. Note that due to the limited degrees of freedom created by the small sample size used in this study, as well as the desire to include all influential factors that held the promise of influencing tree canopy, some explanatory variable moderations, such as indices, were used.

Tree management (*mgt*) was created using a dummy variable that accounted for whether or not a county had established either a manager or department whose responsibilities included overseeing the well-being of trees in the community. Although this person and/or department were often appointed by the county and in charge of the tree ordinance locally, it did not necessarily imply that counties with an entity to care for trees had an established tree ordinance. Tree ordinance establishment was not considered when accounting for the presence of a tree board.

Communication (*comm*) was also considered an important factor when assessing tree canopy, since public support and input has been shown to have a positive effect on trees (Green and Howe, 1998). Therefore, the survey for this study included a question asking whether or not the county had made an attempt to communicate to citizens in the area about trees through public events, educational programs, radio, television, printed material, or other mediums. The results from this multiple choice question were condensed using a composite index, which accounted for each individual communication medium used, with counties having the ability to score on a 0-6 scale, 6 meaning the county communicates to the community using all six possible mediums.

The effect of zoning on the percent change on tree canopy (*zoning*) was a bit problematic. Since zoning was partially accounted through the land use variable previously mentioned, a need to account for the direct effects of both planning and zoning was desired. This was done using two questions. Both were designed to give participants the opportunity to rate planning and zoning using a Likert scale of 1 to 10. The first question asked participants to rate the planning and zoning regulations in their county in terms of helping to promote quality growth, with 10 being the most effective. Second, participants were asked to rate the planning and zoning regulations in their county in terms of protecting and promoting tree canopies, with 10 being the most regulated. In order to gain a comprehensive view of both the effectiveness and regulation through planning and zoning in regards to tree quality, these two questions were combined into one regressor, with counties having the ability to attain a score on a 0-20 scale, with 20 signifying that the county's planning and zoning are designed to promote both effective quality growth and tree protection, both of which are hypothesized to positively influence tree canopy.

Development regulation (*develreg*) was represented using a multiple choice question. Specifically, survey participants were asked if development in the county was unregulated,

somewhat regulated, or heavily regulated. The subjective nature of this question may pose problems that could affect the validity and significance of this regressor. Although the same issue with subjectivity exists for the zoning questions included in this survey, less bias is expected due to both the larger scale and the dual explanation provided by these similar questions.

Finally, participants were asked whether any inhibitors (*inhibit*) existed that prevented the county from attaining their desired quality of tree management. These inhibitors included insufficient budget, insufficient staff and equipment, competing priorities, lack of public support and political will, and lack of community recognition concerning the importance of tree management. The results from this multiple choice question were condensed using a composite index, which accounted for each inhibitor, with counties having the ability to score on a 0-7 scale, 7 meaning the community is inhibited by all of the problems presented in the question.

In addition to the survey created for this study, another survey was conducted in April of 2005 by Connie Head and the Georgia Urban Forest Council (GUFC) entitled *Survey of Community Tree Regulation in Georgia*. This survey reviewed tree ordinances and management practices in 686 communities throughout Georgia (Head, 2006). The study comprised both a review of ordinances and a survey to tree managers in each of the communities, whose questions in several cases aligned with questions asked in the survey for the study at hand. Therefore, when possible, results from this study were compared to, and in some cases added to, the results of our own study in order to enrich the depth and reliability of the regressors.

Information on a county's tree board (*board*) and ordinance establishment (*treeord*), as well as well as information on the clauses within a county's tree ordinances (*clauses*) were collected. The existences of a county tree board and tree ordinance were recorded using binary

dummy variables, with one implying the county has established a tree board or tree ordinance, zero otherwise. This information was collected from two ordinance reviews and two surveys. The first ordinance review was conducted for the survey at hand, using information given in county ordinances listed on Municode (Municode, 2006). However, due to missing and/or outdated ordinances, questions were included in this study's survey to gather more up-to-date information on specific tree ordinances. Head's review of ordinances and results from her survey were also used to supplement any missing information. Of the possible clauses to include in a tree ordinance, nine were hypothesized to have a positive influence on tree canopy, including:

1. Establishment of tree banks or alternative compliance
2. Site requirements during development, such as specification of tree preservation areas, allowances on tree removal, landscape plans, or tree replacement
3. Requirement of a tree removal permit for previously developed private land
4. Requirement of a tree removal permit for new development
5. Buffer requirements for root zone protection during development
6. Adherence to protect exceptional trees during development (i.e. specimen and historic tree protection)
7. Allowance for tree unit credits or replacement fees of no less than 100% the costs of the tree removed
8. Requirement of street trees (i.e street lining, minimum quantities, and species requirements)
9. Parking lot requirements (i.e. islands, trees per space, and percent of parking lot dedicated to tree requirements).

In order to include the effects from all of these factors, an index was created which assigned each clause one point for being included in a county's tree ordinance, and zero otherwise. Therefore, the possible values attainable by each county ranged from 0 to 9 for this

regressor, 9 meaning all clauses were included, and 0 meaning none had been established, (which in most cases implied that the county had not established a tree ordinance).

In all, 2,380 people were invited to participate in this study's survey, 308 surveys were collected through internet and postal mail for a response rate of 12.94%. Although this response rate is relatively low, the survey responses are best characterized as expert opinions, which was the goal of this survey. The survey results are not meant to represent an estimate of some true population value, so response rate is somewhat less important than in most surveys.

Furthermore, of the returned surveys, 22 were either unusable or the participant asked to have it discarded, which resulted in a final sample size of 12.02% of the initial sample population. This number is not surprising given the high level of knowledge required about community trees to complete this survey, which likely reduced the number of qualified survey participants.

However, people from 22 out of the 28 counties in the Atlanta MSA region responded with useable results, which is a response rate of 78.57%. Of the incorporated cities within the study area, people from 68 of the 131 responded, which is a response rate of 51.90%. On average, the response rate throughout all of the communities surveyed is 56.60%. Using GUFC's study as a baseline for survey response comparison, their response rate was 30% for their surveyed communities. Furthermore, although GUFC's survey was administered to the entire state of Georgia, their response for the Atlanta MSA counties was 14 out of 28 counties, which is a 50% response rate.

This subjective comparison of response rates makes our sample size appear adequate; however, in order to rigorously demonstrate that our presumption of reasonable survey error is sufficient, statistical evidence can be determined using the formula:

$$N_s = \frac{(Np)(p)(1 - p)}{(Np - 1)(B / C)^2 + (p)(1 - p)}$$

Where:  $N_s$  = sample size needed  
 $Np$  = population size  
 $B$  = acceptable sampling error  
 $C$  = the critical value  
 $p$  = response distribution

Given that  $Np$  is 2380,  $B$  will be set at  $\pm 5\%$ ,  $C$  is 1.645, since our assumed confidence level is 90%, and  $P$  will be set as a 50/50 split then  $N_s$  will be 223 people.<sup>8</sup> Given that we are able to use 286 responses, we clear the requirement to guarantee that our sample size is sufficient (Dillman, 2007). Thus, our survey responses should be within five percent of the population values.

In addition to sampling error, another possible shortcoming of internet surveys is coverage error, which may be present in our survey for several reasons. First, given inherent diversity between counties, such as differing population and the number of persons employed to work on behalf of the community, an internet survey may be less likely to include potential participants in smaller counties. Although contact information for the counties was obtained through the Georgia Forestry Commission, no guarantees exist that reliable and knowledgeable participants were reached for all counties. On the same note, due to financial limitations that smaller counties face, they may not be able to afford resources such as computers or websites, which is crucial not only for initially contacting potential participants to take the survey, but also for potential participant's to respond. Allowing cross-community responses may have helped to alleviate this potential problem; however, given that there is no rigorous way to test for coverage

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<sup>8</sup> An 80/20 split is more likely; however, in case it isn't, a conservative 50/50 split estimate for the response distribution is used.

error, we can only hope that it was minimized through the precautionary measures used in this study.

Another potential problem with internet surveys is that some respondents may not choose to participate due to concern about confidentiality and security. Participants were notified in the initial cover letter that this survey was both confidential and secure, and although highly unlikely, some risk of a security breach exists (Dillman, 2007).<sup>9</sup> However, the effect from this was likely small, given the use of familiar survey and security software.

Finally, given the drastically different makeup of each county's characteristics in the Atlanta MSA, consideration was given towards creating a variable to indicate the difference between the five core counties of the Atlanta MSA, which includes the counties of Cobb, Fulton, Gwinnett, Clayton, and DeKalb. However, within these five counties vast differences in policies exists, raising the question of whether or not it would be appropriate to dummy out all five of these counties, or instead to only dummy out part of them. To investigate this, the Euclidean distance between each county's vectors of explanatory variables was considered. The results from this procedure show that a minimal difference exists between the sum of the squared explanatory variables for Clayton and Cobb counties, but Fulton, Gwinnett, and DeKalb were considerably different. In order to account for this unique relationship, an indicator variable was created, with one indicating Clayton or Cobb County, zero otherwise (*CCdum*).

### Methodology

The explanatory variables included in the data set will hopefully provide a large amount of information in regards to what factors influence the percent change of tree canopy in the

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<sup>9</sup> SSH Secure Shell Client was used to reduce the risk of a security breach.

Atlanta MSA counties. In summary, Table 1 provides variable names and descriptions, while Table 2 shows the summary statistics for these variables.

Given that this study will be examining factors that affect the percent of tree canopy coverage from 1990 to 2000, the time trend representing the change in percent of tree canopy between these two dates is a linear relationship giving only its change, rather than how it evolved. This simplifies the design of the model significantly, since the dependent variable can be represented as the percent change of tree canopy coverage from 1990 to 2000. In order to maintain consistency throughout the model, the percent change was also found for variables that had observations for the two respective points in time. Variables for which only one observation existed remained unchanged, apart from indexing alterations previously mentioned.

A major concern when choosing what form of parameter estimation to use is the possible endogeneity of independent variables. If this exists, then orthogonality between the error term and regressors is lost, violating the most important assumption of the OLS estimator (Hayashi, 2000; Wooldridge, 2001). Specifically, in the mangament variable, concern exists that it may be correlated with unobserved factors that can also affect the percent change in tree canopy coverage, such as the percent change in the population from 1991 to 2001, average urban population, average household income, average median age, percent change in impervious surface from 1991 to 2001, landuse, and development regulation. In order to account for this, these factors may be used as instruments on any exogenous variables that appear to be overidentifying the model. Given that one cannot use OLS when including instrumental variables, two primary model choices exist: 2SLS and GMM. GMM will be used several

**Table 1: Variable Names and Descriptions**

| <i>Variable</i> | <i>Description</i>                                                                                   |
|-----------------|------------------------------------------------------------------------------------------------------|
| canopy          | Change in the percent of tree canopy cover, 1992 to 2001                                             |
| IS              | Change in the percent impervious surface, 1992 to 2001                                               |
| landuse         | Weighted index of land use types: Residential (.50), Commercial (.25), Industrial (.15), Other (1.0) |
| pop             | Change in the percent population, 1990 to 2000                                                       |
| ex              | Index of the number of exemplary quality growth examples                                             |
| mgt             | County has established a tree care entity                                                            |
| comm            | Index of mediums used by county to communicate about trees                                           |
| zoning          | Index of quality growth and tree canopy efforts exhibited in zoning (0-20)                           |
| develreg        | Degree of development regulation (none, somewhat, and significant regulation)                        |
| inhibit         | Index of inhibitors faced by a county that prevent meeting tree goals                                |
| board           | County has established a tree board                                                                  |
| treeord         | County has established a tree ordinance                                                              |
| clauses         | Index of tree preserving clauses in tree ordinance                                                   |
| CCdum           | Dummy variable defining Cobb and Clayton County as one, otherwise zero.                              |

**Table 2: Summary Statistics**

| <i>Variable</i>               | <i>Observations</i> | <i>Mean</i> | <i>Standard<br/>Deviation</i> | <i>Minimum</i> | <i>Maximum</i> |
|-------------------------------|---------------------|-------------|-------------------------------|----------------|----------------|
| $\Delta$ % tree canopy        | 28                  | -0.034      | 0.033                         | -0.121         | 0.029          |
| $\Delta$ % impervious surface | 28                  | 0.021       | 0.021                         | 0.001          | 0.078          |
| Landuse                       | 28                  | 0.828       | 0.113                         | 0.535          | 0.968          |
| % $\Delta$ population         | 28                  | 0.428       | 0.294                         | 0.005          | 1.232          |
| Quality growth examples       | 28                  | 1.536       | 2.925                         | 0.000          | 13.000         |
| Management                    | 28                  | 0.393       | 0.497                         | 0.000          | 1.000          |
| Communicate                   | 26                  | 1.654       | 1.623                         | 0.000          | 5.000          |
| Zoning                        | 22                  | 11.206      | 2.849                         | 3.500          | 16.000         |
| Degree of regulation          | 22                  | 2.405       | 0.359                         | 2.000          | 3.000          |
| Inhibitors                    | 28                  | 3.196       | 2.315                         | 0.000          | 7.000          |
| Tree board                    | 28                  | 0.179       | 0.390                         | 0.000          | 1.000          |
| Tree ordinance                | 28                  | 0.571       | 0.504                         | 0.000          | 1.000          |
| Ordinance clauses             | 28                  | 3.571       | 3.501                         | 0.000          | 9.000          |
| Cobb/Clayton dummy            | 28                  | 0.071       | 0.262                         | 0.000          | 1.000          |

reasons. First, utilizing generalized method of moments (GMM) rather than ordinary least squares (OLS) can improve a model that has heteroscedasticity through a weighting matrix that accounts for heteroscedasticity of unknown forms (Craig, 1983).<sup>10</sup> Additionally, the reason for choosing GMM over two-stage least squares (2SLS) is that if heteroscedasticity exists, GMM will account for it, whereas two-stage least squares does not—the two methods' only similarity lies in that the same instrumental variables should be used in each one for the same independent variables that may be endogenous to the model. To clarify, in cross-sectional applications such as the one at hand, it can't hurt to use GMM rather than 2SLS; however, GMM may result in substantial consistency gains relative to 2SLS if heteroscedasticity exists (Wooldridge, 2001).

