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Estimating the economic value of cultural ecosystem services in an urbanizing area using hedonic pricing

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ABSTRACT

A need exists to increase both knowledge and recognition of the values associated with ecosystem services and amenities. This article explores the use of hedonic pricing as a tool for eliciting these values. We take a case study approach, valuing several services provided by ecosystems, namely aesthetic quality (views), access to outdoor recreation, and the benefits provided by tree cover in Dakota County, Minnesota, USA. Our results indicate that these services are valued by local residents and that hedonic pricing can be used to elicit at least a portion of this value. We find that many aspects of the aesthetic environment significantly impact home sale prices. Total view area as well as the areas of some land-cover types (water and lawn) in views positively influenced home sale prices while views of impervious surfaces generally negatively influenced home sale price. Access to outdoor recreation areas significantly and positively influenced home sale prices as did tree cover in the neighborhood surrounding a home. These results illustrate the ability of hedonic pricing to identify partial values for ecosystem services and amenities in a manner that is highly relevant to local and regional planning. These values could be used to increase policy-maker and public awareness of ecosystem services and could improve their consideration in planning and policy decisions.

1. Introduction

Ecosystem services and amenities are clearly valuable, but, because their economic values are poorly recognized, they are often neglected in planning and policy making in the US. As a result, these services and amenities typically decline as American communities urbanize. Improved monetization of local and regional ecosystem services would serve to increase their consideration in local and regional policy making and planning, making them more difficult to disregard.

A number of methods exist for valuing these services and amenities. These include production function methods in which an ecosystem service or amenity is viewed as an input into the production of a marketed good and its value is estimated based on that good's price (e.g., Barbier, 2007; Barbier and Strand, 1998; Bell, 1997; Klemick, 2011; Richmond et al., 2007; Sathirathai and Barbier, 2001; Simonit and Perrings, 2011), replacement cost analyses that use the price of the least-cost alternative means for providing a service as a proxy for its value (e.g., Allsopp et al., 2011; Ashendorff et al., 1997; Hougner et al., 2006; Kovacs et al., 2011; NRC, 2000), stated preference approaches that use survey results to determine individuals' willingness-to-pay for an increase in a service or willingness-to-accept compensation for a decrease in a service (e.g., Boyle et al., 1994; Campos et al., 2009; Carson et al., 1992; del Saz-Salazar and Rausell-Köster, 2008; Earnhart, 2006; McGonagle and Swallow, 2005; Sayadi et al., 2009), and household production functions that value environmental goods and services based on the sale prices of marketed goods related to them (e.g., Abdalla et al., 1992; Bolitzer and Netusil, 2000; Brasington and Hite, 2003; Cavailhès et al., 2009; Cho et al., 2010, 2011; Conway et al., 2010; Geoghegan, 2002; Hardie et al., 2007; Harrington et al., 1989; Irwin, 2002; Jim and Chen, 2010; Leggett and Bockstael, 2000; Lew and Larson, 2005; Munroe, 2007; Netusil et al., 2010; Phaneuf et al., 1998; Poudyal et al., 2009; Siderelis et al., 1995; Snyder et al., 2008; Tyrväinen and Miettinen, 2000; Wilson and Carpenter, 1999). Each of these methods can estimate a portion of the economic value of an ecosystem service and is thus relevant to different applications for which economic values for services are desirable.

We consider hedonic pricing, a household production function approach, to provide a particularly relevant means for measuring

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the local and regional values of ecosystem services. Using this method, one can elicit the economic values for different levels of service delivery as reflected in the amount individuals pay for their residences or related goods. As such hedonic pricing models can help us understand an important portion of the value of ecosystem services, the portion that contributes directly to tax bases and that is thus particularly pertinent to community land-use policy. Using this method, the values of ecosystem services may be estimated straightforwardly using readily-available data. This method is also transparent such that local and regional planners and policy makers can readily understand how values are calculated and may apply them to decision making.

The present study explores the use of hedonic pricing to elicit the values of several cultural ecosystem services, ecosystem services from which people derive nonmaterial (e.g., recreational, educational, aesthetic, cultural) benefits (Millennium Ecosystem Assessment, 2005) using Dakota County, a rapidly-developing county in the Twin Cities metropolitan area (TCMA) of Minnesota, USA, as our study area. The services examined in this study include local aesthetic quality, access to outdoor recreation areas, and tree cover and associated services. This research makes a number of contributions to the existing literature:

1. Through this research, we identify the economic values residential property owners hold for the target services in this study area thus improving our understanding of the values of these services regionally.
2. This research provides valuable information for the evaluation of land-use policy. Several cities in Dakota County are considering policies aimed at protecting or providing vegetation, particularly trees, and public open space as well as preserving the local aesthetic quality of their environment. The results of this study will inform these policies.
3. This analysis and its results illustrate the utility and relevance of hedonic pricing as a method for estimating the values of ecosystem services and amenities and informing policy in general.
4. This study provides evidence to resolve discrepancies in the values of these ecosystem services as estimated by previous research in this study area as well as to provide a more thorough evaluation of their values through the calculation of a single hedonic model that incorporates these multiple services.

