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

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Abstract

Many communities in the United States face the decision about whether to protect or restore forests on environmentally sensitive sites. 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 individuals' 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 differences in values attached to housing prices of multiple potential sites for restoration projects values. This approach 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 across different proximities to potential restoration sites. 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 the acreages of potential target sites, the number of houses in the surrounding area, and the proximity of houses surrounding the site.

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

Introduction

Knox County, Tennessee has experienced a rapid rate of growth in recent years as the county population grew from 335,749 to 435,725 (29.78%) between 1990 and 2009, a rate more than five percentage points greater than the overall growth rate in the United States (US Census Bureau 2010). Consequently, population density has increased from 660 to 857 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% or more canopy, were lost due to urban land expansion from 1989 to 1999 (American Forests 2002).[1]

The deforestation that has been occurring in the county over recent decades 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 help reduce erosion and filter pollutants before they reach fresh water sources. The county's Metropolitan Planning Commission (MPC 2009) reports that the forest land could have removed up to 115,000 tons of pollutants from the air annually, had the 15,000 acres of the forest lands lost between 1989 and 1999 been conserved. The removal of these 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 storm water could have been retained by those 15,000 acres of forest, and the cost of building the infrastructure to handle this amount of storm water would have been $128 million dollars (NRCS 1986).

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[1] Forest areas are defined as areas with 20% or more canopy in the study by American Forests; however, the national land cover data (NLCD) defines forest area as "Areas 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 the concerns over the 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. The main concern of the Taskforce is the long-term impact of development on ridge tops, steep slopes, and hillsides of the area. They are charged with creating development policies aimed at protecting the ridge lines and hillsides that make up 60% 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 limiting development on hillsides, land with slopes greater than 15 degrees, the draft also lays 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). Funding reforestation projects can be expensive and its allocation competes 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. Such prioritization requires guidelines to follow, which allow for more efficient policy recommendations. When establishing these guidelines, a number of different factors (i.e., environmental sustainability, health and safety, and economic impact) need to be considered (MPC 2009). Two of the key components to consider in establishing the guidelines are the costs and benefits of each reforestation project.

Reforestation costs are grouped into explicit costs and implicit costs. Explicit costs include costs for land acquisition, material (e.g., purchased seed and planting stock), and labor used in restoration (e.g., site preparation and planting) while implicit costs (hereafter refer to as "opportunity costs") are the benefits of other purposes of the land given up for reforestation.[2] Considering opportunity cost is important because the estimated value of reforestation will be over– or underestimated unless the opportunity cost is considered in the measure of the cost side of reforestation. For example, if a priority target site for reforestation that is currently grasslands 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. Specifically, direct use values include values from recreational uses and indirect use values are the values provided by reforested lands that sustain natural and human systems through services such as erosion control, storm water retention, and air pollution reduction (Glück 2000; Harris 2006). 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 species existence value and aesthetic value associated with enhanced views and appreciation of a unique culture and heritage (Lazo *et al*. 1997).

[2] The cost for land acquisition also could be perceived as an opportunity cost for maintaining 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 primarily has focused on the use values (e.g., indirect use values associated with the cleansing of air and water of pollutants) (MPC 2009). While the Taskforce acknowledged that trees surrounding a house can increase a house's value by 10–20% (MPC 2009), it makes little effort to incorporate such values into the funding for reforestation projects. Likewise, the cost side of the projects (both explicit and opportunity costs) has not been 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 to complement 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 (or the opportunity costs) and the explicit costs associated with the reforestation.

Literature Review

Interest has grown in investigating the economics of reforestation. A variety of analytical approaches have been applied to assess the economic effects of restoration projects. 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 in those studies is that, while reforestation provides a cost effective way to curb pollutants and greenhouse gasses, the opportunity cost to land owners for even marginal agricultural land is often higher than the expected return from reforestation with voluntary programs.

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 the 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 its implementation has to balance future environmental services with the sustainability of the local economies.

The contingent valuation method 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). The contingent valuation method estimates individuals' willingness to pay for restoration as a guide for selecting sites for restoration. This method works well for evaluating a specific project site and the services it provides, but 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 is mainly due to difficulties in designing surveys that involve multiple sites and respondents' difficulties in assessing them (Barrio and Loureiro 2010).

