The Amenity Value of Trees: a Meta-analysis of Hedonic, Property-value Studies

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ABSTRACT

Tree species migration as a result of climate change may alter the composition of trees in local communities. Shifts in tree diversity, stand age, species predominance and the overall number of trees are potential changes. Community tree programs may also change the characteristics of local trees through planting or preservation efforts, but these programs may also mitigate the effects of climate induced tree migration. Numerous hedonic property value studies have estimated the implicit price of tree amenities associated with residential properties. Quantitative analysis of the results from multiple studies valuing trees can identify if the relationship between implicit price and tree amenities extended across these studies.

The results of the meta-regression found systematic variation was present across positive implicit prices for local tree cover. The scarcity, age and type of local trees were also significantly related to the implicit price of amenity tree cover. The amenity tree cover findings suggest that county tree canopy cover of about 42% optimizes implicit price. Recent extreme weather events and ownership of trees contributed to negative implicit prices. These results may assist in planning and goal setting for community tree programs to mitigate the effects of climate induced tree migration.

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I. INTRODUCTION

Trees provide many benefits to local communities from energy savings to improved quality of life for residents (USDA Forest Service, 2008). Trees also provide important ecosystem services such as better air quality, preventing erosion and absorbing greenhouse gases. And while trees are valued for their role in absorbing greenhouse gases, climate change due to increased levels of greenhouse gases is a growing threat to trees. The U.S. Forest Service (2010) has identified northern migration by some tree species, and increasing temperatures is likely to continue the trend of tree species migration.

Tree species migration may pose significant changes in the composition and number of trees in locations worldwide. Woodall et al. (2009) found that for northern U.S. tree species, young trees were growing at more northern latitudes than older trees on average, indicating a migration in these species. These authors concluded that many tree species are migrating at a rate of 100 km per century. Iverson and Prasad (2001) predicted that climate change could increase the number of different tree species present in a county on average, but some species would no longer exist in their present locations. They find that the ranges of forest types like aspen-birch will decrease, while the range of other species will increase. Further, Prasad et al. (2009) predicted the geographic range of forest types under future climate scenarios as shown in Figure 1. The potential effects of climate change on local tree species may impact how individuals value trees, and the consequent actions communities may take to adapt to climate change based on these preferences.

In addition, there is a growing interest from local governments in municipal tree programs. For example, under a joint program between the USDA Forest Service, the Arbor Day Foundation and the National Association of State Foresters over 3,400 localities (Arbor Day

FIGURE 1. CURRENT DISTRIBUTION AND POTENTIAL FUTURE RANGE OF TREE SPECIES

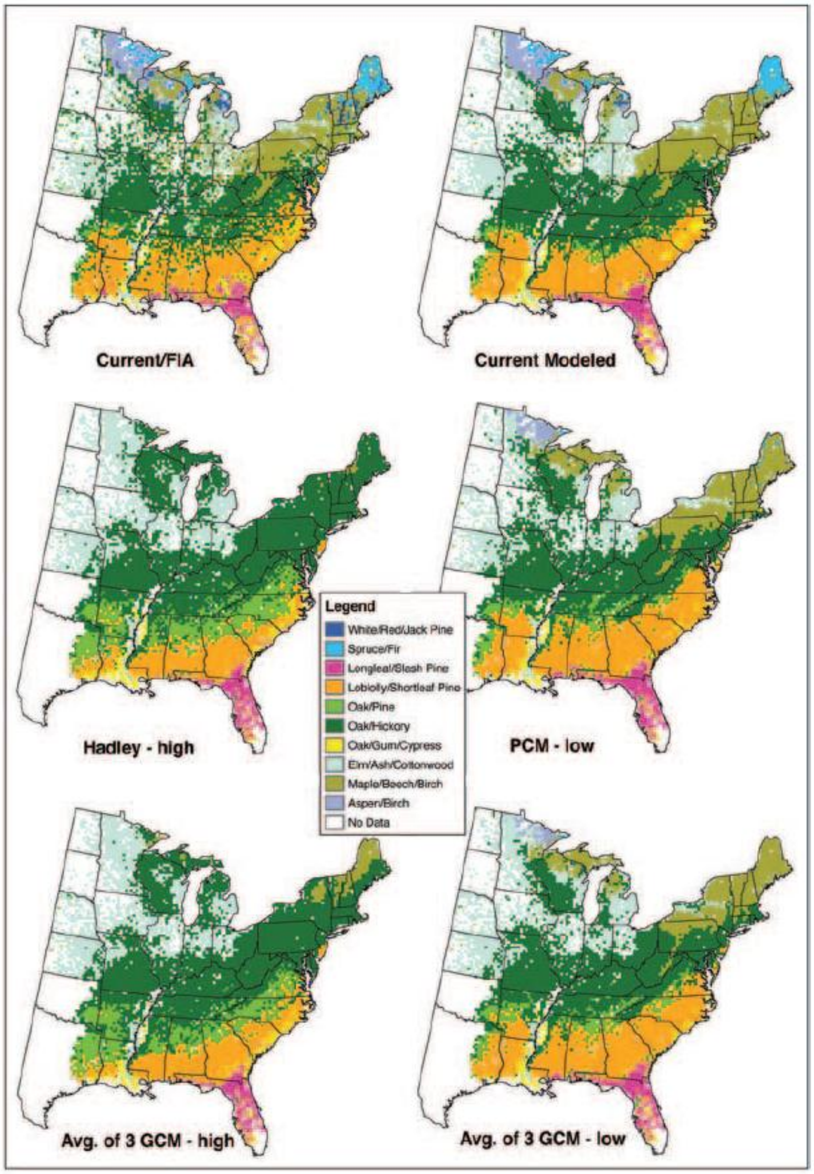


Figure 2. Maps of current and potential future suitable habitat for the USDA Forest Service forest types for FIA and modeled current (top row) and future climates. Hadley High is the harshest of the future scenarios and PCM Low the mildest (middle row). The bottom row represents the averages of PCM, HadleyCM3 and GFDL general climate models (GCM) for high and low carbon emission scenarios.

Source: Prasad, Iverson, Matthews and Peters (2009)

Foundation, 2012) are recognized as a “Tree City USA” for their regulatory and financial commitment to community trees. Further, a survey in Illinois found that policymakers believe trees are important in their communities for aesthetic and environmental benefits (Schroeder et al., 2003). Insights into the characteristics of trees that appeal to residents can be useful in developing and refining local tree programs.

Previous survey research has identified some preferred attributes of trees to residents in various communities. Getz et al. (1982) found that in Detroit highly preferred characteristics of trees included shade and privacy, as well as seasonal aesthetic characteristics like changing colors in the fall and flowering in the spring. Additionally, the researchers found that most residents preferred a mix of street trees. This indicates that species diversity is an important characteristic of trees. Additionally, preferences for shade and privacy may indicate that mature trees, which can provide these benefits are favored by residents. Additionally, these findings indicate that hardwood trees may be preferred since they typically provide seasonal aesthetic qualities such as flowering and shedding their leaves. Wolf (2004) found that large trees and a full canopy are preferred tree attributes in retail settings in Athens, GA. Again, indicating that mature trees are preferred by community residents. Further, Schroeder et al. (2006) compared preferences for trees in the U.S. and U.K., and found that different attributes were preferred by residents in a Chicago suburb than residents in two southwest England communities. These authors conclude that the U.S. community’s preference for larger shade trees may have been related to hotter summers, while in the typically cooler England residents prefer smaller trees in part because shade is not as important. Since residents in a variety of communities have previously shown they prefer specific aspects of trees, this study will look at whether they also value trees differently due to the attributes of those trees. Since climate induced tree migration is predicted to alter local tree characteristics, identifying highly valued attributes of trees can provide a resource for localities in addressing impending changes in local tree composition.

Homebuyer preferences for environmental amenities, such as trees, have been studied using a variety of methods. The hedonic method is a common economic tool used to measure the value homeowners put on environmental amenities associated with residential properties (Taylor, 2003). This method uses the purchase prices of similar, but distinct properties to estimate the value homebuyers place on certain attributes of single-family residences. By looking at a large number of property sales in a specific area, the hedonic method attempts to estimate the premium (or diminution) homebuyers place on attributes of the property that impact price. This process controls for attributes that are not the primary focus of the research (i.e. house size, bedrooms, etc.) to determine the value of non-market environmental amenities. By separating out the values associated with the house's attributes, the hedonic method tries to identify what consumers are willing to pay (implicit price) for each attribute. The marginal implicit price of an amenity is amount consumers are willing to pay for a small increase in that amenity (Taylor, 2003). The implicit price is found in the difference in price between properties with varying levels of the amenity, holding all other factors constant. The present study utilizes the results from hedonic valuation studies that have estimated the value of trees. Individual hedonic valuation studies conducted in different locations provide insights into location specific values. The current research will identify if the relationship between the quantity of an amenity and the amenity's value from each study can be generalized by looking across these studies and their respective locations to provide collective insights into the value home-buyers associate with trees.