2. Past value estimates for ecosystem services

This study focuses on three ecosystem amenities and services of particular concern in the study area: the provision of areas for outdoor recreation, scenic quality, and tree cover. The first two of these are cultural ecosystem services. The last, tree cover, is not a service *per se*, but, rather provides a series of cultural, supporting, regulating, and provisioning services, among them carbon storage, local and regional climate regulation, enhancement of the aesthetic environment, and air pollution mitigation (Beckett et al., 2000; Brack, 2002; Dwyer et al., 1991, 1992; Ellis et al., 2006; Laverne and Lewis, 1996; Laverne and Winson-Geideman, 2003; McPherson et al., 2005; Nowak and Crane, 2002; Nowak et al., 2006a, 2006b, 2000c; Sailor, 1995; Scott et al., 1998; Simpson, 1998; Simpson and McPherson, 1996). The present study estimates the values of the services provided by tree cover with percent tree canopy cover acting as a proxy for these services. All services and amenities on which this study focuses have received some degree of attention in the economic valuation literature and were in many cases found to be valuable to humans, so it was expected they would be readily valued in our study. However, the values estimated in these studies vary dramatically even within the study area on which this paper focuses. Additionally, no studies have examined all of these services simultaneously. Thus, through this study we hoped to both resolve issues related to service values as well as to combine them in one hedonic model so that we might better elicit their values.

Open space, which provides many services including areas for outdoor recreation and enhanced scenic quality, has previously been found to contribute positively to property values. A literature review of 30 studies on the impact of parks on residential property values found that parks nearly always positively impacted property values (Crompton, 2001). Although these benefits varied considerably with the characteristics of parks, they were generally 10–20 percent of total property values and extended 500–2000-feet (approximately 150–610-m) from parks. More recent studies have supported these conclusions (Asaber and Huffman, 2009; Bolitzer and Netusil, 2000; Cho et al., 2006, 2010; Conway et al., 2010; Earnhart, 2006; Hobden et al., 2004; Jim and Chen, 2010; Lutzenhiser and Netusil, 2001; MacDonald et al., 2010; Poudyal et al., 2009; Waltert and Schläpfer, 2010; Wu et al., 2004). In general, these studies indicate the impact of open space on property values to be greater for natural area parks (Lutzenhiser and Netusil, 2001; Waltert and Schläpfer, 2010), larger parks (Cho et al., 2010; Tajima, 2003), and permanently-protected parks (Earnhart, 2006; Geoghegan, 2002; Irwin, 2002) and that the impact of open space on home sale price may vary with neighborhood context (Cho et al., 2008, 2010; Munroe, 2007). Although many studies have examined the value of open space, these studies are difficult to compare due to differences in their methodologies, study areas, and temporal coverage. However, nearly all studies indicate a positive economic value. As such, loss or creation of open space is likely to impact communities economically.

Scenic quality is commonly assessed by examining the characteristics of views. Previous studies that assessed view quality found that its value was often reflected in property values. A review of the economic values associated with views found that their impact varied, but that many view types had positive impacts on residential home values (Bourassa et al., 2004). Examination of the studies reviewed in this article as well as subsequent studies indicates that views of certain land-use and cover types, notably water (Benson et al., 1998; Bishop et al., 2004; Bourassa et al., 2004; Jim and Chen, 2006, 2009, 2010; Loomis and Feldman, 2003; Luttik, 2000; Sander and Polasky, 2009), forests (Cavailhès et al., 2009; Tyrväinen and Miettinen, 2000), grassy areas (Des Rosiers et al., 2002; Sander and Polasky, 2009), and urban parks (Bishop et al., 2004; Jim and Chen, 2006), positively impact home sale prices as do views with larger areal extents (Sander and Polasky, 2009). Views of built and industrial land-use types may negatively impact property values (Jim and Chen, 2009; Lake et al., 2000a, 2000b), while views of other land-use and cover types may have little or no impact on property values. The arrangement of features in views has also been found to impact home sale prices (Cavailhès et al., 2009; Cho et al., 2008). Thus, as view characteristics impact the values of single-family homes, they are likely to impact local tax bases. Because views are readily and irreversibly impacted by land-use change, they should receive consideration in land-use planning and policy making.

