Evaluating the Impact of Government Land Use Policies on Tree Canopy Coverage

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Background

Many cities are experiencing the negative effects associated with not sustaining a sufficient level of tree canopy coverage. Tree canopy plays a crucial 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 standards, increasing energy efficiency, and reducing medical costs related to health issues, such as asthma, that are associated with environmental degradation (Georgia Forestry Commission).

To study how local government policies may be related to changes in tree canopy, an empirical study was performed using Greater Metropolitan Atlanta as the study area. This region has suffered significant loss of tree canopy coverage, averaging a loss of 58 acres per day from 1991 to 2001. It has also experienced explosive population growth: 27% from 1970-1980, 33% from 1980-1990, and 39% from 1990-2000 (CensusScope, 2006). These trends are troubling, given the environmental and economic benefits of tree canopy listed above.

A significant problem that may affect tree canopy loss is that many relatively rural counties in the Atlanta region are incurring high rates of population growth that they historically have not experienced. Excess housing demand has led homeowners to settle in neighboring counties where 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 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 broad question, this study examined a variety of land use and growth management policies to see which can be empirically linked to the protection of tree canopy. The results of our empirical study should prove useful to policy makers, environmental advocates, and developers who wish to preserve tree canopy but need to know what policies are actually effective as opposed to those which look good on paper but do not actually produce results.

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

Urban morphology, which can primarily be described by development patterns, local land use, and population density can have considerable effects on tree canopy coverage. A popular local government decision-making program created by CITYgreen (American Forests, 2002) 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%), undeveloped 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, undeveloped, or parkland will have higher levels of tree canopy coverage (Nowak et. al, 1996). This finding is reflected in American Forests 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).

It is widely accepted that particular land use policies used by local governments 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).

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. These 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.

These studies provide some evidence on variables to investigate in our study. Overall, they show that simply passing policies is not sufficient to preserve tree canopy; instead a community must have the correct, effective policies and then must enforce them.

Study Area

This analysis will use data for the 28-county Metropolitan Statistical Area (MSA) defined for metropolitan Atlanta, Georgia. 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). The region has had 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).

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).[1] 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 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.[2] 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,

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[1] Bartow and Paulding County partially lie in the Tennessee physiographic region, and Dawson partially lies in the Southern region.
[2] Data for 2005 was unused due to a lack of available and reliable explanatory variables.

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).

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 $30m^2$ pixel scales, and with the same collection methods, no additional discrepancies in positional accuracy are created by this spatial data (Lo, 2002).

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.[3] 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

[3] Data for 1991 was unavailable.

possible to designate expected percent tree canopy weights to land use types considered in this study. In constructing a county-wide goal value that would serve to correct different tree canopy levels for each county's specific mix of land use types, these weights are multiplied by acreage in each land use category and then the sum was divided 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 that should have less trouble sustaining tree canopy, given that a large majority of their land is undeveloped/sparsely developed land.

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 available parcels surrounded by

previously developed 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 open space by protecting land during development through the use of compact building location designs and mixed-use development patterns.
3. Conservation subdivision ordinance: This quality growth tool sets aside and permanently protects undeveloped land within residential developments, 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 200 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.[4] 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

[4] 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.

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 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. 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 was 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:

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

Where: Ns = 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 Ns will be 223 people.[5] 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

[5] 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.

alleviate this potential problem; however, given that there is no rigorous way to test for coverage 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 choose not 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).[6] 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 and demographics exist, 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 some of them. To investigate this, the Euclidean distance between each county's vectors of explanatory variables was computed. 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*).

[6] SSH Secure Shell Client was used to reduce the risk of a security breech.

The Model

To estimate the effect of local government policies on the preservation of tree canopy in the Greater Atlanta region, we estimated the linear regression 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 the variables are defined in Table 1, constructed as described in the previous section, and have their summary statistics displayed in Table 2. The β's are parameters to be estimated and the subscript *i* refers to the county, which is our level of observation.

Because of questions about endogeneity with regard to certain variables (that is, does a county appoint a person to manage tree issues because they are losing or have lost significant tree canopy?), the model was estimated by generalized method of moments using as instruments data on population, percent of urban population, age, income, and college education levels in each county. Data on these variables were collected from the decennial 1990 and 2000 U.S Census Bureau long-forms. The GMM estimates of the above model are presented in Table 3.

Empirical Results

The R^2 of 0.80 is excellent for this type of cross-sectional data. Furthermore, nine out of fourteen explanatory variables are statistically significant, a pretty good percentage given the small number of degrees of freedom. Diagnostic tests indicate the model is well-specified and does not suffer from undue heteroscedasticity or multicollinearity. Endogeneity issues are handled through the use of GMM estimation. Select estimation results are discussed below. In the discussions, all references to gains (or losses) in tree canopy refer to increases in canopy coverage relative to the expected change without a particular policy or event; relative gains might lead to actual tree canopy changes over the time period that are positive or negative depending on what other factors, events, and policies in each county were over the study period.