Meta-analysis was applied in this study to investigate whether multiple hedonic studies estimating the value of trees as a group can expand the individual findings from each study. By using multiple studies, meta-analysis allows the research to use a greater source of variation than within any one study individually. This variation exists because the hedonic studies have been conducted over different points of time and in various locations. Since different locations have different natural landscapes, the variation in tree cover is expected to be greater across locations than within one location. For instance, take studies measuring the contribution of tree cover on house prices. Within a study the range of tree cover may be limited because of the natural vegetative landscape. Within cities such as Cincinnati, Phoenix and Roanoke residential properties may have similar amounts of tree cover, but across these three locations the variation in tree cover will be much larger. By utilizing the variation in tree amenities from many studies, this research will attempt to identify if there is a relationship between the characteristics of an amenity and the implicit value of the amenity. The substantial diversity within the current dataset may provide insight whether systematic variation in tree amenity valuation was present across the studies.

In light of the potential changes to the composition of local trees from tree migration and the planting and tree management goals of community programs it is important to understand if tree amenity values are related to their characteristics. Local tree characteristics, such as age and species and overall resource abundance, may influence preferences towards trees. Therefore, in addition to analyzing data from the hedonic studies the current study will incorporate exogenous data on the characteristics of local trees. This data will be collected consistently across the study locations. Auxiliary information from U.S. government resources will include the breakdown of hardwood vs. conifer trees, tree ages, species diversity and proportion of tree canopy cover in study communities. Variation in this auxiliary data across locations will be used to see if these factors are related to the implicit price of tree amenities.

In addition to tree migration, climate change is expected to harm trees in a number of ways. An increase in extreme weather events like forest fires and high winds during hurricanes can damage and kill trees. Additionally, changes in precipitation and temperature levels from climate change can provide a favorable habitat for invasive species like Bark Beetles (Bentz, 2008) and forest diseases such as Sudden Oak Death (Frankel, 2008). Increases in tree mortality and damage from these negative impacts of climate change may influence whether trees were regarded as an amenity or disamenity to home-buyers. Other locational factors may also influence if trees were regarded as an amenity. In hot, dry climates trees may be more valuable because of the shade they provide. Whether trees are viewed negatively or positively may also depend on whether homeowners were responsible for the maintenance of trees. Comparing the characteristics associated with positive and negative implicit prices can identify the factors that influence if trees were valued by home-buyers and assist local policymakers in planning the goals of community tree programs based on the type of tree resource present in the locality.

There were four primary goals of the current study. The first goal was to identify the body of existing hedonic property value literature that includes a measure of tree amenities on properties values and determine what type of measurements are common across the studies. The second was to identify if there is a systematic relationship between geographically distributed hedonic studies measuring the marginal implicit price of tree amenities. The third goal was to determine if merging hedonic data with ancillary data on the composition of local trees can improve implicit price predictions. Lastly, the study will try to identify the factors that influence if trees were valued positively or negatively by home-buyers. The results confirm that the implicit price of trees increases with tree cover up to a diminishing point across the studies. Ancillary data are also found to link tree amenity values to the scarcity and characteristics of local trees. The value of a nearby forest is found to decrease as distance to the forest increases across studies

II. LITERATURE REVIEW

Research on the economic impacts of climate change on forests and trees has historically looked at large forest disturbances, such as fires and invasive species. Dale et al. (2001) predicted an average cost of at least $3.6 billion annually from forest disturbances including extreme weather events, fires, insects and exotic species. Another area of research on the impacts of climate change on trees has looked timber values. For example, Hodges et al. (1992) found annual decrease of $400 million in the timber value of forests in the southern U.S. due to lower yields and increased management costs. The current study hopes to expand the existing scope of knowledge on the impacts of climate change on trees to explore how potential changes in the composition of local tree amenities can impact the value of trees to residential properties.

Within economics, meta-analysis has been a widely used technique to synthesize the findings from multiple studies using regression analysis since the late 1980s (Nelson and Kennedy, 2009). Meta-analysis has been previously used to study value of trees. These studies have incorporated the findings of contingent-valuation studies (Barrio and Louriero, 2010), travel-cost studies (Zandersen and Tol, 2009), and both contingent-valuation and choice-experiment studies (Lindhjem, 2007) to look for systematic variation in forest valuation studies. Table 1 presents a summary of these studies. Additionally, a qualitative review of open space amenity research by Waltert and Schläpfer (2010) summarized the directional impact of trees on property prices, but did not perform any quantitative analysis.

TABLE 1. SUMMARY OF EXISTING FOREST VALUATION META-ANAYSES

Author	**Year**	**Location**	**# of Studies**	**Primary Study Valuation Method**	**Resource Valued**
Barrio and Loureiro	2010	Worldwide	35	Contingent valuation	Forest management programs
Lindhjem	2007	Scandinavia	29	Contingent valuation and choice experiment	Non-timber forests
Zandersen and Tol	2009	Europe	26	Travel cost	Forest recreation

Barrio and Loureiro found that forests managed for recreation were highly valued compared to those managed for other reasons, suggesting that people value forests when they have access to them for their own enjoyment (i.e. recreation uses). Additionally, the researchers found scarcity of forests to impact value with forest values higher in countries with less forested land. Further, Zandersen and Tol found that characteristics of a forest, such as size and age diversity, to significantly influence the value placed on a forest. Finally, somewhat contrary findings of a meta-analysis conducted by Lindhjem (2007) found that forest size was not significantly related to forest value. The findings from previous meta-analyses suggest that the attributes of a tree amenity may be an important contributing factor in the implicit price of that amenity.

While prior meta-research related to forest valuation exists, the use of consistent ancillary data in the current study makes a marginal improvement over prior research. In Barrio and Lourerio's meta-regression, exogenous data was only included on a broad level to describe the amount of forested area in the country. Zandersen and Tol's meta-research includes exogenous data on the characteristics of forests such as species and age diversity, but this data was collected from the forest managers of each forest site individually. Consistency between sites may not be present due to reporting and measurement differences between sites, particularly since the forests are located in different countries. The ancillary data used in the current research was obtained from a U.S. government resource that collects data across the country using a mix of remote sensing and field data collection. Therefore, the current study improved upon previous use of ancillary data by incorporating consistent data across study location and at a greater level of resolution.

Additionally, while previous forest meta-analyses have used broad definitions in how they classify similar forest valuation observations, the present study used a restricted set of observations to analyze values that all measure the same good. The meta-analysis of Barrio and Lourerio included observations from a methologically diverse set of contingent valuation studies. The studies included in their research varied by survey and forest type and program goals, although they controlled for these differences with dummy variables. Similarly, the travel cost studies analyzed by Zandersen and Tol varied in survey and cost estimation methods. Again, the authors used dummy variables to account for these differences, but the concern of varied measurements across studies remains. Lindjhem's research also included studies that had measured the value of forest programs with different goals and with different methods of measuring and obtaining the forest values. The present study uses a dataset with greater uniformity by using only observations from hedonic studies that measure trees in the same way.

The current study expanded on the scope of existing knowledge in a few ways. First, this study expanded on existing research on the tree related impacts of climate change to see how incremental changes in the composition of trees from tree migration may impact the value of trees to residential properties. Second, by incorporating consistent exogenous data on the characteristics of local trees, the current study increased the scope of the meta-analysis beyond just the hedonic studies to identify how the local landscape influenced homeowner preferences for trees. Due to the slight differences inherently present from using the results of research from different authors and in different years, the exogenous data provided consistency throughout the observations for local tree qualities. Additionally, the study pared down the whole set of identified observations to model only those observations that measured trees the same way. The current study also explored the characteristics of trees, climates and communities associated with positive and negative implicit prices to see how these factors influence whether or not trees were valued by home-buyers. Additionally, this study included a focus on valuing neighborhood trees, moving past the historical focus on forest valuation.

III. CONEPTUAL MODEL

Despite classification in the same broadly product category, differentiated goods have distinct characteristics that result in their sale at different prices. The differentiated good used in the present study is residential properties. Consumers purchased differentiated goods such as a property based on the price of that good and its characteristics. Property price was related to the characteristics of the house such that:

$$HP_h = f(S_h, L_h, Y_h) \tag{1}$$

where, the price consumers were willing to pay for a property (HP_h) was dependent on a S_h, which was a vector of structural characteristics of the home and property (house size, number of bedrooms, etc.), L_h a vector of features related to the location of the property (school district, distance to downtown, etc.) and Y_h a vector of natural amenities present at or near the property (mature trees, waterfront, mountain view, etc.).