This study used the two-step efficient GMM estimator, which follows the same methodology as the efficient GMM estimator, but also uses an optimal weighting matrix which is the inverse of the estimated covariance matrix of moment conditions.<sup>11</sup>

### Model Diagnostics

In order to ensure that the GMM model used was properly specified, several measures were taken to examine the specification of our regressors to guarantee that no heteroskedasticity existed and that our model did not suffer from multicollinearity.<sup>12</sup> Additionally, before conducting the two step efficient GMM estimation, a J-test was used to determine if it was necessary to include instrumental variables in the regression. The initial OLS regression was compared to a 2SLS regression, in which tree ordinance and management was instrumented to

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<sup>10</sup> The weighting matrix accounts for an additional requirement that the error term has a zero mean conditional of the covariates, therefore guaranteeing that regardless of the function of the covariates, it is uncorrelated with the error term (Wooldridge, 2001).

<sup>11</sup> Coefficient estimates using OLS were qualitatively the same as those found using 2SLS and GMM.

<sup>12</sup> Complete results for model diagnostics in Appendix D.

account for their possible endogeneity. The Hausman test suggests that there is no significant difference between the instrumental variables and OLS, indicating that OLS is a consistent estimator in this model. However, to protect against any bias due to endogeneity of these variables, GMM was used to guarantee that orthogonality existed between the error terms and the regressors.

After applying the optimal weighting matrix to the GMM estimator (the second-stage), tests were run to ensure that the instrumental variables used to instrument tree ordinances and management was correctly chosen. To do this, the Hansen J Statistic was used, whose joint null hypothesis is that the instruments chosen are uncorrelated with the error term and that instruments that were left out were correctly excluded. Results indicated our instruments were not overidentified. Overall, given the results that model diagnostics have provided, sufficient verification exists that model specification may be rightly kept, and that no serious specification errors are present in the model.

## CHAPTER IV: ANALYSIS RESULTS

In order to explore this study's hypothesis to analyze the percent change in tree canopy of county land over the ten year period from 1991 to 2001, the GMM estimator is obtained by minimizing the quadratic objective function:

$$\min_b \left[ \sum_{i=1}^N Z_i (y_i - X_i b) \right]' \hat{W} \left[ \sum_{i=1}^N Z_i (y_i - X_i b) \right]$$

which is solved by

$$\hat{\beta} = (X'Z\hat{W}Z')^{-1} (X'Z\hat{W}Z'Y)$$

where  $Z_i$  is a matrix of observable instrument variables and  $\hat{W}$  is a function of sample averages, which is a consistent estimate of the population moments. The above function and solution can be applied to the model:

$$\begin{aligned} canopy_i = & \beta + treeord_i \beta_{treeord} + mgt_i \beta_{mgt} + pop_i \beta_{pop} \\ & + comm_i \beta_{comm} + IS_i \beta_{IS} + ex_i \beta_{ex} + inhibit_i \beta_{inhibit} \\ & + landuse_i \beta_{landuse} + clauses_i \beta_{clauses} + zoning_i \beta_{zoning} \\ & + board_i \beta_{board} + develreg_i \beta_{develreg} + CCdum_i \beta_{CCdum} + \varepsilon_i^{canopy} \end{aligned}$$

where  $Z_i$  will be used to instrument  $mgt$  in the auxiliary regression:

$$\begin{aligned} mgt_i = & pop_i \gamma_{pop} + college_i \gamma_{college} + urbpop_i \gamma_{urbpop} \\ & + income_i \gamma_{income} + age_i \gamma_{age} + \varepsilon_i^{mgt} \end{aligned}$$

The results from this estimation are the shown in Table 3:

**Table 3: Results for the GMM Estimation (n=21)**

| <i>Variable</i>               | <i>B</i> | <i>Standard Error</i> | <i>z Score</i> | <i>Sig.</i> |
|-------------------------------|----------|-----------------------|----------------|-------------|
| Constant                      | -0.1866  | 0.0371                | -5.03          | 0.000       |
| Tree ordinance                | 0.0037   | 0.0165                | 0.23           | 0.821       |
| Management                    | -0.0565  | 0.0091                | -6.2           | 0.000       |
| % $\Delta$ population         | 0.0218   | 0.0136                | 1.61           | 0.108       |
| Communicate                   | -0.0025  | 0.0021                | -1.19          | 0.233       |
| % $\Delta$ impervious surface | -1.5633  | 0.3883                | -4.03          | 0.000       |
| Quality growth examples       | 0.0058   | 0.0016                | 3.6            | 0.000       |
| Inhibitors                    | 0.0115   | 0.0026                | 4.34           | 0.000       |
| Landuse                       | 0.1200   | 0.0328                | 3.66           | 0.000       |
| Ordinance clauses             | 0.0103   | 0.0028                | 3.74           | 0.000       |
| Zoning                        | 0.0026   | 0.0009                | 2.93           | 0.003       |
| Tree board                    | -0.0089  | 0.0128                | -0.7           | 0.486       |
| Degree of regulation          | -0.0137  | 0.0101                | -1.36          | 0.175       |
| Cobb/Clayton dummy            | 0.0864   | 0.0212                | 4.08           | 0.000       |
| R2 = .8015                    |          |                       |                |             |

This model shows that variables that are insignificantly correlated with the change in percent tree canopy covering county land area from 1991 to 2001 include tree ordinance (*treeord*), percent change in population (*pop*), communication (*comm*), development regulation (*develreg*), and tree board (*board*).

The results indicate that the effects from the change in percent impervious surface (*IS*), land use (*landuse*), and the Cobb/Clayton dummy (*CCdum*) were of the expected sign and significant (at the .01 level). Coefficients on policy variables that were significant and of the expected sign included zoning emphasis (*zoning*), tree ordinances clauses (*clauses*), and exemplary quality growth examples (at the .01 level).

Results on policy variables that are more complicated to interpret due to unexpected signs include management (*mgt*) and inhibitors (*inhibit*) which were significant (at the .01 level). The domination of highly densely populated counties establishing policies to prevent the loss of trees relative to less densely populated counties appears to be the main reason for these

counterintuitive results. Further interpretation and explanation of all of the significant results in this model will be discussed in the following section.

## CHAPTER V: DISCUSSION

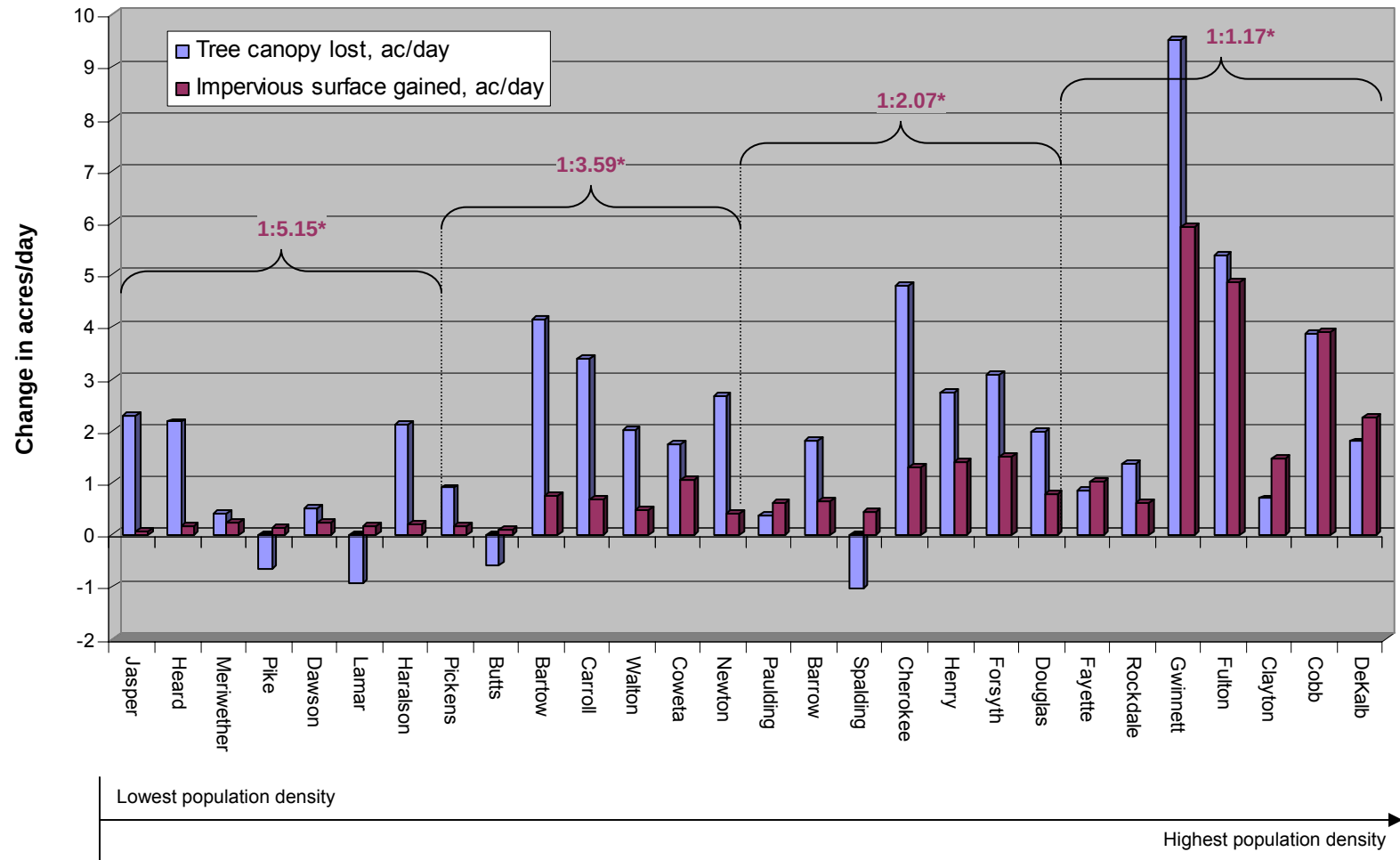
The  $R^2$  for this type of data was excellent, with the model explaining 80.15% of the change in the percent of tree canopy from 1991 to 2001 in the Atlanta MSA region. Furthermore, since every significant explanatory variable in this model either represented urban morphology or county policies that were expected to influence tree canopy, these results suggest that such factors should be highly considered by counties who wish to prevent further loss of the percent tree canopy covering the county's land. In order to better understand the results of this model, interpretations and observations for each of the significant explanatory variables will be explored.

The coefficient on *IS* suggests that, holding all other factors equal, for every additional one percent increase in a county's land area covered by impervious surface from 1991 to 2001, it is expected to have lost tree canopy equal to 1.56% of county land area at the end of the time period. Figure 1 further explores the relationship between impervious surface and county tree canopy loss by comparing the change in the number of acres of tree canopy per day in each county between 1991 and 2000 to the change in the percent of impervious surface per day during that time period.<sup>13</sup> The regression's results and figure both show that tree canopy loss is somewhat greater than proportional to the increase in impervious surface.

Furthermore, this graph offers insight into changes in tree canopy loss and impervious surface gains that are associated with each county's level of urbanization (i.e. population

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<sup>13</sup> Note that this graph illustrates the change in impervious surface and tree canopy acres per day, whereas the results provided by the model represent the change in amount of county land covered by impervious surface/tree canopy.



Note: Four groups of seven counties created in order of lowest density to highest density.

\* Average ratio of the gain in impervious surface to tree canopy lost (ac/day) for bracketed counties.

