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# Amenity Value and Home Prices: An Examination of the Effects of the Ridge, Slope, and Hillside Protection Taskforce in Knox County, Tennessee

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I am submitting herewith a thesis written by Matthew Honeywell Chadourne entitled "Amenity Value and Home Prices: An Examination of the Effects of the Ridge, Slope, and Hillside Protection Taskforce in Knox County, Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Economics.

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# Amenity Value and Home Prices: An Examination of the Effects of the Ridge, Slope, and Hillside Protection Taskforce in Knox County, Tennessee

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**Amenity Value and Home Prices: An Examination of the Effects of the Ridge, Slope, and Hillside Protection Taskforce in Knox County, Tennessee**

**ABSTRACT:** This thesis concerns two topics related to policy effects of hillside and ridgeline development in Knox County, TN and attempts to quantify the values of different aspects of forest land in the area, particularly how the amenity values of forest land affect the prices of surrounding houses. The first essay conducts a cost-benefit analysis to determine the willingness of individual landowners for reforestation given explicitly stated costs and benefits of reforestation. A sequence of hedonic models was used to estimate differences in non-use values attributable to deforested and to forested areas, allowing the establishment of an overall price-distance relationship between the amenity values attributable to both areas and their proximities to housing locations. The results showed that the benefits from reforestation were greater than the opportunity costs of barren/grassland replaced and the houses with the greatest gains from reforestation were within one mile of the target site. Amenity value benefits for reforestation vary between sites but the sites with the greatest gains were those with the largest area, the lowest land cost, and the most houses within one mile. The second essay examined the effects of forest views on house prices and also the effect that the economy had on consumers' value of those views. This study applied a sales hedonic model to two time periods with markedly different economic climates, the housing boom of 2002-2006 and the recession of 2008. Amenity value gains from forest views were then mapped out for the county for both periods to find those areas that had the highest gains in both periods. The results showed that while the views of forest land increase house values in both periods, the average marginal implicit price gain decreased over 13 percent from the boom period to the recession. Maps of the value gains highlighted the south-western, eastern and northern parts of the county, which contain high income suburban communities, with consistent value gains in excess of $70 per acre.

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## Part I. Overview

The City of Knoxville and Knox County, which surrounds the city, recently created the Joint City-County Taskforce on Ridge, Slope, and Hillside Development and Protection (hereafter referred to as “the Taskforce”) to address the community’s concerns about the impact of increased development on the county’s hillsides in this densely forested and hilly area. Ridgeline development in the city and country has led to deforestation, diminished views, and greater infrastructure expenses to local governments. The Taskforce has therefore been charged with 1) assessing the potential effects of development and 2) drafting policy recommendations that balance the need for development with the need to maintain the benefits provided to the surrounding community by these areas.

Because the areas under “the Ridge, Slope, and Hillside Development and Protection Plan” (hereafter referred to as “the Plan”) in the county are distributed throughout the county and because protection projects can be expensive, decision makers for the plan must establish high-priority target areas for protection. Therefore, the main goal of this thesis is to identify high-priority areas for forest land restoration and conservation under the Plan. This thesis is composed of two essays that address that goal together.

A cost-benefit analysis is conducted in the first essay to determine the willingness of individual landowners to accept reforestation as a substitute for other potential land uses, given the explicitly stated costs and benefits of reforestation. A sequence of hedonic models is used to estimate differences in non-use values attributable to deforested and to forested areas, an approach which allows the establishment of an overall price-distance relationship between the amenity values attributable to both deforested and forested areas and their proximities to housing locations within the county. Based on the overall price-distance relationship, the sum of the differences between amenity values of deforested and forested areas is estimated as reflected in housing prices in locations at different proximities to potential restoration sites. The sum of the differences for a particular site may then be considered as a proxy for the value added to nearby houses by a given potential reforestation project. The cost-benefit analysis allows estimation of the net benefits of implementing reforestation projects to the surrounding community and also helps prioritize potential sites for reforestation.

The main objective of the second essay is to contribute to the process of identifying priority target areas for the Plan by estimating the aesthetic value of nearby properties. Changes in the value of visual amenities provided by forested hilltop land during a real-estate boom and during a recession are estimated to accommodate the different real-estate conditions and spatial dynamics. For this purpose, two separate locally weighted regressions in a hedonic housing-price model were estimated using repeat sales of houses during 2000–2006 (boom) and 2008 (recession). This finding helps us understand how the visual amenity values of forest land at the hilltop locations vary under different real-estate conditions, and this understanding contributes to the process of identifying priority target areas for the plan. Specifically, forested hilltop locations with consistently high visual amenity values during both boom and recession (periods) are to be recommended as priority target areas. The underlying premise for this recommendation is that the consistent premiums of visual amenity values may help keep housing prices stable regardless of real-estate market conditions, information of potential use in tight times.

The rest of this thesis is organized as follows. Part II discusses the first essay of the thesis. Part III focuses on the second essay of the thesis.

# Part II. Ridge, Slope, and Hillside Protection Taskforce Projects in Knox County, Tennessee: Costs and Benefits of Target Area Reforestation

Ridge, Slope, and Hillside Protection Taskforce Projects in Knox County, Tennessee: Costs and Benefits of Target Area Reforestation


## Abstract

The objective of this research is to identify priority areas for forest landscape restoration in Knox County, Tennessee. A cost-benefit analysis is conducted to determine individual landowners' willingness to accept reforestation as a substitute for other potential land uses, given the explicit costs and benefits of reforestation. A sequence of hedonic models is used to estimate the differences in housing values of multiple potential sites for restoration projects, an approach which allows us the establishment of an overall price-distance relationship between the amenity values attributable to both deforested and forested areas and their proximities to housing locations within the county. Based on the overall price-distance relationship, the sum of the differences between the amenity values of deforested land and those of forested areas is estimated as reflected in housing prices at different proximities to potential restoration sites. The results of this study show that there are potentially large gains to the community through reforestation projects but that those net benefits can vary greatly depending on the acreage of the potential target sites, land prices, the number of houses in the surrounding area, and the proximity of surrounding houses to the site.



*Key Words:* Amenity Valuation of Forest Land, Cost-Benefit Analysis, Hedonic Price Model, Reforestation Decision.

## Introduction

Knox County, Tennessee has in recent years experienced a rapid rate of growth; the county's population grew from 335,749 to 435,725 (29.78%) between 1990 and 2009, a rate more than 5 percent greater than the overall U.S. growth rate (U.S. Census Bureau 2010). Consequently, population density has increased from 660 to 857 persons per square mile, and a significant amount of deforestation has resulted from the development associated with this substantial increase in population. Approximately 15,000 acres (or 4%) of the county's forested lands, defined as areas with 20 percent or more forest canopy cover, were converted to urban uses between 1989 and 1999 (American Forests 2002).[1]

The recent decades' deforestation has implications for the county's economic and environmental well-being. Trees remove air pollutants from the atmosphere (e.g., carbon dioxide, nitrogen dioxide, sulfur dioxide, carbon monoxide, ozone, and particulate matter of 10 microns or less), and they also help reduce erosion and filter pollutants before they reach freshwater sources. The county's Metropolitan Planning Commission (MPC 2009) has reported that had the 15,000 acres of the forest land lost between 1989 and 1999 been conserved, it could have taken up to 115,000 tons of pollutants out of the air annually. The removal of this amount of air pollutants is estimated to be worth $3.5 million per year based on the estimates from a model developed by Nowak et al. (1998). Additionally, over 64 million cubic feet of stormwater could have been retained. Whereas, the cost of building the infrastructure to handle this amount of stormwater was estimated to be $128 million dollars (NRCS 1986).

[1] Forest areas are defined in the study by American Forests as areas with 20% or more canopy ; however, the USGS's National Land-Cover Database (NLCD) defines forest area as "[a]reas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); tree canopy accounts for 25-100 percent of the cover" (USGS 2001b). The NLCD definition of 25% or more canopy is used in this study.

In response to concerns over deteriorating environmental quality and its economic consequence, due in part to the significant amount of deforestation in the county, the Joint City-County Taskforce on Ridge, Slope, and Hillside Development and Protection (hereafter referred to as "the Taskforce") was formed in 2008, charged with assessing the long-term impact of development on the ridge tops, steep slopes, and hillsides of the area and creating development policies to protect the ridgelines and hillsides that make up 60 percent of the forested area of the county (MPC 2009). While the draft policies released by the Taskforce in 2009 (MPC 2009) are geared primarily toward sustainable development on hillsides (land with slopes greater than 15 degrees), they also lay out plans for retaining, protecting, and reforesting hillside areas within the county.

The Taskforce has laid out various action plans to achieve these goals, including identifying areas for protection and reforestation (see Figure 1). Reforestation can be expensive, and allocations for it compete with funding for other public purposes, e.g., schools and law enforcement (Barrow 2002). Thus, the Taskforce has to establish high-priority target areas for reforestation, with the creation of guidelines that allow for more efficient policy recommendations. Furthermore, a number of different factors (i.e., environmental sustainability, health and safety, and economic impact) need to be considered in the establishment of these guidelines (MPC 2009). Two key components are the costs and benefits of each reforestation project.

Reforestation costs include both explicit and implicit costs. Explicit costs include the cost of land acquisition, material (e.g., purchased seed and planting stock), and labor used in restoration (e.g., site preparation and planting). Implicit costs (hereafter refer to as "opportunity costs") are the benefits that would have accrued if the land given up for reforestation had been used for other purposes.[2] It is important to consider opportunity costs because the estimated value of reforestation will be over- or underestimated unless the opportunity cost is considered in the cost measure of reforestation. For example, if a grassland area that is a priority target site for reforestation has a positive non-use value attached to housing prices, which can be viewed as the opportunity cost of current use, the costs for reforestation should be adjusted by adding the explicit costs and the opportunity costs of the lands given up for reforestation. Alternately, if currently deforested lands selected as potential target sites are negatively associated with housing prices, the costs for reforestation should be adjusted by subtracting the absolute value of the opportunity costs of the lands given up for reforestation from the explicit costs.

The benefits of reforestation can be divided into those that qualify as "use" values and those that qualify as "non-use" values (Harris 2006). Use values consist of the benefits an individual receives from the direct or indirect use of reforested land. Direct-use values include values from recreational uses. Indirect-use values are the values provided by reforested lands that sustain natural and human systems through services such as erosion control, stormwater retention, and air-pollution reduction (Glück 2000; Harris 2006). Alternatively, non-use values are those values that people derive from economic goods independent of any possible use, present or future, of those goods (Chopra 1993). The non-use values emanate from the enhanced biological diversity resulting from reforestation, which provides economic value in the form of the value attached to species' existence as well as the aesthetic value associated with enhanced views and appreciation of a unique culture and heritage (Lazo et al. 1997).

[2] The cost for land acquisition could also be perceived as an opportunity cost for guarding non-forest land against deforestation; however, the cost for land acquisition is considered an explicit cost in this study because an explicit payment would be made to acquire the land.

In terms of benefit assessment, among the use and non-use values of a reforestation project, the Taskforce has primarily focused on the use values (e.g., the indirect use values associated with the cleansing of air and water pollutants) (MPC 2009). While the Taskforce acknowledged that trees surrounding a house can increase a house's value by 10–20 percent (MPC 2009), little effort was made to incorporate such values into the funding for reforestation projects. Likewise, the cost of the projects (both explicit and opportunity costs) was not examined closely by the Taskforce (2009). Therefore, the values and opportunity costs attached to house prices and their incorporation into both the costs and benefits of a project need to be examined closely, complementing the use values obtained by the MPC (2009), for any cost-benefit analysis of potential reforestation sites.

The objective of this research is to identify priority areas for forest landscape restoration in support of the Ridge, Slope, and Hillside Development and Protection Taskforce in Knox County, Tennessee. A cost-benefit analysis is applied to prioritize the potential target sites for reforestation. The analysis focuses on estimating individuals' willingness to accept reforestation (or the benefit) in exchange for giving up other purposes of land (opportunity costs) and enduring the explicit costs associated with the reforestation.

## Literature Review

As interest has grown in investigating the economics of reforestation, a variety of analytical approaches has been applied to assess its effects. For instance, cost-benefit analysis has been applied to assess the air-pollution mitigation and carbon sequestration potential of reforesting marginal agricultural lands (e.g., Parks and Hardie 1995; Alig et al. 1997; Stavins 1999; Plantinga et al. 1999; Juutien et al. 2009). A common finding with voluntary programs in those studies is that, while reforestation provides a cost-effective way to curb pollutants and greenhouse gases, the opportunity cost to land owners for even marginal agricultural land is often higher than the expected return from reforestation.

Another set of studies has applied cost-benefit analysis to assess the economic impact of reforestation (e.g., McElwee 2009; Zhou et al. 2007; Xu et al. 2006; Yin et al. 1999). For example, Zhou et al. (2007) focused on estimating the effects of reforestation on a rural economy using a cost-benefit analysis associated with reforestation areas. Their study examined the "Grain to Green" program in China, which is similar to the program proposed by the Taskforce in that it focuses on land on hillsides with steep slopes. The opportunity costs of the land were represented by the net return to the community from agricultural crops (e.g., rice, corn, soybeans, potatoes, and sweet potatoes) versus reforesting the land for agroforestry (e.g., bamboo, pear, pine, orange, and chestnut). The general conclusions of these studies are that reforestation can have enormous positive economic impacts on the surrounding economy, but not without government intervention in the form of subsidies or tax breaks and implementation has to balance future environmental services with the sustainability of the local economies.

The contingent valuation method estimates individuals' willingness to pay for restoration as a guide for selecting sites for restoration. This method, which has been widely used when performing cost-benefit analysis of restoration projects (e.g., Breffle et al. 1998; Lee and Mjelde 2007; Adams et al. 2008; Laitila and Paulrud 2008; Petrolia and Kim 2009, works well for evaluating a specific project site and the services it provides.  However, the method lacks the flexibility to examine multiple potential sites for prioritization because of its limited ability to obtain willingness to pay across multiple sites (Carson et al. 2001). Such a limitation primarily results from difficulties in designing surveys that involve multiple sites and respondents' difficulties in assessing them (Barrio and Loureiro 2010).

Responding to the contingent valuation method's lack of flexibility, Cho et al. (2011) have developed a sequence of hedonic models to estimate differences in values attached to housing prices among multiple potential sites being considered for restoration projects. The estimation is based on the assumption that the economic benefits of reforestation are likely to be capitalized into local residential real-estate markets (hereafter referred to as "amenity values"). The key to addressing the need for flexibility in examining multiple potential sites is the ability to estimate amenity values received by households from each site. The amenity values over different ranges of area that surround houses, which are calculated based on a sequence of hedonic models, allow the establishment of an overall price-distance relationship between the amenity values attributable to both deforested and forested areas and their proximities to housing locations within a given community. Based on the overall price-distance relationship, the sum of the differences between amenity values of deforested and forested areas, as reflected in housing prices across different proximities to each site among multiple potential sites, is estimated. The sum of the differences is used as a proxy for the value added to nearby houses by a given reforestation project for any given number of multiple potential target sites.

While the method developed by Cho et al. (2011) is directly applicable to the estimation of amenity values and costs of potential reforestation sites, the amenity value itself is not sufficient to use in a cost-benefit analysis as a guide for prioritizing potential target sites because the amenity values of deforested and forested areas, as reflected in housing prices, do not account for other benefits not valued in the housing market or for any explicit costs of reforestation. Thus, it is necessary to apply a cost-benefit analysis to the framework developed by Cho et al. (2011) to incorporate the benefits of implementing a reforestation project, estimated as use values and non-use values, as well as the explicit and opportunity costs associated with reforestation. The cost-benefit analysis incorporates the sequence of hedonic models and allows the estimation of net benefits to the surrounding community from implementing reforestation projects at multiple sites; this estimation can then be used for site-specific prioritization.

