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## The Value of Canopy Cover: Hedonic Pricing Study in Lakeland, Tennessee

Lee Eric Bridges

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The value of canopy cover: a hedonic pricing study in Lakeland, Tennessee

By

Lee Eric Bridges

A Thesis  
Submitted to the Faculty of  
Mississippi State University  
in Partial Fulfillment of the Requirements  
for the Degree of Master of Science  
in Forestry  
in the Department of Forestry

Mississippi State, Mississippi

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2016

The value of canopy cover: a hedonic pricing study in Lakeland, Tennessee

By

Lee Eric Bridges

Approved:

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Stephen C. Grado  
(Major Professor)

---

Donald L. Grebner  
(Committee Member)

---

John D. Kushla  
(Committee Member)

---

Jason S. Gordon  
(Committee Member)

---

Andrew W. Ezell  
(Graduate Coordinator)

---

George M. Hopper  
Dean  
College of Forest Resources

Name: Lee Eric Bridges

Date of Degree: May 6, 2016

Institution: Mississippi State University

Major Field: Forestry

Major Professor: Stephen C. Grado

Title of Study: The value of canopy cover: a hedonic pricing study in Lakeland,  
Tennessee

Pages in Study 57

Candidate for Degree of Master of Science

Urban forests have been shown to impact residential property values. This research demonstrates the results of a hedonic pricing study to determine the impact of canopy cover on single family residential property values in Lakeland, Tennessee during the period 2001-2005. The influence of canopy cover was evaluated on the lot within buffers of 100m, 500m, and 1km surrounding the lot. The study shows that canopy cover on the lot was not a significant contributor to property values while canopy cover in the buffers had a significant positive influence on home sales prices. Results also indicate that the increased property values lead to increased municipal tax revenues of 1.2-1.7% for every 10% increase in canopy cover. Results of this study can be used to develop similar processes and analyses leading to subsequent benefit-cost ratios for urban forestry programs while providing guidance on strategic tree retention and replacement efforts.

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## CHAPTER I INTRODUCTION

### **Background**

In the twenty-first century, human populations became centered in urban areas for the first time in recorded history (Turner et al., 2004). This trend is projected to increase for the foreseeable future. With increasing urbanization, conservation, and management of urban forests has become an important policy issue in the United States (Goeghegan, 2002). Urban forests provide a wide variety of societal goods and services recognized and studied by researchers. Dwyer et al. (1992) described the benefits provided by urban forests as falling into two categories; those that accrue as part of the physical and ecological processes of the forest, and those related to social processes. Examples of benefits associated with physical processes included energy conservation, air quality improvements, hydrological benefits, noise reduction, and others (Nowak et al., 2007). Examples of benefits associated with social processes included human health improvements, psychological benefits, and real estate value impacts (Brander & Koetse, 2011; Dwyer et al., 1992).

Other researchers have categorized the benefits of urban forests in terms of the services they provide to society. These benefits are typically termed ecosystem services (Escobedo et al., 2011) and can include outdoor recreation, property value improvements, climate stabilization, energy conservation, air pollution mitigation, and others. It is

important to note that urban forests also have associated costs and ecosystem disservices including the emission of volatile organic compounds from chemicals, such as isoprene and monoterpene, which contribute to ozone and carbon monoxide formation (Escobedo et al., 2011; Nowak, 2002). Costs of managing urban forests include hazard reductions, insect and disease mitigation, planting, pruning, watering, fertilizing, and other tree management tasks (Miller, 1988), and vary by location, size, ownership type, and other associated factors (Fausold & Lilieholm, 1999). With these highly varied benefits and costs, it is imperative that urban forest management and policy decisions be guided by appropriate benefit-cost analysis.

One of the challenges of valuing urban forests, and the wide variety of benefits provided, stems from the fact that these benefits are not typically considered to hold market values. Also, urban forest benefits tend to be nonrival and nonexclusive. They are nonrival in that the consumption of one particular good or service does not preclude others from also consuming that good or service (Rideout & Hessel, 1997). Urban forest benefits are also nonexclusive in that their use cannot typically be prohibited by others (Freeman, 2003). For example, improved air quality is both nonrival and nonexclusive. One person's consumption of clean air provided by the urban forest does not preclude others from enjoying the same benefit, nor can that benefit be kept exclusive to any person or community. They are typically considered public goods because of these attributes (Fausold & Lilieholm, 1999) and thus, private markets have no mechanism to properly allocate their appropriate quantity and distribution (Freeman, 2003). Therefore, concerns exist about potential underproduction (Fausold & Lilieholm, 1999) and

inequitable distribution (Wolch et al., 2005; Nechyba & Walsh, 2004) of these goods and services. Often, public intervention may be necessary to address this market failure.

Public intervention has included the use of municipal planning and policy as a tool to promote the retention of open space and forest resources within them or the retention of individual or groups of trees during land development (Bowman et al., 2012). Other tools include budgeting for the development of urban forest management programs (American Public Works Association, 2007) to maximize the long-term health and viability of the urban forest. However, increasingly limited municipal budgets and concerns over opportunity costs has led to a need for economic justification of policies promoting urban forest retention and urban forest management (Fausold & Lilieholm, 1999). For example, a municipal requirement that a forested area remain as open space results in an opportunity cost in the form of lost property tax revenues that would come from increased home or commercial construction. However, for example, research findings have suggested that tax revenues generated from residential development in the United States do not cover the costs of providing community services to developed properties (American Farmland Trust, 2002). In addition, research studies have indicated that urban forests and tree covered open spaces can have a positive impact on property values which can lead to higher property tax revenues for municipalities (Donovan & Butry, 2010; Tyrvaainen, 1997) possibly offsetting their opportunity costs.

### **Nonmarket valuation techniques**

Given the need to make clear these economic tradeoffs to allow informed urban and community forestry policy decisions and, given the public goods nature of urban forest benefits, market valuation techniques are not adequate enough to allow for

complete benefit-cost analysis. To address this deficiency, researchers have developed nonmarket valuation techniques to estimate, and compliment, the values of urban forests and their benefits (McConnell & Walls, 2005).

### *Stated preference methods*

Nonmarket valuation techniques include those based on stated preferences and those based on revealed preferences. One of the most common stated preference techniques is the contingent valuation method (CVM). Contingent valuation creates a hypothetical market and asks participants to state their willingness-to-pay (WTP) for a particular benefit or alternatively what they would be willing to accept for a reduction in a particular benefit (Tyrvainen & Vaananen, 1998). This technique has proven useful in analyzing a wide range of environmental resources and amenities especially those non-use related benefits such as existence, option, and bequest values (Holmes & Kramert, 1996). Existence value is essentially the valuation of the sense of satisfaction humans derive from knowing that a resource such as a rare habitat or species exists regardless of whether they actually will visit or otherwise use that resource. Other non-use values can be measured through contingent valuation such as aesthetics. For example, Grala et al. (2012) used the CVM to measure the WTP for the aesthetic value of windbreaks in agricultural settings in Iowa. Results show that windbreaks have a positive economic aesthetic value in the study area (Grala et al., 2012). Thus, contingent valuation revealed that the true value of these agricultural features is a combination of their use values, such as hunting, and their non-use values such as aesthetics. Therefore, a true benefit-cost analysis of forested windbreaks would account for as many of their benefits as possible.

Drawbacks from using CVM include reported discrepancies between actual and stated WTP (Loomis et al., 1996). Given that this technique is based on hypothetical markets, there is a concern that respondents will overestimate their WTP knowing that there will be no actual monetary transaction (Morrison & Brown, 2009). There are also concerns over the lack of a clear boundary for the extent of the distribution of public goods (Loomis, 1996). For instance, Loomis (1996) used contingent valuation to measure the impact of a salmon habitat restoration project across the entire United States and found that values associated with the project were widespread across a large geographic area. Researchers have historically been developing techniques and methodologies to help minimize the discrepancy between actual and stated WTP and to better understand the extent of the market for public goods (Morrison & Brown, 2009; Loomis et al., 1996; Loomis, 1996).

### ***Revealed preference methods***

Revealed preference methods of nonmarket valuation are based on observations of actual spending behavior. The travel cost method (TCM) is an example of a revealed preference technique where time and travel costs incurred by an individual to utilize or enjoy some resource are measured and used to represent a value for that resource. This method is often applied to visits to recreational sites as it is a valuation method based on use of a resource (Simoes et al., 2013). TCM has limited applicability to this study given that the urban forests in Lakeland are not regional attractions but instead are local amenities that, therefore, do not require an expenditure or significant travel to enjoy (Boslett, 2011).

Another revealed preference technique is the hedonic pricing method (HPM) which was introduced by Rosen (1974) and has been widely used in housing market analyses (Anthon et al., 2005). In hedonic pricing it is assumed that the price of any good is made up of the value of the various associated characteristics of that good (Freeman, 2003). For example, the selling price of a car can be related to amenities of the particular car such as engine size, interior comforts, and fuel economy (Taylor, 2003). Similarly, the selling price of a home can be thought of as a compilation of the various characteristics of that home and its surroundings such as tree cover (Sander & Haight, 2012). Theoretically, then, the difference in selling prices between two homes can be attributed to the value that the buyer places on those associated characteristics.