**Figure 1: Comparison of Change in Acres per Day of Tree Canopy and Impervious Surface in Atlanta MSA Counties, 1991-2000**

density). This was accounted for by recording the ratio of the gain in impervious surface to the loss in tree canopy (acres/day) for each of the 28 counties. These values were then divided into four groups of seven population density-based groups, and the average ratio for the groups was taken.<sup>14</sup>

Results indicate that as urbanization increases, the ratio of tree canopy removed to gains in the impervious surface tends to decrease, moving towards a one-to-one ratio. One possible driver for this trend is that as population density increases, urbanized counties will experience more infill and smaller scale development, therefore resulting in less trees being removed than would be in large scale land development. Another reason that impervious surface is low relative to tree canopy loss in more rural counties may be due to land speculation. In most cases, residential land use is created on previously undeveloped land, with the occurrence of this transformation increasing as the need for residential developments increases. Therefore, as more residential development increases in less urbanized counties, landowners of undeveloped land may wish to sell it for residential uses. In doing this, landowners will often cut down trees on their undeveloped land in order to prepare it for residential development. Furthermore, these harvested trees may be sold for additional revenue. Therefore, during the transitional phase where land is no longer forested but has not yet been developed for residential purposes, the ratio of the gain in impervious surface to tree canopy loss will be quite different. As more transitional land becomes residentially developed, the ratio of impervious surface gain to tree canopy loss will tend closer to a one to one relationship.

The coefficient on *landuse* (0.12) is significant (at the .01 level) and of the expected sign. Table 4 provides calculations for the effects on tree canopy from changing undeveloped land to

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<sup>14</sup> The average ratio of the change in impervious surface to tree canopy loss for the 28-county Atlanta MSA was 1:1.85, with a decrease of 57.28 acres of tree canopy per day and an increase of 31.34 acres of impervious surface per day.

residential, commercial, or industrial uses in intervals of a ten percent change in land use. In interpreting this table, consider the following example. If ten percent of land within the county land was transformed from undeveloped into residential land use, we would expect to see a five percent decrease in the percent of land within the county covered in tree canopy, given the weights that were assigned to each land use type to account for their ideal percent tree canopy coverage. However, the coefficient on *landuse* suggests that, holding all else constant, this change in land use would lead to an expected decrease of tree canopy equal to 0.6 percent of land area.

**Table 4: Comparison Matrix for the Change in the Percent of Tree Canopy Covering County Land Given a Land Use Transformation from Undeveloped Land (in increments of 10%)**

| Initial Land Use Type | Percent reduced | Transformed Into: |                  |                  |
|-----------------------|-----------------|-------------------|------------------|------------------|
|                       |                 | Residential (50%) | Commercial (25%) | Industrial (15%) |
| Undeveloped           | 10%             | -0.60%            | -0.90%           | -1.02%           |
|                       | 20%             | -1.20%            | -1.80%           | -2.04%           |
|                       | 30%             | -1.80%            | -2.70%           | -3.06%           |
|                       | 40%             | -2.40%            | -3.60%           | -4.08%           |
|                       | 50%             | -3.00%            | -4.50%           | -5.10%           |
|                       | 60%             | -3.60%            | -5.40%           | -6.12%           |
|                       | 70%             | -4.20%            | -6.30%           | -7.14%           |
|                       | 80%             | -4.80%            | -7.20%           | -8.16%           |
|                       | 90%             | -5.40%            | -8.10%           | -9.18%           |
|                       | 100%            | -6.00%            | -9.00%           | -10.20%          |

The coefficient on *ex* shows that, holding all other factors constant, each additional exemplary quality growth example that a county reported led to a gain in tree canopy equal to 0.58 percent of the county land area during the period from 1991 to 2001 over the amount of tree canopy had they not implemented the quality growth example during that time period (significant at the .01 level). Therefore, if a county were to implement one of each of the nine

examples considered in this study, they would experience a gain in tree canopy equal to 5.26 percent of the county land area during that time. Note that counties could have implemented more than one quality growth example, such as in the case of Fulton County, which implemented 13 examples, which implies that they experienced a gain in tree canopy equal to 7.60 percent of the county land area during the decade. Furthermore, in exploring what types of counties reported implementing exemplary quality growth examples, it appears that, given Figure 3, there is a skew on the distribution, indicating that in many cases, the counties that experienced the highest population density were the most likely to have implemented quality growth examples. Given that Fulton County has the greatest number of examples may lead some to argue that implementing exemplary quality growth examples is related to a county's population, not to its level of urbanization. However even with the number of examples weighted by the county population, counties who would be expected to have quality growth examples based on their population, such as the counties of Clayton, Rockdale, and Fayette, do not. Furthermore, five counties have a greater number of exemplary examples per 100,000 than Fulton County, as shown in Table 5, therefore contradicting the argument's basis.<sup>15</sup>

**Table 5: Top Six Counties in Terms of the Number of Exemplary Quality Growth Examples per 100,000 People**

| County  | Number of<br>exemplary<br>exemplars per<br>100,000 people |
|---------|-----------------------------------------------------------|
| Fulton  | 1.593                                                     |
| Barrow  | 2.167                                                     |
| Carroll | 2.292                                                     |
| Forsyth | 3.049                                                     |
| Douglas | 3.255                                                     |
| Coweta  | 4.484                                                     |

<sup>15</sup> See Table 7 in Appendix C for a complete listing of county ratios.

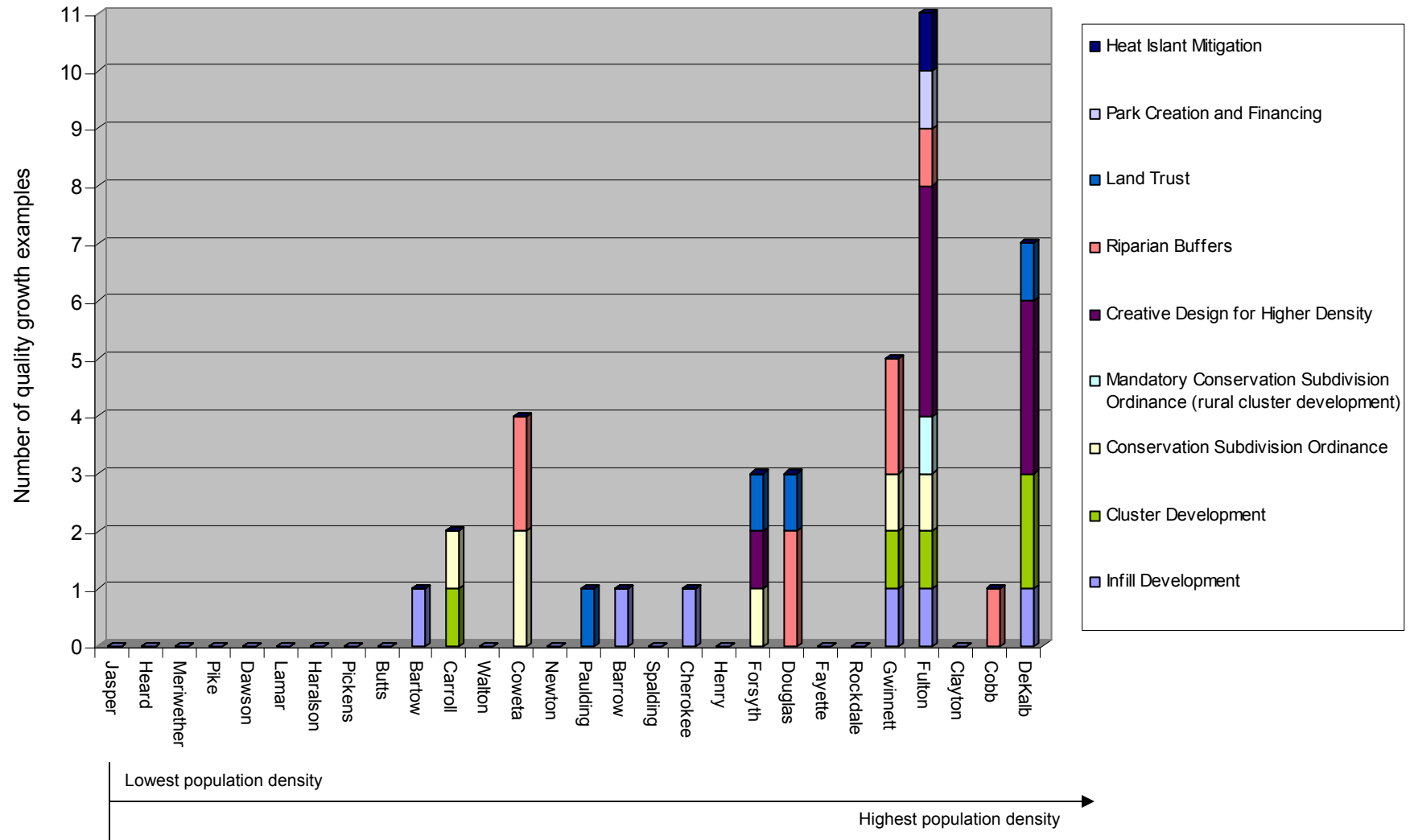


**Figure 2: Comparison of the Number of Exemplary Quality Growth Examples that are Expected to Influence the Tree Canopy based on Population Density of Counties within the Atlanta MSA**

All other factors being equal, the coefficient on *mgt* indicates that if a county establishes a department and/or person who is responsible for the management of a county's trees, the county is expected to lose tree canopy equal to 5.65 percent of the county land area during the ten year period over and above the change had they not established a management entity during that time (at the .01 level). This result is surprising, since it was expected that management would have a positive effect on tree canopy coverage.

The coefficient on *zoning* implies that, holding all else constant, each additional point gained on the composite scale of 0 to 20 that was used to measure a county's emphasis on quality growth and tree canopy protection led the county to gain tree canopy equal to 0.26 percent of the county's land area during the period from 1991 to 2001 over the change in tree canopy had the county not gained the point (significant at the .01 level). This implies that if a county were to gain all 20 points, it could expect to gain tree canopy equal to 5.14 percent of the county land during that time period. This is an unlikely situation; however, given that the mean value for a county's zoning score was 11.2, then it would not be improbable that a county could put forth the effort to gain five points, which would lead to a gain in tree canopy equal to 1.29 percent of the county land area during the decade. Another consideration is that counties who are below the mean could feasibly gain tree canopy by improving zoning to a point where they are at the mean. For example, the minimum value that a county scored in regards to zoning was 3.5, which implies that if they were to gain 7.7 points to be at the mean value of 11.2, they could gain tree canopy equal to 1.98 percent of the county land area.

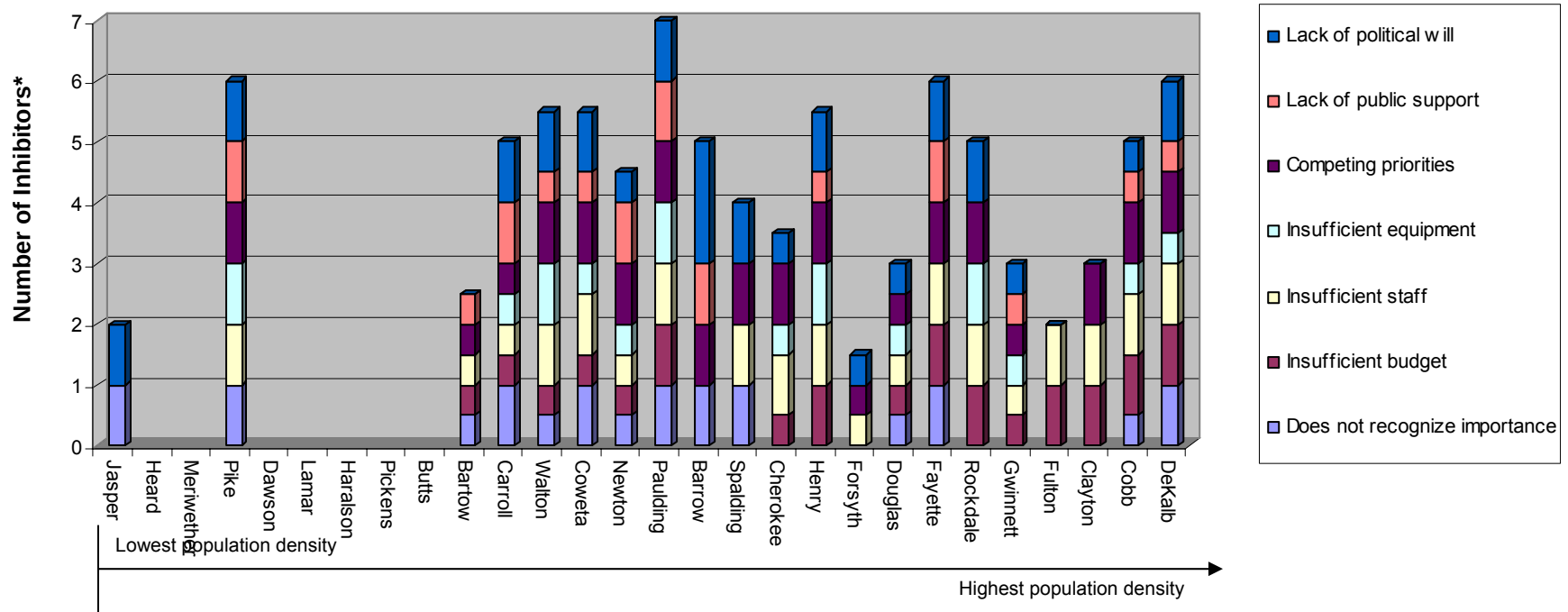
The results for *inhibit* illustrate that, holding all else constant, each additional factor that inhibits a county from successful tree management leads to a gain in tree canopy equal to 1.15 percent of the county land at the end of the period from 1991 to 2001 compared to the change if

they did not face the inhibitor. If a county faces all seven of the inhibitors accounted for in this study, it suggests that a county would expect a gain in tree canopy equal to 8.02 percent of the county land at the end of the ten year period. One explanation for the sign on this coefficient is that broadly speaking, *inhibit* reflects the need for resources and support to protect trees in a county. Therefore, it makes sense that in order for counties to feel they are facing inhibitors, they must be making an effort to acquire resources and support to protect trees in the county. The question then is: what type of county is making the effort to protect their trees? Intuition leads one to believe that counties that have fewer trees than desirable would be the counties that feel they face inhibitors to acquiring the demanded level of resources and support. To explore this, Figure 5 illustrates the factors that survey respondents deemed inhibiting, with counties organized from lowest to highest population density.<sup>16</sup> Although this graph does not show that counties with a higher population density have more inhibitors, the figure does imply that different inhibitors are faced by more urbanized counties than by less urbanized ones. Specifically, it appears that highly urbanized areas are inhibited more by an insufficient budget, while less urbanized counties' inhibitors include lack of public support, lack of political will, and insufficient equipment. However, nearly all counties, no matter what urbanization level, face inhibitors in the form of competing priorities and insufficient staff. In support of this observation is the fact that by taking the sum of the inhibitors across all of the counties in the Atlanta MSA, the prevalence of the inhibitors amount the counties, in order from most prevalent to least, is: competing priorities, insufficient staff, lack of political will, insufficient budget, county does not recognize importance, and insufficient equipment.<sup>17</sup>

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<sup>16</sup> Note that counties with zero inhibitors were nonrespondents to the survey.