Tree cover in urban areas provides multiple ecosystem services some of which, particularly the provision of local scenic quality and climate regulation, may be capitalized in home sale prices. In general, studies indicate that tree cover enhances home sale prices and that impacts vary with geographic location, tree species, landscape configuration, and tree health (Cho et al., 2009; Dombrow et al., 2000; Holmes et al., 2006; Kovacs et al., 2011; Mansfield et al., 2005; Morales, 1980; Morales et al., 1976; Price et al., 2010; Thompson et al., 1999). Studies also indicate that the level of tree cover in a neighborhood (i.e., low versus high) impacts the extent to which increasing tree-cover percentages impact home sale prices and that, in areas with already high levels of tree cover, increases in tree cover may reduce home prices (Des Rosiers et al., 2002; Netusil et al., 2010). The impact of tree cover on home sale prices has also been found to vary with neighborhood context. For example, in a highly urban environment, tree cover negatively impacted sale prices (Kestens et al., 2004). Additionally, studies indicate that the level of tree cover within different neighborhood areas around homes impacts sale prices, with higher levels of tree cover in areas close to parcels (i.e., within 250-m) having relatively high and positive impacts on home sale prices while tree cover in more distant neighborhoods has little impact (Sander et al., 2010). Because tree cover is readily altered by development and impacts on home sale prices, these values could improve land-use decision-making and policy.

Previous studies have estimated the values of some ecosystem services in the TCMA, but their findings do not fully agree and none have examined these services in concert. Doss and Taff (1996) examined the impacts of wetland types and proximity on the assessed values of residential properties in Ramsey County, MN, a heavily-urbanized county located directly north of Dakota County that includes the city of St. Paul. Their findings indicate that wetland and lake proximity generally increases home values with a move 10 m closer to a wetland or related feature increasing home values by between $99 and $145 (1990US$), and a lake view adding approximately $45,950 to a home's assessed value. Anderson and West (2006) examined the impacts of open space proximity, type, and size on residential property values in the seven-county TCMA that includes Dakota County. Their findings indicate that proximity to neighborhood and specialty parks, lakes, and rivers increases a home's sales prices by between 0.0035% and 0.0342% per one percent decrease in distance such that reducing the distance from a home to a neighborhood park or specialty park increases sales prices by about $246 and $1790 (1997US$) respectively. They also found that a home's location and neighborhood characteristics influence the effect of open space on sales price, for example with the impact of parks on sale prices being much higher in more dense, wealthier neighborhoods. Because these studies used sale and tax assessor data from a time period before the TCMA housing boom, however, the values they estimate are difficult to compare to values estimated based upon sales occurring during and after this boom.

Two additional papers valued ecosystem services like those examined in this study for a corresponding time period (2005) and similar location (Table 1). The first of these (Sander and Polasky, 2009) focused on Ramsey County. This study valued two services examined in this study, scenic quality and access to outdoor recreation areas, finding that increasing access to all types of

Table 1
Marginal implicit prices calculated for ecosystem services in the metropolitan Twin Cities area of Minnesota for 2005 from three studies. Sander and Polasky (2009) was conducted in highly urbanized Ramsey County. Sander et al. (2010) focused on both Ramsey County and an urbanizing county to the south, Dakota County. The current paper examined Dakota County alone. Marginal implicit prices were calculated at the mean home sale price for the counties of focus: $255,955 for Ramsey County, $287,637 for Dakota and Ramsey Counties together, and $319,073 for Dakota County alone.

