THE ECONOMIC IMPACTS OF HEMLOCK WOOLLY ADELGID ON RESIDENTIAL LANDSCAPE VALUES: SPARTA, NEW JERSEY CASE STUDY

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ABSTRACT

In this paper, we provide preliminary estimates of the impacts of the hemlock woolly adelgid on residential property values in Sparta, New Jersey, using the hedonic property value method. The literature on the aesthetic perceptions of forest landscapes is briefly reviewed to provide guidance in formulating economic hypotheses based on the assumption of an informative relationship between forest aesthetics and economic value. The hedonic property value literature regarding the ornamental and landscape value of trees is also reviewed. The empirical results show that healthy and lightly defoliated hemlocks contribute positive value to residential properties, and that moderately defoliated hemlocks reduce property values. Value 'spillovers', or externalities, are also observed where hemlock health has an impact not only on individual parcels containing hemlock resources, but also on neighboring property values. The implications of our results for forest managers are discussed.

INTRODUCTION

The hemlock woolly adelgid (HWA), *Adelges tsugae*, is an exotic insect causing severe decline and mortality to forests of eastern and Carolina hemlock (*Tsuga canadensis*, *Tsuga caroliniana* Engelm.) throughout their geographical range. The HWA is currently established in 15 eastern states from Georgia to Maine and is perceived as a threat to the remaining states with eastern and Carolina hemlock resources. Hemlocks play a unique role in eastern forest landscapes. Accordingly, the loss and damage of hemlocks may potentially result in enormous ecological impacts that may be similar to the dramatic decline of eastern hemlock forests approximately 4,800 years ago (Orwig and Foster 1998).

The economic impacts of the spread of the HWA have not been systematically quantified. Quantification of the economic damages due to HWA is important for a variety of reasons. First, overall estimates of these impacts may be used by policy-makers to justify expenditures on control or mitigation of HWA. Second, detailed information on the spatial distribution of these impacts may assist policy makers in determining how and where funds should be allocated to the management of this forest pest. Contrasting these economic impacts with the costs of control allows for policy-makers to evaluate management actions and to establish priorities in terms of targeting control efforts.

It is hypothesized that economic damages from HWA may be large because hemlock forests provide a variety of ecosystem services that are valued by people. Ecosystem services derived from hemlock forests include the protection of riparian habitat supporting coldwater species such as trout, the aesthetic value of old growth hemlock stands, particularly on public land where trees may exceed 500 years of age, and the aesthetic value of ornamental and native hemlocks in private residential landscapes. The research reported here examines the economic impact of changes in the health of hemlock stands on the value of residential landscapes.

The economic valuation of landscape aesthetics is in a formative stage. However, if it is assumed that aesthetic values uncovered in psychological studies of human preferences for landscape characteristics are related to economic values, then the scientific literature regarding what is known about the aesthetic perception of landscapes can provide guidance in the specification and interpretation of economic models.

In the next section of this paper, we review and summarize the scientific literature regarding what is known about the perception of scenic beauty of forest stands and, in particular, how changes in forest health may impact forest aesthetics. Then we review the literature on the economic valuation of the arboreal landscape, which has been focused primarily at the parcel level scale, but which recently has come to include the larger landscape scale. Next, we describe the data obtained for a case study of the impact of changes in hemlock health on the value of residential properties in a township in northern New Jersey that has experienced severe hemlock mortality resulting from HWA infestations. In the subsequent section we provide an empirical analysis of how hemlock health has impacted private property values in this township. Finally, we present a summary of our findings and present the implications for forest policy and management.

AESTHETIC PERCEPTION OF FOREST LANDSCAPES

The primary approach to studying the relationship between forest landscapes and aesthetic perceptions is based on psycho-physical methods. These methods seek to identify quantitative relationships between a visual stimulus (often using photographs) and a perceptual response. A widely used psycho-physical model is the scenic beauty estimation (SBE) method, as pioneered by Daniel and Boster (1976). This method typically uses linear regression methods to isolate the impact of singular forest attributes on perceptions of scenic beauty. Ribe (1989) provides a good overall review of research on the aesthetics of forestry and forest management, particularly what has been learned using psycho-physical methods.