## Data

*Data associated with explicit costs*

Three types of explicit costs are involved with the reforestation of a specific site: land acquisition, material, and labor for mechanical site preparation and planting. The costs for land acquisition vary by site because land prices differ across sites. In contrast, material (e.g., purchase of seed and planting stock) and labor costs are assumed to be constant over the sites because such costs are unlikely to vary greatly within a county. The sale price for the parcels that contain the target sites, adjusted to 2001 values using a housing price index calculator (FHFA 2011), was provided by the KGIS website (2011) and was used as the cost for land acquisition for all sites.

Other explicit costs associated with reforestation (i.e., material and labor costs) were directly taken from the biannual report “Costs and Cost Trends for Forestry Practices in the South” (Dubois et al. 2001), which provides per-acre cost estimates for site preparation (including labor and equipment), planting (including labor costs), and materials (pine tree seedlings). While the species of trees to be planted may not be limited to pine trees, the estimates for seedling cost in this study are based on Eastern White Pine, which is native to the county and is also the most common type of tree for commercial foresting in the South. Dubois et al. (2001) classified costs for forestry practices into three categories: mechanical site preparation, planting cost, and cost of seedlings, based on surveys of private firms and public agencies in 12 southern states. Respondents to the survey reported planting an average of 631 seedlings per acre. They estimated the costs for mechanical site preparation, herbicide, and other chemical preparation, fertilizing, planting, and seedlings to be $153.73, $279.90, $43.08, $40.38, and $40.40 per acre, respectively (Table 1). These estimates were used as other explicit costs of reforestation for the cost-benefit analysis.

The indirect use values of deforestation derived from stormwater control ($233.33 per acre per year) and air pollution mitigation ($8,533.33 per acre) were acquired from the Taskforce's report (MPC 2009). Those values were estimated by American Forests (2002) and were based on both a hydrological model developed by the U.S. Natural Resources Conservation Service (NRCS 1986) and an Urban Forest Effects Model developed by Nowak et al. (1998) (Table 1).

The hydrological model estimates the amounts of stormwater absorbed and retained by urban trees as well as the amount of erosion control and subsequent improvement of water quality by the reduction in particulate matter in waterways (NRCS 1986). The model estimates were used to calculate the construction costs not spent on the infrastructure that would have been needed to control and purify the same amount of water. The calculated construction costs were then used as the indirect use values of stormwater control for reforestation.

The Urban Forest Effects Model was used to estimate the quantities of air pollutants (e.g., the amount of carbon) that are sequestered by an average acre of urban forest. The model was established based on a functional relationship between the amount of air pollution absorbed by forest areas and the quantified amount of biomass in the forest areas based on the amount of tree canopy and the size of the trees. The annual benefit attributed to air pollution control was estimated as the value of the avoided healthcare costs to society by the removal of these air pollutants from the atmosphere. In addition, the Urban Forest Effects Model estimated the reduced amount of air pollution attributable to the ways that urban forest canopy conserves energy: regulating temperatures by providing windbreaks in the winter and shade in the summer.

*Data associated with multiple hedonic spatial regressions*

Creating a sequence of multiple hedonic spatial regressions for estimates of amenity values of reforested areas and opportunity costs of the lands given up for reforestation involved four GIS data sets: individual parcel data, satellite imagery land-cover data, census-block group data, and boundary data. The Knoxville-Knox County Metropolitan Planning Commission provided a GIS shape file of all the individual parcels in Knox County, Tennessee in 2009 (MPC 2010). The Knox County Tax Assessor's office provided a spreadsheet file (2010) of individual parcels consisting of land-sales information and structural information about houses (e.g., number of bedrooms, age, number of stories, number of fireplaces, and existence of a garage, pool or brick facade).

The spreadsheet file was merged with the attribute table in the GIS shape file to create the geospatial information associated with the physical locations of parcels (i.e., land-cover and neighborhood variables). The individual parcel data are for single-family houses sold during 2001 in Knox County, Tennessee. A total of 3,915 sales transactions were undertaken during this period. To eliminate sale transactions that did not reflect true market value (e.g., houses that were sold as gifts, inheritance, and divorce settlements), sales with prices below $40,000 were removed, a level based on suggestions by Knox County officials, leaving 3,608 observations for analysis.

Land-cover data derived from satellite imagery in GIS raster files were downloaded from the National Land-Cover Database (NLCD) (USGS 2001a). The dataset contains 21 types of land-cover categories at a resolution of 30 m by 30 m (USGS 2001b). For this study, these NLCD land-cover categories were either combined or were split into six land-cover groups: “forests,” “barren/grassland,” “water,” “parks,” “golf courses,” and “other developed open space.” Specifically, the forests group combines three NLCD categories: deciduous forests, evergreen forests, and mixed forests, and the barren/grassland group combines scrub land, barren land, and grassland categories. The developed open space NLCD category includes public parks and golf courses as well as other types of developed open space (e.g., highway medians and shoulders and residential properties). Based on previous literature indicating that a community would potentially have different values for different types of green open spaces, such as parks and golf courses (e.g., Cho et al. 2007, 2011), the single developed open space NLCD category was split into three land-cover groups: parks, golf courses, and all other developed open space. Descriptions of the six land-cover groups and other variables used in the sequence of multiple hedonic spatial regressions are reported in Table 2.

The distances from each sales transaction to the nearest physical features were calculated using information from the Environmental System Research Institute maps (ESRI 2001) and the Spatial Join tool in ArcGIS (ESRI 2008). The measure is the distance from the location of a sales transaction to the centroid of the nearest polygon or the polyline representing a physical feature.[3]

[3] Polygons and polylines are shapes in GIS maps. Polygons are two-dimensional shapes that represent objects on a map as seen from above, such as land parcels, lakes, counties, states, or countries. Polylines are, essentially, one-dimensional lines that represent objects on a map, such as roads, rivers, railroad tracks, or, sometimes, borders.

## Methods and Procedures

This section is devoted to describing the sequence of multiple hedonic spatial regressions used to estimate the amenity values and the opportunity costs of reforestation. The explicit costs and use values for stormwater and air pollution mitigation were derived from existing reports, and their estimation procedures were previously described in the data section ("Data associated with explicit costs"). These explicit costs and use values are added to the estimated amenity values and opportunity costs then summarized for the cost-benefit analysis at the end of this section.

A four-step procedure developed by Cho et al. (2011) was used to generate amenity values of reforested areas and opportunity costs of the lands given up for reforestation. The first step entails drawing concentric radii around the location of each housing sales transaction with a sequence of 50 radii between 0.1 and 5 miles in 0.1-mile increments using the ArcMap Buffer Wizard tool for 180,400 radii (50 radii for 3,608 observations). Areas were aggregated for each land type for the six land-cover groups within each radius using the ArcView Spatial Statistics tool (ESRI 2008).

In the second step, a sequence of 50 hedonic regressions was estimated, systematically replacing the six land-cover variables with those for the next largest radius constructed in the first step with each regression. The sequence was estimated using a spatial autoregressive model with autoregressive (AR) disturbance of the order SARAR (1,1) (Anselin and Florax 1995). The general functional form is: $\mathbf{P} = \rho \mathbf{W}_1 \mathbf{P} + \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}$, $\boldsymbol{\varepsilon} = \lambda \mathbf{W}_2 \boldsymbol{\varepsilon} + \mathbf{u}$, $\mathbf{u} \sim \text{iid}(\mathbf{0}, \boldsymbol{\Omega})$, where $\mathbf{P}$ is a vector of the natural log of a house's sales price; $\mathbf{X}$ is a matrix of variables including land-cover as well as structural and neighborhood characteristics (see Table 2 for detail description and summary statistics of the variables); $\boldsymbol{\beta}$ is a vector of exogenous variable coefficients; and $\mathbf{W}_1$ and $\mathbf{W}_2$ are (possibly identical) matrices defining neighborhood interrelationships between spatial units that are caused by spatial correlation among house prices and as a consequence of spatial correlation in the errors. If the **W** matrix is asymmetrical, the model is heteroskedastic (Anselin 2003), and E[**uu′**] = **Ω**. For simplicity, notation for the 50 regressions is suppressed as the same model is applied to each regression for each radius. Three types of spatial weight matrices **W** (i.e., the Thiessian polygon, the *k*-nearest neighbor, and the hybrid spatial weight matrices) were considered to test various neighborhood structures based on the idea that "near things are more related than distant things" (Tobler 1970).

The Thiessian polygon weight matrix calculates the areas surrounding a sales transaction in a way that identifies the nearest neighbors (Anselin 1988). This method involves the construction of a polygon around the centroid of a sales transaction so that it has an area defined by boundaries identified by the median distance between the centroid of the sales transaction and the centroids of the nearest sales transactions. When the contiguous polygons, defined as those that share either a border or vertex, are identified, those two sales transactions, *i* and *j*, are identified as neighbors. In this way, the off-diagonal elements of the spatial weight matrix $W_{ij}$ are given a value of 1, and 0 otherwise. All diagonal values are also 0.

The *k*-nearest neighbor (KNN) matrix identifies the number (*k*) of nearest houses based on the Euclidian distance between the centroids of sales transactions. This KNN matrix assumes that outside of the *k* closest houses, no other houses have an effect on that specific observation. Four values of *k* were created by taking the value of the square, third, fourth and fifth roots of the total number of observations (n=3,608) then rounding to the nearest whole number. The values are *k*= 60, 15, 8, and 5, respectively.

The hybrid matrix was constructed by combining an inverse distance weight matrix and either a Thiessian polygon weight matrix or a KNN weight matrix. This method calculates the

Euclidian distances between the sales transaction centroids before taking the inverse values and inserting them as the off-diagonal elements of the spatial weight matrix. All diagonal elements are 0. This method measures the distances from each individual sales transaction to every other sales transaction in the study area (3,608). The hybrid method then takes the resulting matrix and limits the results of the nearest neighbors by element-wise multiplication of the inverse distance weight matrix with the Thiessian polygon weight matrix or one of the four KNN weight matrices. This method accounts for distance decay effects among sales transactions at different distances.

In the third step, the marginal implicit prices of the six land-cover groups ( $m^j$, $j = 1,...,6$ ) were estimated from each of the 50 regressions. For example, for the *r*th regression, $r = 1,\ldots, 50$, the marginal implicit price of a particular land-cover group is the partial derivative of the hedonic price function with respect to the area ($A^j$) of the *j*th land-cover group when price and area are logged:

$$\hat{m}_r^j = \frac{\partial \hat{P}_i}{\partial A_{ir}^j} = \frac{\partial e^{x_i'\hat{\beta}_r + \sum_{j=1}^{6} \hat{\theta}_r^j \ln A_{ir}^j}}{\partial A_{ir}^j} = \hat{\theta}_r^j \times \frac{\overline{P}_i}{\overline{A}_{ir}^j}, \qquad (1)$$

where "^" denotes a consistent estimate of ( $\boldsymbol{\beta}_r, \theta_r$ ). The estimated parameter $\hat{\theta}_r^j$ is the elasticity of the *j*th land-cover group for the housing price estimated with the *r*th buffer due to the log-log functional form of the hedonic model. These marginal implicit prices are equal to the per-acre amenity value added to houses within a given distance of the given land-cover. For example, the marginal implicit price of forests estimated with the *r*th buffer ($*x* per acre) suggests that a one-acre increase in forested area within the *r*th buffer distance of a house increases the average housing price by $*x*, *ceteris paribus*.

In the fourth step, fitted curves between the estimated marginal implicit prices from the third step and the 50 radii illustrate the relationships between the average amenity values attributable to different land types and the distance from housing locations (hereafter referred to as "distance decay curves"). The distance decay curves for the currently existing land types targeted for reforestation (e.g., barren/grassland) are referred to as the opportunity cost of reforestation in terms of foregone values of the current land types at different distances from housing locations. Therefore, for example, the difference between the marginal implicit prices of forests and barren/grassland at a given distance from housing locations that is reflected in the vertical distance between the distance decay curves for the barren/grassland and forest lands is the amenity value gained by reforestation minus the amenity value lost by giving up barren/grassland at a given distance from housing locations (see Figure 2). Such differences are assumed to be net gains in amenity values from reforestation of barren/grassland under the premise that the amenity value of forests is greater than amenity value of barren/grassland.

Several hypothetical target sites were identified for cost-benefit analysis of forest landscape restoration. Based on Taskforce (MPC 2009) guidelines, areas selected for target sites have two criteria: unproductive gray lands (i.e., barren/grassland) and Hillside and Ridgeline Protection Areas. The 7,632 sites that met both of these criteria were sorted by size for each of three regions within Knox County, and the five largest sites within each region were selected as the hypothetical target areas for the evaluation (See Figure 1 for target site locations).[4] The three regions (and associated sites) of Knox County were the City of Knoxville (sites designated K1 – K5), the Town of Farragut (F1 – F5), and the unincorporated sections of the County (C1 – C5). These fifteen sites range in size from less than 1 acre to over 43 acres, which provides an

[4] Knoxville is a traditional metropolitan area whereas Farragut is primarily a bedroom community located west of Knoxville. The remainder of the county is more rural and less densely populated than either Knoxville or Farragut.

opportunity for determining whether different sized reforestation sites and housing densities have different effects on the amenity values gained by reforestation. Although this analysis was done for 15 sites, the process could be extended to any of the 7,632 sites that meet the criteria.

The number and distance of all single-family houses within five miles of the center of each of the 15 potential sites were then quantified. These distances were placed into the equations for the distance decay curves for barren/grassland and forest land to account for the marginal implicit value of each land type at given distances from housing locations. The difference between these values is the proxy for the value added to houses from conversion to forest land. After the aggregate benefits to house values from reforestation within five miles of each target site were measured, indirect use values for air pollution and stormwater control as well as explicit costs from existing reports were used to complete the cost-benefit analysis of each reforestation project.

## Results

### *Overall estimates and control variables*

In the general spatial model, the selection of an appropriate weight matrix **W** had effects on the overall measure of fit for the series of hedonic regressions. The adjusted $R^2$s for the hedonic model based on the Thiessian polygon, KNN, and hybrid spatial weight matrices range from 0.774 to 0.902, 0.365 to 0.762, and 0.702 to 0.914, respectively (Table 3). The spatial LM statistics for the Thiessian, KNN, and hybrid matrix specifications ranged from 68 to 95, 344 to 443, and 42 to 64, respectively (Table 3). The null hypothesis of no spatial autocorrelation was rejected for all matrices with p-values < 0.01 for all regressions. The spatial lag ($\rho$) parameters were also significant for all matrix specifications at the 5% level. Given these results, the general spatial models were estimated using the hybrid Thiessian matrix specifications, which had the best average fit. The results from four of the 50 hedonic regressions based on 0.1, 1.0, 2.0, 3.0, and 4.0-mile radii are reported in Table 4. Hereafter, coefficients of variables are considered statistically significant if their $p$ values $\leq 0.05$. With a few exceptions, only statistically significant variables are discussed in the remainder of this section (Table 4).

The structural variables (i.e., finished area, stories, bedrooms, fireplaces, garage, pool, quality of construction, condition, and age) were significant in all 50 regressions using the hybrid Thiessian matrix. These variables also maintained consistent signs across regressions and in keeping with expectations. More finished area, stories, bedrooms, and fireplaces added value to the houses, *ceteris paribus*. Pools, garages, brick siding, quality of construction, condition of the house, and sales occurring during spring and summer were also positively associated with sales price. Age was negatively associated with price, implying that older houses were less valued. Among the neighborhood variables, ACT scores, which was a proxy for school district quality, also had a positive effect on housing prices, implying that people would pay more to live in better school districts.