Implicit prices of trees were calculated from equation (1) by taking partial derivative of house price with respect to the tree variable, holding all other variables constant. The marginal implicit price (IP_i) was:

$$IP_i = \frac{\partial HP}{\partial y_i} \tag{2}$$

In the meta-equation, the dependent variable was the marginal implicit price of the tree amenity as derived in equation (2). The (implicit) price home buyers pay for a tree amenity depends on the level of that amenity (i.e. proportion of land in tree cover) at the property level. Additionally, implicit price was also believed to be related to the relative amount of the amenity in the community. The quantity of the resource in the community was thought to influence implicit price, since it is a measure of the overall scarcity of the resource. In addition to the quantity, implicit price of a tree amenity was assumed to depend on the quality of the resource. Measures of tree quality may include the predominant tree type, species diversity and age distribution. The implicit price was also directly related to the sale price of the property, since implicit price was a component of property price. Property prices were also an indication of wealth in the locality. Therefore, property price was a key control variable in the meta-equation. Socioeconomic conditions, such as income and unemployment and population density, which vary across study locations may also impact implicit price. While these variables were not the focus of the research, they may help to control for differences between study locations. The meta-equation was specified as follows:

$$IP_j = f(R_j, K_j, M_j) \tag{3}$$

In this equation, the implicit price of the amenity (IP_j) was a function of R_j study characteristics (i.e. average house price, level of the tree amenity), K_j tree amenity characteristics (i.e. average stand age, tree species composition) and M_j socio-economic characteristics (i.e. population density, income) for each observation j. Under this equation, the implicit price or value of a natural amenity was related to the average quantity of the resource, the characteristics or qualities of the resource and the characteristics of the local population.

To study the factors that influence whether tree cover is valued positively or negatively, a binary outcome equation was used. The binary dependent variable was a positive or negative implicit price. Whether or not tree cover was valued positively was expected to depend on characteristics of the local climate like the average temperature and amount of precipitation, since these variables may indicate how important shade was to a home-buyer. Additionally, being in a more urban area or a location in the US where trees are naturally less plentiful (i.e. U.S. Southwest) was also likely to have influenced whether trees were valued as an amenity. Another important factor was whether the home-buyer was responsible for maintenance of the trees. Home-buyers may have considered it a bother to spend money and time to maintain trees, and so home-buyers may value trees more when they were not responsible for the upkeep. Similarly, extreme weather events like hurricanes that cause tree branches to fall down or forest fires may have influenced a home-buyer's perception of the risks and costs of trees and therefore cause them to negatively value trees. Lastly, forest health (i.e. presence of an invasive species) may also influence if trees were considered an amenity, since this may also influence the level of tree maintenance or care required from the homeowner. The binary response model was:

$$P(y = 1) = G(M, N, O) \tag{4}$$

where, P was the probability of an amenity outcome, G was a function that varies between zero and one, and M, N, and O were explanatory variables such that M was a vector of climatic variables, N was a vector of locational variables and O was a vector of forest health variables.

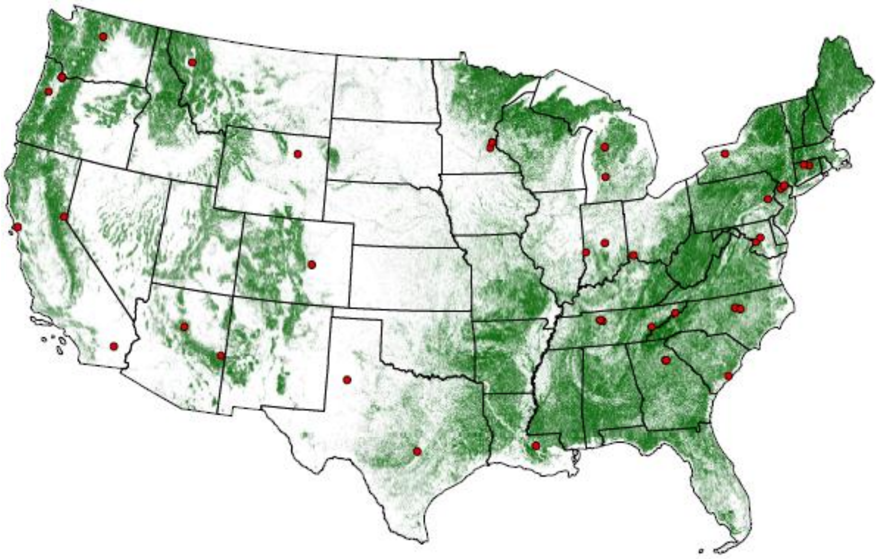
IV. DATA

A review of existing hedonic literature identified a total of 55 hedonic property valuation studies of both forest and neighborhood tree amenities. The review was conducted in the summer of 2011. The study identification process included a search of relevant databases including AgEcon Search, CABDirect, and Google Scholar. Additionally, the cited research of identified studies was examined for applicability to the present study. There was no date restriction on the search, and the resulting set of studies was conducted over 33 years. Only studies that focused on sales of residential properties were included in the analysis. Studies that used commercial, rental or vacant land sales were excluded from the analysis. The studies include published literature, Master's and Ph.D. theses, and working papers.

Forty-three of the studies were from the United States and the remaining twelve studies were conducted in Canada, China, Denmark, Finland, France, and the United Kingdom. A summary of these studies can be found in Appendix A. Since the majority of studies were conducted in the United States, the meta-regression focused on these studies. The U.S. studies were widely dispersed geographically and with regards to the amount of tree cover (Figure 2a) and population density (Figure 2b).

The studies were selected based on the criteria that they used the hedonic property valuation method to determine the contribution of trees to house prices. While all of the studies measured the impact of trees on property prices, the method for measuring trees varied

FIGURE 2a. GEOGRAPHIC DISTRIBUTION OF HEDONIC STUDIES AND TREE CANOPY IN THE U.S.

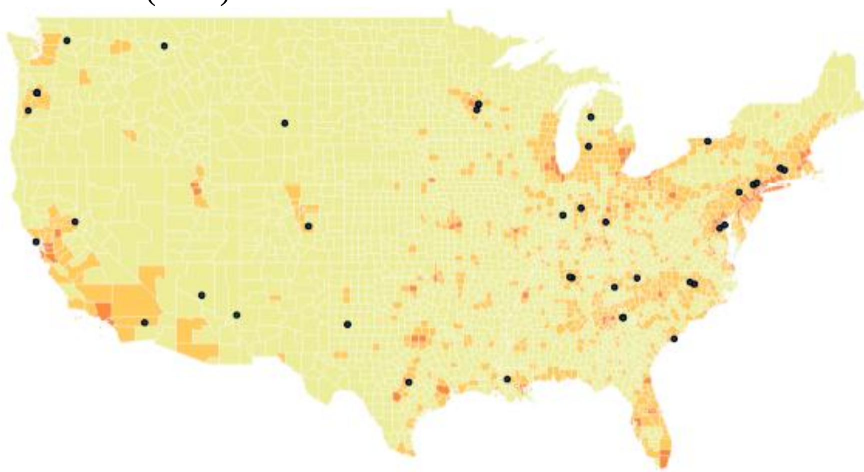


Legend

●: Approximate study location

■: Tree Canopy (Source: Homer et al., 2007)

FIGURE 2b. GEOGRAPHIC DISTRIBUTION OF HEDONIC STUDIES AND POPULATION DENSITY (2010) IN THE U.S.



Legend

Population Density by County (Source: Esri, 2011 (with data from U.S. Census 2000))

- : 0-100 people per square mile
- : 101-1,000 people per square mile
- : 1,001-10,000 people per square mile
- : 10,001-25,000 people per square mile
- : 25,001-71,564 people per square mile
- ● : Approximate study location

considerably between the studies. A summary of the types of tree measurements found in more than one study is provided in Table 2. Because of these significant differences only a subset of the data was appropriate for the meta-analysis.

TABLE 2. SUMMARY OF TREE MEASUREMENTS

Type of Measurement	# of Studies	# of Total Obs	# of Obs in Analysis*
Variables in Meta-Regression			
Proportion of land in tree cover	17	133	77
Distance to a forested area	15	59	29
Area in tree cover	7	65	24
Variables not in Meta-Regression			
Presence of trees	6	11	
View of forested area	5	8	
Bordering a forested/wooded area	5	41	
Within a distance of forested area	4	13	
Number of trees	3	9	
Number of forest patches	3	8	
NDVI (Normalized Difference Vegetation Index) Rating	3	18	
Size of nearest forest	2	6	

*Excludes observations from outside the U.S., from studies that didn't not provide average study values, and those that did not provide enough information to calculate the implicit price. Only positive observations were included in the distance models.