The perception of what constitutes a scenic landscape may be traced back to antiquity and, in its most primitive form, has been suggested to reflect Arcadian pastoral idylls that seek a peaceful balance between raw nature and human influence (Parsons and Daniel 2002). Some researchers have hypothesized that aesthetic landscape preferences result from human evolution in savanna environments, leading to preferences for landscape elements conferring opportunities for prospect and refuge—that is, the ability to see but not be seen. This perspective is exemplified by prescriptions for silvicultural practices that create well-lit, park-like forest environments (Brush 1976).

Among the factors influencing the aesthetic perception of forest landscapes, a few are particularly relevant for our analysis. First, a number of studies have found that species diversity can increase scenic beauty (Cook 1972, Daniel and Schroeder 1979, Brown and Daniel 1984). Because hemlocks are typically a relatively minor species in forest composition, their presence contributes to the visual diversity of forest landscapes. Thus, we would anticipate that, if a monotonic relationship exists between scenic beauty and economic value, the presence of healthy hemlock trees would increase private property values. Conversely, if hemlock mortality induces the regeneration of more common species, such as black birch (*Betula lenta*) and other hardwoods (Orwig and Foster 1998, Kizlinski et al. 2002), we would anticipate that loss of the hemlock component would decrease property values.

Second, psycho-physical research has shown that aesthetic perceptions of forests are influenced by forest health. Buhyoff and Leuschner (1978) found that people disliked stands damaged by southern pine beetle (*Dendroctonus frontalis*) and that scenic preference values decreased more precipitously when they were informed about the source of the damage. Further, they estimated that the scenic impacts of insect damage increased rapidly up to about 10 percent of the visual area, above which additional damage had a relatively small impact on scenic preference. Similar results were obtained in a later replication of the experiment (Buhyoffet al. 1980). These studies suggest that a conservative estimate of economic losses from HWA can be obtained by considering a 10 percent increase in hemlock decline, and this level of change is used in the computations below.

Finally, it is noteworthy that Brush (1979), in a study of the perceptions of forest landowners in Massachusetts for twenty different forest sites, found that old hemlock stands were rated, on average, above all other sites for scenic beauty. Thus, hemlocks may possess unique scenic attributes not shared by other species.

ECONOMIC VALUE OF ORNAMENTAL TREES AND FOREST LANDSCAPES

A number of methods are available for estimating the economic impacts of changes in forest health, including the contingent valuation method, the averting behavior method, and the hedonic property value method. The contingent valuation method asks people how much they are willing to pay for changes in environmental quality, and a good review of the application of this method to forest health problems is contained in the study by Kramer et al. (2003). The averting behavior method investigates how much money homeowners actually spend for protection of environmental attributes. This method has been applied to analysis of gypsy moth protection programs by Moeller et al. (1977).

The hedonic property value method uses linear regression to estimate the empirical relationship between real estate prices and environmental attributes after controlling for a suite of relevant housing attributes. This method is methodologically similar to psycho-physical measures of landscape amenities where preference ratings or rankings are replaced by prices. Although the hedonic property value model is useful for estimating the private benefits of environmental attributes, the method relies upon market prices for value inference. Other dimensions of economic value that are not revealed by market prices, such as the value of ecosystem services to future generations, cannot be estimated using hedonic valuation methods.

An early study of this type was conducted by Morales et al. (1976), who examined 60 "comparable" houses in three neighborhoods in Manchester, Connecticut. They found that good tree cover added an average of about 6 percent to the property value. Anderson and Cordell (1988) examined the relationship between the presence of front yard trees and property values of single-family houses in Athens, Georgia, and found that trees in the front yard increased housing prices by roughly 3-5 percent relative to houses without trees. Dombrow, et al. (2000) investigated the contribution of mature trees to the market value of single-family homes in Baton Rouge, Louisiana, and found that that mature trees contributed about 2 percent to housing values.