*Six land-cover variables*

The six land-cover variables were not always significant at all distances, but when they were significant, the signs were mostly consistent with expectations and across regressions. Open water (i.e., rivers and lakes), forest land, parks, and golf courses had consistently positive association with house prices in all regressions where they were significant, implying the more land-cover in the area, the greater the value added to houses, *ceteris paribus*. Developed open space and barren/grassland had negative effects on house prices in all regressions where significant. Developed open space may have had negative effects on house prices because it mostly consisted of public land in close proximity to highways (i.e., interchanges and medians), and proximity to highways has had a negative or insignificant value in previous literature (e.g., Hughes and Sirmans 1992; Cho et al. 2010).

Figure 2 shows the distance decay curves based on the marginal implicit prices for the forest and barren/grassland variables for all distances regardless of their significance levels. The pattern for the distance decay curve for forest land shows that the implicit value of forest land was at its highest at $166.59 per acre where the distance to housing locations was the least (0.1 miles). The values decrease drastically from 0.1 miles to about 1.0 miles and decrease gradually beyond 1.0 miles. The pattern of change with increasing distance suggests that the highest values for forest land occur within walking distance of a house or for forest land that is visible from a house whereas the value gained beyond those distances is fairly small.

Figure 2 also shows the distance decay curve for barren/grass land. The effect of barren/grass land was negative for all but two points. This suggests that barren/grass land reduces the values of surrounding houses in a fairly consistent pattern. This land-cover effect also approaches zero as the distance from the house increases but at a somewhat steadier rate compared with the sharp decline seen with the values of forest land.

*Cost-benefit analysis of 15 hypothetical target sites for reforestation*

Table 5 presents the total net value gains from reforestation for the 15 hypothetical target sites, calculated from the estimated amenity values and opportunity costs discussed in the previous section and all other costs and benefits listed in Table 1. Table 5 also shows the return per dollar spent, which means the total return in terms of the total amenity value and environmental value gain divided by dollars spent on land and reforestation costs. This per dollar return may be a more revealing number than the net return as it shows the cost effectiveness of each site. Land acquisition prices outweighed any value gains for a number of sites, especially the small sites in Farragut. The high property values there made potential reforestation projects unfeasible as they yield net losses to the community and have low returns in terms of each dollar spent. The site with the largest gain in total net value was site C2, which also has the largest acreage and the most houses within five miles of the site. This site had over $440,000 in total value gain, due in large part to an amenity value gain of over $1.3 million from the current use due to reforestation. This represented a return of $1.34 per dollar spent, the largest amount for any site, meaning the community has a 34 percent return on the money spent for reforestation and land purchases.

Sites with the most acreage had the largest net value gains in many cases. This finding implies a strong correlation between the size of the reforested area and the value gained by the community. However, among the Knoxville target sites, K2 had a larger gain in total net value than K5, which had a net loss ($188.67 for K2 versus -$731.14 for K5), despite K2 being a slightly smaller site (3.33 for K2 acres versus 3.55 acres for K5), similar land prices ($51,039.41 for K2 versus $54,442.04 for K2), and having nearly half as many houses within five miles (478 for K2 versus 825 for K2). Since the acreages of these two sites are very similar, the costs and benefits, calculated on a per-acre basis (i.e., reforesting costs and indirect use values), are similar. The key difference between these two sites is that the amenity value gained through the reforestation of K2 is more than two times greater than that for K5 ($7,472.44 for K2 versus $3,022.22 for K2). This result shows that while the area of a target site and the total number of houses within five miles of the site are important factors in determining which sites will yield the greatest net benefit, the distribution of houses within five miles of the site is also an important factor. For example, 6 percent of the houses (27 houses) are within one mile of K2 versus 1 percent of houses (10 houses) within the same distance of K5. Thus, a greater percentage of houses within five miles of K2 are within the distance that yields the highest amenity values from reforestation.

## Conclusion

In support of the Joint City-County Taskforce on Ridge, Slope, and Hillside Development and Protection, an analysis was conducted on the costs and benefits of reforesting lands on the hillsides and ridgelines of Knox County, Tennessee. The results of this study show that there are potentially great gains to the community through reforestation projects but those benefits can vary greatly depending on a number of factors, including the acreage of a potential target site, the number of houses in the surrounding area, property values, and proximity of houses surrounding the site. Proximity of houses to a site may be the greatest factor in identifying the reforestation project sites with the greatest potential return because the greatest value gains are to those houses within one mile of the site. Conversely, if the distribution of houses is skewed away from a target site, the site is less likely to yield a positive return from reforestation. Thus, the distribution of houses surrounding a restoration site is an important factor in determining which sites will yield the greatest net benefit or return on investment to a community.

An important caveat to this cost-benefit analysis is that it may underestimate the returns to the community from reforestation because not all benefits could be estimated. Direct-use values for forest land, such as those for recreation (i.e., hunting, camping, and hiking) and view, are not explicitly included. Additionally, non-use values for benefits such as enhanced biodiversity and the existence values of various plant and animal species as well as the aesthetic value associated with the appreciation of a unique culture and heritage embodied by native forest lands were also not included in this study. Obtaining these direct-use and non-use values may require a survey of the residents, property owners, and non-residents in and outside of the county. As such, the estimates presented with this study should be considered baseline estimates of the returns to the surrounding community, which, while more complete than prior estimates, are a significant step towards more complete valuation of these areas.

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## Appendix

Table 1. Explicit costs and indirect use values per acre

| Explicit costs | | Indirect use values | |
|---|---|---|---|
| Labor and mechanical site preparation : | $153.73 | | |
| Herbicide and other chemical prep.: | $279.90 | | |
| Fertilizing: | $43.08 | | |
| Planting: | $40.38 | Stormwater control: | $8,533.33 |
| Seedlings: | $40.40 | Air pollution control: | $233.33 |
| Explicit costs per acre (except land): | $557.49 | Indirect use values per acre: | $8,766.67 |

Table 2. Names and descriptions of variables

| Variable | Definition | Unit | Mean | Std. Dev. |
|---|---|---|---|---|
| ***Dependent Variable*** | | | | |
| House price | Housing Sale Price | $ | $126,313.12 | $99,289.08 |
| ***Structural variables*** | | | | |
| Finished area | Total finished square footage of the house | Sq Feet | 1830.33 | 897.9 |
| Stories | Height of house in number of stories | | 1.26 | 0.42 |
| Bedrooms | Number of bedrooms | | 3.1 | 0.96 |
| Fireplace | Number of fireplaces | | 0.7 | 0.59 |
| Brick | Dummy variable for brick siding (1 if brick, 0 if otherwise) | | 0.23 | 0.42 |
| Garage | Dummy variable for garage (1 for garage, 0 otherwise) | | 0.49 | 0.5 |
| Quality of construction | Dummy variable for quality of construction (1 if excellent, very good or good, 0 otherwise) | | 0.31 | 0.46 |
| Condition of structure | Dummy variable for condition of structure (1 if excellent, very good or good, 0 otherwise) | | 0.65 | 0.48 |
| Pool | Dummy variable for pool (1 for pool, 0 otherwise) | | 0.03 | 0.17 |
| Age | Year house was built subtracted from 2001 | Years | 29.37 | 23.94 |
| Season | Dummy variable for season of sale (1 if April through September, 0 otherwise) | | 0.57 | 0.495 |
| ***Neighborhood variables*** | | | | |
| ACT score | American College Test score by high school district | | 20.52 | 1.55 |
| Distance to CBD | Distance to the nearest central business district | Feet | 10.49 | 0.61 |

Table 2. Continued

| Variable | Definition | Unit | Mean | Std. Dev. |
|---|---|---|---|---|
| ***Land-cover variables*** | | | | |
| Water open space | Area of water within a buffer of 0.1 miles (one of 50 buffers) drawn around each house sales transaction. | Acre | 10.235 | 33.15 |
| Developed open space | Area of developed open space within a buffer of 0.1 miles (one of 50 buffers) drawn around each house sales transaction. | Acre | 81.72 | 78.2 |
| Forest land | Area of forest within a buffer of 0.1 miles (one of 50 buffers) drawn around each house sales transaction. | Acre | 186.7 | 154.2 |
| Barren/grassland | Area of scrub/grassland within a buffer of 0.1 miles (one of 50 buffers) drawn around each house sales transaction. | Acre | 35.58 | 30.3 |
| Parks | Area of parks within a buffer of 0.1 miles (one of 50 buffers) drawn around each house sales transaction. | Acre | 0.3 | 1.2 |
| Golf courses | Area of golf courses within a buffer of 0.1 miles (one of 50 buffers) drawn around each house sales transaction. | Acre | 0.68 | 3.2 |

Table 3. Model Selection Criteria

| | Log Likelihood | | McFadden's $R^2$ | | LM Test Statistic | |
|---|---|---|---|---|---|---|
| | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum |
| Thiessian Polygon | 0.181 | 0.209 | 0.774 | 0.902 | 68.181 | 95.329 |
| K nearest neighbors of order q [*KNN*(*q*)]: | | | | | | |
| KNN($n^{1/5}$) = 5 | 0.370 | 0.396 | 0.548 | 0.762 | 359.163 | 438.381 |
| KNN($n^{1/4}$) = 8 | 0.518 | 0.560 | 0.433 | 0.637 | 343.751 | 439.167 |
| KNN($n^{1/3}$) = 15 | 0.968 | 1.045 | 0.365 | 0.602 | 345.881 | 443.395 |
| KNN($n^{1/2}$) = 60 | 3.857 | 4.164 | 0.367 | 0.603 | 345.598 | 442.984 |
| Inverse distance Hybrids: | | | | | | |
| W/Thiessian | 0.123 | 0.146 | 0.702 | 0.821 | 44.586 | 63.502 |
| W/KNN($n^{1/5}$) = 5 | 0.127 | 0.148 | 0.747 | 0.914 | 42.136 | 59.886 |
| W/KNN($n^{1/4}$) = 8 | 0.127 | 0.148 | 0.747 | 0.914 | 42.136 | 59.886 |
| W/KNN($n^{1/3}$) = 15 | 0.127 | 0.148 | 0.747 | 0.914 | 42.136 | 59.886 |
| W/KNN($n^{1/2}$) = 60 | 0.127 | 0.148 | 0.747 | 0.914 | 42.136 | 59.886 |

Table 4. Selected estimates for SARAR (1,1) spatial process models

| | Mile 0.1 | Mile 1.0 | Mile 2.0 | Mile 3.0 | Mile 4.0 |
|---|---|---|---|---|---|
| Intercept | 4.575* | 4.751* | 4.343* | 4.941* | 4.593* |
| | (0.17068) | (0.019) | (0.216) | (0.351) | (0.478) |
| ***Structural Variables*** | | | | | |
| Ln(Finished Area) | 0.592* | 0.589* | 0.592* | 0.596* | 0.597* |
| | (0.018) | (0.018) | (0.018) | (0.018) | (0.018) |
| # of Stories | 0.062* | 0.063* | 0.064* | 0.060* | 0.058* |
| | (0.011) | (0.012) | (0.012) | (0.012) | (0.012) |
| # of Bedrooms | 0.017* | 0.016* | 0.017* | 0.018* | 0.018* |
| | (0.004) | (0.003) | (0.003) | (0.004) | (0.003) |
| # of Fireplaces | 0.034* | 0.031* | 0.032* | 0.030* | 0.033* |
| | (0.008) | (0.008) | (0.009) | (0.009) | (0.009) |
| Brick | 0.055* | 0.058* | 0.055* | 0.056* | 0.055* |
| | (0.009) | (0.009) | (0.009) | (0.009) | (0.010) |
| Garage | 0.068* | 0.072* | 0.073* | 0.074* | 0.073 |
| | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) |
| Quality | 0.165* | 0.164* | 0.165* | 0.167* | 0.164* |
| | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) |
| Condition | 0.066* | 0.065* | 0.060* | 0.061* | 0.063* |
| | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) |
| Pool | 0.114* | 0.105* | 0.114* | 0.116* | 0.123* |
| | (0.024) | (0.024) | (0.025) | (0.024) | (0.025) |
| Age | -0.003* | -0.003* | -0.003* | -0.003* | -0.003* |
| | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) |

Table 4. Continued

| | Mile 0.1 | Mile 1.0 | Mile 2.0 | Mile 3.0 | Mile 4.0 |
|---|---|---|---|---|---|
| Season | 0.021* | 0.018* | 0.020* | 0.021* | 0.018* |
| | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) |
| ***Neighborhood Variables*** | | | | | |
| ACT Score | 0.0173* | 0.013* | 0.015* | 0.020* | 0.008 |
| | (0.004) | (0.005) | (0.006) | (0.006) | (0.005) |
| Ln(Distance to CBD) | -0.014 | -0.010 | -0.009 | -0.017 | 0.010 |
| | (0.013) | (0.014) | (0.015) | (0.017) | (0.018) |
| ***Land-cover Variables*** | | | | | |
| Open Water | 0.087* | 0.007* | 0.002 | -0.004 | -0.004 |
| | (0.021) | (0.002) | (0.002) | (0.003) | (0.003) |
| Developed Open Space | -0.018* | -0.025* | -0.015* | -0.078* | -0.036 |
| | (0.005) | (0.010) | (0.006) | (0.003) | (0.027) |
| Barren/Grassland | 0.001 | -0.003 | 0.001 | -0.013 | -0.033* |
| | (0.006) | (0.004) | (0.007) | (0.009) | (0.012) |
| Forest Land | 0.006* | 0.009 | 0.032* | 0.037* | 0.044 |
| | (0.003) | (0.006) | (0.013) | (0.017) | (0.023) |
| Parks | 0.078 | -0.002 | 0.005 | 0.006 | 0.002 |
| | (0.040) | (0.004) | (0.003) | (0.004) | (0.005) |
| Golf Courses | 0.018 | 0.008* | 0.008* | 0.009* | 0.0003 |
| | (0.032) | (0.004) | (0.003) | (0.002) | (0.002) |
| Number of Observations | 3,608 | 3,608 | 3,608 | 3,608 | 3,608 |

The asterisks represent p-values: * P<0.05

Table 5. Total net value gains from reforestation for 15 hypothetical target sites

| Site | Acres | Number of Houses | Explicit Costs (A) | | Opportunity Cost of Foregone Values of Barren/ Grassland Attached to House Prices (B) | Indirect Use Values Associated With the Cleansing of Air and Water of Pollutants (C) | Amenity Value of Forest Land Attached to House Prices (D) | Net Benefit: [(C)+(D)-(A)-(B)] | Return Per Dollar Spent |
|---|---|---|---|---|---|---|---|---|---|
| | | | Land Acquisition | Material and Labor[5] | | | | | |
| F1 | 0.444788 | 436 | $36,571.00 | $247.96 | -$2,595.55 | $3,899.31 | $1,267.20 | -$29,056.91 | $0.21 |
| F2 | 1.334364 | 498 | $164,367.00 | $743.89 | -$8,816.51 | $11,697.93 | $4,273.13 | -$140,323.33 | $0.15 |
| F3 | 0.222394 | 497 | $28,382.00 | $123.98 | -$1,504.38 | $1,949.65 | $568.29 | -$24,483.65 | $0.14 |
| F4 | 0.222394 | 680 | $50,000.00 | $123.98 | -$2,217.14 | $1,949.65 | $568.29 | -$45,388.89 | $0.09 |
| F5 | 0.222394 | 759 | $87,771.00 | $123.98 | -$2,149.03 | $1,949.65 | $685.65 | -$83,110.64 | $0.05 |
| K1 | 3.113515 | 578 | $47,636.78 | $1,735.75 | -$15,185.24 | $27,295.16 | $3,152.55 | -$3,739.58 | $0.92 |
| K2 | 3.335909 | 478 | $51,039.41 | $1,859.74 | -$16,370.55 | $29,244.81 | $7,472.44 | $188.67 | $1.00 |
| K3 | 2.668727 | 661 | $40,831.52 | $1,487.79 | -$16,191.58 | $23,395.85 | $5,611.59 | $2,879.71 | $1.07 |
| K4 | 2.001546 | 293 | $30,623.65 | $1,115.84 | -$3,587.69 | $17,546.89 | $3,022.22 | -$7,582.70 | $0.76 |
| K5 | 3.558303 | 825 | $54,442.04 | $1,983.72 | -$21,408.56 | $31,194.47 | $3,091.58 | -$731.14 | $0.99 |
| C1 | 27.57685 | 1441 | $814,339.00 | $15,373.82 | -$608,954.13 | $241,757.14 | $123,603.49 | $144,601.94 | $1.17 |
| C2 | 43.144427 | 2024 | $1,275,961.48 | $24,052.59 | -$1,167,256.74 | $378,232.95 | $198,420.45 | $443,896.08 | $1.34 |
| C3 | 25.130517 | 1680 | $743,214.68 | $14,010.01 | -$593,008.01 | $220,310.95 | $88,822.98 | $144,917.24 | $1.19 |
| C4 | 21.794607 | 995 | $644,557.85 | $12,150.28 | -$264,571.33 | $191,066.13 | $54,634.84 | -$146,435.83 | $0.78 |
| C5 | 36.91740 | 515 | $1,091,802.08 | $20,581.08 | -$359,344.96 | $323,642.63 | $90,324.33 | -$339,071.24 | $0.70 |

[5] Materials and labor costs are based on an estimated per acre values which are listed in Table 4.