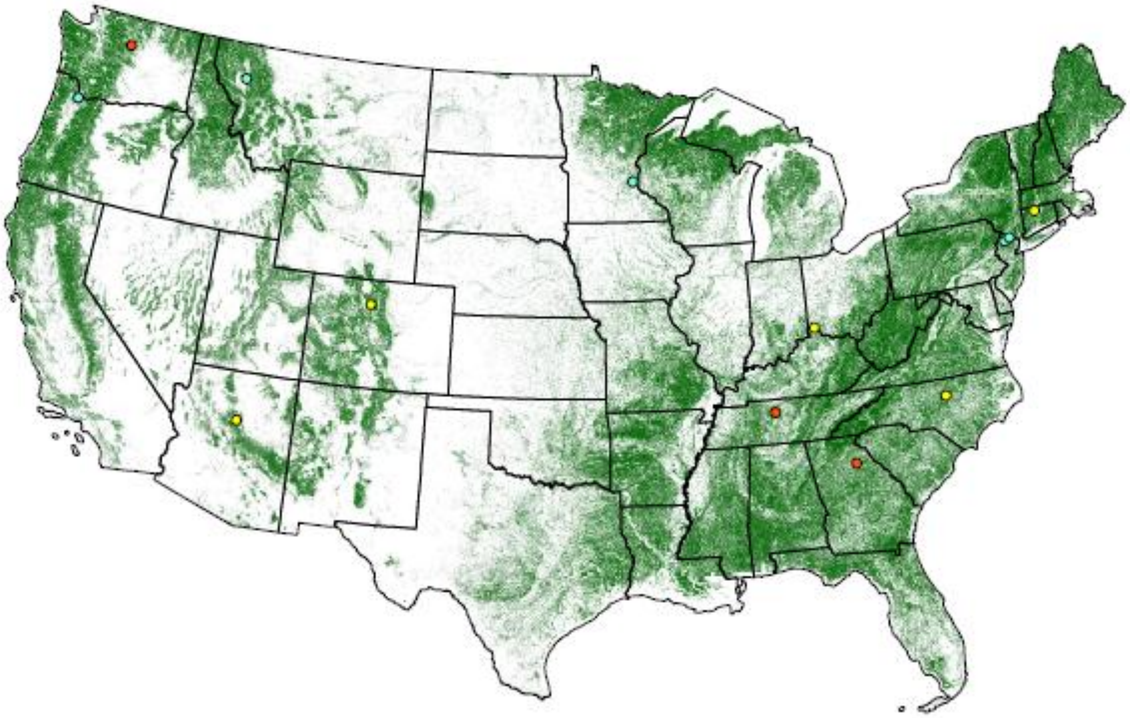
As shown in Table 2, the greatest number of studies measured trees using the amount of tree cover around a property and the distance from a property to a forested area. These two measures were the focus of two separate regression analyses in the present study. The tree cover observations measured the contribution of either area or proportion of tree cover on or near the property on property price. The area for measuring tree cover ranged from the property-level to an area surrounding the property with up to a one mile radius. Implicit prices for area observations were converted to a proportion by estimating the model at the variable means and then with a one percent change in the proportion of tree cover. The distance observations measured the impact of proximity to a forest on property prices. The studies and the number of observations from each study included in the meta-regression are described in Appendix A. The observations used in the meta-analysis came from studies that provided enough information to calculate the implicit price(s) and that provided the mean level of the tree measurement for the houses in the study. Since not every observation identified had the relevant supporting information, the total number of observations and those used in the analysis are identified in Table 2.

In the tree cover dataset, 101 observations were identified from 14 studies. This includes both positive and negative observations. The positive and negative implicit price observations were jointly used to look at the factors that influence whether tree cover was valued positively or negatively by home-buyers. The geographic distribution of hedonic studies that measured tree cover including the location of observations that identified positive, negative or both positive and negative implicit prices is displayed in Figure 3. The positive and negative observations can be into two sub-groups, which resulted in 64 positive observations from 11 studies and 37 negative observations from 9 studies in the tree cover models. The first sub-group includes only implicit price observations that value tree cover as an amenity and the second includes only implicit price observations that value tree cover as a disamenity.

In the distance dataset, 7 studies provided the 29 observations used for the meta-regression. The distance data contains only positive values. Because of the limited number of negative observations, they were not included in the meta-regression. In both the tree cover and distance datasets, statistically significant and non-significant observations from the hedonic studies were used in the meta-regression.

The data collected from the hedonic studies included type of measurement (i.e. distance or tree cover), marginal implicit price, average home price, average property characteristics,

FIGURE 3. GEOGRAPHIC DISTRIBUTION OF THE HEDONIC STUDIES MEASURING TREE COVER AND TREE CANOPY IN THE U.S.



●: Approximate study location (negative implicit prices)
●: Approximate study location (positive implicit prices)
●: Approximate study location (positive and negative implicit prices)
■: Tree Canopy (Source: Homer et al., 2007)

functional form, model type, number of observations, dates of the home sales, publication date and location of the study. The marginal implicit price was calculated using the regression coefficients from the hedonic model. When the functional form of the hedonic model required the implicit price to be calculated one level of the data, the mean study value for each relevant variable was used. The implicit prices were all put into 2011 dollars. The data was coded by two separate individuals and then crosschecked to ensure accuracy in the database. The data from multiple hedonic property value studies will be used to test the hypothesis that systematic variation in implicit price is present across the studies with respect to the average tree amenity measures. Specifically, in the tree cover data, there is expected to be a positive diminishing relationship between implicit price and property tree cover. In the distance data, it is predicted that the relationship between proximity to a forest and implicit price will be negative. In both the tree cover and distance data, the relationship between the tree amenity and implicit price across locations was expected to follow the typical pattern observed within a single location.

Ancillary data were added to the datasets to provide information on characteristics of local trees. Data were collected from the USDA Forest Inventory and Analysis program using the Forest Inventory Data Online (FIDO) tool (http://fiatools.fs.fed.us/fido/index.html). This data source was selected since it provides consistent data across the US study locations. As previously mentioned, the consistency of the ancillary data was an important feature of this study.

The FIDO data is reported is at the county level for U.S. counties. For studies that used a county as the study area, FIDO data was collected for the county. In studies that took place in multiple counties, the FIDO data was aggregated for all relevant counties by summing the data from each county. When a one or more localities comprised the study area, FIDO data for the county in which they were located was obtained. Therefore, for studies conducted in locations smaller than a county, the FIDO data represents a greater area.

FIDO data was obtained for the number of trees by species and acreage in tree stand age categories. In the species data, living trees one inch in diameter or larger at breast height are included in the tree counts. The number of trees in each hardwood species was summed and then divided by the total number of trees to determine the proportion of trees that were hardwoods in each county. The same method was used to identify the percent of trees that were conifers. The acreage of trees by stand age was summed into three broad age groups Young tree stands were those under 40 years in age, medium aged stands were aged between 40 and 119, and old tree stands were over 120 years old (see Table 3). The data was collected to match the publication

TABLE 3. VARIABLES AND SUMMARY STATISTICS

Variable	Description	Tree Cover Data (positive)			Tree Cover Data (negative)			Distance Data		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
TreeCover	*Mean proportion of tree cover (on or up to 1 mile around the property) associated with the implicit price observation (%)*	20	0	61	11	0	40	-	-	-
Distance	*Average distance to a forested area associated with the implicit price (meters)*	-	-	-	-	-	-	9,223	326	71,000
House Price	*Mean house price from the hedonic study (in $2011)*	294,698	139,369	498,209	293,545	128,328	498,209	201,924	115,832	389,578
County Cover	*Proportion of the county(s) in tree canopy cover (%)*	46	13	66	49	16	66	41	9	61
Hardwood	*Percent of trees in the county(s) that are hardwoods (%)*	63	1	99	54	1	99	53	1	97
Young	*Percent of acres in tree stands aged 0 to 39 years in the county(s) (%)*	19	0	43	21	0	92	31	19	43
Medium	*Percent of acres in tree stands aged 40 to 119 years in the county(s) (%)*	69	47	91	65	8	91	59	45	73
Old	*Percent of acres in tree stands aged 120 years or older in the county(s) (%)*	12	0	44	14	0	26	10	0	24
Shannon	*Shannon Diversity Index rating*	1.92	1.32	2.47	1.93	1.32	2.47	2.14	1.23	2.79
Simpson	*Simpson Diversity Index rating*	0.77	0.63	0.89	0.78	0.63	0.89	0.82	0.56	.92
Latitude	*Latitude of the study location (decimal degrees)*	43	35	48	44	34	48	41	36	48

Variable	Description	Tree Cover Data (Amenity)			Tree Cover Data (Disamenity)			Distance Model		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Density	*Population density of the county(s) the study was conducted (people per mile^2)*	1,417	0.2	2,715	1,252	18	2,715	352	9.8	851
Unemploy-ment	*Unemployment rate in the county(s)*	7.26	4.1	11.6	8.23	4.1	11.6	7.24	4.1	11.4
OnProperty	*Observation measures tree cover at the property level only (binary)*	0.38	0	1	0.43	0	1	-	-	-
EastCoast	*Study location is east of the Mississippi River (binary)*	0.64	0	1	0.54	0	1	-	-	-
PacificNW	*Study location is in Oregon or Washington (binary)*	0.25	0	1	0.38	0	1	-	-	-
Year	*Year the study was published*	2008	2002	2011	2008	2003	2011	2006	2002	2012
Price	*Marginal implicit price* ($2011)	7,984	1	85,463	-2,266	-19,607	-9	6	0	37

year of the article as closely as the FIDO data was available. From the FIDO data on the number of trees by species, two species diversity indexes were calculated. The widely used Shannon and Simpson Diversity Indexes (Pielou, 1977) were calculated to account for tree species diversity and richness in the communities. Both indexes account for the number of species present and the abundance of trees within each species group. The Shannon Index was calculated by summing across all species the product of the proportion of trees in each species group and the negative of the natural log of the proportion in each species group. The Simpson Index summed across all species the product of the number of trees in a species group and the number of trees for the species group minus one divided by the product of the total number of species present and the total number of species minus one. That number was then subtracted from one, resulting in a score ranges from zero to one and increases as diversity increases. County level data was also collected from USDA Forest Service's Urban Forest Data resource (USDA, 2010) on the percent of tree canopy cover.