Variable	Sander and Polasky (2009)				Sander et al. (2010)				Current paper			
	Measurement	Coeff	MIP	% Change	Measurement	Coeff	MIP	% Change	Measurement	Coeff	MIP	% Change
Access to outdoor recreation areas												
Distance to park	Road distance (m)	Neg	$136[a]	0.0465	Road distance (m)	NS			Road distance (m)	Neg	$13[a]	0.0404
Distance to trail	Euclidean distance (m)	Neg	$119[a]	0.0531	Euclidean distance (m)	NS			Not used			
Distance to lake	Euclidean distance (m)	Neg	$216[a]	0.0844	Euclidean distance (m)	Neg	$134.58[a]	0.0469	Euclidean distance (m)	Neg	$129[a]	0.0041
Distance to stream	Euclidean distance (m)	Neg	$127[a]	0.0496	Not used				Not used			
Tree cover												
Tree cover parcel	Not used				Mean % tree cover	NS			Mean % tree cover	NS		
Tree cover in 100 m neighborhood	Not used				Mean % tree cover	Pos	$1371[c]	0.4766	Mean % tree cover	Pos	$1853[c]	0.5807
Tree cover in 250 m neighborhood	Not used				Mean % tree cover	Pos	$836[c]	0.2906	Mean % tree cover	Pos	$1030[c]	0.3228
Tree cover in 500 m neighborhood	Not used				Mean % tree cover	NS			Mean % tree cover	Pos	$1947[c]	0.6102
Tree cover in 750 m neighborhood	Not used				Mean % tree cover	NS			Mean % tree cover	Pos	$1102[c]	0.3454
Tree cover in 1000 m neighborhood	not used				Mean % tree cover	NS			Mean % tree cover	NS		
View												
View area	Area in m^2	Pos	$386[b]	0.1508	Area in ha	Pos	$213.64[d]	0.0743	Area in ha	Pos	$181[d]	0.0568
View richness	%	Neg	−$2834[c]	−1.1072	Not used				Not used			
Grass view	% of view	Pos	$5517[c]	2.1555	Not used				m^2 in view	Pos	$1741[d]	0.5456
Water view	% of view	Pos	$7417[c]	2.8978	Not used				m^2 in view	Pos	$81[d]	0.0253
View of 26–50% impervious surfaces	Not used				Not used				m^2 in view	Neg	−$831[d]	−0.2604
View of 51–75% impervious surfaces	Not used				Not used				m^2 in view	Neg	−$1,035[d]	−0.3244
Forest view	% of view	ns			Not used				m^2 in view	NS		
Downtown St Paul view	Presence/absence	Neg	−$11,944	−4.6664					Not used			

[a] Per 100 m decrease.
[b] Per 100 m^2 (10%) increase.
[c] Per 10% increase.
[d] Per ha increase.

outdoor recreation areas and many view characteristics increased home sale prices. The second study (Sander et al., 2010) focused on both Ramsey and Dakota Counties and estimated values for tree cover as well as recreational access. This study's results indicated that increased access to some types of outdoor recreation areas increased home sale prices and that tree cover in the local neighborhoods around homes was positively related to home sale price. This study measured only view area, but found a significant and positive relationship between this variable and home sale prices. The values estimated by the later study (Sander et al., 2010) generally were somewhat lower than those estimated by the earlier one for comparable variables. The lack of agreement between these two studies in many of their aspects as well as the lack of relevant view and tree cover-related variables to compare between them makes drawing general conclusions about the value of these amenities in this area difficult. As such this study, by calculating values for many of these amenities, will improve our understanding of their value in this region and of how this value varies with locational context.

3. Methods

3.1. Hedonic pricing

This study uses hedonic pricing, a household production function technique that estimates the partial economic value of changes in an ecosystem service or amenity based on the sale prices of similar properties (e.g., residential homes) with different levels of that amenity, to assess the economic values of the three target services and amenities in the year 2005. Hedonic pricing models typically estimate the marginal implicit prices associated with a change in the attributes of a property by estimating the relationship between these attributes and the property's sale price or assessed value (Freeman, 2003). Most commonly, these studies focus on the values of single-family residential homes, but may also utilize lease values for commercial or residential rental units. The present study uses the sales prices of single-family residential homes to construct a hedonic pricing model that relates sale price to the structural, neighborhood, and environmental aspects of homes through the use of ordinary least squares (OLS) regression and spatially simultaneous autoregressive (SAR) error modeling. The OLS model used may be written as:

$$\ln P_i = \beta_0 + \beta_1 S_i + \beta_2 N_i + \beta_3 Q_i + \varepsilon_i$$

Here, $\ln P_i$ represents the natural log of property i's sale price, S_i represents a vector of property i's structural characteristics (e.g., lot size, home age), N_i is a vector of neighborhood characteristics (e.g., development intensity), Q_i is a vector of environmental characteristics (e.g., recreation area access, percent tree cover on parcel), and ε_i is an error term. Because we expected the impact of some variables (e.g., distance variables, home square footage, lot acreage) to decline as their values increased, we used their natural logs in our model. We also included a squared term for home age because we expected its impact to become insignificant or change direction at some value, such that newer homes would decrease in value with increasing age to a certain age and then would increase in value.

