The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

333
S45
1999

WESTERN REGIONAL RESEARCH PUBLICATION

W-133
BENEFITS AND COSTS OF RESOURCES POLICIES AFFECTING
PUBLIC AND PRIVATE LAND

12TH INTERIM REPORT
JUNE 1999

Compiled by
W. Douglass Shaw

Department of Applied Economics and Statistics
Mail Stop 204
University of Nevada
Reno, Nevada 89557-0105

INTRODUCTION

This volume contains the proceedings of the 1999 W-133 Western Regional Project Technical Meeting on "Benefits and Costs of Resource Policies Affecting Public and Private Land." Some papers from W-133 members and friends who could not attend the meeting are also included. The meeting took place February 24th - 26th at the Starr Pass Lodge in Tucson, Arizona. Approximately 50 participants attended the 1999 meeting, are listed on the following page, and came from as far away as Oslo, Norway.

The W-133 regional research project was rechartered in October, 1997. The current project objectives encourage members to address problems associated with: 1.) Benefits and Costs of Agro-environmental Policies; 2.) Benefits Transfer for Groundwater Quality Programs; 3.) Valuing Ecosystem Managment of Forests and Watersheds; and 4.) Valuing Changes in Recreational Access.

Experiment station members at most national land-grant academic institutions constitute the official W-133 project participants. North Dakota State, North Carolina State, and the University of Kentucky proposed joining the group at this year's meeting. W-133's list of academic and other "Friends" has grown, and the Universities of New Mexico and Colorado were particularly well represented at the 1999 W-133 Technical Meeting. The meeting also benefitted from the expertise and participation of scientists from many state and federal agencies including California Fish and Game, the U.S. Department of Agriculture's Economic Research and Forest Services, the U.S. Department of Interior's Fish and Wildlife Service, and the Bureau of Reclamation. In addition, a number of representatives from the nation's top environmental and resource consulting firms attended, some presenting papers at this year's meeting.

This volume is organized around the goals and objectives of the project, but organizing the papers is difficult because of overlapping themes. The last section includes papers that are very important to the methodological work done by W-133 participants, but do not exactly fit one of the objectives. -- I apologize for the lack of consistent pagination in this volume.

On A Personal Note... Any meeting or conference is successful (and fun!) only because of its participants, so I would first like to thank all the people who came and participated in 1999 - listed below. I also want to thank Jerry Fletcher for all his help at this meeting and prior to it, and John Loomis who passed on his knowledge of how to get a meeting like this to work, and who continues to have the funniest little comments to lighten the meetings up. I especially thank Paul Jakus, who helped me to organize this conference and have a lot of fun during it and afterward. Finally, I want to thank Nicki Wieseke for all her help in preparing this volume, and Billye French for administrative support on conference matters.

W. Douglass Shaw, Dept. of Applied Economics & Statistics, University of Nevada, Reno.
June, 1999

P.S. P.F. and J.C. - As far as I can tell, that darn scorpion is still dead!

Land Use Diversity and Urban Watersheds: The Case of New Haven County

Gayatri Acharya and Lynne Lewis Bennett

School of Forestry and Environmental Studies, Yale University,
New Haven CT 06511
Emails: gayatri.acharya@yale.edu, lynne.bennett@yale.edu

Prepared for the W-133 meetings
Tucson, AZ, February 1999

Land Use Diversity and Urban Watersheds: The Case of New Haven County

ABSTRACT : This paper presents the results of a hedonic property value analysis for an urban watershed in New Haven County, Connecticut. We use spatially referenced housing and land use data to capture the effect of environmental variables around the house location. We calculate and incorporate data on open space, land use diversity and other environmental variables to capture spatial variation in environmental quality around each house location. We are ultimately interested in determining whether variables that are reflective of spatial diversity do a better job of describing human preferences for housing choice than broad categories of rural versus urban areas.
Using a rich data set of over 4000 houses we study these effects within a watershed which includes areas of high environmental quality and low environmental quality as well as varying patterns of socio-economic conditions. Our results suggest that, in addition to structural characteristics, variables describing neighborhood socio-economic characteristics and variables describing land use and environmental quality are influential in determining human values. We also find that the scale at which we measure these spatially defined environmental variables is important.

INTRODUCTION

Over the past decade, various papers applying hedonic property analysis to environmental valuation issues have suggested that the location or proximity of a house with respect to environmental features in the landscape is of some importance in determining its market value. These studies provide evidence that the market price of a house reflects the level of some environmental good home owners are aware of and are willing to pay for. Various papers in the literature suggest that variables describing land use and environmental quality are influential in determining human values. The question of scale and pattern in land use is a less studied area, with relatively few studies published on these elements of assessing environmental preferences (Bockstael, 1996; Geoghegan, *et al.*, 1997). We suggest that these questions are important for understanding the impact of land use planning regulations on housing preferences.

The present paper therefore studies the effect of land use variables, such as open space, commercial areas and forest land on house prices and people's willingness to pay for these features in relation to the land use around their houses. We ask whether scale matters – do people consider land use features at varying distances from their house and do these factors affect property values? We also ask a similar question with regard to the spatial distribution of various types of land uses, i.e. is there a preference for homogenous or chaotic land use planning? We then compare these results with the information we receive from using the more traditional urban/rural categorization of land use in the hedonic model estimation. The use of sophisticated spatial variables is relatively new in the hedonic property value literature. We find that variables representing urban watershed health and integrity, including land use and open space, significantly affect consumer choices of location and willingness to pay for housing.

The hedonic price technique is based on isolating the contribution of various factors to the market price of a good, through the use of econometric techniques. Hence it may be used to estimate the value of a public good, such as environmental quality, by using market prices for private goods, such as houses. We apply the hedonic property model in the New Haven watershed system to measure the direct use of environmental quality. This watershed is composed of three rivers – the Quinnipiac, Mill and West rivers – which together drain an area of 600 km^2 and converge in New Haven harbor on Long Island Sound. The watershed supports a population of 610,000 people (see Figure 1) and covers a range of rural, suburban and urban levels of development. This therefore provides an opportunity for us to study linkages between ecological and economic systems, including variations in physical characteristics within the watershed. In order to effectively apply the hedonic price technique and to accurately represent the environmental conditions within the watershed we use spatial techniques and geographically referenced maps of land use. The spatial distribution of land uses within the watershed is not uniform. We therefore incorporate into our database a number of land use variables intended to capture spatial variation in environmental factors.

THE HEDONIC PROPERTY MODEL

The hedonic property value method is a revealed preference technique that utilizes actual market transactions in housing real estate. The idea is that when home buyers select a house, they are purchasing more than just the physical structure and the plot of land. They are also purchasing the site specific attributes of the neighborhood where the house is located. These site specific attributes include environmental quality, safety, demography, and the quality of local government services such as schools. Therefore, the prices paid for homes should reflect the capitalized value of environmental quality to the homeowner.