Socioeconomic data were collected from the US Census Bureau (2010). This data includes median income, unemployment rate and population density at the county level.

The supplemental information collected about the type and condition of trees in the communities expanded the scope of the data to help tie the value of trees to their characteristics. In addition to the hypothesis of systematic variation across studies, the meta-analysis will also identify if there is a relationship between implicit price and the quantity and quality of trees in the locality. The supplemental information will be used to test the hypothesis that on the county level there is a non-linear relationship between implicit price and the amount of the tree amenity in the community. Additionally, it is hypothesized that there is a significant relationship between implicit price and amount of hardwoods, age of tree stands, and species diversity in the counties.

Finally, data was also collected to identify factors that may have influenced whether trees were valued as an amenity or disamenity. Data indicating if an extreme weather event occurred in the study location in the one year before or during the property sale dates was collected from the National Ocean and Atmospheric Administration's (NOAA) "Billion Dollar U.S. Weather/Climate Disasters 1980-2011" (Lott et al., 2012). This data was used to create a binary variable for an extreme weather event in the community. Additionally, another binary measure describing if an invasive species or pathogen was present in the study location at the time of the property sales was created. This measure was based on data collected from the USDA Forest Service's "Annual Insect and Disease Conditions Reports". Additionally, data on the crime rate per 100,000 inhabitants in the average property sales year for the study was collected from the Federal Bureau of Investigation's (FBI) "Crime in the United States" annual reports. Data was also collected for each study location on the amount of annual precipitation and the annual number of days with high temperatures above 90 degrees Fahrenheit for the average property sales year. This data was collected from NOAA's National Climatic Data Center (http://www.ncdc.noaa.gov/cdo-web/). Additionally, data was collected from the hedonic studies to identify if the study location was east of the Mississippi River or in the Pacific Northwest and whether each implicit price was only for a property-level measurement or if it included a greater area. This data will be used to test the hypothesis that trees are viewed as an amenity or disamenity based on climatic and locational factors and the health of trees in their community.

Table 4 provides a summary of these variables for the positive and negative implicit price observations. There are a few notable differences between the positive and negative implicit price observations. For example, recent extreme weather events were observed in locations with negative implicit prices (68%) more often than in locations with positive implicit prices (53%).

TABLE 4. SUMMARY OF TREE COVER OBSERVATIONS

	# Studies	# Obs	% Observations at Property Level (*OnProperty*)	% of Observations in the East Coast (*EastCoast*)	% of Observations in the Pacific Northwest (*PacificNW*)	Annual Days above 90 ℉ (*Days90degrees*)	Annual Precipitation (inches) (*Precipitation*)	Crime Rate (crimes per 100,000 people) (*Crime*)	Average Population Density (people per mile^2) (*PopDensity*)	Extreme Weather Event (% of Observations)* (*ExtremeWeather*)	Presence of Invasive Species or Pathogen (% of Observations) (*InvasiveSpecies*)**	Average Stand Age (years) (*StandAge*)	% Acres >120 years (*Old*)	% Hardwoods (*Hardwoods*)
Negative Observations	10	37	43%	54%	38%	15	33	3,713	1,266	68%	76%	60-79	14%	54%
Positive Observations	11	64	38%	64%	25%	13	39	4,375	1,421	50%	73%	60-79	12%	63%

*Presence of a major extreme weather event (i.e. hurricane, tornado, fire) in the 1 year before and during the property sale dates
**Presence, defoliation or mortality of trees due to an invasive species or pathogen in the study location

Additionally, there are a higher percent of negative observations that measured tree cover just on the property (43%) compared to the positive observations (38%). The positive observations were in locations with a slightly higher population density and annual precipitation on average.

V. EMPIRICAL MODEL

Separate meta-equations were estimated for the tree cover and distance amenity measures. A linear functional form was employed in the meta-regression for all variables except the variables for observation and county tree cover, which used the quadratic form. The quadratic form was used for the tree and county cover data because of the assumption that these variables will have a non-linear relationship with implicit price. Additional function forms, such as log-odds and semi-log, were considered in the exploratory analysis but the relative similarity in results led to the use of the linear model in further analysis. The models do not weight the studies by number of observations each contributed to the meta-analysis. Each observation is counted equally in the models[1]. Since heteroscedasticity is commonly present in meta-data (Nelson and Kennedy, 2009), the regression analysis will use robust standard errors to correct for this.

The tree cover meta-regression analyzed hedonic data related to tree canopy cover. The first set of models uses the positive values (Amenity Model) and the second model uses the negative values (Disamenity Model). The dependent variable in both the Amenity and Disamenity Models is the marginal implicit price of tree cover. Due to differences in the characteristics of the Amenity and Disamenity Model observations shown in Table 4, they were considered separate groups of data and were modeled independently. Any observations that

[1] A fixed effects specification was also initially explored, but because of the limited number of observations over-specification in the model was a concern. The results of the fixed effects model are included in Appendix B.

specifically measured trees as a disamenity a priori (i.e. due to incidence forest fires or invasive species) were not included in the analysis.

Explanatory variables from the hedonic studies included average amount of tree cover (*treecover*) for the observation and average house price (*houseprice*). A variable measuring the amount of trees in the community (*countycover*) was also included in the base model. Summary statistics and a description of these variables can be found in Table 2. The tree cover base model was:

$$IP(\$) = \alpha + \beta_1 treecover + \beta_2 treecover^2 + \beta_3 houseprice + \beta_4 countycover + \beta_5 countycover^2 + \varepsilon \qquad (5)$$

To identify if there was a relationship between the characteristics of local trees and implicit price, the subsequent model (Model 2) added three variables on the composition of the local trees: (1) proportion of trees that are hardwoods (*hardwood*), (2) forest stands aged 40 to 199 (*medium*), and (3) forest stands over 120 years (*old*). The third age variable (*young*) is the base group and so it is not included in the model. Tree age and species are two characteristics that are most easily understood and observed by the general public, so it thought they would impact implicit prices. Two additional models incorporated the Shannon (*shannon*) (Model 3) and Simpson (*simpson*) (Model 4) Diversity Indexes into the base model iteratively. These indexes are more complex measures of the local composition of tree species than the hardwood variable. A mix of tree types has been observed to be preferred in some areas, and so this research will help to identify if there is a relationship among property buyers between implicit price of tree cover and species diversity across locations. Then a model was estimated to add a binary variable to Model 2 that indicated if tree cover was measured just on the property (*onproperty*) or in a larger area (Model 5). Tree cover on the property may indicate that home-buyers were responsible for the maintenance of trees which may impact their preference for trees. Lastly, Model 6 added two geographic variables to Model 2 that identify if the hedonic studies were conducted in a location east of the Mississippi River (*eastcoast*) or in the Pacific Northwest (*pacificnw*).

The combined tree cover dataset was then used to look at factors that influence whether tree cover is viewed as an amenity or disamenity. In this model the dependent variable is binary outcome, where 1 is an amenity implicit price and 0 is a disamenity implicit price. Using a probit model, the impact of locational variables such as the latitude of the study location (*latitude*), population density (*popdensity*), crime rate (*crime*), if the study was east of the Mississippi (*eastcoast*) or in the Pacific Northwest (*pacificnw*) and whether the implicit price was for trees only on the property (*onproperty*) on an amenity outcome was estimated. Additionally, climate variables such as annual precipitation (*precipitation*), the annual number of days with a high temperature over 90 degrees Fahrenheit (*days90degrees)*, and a recent extreme weather event in the study location (*extremeweather*) were also expected to influence if trees were an amenity. Finally, forest health variables for the presence of an invasive species or pathogen (i*nvasivespecies*) and the average age of tree stands in the study location (*standage)* on an amenity or disamenity outcome will be estimated. Table 4 presents a summary of these variables. The binary response model was:

$$P(amenity = 1|x) = G(\beta_0 + \beta_1 latitude + \beta_2 popdensity + \beta_3 crime + \beta_4 eastcost + \beta_5 pacificnw + \beta_6 onproperty + \beta_7 precipitation + \beta_8 days90degrees + \beta_9 extremeweather + \beta_{10} invasivespecies + \beta_{11} standage) \quad (6)$$

The Distance Model used positive implicit price calculations related to the proximity of properties to a forest as the dependent variable. This model included the study mean for distance to a forested area (*distance)* in place of study tree cover in equation 5. The remainder of the explanatory and study variables was the same as in equation 5. Table 3 presents a summary of these variables. The distance base model was:

$$IP(\$) = \alpha + \beta_1 distance + \beta_2 houseprice + \beta_3 countycover + \beta_4 countycover^2 + \varepsilon \quad (7)$$

As mentioned above, the functional form of the distance models were the same as the tree cover model except that it contained a linear distance variable in place of the quadratic tree cover variable. Additionally, the same tree characteristic variables are included in the subsequent distance models in the same form as the tree cover models above.