In response to the lack of flexibility of the contingent valuation method, Cho *et al.* (2011) 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 refer to as "amenity values"). The key to responding to 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 based on a sequence of hedonic models 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 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 in their study. The sum of the differences is used as a proxy for the value added to nearby houses resulting from a given reforestation project for any given number of multiple potential target sites (Cho *et al.* 2011).

While the method developed by Cho *et al.* (2011) is directly applicable for 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 prioritizating potential target sites. The reason for the insufficiency is that 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 any explicit costs of reforestation. Thus, there is a need 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 estimation of net benefits to the surrounding community from implementing reforestation projects at multiple sites, which can be used for site-specific prioritization of those sites.

Data

Data associated with explicit costs

There are three types of explicit costs involved with reforestation of a specific site: land acquisition, material, and labor, both 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 those costs are unlikely to vary greatly within a county. The average land price of parcels sold during 2001 within all target sites was used as the cost for land acquisition for all sites. Sale prices were provided by Knox County Tax Assessor's office (2010).

Other explicit costs associated with reforestation (i.e., material and labor costs) were directly taken from the bi-annual 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 seedlings of pine trees. 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 also is 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, costs of planting, and cost of seedlings, based on surveys of private firms and public agencies in 12 southern states. Respondents of the survey reported planting an average of 631 seedlings per acre. They estimated the costs per acre for mechanical site preparation, planting, herbicide and other chemical preparation, fertilizing, and seedlings to be $153.73, $40.38, $279.90, $43.08 and $20,898.72, 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 storm water 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) based on both a hydrological model developed by the US 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 storm water 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). Those model estimates were used to calculate the construction costs not spent on the infrastructure needed to control and purify the same amount of water. These calculated construction costs were used as the indirect use values of storm water control for reforestation.

The Urban Forest Effects Model was used to estimate the quantities of air pollutants (e.g., the amount of the 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 health care 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 by regulating temperatures through wind breaks in the winter and shade in the summer.

Data associated with multiple hedonic spatial regressions

Creating the sequence of multiple hedonic spatial regressions for the estimations 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 (e.g., number of bedrooms, age, number of stories, number of fireplaces, 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 6 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 the 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 the community potentially would 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 6 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 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 storm water and air pollution mitigation were borrowed from existing reports and their estimation procedures were previously described in the data section under "*Data associated with explicit costs*". The borrowed explicit costs and use values are added to the estimated amenity values and opportunity costs, and 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 construction of concentric radii around the location of each housing sales transaction with a sequence of 50 radii between 0.1 to 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, each time replacing the six land cover variables with those for the next largest radius constructed in the first step. The sequence of 50 hedonic regressions was estimated using a spatial autoregressive model with autoregressive (AR) disturbance of order (1,1) (SARAR) (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, 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 regression 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, *k*-nearest neighbor, and hybrid spatial weight matrices) were considered to test various neighborhood structures.

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 that are identified by the median distance between the centroid of the sales transaction and the centroids of the nearest sales transactions. Then the contiguous polygons, defined as those that share either a border or vertex, are identified. When 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. The inverse distance weight matrix is based on the idea that “near things are more related than distant things” (Tobler 1970).

This method calculates the Euclidian distances between the sales transaction centroids then takes the inverse values and inserts 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 transactions in the study area, which in this case is 3,608. The hybrid method then takes the resulting matrix and limits the results to just a few of the nearest neighbors by element-wise multiplication of the inverse distance weight matrix and the Thiessian polygon weight matrix or one of the four KNN weight matrix. 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:

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

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 that 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 forests 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 the 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. The five largest sites within each region were selected as the hypothetical target areas for the evaluation (See Figure 1 for locations of target sites)[4]. The three regions (and associated sites) of Knox County were the City of Knoxville (sites designated K1 – K5), the Town of Farragut Town (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 both Knoxville and Farragut

opportunity to see if 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 5 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/grass land 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 5 miles of each target site were measured, indirect use values for air pollution and storm water control as well as explicit costs borrowed 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^2s for the hedonic model based on the Thiessian polygon, *k*-nearest neighbor, and hybrid spatial weight matrices range 0.774-0.902, 0.365-0.762, and 0.702-0.914, respectively (Table 3). The spatial LM statistics for the Thiessian, KNN, and hybrid matrix specifications ranged from 68-95, 344-443, and 42-64, 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 (ρ) 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 ≤ 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 quality of school district, 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 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 of those land covers 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 they were 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 had 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 that were significant. The pattern for the distance decay curve for forest land shows that the implicit value of forest land was at its highest at $713.22 per acre where the distance to housing locations was the least (0.1 miles). The values decrease drastically from 0.1 miles to about 1.5 miles and decrease gradually beyond 1.5 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 marginal.