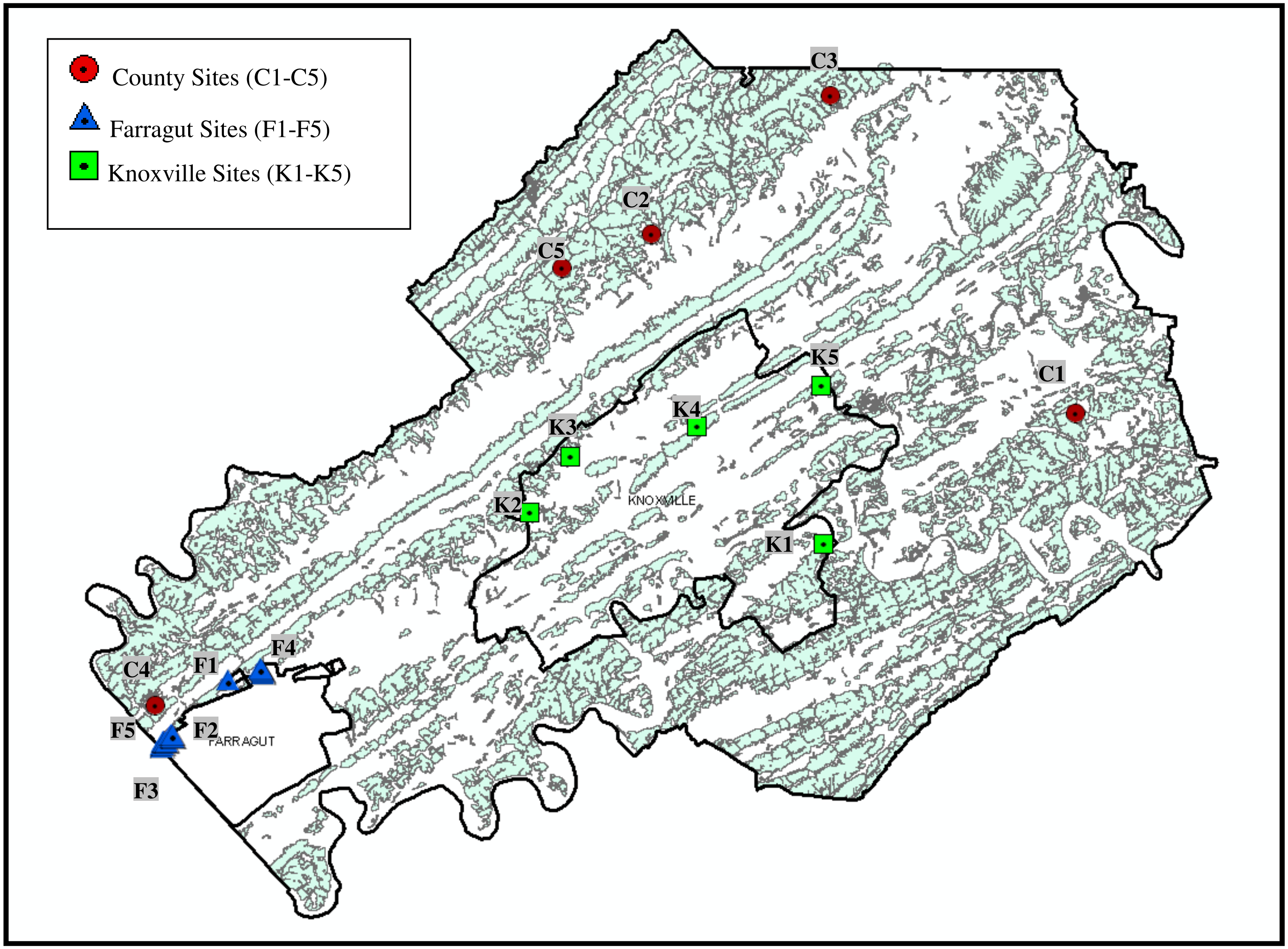


Figure 1. Map of Knox County, TN (Tennessee Spatial Data Server 2011) with Hilltop Restoration and Protection Area highlighted and the 15 target sites marked.

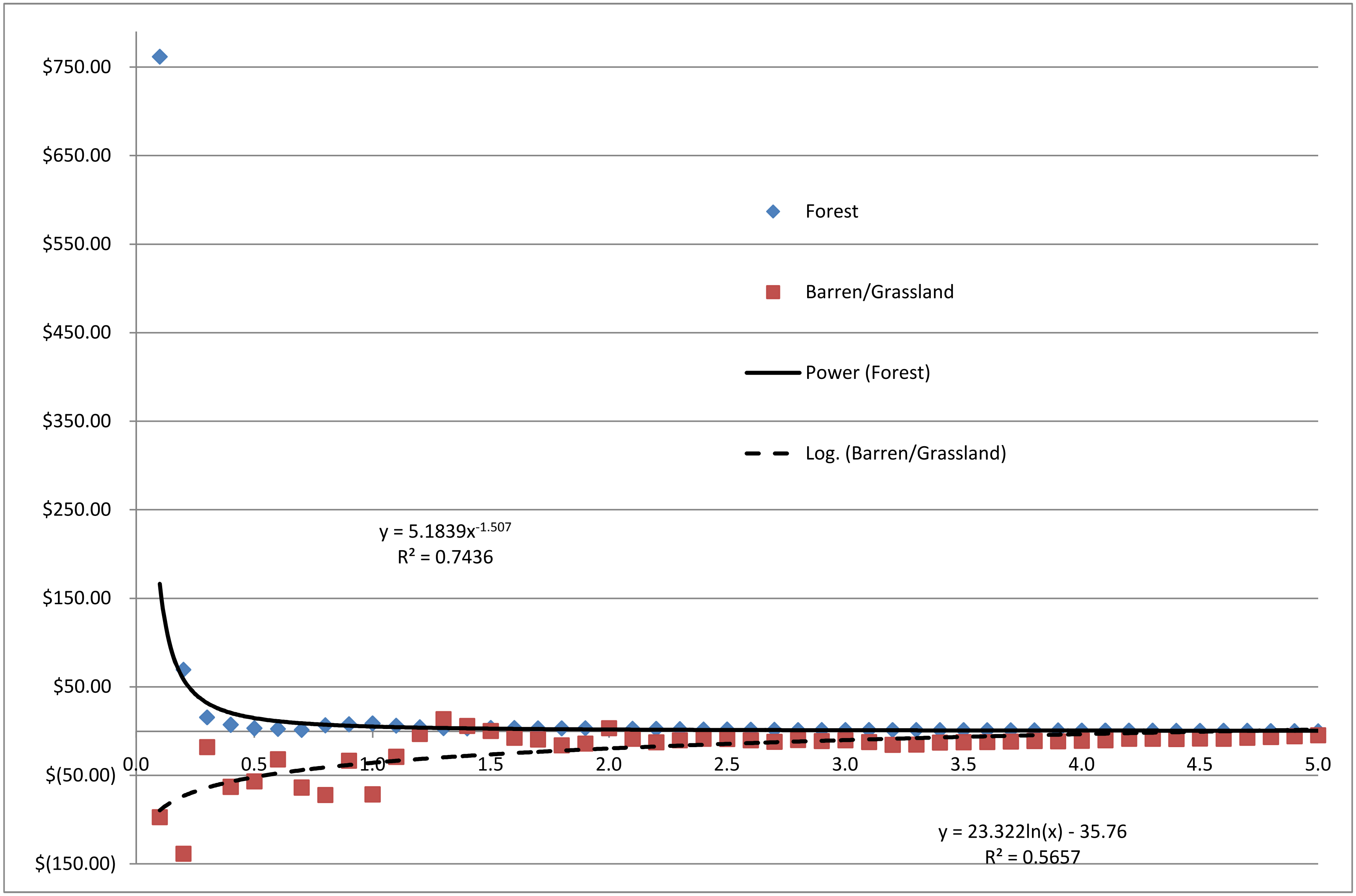


Figure 2. Distance decay function of marginal implicit prices for the hybrid Thiessian regressions

## Part III. Identifying Priority Target Areas for the Knoxville-Knox County Hillside and Ridgetop Protection Plan: Using the Value of Visual Amenity during the Real Estate Boom of 2002-2007 and the Recession of 2008

**Abstract**

In support of future development goals in Knox County, Tennessee, this study endeavored to find those areas within the county where the views of the hillside and ridges were most valued and to understand how those values were affected by different economic climates. The amenity values added to houses by their individual vistas were quantified for houses sold in the county during the housing boom of 2002-2006 and again during the recession of 2008. These marginal implicit prices were mapped to show where in the county the views were most valued. The results of this study show that forest views add significant value to homes both during a boom time and during a recession. However, from the boom period to the recession, the added amenity value decreased 13 percent (from $10.99 to $9.50 per acre of visible forest area). When forested land values were mapped out, the south-western, north-eastern, and northern parts of the county, which contain high income suburban communities, stand out with consistent value gains in excess of $70 per acre of visible forest area. Therefore, it would appear that the areas that the county should consider as highest priority are those in the portions of the county with a concentration of high value houses.

## Introduction

Hillside development is common in Southern Appalachia because the scenic hillside properties of the region are attractive places to live (Cho et al. 2009). Additionally, a lack of zoning and building regulation in the region has fostered hillside development (MPC 2009). This development poses challenges to maintaining sustainable growth because it is associated with a high risk of erosion, landslides, and degradation of water quality (Olshansky 2007). As Knox County, Tennessee has experienced controversy with regards to hillside development and its regulation,  in 2008 the Metropolitan Planning Commission (MPC) of the City of Knoxville and Knox County was commissioned to create The Joint City-County Taskforce on Ridge, Slope, and Hillside Development and Protection (hereafter referred to as "the Taskforce") to assess the long-term impact of development on the ridge tops, steep slopes, and hillsides of the area and propose a hillside and ridgetop protection plan (hereafter referred to as "the Plan").

The areas under consideration for protection contain different types of land use and are widely distributed throughout the county (see Figure 3). They are also highly visible throughout the county and contain 60 percent of the county's forested area (MPC 2009). The taskforce is focused on protecting the ridge lines and hillsides by altering existing or creating new development policies, including revising zoning laws, imposing limits on development in new areas, increasing density requirements in new housing developments, placing restrictions on building height, changing rules on hill side grading, and planning possible reforestation and restoration efforts (MPC 2009).

However, the plan is currently facing significant implementation barriers The Knox County mayor announced opposition to the plan in February 2011 and the Knox County

Commission voted down the plan in its current form in April 2011 (Donila 2011a, 2011b). Based on current perceptions of the proposed plan by county leaders and residents, it is likely the Taskforce's plan will have to be revised in the future. Consequently, high priority target areas selected from those under consideration by the current taskforce may need to be excluded from an anticipated compromise plan.

When the proposed plan was established by the Taskforce, the main considerations were protecting aesthetics and property values and achieving long-term improvement of air and water quality (MPC 2009). While the Taskforce intended to take into account all of these benefits, thus far they have primarily focused on improving long-term air and water quality; quantitative measures of protecting aesthetics and property values have not been explicitly considered in the plan. While the plan makes efforts to estimate the costs of infrastructure for stormwater control, pollution control, and erosion control, it only mentions the effects on viewsheds as a "concern for many citizens" (MPC 2009) without quantifying those effects.

The goal of this research, therefore, is to contribute to the process of screening high priority target areas among the areas (hereafter referred to as "the planned area") under consideration in the current Taskforce plan by providing estimates of visual amenity values with their spatial and temporal variations for the planned area in the housing market. The areas with consistently high visual amenity values over two separate periods (i.e., during both economic boom and recession) are considered high priority areas because the consistent premiums of visual amenity values support stable housing prices regardless of real estate market conditions.

To achieve the goal, the following three steps were conducted: (1) spatial hedonic models were estimated using repeat sales of two separate periods (i.e., an economic boom and a recession); (2) the coefficients for the visual amenity variables were used to map marginal implicit prices of those variables to visually highlight the spatial variation between the two periods; and (3) areas with consistently high visual amenity values across both periods within the planned area were identified as high priority target areas for use by the Taskforce in revising its plan.

**Literature Review**

Advances in spatial econometrics and geographic information systems (GIS) have allowed hedonic studies focusing on the spatial dynamics of the effect of environmental landscape attributes on property values (e.g., Geoghegan et al. 1997; Acharya and Bennett 2001; Geoghegan 2002; Irwin 2002; Cho et al. 2006, 2007; Conway et al. 2010; Sander et al. 2010). A common finding in these studies is that green spaces of different types increase the values of nearby residential properties to different extents. For example, Irwin (2002) and Geoghean (2002) both found that "permanent open space" (open space that was certain to remain undeveloped) had a positive effect on the prices of surrounding homes and that different types of open space (i.e. parks, forests, agricultural land) had different values to home buyers.

A few studies have also considered how the premium of amenity values vary over time in hedonic models (e.g., Lee and Linneman 1998, Riddel 2001, Smith et al. 2002, Cho et al. 2009, 2011). Collectively, these studies illustrate that the marginal value added to house prices by open space can fluctuate over time. Lee and Linneman (1998) found that the value added to houses by a greenbelt surrounding Seoul, Korea, diminished over time by externalities caused by the increased density of the city within the green belt. This decline was mitigated to some extent by other factors such as distance and house value. Smith et al. (2002) found that as open space decreased over time due to increases in development of an area, the value added by the remaining open space increased. Later, Cho et al. (2011) examined how changes over time in the broader economy (from boom periods to recessions) could affect the value added by surrounding open space. Their conclusion was that the value added by open space dropped off during recessions compared to periods when the economy was growing. In total, these studies show how open space has a positive effect on the prices of surrounding homes but also how those values can fluctuate over time depending on subsequent development, policy changes, or changes in the economy.