Two issues, heteroscedasticity and spatial autocorrelation, may complicate the estimation of hedonic pricing models, and, indeed, any model generated using OLS regression with spatial data. To identify whether these issues complicate a particular model, one may test for spatial autocorrelation using Moran's I statistic. If the result is significant, one may then use Lagrangian multiplier diagnostics to assess whether this autocorrelation is best explained by assuming spatial autocorrelation in the error term (e.g., when a spatially-structured predictor variable is omitted from a model); in the lag term (e.g., when spatial autocorrelation is present only in the dependent variable); or in both terms. Once the likely source of spatial autocorrelation is identified, a number of modeling methods exist to address it. One of these is SAR modeling, which augments standard OLS models by adding a term to incorporate the spatial structure of the autocorrelation in the dataset (Cressie, 1993; Haining, 2003). In SAR models a user-defined spatial weights matrix that identifies the weight of each neighbor to a given observation is used to implement the added term. This weights matrix may be defined in a number of ways (Anselin and Bera, 1998; Fortin and Dale, 2005), most commonly based on distance such that closer neighbors receive higher weights in accounting for patterns in the dependent variable not accounted for by the independent variables.

Three types of SAR models exist: error, lag, and mixed (Anselin, 1988; Cliff and Ord, 1981; Haining, 2003). SAR error models are used to address autocorrelation in the error term. These models add an additional term, λWu, to the OLS expression to represent the spatially-dependent error term's spatial structure. The SAR error model may be summarized as:

$$Y = X\beta + \varepsilon_i + \lambda Wu$$

where Y is the dependent variable, X is a matrix, β is a vector that represents the slopes associated with the explanatory variables in the original predictor matrix, λ is the spatial autoregression coefficient, W represents a spatial weights matrix used in model estimation, and u represents a spatially-dependent error term. The SAR lag model, which is used to address spatial autocorrelation in the lag term, adds a term to account for spatial autocorrelation in the dependent variable to the standard OLS regression such that:

$$Y_i = X\beta + \varepsilon_i + \rho WY$$

where ρ is the autoregression coefficient and Y is the response variable. When spatial autocorrelation exists in both the lag and error terms, a SAR mixed or Durbin model may be used. This model adds an additional term, $WX\gamma$, to represent the autocorrelation coefficient of the lagged independent variables, where γ is the autoregression coefficient. SAR mixed models may thus be represented as follows:

$$Y_i = X\beta + \varepsilon_i + \rho WY + WX\gamma$$

In implementing our hedonic pricing model, we use these models in cases where statistical tests indicate they are appropriate.

3.2. Study area

Dakota County, located in east-central Minnesota in the southeastern portion of the TCMA (Fig. 1), consists of 21 cities and 13 townships with a total population of approximately 390,000. In the last 20 years, this county has experienced rapid population growth and associated urbanization, changing from a largely agricultural to a more suburban county that acts as bedroom community for the cities of Minneapolis and Saint Paul. As calculated from a historical land use dataset available from the Twin Cities Metropolitan Council (TCMC), in 1984, for example, 80% of the county was occupied by agricultural land use while 10% was occupied by built land uses. By 2005, the year on which this study focuses, agriculture land use had declined to occupy less than 65% of the county while built land uses had grown to cover approximately 20%. The county presently contains a mix of land uses ranging from urban and suburban to agricultural and is dominated by urban and suburban