In HPM property valuation studies, researchers have typically categorized these house characteristics as structural, neighborhood, and environmental (Anthon et al., 2005). Structural characteristics have included home age, lot size, house size, number of bedrooms and bathrooms, and other physical characteristics. Neighborhood characteristics have included school districts, distance to shopping centers, housing density, and crime rates among other features (Donovan & Butry, 2011; Sander et al., 2010). Environmental characteristics have included distance to open spaces and parks, amount of forest cover within a certain distance of the house, presence or absence and amount of trees on the lot, prevalence of street trees, and other physical environmental characteristics surrounding the house (Geoghegan, 2002; Irwin, 2002).

HPM generates results through the use of multiple regression analysis (Freeman, 2003). In the simplest form of this regression, the selling price of the house is the dependent variable while the various structural, neighborhood, and environmental

characteristics are represented as independent variables (Morales, 1980). By utilizing a regression function, the individual contribution of each characteristic can be isolated and estimated while holding all the other variables in the model constant (Sander et al., 2010).

In the earliest studies on hedonic pricing in urban forestry the simplest linear regression form was utilized similar to a formula generated by Morales (1980):

$$y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6x_6 + b_7x_7 + b_8x_8 \quad (0.1)$$

In this formula,  $y$  is the predicted sales price of the house,  $x_1$  through  $x_8$  were the sale date, number of bathrooms, square footage of the house, number of garages, number of fireplaces, tree cover, and two location independent variables. Variables  $b_1$  through  $b_8$  were coefficients associated with those independent variables. These coefficients represented incremental change in the dependent variable with each unit increase in the associated independent variable (Mansfield et al., 2005). In this example, the coefficient for tree cover was \$2,941.85 (Morales, 1980). Since tree cover was measured as a dichotomous variable in this study, tree cover presence on the lot led to a \$2,941.85 increase in predicted house sales price. In this way, the incremental value of tree cover can be estimated from a hedonic regression function.

The simple linear model used by Morales (1980) was dependent on a linear relationship between predictor variables and the response variable. Research has revealed that this relationship is often not linear which has led to the need for more complex HPMs. For instance, Sander et al. (2010) utilized a semi-log model:

$$\ln P_i = \beta_0 + \beta_1 S_i + \beta_2 N_i + \beta_3 Q_i + \epsilon_i \quad (0.2)$$

In this model,  $\ln P_i$  represented the natural log of the property sales price while the  $S$ ,  $N$ , and  $Q$  terms represented the structural, neighborhood, and environmental characteristics

associated with each property and  $\varepsilon_i$  was the error term (Sander et al., 2010). By utilizing the natural log transformed sales price the authors accounted for the predicted nonlinear relationship between the dependent and independent variables (Donovan & Butry, 2011).

Other nonlinear relationships have been noted such as the relationship between number of bedrooms and sales price, all other variables being held constant. Instead of a linear relationship, it has been shown that, holding all other model variables constant as the number of bedrooms increases, the sales price of a house also increases but at a decreasing rate (Laurice & Bhattacharya, 2005). Use of a quadratic hedonic pricing model has been proposed to properly reflect this nonlinear relationship. The functional form of the hedonic pricing model has also been modified by transformation of the variables by the Box-Cox method (Lutzenhiser & Netusil, 2001). In Box-Cox transformations, variables are transformed by a power function. That is, each variable is raised to a certain power,  $\lambda$ , as determined most appropriate by a likelihood function (Box & Cox, 1964). For example, Halvorsen and Pollakowski (1981) proposed a form:

$$\rho_i(\mu) \equiv \sum_{c=1}^C \alpha_c z_{ic}(\lambda) + 0.5 \sum_{c=1}^C \sum_{g=1}^C \beta_{cg} z_{ic}(\theta) z_{ig}(\theta) + \varepsilon_i$$

where  $\varepsilon$  was the error term;  $\alpha$  and  $\beta$  were coefficients of the variables ( $z$ ); and  $\lambda$ ,  $\theta$ , and  $\mu$  were exponents by which the variables were transformed. This method was used to correct for non-normal distributions of data and to simplify the regression model (Box & Cox, 1964). The Box-Cox transformation can be combined with the quadratic form creating the quadratic Box-Cox form (Cropper et al., 1988) of the HPM. Other studies have proposed a logarithmic transformation of the independent variables that have a nonlinear relationship to the dependent variable (Boslett, 2011). For instance, Sander et

al. (2010) used the natural log of all distance measures in their hedonic pricing model to account for the diminishing effect these variables had on the sales price as distance increased.

### ***Limitations***

Historically, the literature has provided little guidance on selecting the most effective functional form of the hedonic pricing model (McConnell & Walls, 2005). This lack of guidance has been considered a limitation of the HPM. However, later research has made new model forms more accessible and provided more insight into the appropriate choice of the model form (Kuminoff et al., 2010). In addition to questions and debate over the functional form of the hedonic model, there have been concerns over how to handle missing inputs into the model. For instance, when evaluating the sales price of a house, if the model overlooks an important contributing independent variable, other contributing variables could be misrepresented or misunderstood. Also, the model's explanatory power may be diminished and the error increased if variables are omitted (Kuminoff et al., 2010). Given that omitted variables are possible in hedonic pricing studies, if a wide variety of housing characteristics are not available, researchers have investigated how the functional form of the model can affect bias and accuracy of results (Irwin, 2002). When all variables are included, the quadratic Box-Cox transformed model provided the most accurate prediction of the dependent variable (Cropper et al., 1988). However, when independent variables were missing from the model, Cropper et al. (1988) found that simpler models such as linear and semi-log, and linear Box-Cox performed best.

The model also has some limitations due to its assumptions. These assumptions include the differentiation of the characteristic or amenity being studied such that the consumer has a large supply of available choices (Freeman, 2003). Thus, if a particular market is somewhat homogenous in relationship to any particular attribute, the method may not accurately represent its value. Markets must also be in equilibrium for hedonic pricing to work effectively (Freeman, 2003). If this assumption is not met, values of model coefficients can be misleading. Studies have generally attempted to control for this concern by limiting the time frame within which data on market transactions are analyzed (McConnell & Walls, 2005). HPM also assumes that consumers have access to perfect information and there is perfect competition in the market (Sander & Polasky, 2009). To the degree that some of these assumptions may not always be met in any housing market, the method may have difficulty accurately estimating marginal impacts of a characteristic or amenity (Boslett, 2011). The model also depends on the assumption of independence (Irwin, 2002). That is, each observation is independent of the others. When this assumption is violated, spatial dependencies may occur.

Spatial dependencies can create issues with the HPM such as spatial auto-correlation (Sander et al., 2010). Spatial auto-correlation occurs when the price of a home is influenced by all of the independent variables as well as the price of homes surrounding it, causing a violation of the assumption of independence in the response variable (Irwin, 2002). However, various spatial statistics methods have been developed to identify the source of spatial autocorrelation or other spatial dependencies and to control for its presence (Anselin & Rey, 2014; Begueria & Pueyo, 2009; Haining, 2003). For instance, Sander and Haight (2012) employed spatially simultaneous autoregressive

error modeling while Begueria and Pueyo (2009) examined the use of generalized least squares modeling. Geographically weighted regression is also used to model spatially varying relationships (Fotheringham et al., 2002). These methods, while complicated in form, can be executed with spatial software or within statistical software packages capable of spatial analysis.

Research has revealed other limitations to the HPM whereby the results are regionally specific (Brander & Koetse, 2011) making generalizations from any study of limited use to policy makers, although the methodology is certainly transferrable. Therefore, locally specific studies are the most useful urban forestry policy analysis tools. Finally, it is also important to note that hedonic pricing does not capture value for all benefits provided by urban and community forests. Benefits that exist on a more global, and less local, scale such as carbon sequestration will not be fully captured in the sales price of a particular home (Boslett, 2011).

Despite these limitations, hedonic pricing is considered a powerful tool for estimating real economic influences because it measures a revealed preference relying on actual spending behavior as opposed to stated preferences which measures hypothetical market transactions (Freeman, 2003). Another benefit of utilizing the HPM is that data necessary for analysis are often readily accessible. Data on home sales prices, finished home sizes, age of house, number of bedrooms and bathrooms, and other structural information are more than likely available from county Assessor offices. Neighborhood variables such as school districts and shopping centers are also available at county or city offices or from other credible sources. Overall, the amount of data available to researchers is greater now than in the past (Kuminoff et al., 2010) making the problem of

omitted variables less likely. Finally, because hedonic pricing uses regression analysis, the marginal impact on property prices of each of the various characteristics is easily describable and readily understandable (Kim & Wells, 2005) making it a benefit to policy makers and managers.