Figure 2 also shows the distance decay curve for barren/grass land. The effect of barren/grass land was negative. This suggests that barren/grass land reduces the values of surrounding houses. 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. The largest gain in total net value was over $1.4 million at C2, which also has the largest acreage and the most houses within five miles of the site. Sites with the most acreage had the largest net value gains in almost all cases, which 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 ($3,243.40 versus -$7,556.67, respectively), despite K2 being a slightly smaller site (3.33 versus 3.55 acres, respectively) and having nearly half as many houses within five miles (478 versus 825, respectively). Since the acreages of these two sites are very similar, the cost and benefits calculated on a per acre basis (i.e., land acquisition and reforesting costs and indirect use values) are similar. The key difference between these two sites is that the amenity value gained through reforestation of K2 is nearly five times greater than that for K5 ($27,710.83 versus $5,855.67, respectively). 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, 12% of the houses (57 houses) are within 1.5 miles of K2 versus 4% of houses (33 houses) within the same distance of K5. Thus, a greater percentage of houses within five miles of K2 are within the distances that yield 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 benefits and costs of reforesting lands in the hillsides and ridgelines of Knox County, Tennessee. This research sought to analyze the values gained by forest land in terms of amenity value added to house prices in the surrounding community to add to the costs and benefits already under consideration by the Taskforce. This additional information is intended to help the Taskforce to weigh the returns on potential reforestation sites when allocating time and resources to these projects. 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, 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 1.5 miles of the site. Alternatively, 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 is an important factor in determining which sites will yield the greatest net benefit to a community.

The results of this study suggest that this cost-benefit analysis should provide a useful tool to policy makers in Knox County not only in assessing the returns on investments but also in influencing public perception of conservation efforts, which historically have been contentious and are perceived by many citizens to infringe on property rights and to provide little benefit to the community (Marcum 2011). This alternative approach to presenting public work restoration projects is much less esoteric than quantifying environmental value gains, because house prices are more concrete, directly observed, and applicable to citizens than non-market estimates of dollars gained from improved air or water quality.

An important caveat to this cost-benefit analysis is that it potentially underestimates the returns to the community 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 for 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 far from perfect.

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Table 1. Explicit costs and indirect use values per acre

Explicit costs		Indirect use values	
Ave. cost of an acre of land in 2001:	$2,525.30		
Labor and mechanical site preparation :	$153.73		
Herbicide and other chemical prep.:	$279.90		
Fertilizing:	$43.08		
Planting:	$40.38	Storm water control:	$8,533.33
Seedlings:	$20,898.72	Air pollution control:	$233.33
Explicit costs per acre:	$23,941.11	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 1. 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)
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)]
			Land Acquisition	Material and Labor[a]				
F1	0.444788	436	$1,123.22	$9,525.50	-$3,704.56	$3,899.31	$5,766.16	$2,721.31
F2	1.334364	498	$3,369.67	$28,576.49	-$12,626.98	$11,697.93	$18,394.53	$10,773.29
F3	0.222394	497	$561.61	$4,762.75	-$2,133.12	$1,949.65	$2,610.11	$1,368.52
F4	0.222394	680	$561.61	$4,762.75	-$3,056.18	$1,949.65	$1,266.11	$947.58
F5	0.222394	759	$561.61	$4,762.75	-$3,129.04	$1,949.65	$3,306.18	$3,060.51
K1	3.113515	678	$7,862.56	$66,678.45	-$26,665.11	$27,295.16	$8,923.58	-$11,657.16
K2	3.335909	478	$8,424.17	$71,441.19	-$26,153.12	$29,244.81	$27,710.83	$3,243.40
K3	2.668727	661	$6,739.34	$57,152.95	-$27,270.00	$23,395.85	$19,522.29	$6,295.86
K4	2.001546	293	$5,054.50	$42,864.73	-$7,510.42	$17,546.89	$13,680.60	-$9,181.32
K5	3.558303	825	$8,985.78	$76,203.94	-$40,583.91	$31,194.47	$5,854.67	-$7,556.67
C1	27.57685	1,441	$69,639.82	$590,580.58	-$825,910.52	$241,757.14	$299,925.76	$707,373.03
C2	43.14443	2,024	$108,952.62	$923,972.85	-$1,666,836.51	$378,232.95	$428,687.72	$1,440,831.71
C3	25.13052	1,680	$63,462.09	$538,190.38	-$830,715.56	$220,310.95	$183,350.09	$632,724.13
C4	21.79461	995	$55,037.92	$466,749.16	-$392,012.11	$191,066.13	$132,842.39	$194,133.55
C5	36.91740	515	$93,227.50	$790,615.94	-$454,067.20	$323,642.63	$240,833.88	$134,700.28