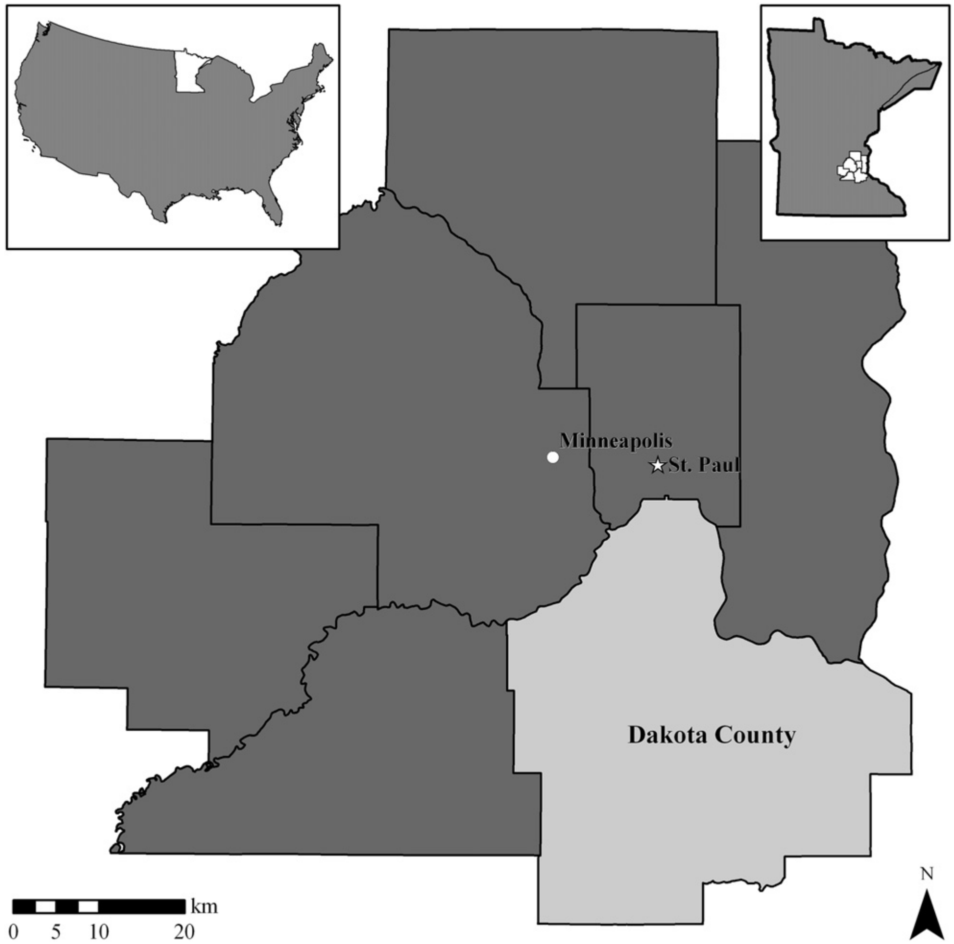

Fig. 1. The location of the study area, Dakota County, Minnesota, USA.

land uses in the north and west and agricultural land uses in the south and east. Rapid urbanization is expected to continue into the foreseeable future. As such Dakota County may be considered typical of many rapidly-urbanizing areas of the U.S.

Previous studies (Anderson and West, 2006; Sander and Polasky, 2009; Sander et al., 2010) have considered this county as well as other counties in the seven-county TCMA to be one housing market that contains residential areas that support the centers of employment found in the cities of St. Paul and Minneapolis. Home buyers act to maximize their utility be selecting among the neighborhood submarkets in these counties. In the present study, we examine the Dakota County housing market in which even rural areas over an hour's drive from Minneapolis and St. Paul act largely to support the Twin Cities with these cities acting as employment centers for this county.

3.2.1. Data

Many of the data used in constructing the hedonic pricing model originated in the Metropolitan Twin Cities Parcel Dataset, which consists of spatially-referenced sale, tax, and structural data for all parcels in the seven-county TCMA and is available from the TCMC. We identified a total of 5094 single-family residential properties that sold in Dakota County during the year 2005 for which full valid data were available. Excluded observations included properties for which data for one or more variables of interest were missing or that had unlikely values for any variables, for example, indicating that the home had been built in the year 1602 or that a 900-square-foot home sold for over $2,000,000. These 5094 properties acted as our sample in constructing our hedonic pricing model.

For each of our sample properties, we identified a series of structural, neighborhood, and environmental attributes related to property sales price (Tables 2 and 3). Most structural attributes as well as sale prices came directly from the Twin Cities Parcel Dataset. Structural attributes included finished square footage, lot size, property tax rate, and home age variables as well as dummy variables to indicate sale month. The parcel dataset did not contain some variables (e.g., numbers of bedrooms, numbers of bathrooms) that are typically significant predictors of home sale price in hedonic pricing studies. This creates the potential for omitted variable bias which could impact estimates from this study if significant variation exists within neighborhoods used as fixed effects (see below) or the spatial weights matrix used did not accurately identify neighbors. We addressed this using the best available data on structural characteristics and by carefully selecting our spatial weights matrix and neighborhood fixed effects. In addition to these variables, we calculated a dummy variable to identify whether or not a home was situated in a Federal Emergency Management Agency (FEMA) floodway using a GIS dataset that delineated such floodways available from the Minnesota Department of Natural Resources (MNDNR).

We quantified neighborhood characteristics in a GIS environment using several additional datasets. We estimated mean percent impervious surface to quantify development intensity in a neighborhood as the mean percentage of impervious surface within

Table 2
Definitions of variables used in the hedonic pricing model with predicted effects on home sale price.