A basic assumption of the hedonic property value model is that the study area can be treated as a single market for housing and that this housing market is in equilibrium. In addition it is assumed that individuals have information on housing choices and are mobile enough to choose a house anywhere in the market area (Freeman 1993; Palmquist 1991). These assumptions imply that individuals choose housing based on utility maximization, given the prices of alternative housing choices, and that the prices just clear the market. While sometimes criticized as restrictive we feel these assumptions are not unrealistic for the relatively small area that is the subject of this study.

Houses are differentiated from each other in a variety of dimensions including structural characteristics such as the material the house is constructed from, accessibility to highways, neighborhood characteristics such as average income, racial composition and natural environmental characteristics such as land use and water quality. It is therefore necessary to control for structural housing characteristics and neighborhood characteristics if we are interested in understanding the role of land use and environmental quality on consumer preferences and willingness to pay. As is well established in the literature, we can use the hedonic price equation to estimate the equilibrium price schedule for the environmental variables we are interested in studying.[1] This function relates the price of a house, *h*, to its structural and environmental characteristics and may be represented by the following function:

$$P_h = f_h(S_{h1},\ldots,S_{hj},N_{hk},\ldots,N_{hk},Z_{h1},\ldots Z_{hm}) \qquad \textbf{for all } h \tag{1}$$

where S = a vector of structural characteristics

N = a vector of neighborhood characteristics

Z = a vector of environmental characteristics

A utility maximizing consumer is therefore assumed to maximize the following utility function:

$$\textbf{Max } U = U(S,N,Z,X) \tag{2}$$

Subject to a budget constraint:

$$Y = P_x X + P_h(S,N,Z) \tag{3}$$

where X is a composite commodity or numeraire consumed by the individual, S,N,Z are as defined earlier; Y refers to household income and P_x is the price vector of the commodity X, where we assume $P_x = 1$. Assuming utility maximizing behavior and an interior solution to this utility maximization problem, and assuming preferences are weakly separable in housing and its

[1]The theory underlying hedonic models was first developed by Griliches (1971) and Rosen (1974).

characteristics, we expect that the individual will set marginal willingness to pay for a housing characteristic equal to the marginal implicit price for the characteristic:

$$\frac{\partial U}{\partial Z_i} = \frac{\partial P_h}{\partial Z_i} \tag{4}$$

The hedonic price function (1) is therefore an implicit price relationship that gives the price of a house as a function of its various characteristics and the partial derivative of the hedonic price function with respect to any characteristic defined in (1) gives us the marginal implicit price of that characteristic. That is:

$$\frac{\partial P_h}{\partial Z_j} = P_{hZ_j}(S_{h1},...,S_{hj},N_{hk},...,N_{hk},Z_{h1},...Z_{hm}) \tag{5}$$

Since the price schedule represents a locus of the equilibrium marginal willingness to pay of all households, it cannot be interpreted as representing either the demand or the supply of characteristics. However, if the hedonic price function can be determined, then the individual's marginal willingness to pay for a characteristic may be estimated from the slope of the function with respect to the characteristic. The functional form for the hedonic equation is not determined theoretically and need not be linear since it is determined by the interaction of both supply and demand within the housing market. The hedonic equation must therefore be determined empirically.

A number of studies now exist which make use of hedonic property models to examine the effects of environmental disamenities and amenities. These studies include those highlighting the impact of variations in site-specific factors such as local climate (Haurin, 1980), air pollution (Harrison and Rubinfeld, 1978, Palmquist, 1982, Murdoch and Thayer, 1988) water quality (Brashares, 1985, Feenberg and Mills, 1980) and other amenities (Rosen, 1979; Roback, 1982). Various empirical studies also include the effects of crime, recreational opportunities, and population demographics (Berger and Blomquist 1992; Potepan 1996). Some studies have also included measures of school quality when explaining house price variations (e.g. . Li and Brown, 1980 and Pogodzinski and Sass, 1991.

CAPTURING ENVIRONMENTAL VARIATION IN THE HEDONIC MODEL

Models that address environmental externalities which characterize land use have a strong spatial component. The value of a parcel of residential land is affected by the pattern of surrounding land uses, not just the specific features of point locations (Bockstael, 1996, Geoghegan *et al.*, 1997). Hedonic models have generally utilized access and distance variables to represent these spatial components or uni-dimensional spatial variables such as neighborhood socioeconomic census data. Bockstael and Bell, 1997 suggest that the nature of the surrounding landscape will affect house values. Geoghegan *et al.*, 1997 point out that the problems with these traditional approaches are that "locational characteristics are more likely characterized by a gradient than by discrete levels that change abruptly," (i.e., census tract boundaries) and that it may not be just neighborhood effects causing the externalities, but patterns. Geoghegan *et al.* attempt to account for these patterns by including diversity and fragmentation indices which measure land use and pattern. Leggett and Bockstael, 1998 examine the impacts of the percentage of area in various types of land use in determining house values in coastal areas. In this paper we draw on the findings of these recent applications but we also compare the use of ecological indices to traditionally defined categories of urban and rural areas. Determining the extent of the differences between these measures could have important policy implications.

In this paper, we describe the nature of the landscape surrounding each house by using a set of variables which describe landscape pattern. In particular, we utilize a data set for one watershed and county. We geo-code the houses as points using their exact latitude/longitude data and are interested in showing that the value of aggregate measures of land use and landscape pattern, which affect the ecosystem's ability to provide certain types of habitat and support natural processes, are reflected in human perceptions of their environment and the value they indirectly associate with their natural surroundings. We introduce a set of land use related variables to understand the importance of using appropriate explanatory variables as well as investigate the importance of scale. We are ultimately interested in determining whether variables that are reflective of spatial diversity do a better job of describing human preferences for housing choice than traditional variables. In addition, we address potential spatial auto-correlation problems within our data set.

An explanation of the types of landscape variables we use is required before we proceed.

Aggregate variables

These categories are based on assessing the majority land use around each house using land use data. The land use categories are then aggregated into broad categories of rural, urban and semi-urban where:

Rural: open space, forest, water, fields and agriculture land use

Urban: impervious surfaces, high density residential & commercial, roof, pavement, and major roads.

Sub-urban: medium and low density residential land use.

Mosaic variables:

Diversity, richness, evenness, dominance measures are some ways of determining the relative numbers of types, sizes or shapes of land use patches present in a landscape mosaic (Forman, 1995). By analyzing the heterogeneity of a landscape, ecologists attempt to address the question of whether the abundance of patches in a landscape is ecologically important. Equally, the location of patches with reference to each other is an important area of research (see Forman, 1995, Turner, 1989).

Similarly, it is suggested that heterogeneity in land use/land cover and spatial patterns and features of the landscape may be important for property values. We investigate the importance of the following landscape features:

Diversity: This variable, used by Geoghegan *et al* (1997), measures whether an area is dominated by a few or many land uses and is defined as: $H = -\sum_i P_i \ln P_i$. The index measures the proportion of land in the number of identified land use types within the watershed.