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

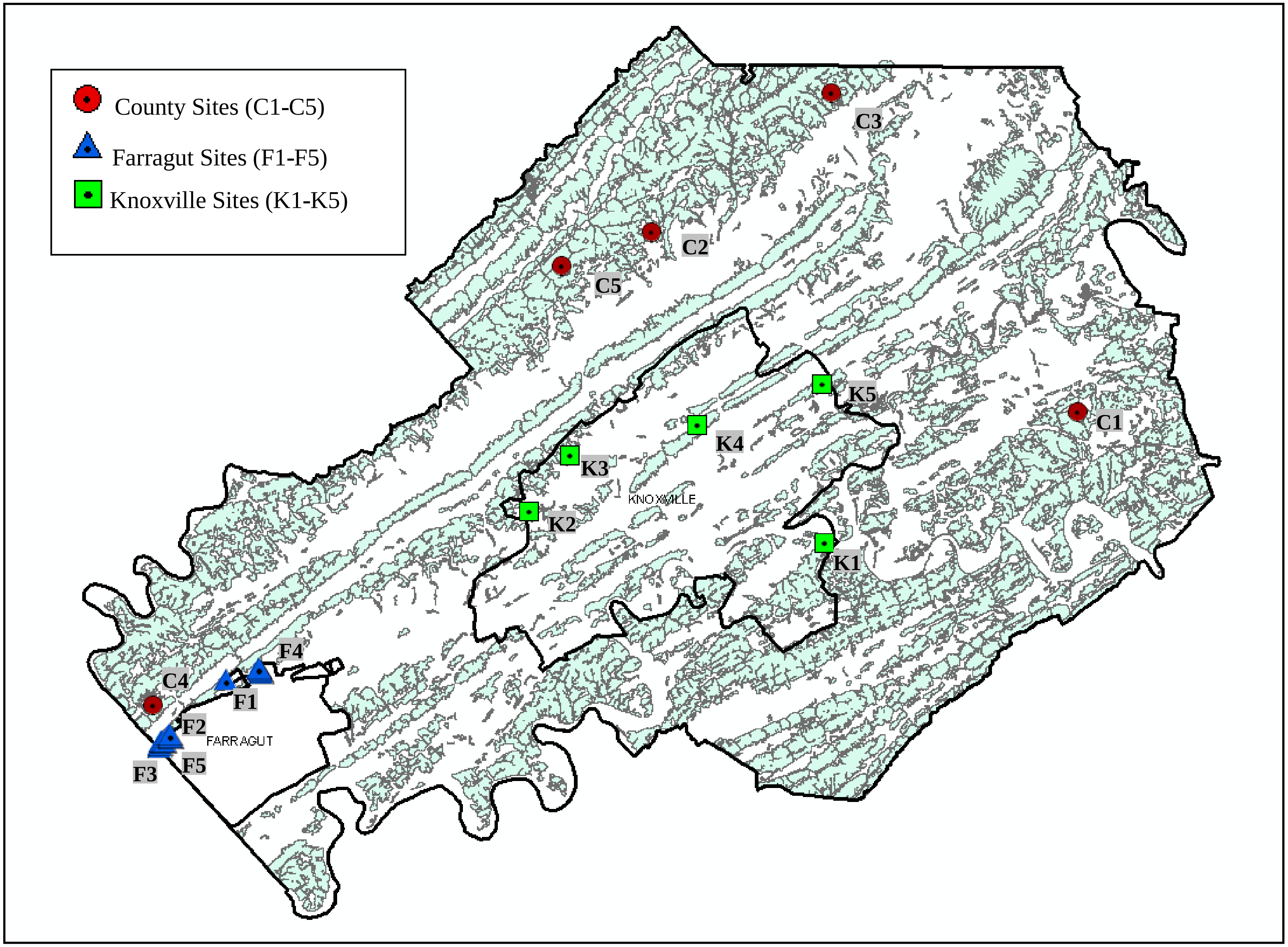

Figure 1. Map of Knox County, TN with Hilltop Restorationa and Protection Area highlighted and the 15 target sites marked