Variable	Definition	Expected relationship to home sale price
Structural variables		
Price	Sale price for home	N/A
Acres	Lot size in acres	Positive
Finsqft	Home finished square footage	Positive
Home_age	Age of home in years	Positive/negative[a]
Tax_rate	Home's tax rate as a percentage	Negative
Flood	Dummy variable for location in a FEMA floodway (0 if no, 1 if yes)	Negative
Neighborhood variables		
Impervious	Mean percent impervious surface within 500 m of home	Negative
CBD	Euclidean distance in meters from home to closest central business district (downtown Minneapolis or St. Paul)	Negative[b]
Sale month dummy variables (ref. month is February; 1 for sale in month, 0 otherwise)		
Jan	Dummy variable for sale in January	Positive
Mar	Dummy variable for sale in February	Positive
Apr	Dummy variable for sale in April	Positive
May	Dummy variable for sale in May	Positive
June	Dummy variable for sale in June	Positive
July	Dummy variable for sale in July	Positive
Aug	Dummy variable for sale in August	Positive
Sept	Dummy variable for sale in September	Positive
Oct	Dummy variable for sale in October	Positive
Nov	Dummy variable for sale in November	Positive
Dec	Dummy variable for sale in December	Positive
Submarket dummy variables (ref. location is Simley HSD; 1 in district, 0 otherwise)		
Applevalley	Dummy variable for location in Apple Valley High School district	Positive
Burnsville	Dummy variable for location in Burnsville High School district	Positive
Eagan	Dummy variable for location in Eagan High School district	Positive
Eastview	Dummy variable for location in Eastview High School district	Positive
Farmington	Dummy variable for location in Farmington High School district	Positive
Hastings	Dummy variable for location in Hastings High School district	Positive
Lakeville	Dummy variable for location in Lakeville High School district	Positive
Rosemount	Dummy variable for location in Rosemount High School district	Positive
S_Stpaul	Dummy variable for location in South St. Paul High School district	Positive
W_Stpaul	Dummy variable for location in West St. Paul High School district	Positive
Nfld_Rndlph	Dummy variable for location in Northfield or Randolph High School districts	Positive
Ecosystem service and amenity variables		
Access to outdoor recreation areas		
Lake	Euclidean distance in meters from home to closest lake	Negative[a]
Park	Road distance in meters from home to closets 1 ha or large park	Negative[a]
Tree cover		
Tree_parcel	Mean percent tree cover on the home's parcel	Positive
Tree_100	Mean percent tree cover in 100 m neighborhood around parcel	Positive
Tree_250	Mean percent tree cover in 100–250 m neighborhood around parcel	Positive
Tree_500	Mean percent tree cover in 250–500 m neighborhood around parcel	Positive
Tree_750	Mean percent tree cover in 500–750 m neighborhood around parcel	Positive
Tree_1000	Mean percent tree cover in 750–1000 m neighborhood around parcel	Positive
View		
View_area	Total areal extent of a home's viewshed in ha	Positive
IMP5_10	Area of 5–10% impervious land cover in home's viewshed in meters	Negative
IMP11_25	Area of 11–25% impervious land cover in home's viewshed in meters	Negative
IMP26_50	Area of 26–50% impervious land cover in home's viewshed in meters	Negative
IMP51_75	Area of 51–76% impervious land cover in home's viewshed in meters	Negative
IMP76_100	Area of 76–100% impervious land cover in home's viewshed in meters	Negative
Lawn	Area of short grass (lawn) land cover in home's viewshed in meters	Positive
Mtd_tallgr	Area of maintained tall grassland cover in home's viewshed in meters	Positive
Forest	Area of forest land cover in home's viewshed in meters	Positive
Shrub	Area of shrub land cover in home's viewshed in meters	Positive
Grassland	Area of unmaintained grassland land cover in home's viewshed in meters	Positive
Emer_veg	Area of emergent vegetation land cover in home's viewshed in meters	Positive
VW_H20	Area of open water land cover in home's viewshed in meters	Positive
Wood_wet	Area of woody wetland land cover in home's viewshed in meters	Positive
AG	Area of agricultural land cover in a home's viewshed in meters	Negative

[a] We expected home sale price to be negatively related to home sale price to a certain age, then positive.
[b] A negative relationship between distance variables and home sale price implies that home sale price decreases with increasing distance.

500-m of each property as identified by an impervious surface percentage map for the region available from the University of Minnesota's Remote Sensing and Geospatial Analysis Laboratory. Additionally, because ease of access to business centers may influence home sale prices, we calculated distances to the central business districts of Minneapolis and St. Paul as identified in a GIS dataset depicting fare zones for regional transit systems available from the TCMC. In this case, we calculated the Euclidean distance between each property and the border of the closest central business district. To account for the impact of the submarket in which a home is situated on its sale price, we also generated a series of housing submarket dummy variables based on the home's high

Table 3
Descriptive statistics for continuous variables used in the hedonic pricing model for Dakota County in 2005.