Richness: Relative richness is an alternative diversity measure where $R = (s/s_{max}) \times 100$. This measure looks at the relative richness of land uses in an area (s) in terms of the total number of land use types (s_{max}) found within the watershed. Therefore it differs from the diversity index in that it is not a measure of area but a ratio of land use types relative to the maximum possible land use types found in the watershed.[2]

In addition, the percentage of open space around each house within a 1 mile and ¼ mile radius is included as an additional variable.

Spatial pattern:

The location of a house is, as the joke goes, the first, second and third most important criteriá in purchasing a house. Location in relation to work, roads, schools, shops, open space, water bodies etc., can be relatively easily incorporated into our study because of geographically referenced data. We examine the following features: distance to open space, distance to lakes, distance to streams, distance to ocean, distance to parks, distance to highways.

THE DATA SET

The data set includes over 4,000 houses sold in New Haven County between 1995 and 1997 (see Figure 2).[3] This data comes from actual house sale prices obtained from real estate multiple listings that are compiled by local real estate boards. The multiple listings also include detailed information about house characteristics (e.g. lot size, number of rooms, type of heating, etc.). This property information is combined with demographic, land use and socioeconomic information obtained from the 1990 U.S. Census. The data set is unique for two reasons: First, this is a small urban watershed varying on a gradient of both population density and environmental quality. Second the local economy was relatively stagnant during this time period which will allow us to isolate the effects of environmental variables on housing price without

---

[2] Using a land use map and an indicated analysis radius we determined the proportion of land in each of the 5 broad land use categories established. High density land use includes: impervious surfaces, high density residential & commercial, roof, pavement, and major roads. Medium density land use is medium density residential. Forest land use includes deciduous forest and coniferous forest. Water land use includes deep water, shallow water, non-forested wetland, forested wetland, low coastal marsh, and high coastal marsh. Fields and agriculture land use includes: turf & grass, soil/grass & hay, grass & hay & pasture, soil/corn, grass/tobacco, barren land, and bare soil.

[3] The real estate market in Connecticut during this time period was stagnant or falling in some places. We thus assume these to be real prices for the time period used.

introducing the bias caused by a rapidly changing economy with the associated large swings in population.[4]

To estimate a model that can discover the environmental values held by home buyers, it is critical to be able to relate the location of each home to the attributes of its surrounding environment. The geocoding process was performed for each of the 13 towns in the New Haven Watershed. These 13 towns are: Berlin, Bethany, Cheshire, Hamden, Meriden, New Haven, North Haven, Plainville, Prospect, Southington, Wallingford, West Haven, and Woodbridge. Data on land use, roads, municipal and private open space, state owned open space, and Census block groups are also incorporated into the data set. Since the watershed is demarcated based on hydrological criteria, and does not necessarily conform to economic activity, it is important to select land use and land cover features on the outer edge of the watershed map to allow spatial statistics to be properly calculated for homes near the outer edges of the New Haven watershed.

METHODOLOGY

In order to compare traditional land use measures with those utilizing indices found in the ecological literature, we examine two different models. The first model incorporates traditional measures of land use representative primarily of housing/population density. The second model incorporates variables that represent both scales and patterns of land use at varying distances from the houses.

One set of variables relates to determining whether the majority land use around a house can be classified as urban, suburban or rural. These land use categories are determined by assessing the majority land use within a 1 mile and $1/4^{th}$ mile radius around each house. We then assign dummy variables to place the land within our three categories of urban, rural and sub-urban as defined earlier.

[4] A concern associated with the hedonic property value model is that if there are market forces moving consistently in one direction or if environmental quality variables are rapidly changing, bias may be introduced into the model (Freeman 1993). The stagnant economy should help us reduce any potential bias in our model.

A second set of variables concerns those explanatory variables which describe the pattern of the landscape surrounding each house. We determine the percentage of area around each house that is considered open space[5]. A summary of land use within the New Haven watershed is shown in Table 1. To describe distribution and diversity of land use within the watershed we calculate a diversity index defined earlier as a measure of how diverse land use is within a certain area (Turner, 1989; Goegehan *et al.*, 1997). The value of this index depends both on the diversity of land use and the evenness with which these land uses are distributed within the specified area. The more land use categories there are and the more even their distribution, the greater the diversity[6]. We define "land use chaos" as reflecting a higher diversity of land use, but note that an increase in the diversity index may occur with increased evenness in the distribution of land use. Figure 3 illustrates the diversity index at a ¼ mile radius. We also calculate a richness index which should be able to explain the additional effect of local variety in land use, relative to that found within the entire watershed. So, for example, if the watershed has 5 types of land use and only one is found in the vicinity of your house, you have a low relative richness of land use around your house. If an area has high diversity it may not have a high relative richness if it does not include a majority of the representative land use types found within the watershed. In general, the higher the value of these indices, the higher the number of uses within the area. Conversely, a low value suggests a single land use or relatively few land uses.

---

[5] All grid maps for this project have a cell size of 100 feet and use the same road map for extent. Open space was defined to include the following land use categories: turf/grass, soil/grass/hay, grass/hay/pasture, soil/corn, soil/tobacco, grass/tobacco, deciduous forest, coniferous forest, deep water, shallow water, non-forested wetland, bare soil, low coastal marsh, and high coastal marsh. Non-open space includes: impervious surfaces, high density residential and commercial, medium density residential, roof, pavement, barren land, and major roads.

[6] The Shannon index, as traditionally used as a biodiversity measure, is sensitive to changes in the abundance of rare species (i.e., a Type 1 index). In the context of this study, the value of this index is likely to be higher if rare or very abundant land use types are lower in an area because the distribution of land use types is more even. An increase in the index value can occur despite a decrease in the abundance of rare land uses. Similarly a decrease in the index value can occur with reduced evenness in the distribution of land use types.
The Simpson index, which is sensitive to changes in the abundance of the most common species (dominance), may be an alternative index for us to try. It is calculated as: $D = \sum p_i^2$ where p_i = proportion of land in category *i*. So as D increases (or $1-D$ decreases), diversity decreases. If there are changes in the abundance of the most common land use within the given area this index will be more affected than if there are changes in the rare land uses within the area.

We have no prior expectations on the sign of the coefficient on the diversity variable or of the richness variable. In order to use these variables in the context of development levels within the watershed, we suggest the relative richness of an area weighted by the population density in the area would be a good indicator of the level of development of that area. We therefore multiply richness by population density and use this variable to examine the differences between densely populated areas with high relative richness in land use/land cover and sparsely populated areas with low relative richness in land use/ land cover.