<sup>17</sup> The non-weighted results indicate the same results, except that insufficient budget and competing priorities were equally cited by survey respondents as being inhibiting.



\* Due to differing opinions, inhibiting factors received:

- A score of 0 if:  $< \frac{1}{4}$  of respondents deemed the factor an inhibitor.
- A score of 0.5 if:  $\geq \frac{1}{4}$  and  $< \frac{3}{4}$  of respondents deemed the factor and inhibitor.
- A score of 1 if:  $> \frac{3}{4}$  or more of respondents deemed the factor an inhibitor.

Figure 3: Comparison of Inhibitors to Tree Management Faced by Atlanta MSA Counties by Population Density per Square Mile

The coefficient on *clauses* suggests that, with all other factors constant, each ordinance clause added to a tree ordinance leads to an expected 1.03 percent increase in county land area covered with tree canopy at the end of the ten years over the change expected without the clause (significant at the .01 level). This means that if a county were to enact all nine of the clauses accounted for in this study, it would have an expected 9.25 percent increase in land covered with tree canopy at the end of the ten year period. This result is quite interesting, given that the act of establishing a tree ordinance is not significant in itself. It is the clauses within the tree ordinance that can significantly influence the change in the percent of tree canopy covering land in the county. Therefore, having an ordinance that is robust with meaningful clauses should be regarded as what is essential in the establishment of policies to alleviate the loss of tree canopy. In further examining this variable, Figure 6 illustrates the makeup of each county tree ordinance in the Atlanta MSA. Throughout the counties, all counties with an established tree ordinance enacted a clause to require a tree removal permit for new development and all but one county enacted a clause in their tree ordinance that included site requirements during development. Furthermore, some clauses that seem to be the hardest to establish and manage were only used in nine to ten counties, all of which were found in highly robust tree ordinances. These clauses include establishment of tree banks or alternative compliance, buffer requirements for root zone protection during development, and allowance for tree unit credits or replacement fees of no less than 100% the costs of the tree removed. Therefore, this suggests that counties that have established a tree ordinance but would like to improve it should consider these clauses as possible additions.

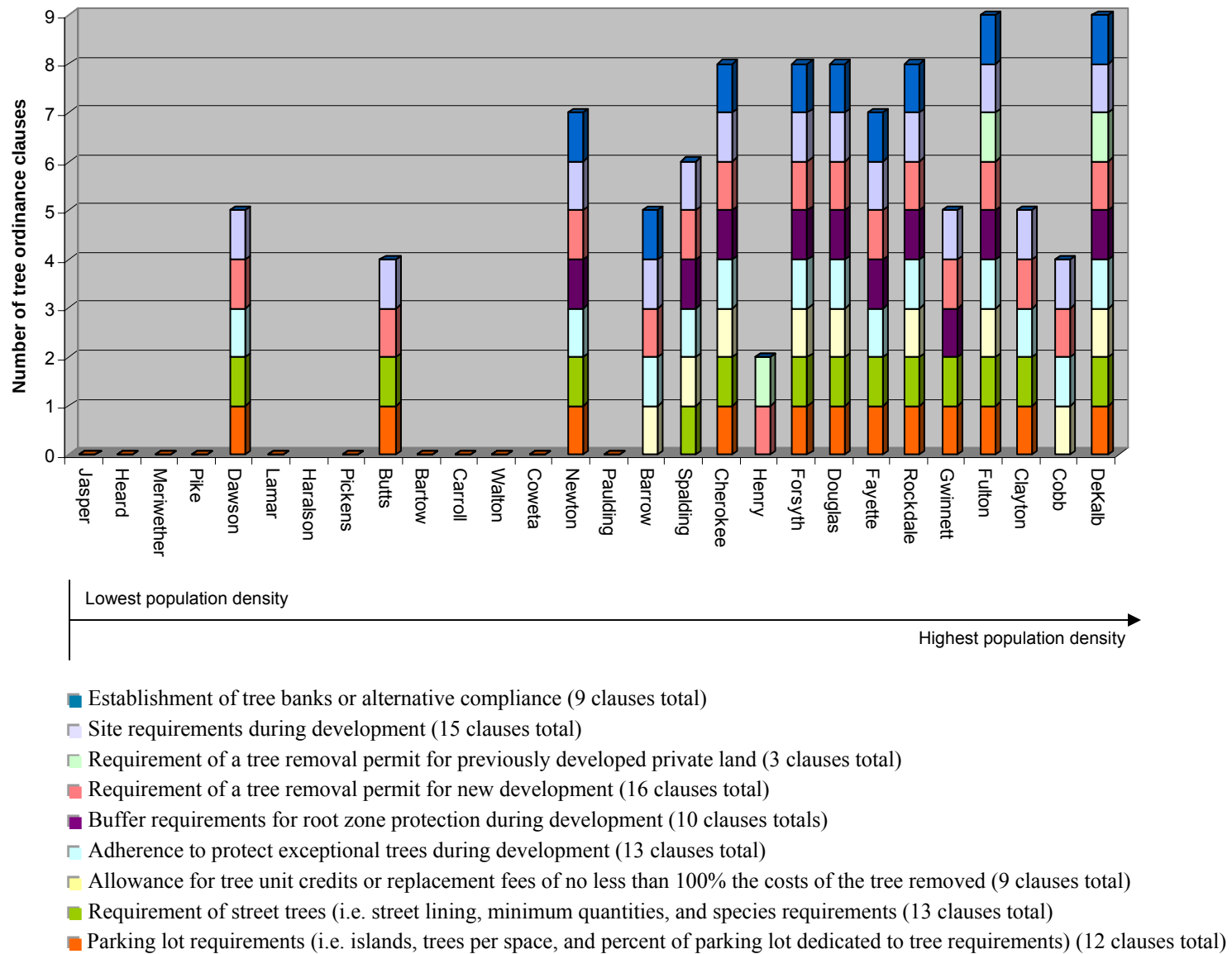


**Figure 4: Comparison of Tree Ordinance Clauses Established in Atlanta MSA Counties by Population Density Per Sq. Mile**

In order to determine the economic implications for counties associated with sustaining tree canopy cover, costs from increased stormwater runoff, air quality degradation, and decreased summer energy savings were considered. To do this, a representative county, which represents the average Atlanta MSA County, will be used, with land area equaling 200,000 acres.<sup>18</sup>

In terms of economic benefits to society, a representative county annually gains an average of \$8.02 in terms of energy savings and approximately \$240 in terms of air quality for each acre of tree canopy within the county.<sup>19</sup> Benefits to the county also appear in the form of reduced costs associated with stormwater runoff. Based on a 1996 study created by American Forests for the City of Atlanta, each acre of tree canopy provides \$5,856 in savings and other benefits from reduced stormwater runoff. This, however, is also a function of factors such as a county's existing impervious surface, which is six times greater in the City of Atlanta than in a representative county; therefore, \$976, which is one-sixth of the estimated value per acre associated with stormwater runoff in the City of Atlanta, will be used as a more realistic estimate for the benefit that tree canopy provides to a representative county in the Atlanta MSA.<sup>20</sup>

These values are useful as a means for reflecting on the costs that a county and its residents incur due to average tree canopy loss. However, to derive useful information from these figures regarding the benefits that better land use policies can provide, consider an example in which the representative county establishes a tree ordinance containing five meaningful clauses. Since each tree ordinance clause is expected to lead to a 1.03 percent increase in county land

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<sup>18</sup> The average area of a county within the Atlanta MSA was 191,451 square acres; for simplicity, this area was rounded up to 200,000 square acres.

<sup>19</sup> These values were created using energy savings estimates proposed by American Forest for the City of Atlanta and air pollution savings calculated using the U.S. Forest Service's Effects of Urban Forests and their Management on Human Health and Environmental Quality Pollution Program.

<sup>20</sup> The average of the ratios of impervious surface in the City of Atlanta to the representative county was taken for 1991 (7.32 times greater) and 2001 (4.95 times greater) in creating this number.

covered with tree canopy for the period from 1991 to 2001, then it is expected that five tree ordinance clauses will lead to a 5.15 percent increase in county land covered with tree canopy from 1991 to 2001. This implies that by establishing five ordinance clauses, the representative county and its residents would annually gain benefits of \$82,606 in energy savings, \$2,472,000 in air quality improvement, and \$10,052,800 in stormwater management, for a total benefit of \$12,607,406.

Consider another example of the benefits from implementing land use policies in which counties improved their score on *zoning* by five points. Recall that each additional zoning point leads to a 0.26 percent increase in tree canopy covering land within the county from 1991 to 2001. This means that by adding five points, the county would have a 1.3% increase in tree canopy covering land within the county from 1991 to 2001. This implies that by gaining the five zoning points, the representative county and its residents could annually experience \$19,248 in energy savings, \$576,000 in air quality improvement, and \$2,342,400 in stormwater management benefits, for a total benefit of \$2,937,648. Overall, if a county were to enact five meaningful tree ordinance clauses and gain five zoning points, after a decade under those new policies the average county in the Atlanta MSA could capture approximately \$15.5 million annually in benefits to its citizens and the local government compared to if it had not enacted these land use policies.

## CHAPTER VI: CONCLUSIONS

The primary objective of this study was to examine what land use policies have effects on the percentage change in tree canopy in the Atlanta MSA region. Past research has provided proof of the monetary benefits associated with maintaining a greater amount of tree canopy coverage. Therefore, this study took the next advance in this line of research—to provide evidence of what actions policy makers should consider as being most effective in respects to slowing down the loss of tree canopy in their county. Although past studies have examined the effect on tree canopy coverage of the existence of certain policies, such as tree ordinances, this study is unique in that it not only accounts for policy existence, but also for the internal workings of each policy in order to determine the policies robustness, effectiveness, and efficiency at reducing the percent loss of tree canopy covering county land area.

Through the use of a statistical regression model, this study found several policies that reduced the percent change in tree canopy on county land areas. Findings include:

1. Reducing the number of trees that are removed when increasing the percent of impervious surface is a highly effective way to reduce the loss of tree canopy covering county land.
2. Considering innovative development regulations that reduce the amount of impervious surface that is created on a per capita basis can reduce the loss of tree canopy.
3. Although establishing a tree ordinance does not influence the change in tree canopy covering county land area, creating a tree ordinance that is robust with numerous

meaningful clauses can significantly lessen the percent loss of tree canopy covering land area in a county. This ultimately will decrease costs that are incurred when tree canopy is removed.

4. Establishing exemplary quality growth examples that are believed to positively influence tree canopy can help lessen the loss of the percent of tree canopy covering land area in a county.
5. Increasing the focus of a county's planning and zoning on helping to promote quality growth and protect and promote tree canopy can have a positive influence on the percent of tree canopy covering county land area, which ultimately decreases costs that are incurred when tree canopy is removed.

Overall, this study suggests that by implementing land use policies designed to conserve county tree canopy, counties within the Atlanta MSA may be able to prevent some of the costly negative externalities associated with tree canopy loss. Furthermore, although the implementation of land use policies to alleviate tree canopy loss is often more prevalent in urbanized counties in the Atlanta MSA, rural counties will soon be, if not already, facing a growing demand for land development due to escalating population growth rates in the region. Therefore, all counties in the Atlanta MSA region can benefit both environmentally and economically from implementing effective land use policies to protect tree canopy, no matter how urbanized they might be.