### **Literature review**

Given its many benefits, HPM has been widely used in urban forest and open space valuation studies. For instance, Brander & Koetse (2011) identified over 52 open space valuation studies using hedonic pricing published within the past 30 years. Studies on urban forests and open spaces date to the 1960s and include estimations of marginal implicit prices from parks, natural areas, greenbelts, forest preserves, wetlands, agricultural lands, canopy cover, and a variety of other environmental attributes (McConnell & Walls, 2005). Results derived from these hedonic pricing studies have been summarized by various authors (Brander & Koetse, 2011; Wolf, 2007; McConnell & Walls, 2005). Table 1.1 presents a brief description of a few of the urban forestry valuation studies in the literature and describes their diversity in terms of urban forest variables, and sample sizes expressed as number of housing sales transactions.

Table 1.1 Urban forestry valuation studies in the United States and Europe using the hedonic pricing method

<b>Study</b>	<b>Sample size</b>	<b>Urban forestry variable</b>
Morales (1980)	60	Presence or absence of "good" forest cover on lot.
Anderson & Cordell (1988)	844	Number of trees in front yards. Impact on property tax revenues.
Tyrvainen (1997)	1006	Impact on row house apartment prices. Distance to forested area.
Mansfield et al., 2005	11,200	Level of forested area on parcel. Percent forested land within 400 m, 800 m, and 1,600 m. Distance to forest land.
Anthon et al. (2005)	702	Impact on property tax revenues. Distance to afforestation projects.
Mueller et al. (2009)	2,520	Days since forest fire. Distance to forest land.
Sander et al. (2010)	9,992	Percentage of tree cover within 100 m and 250 m.
Price et al. (2010)	4,148	Number of beetle killed trees in 0.1 km, 0.5 km, and 1 km.
Donovan & Butry (2010)	2,608	Number of street trees. Characteristics of those street trees. Impact on property tax revenues.
Donovan & Butry (2011)	985	Number of street trees. Number of lot trees. Influence of trees on rental prices.

Brief selection of hedonic pricing studies demonstrating the diversity of urban forest valuations variables and sample sizes.

Based on an examination of the urban forestry literature, one of the trends revealed when using HPM is that the presence of forests has a generally positive impact on property values. Early attempts at determining urban forest influences on property values by the HPM were generally anecdotal and of questionable validity. Specifically,

they were criticized as not being necessarily indicative of actual sales prices and absorption rates. In 1980, Morales performed a study in response to these criticisms. While the study was considered somewhat simplistic, and with a small sample size, it introduced HPM to urban forestry and showed that multiple regression could be used to determine the contributory effect of urban trees on home sales prices. This was the first study to attempt to statistically control for the effect of other contributory variables such as square footage and number of bathrooms. Morales' study utilized the Assessor's property data for recent home sales to demonstrate that, after controlling for the other variables in the model, tree cover accounted for a 6-9% increase in sales price. While the sample size was low, at 60 homes, the variability was controlled by performing the study within the boundaries of three neighborhoods in Manchester, Connecticut. Morales also limited the environmental variable to “good” forest cover, which was defined as 50-60% mature tree cover on the lot, or no forest cover and did not include any information about other tree attributes such as species, size, condition, or height.

Later studies continued to focus on the presence or absence of trees on the house lot but expanded on Morales' work by including adjustments to the methodology and expanding implications for economics and land use decision support. For instance, Anderson & Cordell (1988) tested to see if Morales' results held true with larger sample sizes. The authors increased the sample to 844 property transactions distributed over the entire study community of Athens, Georgia as compared to Morales' use of 60 transactions within three residential neighborhoods. Results were fairly similar indicating that the presence of trees was associated with a 3.5-4.5% increase in home sales prices as compared to the Morales result of 6-9%.

Over time, hedonic pricing studies began analyzing a wider range of urban forest variables. For example, Tyrvaainen (1997) evaluated whether distance to a forested area, rather than tree cover on an individual lot, had an influence on property values. The author measured three urban forest variables: distance to nearest wooded recreation area, distance to nearest forested area, and relative amount of forested area in the housing district. After analyzing data on 1,006 transactions in Joensuu, North Carelia, Finland, the author concluded that after controlling for the other variables, row house apartments closer to forested areas had a higher property value measured in price per square meter. The author also measured this impact on row house apartments rather than single family residential homes. The use of this particular housing type limited variability in property characteristics.

Measuring not just distance to forested areas, but the amount of forest canopy cover within those distances, Sander et al. (2010) determined that increases in neighborhood forest cover in Ramsey and Dakota Counties in Minnesota had positive impacts on property prices. This effect, however, was limited to within the first 250 m of the home. The authors also found that any tree cover beyond approximately 50% canopy cover led to declines in property values.

Anthon et al., (2005) provided a unique evaluation of afforestation projects and their impact on property values in the European cities of Arhus and Zealand, Denmark. They found that distance to afforestation sites was negatively related to property values for the 702 homes. That is, those properties closest to the planting sites had higher sales prices than those further away. Property values increased by over 9% in both cities (Anthon et al., 2005).

Donovan & Butry (2010) took another approach and examined the impact to property values from street trees rather than lot trees in their hedonic pricing study located in Portland, Oregon. This study also attempted to add variables related to specific characteristics of trees such as diameter, tree height, health, single or multiple stemmed form, crown area, and tree type (i.e., flowering, deciduous). The authors found that only number of trees and canopy cover were significant tree characteristics in the model. These two street tree structural variables combined were associated with an average of a 3% increase in the home sales price (Donovan & Butry, 2010). In a separate study, Donovan & Butry (2011) evaluated the impact of street trees in Portland, Oregon on rental prices for single family homes. While the study was potentially biased by using only advertised rental prices rather than actual transactions, it did reveal an increase in rental prices associated with street tree presence. Specifically, street trees accounted for a \$21 (2011 USD) increase in rental price while the presence of trees on the lot was associated with an increase of approximately \$5.

Mansfield et al., (2005) employed a complex design of the hedonic pricing model to assess effects of urban forests on property values. Whereas previous studies generally focused on presence or absence of trees or distance to a forested area, little analysis was provided on forest structure or size. This study utilized geographic information systems (GIS) and satellite imagery to analyze 11,200 property transaction records in the Research Triangle Park area of North Carolina. The authors included variables for tree cover on each parcel as well as distance to various types and sizes of forest land, both private and institutional. Consistent with other studies, when all other variables were held constant, distance to forested areas was inversely related to property value. That is,

parcels located closer to forested areas have higher property values than those located farther away. Also, tree cover on a parcel was associated with an increase in property values. However, when both variables were used in the model, interaction effects became apparent. For instance, as the amount of forest cover on an individual lot rose, there was a decrease in the effect on property value from adjacent forested areas. This was suggested as a substitution effect wherein as the forest cover in the private yard increased, there was less importance placed on nearby forested lands. The study did not investigate whether or not the reverse was true or whether increased forest cover *near* the lot led to a lesser importance of forest cover *on* the lot.

Hedonic pricing has also been used to estimate the negative economic effects on property values from forest pests and wildfire. Price et al. (2010) utilized a hedonic pricing model to measure the impact of dead trees from the mountain pine beetle (*Dendroctonus ponderosae*) epidemic in Colorado. The authors found that for every beetle killed tree within 0.1 km from the house there was an associated \$648 reduction in property value (2007 USD). This effect tapered as distance from the house increased. Results could be useful for policy makers when determining appropriate and justifiable levels of beetle control. Others have used the HPM to evaluate the impact of forest fires on property values especially in fire prone ecosystems (Mueller et al., 2009; Donovan et al., 2007). Mueller et al. (2009) found in Los Angeles County, California that the occurrence of a single fire was associated with a property value reduction of approximately 10%. However, the occurrence of a second fire related to a 23% reduction in property value. Results could provide useful insights to policy makers in their development of risk awareness programs.

Hedonic pricing has also been used to examine the impact of urban forests on property tax generation. Theoretically, an increase in home values will lead to an increase in tax appraisals which, in turn, will lead to the generation of greater property tax revenues. Anderson and Cordell (1988) were the first to study this influence by extrapolating the increase in property values observed in their study in Athens, Georgia for treed lots to an increase in property tax generation. Specifically, they concluded that in 1988 the increase in property values associated with treed lots represented a contribution of approximately \$100,000 (1988 USD) in municipal tax revenue. Additionally, Anthon et al. (2005) provided estimates of the impact to property tax revenues from their study on afforestation projects in Denmark. While the authors acknowledged the study limitations of only comparing two small cities in Denmark, results indicated a substantive impact on municipal tax revenues. They concluded that the overall increase in property values was about 4.7 million Euros (2003 Euros) for both cities. This increase translated into an approximately 1.5 million Euro increase in property tax revenue for both cities combined. These results could clearly be used to analyze management decisions regarding afforestation projects in urban areas. The authors also pointed out that the increase in property values typically reported from hedonic pricing studies may under-represent the total value of these attributes and amenities to the consumer. They noted that the consumer has also indicated a WTP increase in property taxes as well as an increase in purchase price.