We also expect that social and demographic neighborhood characteristics could affect housing prices and our measures of neighborhood characteristics include variables such as percentage of white households, crime rate per 1000 people and average income. We considered various measures of school quality such as test scores, attendance rate, dropout rate, etc. In addition, to account for the variation created by differences in property taxes, we include the town mill rate which is representative of the property tax for each community. Other explanatory variables in the house value equation include those suggested by various empirical studies of urban housing demand such as distance of a property to large cities such as New Haven and Hartford in this case. These were however found to be consistently insignificant and were omitted from the final model. We include a variable for average time taken to travel to work (WORKTIME) derived from the aggregate time to work reported by households in the census data. Variable names and definitions for the variables used in the formal analysis are presented in Table 2.

RESULTS AND DISCUSSION

Keeping in mind that the hedonic price function is determined empirically and that the functional specification of the price function will have a significant effect on the estimates of the coefficients, we considered some common functional forms (linear and double log forms) of which the semi-logarithmic form provided the best fit, yielding the following hedonic model:

$$\ln(VALUE) = \alpha_0 + \alpha_1 S + a_2 N + a_3 Z + \varepsilon \qquad (6)$$

The dependent variable, *ln(VALUE)*, is the natural logarithm of the house value. A number of structural and neighborhood variables were included to control for additional factors that determine house prices.

While we found considerable heteroscedasticity in the linear and double-log models, White's χ^2 test fails to reject the null hypothesis of homoscedasticity for the log-linear model. We are however concerned that we may have a problem of spatial autocorrelation due to omitted variables which may be spatially autocorrelated. Although a map of the residuals suggests no significant spatial pattern, we test for possible spatial interaction between our observations by proposing the following spatial error model:

$$Y = X_1 B_1 + X_2 B_2 + \ldots + \varepsilon$$
$$where \quad \varepsilon = W\varepsilon + \mu \;\; and \;\; \mu \sim N(0, \sigma^2) \qquad (7)$$

W is a spatial weights matrix where W_{ij} is a normalized measure of the associated between the i^{th} and the j^{th} residuals[7]. We hypothesize that $\varepsilon_i = f(\varepsilon_j \ldots \varepsilon_k)$ where $\varepsilon_j \ldots \varepsilon_k$ are residuals of observations within a one mile radius of ε_i. We define W_{ij} as the average of the OLS residuals within this 1 mile radius. We then test our hypothesis that there may be spatial autocorrelation by running a new OLS regression with the average error term, W_{ij} , as an additional regressor. We find that the new variable has no explanatory power in our regression and does not affect the stability of the model results. Given our large data set, we suggest that this is an adequate measure of spatial autocorrelation and reject our hypothesis that there is perceptible spatial autocorrelation due to omitted spatially correlated variables within our study area.

Table 4 presents the selected results of both model 1 and model 2. Complete model results are presented in the appendix. The first column of Table 4 presents the results from model 1 which uses simple dummy variables for urban and rural areas. We define urban areas as areas where

[7] Traditional spatial weights matrices generally provide a means for comparing information on the proximity of observations in terms of their location, with information on some other variable which measures the location (Odland,1988: Anselin, 1988). We believe that unless houses are located next to each other, they are unlikely to have an impact on neighbouring house values. We are therefore interested in examining the effect of some other

the majority land use within a $1/4^{th}$ and 1 mile radius is high density residential or commercial development and rural areas as areas where the majority land use is forest cover and wetlands. Medium density residential areas are defined as medium level or suburban development. We use two dummy variables, URBAN1 and RURAL1 to capture the effect of land use on house prices. The coefficients on URBAN1 is positive and somewhat significant while the coefficient on RURAL1 and RURAL4 were found to be consistently insignificant. While providing some information on the effect of housing density on property value, this classification tells us relatively little about the type of landscape or development levels preferred by house buyers.

The second model in which we include the landscape pattern variables and omit the broad rural/urban categories, includes the variable DEVELOP as an indicator of the level of development around the house. Using the second model where the spatial patterns are more explicit we see that the spatial distributions as well as the types of land use present have fairly substantial effects on property values. The results (also shown in tables 4 and the appendix) that follow support our hypothesis that both environmental conditions and population density are important in determining the level of development in an area.

The results suggest that 77% of the variation can be explained by both models. Most of the structural characteristics of the houses in the sample were found to be significant with interior space (SQFT) indicating that there are decreasing returns from the physical area of the house. The percentage of open space within ¼ mile also exhibits decreasing returns. Demographic and neighborhood effects are also significant. Average education (EDULEV) is used as a proxy for community income and social status and the coefficient on this variable is found to be significant and positive. Crime, as expected, has a negative effect on property prices as does higher population density. We also find that houses sold in the winter have a somewhat lower selling price than houses sold during the remaining parts of the year. We find that travel time to the nearest highway has a significant and positively signed coefficient. This effect we believe is reflective of a preference to live in less noisy and more suburban areas. The selling price is negatively correlated with distance to the ocean and distance to lakes as expected.

---

spatially correlated variable we may have omitted in our model specification and which may be therefore reflected in the distribution of the residual terms.

Percentage of open space around a house and the diversity of land use are both found to be significant variables in determining property values. An increase in the percent of open space within a ¼ mile radius of a home increases the value of the property. Interestingly we note that the coefficient on the diversity index at a ¼ mile radius is negatively signed, indicating that people prefer to live in places with more homogenous land use in the immediate vicinity of their houses. However, as noted earlier, this index does not reflect the type of land use and therefore houses in commercial areas and near forested areas are both likely to have higher property values due to low diversity index values. The sign on this coefficient therefore establishes that there is a tendency for property prices to be higher in areas with a single land use. This is very likely influenced by zoning regulations and this effect would need to be more fully incorporated into the model in order to understand the effect of the diversity index more clearly.[8] These results are of particular interest to planning policies given that there is a higher value associated with certain types of land use and indeed with particular patterns in land use as shown by the diversity index.

The coefficient on the variable DEVELOP is found to be positive and significant. This suggests that houses in areas with high population density and high relative richness in land use fetch a higher selling price whereas houses in areas with low population density and low relative richness in land use have a lower selling price. If we translate this to urban and rural categories, based on population density, this result suggests that houses in urban areas with higher land use richness have a higher selling price than houses in urban areas with lower land use richness. This makes intuitive sense since, in urban, populated areas, there may be a preference for different amenities such as parks, shopping areas etc. Similarly, in rural areas where population density is lower, a low relative richness in land use/land cover results in lower selling prices for houses.

The interaction term implies that the elasticity of population density and richness will vary. We calculate the elasticity effect of the richness variable and estimate that the richness elasticity ranges from –0.0008 in areas of low population to 0.0045 in high population areas. This suggests that although house values are relatively inelastic with respect to the relative richness in land use/land cover, areas of high population density have a higher elasticity. As populations increase, the value of the house becomes more elastic with respect to land use/land cover.

CONCLUSIONS

This paper studies the value of environmental variables such as open space and land use diversity to choices made by human beings within a watershed context. In this it adds to the growing evidence that spatial patterns are influential in determining human preferences for their living spaces. We have also suggested an alternative test for spatial autocorrelation where we test whether our regression residuals are spatially correlated and whether these explain any variation in the model. We find that this is a simple test to use with a large data set such as ours where there is no basis for using the proximity of houses as a weighting matrix.