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## APPENDIX A: MAPS

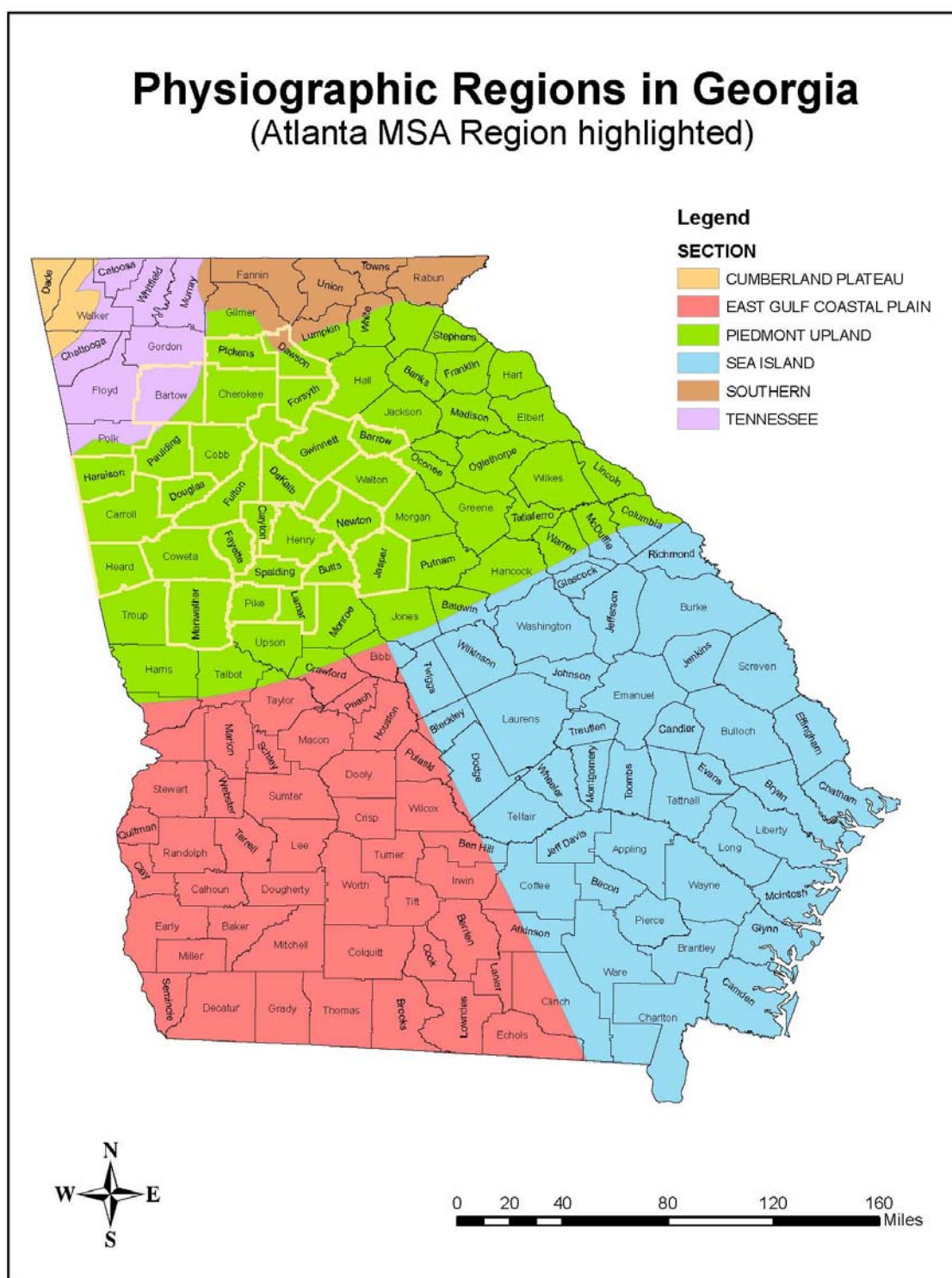


**Figure 5: Physiographic Regions in Georgia**

# Atlanta Metropolitan Statistical Area

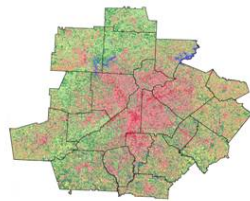
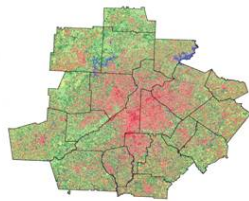
1991



2001



2005



0 15 30 60 90 120 Miles

|                 | Barrow | Bartow | Carroll | Cherokee | Clayton | Cobb    | Coweta |
|-----------------|--------|--------|---------|----------|---------|---------|--------|
| Population 1990 | 29,721 | 55,911 | 71,422  | 90,204   | 182,052 | 447,745 | 53,853 |
| Population 2000 | 46,144 | 76,019 | 87,268  | 141,903  | 236,517 | 607,751 | 89,215 |

|                 | DeKalb  | Douglas | Fayette | Forsyth | Fulton  | Gwinnett | Henry   |
|-----------------|---------|---------|---------|---------|---------|----------|---------|
| Population 1990 | 545,837 | 71,120  | 62,415  | 44,083  | 648,951 | 352,910  | 58,741  |
| Population 2000 | 665,865 | 92,174  | 91,263  | 98,407  | 816,006 | 588,448  | 119,341 |

|                 | Newton | Paulding | Pickens | Rockdale | Spalding | Walton |
|-----------------|--------|----------|---------|----------|----------|--------|
| Population 1990 | 41,808 | 41,611   | 14,432  | 54,091   | 54,457   | 38,586 |
| Population 2000 | 62,001 | 81,678   | 22,983  | 70,111   | 58,417   | 60,687 |

## Time lapse of change in impervious surface from 1991 to 2005

|           |           |           |           |            |
|-----------|-----------|-----------|-----------|------------|
| 1% - 5%   | 21% - 25% | 41% - 45% | 61% - 65% | 81% - 85%  |
| 6% - 10%  | 26% - 30% | 46% - 50% | 66% - 70% | 86% - 90%  |
| 11% - 15% | 31% - 35% | 51% - 55% | 71% - 75% | 91% - 95%  |
| 16% - 20% | 36% - 40% | 56% - 60% | 76% - 80% | 96% - 100% |

|                                    | Barrow  | Bartow  | Carroll | Cherokee | Clayton | Cobb    | Coweta  | DeKalb  | Douglas | Fayette |
|------------------------------------|---------|---------|---------|----------|---------|---------|---------|---------|---------|---------|
| Total Acres                        | 104,295 | 301,824 | 323,330 | 278,232  | 92,485  | 220,903 | 286,060 | 173,623 | 128,445 | 127,749 |
| 1991 Percentage Impervious Surface | 2.00    | 1.64    | 1.56    | 1.41     | 14.26   | 9.98    | 1.22    | 13.53   | 3.37    | 2.47    |
| 2001 Percentage Impervious Surface | 4.15    | 2.50    | 2.32    | 3.06     | 19.85   | 16.26   | 2.54    | 18.13   | 5.50    | 5.27    |
| 2005 Percentage Impervious Surface | 5.53    | 3.44    | 3.16    | 4.35     | 24.77   | 20.07   | 3.68    | 21.95   | 8.07    | 7.12    |

|                                    | Forsyth | Fulton  | Gwinnett | Henry   | Newton  | Paulding | Pickens | Rockdale | Spalding | Walton  |
|------------------------------------|---------|---------|----------|---------|---------|----------|---------|----------|----------|---------|
| Total Acres                        | 158,512 | 342,745 | 279,811  | 207,938 | 178,848 | 202,114  | 149,230 | 84,657   | 127,935  | 211,397 |
| 1991 Percentage Impervious Surface | 1.66    | 10.28   | 7.34     | 2.02    | 1.32    | 1.19     | 0.62    | 4.23     | 2.06     | 1.14    |
| 2001 Percentage Impervious Surface | 4.98    | 15.32   | 14.85    | 4.40    | 2.09    | 2.23     | 1.01    | 6.76     | 3.28     | 1.92    |
| 2005 Percentage Impervious Surface | 6.74    | 18.65   | 19.20    | 7.46    | 3.42    | 4.11     | 1.45    | 8.79     | 4.12     | 2.75    |

## Time lapse of change in landcover from 1991 to 2005

|                      |                        |                                   |
|----------------------|------------------------|-----------------------------------|
| Beaches, Dunes, Mud  | Quarries, Mines, Rocks | Forested Wetland                  |
| Open Water           | Deciduous Forest       | Non-Forested Wetland (salt)       |
| Low Intensity Urban  | Evergreen Forest       | Non-Forested Wetland (freshwater) |
| High Intensity Urban | Mixed Forest           |                                   |
| Clearcut, Sparse     | Agriculture            |                                   |

## Time lapse of change for tree canopy cover from 1991 to 2005

|          |           |            |
|----------|-----------|------------|
| 0%       | 26% - 50% | 76% - 100% |
| 1% - 25% | 51% - 75% |            |

|                             | Barrow  | Bartow  | Carroll | Cherokee | Clayton | Cobb    | Coweta  | DeKalb  | Douglas | Fayette |
|-----------------------------|---------|---------|---------|----------|---------|---------|---------|---------|---------|---------|
| Total Acres                 | 104,295 | 301,824 | 323,330 | 278,232  | 92,485  | 220,903 | 286,060 | 173,623 | 128,445 | 127,749 |
| 1991 Percentage Tree Canopy | 43      | 62      | 51      | 68       | 42      | 53      | 57      | 50      | 61      | 50      |
| 2001 Percentage Tree Canopy | 37      | 47      | 47      | 62       | 39      | 47      | 55      | 47      | 56      | 48      |
| 2005 Percentage Tree Canopy | 39      | 49      | 46      | 59       | 34      | 43      | 53      | 44      | 52      | 47      |

|                             | Forsyth | Fulton  | Gwinnett | Henry   | Newton  | Paulding | Pickens | Rockdale | Spalding | Walton  |
|-----------------------------|---------|---------|----------|---------|---------|----------|---------|----------|----------|---------|
| Total Acres                 | 158,512 | 342,745 | 279,811  | 207,938 | 178,848 | 202,114  | 149,230 | 84,657   | 127,935  | 211,397 |
| 1991 Percentage Tree Canopy | 53      | 55      | 53       | 48      | 52      | 63       | 72      | 55       | 45       | 46      |
| 2001 Percentage Tree Canopy | 46      | 51      | 41       | 43      | 46      | 62       | 70      | 49       | 48       | 42      |
| 2005 Percentage Tree Canopy | 42      | 48      | 37       | 40      | 48      | 57       | 66      | 47       | 47       | 45      |

Source: Natural Resources Spatial Analysis Laboratory

NARSAL  
Institute of Ecology  
University of Georgia  
Better science for better decisions making

Figure 6: Time Lapse of the Change in Impervious Surface, Landcover, and Tree Canopy in the Atlanta Metropolitan Statistical Area

## APPENDIX B: SURVEY



2006

## METROPOLITAN ATLANTA PLANNING AND LAND USE POLICY SURVEY

Conducted by the Department of Agricultural and Applied Economics and the Department  
of Ecology at the University of Georgia



The University of Georgia



Made possible by funding from the United States Forest Service

Next >>



## METROPOLITAN ATLANTA PLANNING AND LAND USE POLICY SURVEY

2006

### Instructions:

**To evaluate a county:** Select the county from the list

**To evaluate a city:** Select the county in which the city is located

- |                                   |                                  |                                     |                                   |
|-----------------------------------|----------------------------------|-------------------------------------|-----------------------------------|
| <input type="checkbox"/> Barrow   | <input type="checkbox"/> Coweta  | <input type="checkbox"/> Gwinnett   | <input type="checkbox"/> Newton   |
| <input type="checkbox"/> Bartow   | <input type="checkbox"/> Dawson  | <input type="checkbox"/> Haralson   | <input type="checkbox"/> Paulding |
| <input type="checkbox"/> Butts    | <input type="checkbox"/> DeKalb  | <input type="checkbox"/> Heard      | <input type="checkbox"/> Pickens  |
| <input type="checkbox"/> Carroll  | <input type="checkbox"/> Douglas | <input type="checkbox"/> Henry      | <input type="checkbox"/> Pike     |
| <input type="checkbox"/> Cherokee | <input type="checkbox"/> Fayette | <input type="checkbox"/> Jasper     | <input type="checkbox"/> Rockdale |
| <input type="checkbox"/> Clayton  | <input type="checkbox"/> Forsyth | <input type="checkbox"/> Lamar      | <input type="checkbox"/> Spalding |
| <input type="checkbox"/> Cobb     | <input type="checkbox"/> Fulton  | <input type="checkbox"/> Meriwether | <input type="checkbox"/> Walton   |

**Note:** You will be given the opportunity to complete surveys for any of these counties and/or their incorporated cities at the end of each finished survey.

Click [here](#) if you would like to view this survey as a PDF file.