Donovan and Butry (2010) also analyzed the effect of urban forests on citywide property values and property tax revenues in Portland, Oregon. The increase in property values due to street trees was estimated at \$1.12 billion (2007 USD) according to the

hedonic model. The authors estimated that the annual impact of this increased property value was an increase of \$12.6 million in property tax revenues based on tax rates at the time of the study. The authors took their analysis even further and compared this tax revenue to the street tree maintenance costs from the city to calculate a benefit-cost ratio of Portland street trees of 12 to 1. This ratio indicated that investing in urban forestry could be justified from an economic perspective. Also, from a policy standpoint, the authors posit that since values were being derived from street trees on adjacent properties, the city's policy of passing the responsibility for street tree maintenance to abutting property owners could result in an under investment in street trees from a societal perspective. Similarly, Maco & McPherson (2003) found a benefit-cost ratio of 3.8 to 1 for street trees in Davis, California. While the authors attempted to capture the value of environmental benefits such as energy reduction and air quality improvements, increases in property values were the largest portion of the street tree values. In their 2005 study, McPherson et al. found that benefits of urban trees in five western cities, Berkeley, California; Bismarck, North Dakota; Cheyenne, Wyoming; Fort Collins, Colorado; and Glendale, Arizona, outweighed costs of management by ratios ranging from 1.37 to 3.09. Similar to Maco & McPherson (2003) the authors calculated the value of a variety of urban forest benefits with property value increases having the largest impact. While these latter studies produced benefit-cost ratios with a similar intent, it should be noted that, with the exception of Donovan and Butry (2010), ratios from hedonic pricing studies are scarce.

Given its reliance on actual spending behavior, its easily interpretable results, and use of readily available data, the HPM represents a powerful tool for providing useful

information on urban forest values to policy makers. Despite its limitations, researchers are continuing to refine the methods, analytical techniques, and applications. For these reasons, it is a widely used technique for estimating the economic impacts of urban forests and was chosen as the study model.

### **Objectives**

Given that hedonic pricing studies of urban forest values are regionally specific (Brander & Koetse, 2011), and that no known hedonic pricing studies have been conducted in Lakeland, Tennessee or the Memphis, Tennessee metropolitan area, the goal of this study was to provide a meaningful contribution to the literature and provide data useful for policy makers in this area. The specific study objectives were to determine:

- 1) if urban forest canopy cover is exhibiting an influence on property values in the suburban community of Lakeland, Tennessee, and
- 2) the magnitude of that influence.

Also of interest:

- 3) was the high level of existing canopy cover in the City, which was 42% at the time of the study, limiting the economic benefits of forest cover, and
- 4) to use HPM to analyze the economic effects of an urban forestry program and tree protection policies.

## CHAPTER II

### METHODS

#### **Study Area**

This study took place within the municipal boundaries of Lakeland, Tennessee. Lakeland is a suburban community with approximately 10,848 residents at the time of the study (U.S. Census Bureau, 2011), located within Shelby County and the Memphis, Tennessee metropolitan area (Figures 2.1 and 2.2). Lakeland was established in 1977 as a residential community. The earliest homes were centered around the 95 ha Garner Lake. The median household income was \$84,851 per year and median home value was \$232,000 (2011 USD; U.S. Census Bureau, 2011). The housing density is approximately 0.75 density units per hectare. The City consists of approximately 27% residential land use, 28% non-forestry related agricultural use such as row crop farming and cattle grazing, 2% commercial and industrial use, and 43% open space (City of Lakeland, 2007a). Open spaces within the City consisted of active use public parks such as soccer fields, private common open spaces within neighborhoods, private nonindustrial forest lands, undeveloped passive use areas such as wooded parks with walking trails, agricultural lands, and lakes (City of Lakeland, 2007a).

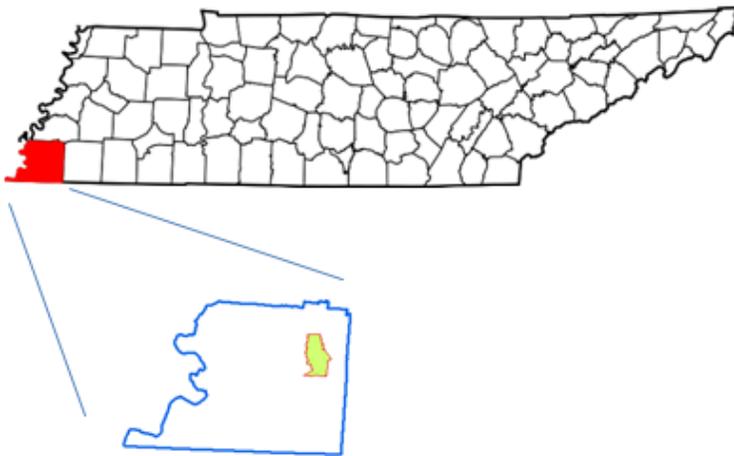


Figure 2.1 Location of Shelby County, Tennessee and City of Lakeland.

Shelby County (red) is the westernmost county in Tennessee. The City of Lakeland (green) is located in the northeastern portion of Shelby County.

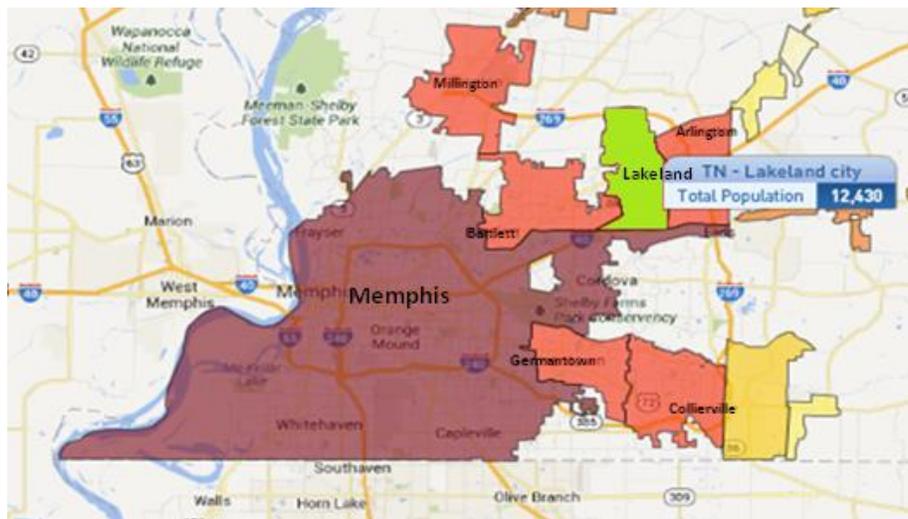


Figure 2.2 Location of Lakeland, Tennessee.

The City of Lakeland, Tennessee (green) in relation to other municipalities in the Memphis, Tennessee metropolitan area (U.S. Census Bureau, 2011).

## **Data collection**

This study utilized property transactions from 2001 to 2005 to evaluate how several independent variables influenced home values in Lakeland, Tennessee. These independent variables were classified into three types: structural, neighborhood, and environmental.

## **Sample period**

Data were collected on each property transaction within Lakeland during the period 2001 to 2005. This period was chosen to minimize influences from market volatility associated with the market disruptions of 2007 and beyond (Federal Housing Finance Agency, 2013), while not confounding the study by utilizing dates too early to accurately identify tree cover (Smith et al., 2002). Market volatility can cause a violation of the assumption of market equilibrium on which HPM depends (Freeman, 2003). Market volatility was estimated using a four-quarter percent change in Federal Housing Finance Agency (FHFA) metropolitan statistical area level house price indexes. Specifically, the All Transactions Index was utilized from 1979 through 2013 (Figure 2.3). This index is a repeat-sales measure reporting the average four-quarter price change in refinancing or repeat sales of the same property. The index is limited to single-family properties whose mortgages have been purchased or securitized by Fannie Mae or Freddie Mac (Federal Housing Finance Agency, 2013). While not all mortgages were purchased or secured by Fannie Mae or Freddie Mac, the FHFA has compared house price indexes using these data to those using an expanded data set supplemented with county recorder data and Federal Housing Administration (FHA) mortgages and found comparable results (Federal Housing Finance Agency, 2015). Therefore, the FHFA All

Transactions Index can be considered a reasonable estimate of overall market conditions in the U.S.

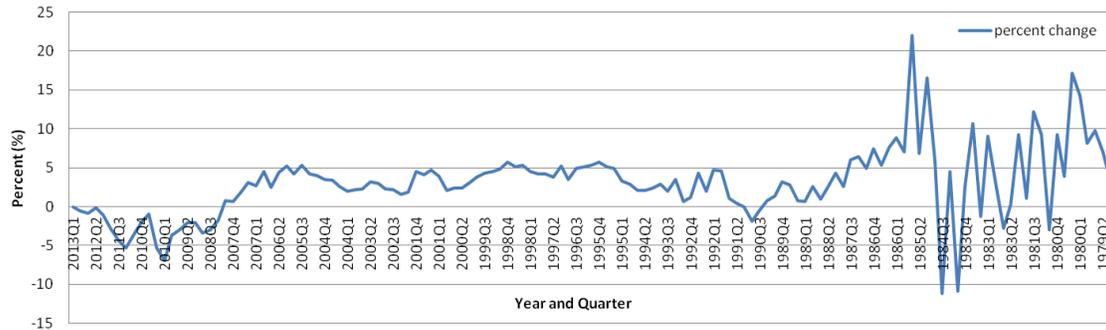


Figure 2.3 Housing market volatility from 1979 - 2013

Four-quarter percent change in Federal Housing Finance Agency's Metropolitan Statistical Area - Level House Price Index, All Transactions Index through 2013 quarter 1. Data downloaded from [www.fhfa.gov](http://www.fhfa.gov) on July 21, 2013. Metropolitan statistical area as defined by the United States Office of Management and Budget.