This paper has used a rich data set to show that variations in neighbourhood variables and land use pattern can have an effect on house values. In particular, we have contrived to show that the use of simple dummy variables to differentiate between rural and urban land use categories give us ambiguous and uninteresting results. On the other hand, the use of variables which attempt to capture some of the spatial characteristics of land use and land cover together with population density support the hypothesis that both scale and pattern are important in hedonic property analysis.

Acknowledgements: We would like to thank George Silva for his research assistance on the data set and Jackie Geoghegan, George Parsons and Robert Mendelsohn for useful comments on this paper.

[8] The diversity indices were calculated for both a ¼ mile and a 1 mile radius around each house. The ¼ mile radius was chosen to be representative of immediate walking distance or visual distance from a house. This latter variable was dropped due to insignificance.

The New Haven Watershed

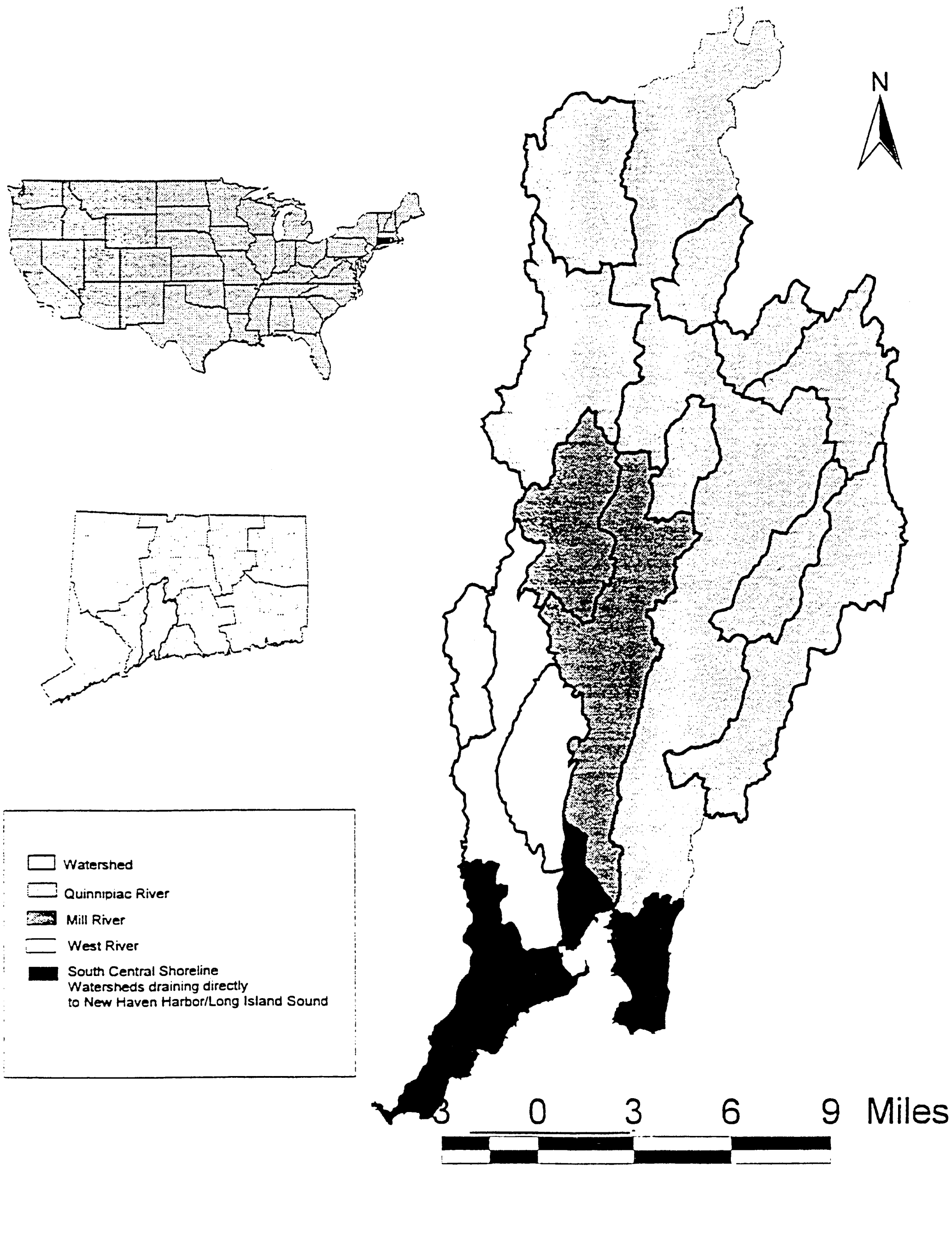
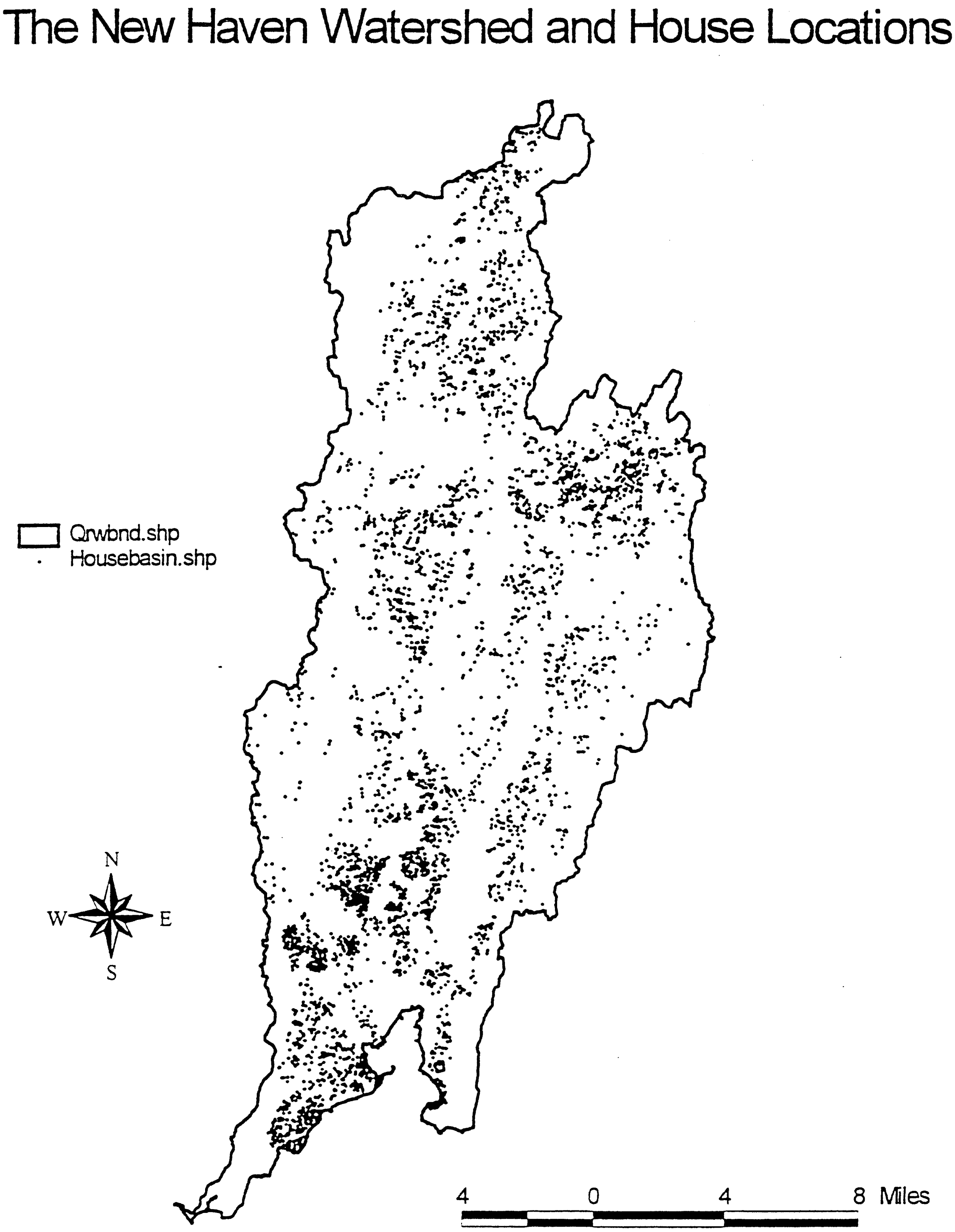