A recent innovation in conducting hedonic property value studies is to use remote sensing data derived from satellite imagery. Geoghegan et al. (1997) used GIS data to test the hypothesis that the value of land parcels in residential areas is affected by the pattern of surrounding land uses. Using data obtained within a 30-mile radius of Washington, D.C., they found that people in residential areas care about landscape features such as open space, landscape diversity, and fragmentation. Further, they found that landscape context matters: that is, the degree to which landscape features are capitalized into property values depends on whether parcels are located in a highly developed area, a suburban area, or a relatively rural area. Paterson and Boyle (2002) examined how property prices in a relatively rural area of Connecticut (Simsbury and Avon) are affected by the extent of different land use patterns within a 1-kilometer radius around each property. They found that people enjoy the amenities associated with nearby forestlands, but prefer views of other types of cover, as a view of too much forest could lead to a feeling of being "closed-in." A study by Mansfield et al. (2002) in the Research Triangle Park region of North Carolina used a "greenness" index for forest cover to evaluate the importance of tree cover on property values in this rapidly urbanizing area. Their results showed that houses closer to institutional and private forests had greater sales prices and that parcels with a larger proportion of forest cover also had a higher value.

We were only able to identify one study that used the hedonic price model to examine the economic losses to residential property value from tree mortality caused by insect damage (Payne and Strom 1975). The valuation method employed was indirect in that it used the hedonic property value technique to estimate a relationship between the number of trees on a lot and the value of the lot. Then, using this information, estimated losses were simulated for varying degrees of potential tree loss from gypsy moth. The method is limited in that it does not directly estimate the impact of gypsy moth mortality on property value, and it does not consider the lost value from trees that are unsightly or unhealthy as a consequence of gypsy moth infestations.

CASE STUDY DATA – SPARTA, NEW JERSEY

In this paper, we report a hedonic property value analysis for the town of Sparta, in Sussex County, New Jersey Murphy 2005). The 39-square-mile township is located in the northwestern New Jersey highlands and has a population of 17,500. The area is know for its many lake communities and is located 45 miles from New York City. Housing data were obtained from the town clerk of Sparta, New Jersey, and a data set was compiled by an independent computing firm. The raw data had 5,108 house sale records over the period 1970 to 2003. After cleaning the raw data, there were 3,379 usable observations. Available in the data were sales prices and the date each residential property was sold. Structural housing characteristics collected for the hedonic estimation include: square footage of living area, number of bedrooms, number of bathrooms, the size of the parcel in acres, the year the house was built, and whether the basement and/or attic had been finished. Digital tax parcel maps for Sparta were provided by the township's engineering office. Among the salient housing characteristics, the average sale price was $382,180 (adjusted to constant 2002 dollars), and the average lot size was just under 1 acre.

Environmental variables were constructed for each individual parcel and three different spatial scales around each parcel centroid. These variables include measurements of hemlock health change, as well as land cover types, publicly owned open space, golf courses, and water bodies. Various spatial buffers around parcel centroids were examined to investigate the relationship between landscape features and property values across spatial scales. In particular, it is hypothesized that environmental amenities found on any particular parcel will "spillover" and influence the value of neighboring parcels. As there does not seem to be any consensus in previous spatial hedonic studies as to what buffer zone radius to use, a range of distances were chosen for analysis: 0.1 km, 0.5 km and 1.0 km from the parcel centroid. Land cover variables were measured as the number of pixels falling within individual parcels and respective spatial buffers and then converted to proportions of the total number of pixels within those measurement units.

The environmental variables were created at the Center for Remote Sensing and Spatial Analysis, Rutgers University. Landsat satellite data were used to create the environmental variables used in this analysis. The level of resolution was 30m, so classification of hemlock land cover does not represent individual trees, but rather represents hemlock stands. Royle and Lathrop (1997 and 2002) previously used Landsat imagery and change detection techniques to model and map hemlock canopy condition for over 8,000 ha of hemlock stands throughout northern New Jersey for the years 1984, 1992, 1994, 1996, 1998, and 2001. A subset of these data was used in the hedonic property value analysis for Sparta. Four hemlock health classes were created: (1) a combination of healthy and lightly defoliated hemlocks (less than 25 percent defoliation), (2) moderately defoliated hemlocks (25-50 percent defoliation), (3) severely defoliated hemlocks (50-75 percent defoliation), and (4) dead hemlocks (greater than 75 percent defoliation).