### Sample selection

Sample sites for this study were collected from the Certified Roll of the Shelby County Tennessee Assessor of Property. Samples were selected from a range of home sales filtered by several criteria. All sales transactions, (N = 22,008), within the city limits of Lakeland were first identified and saved in a spreadsheet format. These transactions were then filtered by date of sales from 2001 to 2005. The instrument type was then limited to warranty deeds, and multiple parcel transactions were eliminated because they were often homebuilders buying lots from developers. Multi-family and rental properties were then removed and data were filtered by land use class, retaining only those identified as residential. Finally, non-arms length transactions, as indicated in the sale value code from the Assessor's data, were identified and removed from the sample. Non-

arms length transactions were considered as those records labeled as being between related parties, forced sales, business or corporate transactions, rights-of-way and cemetery sales, limited sales, timber and mineral rights sales, tax exempt sales, and corrections. The remaining data for this study comprised  $n = 1,706$  property transactions.

For each transaction, the parcel upon which it occurred was identified using the Shelby County Assessor's parcel identification number. These parcels were then selected from a GIS feature class of all parcels in Lakeland. The Assessor's parcel card data was then appended into the feature class attribute table using the *Join* tool in GIS. Parcel cards contained information on structural characteristics for the house as well as appraisal and sales data. Using data from the City of Lakeland Zoning Map (2007b), parcels that were zoned agricultural and commercial were excluded from the sample. Finally, parcels with lot sizes greater than 0.5 ha were removed from the study to minimize the substitution effect noted by Mansfield et al. (2005) wherein large forested areas on the parcel were associated with a decrease in importance of adjacent forest cover. The final sample size for the study was  $n = 1,257$ . For each of these sample sites, data were collected on the structural, neighborhood, and environmental characteristics of the house and its surroundings.

### **Structural variables**

Variables on the structural characteristics of the house and parcel are common in the hedonic pricing literature (Bowman et al., 2012; Freeman, 2003). For this study, structural variables included lot size, finished floor area, number of bathrooms, age of house at the time of sale, and presence or absence of a fireplace or pool. These data were gathered from the Assessor's parcel card for each lot. Each of these data was then added

to the attribute table for each of the sample parcels. A complete list and characteristics of these structural variables was developed for this study (Table 2.1).

Lot size and finished floor area were gathered from the Assessor's parcel cards and converted from square footage to square meters. It was assumed that, in general, larger lots and larger homes would command higher sales prices (Taylor, 2003). However, it was also assumed that this relationship was not linear (Boslett, 2011). That is, as lot size and house size increased, house price was expected to increase at a decreasing rate. To account for this non-linear relationship, lot size and house size variables were logarithmically transformed using the natural log as is common in hedonic pricing studies (Sander et al., 2010). Lot sizes in the sample ranged from 423-3,883 m<sup>2</sup> with an average of 1,336 m<sup>2</sup>. House size ranged from 106-541 m<sup>2</sup> of finished floor area with an average of 251 m<sup>2</sup>.

Number of bathrooms was obtained by combining the number of full and half baths from the Assessor's property cards. Bathrooms were expected to have a positive impact on property values as is often shown in the hedonic pricing literature (Irwin, 2002). The number of bathrooms ranged from two to five with an average of two and a half.

Table 2.1 Minimums, maximums, and means of variables in the hedonic model.

<b>Variables</b>	<b>Minimum</b>	<b>Maximum</b>	<b>Mean</b>
<b>Dependent</b>			
Price05 (2005 USD)	\$115,539	\$756,884	\$246,592
<b>Structural</b>			
LotSize (m <sup>2</sup> )	423	3,883	1,336
HouseSize (m <sup>2</sup> )	106	541	251
SaleAge (yrs)	0	34	5
Bath (#)	2	5	2.5
	<i>% with</i>	<i>% without</i>	
Fireplace	86	14	
Pool	13	87	
<b>Neighborhood</b>			
NearArt (m)	19	1,588	686
NearC2 (m)	1	5,402	1,465
Density (du/ha) <sup>1</sup>	.55	2.4	1.03
	<i>% Donelson</i>	<i>% Lakeland</i>	
Elem_Dist	16	84	
	<i>% Arlington</i>	<i>% BonLin</i>	
Middle_Dist	53	47	
<b>Environmental</b>			
CanPER_Lot (%)	0	80	8
Canopy_100 m (%)	0	65	12
Canopy_500 m (%)	7	65	27
Canopy_1 km (%)	15	67	35
DistPubPar (m)	0	744	158
DistLake (m)	0	2,840	575
DistGolf (m)	0	6,654	2,054

<sup>1</sup> du/ha = dwelling units per hectare

Variables used in the hedonic pricing model organized by category and demonstrating the range of values.

Age of the house was calculated by subtracting the date of sale from date of initial purchase. This measure can be positively or negatively correlated with sales price (Donovan & Butry, 2011). For instance, Sander et al. (2010) found that sales price decreased as the home age increased up to about 88 years, after which sales price increased with age of homes. Because the oldest home in this study was 34 years, it was anticipated that older homes would have a lower value due to the potential for increased maintenance costs and the need for potentially costly upgrades. Ages of houses at the time of sale ranged from 0-34 years. The average age was five years.

The presence or absence of fireplaces and pools was recorded directly from the Assessor's parcel card. No distinction was made between masonry and pre-fabricated fireplaces. Also, no distinction was made for type of pool construction. It was anticipated that homes with fireplaces and pools would have higher sales prices, all other variables being held constant, because of their amenity values (Cho et al., 2008). Number of homes with fireplaces was 1,077 (86%) while the number of homes with pools was 160 (13%).

### **Neighborhood variables**

Neighborhood variables are common in hedonic pricing studies and help control for effects of the surrounding built environment (Schlapfer et al., 2015). The neighborhood variables included in this study were distance to arterial roadway, distance to shopping center, housing density in neighborhood, and school district. These data were collected or created using a GIS and from various City of Lakeland documents and plans. Neighborhood variables used in this study were thereby summarized (Table 2.1). Also, for this study, neighborhood was defined as the subdivision recorded in the Shelby

County Register's Office. There were 21 neighborhoods with at least one sale transaction included in this study.

Streets were categorized as arterial roadways based on the City's Major Road Plan. Streets with a listed capacity of greater than a collector street were considered arterial as well as all streets that were four lanes or more and with posted speed limits of 72 km per hour or greater. These roadways were selected from the City's streets file and saved as a GIS layer. The Euclidean distance from each sample parcel to the nearest arterial roadway was then determined using the *Near* command within the GIS proximity tools. Results, in meters, were added to the attribute table of the study sample. It was assumed that, with all other variables held constant, the closer a home was to an arterial roadway, the lower its value due to noise and potential traffic congestion (Lutzenhiser & Netusil, 2001). However, this relationship was also assumed to be non-linear in that the negative effect of proximity to arterial roadways was expected to increase at a decreasing rate (Boswell, 2011). Therefore, this variable was logarithmically transformed using the natural log before being applied in the model. Distances to arterial roadways in this study ranged from 19-1,588 m with an average of 686 m.

Distance to shopping centers was calculated in a similar manner to distance to arterial roadways. Shopping centers were first identified using the Assessor's land use codes and confirmed by the City of Lakeland Zoning Map (2007b). Each property identified was visited during the study to confirm its commercial land use. Examples of uses included in this designation were restaurants, retail centers, supermarkets, convenience centers, and shopping plazas. The GIS proximity tool was used to determine the Euclidean distance in meters to the nearest shopping center from each sample parcel

and the results were added to the attribute table. It was assumed that as distance to shopping centers decreased, the sales price of a home would, all other variables being held constant, increase (Sander & Haight, 2012) due to the convenience of close shopping. However, an increase in traffic congestion and traffic lights may counter this positive impact. As with distance to arterial roadways, it was assumed that as the distance to shopping centers decreased, the positive impact would increase at a decreasing rate (Sander & Haight, 2012). Thus, this variable was logarithmically transformed using the natural log. Distances to shopping centers ranged from 1-5,402 m with an average of 1,465 m.