Despite a few studies that have considered the spatial or temporal dynamics of amenity values using hedonic studies, surprisingly few studies have considered both the spatial and temporal dynamics of the amenity values provided by environmental landscapes such as hillsides and ridgetops. Research by Cho et al. (2009) was one of the rare studies that analyzed spatial and temporal variation in the effects of open space on residential home values. Geographic variation in the marginal effects of proximity to open space was analyzed using locally weighted regression in a hedonic housing-price framework. While Cho et al. (2009) correctly highlights the need to analyze the dynamics of spatial and temporal dimensions, some issues remain: (1) the choice of two periods (1989–1991 and 1999–2001) for the analysis of temporal dynamics used in the study is random; (2) the locally weighted regression used in the study admittedly fails to adequately address the spatial autocorrelation in the data; (3) the implication drawn from the analysis is not directly applicable to real policy adoption; and (4) the comparison of the marginal effects of proximity to open space is done using two separate hedonic models based on two different sets of sales transactions, a comparison which suffers from a lack of control for variations in household location patterns and structural differences across time periods.

To accommodate all the corresponding caveats in Cho et al. (2009), (1) two temporally significant time periods, real estate boom and recession, are chosen to represent differing market conditions; (2) a modified version of locally weighted regression that corrects for spatial autocorrelation is used; (3) the spatial and temporal dynamics of amenity values using hedonic studies are designed to contribute to the process of screening high priority target areas directly applicable to the plan currently pending consideration by the Knox County Commission; and (4) two separate hedonic house price models are estimated for repeat sales of the same houses in two different time periods. While this repeat sales hedonic model cuts down on the total number of observations, it should perform more efficiently and eliminate more bias than the prior methodology because it better eliminates the effect of outlying observations and better estimates changes in the housing attribute values (Case et al. 1991; Clapp and Giaccotto 1998; Hansen 2009).

## Study Period and Data

The United States experienced a real estate boom characterized by an increase in both house purchases and house values during the period of 2002–2006. Fuelled by low mortgage rates and a national push toward homeownership, housing prices increased rapidly during the period. This boom eventually started its slow down in 2006 as new house sales diminished from the record highs of 2005 and house inventories began to grow (Peters 2006, Census Bureau 2010a). Beginning in mid-2007, the U.S. housing market experienced a sub-prime mortgage market 'meltdown', which led to a housing market bust and, in part, to a recession starting in December 2007 (Hetzel 2009). Based on this information, sales transactions during the 2002–2006 period were chosen as the sample representing a boom period, and the corresponding sales during 2008 were chosen as the sample representing a recession period.

The first step in establishing the data was to retrieve all necessary house sales data from the Knox County Tax Assessor's office. These data include all detached single family houses (hereafter referred to as "houses") in Knox County. The last sales date and price in the data were sorted to identify all houses sold during 2008. Each of the 7,559 sales transactions in 2008 was then checked against the county's property records on the Knoxville Utilities Board's Geographic Information System (KGIS) website to select all those houses that had also been sold during the housing boom (2002–2006). Among the 7,559 observations, 2,300 houses were sold at least once during the 2002–2006 period. The most recent sales during the five-year period were chosen for the repeat sale data. All houses that were transferred through inheritance, divorce, foreclosure, or underwent any other means that was not a market transaction were excluded since the house's sale price would be below the market price (often zero dollars). Houses that had been renovated, torn down and rebuilt, or other type of substantial structural change between sales were also removed from the data set, as were any properties that had been subdivided in the intervening years, to avoid variations in differences across the time periods that would have prohibited a one-to-one comparison of properties.

After removing those transactions, the remaining 553 repeat sales transactions for the 2000–2006 and 2008 data sets were used for model estimation. Pooling sales data over a seven-year time period for the boom period increased concerns over the possibility of unaccounted for changes in market conditions over time. To control for market condition changes, housing sale prices were adjusted to 2008 dollars using the annual housing price index for the Knoxville metropolitan statistical area (FHFA 2011).

Each of the 553 repeat sales transactions was matched via the parcel identification number with a parcel on a Geographic Information System (GIS) map provided by the Metropolitan Planning Commission (MPC 2010). The centroid point of a parcel was determined using ArcGIS software and served as a proxy for housing location (ESRI 2008). House attributes such as lot size, structural information (e.g., number of bed rooms, square footage of finished areas, number of stories), and neighborhood characteristics (e.g., whether the house was in the city of Knoxville and distance from the nearest park) provided by the office and website of Knoxville, Knox County, Knoxville Utilities Board Geographic Information System (KGIS) were added to each point (KGIS 2010). Boundary data for high school districts with their average American College Testing (ACT) scores were supplied by the KGIS website (KGIS 2010). This data was overlaid with the point data of sales transactions to determine which school district contained each sales transaction, and average ACT scores were assigned to each sale transaction per the boundaries. These scores serve as a measure of the quality of the surrounding school district. Additionally, data from the US Census Bureau and the state of Tennessee GIS server provided the maps of nearby highways, railroads, parks, golf courses, and bodies of water. From these maps the distance from each sales transaction to the closest of these features was calculated.

An elevation raster map at a resolution of 1/3 arc seconds of the area was downloaded from the U.S. Geologic Survey's National Map Seamless Server (USGS 2010),[6] used to determine each house's viewshed, the area, in Knox County, that is visible from each sales transaction. Specifically, the viewshed for each sales transaction was established using elevation

[6] A raster map is a GIS file format that stores and displays data in a map format where individual pixels contain a single piece of information such as height above sea level in elevation data in the USGS map or a code for a particular land-cover class in the National Land-cover Database (NLCD) map. The USGS elevation data at the 1/3 arc second level has a resolution of 10 meters by 10 meters and is made from a digital elevation model of the US that is updated bi-monthly.

data and the viewshed tool in ArcGIS and was used to account for all of the visible hilltop area by different land-cover classes. This was accomplished by identifying the land-cover of seven different classes based on the 2001 U.S. National Land-cover Database (NLCD) under consideration for the protection plan using GIS shape files of the boundaries as set out by the Taskforce (see Figure 3).

The 2001 NLCD, derived from satellite imagery and complied in GIS raster files, contains 21 types of land-cover categories at a resolution of 30 *m* by 30 *m* (USGS 2001). The land-cover categories were grouped into seven different classes (i.e., water, developed open space, developed areas, forests, barren/scrub lands, agricultural lands, and wetlands) based on the 16 NLCD categories that exist in the county. Except for water, which includes rivers, lakes and streams, and developed open space, which includes parks, golf courses, private yards, and other public land such as highway medians and interchanges, all five other land classes with similar NLCD categories were combined. The five land classes consist of (1) the class of developed areas that are primarily covered by buildings, parking lots, roads, and highways which are included in the three NLCD categories of low, medium, and high density development land; (2) the class of barren/scrub land that includes the NLCD categories of grasslands, barren lands, and scrub lands; (3) the class of forest land, comprised of the NLCD categories of evergreen, deciduous, and mixed forests; (4) the class of agricultural lands that includes the NLCD categories of pasture/hay and cultivated crop lands; and (5) the class of wetlands that combines the two NLCD wetland classes, woody and emergent herbaceous wetlands.

The 2001 NLCD data were updated to account for changes of the seven different land classes for each successive year (2002-2008) using parcel level data provided by the MPC. The areas that were developed, and subsequently deforested, were removed from each area on a yearly basis by examining construction dates in the parcel level data. This was done by a cross-comparison between the 2001 NLCD maps and the 2009 parcel level data from the county. The 2001 NLCD maps were clipped using the boundaries of the parcels that were developed. The individual viewsheds of all the sales transactions were then laid over the seven different land class land-cover maps for the years of the first purchase during 2002–2006 period and then the 2008 map, revealing the amount of each different land class in every viewshed during/in both periods. Once the amount of each land class in the ridgeline protection area that is visible from each point at both time periods is quantified, these values are placed in a hedonic model for each house transaction along with other house and neighborhood attributes. The variables used in the model are listed and described in Table 6.

## Methods and Procedures

*Spatial hedonic models using repeat sales of two separate periods*

Because the price of a house is strongly influenced by the prices and quality of houses in its immediate neighborhood (Brasington and Hite 2005; Cho et al. 2009, 2010; Cohen and Coughlin 2008), there may be a need to control for neighborhood effects (or spatial dependence) in determining the effects of view of hillside and ridgetop. Consequently, the following general spatial model (Anselin, 1988) is specified to test the null hypothesis that the hedonic price model for the repeat sales of houses for the 2000–2006 (hereafter referred to as "boom model") and 2008 data sets (hereafter referred to as "recession model") contain spatial lag and spatial error components:

$$(1)\quad \begin{aligned} \mathbf{y} &= \rho \mathbf{W}\mathbf{y} + \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \\ \boldsymbol{\varepsilon} &= (\mathbf{I} - \lambda \mathbf{W})^{-1}\boldsymbol{\mu} \end{aligned},$$

where **W** is a spatial weight matrix identifying a neighborhood structure, $\rho$ is the parameter of the spatially lagged dependent variable, and $\lambda$ is the parameter of the spatial autoregressive structure of the disturbance **ε**. Given consistent estimates of the lag and error autoregressive parameters, the null hypothesis that $\lambda = 0$ and $\rho = 0$ is tested for each regression using the Wald statistic. Evidence favors the correction of spatial autocorrelation when $\rho = 0$ and $|\lambda| > 0$, and the converse suggests control for spatial lag. A log-transformed dependent variable is used because taking the natural log of a dependent variable minimizes the possibility of heteroskedasticity in the hedonic model (Wooldridge 2003). A natural log transformation of the distance and area-related variables is used in this study as the log transformation captures the declining effects of these distance variables (Iwata, Murao, and Wang 2000; Mahan, Polasky, and Adams 2000).

In the estimation of equation (1), the selection of an appropriate spatial weight matrix **W** that reflects the intensity of the geographic relationship between observations in a neighborhood remains a challenge. In general, there is no consensus as to which weights are most appropriate for any econometric study (Anselin, 1988). Florax and Rey (1995) discuss some problems that may arise if the spatial weight matrix is poorly selected. Thus, as a sensitivity analysis, several types of weighting matrices were tested. Eleven types of spatial weight matrices **W** were constructed: a Thiessen polygon, an inverse distance, four *k*-nearest neighbor with k corresponding to the nearest whole number of the square, third, fourth and fifth root of the total number of observations ($k$ = 24, 8, 5, and 4, respectively), and five hybrid spatial weight matrices which were the product of the inverse weight matrix times either the Thiessen weight matrix or one of the *k*-nearest neighbor.

Once the null hypothesis that spatial lag or/and spatial error is tested for each regression for the boom and recession models, there may be a need to allow the housing hedonic parameters to vary over space, including parameters that represent the effects of view of hillside and ridgetop, because of potential spatial heterogeneity. In the case of $\rho = 0$ and $|\lambda| > 0$, two separate locally weighted regressions that correct for spatial autocorrelation in the housing-price model are estimated for the boom and recession models. The locally weighted regression with spatially autocorrelated disturbances in a hedonic frame is expressed as:

(2) $\ln p_i = \sum_k \beta_k (u_i, v_i) x_{ik} + \varepsilon_i, \quad \varepsilon_i = \lambda \sum_{j=1, j \neq i}^{n} w_{ij} \varepsilon_j + \xi_i, \quad \xi_i \sim iid\left(0, \sigma^2\right)$,

where $p_i$ is sales transaction price of a house *i*; $x_{ik}$ is a vector of *m* variables including viewshed of hillside forest land; $(u_i, v_i)$ denotes the coordinates of the *i*th house among *n* houses; $\beta_k (u_i, v_i)$ represents the local parameters associated with house *i*; $w_{ij}$ is an element of an *m* by *n* spatial weighting matrix between points *i* and *j*; and λ is a spatial error autoregressive parameter. For simplicity, notation for the two different time periods is suppressed as the same model is applied to each time period.

Given estimation of the equation (2), residuals of the locally weighted regression are tested for spatial error autocorrelation using a Lagrange Multiplier (LM) test (Anselin 1988). The null hypothesis that $\lambda = 0$ is tested for each regression for the boom and recession models. Evidence favors the Cochran-Orcutt method of filtering dependent and explanatory variables to address spatial error autocorrelation (Anselin 1988) with local regression techniques in a parametric framework (Cho et al. 2009) when $|\lambda| > 0$. A convenient procedure to estimate λ is Kelejian and Prucha's (1998) general moments approach, based on the set of the residuals from the locally weighted regression.

Given determination of λ, the closed form solution to the equation (2) is

(3) $$\hat{\beta}(u_i, v_i) = \left( X'(I - \lambda W)' A(u_i, v_i)(I - \lambda W) X \right)^{-1} X'(I - \lambda W)' A(u_i, v_i)(I - \lambda W) P$$ ,

where **A** is a kernel function [$K(d_{ij}/d_{max})$] that maps the neighbourhood of observations through **A** ($u_i$, $v_i$), producing *n* subsets of observations, with diagonal elements identifying the location of other houses relative to house *i* and zeros in off-diagonal positions (Fotheringham et al. 2002). For each observation, a vector of parameters is estimated, generating *n* $\hat{\beta}(u_i, v_i)$'s, and for all $d_{ij} \geq d_{max}$, $K(d_{ij}/d_{max}) = 0$. While there are many possibilities for K, we used four kernel functions: the Gaussian kernel with $K(d_{ij}/d_{max}) = \exp[-(d_{ij}/d_{max})^2/2]$, the bi-square kernel with $K(d_{ij}/d_{max}) = [1 - (d_{ij}/d_{max})^2]^2$, the tri-cube kernel with $K(d_{ij}/d_{max}) = [1 - (d_{ij}/d_{max})^3]^3$, and the Epanechnikov kernel with $K(d_{ij}/d_{max}) = 1 - (d_{ij}/d_{max})^{2,}$ where $d_{max}$ is a bandwidth that identifies the maximum number of neighbors admitted in the neighborhood. A cross-validation (CV) approach as suggested by Cleveland and Devlin (1988) was used. The CV function is $\min_{d_{\max}} \sum_{i=1}^{n} [y_i - \hat{y}_{\neq i}(d_{\max})]^2$.

The filtering mechanism (I – λW), where I is an identity matrix, $\lambda$ is a spatial error autoregressive parameter, and **W** is a spatial weight matrix, partials out spatial error autocorrelation associated with the explanatory and dependent variables while estimating local coefficients. Instead of using the eleven types of spatial weight matrices **W**, one was selected based on the goodness of fit and spatial LM statistics of the general spatial model of the equation (1) to use for the estimation of (3) that employs the four kernel functions. The spatial LM statistic was used to select the best-fit kernel function for the locally weight regression.

Pseudo-standard errors for the *i* sets of regression parameters are based on the covariance matrix (cov):

(4) $$\text{cov}\left(\hat{\beta}(u_i, v_i)\right) = \sigma_i^2 \left( X'(I - \lambda W)' A(u_i, v_i)(I - \lambda W) X \right)^{-1}$$ ,

where $\sigma_i^2 = e'(I - \lambda W)' A(u_i, v_i)(I - \lambda W)e/(q - k)$ is the variance associated with the *i*th regression point (Fotheringham et al. 2002). Statistical significance of the estimates from the locally weighted regression with spatially autocorrelated disturbances at the *i*th regression point is evaluated with Pseudo-t tests derived from the Pseudo-standard errors of the location-specific covariance matrices. Based on the estimates for the hillside forest land and the Pseudo-*t* tests between the 2002 to 2006 and 2008 data sets, marginal implicit prices of the significant hilltop forest land are calculated with the assumption of average home value and viewshed areas. Then, the hilltop locations with consistently high visual amenity values of forest land during both periods are classified to contribute to the process of identifying priority target areas for the plan.