In general, hemlock stands in Sparta were patchily distributed and constituted about 3 percent of the land area. Although most hemlock stands are thought to have been healthy in 1984, the health of hemlock stands declined rapidly during the 1990s. In 1998, only about 30 percent of the hemlock area was classified as being either healthy or lightly defoliated. By 2001, nearly all of the hemlock area was classified as being either severely defoliated or dead. Hemlock health variables were created to represent proportions of land area.

Several land cover types were used in this study. Some land cover types were combined, as previous research indicates that people only distinguish about seven land types at any one time (Palmer 2004) and to reduce statistical problems associated with collinear explanatory variables. The land cover classifications used in the analysis include percent highly developed, percent forested, percent wetland, percent covered by streams, percent in public space, distance to the nearest lake, and distance to the nearest golf course. The land cover data were obtained for three different points in time: 1985, 1995, and 2000.

Table 1. Hemlock parameter estimates at various spatial scales (t-statistics in parentheses).

Hemlock Health Class	**Spatial Scale of Model**			
	Parcel	0.1 km	0.5 km	1.0 km
Healthy & Lightly Defoliated	0.68(3.01)	1.13(3.35)	3.95(4.54)	7.39(6.16)
Moderately Defoliated	-0.95(-3.26)	-1.44(-4.35)	-3.62(-3.65)	-6.10(-4.43)
Severely Defoliated	-0.11(-0.65)	0.16(0.71)	0.07(0.30)	-0.09(-0.24)
Dead	0.13(0.45)	0.05(0.14)	0.09(0.22)	0.86(1.52)

EMPIRICAL METHODS

In the basic hedonic property value model, the price of individual properties is regressed on a vector of explanatory variables including housing characteristics, lot characteristics, and environmental variables for the surrounding area. Although Ordinary Least Squares (OLS) regression is often used, interpretation of empirical results may be confounded by spatial dependence. Spatial dependence may arise either in the dependent variable (leading to 'spatial lag' dependence) or in the equation errors (leading to 'spatial error' dependence). If spatial lags are ignored in the analysis, OLS will give biased and inconsistent parameter estimates. If spatial error dependence is ignored, OLS will have a biased variance estimate, resulting in inefficient parameter estimates. In this study, empirical methods are used to correct for both types of spatial dependence in the data. The equations are specified with the logarithm of sales price as the dependent variable. As the land cover variables were measured as proportions of the respective measurement units (parcels and spatial buffers), parameter estimates are interpreted as the proportionate response of housing price to a marginal change in the proportion of land area in a particular land cover type.

RESULTS

The spatial dependence regression models fit the data well, and the R^2 values were roughly 68 percent for each of the four models we estimated. Estimates for the hemlock parameters are shown in Table 1. The other parameter estimates in the models are not shown to simplify the presentation.

The parameter estimates for healthy and lightly defoliated hemlocks were statistically significant at greater than the 1-percent level at all spatial scales and show that healthy hemlock stands contribute positive economic value to property values in our study area. Although we cannot be certain of the reason that healthy hemlocks confer positive values to residential properties, this result is consistent with findings from the scenic beauty literature that species/ structural diversity is a valued component of forest aesthetics. This result is also consistent with the findings reported by Brush (1979) that hemlocks have a special aesthetic appeal.

The significance of the parameter estimates in the spatial buffer models indicates the presence of ‘spillover’ effects (or ‘externalities’). Healthy hemlocks on any particular parcel convey value not only to that parcel but also to other parcels in the neighborhood. This spillover effect is also observed for moderately defoliated hemlocks: moderate hemlock decline decreases property values both for the parcel and for lots in a rather large radius around the damaged parcel.