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. Detailed examination of the county-by-county ratio of impervious surface gain to tree canopy loss 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 is land speculation. Landowners will often cut down trees on their undeveloped land in order to prepare it for residential development. Therefore, during the transitional phase when land is no longer forested but has not yet been developed for residential purposes tree canopy loss can greatly exceed impervious surface gain.

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 (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 relative to what the tree canopy would have been without those smart growth projects. 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 relative gain in tree canopy equal to 7.60 percent of the county land area during the decade.

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 each additional point gained on the composite scale of 0 to 20 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 (significant at the .01 level). This implies that if a county were to score all 20 points, it could expect to gain tree canopy equal to 5.14 percent of the county land over ten years. This is an unlikely situation; however, given that the mean value for a county's zoning score was 11.2, it is not improbable for a county to raise its score by five points, which would lead to an expected gain in tree canopy equal to 1.29 percent of the county land area during the decade.

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 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 (significant at the .01 level). This means that if a county were to enact all nine of the clauses included 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 (its coefficient is statistically insignificant). 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 is essential in the establishment of policies to alleviate the loss of tree canopy; compromising on content in order to get an ordinance passed would be self-defeating according to our model results.

Potential Economic Benefits of Local Government Policies

In order to determine the economic implications for counties associated with sustaining tree canopy cover, avoided costs for stormwater management, health benefits from air quality improvements, and decreased summer energy savings were considered. To do this, a representative county, which represents the average Atlanta MSA County, was created, with land area equaling 200,000 acres.

The avoided costs or societal benefits are valued on a per acre of tree canopy basis, using earlier studies on the economic value of trees. Existing estimates suggest an average of $8.02 in terms of energy savings and approximately $240 in terms health benefits from improved air quality for each acre of tree canopy.[7] These benefits go to individuals and to local governments to the extent that they subsidize health expenses of their residents. Direct benefits to the county primarily appear in the form of avoided costs associated with stormwater management. Based on a 1996 study created by American Forests for the City of Atlanta, each acre of tree canopy provides $5,856 savings 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 savings per acre associated with stormwater runoff in the City of Atlanta, will be used as a conservative estimate for the benefit that tree canopy provides to a representative county in the Atlanta MSA.[8]

These values are useful as a means for reflecting on the costs that a county incurs 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 covered with tree canopy over ten years, it is expected that five tree ordinance clauses will lead to a 5.15 percent increase in county land covered with tree canopy. This implies that by establishing five ordinance clauses, the representative county would annually gain $82,606 in energy savings, $2,472,000 in air quality benefits, and $10,052,800 in stormwater management savings, for a

[7] 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.
[8] 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.

total of $12,607,406. These savings would be shared among residents, businesses, and the local governments.

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, or a 1.3% increase in tree canopy total. This implies that by gaining the five zoning points, the representative county could annually gain $19,248 in energy savings, $576,000 in air quality benefits, and $2,342,400 in stormwater management savings, for a total savings of $2,937,648. Overall, if a county were to enact five meaningful tree ordinance clauses and gain five zoning points, the average county in the Atlanta MSA could have been saving approximately $15,545,054 annually in 2001 compared to if it had not enacted these land use policies.

Conclusions

The analysis of data from the greater Metro Atlanta area on local government policies clearly shows that some local government policies are effective in preserving tree canopy coverage. However, not all policies are effective, so governments should choose the most beneficial policies if they wish to have the largest impact on tree canopy protection. In particular, a set of effective tree ordinance clauses was shown to be statistically significant in preserving tree canopy in economically and environmentally meaningful amounts, as were zoning ordinances, and having high quality smart growth projects in the community. Some actions, such as simply having a tree ordinance, designating a key management person in charge of tree programs, the presence of a tree board, and multiple communication channels were shown to be ineffective for our data set.

These findings should encourage local governments to focus on effective policies, leading to positive trends in tree canopy protection. Because benefits from tree canopy accrue to the local government's budget and its residents and business owners, the entire community should gain from the passage of effective policies to preserve their local tree canopy.

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Table 1: Variable Names and Descriptions

Variable	*Description*
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

Variable	*Observations*	*Mean*	*Standard Deviation*	*Minimum*	*Maximum*
Δ % tree canopy	28	-0.034	0.033	-0.121	0.029
Δ % impervious surface	28	0.021	0.021	0.001	0.078
Landuse	28	0.828	0.113	0.535	0.968
% Δ 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

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

Variable	*B*	*Standard Error*	*z Score*	*Sig.*
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
% Δ population	0.0218	0.0136	1.61	0.108
Communicate	-0.0025	0.0021	-1.19	0.233
% Δ 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				