The variability in the observed local regression coefficients for the spatial units is compared to the variability of local regression coefficients from a large number of random allocations of the random numbers. Statistically significant differences between the variability of an observed estimate and those computed using the randomized data (hereafter referred to as "spatial variability test") indicate a rejection of the null hypothesis that the individual parameter estimates are stable over space (Fotheringham, Brunsdon, and Charlton 2000).

*Mapping marginal implicit prices of the visual amenity variables*

Coefficients for the visual amenity variables from the locally weighted regression are used to map marginal implicit prices for the visible hilltop area for any land-cover class that is found to be significant at the 5% level in the general spatial model (hereafter referred to as "significant visible hilltop land-cover area"). The mappings visually highlight spatial variations between the two periods. Marginal implicit price for the significant visible hilltop land-cover is equal to housing price coefficient of the significant visible hilltop land-cover area times the housing price divided by the mean value of the visible hilltop land-cover area. This approach applies to a log-log relationship between a dependent and an explanatory variable and is evaluated at mean housing prices and significant visible hilltop land-cover areas.

The marginal implicit prices from the locally weighted regression were mapped using ArcGIS software (ESRI 2008). This software took a shape file map of all the sales transactions represented as points on the map and converted them into a raster map. This was accomplished by using the spatial analyst tool to transform the values for each time period associated with each point into raster data. The tool used an inverse distance method that distributed the values around each point to create new raster maps of the county. Once the new raster maps were created, the new raster maps of Knox County were limited to the planned area by clipping the map using the protection area boundaries. The marginal implicit values added by these areas are then made visible by color coding different categories based on a range of the values. Points that did not have significant values at the 5% level in the locally weighted regression were determined by examining the individual pseudo-t test scores for each coefficient, that is, $\hat{\beta}(u_i, v_i)$ matrix of *n* x (*m+1*) resulting in 10,507 different coefficients for the boom model and 10,507 coefficients for the recession model. The maps for each time period were then compared against each other to determine those areas with consistently high visual amenity values across both periods within the planned protection area.

## Results

*Overall estimates*

The overall performance of the general spatial model of equation (1) with eleven different spatial weight matrices for the boom and recession periods is reported in Table 7. Statistical significance at the 5% level is denoted with asterisks in the table, and henceforth, those variables and test statistics are referred to as “significant” in the discussion below. The spatial error $\lambda$ was significant in 20 out of 22 models, and the spatial lag $\rho$ was significant in only three models. The general spatial model with the Thiessen weight matrix had higher goodness-of-fit criteria (adjusted $R^2$) than the other ten weight matrices for both the boom and recession models. The spatial LM test results reported in Table 7 using the residuals of each regression suggest that the null hypothesis of no spatial autocorrelation was not rejected at the 5% level for either model with the Thiessen weight matrix.

Given these results, the locally weighted regression that corrects for spatial autocorrelation was estimated using the filtered variables based on Thiessen weight matrix, employing the four kernel functions for the boom model and the recession models. The overall performances of the locally weighted regressions under the four kernel functions are compared in Table 8. The adjusted $R^2$s for both the boom and recession models using the four kernel functions range from 0.79 to 0.90. The spatial LM test results reported in Table 8 using the residuals of each locally weighted regression suggest that the null hypothesis of no spatial autocorrelation was not rejected at the 5% level for the Bi-Squared kernel function during the boom period but rejected for all other kernels in both the boom and recessions models. Given these results, the final locally weighted regressions were estimated using Bi-Squared kernel functions for the boom period model. The Epanechnikov kernel functions were chosen for the recession models based on the fact that this kernel function had the highest adjusted $R^2$ value ($R^2$=0.90) and the lowest LM values (LM=8.31) of the four kernel functions.

*Estimates of the general spatial model and the locally weighted regression model*

The coefficients for the general spatial model and the locally weighted regression model for both periods are reported in Table 9. The general spatial model gives an overview of the effects and changes over time each attribute's values while the locally weighted regression model allows a breakdown of significant and not-significant values based on the locations of specific sales transactions and provides as well a means of assessment where the values vary significantly.

The effects of the structural variables, which were assumed to be unchanged between periods, were almost always significant at the 5% level in the general spatial models. Acreage, the number of bedrooms, quality of construction, garage, age, and finished area were all significant during both periods in the general spatial model. All of these variables, except for age, were positively associated with housing prices across the board, implying that more acreage, bedrooms, and finished area add value to houses, as does high quality construction and presence of garage. Age, on the other hand, had a negative coefficient in all cases, implying that new houses are valued more than older ones. The locally weighted regression showed that of all the structural variables, acreage and age varied significantly by location at the 5% level during both periods. For the acreage variable, the significant spatial variation makes sense as land tends to sell at a premium in more densely populated urban areas than in rural regions.

Two structural variables, the number of stories and condition, were not significant in the general spatial model or the locally weighted regression during the boom period but were consistently significant during the recession period. The number of stories had a negative effect on housing prices, implying that fewer stories are valued more, whereas the condition of the house had a positive effect, implying houses in better structural condition have higher value during the recession regardless of geographic location. This switch from insignificance to significance may reflect a change in valuation of a house due to the economy and imply that a house that has fewer stories and is in better structural condition is, perhaps, easier to maintain, heat, and cool in lean times.

The neighborhood variables that accounted for distance to the nearest park and ACT scores were significant in both periods in the general spatial model. ACT scores had a consistently positive effect in all models, implying that being in a school district with higher ACT score adds value to a house regardless of economic condition or geographic location. The distance to the nearest park was consistently negative in the general spatial model which implies significant premium of proximity to parks across time. The spatial variation of the value of ACT scores was not significant during the boom period but was significant during the recession. This change in significance may be due to increased interest in particular school districts.

The dummy variable for a house being inside the city of Knoxville was not significant during the boom period but was significant and positive during the recession in the general spatial model and in the locally weighted regression. This change may be a result of a desire to live closer to work or other amenities and services provided by the city during the recession. owing to significantly diminished disposable income and significantly diminished mobility (Cho et al. 2011). This increased value of residing inside of the city could also partly be a consequence of higher gasoline prices during the recession than during the boom period. As gasoline prices increased during the recession, commuting costs increased, affecting consumers outside of the city more because many workplaces are located within the city.

Among the seven land-cover variables, only forest land-cover had a positive and significant effect on house prices in both time periods in the general spatial model and in the locally weighted regression. This implies that a house's value increases more as the forest area that can be seen from the house increases, *ceteris paribus*. Based on the general spatial model, the marginal effect of the visible area of forest land during the boom period, evaluated at the mean house price of $190,540 (in 2008 dollars) and an initial mean size of 489 acres of visible forest land, means that each acre of visible forest land increases the average house price by $10.99. Evaluated at the mean house price of $196,836 (in 2008 dollars) and a mean size of 429 acres of visible forest land during the recession period, the increased mean house price for/associated with one more acre of visible forest is $9.50. (Marginal implicit prices for the visible area of land are calculated with the same assumptions regarding average house price and land-cover areas throughout this paper. Thus, these assumptions are not repeated.) The amenity value of the visible area of forest land during the recession is valued more than 13% less per acre compared to the same visible area in the boom period. The decline of the marginal implicit price of visible forest land during the recession likely results from decreased demand for houses with views of forest lands. As a house with a forest view is more valued than a house without one, a decrease in real income during the recession lessens the demand for the houses with a forest-view premium.

On the other hand, visible areas of barren/scrub land, while not significant in the boom period, were consistently significant and negative in the general spatial model and in the locally weighted regression in the recession. Each additional acre of visible area of barren/scrub land decreased the mean house value by $112 in the recession. This implies that the disamenity of a view of barren/scrub land devalued the house price significantly during the recession, while the same view did not matter during the boom. The significant disamenity value of a visible area of barren/scrub land as well as the significance of three other variables (number of stories, condition of the house, and whether the house was located in Knoxville) only during the recession suggest increased scrutiny of house features as a house buyer can afford to be pickier about house choice in a buyer's market.

*Mapping marginal implicit prices of the visual amenity variables*

Figures 4 and 5 show the distribution maps of the marginal implicit prices within the proposed Hillside and Ridge Top Protection Area associated with the forest land-cover class during the boom and recession periods, respectively, based on the locally weighted regressions. Four color schemes, (i.e., values smaller than or equal to the lower quartile, values between the lower quartile and the median, values greater than the median and lower than the upper quartile, and values greater than or equal to the upper quartile) were used to visually highlight spatial variations. Figure 6 highlights those planned areas with significant marginal implicit prices that are greater than or equal to the upper quartile across both periods, and the areas are defined as the planned areas with consistently high visual amenity values. Comparing Figures 4 and 5, the maps of the marginal implicit prices share a similar spatial pattern, and thus the planned areas with consistently high visual amenity values across both periods were screened out (of each map) without much deviation.

Areas with high visual amenity values (i.e., values greater than or equal to the upper quartiles) were those values that were greater than or equal to $77 per visible acre in the boom period and those values that were greater than or equal to $73 per visible acre in the recession period. High value areas appear in the northeast corner of the county near the Knoxville suburb of Strawberry Plains and in the northern corner of the county in an area that includes Powell and Heiskell, suburbs of Knoxville, and the city of Oak Ridge in the next county. The areas with the highest concentration of high visual amenity values for both periods are in the southwestern part of the county and contain concentrations of value gains in excess of $100 per visible acre. This part of the county is home to the town of Farragut, a high priced suburb of the Knoxville metropolitan area, and to Sequoia Hills, an affluent neighborhood on the edge of Knoxville. This implies that the value gained by area of visible forest land is less dependent on the economic climate than it is on the neighborhood and the property values of surrounding houses.

The distribution of the values of the views of barren/scrub land shows some variation in the way barren/scrub land is perceived by consumers (see Figure 7). The values in the highest quartile were positive, which may indicate a preference for some types of barren, grass, or scrub land. The areas that have the greatest levels of disamenity correspond, roughly, to the areas that gain the most from the amenity value gains from forest land views: the southwest portion of the county. The area with the positive amenity values extends from the center of the city of Knoxville west to the county border. This positive value may be partly explained by the desire for any green space in an urban environment.

An examination of the two maps in the Figures 4 and 5 shows that the value gains of the areas shifted little between the boom and the recession. The southwest region still has most of the high upper quartile values, values which do not seem to diminish much as the upper quartile only decreases by $4 per visible acre in the recession. Concentrations of values above the median seem to shrink as area in the northern and eastern parts of the county slip below the median implicit value gains. This shows that while values of forest views remain robust, the scope of the effect diminishes when the economy is in a downturn. On the other hand, those areas where the values of forest land views are already high seem to hold onto those values well. It appears that these areas represent the highest potential return on investment for preservation or reforestation efforts and therefore may be the best potential target sites for the Taskforce.

## Conclusion

In support of the Joint City-County Taskforce on Ridge, Slope, and Hillside Development and Protection, this study endeavored to find those areas within the county where the views of the hillside and ridges were most valued and to understand how those values were affected by the broader economic climate. With this goal in mind, the amenity value added to houses by their individual views was quantified for houses sold in the county first during the housing boom of 2002-2006 and then again during the recession of 2008. Once these marginal implicit prices were ascertained, they were mapped to show where in the county the views were most valued, with the hopes that this information would better enlighten the Taskforce when making decisions regarding where to focus preservation or reforestation efforts.

The results of this study show that the view of forest land adds values to homes both during a boom time and during a recession. However, the amenity value added to houses decreased 13% from the boom period to the recession, implying that forest view decreases in value when there is an economic recession. Additionally, the value of the view of barren/scrub land, which was not significant in the 2002-2006 regression, became significant during the 2008 regression, reducing house value almost $112 per visible acre and showing that while consumers are less inclined to pay more for views of forest land, they are also less willing to endure disamenity of negative views during a recession.

When the forest land values were mapped out to highlight planned areas with consistently high visual amenity values across both periods, some exhibited gains totaled in excess of $100 per additional acre of visible forest land. In addition, there was a shift between periods in the distribution of values as the areas that had the highest values of the view of forest land became more concentrated. The implication of these findings is that while the value of forest views may decrease during a recession, they still add value to houses but that the areas that gain the greatest values (values in the upper quartile) become smaller. Therefore, it would appear that the areas that the Taskforce should consider the highest priority are those in the southwest portion of the county. The results of this study might prove an effective tool for policy makers as they attempt to rekindle the debate over the currently stalled hillside and ridge top protection plan. The opposition to the original plan is mainly concern for the erosion of the rights of thousands of property owners (Donila 2011a). Significantly narrowing the planned area based on this study may enable compromise between development and environmental preservation.

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**Appendix**

Table 6. Names and descriptions of variables

| Variable | Definition | Unit | Boom Period | | Recession Period | |
|---|---|---|---|---|---|---|
| | | | Mean | Std. Dev. | Mean | Std. Dev. |
| ***Dependent Variable*** | | | | | | |
| House price | Housing sale price in 2008 dollars | $ | $190,540.26 | $110,230.88 | $196,835.82 | $112,695.33 |
| ***Structural variables*** | | | | | | |
| Finished area | Total finished square footage of the house | Sq Feet | 1851.846 | 866.657 | | |
| Stories | Height of house in number of stories | | 1.363 | 0.455 | | |
| Lot Size | Area of the parcel of the residence | Acres | 0.384 | 0.500 | | |
| Garage | Dummy variable for garage (1 for garage, 0 otherwise) | | 0.738 | .440 | | |
| Quality of construction | Dummy variable for quality of construction (1 if excellent, very good or good, 0 otherwise) | | 0.448 | 0.498 | | |
| Condition of structure | Dummy variable for condition of structure (1 if very good, good, or average, 0 otherwise) | | 0.991 | 0.095 | | |
| Age | Year house was built subtracted from the year sold | Years | 16.743 | 19.153 | 20.345 | 19.270 |
| ***Neighborhood variables*** | | | | | | |
| ACT score | American College Test score by high school district | | 21.735 | 1.395 | | |

Table 6. Continued.

| Variable | Definition | Unit | Boom Period Mean | Recession Period Std. Dev. | Mean | Std. Dev. |
|---|---|---|---|---|---|---|
| Knoxville | Dummy variable for location house (1 if in the city of Knoxville, 0 otherwise) | | | | | |
| Distance to Park | Distance to the nearest park | Feet | 9,477.477 | 6,015.938 | | |
| ***Land-cover variables*** | | | | | | |
| Water open space | Area of water visible from each house. | Acre | 0.524 | 4.083 | 0.315 | 1.469 |
| Developed open space | Area of developed open space visible from each house. | Acre | 80.731 | 84.582 | 84.942 | 84.957 |
| Developed areas | High, medium and low density development visible from each house. | Acre | 123.707 | 134.929 | 122.495 | 129.039 |
| Forest land | Area of forest visible from each house. | Acre | 489.140 | 545.473 | 429.720 | 490.356 |
| Barren/scrub land | Area of barren land, scrub land or grassland visible from each house. | Acre | 28.649 | 43.273 | 30.864 | 43.418 |
| Agricultural land | Area of agricultural land visible from each house. | Acre | 48.455 | 80.970 | 36.996 | 64.2886 |
| Wetlands | Area of wetlands visible from each house. | Acre | 0.354 | 0.745 | 0.219 | 0.5256 |