Figure 2



The New Haven Watershed and House Locations
Qrwbnd.shp
Housebasin.shp
N
W
E
S
4
0
4
8 Miles

Figure 3

Land Use Diversity at 1/4th mile

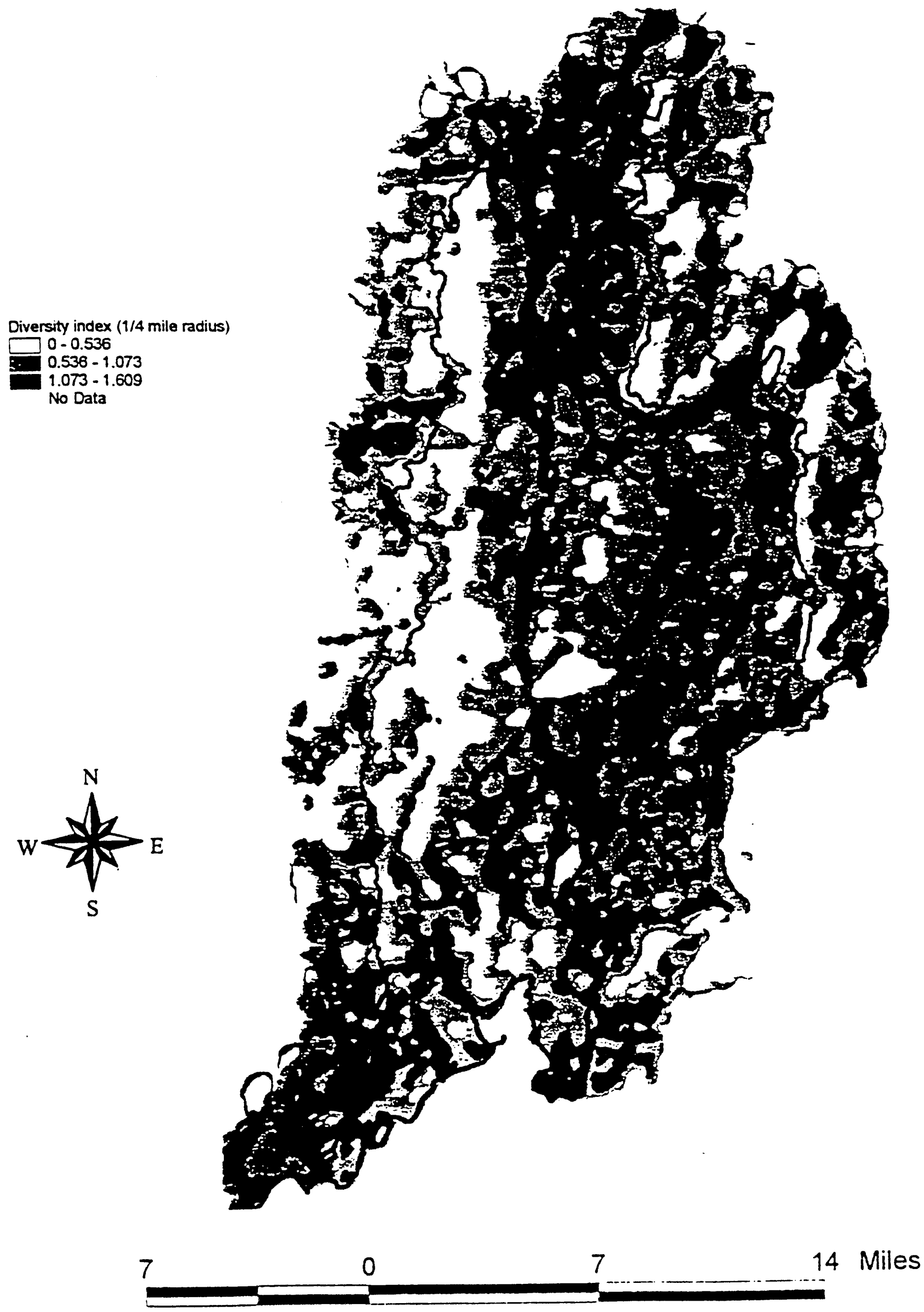


Table 1

Land Use	Land Use Code	Total Area (square feet)	Percentage of Area
Other	0	3,906,527.04	0.05%
Impervious Surface	1	291,959,641.54	4.00%
High Density-Residential/Commercial	2	390,811,852.46	5.35%
Medium Density Residential	3	1,566,848,786.62	21.45%
Surface – Roof	4	11,526,519.52	0.16%
Pavement/Road	5	2,383,238.65	0.03%
Turf/Grass	6	192,659,244.90	2.64%
Soil/Grass/Hay	7	259,141,178.26	3.55%
Grass/Hay Pasture	8	513,471,343.29	7.03%
Soil/Corn	9	27,659,796.81	0.38%
Grass/Corn	10	21,031,831.73	0.29%
Deciduous Forest	13	2,965,612,148.58	40.59%
Conifer Forest	14	92,309,041.32	1.26%
Deep Water	15	97,353,371.43	1.33%
Shallow Water	16	109,912,119.56	1.50%
Non-forest Wetland	17	3,164,307.18	0.04%
Forest Wetland	18	135,782,013.31	1.86%
Barren Land	19	185,268,873.09	2.54%
Bare Soil	20	145,496,886.99	1.99%
High Coast Marsh	22	62,213,104.30	0.85%
Major Road	25	227,096,298.97	3.11%
	Total	7,305,608,125.52	100.00%