Housing density was calculated in one of two ways. First, the recorded plat for the neighborhood was examined for a description of density. If provided, this was transferred directly from the plat to the attribute table of the sample parcel. If density was not provided on the plat, it was calculated in GIS by counting each lot in the neighborhood and dividing by the area encompassed by the neighborhood boundaries. As most plats recorded density in dwelling units per acre, these were converted to dwelling units per hectare (du/ha) before being entered in the attribute table. Increases in housing density were expected to be associated with a decrease in the home sales price (Irwin, 2002). This relationship was considered non-linear (Sander & Haight, 2012) similar to lot size and, therefore, the housing density variable was logarithmically transformed using the natural log. Housing density ranged from 0.55-2.4 du/ha with an average of 1.03 du/ha.

School districts were determined from Shelby County Schools district maps (Shelby County Schools, 2013). At the time of the study there were two elementary school districts, two middle school districts, and one high school district within Lakeland.

Boundaries for the elementary and middle schools were digitized in the GIS. Dummy variables were used to represent the two different districts. Schools were anticipated to have an impact based on their reputation in the community and can have an impact on a family's decision on where to purchase a home (Chin & Foong, 2006). No prediction was made as to the impact or magnitude of school districts without knowledge of their characteristics at the time of the study. However, it was important to include them as variables in the model. Sixteen percent of the sample sites were located in the Donelson Elementary school district and 84% in the Lakeland Elementary school district. Fifty-three percent of the sample sites were located in the Arlington Middle school district and 47% in the BonLin Middle school district.

### **Environmental variables**

Environmental attributes measured in hedonic pricing studies have varied widely in the literature (Brander & Koetse, 2011). For this study, the environmental variable of interest was tree canopy cover. However, Euclidean distance to lakes, public parks, and golf courses were included as it has been shown in the hedonic pricing literature that they often contribute to property values (McConnell & Walsh, 2005). A summary of these environmental variables was provided for this study (Table 2.1).

It was assumed that, as in several studies examined, as canopy cover near the home increased, home sale value would also increase (Sander et al., 2010). It was also assumed that, as distances to the other environmental features of lakes, public parks, and golf courses were reduced, housing prices would increase but at a decreasing rate (Boslett, 2011). Thus, these distance variables were transformed using the natural logarithm. Tree cover was determined using heads up digitizing on a 2006 Shelby County

color orthographic image obtained from the United States Department of Agriculture (USDA), Natural Resources Conservation Service's Geospatial Data Gateway (USDA, 2006). This image was chosen due to having a date close to the study period and having the resolution necessary to accurately determine tree cover, thus allowing the analysis of conditions in the City at the time of the transactions. All areas of the City were digitized for canopy cover. Following Sander et al. (2010), concentric buffers were established around the parcel. Buffers of 100 m, 100-500 m, and 500 m-1 km were created for each parcel in the sample using the GIS *Buffer* tool. Within each of the three buffers, percent canopy was calculated by first using the *Intersect* tool in GIS to determine amount of canopy within the buffer and using the field calculator features of GIS to convert this amount to a percentage. These buffers did not include the area of the lot. Therefore, canopy cover on each lot was calculated using the same methods as implemented for the buffers. Percent canopy on the lot ranged from 0-80% with an average of 8%. Percent canopy within the 100 m buffer ranged from 0-65% with an average of 12%. For the 100-500 m buffer, the percent canopy ranged from 7-65% with an average of 27%. Finally, percent canopy in the 500 m-1 km buffer ranged from 15-67% with an average of 35%.

Proximity to lakes, golf courses, and public parks has been shown to have a positive impact on property values (Boslett, 2011). As distance to these features decreases, home values were expected to rise due to these features providing open space for recreation and aesthetic enjoyment. As with the other distance metrics in this study, these were logarithmically transformed to account for the expected non-linear relationship between distance to the feature and impact on sales price (Sander & Haight, 2012). Lakes over 1 ha were digitized in GIS using the aerial imagery. One golf course

was in business at the time of the study. Parcel boundaries from the Lakeland parcel map were used for its location. All City-owned parks were identified using the City's Comprehensive Land Use Plan (2007a). The parcel boundaries were selected and saved as a GIS layer file. Distances, in meters, to the closest of each of these features were calculated using the GIS proximity tools and saved in the attribute table of the sample parcels. Proximity to lakes ranged from 0 m for lakefront properties to 2,840 m, with an average of 575 m. Distance to nearest golf course ranged from 0-6,654 m, with an average of 2,054 m. Distance to the nearest public park ranged from 0-744 m, with an average of 158 m. Data on all environmental variables are summarized for this study (Table 2.1).

### **Dependent variable**

The dependent variable for this study was chosen as the sales price of the home, compounded to 2005 values and transformed by the natural logarithm as is common in the hedonic pricing literature (Sander & Haight, 2012; Donovan & Butry, 2011; Taylor, 2003). Sales price, labeled in the analysis, was gathered from the Assessor's parcel card and appended into the attribute table of each sample parcel. This amount was then compounded to 2005 levels using the following formula:

$$\text{Price05} = \text{SalePrice} * 1.0242^{(2005-\text{SaleYear})} \quad (0.4)$$

Price05 represents the sales price compounded to 2005 dollars. The interest rate of 2.42% was calculated using the Consumer Price Index (CPI) for the southern region during the study time period (U.S. Bureau of Labor & Statistics, 2005). Compounded sales prices in the study ranged from \$115,539 to \$756,884 (2005 USD) with an average of \$246,592.

## Analysis techniques

An ordinary least squares regression (OLS) was used to estimate the hedonic pricing model similar to Sander et al. (2010). The equation follows as:

$$\ln P_i = \beta_0 + \beta_1 S_i + \beta_2 N_i + \beta_3 Q_i + \varepsilon_i \quad (0.5)$$

In this model, the dependent variable ( $\ln P_i$ ) is the natural log of the property sales price compounded to 2005 prices using the CPI (Mansfield et al., 2005), while  $S_i$  represents a vector of the structural characteristics associated with the  $i^{th}$  property,  $N_i$  represents a vector of the neighborhood characteristics associated with the  $i^{th}$  property,  $Q_i$  represents the environmental characteristics associated with the  $i^{th}$  property, and  $\varepsilon_i$  represents the error term.

The model was then evaluated for heteroscedasticity using the Breusch-Pagan test and for spatial autocorrelation using the Moran's I. If heteroscedasticity was found, standard errors were calculated using White's method (Sander & Polasky, 2009). Using heteroscedastic consistent standard errors allows the OLS model to be interpreted confidently. If the Moran's I revealed spatial dependence, a LaGrange Multiplier (LM) test was conducted to determine the source of that spatial dependence following methods used by Anselin & Rey (2014). Procedures for addressing spatial dependencies were consistent with Donovan and Butry (2010) as well as Boswell (2011). Specifically, if the LM test revealed spatial dependence in the error term only, then it was assumed that a spatially specific variable was omitted and that the OLS model was inefficient but not biased. Therefore, the OLS model was not corrected for spatial dependence if that dependence was in the error term. However, if the LM test revealed spatial dependence in the lag term or both the error and lag terms, then it was assumed that the spatial

dependence was located in the dependent variable and, therefore, the model was biased (Anselin et al., 1996). In this case a Simultaneous Autoregressive Error (SAR) model based on Anselin & Rey (2014) was utilized to account for these potentially biased estimates. The criterion for significance in all tests was 0.05.

## CHAPTER III

### RESULTS

#### **Overall model performance and fit**

In this study, the fit for the hedonic pricing model was high as indicated by the adjusted  $R^2$  of 0.92. Both the Joint F-Statistic and Joint Wald Statistic were significant at the  $p < 0.001$  level indicating that the overall model was significant. Multi-collinearity was estimated using the Variance Inflation Factor (VIF) with the commonly utilized limit of 10 (Boslett, 2011). The largest VIF was six, thus it was assumed that multi-collinearity was not an issue in this model.

Heteroscedasticity and spatial auto-correlation are common issues in hedonic pricing models (Taylor, 2003). Heteroscedasticity was evaluated using the Breusch-Pagan test which was significant at  $p < 0.001$ . Consistent with Sander et al. (2010), heteroscedasticity was accounted for by utilizing White's standard errors which are considered heteroscedasticity-consistent (White, 1980). Spatial auto-correlation was evaluated using the Moran's I test (Sander & Haight, 2012). Test results indicated significant ( $p < 0.001$ ) spatial clustering (Figure 3.1). To better determine the nature of this spatial dependence, LM tests were conducted, consistent with Sander & Haight (2012). The LM test for both error and lag sources of spatial autocorrelation were significant ( $p < 0.001$ ). Thus, a robust LM test was conducted in which the lag term was not significant ( $p = 0.668$ ) and the error term was significant ( $p < 0.001$ ). This indicated

that the spatial autocorrelation was not due to a lag process but rather to a spatial error process (Anselin et al., 1996). Given that the spatial error only leads to inefficiency and not bias, results were not corrected for spatial error and the OLS results were utilized (Donovan & Butry, 2010). Table 3.1 provides a summary of the model diagnostics.