The socioeconomic variables identified for each study location were not included in the final models. While these variables were believed to control for some differences between locations, there were not the focus of the research. Due to the limited sample size in the datasets and concerns about over-specification the socioeconomic variables were not included in the models. Appendix B reports a basic model that includes the socioeconomic variables.

VI. RESULTS

The results of the tree cover and distance models were presented in Tables 5-8[2]. Overall the models fit the data moderately well. The models showed mixed findings for systematic variation across hedonic property valuation studies. Additionally, the findings and significance of the impact of tree characteristics on implicit price varied across the datasets. The binary

[2]Exploratory analysis included a dummy variable to distinguish significant and insignificant observations. Because of the insignificance of this dummy variable, it was dropped from the subsequent modeling.

outcome model showed several factors significantly contribute to the implicit price of tree cover being positive or negative.

TABLE 5. TREE COVER - OLS REGRESSION RESULTS (AMENITY VALUES)
DEPENDENT VARIABLE IN ALL MODELS IS IMPLICIT PRICE ($2011)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	-44,106.2 (12,618.2)***	-68,267.11 (21,795.5)***	-27,761.7 (42,324.1)	-26,373.6 (47,383.1)	-66,872.7 (25,270.2)***	-204,054.2 (32,367.2)***
TreeCover	604.38 (291.85)**	711.82 (347.53)**	736.18 (376.79)*	673.89 (342.26)*	691.74 (399.43)*	1,087.33 (363.21)***
TreeCover^2	-12.65 (4.98)**	-12.44 (4.88)**	-12.29 (4.88)**	-10.52 (4.47)**	-11.88 (6.59)*	-24.91 (4.55)***
HousePrice	0.054 (0.019)***	0.049 (0.024)**	0.060 (0.022)***	0.053 (0.022)**	0.056 (0.045)	0.173 (0.024)***
CountyCover	1,959.11 (688.67)***	2,661.80 (797.53)***	2,236.94 (653.62)***	1,859.33 (913.02)**	2,611.96 (944.92)***	4,542.58 (851.52)***
CountyCover^2	-24.10 (8.26)***	-31.31 (9.33)***	-25.22 (8.63)***	-19.11 (14.12)	-31.06 (10.06)***	-69.96 (13.41)***
Hardwood	-	534.15 (228.66)**	496.79 (192.94)**	491.65 (190.15)**	538.10 (223.50)**	-1,436.25 (560.87)**
Medium	-	-560.70 (235.17)**	-571.14 (245.14)**	-623.41 (293.82)**	-599.51 (213.19)***	131.32 (261.99)
Old	-	1,085.51 (484.72)**	764.01 (251.55)***	675.93 (295.05)**	1,091.91 (478.30)**	3,292.63 (536.51)***
Shannon	-	-	-12,591.91 (15,155.94)	-	-	-
Simpson	-	-	-	-41,844.34 (46,904.23)	-	-
OnProperty	-	-	-	-	1,718.89 (8,533.17)	-
EastCoast	-	-	-	-	-	228,201.3 (56,887.2)***
PacificNW	-	-	-	-	-	38,921.2 (10,265.3)***
N	64	64	64	64	64	64
R^2	0.1535	0.2148	0.2212	0.2227	0.2156	0.2442
Adjusted R^2	0.0805	0.1005	0.0914	0.0931	0.0848	0.1016
Prob > F	0.0012	0.0094	0.0000	0.0000	0.0025	0.0000

Robust standard errors in parenthesis
*indicates significance at the .1 level, ** at the .05 level, and *** at the .01 level

Estimation results from the Amenity Models were reported in Table 5. All variables were significant in the Amenity Models 1 and 2. In all six models, both observation and county tree cover had a positive diminishing effect on the marginal implicit price of tree cover, indicating that systematic variation in implicit price was present across the studies. The signs and levels of the variables were fairly consistent across the Amenity Models. Additionally, the Amenity Models found most of the variables to have a statistically significant relationship with implicit price, with the notable exception of the diversity indexes. The significant relationship between the local tree characteristics for *hardwood, medium* and *old* and implicit price in the Amenity Models indicates that the implicit price of tree cover depended on qualities of local trees.

Across the models implicit price was maximized when tree canopy cover on or near the property is 28% on average. Additionally, implicit price was maximized when county canopy cover is about 42% on average across the models. These findings indicated that home-buyers prefer a greater amount of tree cover in the community and slightly less on their property.

Model 2 was the preferred Amenity Model due to the strong performance of compared to the other models. Models 3 and 4 did not improve much on Model 2, since the diversity indices were not significant in either model. Similarly, in Model 5 the binary variable added for tree cover measurements only on the property level was not found to be significant in the model at the 10% level. While Model 6 performed slightly better than Model 2, the variables *eastcoast* and *hardwoods* are highly correlated and the two geographic binary variables may control for too much of the variation in local tree characteristics across studies. Therefore, the findings from Model 2 were described in more detail.

In Model 2, the findings supported a statistically significant relationship between property tree cover and implicit price. An F-test for joint significance of the *treecover* variables was statistically significant at the 5% level (F-value=4.31). This finding supported systematic variation across studies between implicit price and local tree cover. At the average level of *treecover* in the dataset, a small increase in tree cover increased marginal implicit price by about $214.

The composition of local trees also had a significant relationship with implicit price in Model 2. In addition to being independently significant at the 5% level, the variables for *countycover*, *hardwood*, *medium* and *old* were found to be jointly significant at the 1% level (F-value=3.51). These results strengthened the understanding of what characteristics of trees impact their value to homeowners. When tree cover was an amenity, hardwoods and older trees were positive influences on implicit prices. A one percent increase in hardwood trees results in around a $530 increase in the implicit price of tree cover and a one percent increase in old tree stands would increase implicit price by about $1,000. Old tree stands were the least common in the dataset with only 12% of tree stand acreage in the *old* category, so the relative scarcity of old tree stands may be related to its positive impact on implicit price. Additionally, hardwoods and older trees of trees may be generally associated with amenities like shade and aesthetic views, so it was understandable that home-buyers prefer them.

Few variables were found to have a significant relationship with implicit price in the Disamenity Models (Table 6). The property *treecover* variables were not independently or jointly significant at the 10% level in the models. The non-significance of the tree cover variables suggests that systematic variation in implicit price cannot be extrapolated across study locations for disamenity observations. Additionally, the relationship between implicit price and the tree characteristics are not as strong as observed in the Amenity Models. In the Disamenity Model 2, the *medium* and *hardwood* variables show signs in the opposite direction as the Amenity Model 2 and are independently significant at the 5% and 10% levels, respectively. A joint test for significance of the three tree quality measures in the Disamenity Model 2, finds that they are jointly statistically significant at the 1% level (F-value=4.59). This indicates that the characteristics of trees are important factors in implicit price and that when trees are viewed as a disamenity practically the opposite characteristics are preferred to when they are an amenity.

TABLE 6. TREE COVER - OLS REGRESSION RESULTS (DISAMENITY VALUES)
DEPENDENT VARIABLE IN ALL MODELS IS IMPLICIT PRICE ($2011)

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Constant	7,723.11 (4,626.38)	27,763.69 (15,195.98)*	19,997.78 (19,483.98)	6,633.31 (26,289.16)	25,701.04 (12,914.57)*	320,407.5 (158,114.3)*
TreeCover	-207.12 (350.97)	-339.66 (423.90)	-352.22 (430.39)	-364.89 (431.32)	-348.40 (401.74)	-364.33 (426.93)
TreeCover^2	3.75 (8.04)	9.32 (9.67)	10.12 (10.08)	10.70 (10.19)	10.06 (9.25)	10.95 (10.07)
HousePrice	-0.003 (0.018)	-0.003 (0.020)	-0.007 (0.017)	-0.013 (0.014)	0.015 (0.018)	0.001 (0.026)
CountyCover	-295.91 (153.38)*	-708.20 (450.29)	-722.85 (488.69)	-814.24 (455.06)*	-631.54 (379.14)	-4,689.73 (2,014.48)**
CountyCover^2	2.61 (2.02)	8.17 (6.46)	7.73 (7.24)	8.64 (6.67)	6.03 (5.18)	87.32 (40.15)**
Hardwood	-	-236.10 (123.45)*	-192.32 (118.80)	-146.90 (124.61)	-283.99 (131.06)**	1,173.05 (638.85)*
Medium	-	121.67 (44.80)**	101.23 (50.14)*	99.00 (46.93)**	118.03 (39.44)***	493.20 (216.73)**
Old	-	-667.99 (470.06)	-442.27 (407.71)	-199.65 (450.28)	-736.87 (459.96)	-14,409.39 (7,691.02)*
Shannon	-	-	3,396.66 (4,744.92)	-	-	-
Simpson	-	-	-	23,139.15 (24,190.62)	-	-
OnProperty	-	-	-	-	5,563.56 (2,516.60)**	-
EastCoast	-	-	-	-	-	-412,655.5 (214,387.8)*
PacificNW	-	-	-	-	-	39,093.52 (22,274.3)*
N	37	37	37	37	37	37
R^2	0.0650	0.2095	0.2155	0.2224	0.3530	0.2428
Adjusted R^2	-0.0858	-0.0164	-0.0461	-0.0368	0.1373	-0.0484
Prob > F	0.3785	0.0000	0.0000	0.0000	0.0000	0.0000

Robust standard errors in parenthesis
*indicates significance at the .1 level, ** at the .05 level, and *** at the .01 level

Surprisingly, the tree species diversity indexes do not have a significant relationship with implicit price in both the Amenity and Disamenity Models. This may signify that home buyers value specific tree types rather than species variety. Additionally, this finding may have been a result of measuring species diversity at the aggregate county-level, since diversity generally increases as the area for measuring it increases.