METROPOLITAN ATLANTA  
PLANNING AND LAND USE POLICY SURVEY

2006

<<Prev

Instructions:

To evaluate Barrow County: Select it from the list

To evaluate a city within Barrow County: Select the city from the list

☐ Barrow County

Cities:

☐ Auburn

☐ Bethlehem

☐ Carl

☐ Statham

☐ Winder

To Whom It May Concern,

My name is Elizabeth Hill and I am a graduate student at the University of Georgia under the supervision of Dr. Jeffrey Dorfman and Dr. Elizabeth Kramer. We are inviting arborists, urban planners, decision-makers, community groups, and experts and agents from a variety of fields to participate in our research, which is in the form of an online survey.

The purpose of this research, which is being funded by the United States Forest Service (USFS), is to evaluate the impact of government land use policies on tree canopy coverage. Specifically, it is focusing on the 28-county metropolitan Atlanta region and these counties' respective incorporated cities. The online survey that will be used in this research is unique in that participants will not only be given the opportunity to complete an online survey for their own community, but will also be able to do additional online surveys to evaluate other communities in the metropolitan Atlanta region.

This survey will take approximately 15 minutes to complete. Your participation is voluntary; however, your response is an integral part of this research, and we urge you to respond. Please bear in mind that all responses are equally important, regardless of the size of the community that you wish to assess. Additionally, please feel free to forward this invitation to any groups or individuals whose responses may benefit the results of this research.

To take the online survey, please proceed to the following link: [TAKE ONLINE SURVEY](#)

You are still eligible to participate in this survey if you work or reside outside of the metropolitan Atlanta region. Also, many of the questions in this survey are intended for decision-makers and experts, consequently making it difficult for some participants to answer certain questions. However, there are still several questions that may be answered by those who hold a general knowledge of the community at hand. Therefore, we welcome your participation.

To view the survey as a PDF before participating in this survey, please proceed to the following link: [VIEW PDF](#)

If you'd prefer to complete this survey via postal mail, you may either print a copy of the PDF file or you may send a request for a hardcopy using the contact information given below. In either case, prepaid postage will be provided to you upon request.

The information supplied by participants will be treated as confidential. It should be noted that internet communications are insecure and there is a limit to the confidentiality that can be guaranteed due to the technology itself. However, once materials are received by the researcher, standard confidentiality procedures will be employed. Additionally, to further safeguard your confidentiality, use of a secure server (SSH) will aid in protecting your identifying information.

If you have any queries concerning this research, now or during the course of the project, please feel free to contact me at (336) 207-4525 or [atlantastudy@gmail.com](mailto:atlantastudy@gmail.com), or my supervisor, Dr. Jeffrey Dorfman at (706) 542-0754 or [jdorfman@agecon.uga.edu](mailto:jdorfman@agecon.uga.edu). Postal mail for either Dr. Jeffrey Dorfman or myself may be sent to: The Department of Agricultural and Applied Economics, Conner Hall, Athens, GA 30606. Thank you for your time and cooperation; your input is highly valued.

Sincerely,

Elizabeth Hill  
Graduate Student of Environmental Economics  
The University of Georgia  
305 Conner Hall Athens, GA 30602-7509 Phone: 706-542-0843 E-mail: [T atlantastudy@gmail.com](mailto:T atlantastudy@gmail.com)

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**\* There are no direct benefits to anyone affiliated with this research that is associated with your participation in this survey**  
**\* There are no foreseeable risks or discomforts that would be caused by your participation in this study** \* You may refuse to participate or discontinue participation at any time without penalty Additional questions or problems regarding your rights as a research participant should be addressed to The Chairperson, Institutional Review Board, University of Georgia, 612 Boyd Graduate

# **METROPOLITAN ATLANTA PLANNING AND LAND USE POLICY SURVEY**

## **2006**

Conducted by the Department of Agricultural and Applied Economic  
and the Department of Ecology at the University of Georgia.



Made possible by funding from the United States Forest Service

By completing this survey, you are agreeing to participate in the research. Please provide your signature to indicate that you accept this statement.

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

\*Your name will remain confidential, and will not be shared with outside parties or other survey respondents.

---

---

**County you are completing this survey for:** \_\_\_\_\_

**Last Name:** \_\_\_\_\_

**First Name:** \_\_\_\_\_

**E-Mail:** \_\_\_\_\_

**Affiliation to this county, if any:** \_\_\_\_\_

**Position:** \_\_\_\_\_

**Number of years in position:**

- ☐ Less than one year
- ☐ 1-4 years
- ☐ 5-10 years
- ☐ 10-14 years
- ☐ 15 or more years

**The name of the person who previously held your position (if available):**

\_\_\_\_\_

**Contact information for the person who previously held your position (if available):**

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**1. Has this county adopted a zoning ordinance?**

- ☐ Yes
- ☐ No
- ☐ Don't know

**2. Does this county have a planning department?**

- ☐ Yes
- ☐ No
- ☐ Don't know

**3. Is this county facing rapid residential growth?**

- ☐ Yes
- ☐ No
- ☐ Don't know

**4. Is development in this county:**

- ☐ Unregulated
- ☐ Somewhat regulated
- ☐ Heavily regulated

5.

| <b>What is the general public attitude in this county towards its growth in the following areas?</b> |                                            |                               |                          |                           |                                        |
|------------------------------------------------------------------------------------------------------|--------------------------------------------|-------------------------------|--------------------------|---------------------------|----------------------------------------|
|                                                                                                      | <b>Strongly in<br/>favor of<br/>growth</b> | <b>In favor of<br/>growth</b> | <b>Neutral</b>           | <b>Against<br/>growth</b> | <b>Strongly<br/>against<br/>growth</b> |
| <b>Economic growth</b>                                                                               | <input type="checkbox"/>                   | <input type="checkbox"/>      | <input type="checkbox"/> | <input type="checkbox"/>  | <input type="checkbox"/>               |
| <b>Population growth</b>                                                                             | <input type="checkbox"/>                   | <input type="checkbox"/>      | <input type="checkbox"/> | <input type="checkbox"/>  | <input type="checkbox"/>               |
| <b>Residential growth</b>                                                                            | <input type="checkbox"/>                   | <input type="checkbox"/>      | <input type="checkbox"/> | <input type="checkbox"/>  | <input type="checkbox"/>               |
| <b>Commercial growth</b>                                                                             | <input type="checkbox"/>                   | <input type="checkbox"/>      | <input type="checkbox"/> | <input type="checkbox"/>  | <input type="checkbox"/>               |
| <b>Industrial growth</b>                                                                             | <input type="checkbox"/>                   | <input type="checkbox"/>      | <input type="checkbox"/> | <input type="checkbox"/>  | <input type="checkbox"/>               |
| <b>All forms of growth</b>                                                                           | <input type="checkbox"/>                   | <input type="checkbox"/>      | <input type="checkbox"/> | <input type="checkbox"/>  | <input type="checkbox"/>               |

6.

| <b>Taken as a whole, rate the planning and zoning regulations in terms of helping to promote quality growth on a scale of 1 to 10, with 10 being the most effective.</b> |                       |                       |                       |                       |                       |                       |                       |                       |                       |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| 1                                                                                                                                                                        | 2                     | 3                     | 4                     | 5                     | 6                     | 7                     | 8                     | 9                     | 10                    |
| <input type="radio"/>                                                                                                                                                    | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

7.

| <b>Taken as a whole, rate the planning and zoning regulations in terms of protecting and promoting tree canopies on a scale of 1 to 10, with 10 being the most regulated.</b> |                       |                       |                       |                       |                       |                       |                       |                       |                       |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| 1                                                                                                                                                                             | 2                     | 3                     | 4                     | 5                     | 6                     | 7                     | 8                     | 9                     | 10                    |
| <input type="radio"/>                                                                                                                                                         | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

8.

| Taken as a whole, rate the importance you think the county puts on the preservation of the local tree canopy on a scale of 1 to 10, with 10 being very important. |                       |                       |                       |                       |                       |                       |                       |                       |                       |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| 1                                                                                                                                                                 | 2                     | 3                     | 4                     | 5                     | 6                     | 7                     | 8                     | 9                     | 10                    |
| <input type="radio"/>                                                                                                                                             | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

**9. Does this county have a tree committee and/or a tree board?**

- ☐ Yes
- ☐ No (if No, please skip to question 17)
- ☐ Don't know
- ☐ Other (please specify): \_\_\_\_\_

**10. Has this county established a tree ordinance?**

- ☐ Yes
- ☐ No
- ☐ Don't know

**11. In what year was this county's tree ordinance enacted? \_\_\_\_\_**

(If unknown, please estimate the year and indicate that the number is an estimate in the space provided)

**12. In what year was this county's tree ordinance, attached appendix, or specifications manual last updated? \_\_\_\_\_**

(If unknown, please estimate the year and indicate that the number is an estimate in the space provided)

**13.**

| Taken as a whole, rate the effectiveness of the tree ordinance at protecting and promoting tree canopies on a scale of 1 to 10, 10 being the most effective. |                       |                       |                       |                       |                       |                       |                       |                       |                       |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| 1                                                                                                                                                            | 2                     | 3                     | 4                     | 5                     | 6                     | 7                     | 8                     | 9                     | 10                    |
| <input type="radio"/>                                                                                                                                        | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

**14. Who is responsible for review and implementation of this county's tree ordinance? (Check all that apply)**

- ☐ Public works director
- ☐ Community development office
- ☐ Planning office
- ☐ County foresters/arborists
- ☐ Private forestry consultant
- ☐ Don't know
- ☐ Other (please specify)

**15.**

| Does this county's tree ordinance contain any of the following enforcement provisions? |                          |                          |                          |
|----------------------------------------------------------------------------------------|--------------------------|--------------------------|--------------------------|
|                                                                                        | Yes                      | No                       | Don't know               |
| Section specifying penalties for violations                                            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Section designating who is responsible for enforcement                                 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Stop work clauses                                                                      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Fiscal surety clauses                                                                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Fines for violating the community tree ordinance                                       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

**16.**

| <b>Are the following provisions concerning construction and development in this county's tree ordinance?</b> |                          |                          |                          |
|--------------------------------------------------------------------------------------------------------------|--------------------------|--------------------------|--------------------------|
|                                                                                                              | <b>Yes</b>               | <b>No</b>                | <b>Don't know</b>        |
| <b>Requirement of a permit for tree removal</b>                                                              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Diameter limits on trees that may be removed</b>                                                          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Density limits on the number of trees that may be removed</b>                                             | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Requirements for minimum density or canopy of tree coverage</b>                                           | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Specification of tree preservation areas</b>                                                              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Species preservation requirements</b>                                                                     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Section protecting public trees from construction damage</b>                                              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Maximum allowance on the percent of trees that may be removed</b>                                         | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Maximum allowance on the percent of tree canopy that may be removed</b>                                   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Forbiddance of clear cutting</b>                                                                          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Site requirements for planting trees</b>                                                                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>List of recommended tree species</b>                                                                      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Removal of diseased trees located on private property</b>                                                 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

**17. What methods does this county use to evaluate community trees? (Check all that apply)**

☐ Ground surveys

- ☐ Record keeping
- ☐ Tree inventory
- ☐ Community tree inventories
- ☐ GIS surveys
- ☐ None
- ☐ Don't know

Other (please specify): \_\_\_\_\_

18.

| <b>Does this county review construction plans for possible impacts on trees for either of the following?</b> |                          |                          |                          |
|--------------------------------------------------------------------------------------------------------------|--------------------------|--------------------------|--------------------------|
|                                                                                                              | <b>Yes</b>               | <b>No</b>                | <b>Don't know</b>        |
| <b>Public construction</b>                                                                                   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Private construction</b>                                                                                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

19.

| <b>Has the success of this county's tree management been inhibited by any of the following challenges? (Check all that apply)</b> |                          |                          |                          |
|-----------------------------------------------------------------------------------------------------------------------------------|--------------------------|--------------------------|--------------------------|
|                                                                                                                                   | <b>Yes</b>               | <b>No</b>                | <b>Don't know</b>        |
| <b>Insufficient budget</b>                                                                                                        | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Insufficient staff</b>                                                                                                         | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Insufficient equipment</b>                                                                                                     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Competing priorities</b>                                                                                                       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Lack of public support</b>                                                                                                     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Lack of political will</b>                                                                                                     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Does not recognize the importance</b>                                                                                          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

20. Does this county have a department or employee with assigned responsibility for the care of public trees?

- ☐ Yes
- ☐ No
- ☐ Don't know

**21. In reference to your answer for the previous question, please specify the entity that is responsible for the care of public trees:**

Department: \_\_\_\_\_

Individual Employee: \_\_\_\_\_

Other: \_\_\_\_\_

Don't know: ☐

**22. On average, what training has been attained by the person(s) who are responsible for the public care of trees in this county? (Check all that apply)**

- ☐ College or technical degree
- ☐ International Society of Arboriculture (ISA) Certification
- ☐ No training
- ☐ Don't know
- ☐ Other (please specify): \_\_\_\_\_