Table 7. Model Selection Criteria

| Types of Spatial Weight Matrix | R Squared | | Spatial Lag (λ) | | Spatial Error (ρ) | | LM Test Stat | |
|---|---|---|---|---|---|---|---|---|
| | Boom | Recession | Boom | Recession | Boom | Recession | Boom | Recession |
| Inverse Distance | 0.8134 | 0.7695 | 0.159229* | 0.198452* | 0.000957 | 0.002556 | 4.4742* | 8.9551* |
| Thiessen | 0.8245 | 0.9273 | 0.016013 | 0.068485 | 0.200535* | 0.177374* | 0.0447 | 0.9121 |
| KNN5(n=4) | 0.8243 | 0.7362 | 0.023132 | 0.150355* | 0.13888* | 0.112991* | 0.1236 | 5.747* |
| KNN4(n=5) | 0.6801 | 0.5899 | 0.003564 | 0.118396 | 0.214399* | 0.162682* | 0.0049 | 2.5043 |
| KNN3(n=8) | 0.6411 | 0.3313 | 0.028439 | 0.145223 | 0.174016* | 0.126095* | 0.1028 | 2.695 |
| KNN2(n=24) | 0.2779 | 0.3992 | -0.202268 | 0.149194 | 0.18546* | 0.17177* | 1.8547 | 1.6435 |
| Hybrid with Inverse Distance | | | | | | | | |
| W/Thiessen | 0.6081 | 0.7291 | 0.045324 | 0.103003 | 0.119138* | 0.13051* | 0.8155 | 3.8954* |
| W/KNN5(n=4) | 0.6632 | 0.748 | 0.030023 | 0.087192 | 0.1209* | 0.13624* | 0.3957 | 3.0425 |
| W/KNN4(n=5) | 0.7398 | 0.7936 | 0.031608 | 0.091897 | 0.119226* | 0.133116* | 0.3895 | 2.977 |
| W/KNN3(n=8) | 0.7327 | 0.8631 | 0.036289 | 0.109181 | 0.135065* | 0.13123* | 0.3869 | 3.437 |
| W/KNN2(n=24) | 0.6451 | 0.6967 | 0.01875 | 0.11934 | 0.150861* | 0.138722* | 0.0638 | 2.7057 |

* indicates significance at the level of 5% (P-value ≤ 0.05)

Table 8. LM Values for the four kernel types

| | Boom Period | | | Recession Period | | |
|---|---|---|---|---|---|---|
| | LM Test Stat | P Value | Adj. $R^2$ | LM Test Stat | P Value | Adj. $R^2$ |
| Gaussian | 30.3395* | 0 | 0.7945 | 33.1467* | 0.0000 | 0.8276 |
| Epanechnikov | 8.6268* | 0.0033 | 0.8697 | 8.3117* | 0.0039 | 0.9018 |
| Tricube | 29.9475* | 0 | 0.7939 | 33.0252* | 0.0000 | 0.8246 |
| Bi-Squared | 1.542 | 0.2304 | 0.7951 | 32.5010* | 0.0000 | 0.8259 |

* indicates significance at the level of 5% (P-value $\leq$ 0.05)

Table 9. Parameter Estimates for General Spatial Model and Locally Weighted Spatial Model

| | Boom Period | | | | | Recession Period | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variables | General Spatial Model | Locally Weighted Spatial Model | | | | General Spatial Model | Locally Weighted Spatial Model | | | |
| | Coefficient (Std. Error ) | Lower Quartile (Std. Error ) | Median (Std. Error ) | Upper Quartile (Std. Error ) | P-value | Coefficient (Std. Error ) | Lower Quartile (Std. Error ) | Median (Std. Error ) | Upper Quart (Std. Error ) | P-value |
| Intercept | 5.970* | 9.469* | 9.488* | 9.666* | 0.654 | 4.7065* | 5.0122* | 5.8197* | 8.9494* | 0.956 |
| | (0.303) | (0.355) | (0.369) | (0.372) | | (0.436) | (0.166) | (0.202) | (0.295) | |
| *Structural Variable* | | | | | | | | | | |
| Acreage | 0.096* | 0.083* | 0.137* | 0.146* | 0.006* | 0.0886* | 0.0986* | 0.1861* | 0.2585* | 0.006* |
| | (0.018) | (0.020) | (0.029) | (0.031) | | (0.016) | (0.019) | (0.034) | (0.048) | |
| Bedrooms | 0.0647* | 0.070* | 0.090* | 0.0976* | 0.188 | 0.0675* | 0.0044* | 0.0376* | 0.1000* | 0.098 |
| | (0.0202) | (0.021) | (0.022) | (0.022) | | (0.017) | (0.001) | (0.009) | (0.024) | |
| Stories | -0.027 | -0.027 | -0.022 | -0.010 | 0.554 | -0.0487* | -0.0748* | -0.0302* | 0.0425* | 0.938 |
| | (0.024) | (0.026) | (0.026) | (0.026) | | (0.021) | (0.024) | (0.017) | (0.039) | |
| Quality | 0.160* | 0.180* | 0.187* | 0.188* | 0.462 | 0.1658* | 0.1147* | 0.1598* | 0.2297* | 0.206 |
| | (0.020) | (0.021) | (0.022) | (0.022) | | (0.018) | (0.011) | (0.016) | (0.022) | |
| Condition | 0.079 | -0.148 | 0.214 | 0.296 | 0.214 | 0.1843* | 0.6935* | 4.9750* | 5.7679* | 0.182 |
| | (0.093) | (0.116) | (0.120) | (0.131) | | (0.082) | (0.113) | (1.708) | (2.547) | |
| Garage | 0.096* | 0.095* | 0.096* | 0.098* | 0.282 | 0.0908* | 0.0351* | 0.0803* | 0.1125* | 0.110 |
| | (0.025) | (0.024) | (0.026) | (0.027) | | (0.021) | (0.008) | (0.019) | (0.025) | |
| Age | -0.003* | -0.0034 | -0.0032 | -0.003 | 0.048* | -0.0033* | -0.0056* | -0.0044* | -0.0022* | 0.046* |
| | (0.001) | (0.0006) | (0.0007) | (0.0007) | | (0.001) | (0.0004) | (0.0008) | (0.001) | |
| Ln(Finished Area) | 0.723* | 0.745* | 0.753* | 0.759* | 0.992 | 0.6911* | 0.6094* | 0.6982* | 0.7449* | 1.000 |
| | (0.032) | (0.034) | (0.036) | (0.036) | | (0.029) | (0.025) | (0.029) | (0.031) | |

Table 9. Continued

| | Boom Period | | | | | Recession Period | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variables | General Spatial Model | Locally Weighted Spatial Model | | | | General Spatial Model | Locally Weighted Spatial Model | | | |
| | Coefficient (Std. Error ) | Lower Quart (Std. Error ) | Median (Std. Error ) | Upper Quart (Std. Error ) | P-value | Coefficient (Std. Error ) | Lower Quart (Std. Error ) | Median (Std. Error ) | Upper Quart (Std. Error ) | P-value |
| *Neighborhood Variable* | | | | | | | | | | |
| Ln(Dist to Park) | -0.055* | -0.077 | -0.076 | -0.074 | 0.812 | -0.0451* | -0.0952* | -0.0408* | 0.0101* | 0.544 |
| | (0.012) | (0.015) | (0.016) | (0.017) | | (0.012) | (0.002) | (0.008) | (0.019) | |
| ACT | 0.034* | 0.056* | 0.061* | 0.073* | 0.078 | 0.0278* | 0.0040* | 0.0324* | 0.0690* | 0.030* |
| | (0.007) | (0.009) | (0.009) | (0.010) | | (0.007) | (0.0006) | (0.004) | (0.008) | |
| Knoxville | 0.019 | -0.044 | -0.041 | -0.035 | 0.97 | 0.0509* | -0.0273* | 0.0047* | 0.1372* | 0.484 |
| | (0.025) | (0.028) | (0.030) | (0.031) | | (0.024) | (0.103) | (0.004) | (0.020) | |
| *Land-cover Variable* | | | | | | | | | | |
| Ln(Water) | -0.003 | 0.006 | 0.008 | 0.012 | 0.906 | -0.0017 | -0.0387 | 0.000 | 0.0761 | 0.546 |
| | (0.013) | (0.014) | (0.014) | (0.017) | | (0.012) | (0.031) | (0.000) | (0.066) | |
| Ln(Developed Areas) | -0.009 | -0.003 | 0.01 | 0.012 | 0.528 | -0.013 | -0.0428 | 0.001 | 0.0248 | 0.546 |
| | (0.013) | (0.014) | (0.0157) | (0.016) | | (0.013) | (0.129) | (0.025) | (0.051) | |
| Ln(Developed Open Space) | -0.005 | -0.033 | -0.032 | -0.022 | 0.982 | -0.0006 | -0.0521 | -0.0209 | 0.007 | 0.496 |
| | (0.016) | (0.018) | (0.019) | (0.020) | | (0.017) | (0.005) | (0.016) | (0.038) | |
| Ln(Barren/scrub Land) | -0.008 | -0.018 | -0.016 | -0.012 | 0.346 | -0.0175* | -0.0380* | -0.0224* | 0.0129* | 0.898 |
| | (0.010) | (0.010) | (0.011) | (0.012) | | (0.008) | (0.004) | (0.006) | (0.011) | |
| Ln(Forest Land) | 0.0282* | 0.021* | 0.022* | 0.023* | 0.364 | 0.0207* | 0.0108* | 0.0261* | 0.0530* | 0.532 |
| | (0.011) | (0.011) | (0.012) | (0.012) | | (0.009) | (0.005) | (0.011) | (0.021) | |

Table 9. Continued

| Variables | Boom Period: General Spatial Model | Boom Period: Locally Weighted Spatial Model | | | | Recession Period: General Spatial Model | Recession Period: Locally Weighted Spatial Model | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Coefficient (Std. Error ) | Lower Quart (Std. Error ) | Median (Std. Error ) | Upper Quart (Std. Error ) | P-value | Coefficient (Std. Error ) | Lower Quart (Std. Error ) | Median (Std. Error ) | Upper Quart (Std. Error ) | P-value |
| Ln(Agricultural Land) | -0.005 | 0.006 | 0.007 | 0.008 | 0.746 | 0.0071 | -0.0098 | 0.0012 | 0.0143 | 0.576 |
| | (0.007) | (0.008) | (0.008) | (0.008) | | (0.006) | (0.005) | (0.006) | (0.007) | |
| Ln(Wetlands) | 0.006 | 0.007 | 0.008 | 0.015 | 0.366 | 0.0164 | -0.0447 | 0.0021 | 0.0362 | 0.764 |
| | (0.014) | (0.015) | (0.015) | (0.016) | | (0.014) | (0.031) | (0.002) | (0.025) | |
| Spatial Error (ρ) | 0.126 | | | | | 0.103 | | | | |
| | (0.0916) | | | | | (0.085) | | | | |
| Spatial Lag (λ) | 0.116* | | | | | 0.129* | | | | |
| | (0.041) | | | | | (0.037) | | | | |

* indicates significance at the level of 5% (P-value ≤ 0.05)

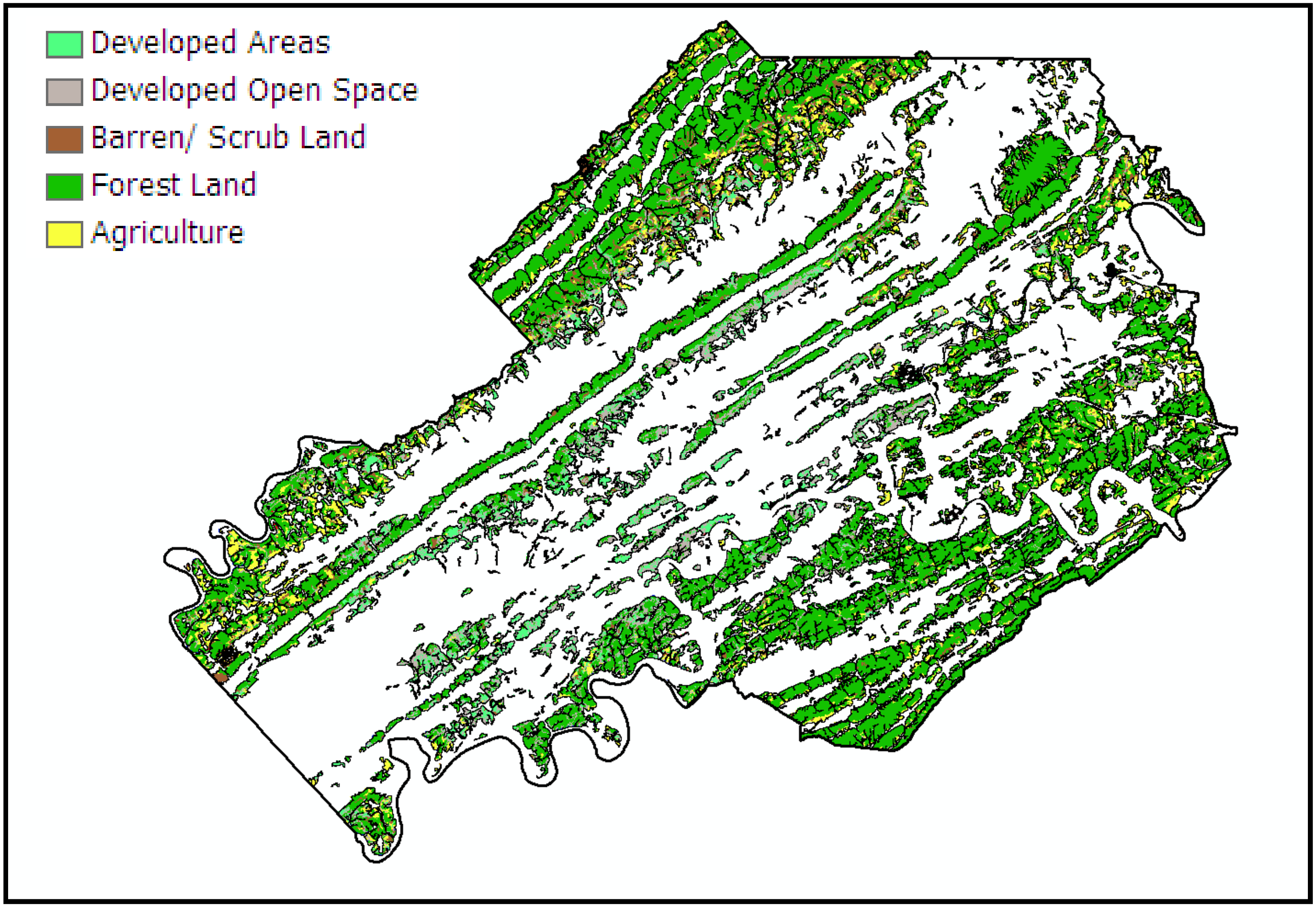


Figure 3. Map of the areas and land uses (USGS 2001) under consideration for The Joint City-County Taskforce on Ridge, Slope, and Hillside Development and Protection in Knox County, Tennessee (Tennessee Spatial Data Server 2011) (updated at June, 2010)