An F-test was conducted for equivalence of parameters between the Amenity and Disamenity Models using Model 2 The null hypothesis of equality between equations was rejected at the 5% level (F-value=2.71). This supported the separate estimation of the Amenity and Disamenity models, since the coefficients are statistically different between models.

In Table 7, positive and negative tree cover observations were jointly used to estimate the impact of locational, climatic and tree health characteristics on finding a positive or negative implicit price associated with tree cover. Across the two models, the variables have consistent signs. In Model 2, a recent extreme weather event has a statistically significant influence at the 1% level on a negative implicit price outcome. This finding may be related to home-buyers being more aware of maintenance costs of having trees on their property after an extreme weather event. Another factor found to contribute to on a negative implicit price outcome is if tree cover was measured only on the property. This variable was significant at the 10% level in Model 2. This variable may indicate that home-buyers value trees less when they own the trees and therefore may be responsible for their upkeep, compared to when trees are the responsibility of other home-owners or the public.

The presence of an invasive species is found to significantly contribute to a positive implicit price outcome at the 5% level. Although this is somewhat surprising, an invasive species might only be present in a certain tree species and may not be a measure of the overall health of trees in the locality.

TABLE 7. PROBIT MODEL FOR AMENITY AND DISAMENITY OUTCOMES TREE COVER DATA – DEPENDENT VARIABLE IS A BINARY OUTCOME (Y=1 for Amenity Implicit Price Outcomes**)**

	Model 1	**Marginal Effects[1]**	**Model 2**	**Marginal Effects[1]**
Constant	-1.46 (1.04)		-5.28 (8.05)	
Latitude	0.017 (0.126)	0.006 (0.046)	0.151 (0.135)	0.052 (0.045)
StandAge	-0.306 (0.340)	-0.110 (0.122)	-0.521 (0.595)	-0.183 (0.209)
Precipitation	-0.083 (0.050)*	-0.030 (0.017)	-0.175 (0.078)**	-0.062 (0.024)
Days90degrees	-0.052 (0.024)**	-0.019 (0.008)	-0.080 (0.028)***	-0.028 (0.009)
Crime	0.001 (0.000)**	0.0003 (0.000)	0.002 (0.001)***	0.0005 (0.000)
ExtremeWeather	-1.573 (0.877)*	-0.503 (0.212)	-2.33 (0.830)***	-0.662 (0.141)
InvasiveSpecies	3.435 (1.72)**	0.890 (0.139)	4.26 (1.72)**	0.941 (0.074)
EastCoast	-1.96 (1.14)*	-0.577 (0.232)	-1.63 (1.57)	-0.488 (.376)
PacificNW	-2.39 (0.602)***	-0.768 (0.117)	-3.34 (0 .638)***	-0.900 (0.063)
PopDensity	0.001 (0.0003)**	0.0003 (0.000)	0.001 (0.000)***	0.0004 (0.000)
OnProperty	-0.926 (0.453)**	-0.337 (0.158)	-0.873 (0.469)*	-0.311 (0.162)
TreeCover			0.030 (0.018)*	0.010 (0.006)
CountyCover			0.016 (0.021)	0.006 (0.007)
N	101		101	
Pseudo R^2	0.1704		0.2042	
Prob > Chi^2	0.0000		0.0000	

*indicates significance at the .1 level, ** at the .05 level, and *** at the .01 level
[1]Partial effect at the sample mean of all independent variables

The geographic variables were also found to significantly influence the direction of a tree cover implicit price outcome. The two variables indicating whether the study was located in the East Coast or Pacific Northwest had a statistically significant influence on a negative implicit price outcome. This may be because trees are plentiful in these locations and so tree cover is not something that home-buyers will pay a premium to have on their property. Lastly, the climatic variables for annual precipitation and days above 90 degrees were significant at the 5% and 1 % level, respectively. Both precipitation and hot days had a negative influence on the implicit price outcome. The directional impact of annual precipitation may indicate that in dryer areas, which probably had more sunny days, the shade provided by tree canopy cover was valued by home-buyers. For a similar reason it was somewhat surprising that the number of hot days also has a negative relationship with an implicit price outcome.

Estimation results from the Distance Models were reported in Table 8. The models fit the data well with R^2 values between 0.34 and 0.77, although the variables in the models are largely not statistically significant individually. In Model 1, *distance* had an expected significant negative relationship with implicit price. This indicated that as distance to a forested area increased, implicit price decreased. This directional relationship was consistent across the models, but not statistically significant in any other models.

The findings for a relationship between the implicit price of proximity to a forest and local tree composition were mixed. County tree cover was not significant in the quadratic form in Model 1, indicating that the amount of trees in an area did not impact the implicit price of proximity to a forest. Although in the subsequent models none of the tree characteristic variables were statistically significant individually, when jointly tested for statistical significance the three tree quality variables were significant at the 1% level (F-value=12.77) in Model 2. Therefore, the combined group of tree quality variables impacts the implicit price of proximity to a forest indicating that the implicit price home-buyers paid for trees varied according to the type of trees living in their community.

TABLE 8. DISTANCE – OLS REGRESSION RESULTS
DEPENDENT VARIABLE IN ALL MODELS IS IMPLICIT PRICE ($2011)

	Model 1	**Model 2**	**Model 3**	**Model 4**
Constant	30.85 (12.10)**	-620.03 (390.81)	-1484.96 (916.00)	-1,755.37 (1,103.77)
Distance	-0.0004 (0.0002)**	-0.002 (0.001)	-0.008 (0.005)	-0.008 (0.005)
HousePrice	-0.00008 (.00004)**	0.0001 (0.0001)	0.00004 (0.00003)	0.00004 (0.00003)
CountyCover	-0.668 (0.764)	0.4355 (1.09)	-20.13 (15.26)	-14.92 (11.63)
CountyCover^2	0.013 (0.013)	0.062 (0.058)	0.406 (0.291)	0.378 (0.271)
Hardwood	-	9.76 (7.28)	20.82 (13.62)	24.87 (16.43)
Medium	-	-5.21 (4.89)	-9.70 (7.065)	-11.75 (8.48)
Old	-	28.67 (21.04)	70.76 (46.44)	79.99 (52.85)
Shannon	-	-	187.16 (130.26)	-
Simpson	-	-	-	399.52 (278.05)
N	29	29	29	29
R^2	0.3494	0.6993	0.7705	0.7705
Adjusted R^2	0.2410	0.5991	0.6787	0.6787
Prob > F	0.0068	0.0002	0.0000	0.0000

Robust standard errors in parenthesis
*indicates significance at the .1 level, ** at the .05 level, and *** at the .01 level

VII. CONCLUSIONS

This study confirmed the hypothesis that consumers take into account the characteristics local trees in their valuation of trees. Additionally, the scarcity of trees in the broader landscape was an important factor in how homeowners value local trees. The Amenity Models for tree cover found that higher levels of tree cover are preferred at the community level (33 to 49%) compared to the property level (22 to 32%). This finding may suggests that homeowners like the aesthetic benefits of trees in the community, but prefer not to pay maintenance cost when trees are on their property. The finding from the binary outcome model that negative implicit prices were related to property-level tree cover also supports this conclusion that home-buyers prefer trees when they do not own them. This finding may be useful to local policy makers to focus community tree planting efforts in public areas.

The research finding that county tree canopy cover of about 42% on average optimized the implicit price of amenity tree cover links the current economic findings with a typical ecological goal associated with community tree cover. In general, a goal of 40% tree canopy cover for communities on the U.S. East Coast has been supported by American Forests. The average urban tree cover in the U.S. is currently about 35% (Nowak et al., 2010), so in many areas overall tree canopy cover could increase to meet this goal. The current findings suggest that economic benefits in the form of increased house prices and therefore a higher property tax base can be achieved by reaching this tree canopy cover target. These potential increases in local revenue from higher property values may be provide a good avenue to finance local tree programs particularly in response to tree migration.

The findings of this study may be helpful to local officials involved in planning community tree programs, since altering the composition of local may impact home-buyers valuation of trees. Overall, the finding of a link between value and the composition of trees indicates that every tree is not the same to a home-buyer. Higher implicit prices were found to be associated with older, hardwood trees when trees were considered an amenity. This may suggest that in communities where trees are positively valued, community tree program resources may best be used in part for maintenance of existing trees to aid trees in reaching this preferred maturity level. Although the findings suggest that hardwoods and old trees are preferred in the amenity tree cover model, there are limitations to these results since the characteristics of local trees were incorporated at the aggregate county-level.