**23.**

| What is the importance of the following sources of funding in terms of funding received? |                              |                                             |                                   |                                 |                          |                          |
|------------------------------------------------------------------------------------------|------------------------------|---------------------------------------------|-----------------------------------|---------------------------------|--------------------------|--------------------------|
|                                                                                          | Primary<br>funding<br>source | Important<br>secondary<br>funding<br>source | Satisfactory<br>funding<br>source | Negligible<br>funding<br>source | No funding<br>received   | Don't<br>know            |
| General revenue stream                                                                   | <input type="checkbox"/>     | <input type="checkbox"/>                    | <input type="checkbox"/>          | <input type="checkbox"/>        | <input type="checkbox"/> | <input type="checkbox"/> |
| Partnerships with utility providers                                                      | <input type="checkbox"/>     | <input type="checkbox"/>                    | <input type="checkbox"/>          | <input type="checkbox"/>        | <input type="checkbox"/> | <input type="checkbox"/> |
| Donations                                                                                | <input type="checkbox"/>     | <input type="checkbox"/>                    | <input type="checkbox"/>          | <input type="checkbox"/>        | <input type="checkbox"/> | <input type="checkbox"/> |
| Local volunteer groups                                                                   | <input type="checkbox"/>     | <input type="checkbox"/>                    | <input type="checkbox"/>          | <input type="checkbox"/>        | <input type="checkbox"/> | <input type="checkbox"/> |
| Developers                                                                               | <input type="checkbox"/>     | <input type="checkbox"/>                    | <input type="checkbox"/>          | <input type="checkbox"/>        | <input type="checkbox"/> | <input type="checkbox"/> |
| Other source(s) of funding:                                                              | <input type="checkbox"/>     | <input type="checkbox"/>                    | <input type="checkbox"/>          | <input type="checkbox"/>        | <input type="checkbox"/> | <input type="checkbox"/> |

**24. Has this county received urban forestry grants or technical support from any of the following?**

**(Check all that apply)**

- ☐ Non-profit organizations
- ☐ Georgia Forestry Commission
- ☐ USDA Forest Service
- ☐ We receive no external grants or technical support
- ☐ Don't know
- ☐ Other (please specify)

**25.**

| Does this county have policies to achieve the following goals? (Check all that apply) |                          |                          |                            |                            |                                                |                                                   |
|---------------------------------------------------------------------------------------|--------------------------|--------------------------|----------------------------|----------------------------|------------------------------------------------|---------------------------------------------------|
|                                                                                       | Policies to<br>preserve  | Policies to<br>increase  | No policies<br>to preserve | No policies<br>to increase | Don't know if<br>policies to<br>preserve exist | Don't know<br>if policies to<br>increase<br>exist |
| Tree canopy coverage                                                                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>   | <input type="checkbox"/>   | <input type="checkbox"/>                       | <input type="checkbox"/>                          |
| Open space                                                                            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>   | <input type="checkbox"/>   | <input type="checkbox"/>                       | <input type="checkbox"/>                          |
| Greenspace                                                                            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>   | <input type="checkbox"/>   | <input type="checkbox"/>                       | <input type="checkbox"/>                          |
| Green parking lots                                                                    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>   | <input type="checkbox"/>   | <input type="checkbox"/>                       | <input type="checkbox"/>                          |
| Watersheds                                                                            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>   | <input type="checkbox"/>   | <input type="checkbox"/>                       | <input type="checkbox"/>                          |
| Tree preservation<br>during development                                               | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>   | <input type="checkbox"/>   | <input type="checkbox"/>                       | <input type="checkbox"/>                          |

**26. Has this county used a cost-share program?**

- ☐ Yes
- ☐ No
- ☐ Don't know

27.

| Which of the following are primary concerns for this county? (Please order from most to least important; 1 being the most important concern, 7 being the least) |                          |                          |                          |                          |                          |                          |                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
|                                                                                                                                                                 | (1)                      | (2)                      | (3)                      | (4)                      | (5)                      | (6)                      | (7)                      |
| Tree topping                                                                                                                                                    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Planting                                                                                                                                                        | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Pruning                                                                                                                                                         | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Urban sprawl                                                                                                                                                    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Tree maintenance                                                                                                                                                | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Removal of hazardous trees                                                                                                                                      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Location of new trees                                                                                                                                           | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

28.

| Does this county use any of the following methods to communicate with its citizens about trees? (Check all that apply) |                          |                          |                          |
|------------------------------------------------------------------------------------------------------------------------|--------------------------|--------------------------|--------------------------|
|                                                                                                                        | Yes                      | No                       | Don't know               |
| Public events                                                                                                          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Radio ads                                                                                                              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Public education programs or events                                                                                    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Television commercials                                                                                                 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Printed materials                                                                                                      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Other (Please specify):                                                                                                | <input type="checkbox"/> | _____                    |                          |

Best wishes,

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Additional Comments:

Additional Comments:

## APPENDIX C: SUPPLEMENTS

**Table 6: Comparison of the Ratio of Tree Canopy Loss per Acre Gain in Impervious Surface from 1991 to 2001 Among Atlanta MSA Counties (ac/day)**

| County       | Tree canopy<br>lost, ac/day | Impervious<br>surface gained,<br>ac/day | tree canopy loss per<br>acre gain in<br>impervious surface |
|--------------|-----------------------------|-----------------------------------------|------------------------------------------------------------|
| Spalding     | -1.044                      | 0.441                                   | -2.369                                                     |
| Lamar        | -0.925                      | 0.150                                   | -6.165                                                     |
| Pike         | -0.668                      | 0.129                                   | -5.169                                                     |
| Butts        | -0.605                      | 0.091                                   | -6.630                                                     |
| Paulding     | 0.373                       | 0.596                                   | 0.625                                                      |
| Meriwether   | 0.391                       | 0.228                                   | 1.715                                                      |
| Dawson       | 0.510                       | 0.223                                   | 2.292                                                      |
| Clayton      | 0.694                       | 1.457                                   | 0.476                                                      |
| Fayette      | 0.844                       | 1.004                                   | 0.840                                                      |
| Pickens      | 0.899                       | 0.164                                   | 5.488                                                      |
| Rockdale     | 1.374                       | 0.604                                   | 2.275                                                      |
| Coweta       | 1.735                       | 1.063                                   | 1.633                                                      |
| DeKalb       | 1.791                       | 2.250                                   | 0.796                                                      |
| Barrow       | 1.793                       | 0.633                                   | 2.834                                                      |
| Douglas      | 1.972                       | 0.773                                   | 2.551                                                      |
| Haralson     | 2.127                       | 0.196                                   | 10.873                                                     |
| Heard        | 2.168                       | 0.153                                   | 14.192                                                     |
| Jasper       | 2.285                       | 0.065                                   | 35.397                                                     |
| Walton       | 2.385                       | 0.463                                   | 5.155                                                      |
| Newton       | 2.674                       | 0.388                                   | 6.895                                                      |
| Henry        | 2.742                       | 1.393                                   | 1.968                                                      |
| Forsyth      | 3.077                       | 1.484                                   | 2.073                                                      |
| Carroll      | 3.375                       | 0.691                                   | 4.881                                                      |
| Cobb         | 3.867                       | 3.907                                   | 0.990                                                      |
| Bartow       | 4.147                       | 0.735                                   | 5.640                                                      |
| Cherokee     | 4.797                       | 1.289                                   | 3.721                                                      |
| Fulton       | 5.376                       | 4.862                                   | 1.106                                                      |
| Gwinnett     | 9.510                       | 5.912                                   | 1.609                                                      |
| <b>Total</b> | <b>57.280</b>               | <b>31.058</b>                           | <b>1.844</b>                                               |

**Table 7: Number of Exemplary Quality Growth Examples per 100,000 People**

| County     | Number of<br>exemplary<br>exemplars per<br>100,000 people |
|------------|-----------------------------------------------------------|
| Jasper     | 0.000                                                     |
| Heard      | 0.000                                                     |
| Meriwether | 0.000                                                     |
| Pike       | 0.000                                                     |
| Dawson     | 0.000                                                     |
| Lamar      | 0.000                                                     |
| Haralson   | 0.000                                                     |
| Pickens    | 0.000                                                     |
| Butts      | 0.000                                                     |
| Bartow     | 1.315                                                     |
| Carroll    | 2.292                                                     |
| Walton     | 0.000                                                     |
| Coweta     | 4.484                                                     |
| Newton     | 0.000                                                     |
| Paulding   | 1.224                                                     |
| Barrow     | 2.167                                                     |
| Spalding   | 0.000                                                     |
| Cherokee   | 0.705                                                     |
| Henry      | 0.000                                                     |
| Forsyth    | 3.049                                                     |
| Douglas    | 3.255                                                     |
| Fayette    | 0.000                                                     |
| Rockdale   | 0.000                                                     |
| Gwinnett   | 1.020                                                     |
| Fulton     | 1.593                                                     |
| Clayton    | 0.000                                                     |
| Cobb       | 0.165                                                     |
| DeKalb     | 1.051                                                     |

## APPENDIX D: STATA DO FILES AND MODEL SPECIFICATION

```
summ treecanopy mgt treeordinance population comm impervious inhibitors
> clauses zoning develreg board examples landuse CCdum
```

| Variable     | Obs | Mean      | Std. Dev. | Min      | Max      |
|--------------|-----|-----------|-----------|----------|----------|
| treecanopy   | 28  | -.0337679 | .0327222  | -.1207   | .029     |
| mgt          | 28  | .3928571  | .4973475  | 0        | 1        |
| treeordina-e | 28  | .5714286  | .5039526  | 0        | 1        |
| population   | 28  | .4280258  | .2941202  | .0054884 | 1.232312 |
| comm         | 26  | 1.653846  | 1.623387  | 0        | 5        |
| impervious   | 28  | .0208079  | .0213866  | .0009949 | .0778668 |
| inhibitors   | 28  | 3.196429  | 2.314765  | 0        | 7        |
| clauses      | 28  | 3.571429  | 3.500567  | 0        | 9        |
| zoning       | 22  | 11.2056   | 2.849269  | 3.5      | 16       |
| develreg     | 22  | 2.4046    | .35899    | 2        | 3        |
| board        | 28  | .1785714  | .390021   | 0        | 1        |
| examples     | 28  | 1.535714  | 2.924762  | 0        | 13       |
| landuse      | 28  | .828188   | .1125446  | .5346085 | .9684685 |
| CCdum        | 28  | .0714286  | .2622653  | 0        | 1        |

```
. collin treecanopy impervious landuse population examples mgt comm zoning de
> velreg inhibitors board treeordinance clauses CCdum
```

## Collinearity Diagnostics

| Variable      | VIF   | SQRT<br>VIF | Tolerance | R-<br>Squared |
|---------------|-------|-------------|-----------|---------------|
| treecanopy    | 5.59  | 2.36        | 0.1788    | 0.8212        |
| impervious    | 15.49 | 3.94        | 0.0646    | 0.9354        |
| landuse       | 4.23  | 2.06        | 0.2364    | 0.7636        |
| population    | 2.60  | 1.61        | 0.3845    | 0.6155        |
| examples      | 7.38  | 2.72        | 0.1354    | 0.8646        |
| mgt           | 9.49  | 3.08        | 0.1054    | 0.8946        |
| comm          | 1.90  | 1.38        | 0.5253    | 0.4747        |
| zoning        | 1.66  | 1.29        | 0.6034    | 0.3966        |
| develreg      | 2.52  | 1.59        | 0.3961    | 0.6039        |
| inhibitors    | 5.01  | 2.24        | 0.1998    | 0.8002        |
| board         | 3.65  | 1.91        | 0.2741    | 0.7259        |
| treeordinance | 11.00 | 3.32        | 0.0909    | 0.9091        |
| clauses       | 21.43 | 4.63        | 0.0467    | 0.9533        |
| CCdum         | 8.72  | 2.95        | 0.1146    | 0.8854        |
| Mean VIF      | 7.19  |             |           |               |

|    | Eigenval | Cond<br>Index |
|----|----------|---------------|
| 1  | 10.4968  | 1.0000        |
| 2  | 1.1535   | 3.0166        |
| 3  | 0.9853   | 3.2639        |
| 4  | 0.8414   | 3.5320        |
| 5  | 0.5894   | 4.2200        |
| 6  | 0.2755   | 6.1725        |
| 7  | 0.2422   | 6.5834        |
| 8  | 0.1303   | 8.9745        |
| 9  | 0.1215   | 9.2958        |
| 10 | 0.0855   | 11.0788       |
| 11 | 0.0465   | 15.0192       |
| 12 | 0.0127   | 28.7956       |
| 13 | 0.0113   | 30.4210       |
| 14 | 0.0064   | 40.3715       |
| 15 | 0.0015   | 83.4967       |

```
Condition Number      83.4967
```

```
Eigenvalues & Cond Index computed from scaled raw sscp (w/ intercept)
```

```
Det(correlation matrix) 0.0000
```

```
. ivreg treecanopy (mgt = population college urbpop income age) treeordinance
population comm impervious inhibitors clauses zoning develreg board examples landuse
CCdum
```