Table 2

VARIABLE NAMES AND DEFINITIONS

Variable	Definition
SPRICE	Selling price of house
WINTER	Dummy variable for transactions occurring in winter months
ACRES	Lot size in acres
LEVELLOT	Dummy variable for a level lot
VIEW	Dummy for view (realtor determination)
SQFT	Number of square feet in the house
BATHS	Number of bathrooms
NGARAGE	Number of cars garage can hold
FIRE	Number of fireplaces
POOL	Dummy variable for the presence of a pool
DECKS	Dummy variable for the presence of a deck
CAIR	Dummy variable for the presence of central air conditioning
PUBWATER	Dummy variable for connection to a public water supply
ATTICP	Dummy variable for the presence of an attic
BNONE	Dummy variable for the lack of a basement
FINBASE	Dummy variable for finished basement
BRICK, CEDAR, CLAP, SHAKE, SHING, STONE, STUCCO, VINYL, WOODEXT	Dummy variables for the exterior construction material. Omitted is other exteriors not listed.
CAPE, COL, RAISE, RANCH, SPLIT, CONT, BUNG, VICT, TUDO, ALUM, EXTASBSES	Dummy variables for house style. Omitted is other house styles not listed.
PETRO	Dummy variable for the use of oil or gas for heating
AGE	Age of the house in years
LAKWTR	Distance to lake
EQUAL_MI	Equalized mill rate
COLLEGE	Percent of students continuing to college education at local high school
CRIME	Crime rate per 1000 people at town level (1994)
PWHITE	Percent of population in the block group that is white
WORKTIME	Average travel time to work in minutes for block group
EDULEV	Average number of years of education (adults over 25) for block group
POPDENSE	Population density for the block group (people/ha)
TCHIGH	Relative distance to nearest highway (weighted by type of road)
DOCEAN	Distance in feet from Long Island Sound
DIVERS1.4	Diversity index for a 1 and ¼ mile radius
POPEN4	Percent of landscape in open space
URBAN/RURAL	Dummy variables for majority land use determined to be either urban, suburban or rural
DEVELOP	Level of development determined by the relative richness of land use and population density

Table 3

DESCRIPTIVE STATISTICS OF SOME VARIABLES

VARIABLE	Minimum	Maximum	Mean
HOUSE VALUE (in US dollars, 1995-1997 selling prices)	$10,509	$729,416	$127,681
ACRES (area of the lot in acres)	0.03	80.7 2	0.6 2
SQFT (area of the house in sq.ft.)	300	14,000	1633.6
BATHS (number of bathrooms)	1	6.3	1.58
NGARAGE (number of garages)	0	8	1.23
FIRE (number of fireplaces)	0	8	0.71
EQUAL_MI (equalized mill rate)	12.25	30.28	21.35
COLLEGE (% of students continuing on to college)	70	86	76.63
CRIME (crime rate per 1000 people)	13.01	130.92	51.88
PWHITE (% of white population)	0	1	0.91
WORKTIME (average time to work in minutes)	9.17	25.22	19.24
EDULEV(average number of years of education (adults over 25))	10.12	17.52	13.3
POPDENSE (persons per hectare)	98.36	28,073.64	3,552.8
TCHIGH (weighted distance to highway in feet)	0.00	190,505.00	12,514.00
OCEAN (distance to Long Island Sound in feet)	100.00	143,252.00	53,003.28
DIVERS4 (diversity index for a ¼ mile radius around each house)	0.013	1.543	1.026
POPEN4 (% of open space within ¼ mile radius of each house)	0.00	100	36.19

Table 4

SELECTED REGRESSION RESULTS

VARIABLE	**Model 1 (log-linear, with urban/rural classifications)**	**Model 2 (log-linear, with spatially explicit variables)**
WINTER	-0.19052E-01 (-2.533)*	-0.19152E-01 (-2.554)*
ACRES	0.23126E-01 (5.708)*8	0.22512E-01 (5.562)**
ACRES2	-0.31502E-03 (-4.716)**	-0.30696E-03 (-4.602)**
SQFT	0.36801E-03 (25.294)**	0.36916E-03 (25.426)**
SQFT2	-0.29954E-07 (-16.452)**	-0.29970E-07 (-16.498)**
LAKWTR	-	-0.46010E-05 (-2.128)*
EQUAL_MI	-0.20317E-01 (-10.388)**	-0.20295E-01 (-10.338)**
COLLEGE	0.29694E-02 (2.767)**	0.34216E-02 (3.181)**
CRIME	-0.80597E-03 (-3.240)**	-0.79071E-03 (-3.176)**
PWHITE	0.58581 (16.448)**	0.58108 (16.301)**
WORKTIME	-0.45805E-02 (-2.703)**	-0.51622E-02 (-2.995)**
EDULEV	0.10547 (24.084)**	0.10421 (23.845)**
PDENSE	-0.15095E-12 (-2.712)**	-0.55421E-12 (-3.276)**
DOCEAN	-0.61457E-06 (-3.562)**	-0.49279E-06 (-2.907)**
URBAN1	0.28438E-01 (1.568)	-
RURAL1	-0.27118E-02 (-0.310)	-
DIVERSITY4	-	-0.76098E-01 (-3.033)**
POPEN4	0.23338 (3.775)**	0.44648 (5.374)**
$POPN4^2$	-0.20390 (-3.139)**	-0.41791 (-4.995)**
RICH14	-	-0.71371E-03 (-2.078)*
DEVELOP	-	0.59072E-14 (2.473)*
CONSTANT	9.2333 (82.710)**	9.3438 (79.943)**
R^2	0.77	0.78
F	413.08	393.83
OBSERVATIONS	4326	4326

t-statistics in parenthesis; * and ** denote significance levels at the 0.1 and 0.01 levels respectively.