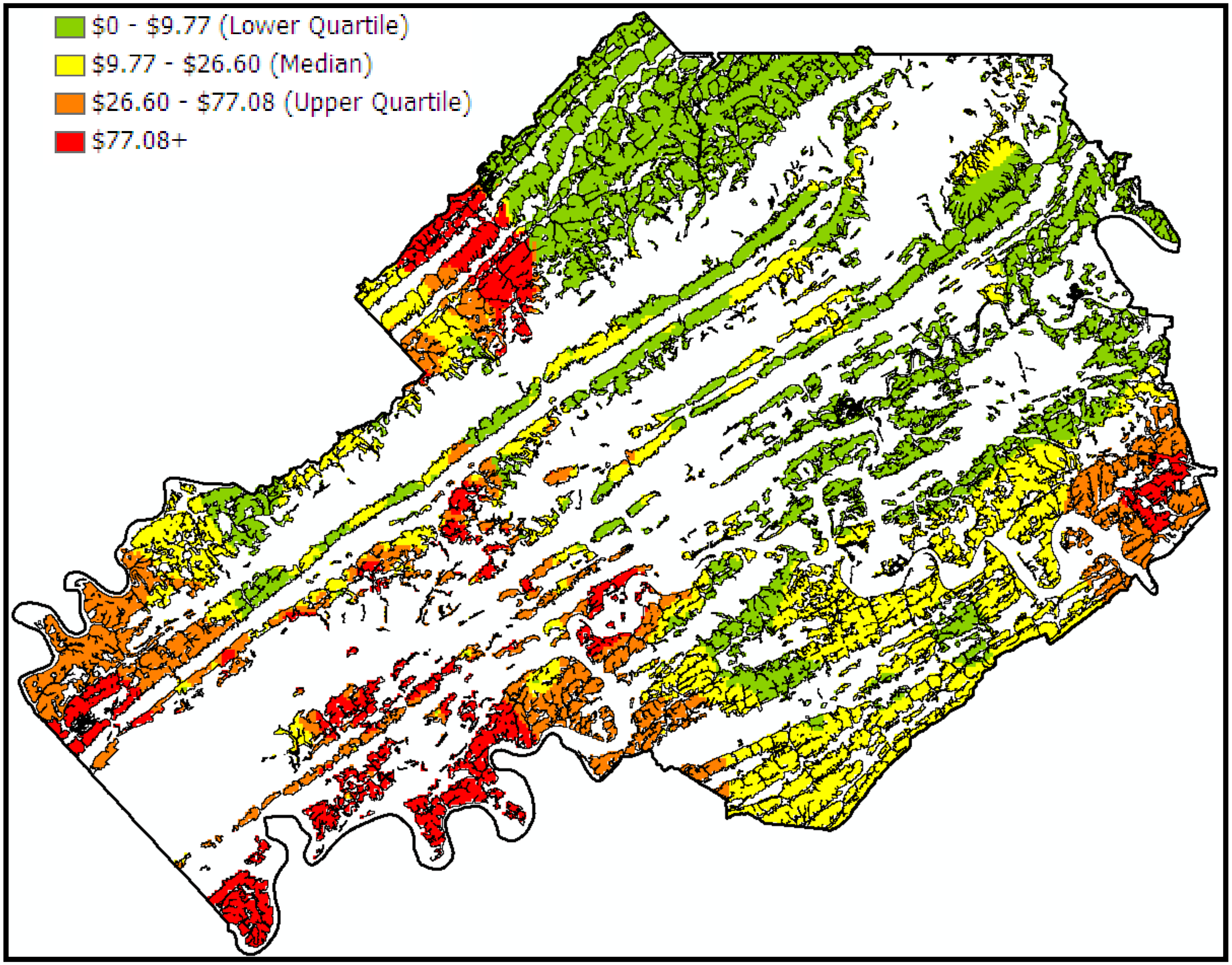


Figure 4. Map of the marginal implicit prices of increasing one acre of the planned area of forest land-cover class during the boom period, evaluated at the mean house price of $190,540 (in 2008 dollars) and an initial mean size of 489 acres of visible

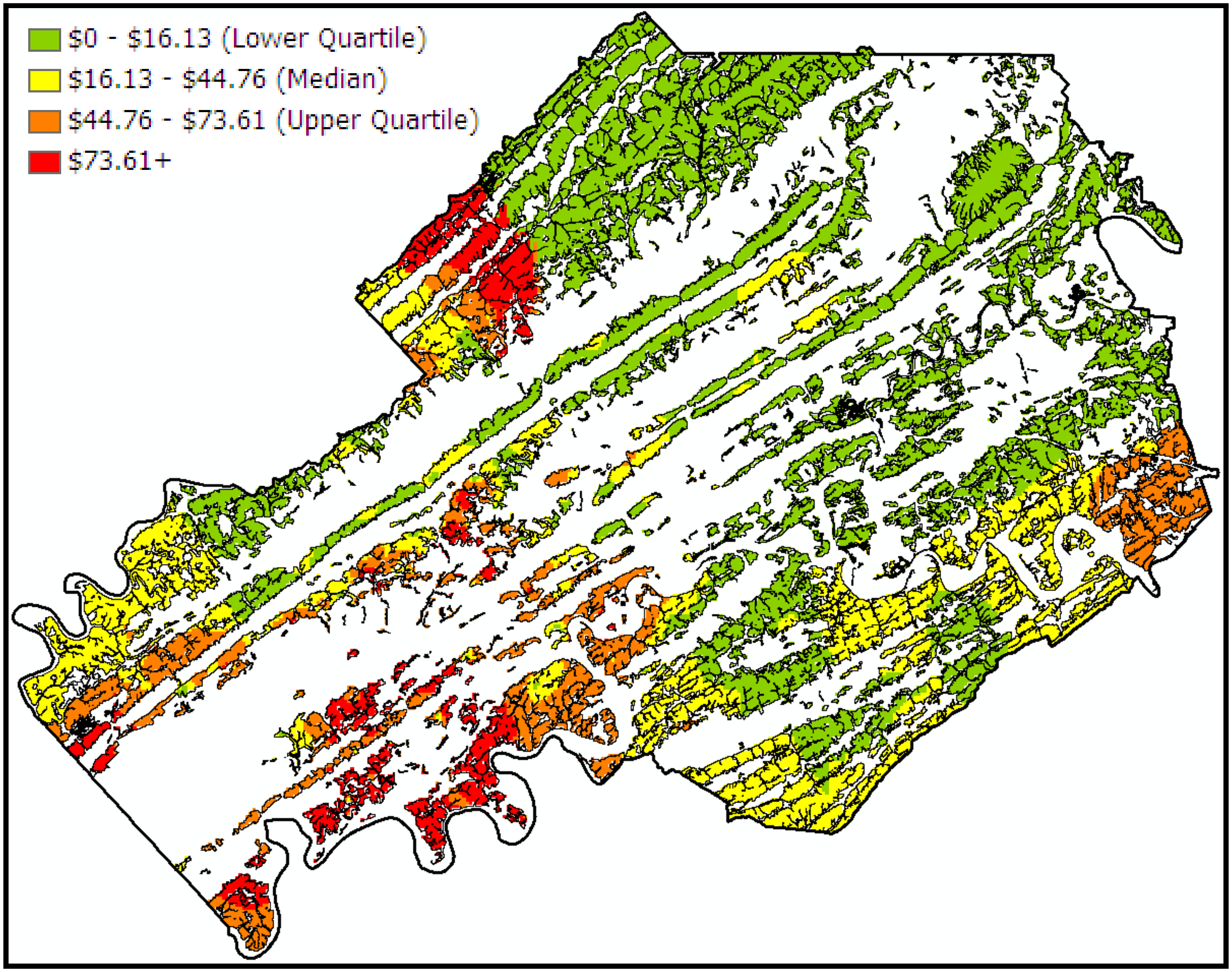

Figure 5. Map of the marginal implicit prices of increasing one acre of the planned area of forest land-cover class during the recession period, evaluated at the mean house price of $196,836 (in 2008 dollars) and an initial mean size of 430 acres of visible forest land

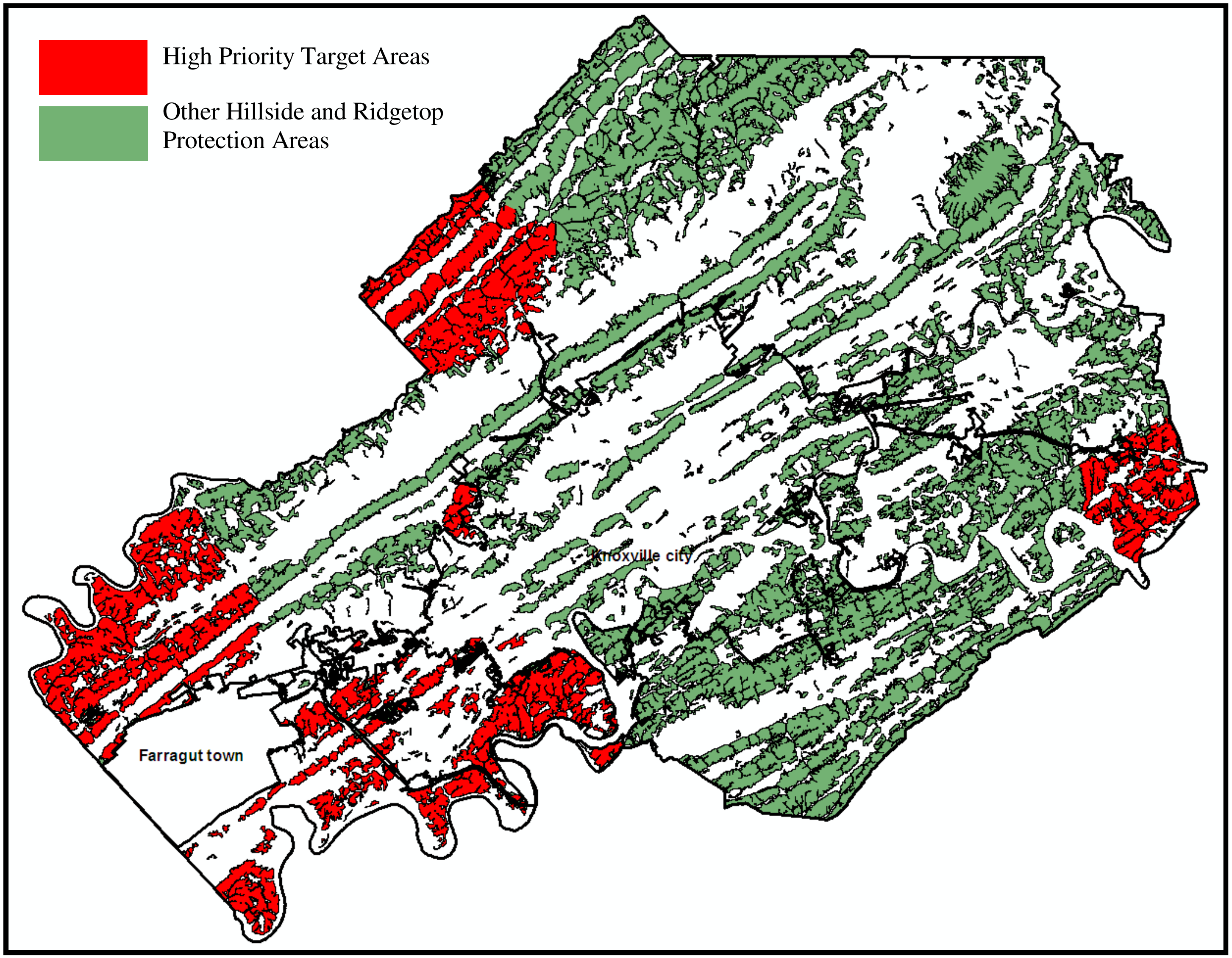


Figure 6. Map of the high priority target areas among the proposed hill side and ridgetop protection area (i.e., those planned areas with significant marginal implicit prices that are greater than or equal to the upper quartile across the both periods)

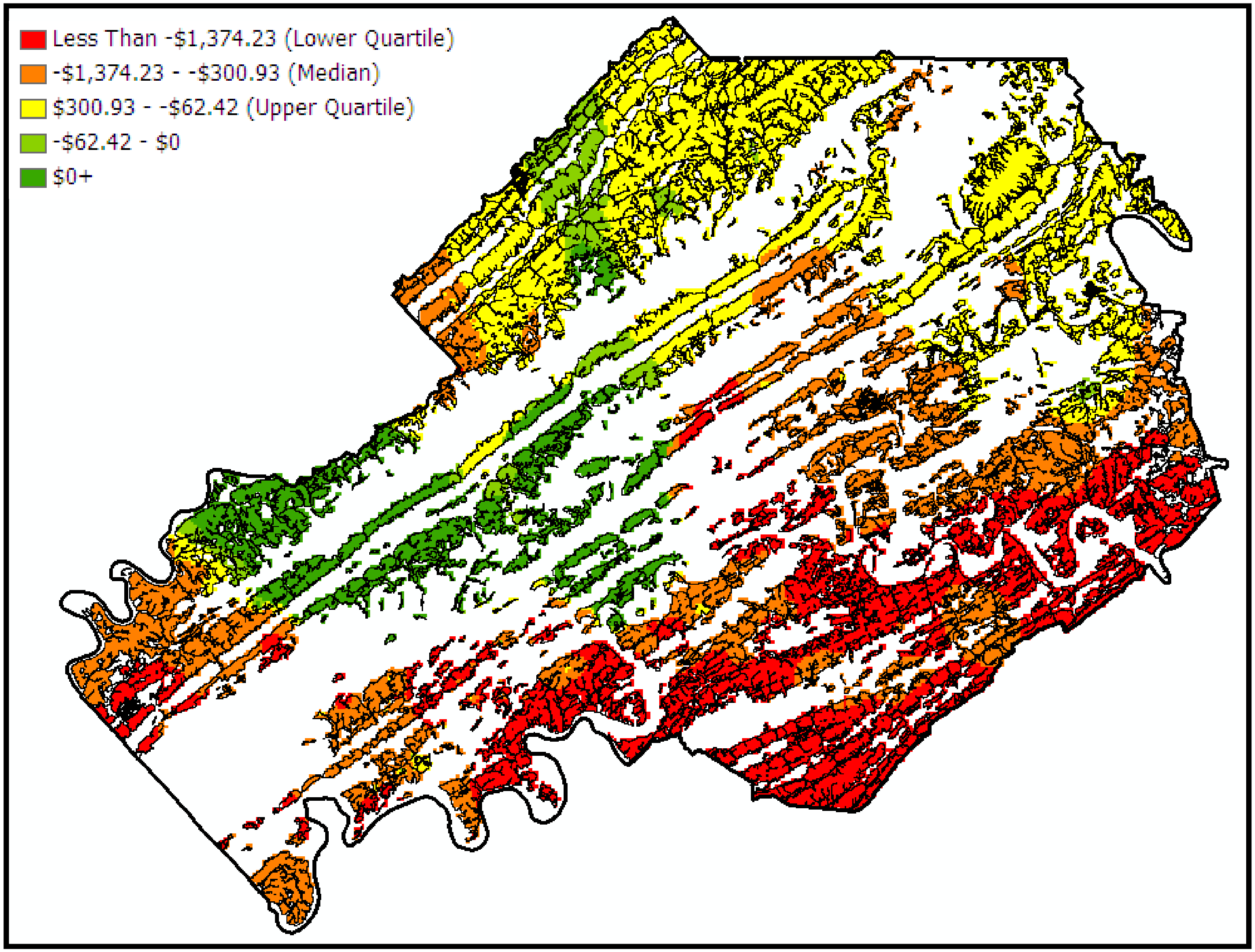


Figure 7. Map of the marginal implicit price loss of increasing one acre of the planned area of barren/scrub land-cover class during the recession period, evaluated at the mean house price of $196,836 (in 2008 dollars) and an initial mean size of 31 acres of visible barren/scrub lan

# Vita

Matthew H. Chadourne was born and raised in Salem, NJ. He received his Bachelor's of Science in Economics from the University of Washington, Seattle in December 2004. He received his Master's Degree in Agricultural Economics, with a concentration in Resource Economics and a minor in Statistics, from the University of Tennessee in August 2011.