It is important to understand the interpretation of the magnitude of the parameter estimates. Due to the way that the model was specified (recall that the dependent variable is the logarithm of housing price and hemlock variables are measured as proportions), the parameter estimates show the proportionate change in housing price in response to a proportionate change in the hemlock variables. Thus, a one percent increase (or decrease) in the area of healthy hemlock increases (or decreases) housing price by about 0.7 percent. Similarly, a one percent increase (or decrease) in the area of moderately defoliated hemlocks decreases (or increases) housing price by about 0.95 percent. The similarity in the value of the parameter estimates for healthy/lightly defoliated stands compared with the (absolute value of the) parameter estimates for moderately defoliated stands across all spatial scales indicates that the loss of healthy hemlocks is approximately equal to the gain in unhealthy hemlocks.

An estimate of economic damages to houses at risk can be obtained by calibrating the parameter estimates shown in Table 1 for the relevant area in each of the spatial scales. Parcels classified as containing moderately defoliated hemlock pixels had, on average, about 20 percent of their land area in this land cover classification. In comparison, parcels classified as containing moderately defoliated hemlock pixels within 1 km had, on average, about 1 percent of their land area in this classification. Thus a 1 percent increase in the area of moderately defoliated hemlocks at the parcel level would change the relevant average area in this land cover type from 20 to 21 percent. This represents a 5 percent increase in the relevant average area (1 out of 20). Using this frame of reference, a 1 percent increase in the area of moderately defoliated hemlock within 1 km of a parcel nearly doubles the relevant average area (1-2 percent). Given this perspective, a 10 percent increase in the relevant average area of moderately defoliated hemlocks at the parcel level (20-22 percent) reduces property value by about $7,261 per house at risk. A 10 percent increase in the relevant average area of moderately defoliated hemlock within 1 km of a parcel (1-1.1 percent) reduces property value by about $2,331 per house at risk. Although the reduction in property value is lower for houses in the neighborhood of damaged parcels, as would be expected, there are a greater number of houses at risk in the neighborhood.

It is somewhat surprising that the parameter estimates for severely defoliated and dead hemlocks were not statistically significant. This might be explained by a number of reasons. Because hemlocks in the study area tend to grow in discrete patches and because areas experiencing moderate defoliation tend to be located close to areas with severe defoliation and dead trees, the absence of statistical significance may be due to the statistical problem of multicollinearity. This effect may be compounded by the relatively few observations in each of the hemlock health classes.

DISCUSSION

In this study, we have used remote sensing techniques, concepts drawn from both the landscape ecology and the forest landscape aesthetics literature, and economic theory and methods to estimate the economic impacts of HWA on property values. This research has allowed us to provide the first estimates of economic damage to private landowners resulting from this exotic pest. We emphasize that these damage estimates are valid for a single housing market, and it is not obvious how they can be directly applied to other areas. However, if the results found in our study area are typical of other regions experiencing hemlock decline, then the total economic damages to property owners in the eastern U.S. may be very large. A more definitive assessment of how typical our study results are of damages in other regions would require replication of the procedures described here in other housing markets.

Results of our case study make it very clear that forest managers need to either prevent infestations by HWA altogether or to manage stands in such a fashion that they only become lightly defoliated in order to prevent economic losses to property values. As our results show, economic damages begin to occur when stands become moderately defoliated (25-50 percent defoliation). Although hemlocks may be able to survive many years of moderate decline, particularly in regions where cold winters reduce HWA populations, maintaining stands in these conditions can result in economic losses to residential property values.

While the costs and efficacy of biological control strategies for the HWA are not yet known with precision, the presence of landscape-level externalities suggests that the formation of neighborhood or community groups to combat this insect may be a viable strategy to protect housing values in this and similar markets. This sort of complementary group response would seem to work particularly well for the case of hemlock resource owners, because the resource is often patchily distributed. Further research should be conducted to determine the viability of HWA control strategies that would take advantage of spatial patterns of resources at risk that could capitalize on complementary group behavior at the neighborhood or community level.

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