Table 3.1 Ordinary Least Squares model diagnostics

	<b>Test</b>	<b>Value</b>	<b>Probability</b>
Model Fit	Adjusted $R^2$	0.9207	
Model significance	Joint Wald	15,527.3055	$p < 0.001$
Heteroscedasticity	Breusch-Pagan	424.087	$p < 0.001$
Spatial dependence	Moran's I	0.3786	$p < 0.001$
	Lagrange Multiplier (lag)	18.047	$p < 0.001$
	Lagrange Multiplier (error)	0.184	$p = 0.668$
	Robust Lagrange Multiplier (lag)	1,833.316	$p < 0.001$
	Robust Lagrange Multiplier (error)	1,815.453	$p < 0.001$

Results of model diagnostic tests including model fit, significance, heteroscedasticity, and spatial dependence.

### **Model results**

All structural variables except Fireplace were significant at the  $p < 0.05$  level. Relationships to the dependent variable were as expected as indicated by the coefficient signs. That is, as lot size (LN\_Lot), house size (LN\_House), and number of bathrooms (Bath) increased, sales price also increased. However, as age of the home (SaleAge) increased, sales price decreased. The presence of a pool was associated with a higher sales price at the  $p < 0.05$  level but not at the  $p < 0.01$  level. Of the structural variables, house size had the biggest influence on sales price with a 1% increase in house size being associated with a 0.49% increase in sales price.

All neighborhood variables were significant at the  $p < 0.01$  level and the coefficient signs all indicated the expected relationships. Specifically, as distance to

shopping centers (LN\_Shop) and arterial roadways (LN\_Art) grew larger in their extent, sales prices of homes also increased. Density had a negative relationship with sales price where higher density neighborhoods were associated with lower sales prices. Finally, school districts revealed that homes in the Lakeland Elementary school district had higher sales prices than those in the Donelson Elementary school district while those in the Arlington Middle school district had higher prices than in the Bon Lin Middle school district. The neighborhood variable with the highest influence on sales price was density where a 1% increase in housing density was associated with a 0.10% decrease in sales price.

The environmental variable, percent canopy on the lot (CanPerLot), was not significant ( $p = 0.4312$ ). The remainder of the canopy variables such as canopy percent in a 100 m buffer, 100-500 m buffer, and 500-1,000m buffer surrounding the lot were all significant at the  $p < 0.01$  level and had the expected relationship to the dependent variable as revealed by the sign of the coefficient. Specifically, as canopy percent rose, sales price also rose. Distance to lake (LN\_Lake) and distance to golf course (LN\_Golf) were both significant at the  $p < 0.01$  level and had a negative sign for the coefficient. This was expected as the distance to these features decreased, home sales prices increased. Distance to a public park (LN\_Park) was not significant ( $p = 0.0528$ ). A summary of coefficients, standard errors, t-values, and p-values for the independent variables is provided in Table 3.2.

Table 3.2 Ordinary Least Squares model results with heteroscedasticity consistent standard errors.

<b>Variables</b>	<b>Coefficient</b>	<b>White's standard error</b>	<b>t-value</b>	<b>p-value</b>
<b><i>Structural</i></b>				
LN Lot	0.0702531	0.0149796	4.6899013	0.0000030
LN House	0.4925945	0.0232289	21.2061386	0.0000000
SaleAge	-0.0079682	0.0007904	-10.0809443	0.0000000
Bath	0.0477077	0.0080813	5.9034505	0.0000000
Fireplace	0.0009769	0.0092886	0.1051735	0.9162551
Pool	0.0218470	0.0097575	2.2390043	0.0253327
<b><i>Neighborhood</i></b>				
LN Shop	0.0360888	0.0061646	5.8542130	0.0000000
LN Art	0.0203335	0.0052320	3.8863877	0.0001071
Density	-0.1000550	0.0155329	-6.4415051	0.0000000
Elem Dist	-0.0772090	0.0121261	-6.3671709	0.0000000
Middle Dist	0.0718194	0.0096301	7.4578179	0.0000000
<b><i>Environmental</i></b>				
CanPerLot	-0.0002250	0.0002857	-0.7874459	0.4311716
Can 100m	0.0011558	0.0003218	3.5915107	0.0003416
Can 100-500m	0.0012851	0.0004424	2.9047832	0.0037404
Can 500m-1km	0.0017027	0.0004372	3.8949493	0.0001035
LN Park	0.0068932	0.0035568	1.9380226	0.0528476
LN Lake	-0.0319938	0.0037911	-8.4392217	0.0000000
LN Golf	-0.0105651	0.0025413	-4.1573342	0.0000344

## CHAPTER IV

### DISCUSSION

The study results provide insights into how purchasers of single family residential homes in Lakeland, Tennessee value tree cover in the areas surrounding those homes. While tree cover on the lot was not a significant contributor to home sales price, the amount of tree cover within the surroundings, specifically within a 100 m, 500 m, and 1 km buffer around the home, was associated with an increase in property value. These results were generally consistent with the literature in that increases in tree cover near the home has typically been shown to have a positive influence on property values (Sander & Haight, 2012; Boslett, 2011; Holmes et al., 2006). However, study results were not consistent with others (Mansfield, et al., 2005; Anderson & Cordell, 1988; Morales, 1980) which showed a significant positive impact to home sales price from tree cover on the lot. More recent studies (Sander & Haight, 2012; Holmes et al., 2006) have found similar, non-significant results for tree cover on the lot. It is possible that by controlling for tree cover beyond the lot, which the earlier studies did not, this study and Sander et al. (2010) and Holmes et al. (2006) may have more accurately reflected the influence of lot level tree cover on home sales price. It is also possible that since canopy levels in the entire City of Lakeland were relatively high, at 42% during the study period, that its relative abundance made this resource less valuable relative to a lot. That is, if forested areas were abundant and accessible, then perhaps they were not as highly valued in the

“yard.” This would, in essence, be a reversal from the trend found in Mansfield et al. (2005) where a substitution of canopy cover on a lot led to a decrease in value for surrounding forest lands. Further investigations would be needed to explore this hypothesis.

The area of influence within which tree cover influences property values varies in the literature (Sander et al, 2010; Tyrvainen & Miettinen, 2006; Mansfield, et al., 2005) with a general theme of diminishing effects as distance to the tree cover from the parcel becomes greater. Similar to Sander & Haight (2012) and Boslett (2011), this study found that increases in tree cover within 100 m of the parcel had a significant, positive influence on sales price. However, unlike these studies, this research did not find that this effect diminished with distance from the parcel. In fact, the study found, similar to Holmes et al. (2006) that significant influences actually increased in the larger buffers of 500 m and 1 km. This may be a reflection of the value purchasers were placing on surrounding forest lands. At the time of this study, Lakeland was 43% open space (City of Lakeland, 2007a), which may account for the higher forest canopy cover in the 1 km buffer (35%) than in the 500 m (27%) and 100 m (12%) buffers.

Distance to public parks was not significant. This was not expected but could be explained by the large amounts of available open space surrounding the lots. While this open space was generally forested and private, it may have been serving as a substitute for developed parkland to the neighborhoods surrounding it. For instance, it was anecdotally known that unplanned trails were common in these private, forested open spaces. It is also possible that the private developments contained internal private common open spaces that effectively served the function of a neighborhood park. That is,

these open spaces may have been community gathering places and places for informal recreational use. No analysis was performed in this study on the effects of adjacent open spaces other than public parks. More research would be needed to determine if different types of open spaces, such as forest lands, agricultural lands, and private common open spaces had an influence on property values.

### **Marginal implicit prices**

The marginal implicit price for percent tree cover was calculated based on Sander et al. (2010). Specifically, because the dependent variable was the natural log of the sales price, the marginal implicit price of tree cover was the home sales price multiplied by the coefficient for tree cover. Using this approach, the marginal implicit price of a 10% increase in tree cover within the 100 m buffer translated to a \$2,850 increase in sales price when evaluated at the mean house value of \$246,592 (2005 USD). Similarly, a 10% increase in canopy cover within the 100-500 m buffer was associated with an increase in sales price of \$3,168 when evaluated at the mean sales price. The impact of canopy cover continues to grow even in the 500 m - 1 km buffer where a 10% increase in canopy cover was associated with a \$4,198 increase in sales price when evaluated at the mean sales price.

### **Property tax revenues**

These property value increases can be used to evaluate the impact of tree cover on property tax revenues at both the county and municipal level. Shelby County, Tennessee has a property tax assessment ratio of 0.25 and a residential property tax rate of 4.37%.

Therefore, when assessed at the mean value of \$246,592 (2005 USD), the average home in Lakeland during this study had an annual county property tax of \$2,694.

$$\$246,592 * 0.25 * 0.0437 = \$2,694 \quad (0.6)$$

An additional 10% canopy cover in the 100 m buffer leads to a sales price of \$249,442. This sales price would have an annual property tax of \$2,725.

$$\$249,442 * 0.25 * 0.0437 = \$2,725 \quad (0.7)$$

Therefore, a 10% increase in canopy within the 100 m buffer would be associated with an increase in property tax revenue of \$31 (\$2,725 - \$2,694) or 1.2% when evaluated at the mean sales price. This property tax increase becomes \$35 or 1.3% for an equal increase in the 100-500 m buffer and \$46 or 1.7% for the 500-1 km buffer.