Further, the changing climate may impact this preference for older hardwoods in the future. The predicted increase in extreme weather events from climate change may result in increased power outages and storm cleanup costs particularly in areas with large, mature hardwood trees. The findings from the binary outcome model suggested that trees are viewed different based on a recent extreme weather event in the community. Lower implicit prices for tree cover were associated with hardwoods and older trees (although insignificant) when trees were viewed as a disamenity. Therefore, local tree programs may want to focus their efforts on more planting efforts when trees are viewed as a disamenity.

While this research provides some basic insight into homeowner preferences of tree composition, over time local policymakers may find it useful to engage residents to refine the goals of local tree programs. Particularly due to the finding that extreme weather events are related to negative implicit price outcomes and the predicted increase of extreme weather events from climate change, the value home-buyers associate with trees may change over time.

The negative direction and the lack of statistical significance of both species diversity indices was an unexpected finding of the study. While it is possible that tree species diversity was not important to homeowners, this result may have developed from the aggregation of species over a fairly large area (i.e. countywide or larger). Since one of the predicted impacts of tree migration on local tree composition was an increase in the number of species present in counties on average, this finding may indicate that an increase in species may not impact the implicit price of tree amenities to home-buyers.

Finally, it is noteworthy to point out the large discrepancy in the tree measurements identified from the hedonic property valuation studies. Particularly in the Distance Models, the absence of statistical significance in many of variables may have been due in part to the limited number of observations in this dataset. While the goal of the hedonic studies was justifiably not to provide data for a future meta-analysis, it can be an important secondary contribution of the research. Identifying best practices on common methods and measurements may improve the use of meta-analysis in environmental valuation. Larger sample sizes obtained from analogous measurements may to increase the potential to find existing relationships in the data.

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APPENDIX

APPENDIX A. SUMMARY OF HEDONIC STUDIES

Author	Year	Country	Observations in Meta-Regression (*Cover Model, **for Distance)
Anderson and Cordell	1985	USA	-
Anderson and Cordell	1988	USA	-
Anthon et al.	2005	Denmark	-
Benefield	2009	USA	-
Bockstael	1996	USA	-
Cavailhès et al.	2009	France	-
Cho et al.	2010	USA	1*
Cho et al.	2008	USA	6**
Cho et al.	2009	USA	4**
Culp	2008	USA	-
Coley	2005	USA	1*
Dimke	2008	USA	8*
Dombrow et al.	2000	USA	-
Donovan and Butry	2010	USA	-
Drake-McLaughlin et al.	2011	USA	12*
Garrod and Willis	1992	United Kingdom	-
Garrod and Willis	1992	United Kingdom	-
Ham et al.	2012	USA	2**
Hand et al.	2008	USA	-
Holmes et al.	2006	USA	16*
Holmes et al.	2010	USA	16*
Huggett, Jr.	2003	USA	6*; 10**
Irwin	2002	USA	-
Jensen et al.	2004	USA	-
Kestens et al.	2004	Canada	-
Kim and Wells	2005	USA	1*
Kim and Johnson	2002	USA	-
Kong et al.	2007	China	-
Kovacs et al.	2010	USA	-
Lake and Easter	2002	USA	3**
Mansfield et al.	2005	USA	4*,6**
Martin et al.	1989	USA	-
Morales	1980	USA	-
Morales et al.	1983	USA	-
Netusil	2005	USA	-
Netusil et al.	2010	USA	12*
Ouesalti et al.	2008	France	-
Paterson and Boyle	2002	USA	3*
Payton et al.	2008	USA	-
Poudyal et al.	2010	USA	-
Powe et al.	1995	Britain	-
Powe et al.	1997	Britain	-
Price et al.	2010	USA	3*
Sander et al.	2010	USA	12*
Sander and Polasky	2009	USA	-
Smith et al.	2002	USA	-
Standiford and Scott	2001	USA	-
Stetler et al.	2010	USA	6*; 3**
Stigarll and Elam	2009	USA	-
Thériault et al.	2002	Canada	-
Thompson et al.	1999	USA	-
Thorsnes	2002	USA	-
Tyrväinen	1997	Finland	-
Tyrväinen and Miettinen	2000	Finland	-
White and Leefers	2007	USA	-

APPENDIX B. SUMMARY OF TREE COVER OBSERVATIONS BY STUDY

Study	Positive or Negative Observations	# positive obs	# negative obs	% Obs on Property	% Negative Obs on Property	Annual Days above 90°F	Annual Precipitation (inches)	Gardening Zone	Crime Rate (crimes per 100,000)	Population Density	Extreme Weather Event*	Presence of Invasive Species/ Pathogen**	Average Stand Age (years)
1	-	0	1	0%	0%	45	41	6	7,838	1,243	Y	N	40-59
2	+/-	10	6	25%	50%	7	38	6	4,722	288	Y	Y	80-99
3	+/-	9	7	100%	100%	7	40	6	3,069	2,715	Y	Y	80-99
4	-	0	6	0%	0%	20	11	5	1,217	25	Y	Y	80-99
5	+/-	6	2	100%	100%	5	47	6	4,542	1,977	Y	Y	40-59
6	+	1	0	0%	N/A	3	29	5	5,862	7	N	N	100-119
7	-	0	1	100%	100%	76	36	7	6,302	979	N	Y	20-39
8	+	4	0	100%	N/A	54	33	7	6,295	635	Y	Y	40-59
9	+/-	7	5	17%	20%	6	35	8	5,047	1,705	N	N	80-99
10	+	3	0	0%	N/A	1	59	5	3,771	1,216	N	Y	120-139
11	+	3	0	0%	N/A	0	14	4	4,665	8	N	Y	100-119
12	+/-	9	3	17%	33%	18	36	4	1,454	2,025	N	Y	40-59
13	+/-	3	3	0%	0%	29	16	5	1,533	18	Y	Y	80-99
14	+/-	9	3	25%	33%	19	52	8	7,613	1,705	N	N	80-99

*Presence of a major extreme weather event (i.e. hurricane, tornado, fire) in the 1 year before and during the property sale dates

**Presence, defoliation or mortality of trees due to an invasive species or pathogen in the study location

APPENDIX C. SUPPLEMENTAL REGRESSION RESULTS

Demographic Model Results

	Model 1 **Amenity Tree Cover**	**Model 2** **Disamenity Tree Cover**	**Model 3** **Distance**
Constant	-69,799.55 (41,317.88)*	-11,839.84 11,013.42)	26.02 (36.38)
TreeCover	406.27 (338.54)	-22.24 (278.56)	-
$TreeCover^2$	-3.07 (4.94)	-1.17 (6.84)	-
Distance	-	-	-0.0005 (0.0001)***
HousePrice	-0.119 (0.052)**	-0.006 (0.009)	-0.0001 (0.0000)*
PopDensity	-11.34 (2.703)***	0.293 (0.868)	0.035 (0.012)**
Unemployment	3,357.23 (1,178.99)***	0.041 (0.128)	4.56 (2.70)
Income	1.30 (0.4853)***	294.23 (446.38)	-0.0002 (0.0002)
Latitude	643.51 (649.17)	159.33 (174.46)	-0.712 (0.321)**
N	64	37	29
R^2	0.153	0.0614	0.6605

Robust standard errors in parenthesis

*indicates significance at the .1 level, ** at the .05 level, and *** at the .01 level

APPENDIX C. SUPPLEMENTAL REGRESSION RESULTS (CONTINUED)

Fixed Effects Model Results

	Model 1 Amenity Tree Cover	**Model 2 Disamenity Tree Cover**	**Model 3 Distance**
Constant	2,372.28 (3,280.52)	-7,374.82 (1,481.52)***	538.55 (346.63)
TreeCover	-691.35 (356.76)*	273.96 (277.51)	-
$TreeCover^2$	15.92 (8.49)*	-4.95 (6.52)	-
Distance	-	-	-0.008 (.005)
HousePrice	0.017 (0.005)***	-0.002 (0.020)	0.00004 (0.00003)
Study9	-	-	-509.32 (347.45)
Study18	-	-	-460.30 (296.61)
Study21	1,526.78 (5,156.82)	2,384.24 (5,237.07)	-
Study22	-3,105.64 (1,345.02)**	7,656.17 (4,936.08)	-
Study23	-	5,767.19 (994.87)***	-517.20 (333.44)
Study27	2,798.05 (1,555.52)*	3,871.55 (1,305.45)***	-
Study34	-	-	**-527.01 (341.10)**
Study37	11,745.38 (1,988.85)***	-	-516.24 (336.52)
Study43	-2,485.216 (1,474.32)*	5,538.03 (2,126.25)**	-
Study46	-25,886.4 (13,569.75)*	-	-
Study52	22214.06 3185.879)***	-	-
Study53	544.71 (1,253.66)	4,848.85 (524.55)***	-
Study57	-542.09 (1,981.85)	4,385.46 (3,398.31)	-513.32 (331.72)
Study66	29,516.44 (12,091.62)**	-7,934.03 (6,021.32)	-
N	64	37	29
R^2	0.4046	0.5004	0.7705

Robust standard errors in parenthesis

*indicates significance at the .1 level, ** at the .05 level, and *** at the .01 level