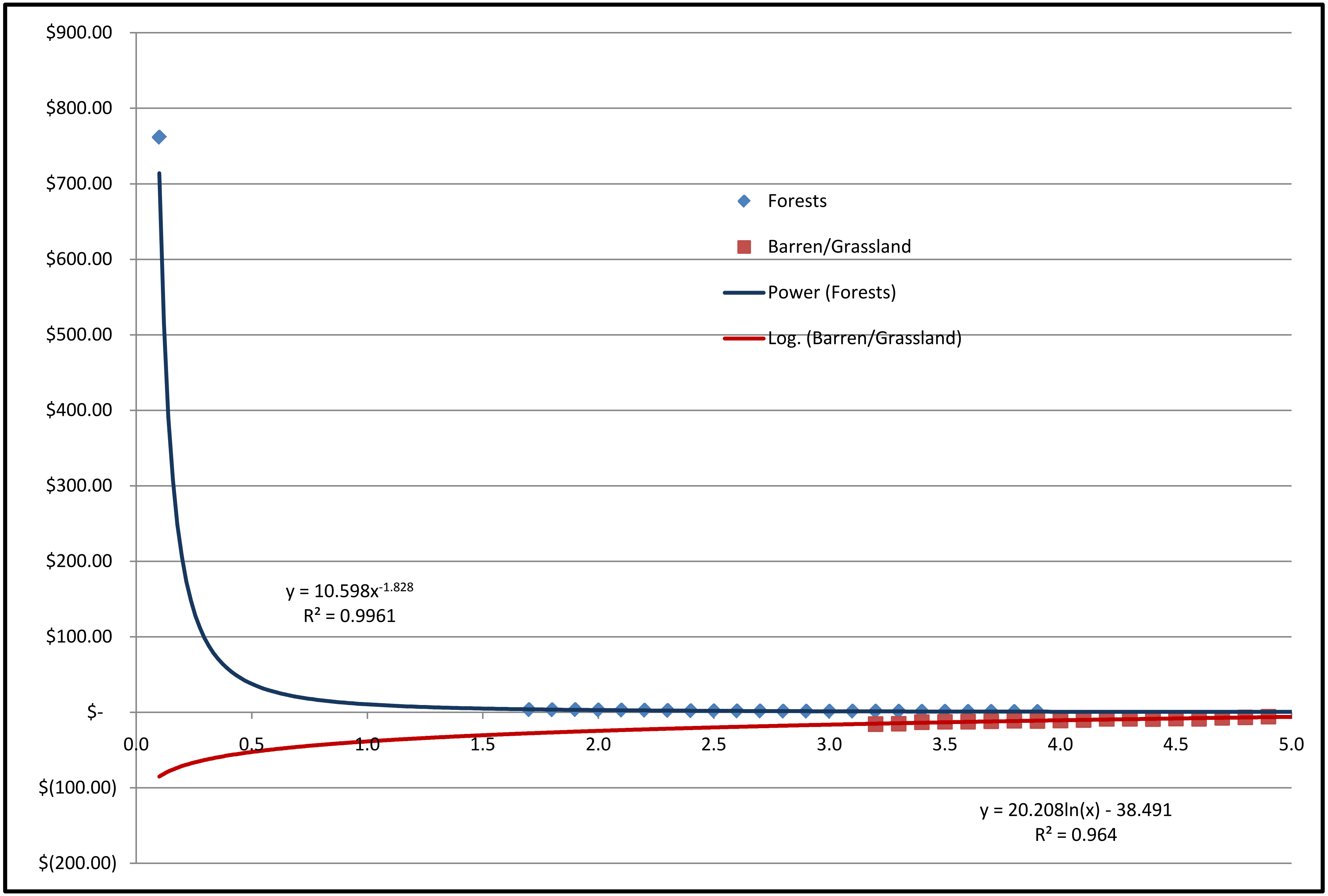

Figure 2. Distance decay function of marginal implicit prices for the hybrid Thiessian regressions