Extrapolating these figures to the entire city may be questionable given that this study did not evaluate all residential properties in Lakeland. However, if it was assumed that properties in this study were a fair representation for the entire city, then for a \$31 increase in tax revenue multiplied by 3,898 single family residential properties in Lakeland, it could potentially result in an estimated \$120,838 (2005 USD) increase in annual county tax revenue accrued from a 10% increase in canopy cover within 100 m of each home. Further investigation would be needed to draw a more robust conclusion regarding canopy cover effects on property tax revenue.

Using the same method of calculation, and the City of Lakeland's property tax rate of 1.4%, a 10% increase in canopy cover within the 100 m buffer would be associated with a \$9.97 increase in property taxes for the City. A 10% increase in the 100-500 m ring would result in a property tax increase of \$11.09 while a 10% increase in the 500 m - 1 km ring would result in \$14.70 property taxes. If the \$9.97 increase in tax

revenue were applied to all 3,898 residential properties in Lakeland, at the average sales price for this study, the results would be an increase of approximately \$38,863 (2005 USD). It should be noted that buffers applied in this study overlap many properties. Therefore, an increase in canopy cover within a buffer would likely have an impact on multiple properties. Policy makers and urban forest managers could use this information to develop strategic tree planting programs designed to provide maximum benefit to properties within communities.

### **Benefit-cost analysis**

The City of Lakeland, Tennessee was a Tree City USA, as noted by the Arbor Day Foundation during the time of this study. Requirements of the Tree City USA program include a minimum expenditure on urban forestry of \$2/capita (Tree City USA, 2015). The population of Lakeland at the time of this study was 10,848 (U.S. Census Bureau, 2011). Therefore, the minimum urban forestry budget would have had to have been at least \$21,696. In 2005, the City of Lakeland filed a Tree City USA application with a budget of \$26,016 (City of Lakeland, 2005). Thus, we can estimate a low and high benefit-cost ratio using the minimum budget and the actual budget, respectively. If it could be argued that the urban forestry program implemented with this budget led to a 10% increase in canopy cover or prevented the loss of 10% canopy cover within 100 m of the majority of single family residential homes, then the benefit-cost ratio would be between 1.49 ( $\$38,863/\$26,016$ ) and 1.79 ( $\$38,863/\$21,696$ ), respectively. Not knowing exactly how this urban forestry program was structured is a limitation to this study. Documents and personal experience reveal, however, that the urban forestry program during the time of this study was focused on maximizing tree cover, either by retention of

individual trees or protection of existing forest lands (City of Lakeland, 2004; Lakeland Tree Management Ordinance, 2004). Therefore, it is likely that the urban forestry program provided a net benefit to the City on the basis of property values alone. Certainly, the cost of implementing the Tree City USA program is economically justified. It should be noted that these property values do not reflect the entirety of urban forest values (Boslett, 2011) and, therefore, a benefit-cost analysis that included all of these values would likely be even higher than these results suggest.

### **Limitations**

A potential limitation to this study includes the length of time over which the study took place, which was five years. Utilizing this relatively long time period could introduce errors due to variations in physical conditions and market conditions. However, to achieve a larger sample size in a small city, a long window of time was chosen. Conversely, a smaller sample size would only be a focused snapshot for that time period, and may not represent the true variations that occur over time. Another study limitation stems from the use of an OLS regression. Using OLS, a global model, has the potential to overlook potentially important local variations in the model coefficients.

### **Management implications**

The finding that canopy cover in the buffers has a significant positive influence on property values has clear management implications. Specifically, urban forest managers and policy makers could use this information to locate priority areas for tree planting or protection such that the benefits would accrue to multiple properties thereby maximizing benefits and minimizing costs. It also suggests that policy makers should

focus their tree protection efforts on the forest lands surrounding these neighborhoods. Given that the City of Lakeland was a Tree City USA during the time of this study and that one of the requirements of the Tree City USA program is a tree ordinance (Tree City USA, 2015), the study results suggest that the City's tree ordinance should focus on tree protection in these surrounding forest lands.

Another management implication of this study is that the HPM can be used to analyze urban forestry budgets. That is, urban forest managers could undertake a local hedonic pricing study to develop, inform, or defend appropriate funding levels. For example, when evaluating existing or proposed tree planting and protection programs, policymakers could use the HPM to compare anticipated program costs to anticipated tax revenues from increased property values. By justifying budgets and prioritizing tree protection efforts, HPM can be used to influence urban forest policy.

### **Future studies**

Future studies could expand the model to enhance both the neighborhood and environmental variables. Neighborhood variables to add to the model could include access to healthcare, socio-economic status, and demographics. Environmental variables could be enhanced by exploring whether the type of open space and its ownership status has an impact on property values. For instance, there were large swaths of forested lands surrounding sample lots in this study as evidenced by the increasing canopy percent in the larger buffers. These surrounding forests were surely providing many urban forest benefits such as privacy, aesthetics, stormwater attenuation, and improved air quality. However, the majority of these forested lands were private and available for land development. Future studies could therefore include forested land as a type of open space

as well as variables indicating whether or not the forest was protected or developable to determine if this landscape was providing value to the community. This information could be useful for policy makers when determining which types of open spaces to prioritize for protection and which tools, such as conservation easements, land acquisitions, or common open space requirements, are most effective at maximizing value to the community. Future research could also investigate at what point the effect of canopy cover stops growing in impact to sales price. As noted in this study, the coefficient for canopy cover increased from the 100 m to the 500 m and the 1 km buffers. Buffers of increasing size could be added to the model until a point of diminishing returns is discovered.

Narrower time frames could be utilized in future work if a large enough sample size can be obtained. Utilization of the narrower time frame may minimize market variations. Also, future research could look for interactions in the model between canopy cover on the lot and canopy cover in the surrounding buffers. This could bring to light any substitution effects where high levels of forest canopy in the surrounding neighborhoods led to decreased importance of tree canopy on the lot.

Local regression models could be used in future work rather than global models. This could include the use of techniques such as the geographically weighted regression which may allow exploration of neighborhood level variations in the model coefficients and may provide more insight into how suburban residents value tree cover.

To make the results of hedonic pricing studies more applicable to land use planners, a model could be developed that guides the user through the data collection, entry, analysis, and interpretation. This model could be developed using a methodology

similar to this study but with modular components to allow customization based on available data, local conditions, and desired information. For instance, some information could be considered fundamental and required such as house size, school district, and age of house at the time of sale. Other information could be considered optional but desired such as lot size, distance to shopping centers, and density. Some features may be only locally appropriate such as fireplaces, swimming pools, and air conditioning. It may be more practical to offer options for urban forest variables based on the capability of the local government. For instance, communities with GIS capable departments may be able to calculate distance and cover variables using locally specific data while other communities may need to use commonly available tools such as i-Tree Canopy to measure their variables of interest.

Data analysis could be driven by pre-packaged statistical analysis software that was specifically able to calculate spatial econometrics such as GeoDa (Anselin & Rey, 2014). Challenges would likely include teaching communities with limited GIS resources how to calculate distances, buffers, and percentages of environmental variables as well as how to interpret results of spatial analysis. Workshops could be developed and offered online and in-person to assist communities with the GIS spatial analysis tasks.

Interpretation of results would need to be guided by users manuals and training and could include information on how to interpret the coefficients in the model.

Finally, more research is needed to make robust evaluations of tree canopy effects on property tax revenues in Lakeland. While general assumptions can be developed from this study, a more accurate picture would include all single family residential parcels and a more accurate list of urban forestry expenditures for the City. A more detailed benefit-

cost analysis could then be used by city managers to defend and justify urban forestry program budgets.

## CHAPTER V

### CONCLUSIONS

The study objectives were to determine if canopy cover exhibited an influence on property values in Lakeland, Tennessee and if so, what was the magnitude and character of that influence. It is apparent from this study that canopy cover does have an impact on property values in Lakeland. The impact is generally positive and the magnitude was revealed through the marginal implicit prices. This research also sought to determine if the existing canopy cover in Lakeland at the time of the study (42%) led to a lack of scarcity and thereby limited its economic benefits. Results of this study did not support this theory directly. It is possible, however, that the observation of no significant effect of canopy cover on the lots was a result of the abundance of canopy cover in surrounding areas. In this way, residents of Lakeland may have been using canopy cover on adjacent properties as a substitute for canopy on their lot. Finally, this study sought to demonstrate whether or not the HPM could be used as a tool to evaluate the economic effectiveness of an urban forestry program and tree protection policies. It seems clear from this study that HPM has the ability to help evaluate urban forestry programs in multiple ways. Benefit-cost analysis using urban forestry budgets and economic influences from HPM can be carefully developed and used elsewhere. These analyses should be careful to include as many benefits and costs as possible. Also, HPM can be used as a tool to help policy makers and urban forestry managers determine the most efficient use of forestry funds

and the most effective tree protection and conservation strategies to maximize benefits to the community.

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