## Instrumental variables (2SLS) regression

| Source   | SS         | df | MS         | Number of obs = | 21     |
|----------|------------|----|------------|-----------------|--------|
| Model    | .016820594 | 13 | .001293892 | F( 13, 7) =     | 2.47   |
| Residual | .003666108 | 7  | .00052373  | Prob > F =      | 0.1174 |
|          |            |    |            | R-squared =     | 0.8210 |
|          |            |    |            | Adj R-squared = | 0.4887 |
| Total    | .020486703 | 20 | .001024335 | Root MSE =      | .02289 |

| treecanopy   | Coef.     | Std. Err. | t     | P> t  | [95% Conf. Interval] |
|--------------|-----------|-----------|-------|-------|----------------------|
| mgt          | -.0587133 | .0225689  | -2.60 | 0.035 | -.1120803 -.0053463  |
| treeordina~e | -.001092  | .0367277  | -0.03 | 0.977 | -.0879392 .0857551   |
| population   | .0128833  | .0277216  | 0.46  | 0.656 | -.0526679 .0784345   |
| comm         | -.0024102 | .0044245  | -0.54 | 0.603 | -.0128724 .0080521   |
| impervious   | -1.601266 | .6847887  | -2.34 | 0.052 | -3.220534 .018002    |
| inhibitors   | .0098389  | .005215   | 1.89  | 0.101 | -.0024925 .0221704   |
| clauses      | .010023   | .0059635  | 1.68  | 0.137 | -.0040784 .0241244   |
| zoning       | .0023311  | .0020851  | 1.12  | 0.300 | -.0025994 .0072616   |
| develreg     | -.0095031 | .0220766  | -0.43 | 0.680 | -.061706 .0426998    |
| board        | -.0056902 | .0223379  | -0.25 | 0.806 | -.0585109 .0471305   |
| examples     | .0049665  | .0038806  | 1.28  | 0.241 | -.0042097 .0141427   |
| landuse      | .0789691  | .0834873  | 0.95  | 0.376 | -.118447 .2763852    |
| CCdum        | .0809245  | .0401758  | 2.01  | 0.084 | -.014076 .1759251    |
| _cons        | -.1399315 | .0917839  | -1.52 | 0.171 | -.3569658 .0771029   |

Instrumented: mgt

Instruments: treeordinance population comm impervious inhibitors clauses  
zoning develreg board examples landuse CCdum college urbpop  
income age

. ivendog

Tests of endogeneity of: mgt

H0: Regressor is exogenous

Wu-Hausman F test: 0.07392 F(1,6) P-value = 0.79483  
Durbin-Wu-Hausman chi-sq test: 0.25556 Chi-sq(1) P-value = 0.61319

. overid, all

Tests of overidentifying restrictions:

Sargan N\*R-sq test 9.390 Chi-sq(3) P-value = 0.0245  
Sargan (N-L)\*R-sq test 3.130 Chi-sq(3) P-value = 0.3720  
Basmann test 3.235 Chi-sq(3) P-value = 0.3568  
Sargan pseudo-F test 1.043 F(3,7) P-value = 0.4308  
Basmann pseudo-F test 1.078 F(3,4) P-value = 0.4531

. predict pl

(option xb assumed; fitted values)

(16 missing values generated)

. estimates store ivreg

. reg treecanopy mgt treeordinance population comm impervious inhibitors c  
> lauses zoning develreg board examples landuse CCdum

| Source   | SS          | df | MS         | Number of obs = | 21     |
|----------|-------------|----|------------|-----------------|--------|
| Model    | .016823186  | 13 | .001294091 | F( 13, 7) =     | 2.47   |
| Residual | .0036663517 | 7  | .00052336  | Prob > F =      | 0.1170 |
|          |             |    |            | R-squared =     | 0.8212 |
|          |             |    |            | Adj R-squared = | 0.4891 |
| Total    | .020486703  | 20 | .001024335 | Root MSE =      | .02288 |

| treecanopy   | Coef.     | Std. Err. | t     | P> t  | [95% Conf. Interval] |
|--------------|-----------|-----------|-------|-------|----------------------|
| mgt          | -.05717   | .0219325  | -2.61 | 0.035 | -.1090322 -.0053078  |
| treeordina~e | -.0004867 | .0366561  | -0.01 | 0.990 | -.0871645 .0861912   |
| population   | .0120783  | .0275742  | 0.44  | 0.675 | -.0531244 .0772809   |
| comm         | -.0025056 | .0044108  | -0.57 | 0.588 | -.0129356 .0079243   |
| impervious   | -1.596913 | .6843842  | -2.33 | 0.052 | -3.215224 .0213986   |
| inhibitors   | .0097396  | .005202   | 1.87  | 0.103 | -.0025612 .0220404   |
| clauses      | .0097349  | .0058791  | 1.66  | 0.142 | -.0041669 .0236367   |
| zoning       | .0023155  | .0020837  | 1.11  | 0.303 | -.0026117 .0072426   |

|          |           |          |       |       |           |          |
|----------|-----------|----------|-------|-------|-----------|----------|
| develreg | -.0089959 | .0220003 | -0.41 | 0.695 | -.0610182 | .0430265 |
| board    | -.0053257 | .022295  | -0.24 | 0.818 | -.0580451 | .0473936 |
| examples | .0049255  | .0038767 | 1.27  | 0.244 | -.0042414 | .0140925 |
| landuse  | .0780547  | .083399  | 0.94  | 0.380 | -.1191525 | .2752619 |
| CCdum    | .0801306  | .0400693 | 2.00  | 0.086 | -.0146183 | .1748795 |
| _cons    | -.1391287 | .0917102 | -1.52 | 0.173 | -.3559888 | .0777314 |

```
. predict p2
(option xb assumed; fitted values)
(16 missing values generated)
```

```
. hausman ivreg . , constant sigmamore
```

Note: the rank of the differenced variance matrix (1) does not equal the number of coefficients being tested (14); be sure this is what you expect, or there may be problems computing the test. Examine the output of your estimators for anything unexpected and possibly consider scaling your variables so that the coefficients are on a similar scale.

|              | ---- Coefficients ---- |           | (b-B)<br>Difference | sqrt(diag(V_b-V_B))<br>S.E. |
|--------------|------------------------|-----------|---------------------|-----------------------------|
|              | (b)<br>ivreg           | (B)<br>.  |                     |                             |
| mgt          | -.0587133              | -.05717   | -.0015433           | .0052876                    |
| treeordina-e | -.001092               | -.0004867 | -.0006054           | .0020742                    |
| population   | .0128833               | .0120783  | .000805             | .0027582                    |
| comm         | -.0024102              | -.0025056 | .0000955            | .0003271                    |
| impervious   | -1.601266              | -1.596913 | -.0043533           | .0149151                    |
| inhibitors   | .0098389               | .0097396  | .0000994            | .0003404                    |
| clauses      | .010023                | .0097349  | .0002881            | .0009871                    |
| zoning       | .0023311               | .0023155  | .0000156            | .0000535                    |
| develreg     | -.0095031              | -.0089959 | -.0005073           | .001738                     |
| board        | -.0056902              | -.0053257 | -.0003645           | .0012487                    |
| examples     | .0049665               | .0049255  | .000041             | .0001403                    |
| landuse      | .0789691               | .0780547  | .0009144            | .0031329                    |
| CCdum        | .0809245               | .0801306  | .000794             | .0027203                    |
| _cons        | -.1399315              | -.1391287 | -.0008028           | .0027506                    |

b = consistent under Ho and Ha; obtained from ivreg  
B = inconsistent under Ha, efficient under Ho; obtained from regress

Test: Ho: difference in coefficients not systematic

chi2(1) = (b-B)'[(V\_b-V\_B)^(-1)](b-B)  
= 0.09  
Prob>chi2 = 0.7704  
(V\_b-V\_B is not positive definite)

```
. summ treecanopy p1 p2
```

| Variable   | Obs | Mean      | Std. Dev. | Min       | Max      |
|------------|-----|-----------|-----------|-----------|----------|
| treecanopy | 28  | -.0337679 | .0327222  | -.1207    | .029     |
| p1         | 21  | -.0401714 | .02917    | -.1071175 | .0210889 |
| p2         | 21  | -.0401714 | .0290027  | -.1072956 | .0201138 |

```
. corr treecanopy p1 p2
(obs=21)
```

|            | treeca-y | p1     | p2     |
|------------|----------|--------|--------|
| treecanopy | 1.0000   |        |        |
| p1         | 0.9061   | 1.0000 |        |
| p2         | 0.9062   | 0.9999 | 1.0000 |

```
.
. ivreg2 treecanopy (mgt = population college urbpop income age) treeord
> inance population comm impervious inhibitors clauses zoning develreg bo
> ard examples landuse CCdum, gmm
Warning - duplicate variables detected
Duplicates:    population
```

```
. ivreg2 treecanopy (mgt = population college urbpop income age) treeord
> inance population comm impervious inhibitors clauses zoning develreg bo
> ard examples landuse CCdum, gmm ffirst
Warning - duplicate variables detected
Duplicates:    population
```

## Summary results for first-stage regressions

| Variable | Shea<br>Partial R2 | Partial R2 | F( 4, 4) | P-value |
|----------|--------------------|------------|----------|---------|
| mgt      | 0.9451             | 0.9451     | 32.51    | 0.0026  |

NB: first-stage F-stat heteroskedasticity-robust

Underidentification tests:

|                                                                        | Chi-sq(4) | P-value |
|------------------------------------------------------------------------|-----------|---------|
| Anderson canon. corr. likelihood ratio stat.                           | 60.94     | 0.0000  |
| Cragg-Donald N*minEval stat.                                           | 361.31    | 0.0000  |
| Ho: matrix of reduced form coefficients has rank=K-1 (underidentified) |           |         |
| Ha: matrix has rank>=K (identified)                                    |           |         |

Weak identification statistics:

Cragg-Donald (N-L)\*minEval/L2 F-stat 17.21

NB: identification statistics not robust

Anderson-Rubin test of joint significance of  
endogenous regressors B1 in main equation, Ho:B1=0

F(4,4)= 5.34 P-val=0.0667

Chi-sq(4)= 112.24 P-val=0.0000

NB: Anderson-Rubin stat heteroskedasticity-robust

|                                   |   |    |
|-----------------------------------|---|----|
| Number of observations N          | = | 21 |
| Number of regressors K            | = | 14 |
| Number of instruments L           | = | 17 |
| Number of excluded instruments L2 | = | 4  |

## GMM estimation

|                       |   |                 |          |
|-----------------------|---|-----------------|----------|
|                       |   | Number of obs = | 21       |
|                       |   | F( 13, 7) =     | 7.06     |
|                       |   | Prob > F        | = 0.0075 |
| Total (centered) SS   | = | Centered R2     | = 0.8015 |
| Total (uncentered) SS | = | Uncentered R2   | = 0.9252 |
| Residual SS           | = | Root MSE        | = .01392 |

| treecanopy   | Coef.     | Robust<br>Std. Err. | z     | P> z  | [95% Conf. Interval] |           |
|--------------|-----------|---------------------|-------|-------|----------------------|-----------|
| mgt          | -.0565353 | .0091154            | -6.20 | 0.000 | -.0744012            | -.0386695 |
| treeordina~e | .0037323  | .0165392            | 0.23  | 0.821 | -.028684             | .0361485  |
| population   | .0218447  | .0135844            | 1.61  | 0.108 | -.0047802            | .0484696  |
| comm         | -.0024987 | .002093             | -1.19 | 0.233 | -.0066009            | .0016035  |
| impervious   | -1.563283 | .3882713            | -4.03 | 0.000 | -2.324281            | -.8022856 |
| inhibitors   | .0114549  | .0026423            | 4.34  | 0.000 | .0062761             | .0166336  |
| clauses      | .0102751  | .0027501            | 3.74  | 0.000 | .004885              | .0156652  |
| zoning       | .0025743  | .0008795            | 2.93  | 0.003 | .0008505             | .0042981  |
| develreg     | -.0137133 | .0101075            | -1.36 | 0.175 | -.0335237            | .006097   |
| board        | -.0089363 | .0128343            | -0.70 | 0.486 | -.034091             | .0162184  |
| examples     | .0058428  | .001622             | 3.60  | 0.000 | .0026637             | .0090219  |
| landuse      | .1200371  | .0327676            | 3.66  | 0.000 | .0558138             | .1842603  |
| CCdum        | .0864282  | .021202             | 4.08  | 0.000 | .0448731             | .1279833  |
| _cons        | -.1866276 | .0370864            | -5.03 | 0.000 | -.2593157            | -.1139396 |

Anderson canon. corr. LR statistic (identification/IV relevance test): 60.936  
Chi-sq(4) P-val = 0.0000Hansen J statistic (overidentification test of all instruments): 8.931  
Chi-sq(3) P-val = 0.0302

Instrumented: mgt  
Included instruments: treeordinance population comm impervious inhibitors  
clauses zoning develreg board examples landuse CCdum  
Excluded instruments: college urbpop income age  
Duplicates: population

. ivhetttest, fileview

IV heteroskedasticity test(s) using fitted value (X-hat\*beta-hat)

Ho: Disturbance is homoskedastic

Pagan-Hall general test statistic : 0.362 Chi-sq(1) P-value = 0.5472

```
. whitetst  
White's general test statistic :      21  Chi-sq(20)  P-value =  .3971
```