APPENDIX

Complete Model Results

VARIABLE	Model 1 (log-linear, with urban/rural classifications)	Model 2 (log-linear, with spatially explicit variables)
WINTER	-0.19052E-01	-0.19152E-01
	(-2.533)*	(-2.554)*
ACRES	0.23126E-01	0.22512E-01
	(5.708)**	(5.562)**
$ACRES^2$	-0.31502E-03	-0.30696E-03
	(-4.716)**	(-4.602)*8
LEVELLOT	0.19697E-01	0.19521E-01
	(2.539)*	(2.520)*
VIEW	0.32624E-01	0.33771E-01
	(1.756)	(1.821)
SQFT	0.36801E-03	0.36916E-03
	(25.294)**	(25.426)**
$SQFT^2$	-0.29954E-07	-0.29970E-07
	(-16.452)**	(-16.498)**
BATHS	0.42591E-01	0.42506E-01
	(5.578)*	(5.579)**
LEVELS	0.56602E-01	0.56282E-01
	(6.698)**	(6.675)**
FIRE	0.62334E-01	0.61777E-01
	(9.959)**	(9.890)**
POOL	0.44885E-01	0.44524E-01
	(4.160)**	(4.137)**
DECKS	0.44399E-01	0.45640E-01
	(5.136)**	(5.291)**
CAIR	0.59056E-01	0.59133E-01
	(6.472)**	(6.496)**
PUBWATER	-0.63203E-02	-0.53575E-02
	(-0.521)	(-0.439)
ATTICP	0.81358E-01	0.82968E-01
	(8.084)**	(8.259)**
BNONE	-0.12208	-0.12503
	(-5.168)**	(-5.302)**
FINBASE	0.23021E-01	0.21325E-01
	(2.973)**	(2.753)**
FWOOD	0.27164E-01	0.26302E-01
	(3.661)**	(3.552)**
RANCH	0.75399E-01	0.73478E-01
	(6.466)**	(6.309)**
LAKWTR	-0.28311E-05	-0.46010E-05
	(-1.335)	(-2.128)*
VINYL	0.35120E-01	0.34468E-01
	(4.306)**	(4.234)**
AGE	-0.25112E-02	-0.24801E-02
	(-17.135)**	(-16.896)**
EQUAL_MI	-0.20317E-01	-0.20295E-01
	(-10.388)**	(-10.338)**
COLLEGE	0.29694E-02	0.34216E-02
	(2.767)**	(3.181)**
CRIME	-0.80597E-03	-0.79071E-03

	(-3.240)**	(-3.176)**
PWHITE	0.58581	0.58108
	(16.448)**	(16.301)**
WORKTIME	-0.45805E-02	-0.51622E-02
	(-2.703)**	(-2.995)**
EDULEV	0.10547	0.10421
	(24.084)**	(23.845)**
PDENSE	-0.15095E-12	-0.55421E-12
	(-2.712)**	(-3.276)**
DOCEAN	-0.61457E-06	-0.49279E-06
	(-3.562)**	(-2.907)**
TCHIGH	0.60932E-06	0.32566E-06
	(2.003)*	(1.046)
URBAN1	0.28438E-01	
	(1.568)	
RURAL1	-0.27118E-02	
	(-0.310)	
DIV1		-0.17540E-01
		(-0.660)
DIV4		-0.76098E-01
		(-3.033)**
POPN4	0.23338	0.44648
	(3.775)**	(5.374)**
POPN42	-0.20390	-0.41791
	(-3.139)**	(-4.995)**
NGARAGE	0.40991E-01	0.41299E-01
	(8.043)**	(8.120)**
RICH14		-0.71371E-03
		(-2.078)*
DEVELOP		0.59072E-14
		(2.473)*
CONSTANT	9.2333	9.3438
	(82.710)**	(79.943)**
R^2	0.77	0.77
F	255.82	260.83
OBSERVATIONS	4326	4326

t-statistics in parenthesis; * and ** denote significance levels at the 0.1 and 0.01 levels respectively.

References:

Berger, M.C. and G.C. Blomquist (1992) Mobility and destination in migration decisions: the role of earnings, quality of life and housing prices. *Journal of Housing Economics.* Vol 2 (1): 37-59.

Blomquist, G. C., M.C. Berger and J.P. Hoehn (1988) New estimates of quality of life in urban areas. *The American Economic Review.* Volume 78 (1). pp. 89-107.

Bockstael, N.E. "Economics and Ecological Modeling: The Importance of a spatial perspective". *American Journal of Agricultural Economics*, December, 1996, pg 1168-1180.

Bockstael, N and K. Bell (1997) Landscape patterns and water quality: the effect of differential land management control. In R. Just and S. Netanyahu (eds.) Conflict and Cooperation in Trans-boundary Water Resources. Kluwer Publishers.

Brashares, F.N (1985) Estimating the instream value of water quality in Southeastern Michigan. Unpublished Phd dissertation, University of Michigan.

Feenburg, D. and E. S. Mills (1980) Measuring the benefits of water pollution abatement. Academic Press. New York.

Forman, R. (1985) Land Mosaics: the ecology of landscapes and regimes: Cambridge University Press.

Freeman, A. Myrick, (1993). The measurement of environmental and resource values: theory and methods. Resources for the Future.

Geoghegan, J., L.A. Wainger and N.E. Bocksteal. (1997) Spatial landscape indices in a hedonic framework: An ecological economics analysis using GIS. *Ecological Economics.* Vol. 23: 251-264.

Griliches, Z (ed.) (1971) Price indexes and quality changes. Harvard University Press, Cambridge, Massachusetts.

Harrison and Rubinfeld (1978) Hedonic housing prices and the demand for clean air. *Journal of Environmental Economics and Management.* Volume 5 (1). pp. 81-102.

Haurin, D. R. (1980) The effect of property taxes on urban areas. *Journal of Urban Economics.* Volume 7 (3). pp. 384-96.

Lansford, N. H., Jr. and L.L. Jones.(1995) Marginal price of lake recreation and aesthetics: an hedonic approach . *Journal of Agricultural and Applied Economics.* Volume 27(1) pp. 212-23, July.

Leggett, C and N. E. Bockstael (1998). Evidence of the Efffects of Water Quality on Residential Land Prices. University of Maryland, AREC working paper.

Li, M.M. and H.J. Brown (1980) Micro neighbourhood externalities and hedonic housing prices. *Land Economics*. Volume 56 (2). pp. 125-41.

Murdoch, J. C. and M.A. Thayer (1988) Hedonic price estimation of variable urban air quality. *Journal of Environmental Economics and Management*. Volume 15 (2) pp. 143-46.

Palmquist, Raymond (1991)..Hedonic Methods. In measuring the demand for environmental quality. In Braden and Kolstad (Eds.) , Elsevier Science Publishers B.V. North-Holland.

Palmquist, R.B. (1982) Valuing localized externalities. *Journal of Urban Economics* Vol 31 : 59-82.

Pogodzinski, J.M. and Sass, T.R. (1991) The theory and estimation of endogenous zoning. *Regional Science and Urban Economics*. Volume 24 (5) pp. 601-630.

Potepan, M.J., (1996) Explaining intermetropolitan variation in housing prices, rents and land prices. *Real Estate Economics*. Volume 24 (2) pp. 219-45.

Roback, J. (1982) Wages, rents and the quality of life. *Journal of Political Economy*. Volume 90. pp. 1257-1277.

Rosen, S. (1979) Wages based indexes of urban quality of life. In P. Miegkowski and M. Straszheim, (eds.) *Current Issues in Urban Economics*. Johns Hopkins University Press, Baltimore.

Rosen, S. (1974) Hedonic prices and implicit markets: product differentiation in perfect competition. *Journal of Political Economy*. Volume 82 (1). pp. 34-55.

Turner,M.G. (1989) Landscape ecology: the effect of pattern on process. *Annual Review of Ecology and Systematics*. Vol 20: 171-197.