Variable	Mean	Std. deviation	Min.	Max.
Structural variables				
Price ($)	319,073.79	141,121.28	100,000.00	2,870,250.00
Acres	0.45	1.20	0.06	43.38
Finsqft	2215.73	812.14	614.00	11,498.82
Home_age	23.50	22.54	0.00	153.00
Tax_rate (%)	0.00	1.69	0.90	0.28
Neighborhood variables				
Impervious (m)	28.60	18.36	0.00	100.00
CBD (m)	22,199.30	9,267,58	1719.86	52,052.08
Ecosystem service and amenity variables				
Access to outdoor recreation areas				
Lake (m)	898.25	824.20	0.00	9320.77
Park (m)	555.43	1132.93	0.00	13,095.19
Tree cover				
Tree_parcel (%)	13.60	22.59	0.00	93.00
Tree_100 (%)	13.40	16.84	0.00	90.00
Tree_250 (%)	14.00	17.13	0.00	88.57
Tree_500 (%)	14.57	17.26	0.00	90.00
Tree_750 (%)	15.10	17.31	0.00	88.39
Tree_1000 (%)	15.80	17.73	0.00	100.00
View				
View_area	33.26	29.83	0.66	246.58
IMP5_10 (m^2)	4487.61	13,978.91	0.00	237,225.00
IMP11_25 (m^2)	4422.93	18,981.18	0.00	368,825.00
IMP26_50 (m^2)	22,979.77	32,983.27	0.00	368,625.00
IMP51_75 (m^2)	6018.01	17,306.61	0.00	676,975.00
IMP76_100 (m^2)	2862.58	12,844.79	0.00	454,700.00
Lawn (m^2)	2583.85	11,517.40	0.00	260,225.00
Mtd_tallgr (m^2)	2731.45	14,538.67	0.00	378,000.00
Forest (m^2)	6339.91	23,697.98	0.00	708,100.00
Shrub (m^2)	232.17	1635.22	0.00	38,250.00
Grassland (m^2)	4760.88	19,999.88	0.00	665,025.00
Emer_veg (m^2)	2313.54	14,894.02	0.00	471,600.00
VW_H20 (m^2)	4904.00	33,990.69	0.00	1,162,775.00
Wood_wet (m^2)	2339.39	25,210.89	0.00	936,600.00
AG (m^2)	19,527.16	111,402.22	0.00	1,836,450.00

school district. We selected high school districts following examination of several alternative methods including elementary and middle school districts, cities and townships, and zip codes as these produced the lowest mean squared errors for hedonic pricing models. In this way, we identified a total of twelve housing submarkets.

We estimated a series of environmental variables for each sample property, focusing on the following previously described ecosystem services. To quantify each parcel's access to outdoor recreation sites, we identified all parks of 1-ha (ha, 10,000 m^2) or more in area using two datasets available from the TCMC, the TCMC Regional Recreational Open Space Features and The Lawrence Group Landmarks. Past hedonic studies have used several different measures to quantify access to open space areas, including the size of the closest open space area to a home (Lutzenhiser and Netusil, 2001), dummy variables to indicate whether or not such areas occur within a given distance of a home (Lutzenhiser and Netusil, 2001; Netusil, 2005), the percentage or area of land within a given buffer distance occupied by open space (Acharya and Bennett, 2001; Geoghegan, 2002; Geoghegan et al., 1997; Irwin, 2002; Kong et al., 2007; Ready and Abdalla, 2005), and, most commonly, the distance between a home and its closest open space area (Wu et al., 2004). Based on previous research in the study area (Anderson and West, 2006; Doss and Taff, 1996; Sander and Polasky, 2009), we chose the last measure, distance, to quantify each property's open space access and calculated the road distance between each sample property and its closest open space area in a GIS. Past research indicates that road distance best matches residents' perceptions of access to the large parks used in this study because these areas are typically accessed using roads (Sander and Polasky, 2009). As this is unlikely to be the case for properties located adjacent to or across the street from parks, we identified such properties and assigned them travel distances of zero since their owners would likely gain access directly from their property.

Lakes also serve as significant sites for outdoor recreation in the study region. As such, we calculated an additional metric to quantify access to recreational open space, distance to lakes. In this case, we identified all lakes in the study area using a dataset available from the MNDNR. Experience and past studies conducted in the region indicate that lakes are typically accessed at a series of points located nearly continuously along their perimeters in an as-the-crow-flies fashion rather than at discrete entry points (Sander and Polasky, 2009). Thus, we calculated Euclidean distances between each sample residence and its closest lake to quantify lake access. We use this variable with the park proximity variable to quantify each property's access to outdoor recreation areas.

We calculated viewsheds, computational approximations of views, in a GIS environment to identify the scenic quality of the environment around each sample home. In so doing, we used several GIS datasets: a bare-earth digital elevation model (DEM) available from the TCMC, a planimetric dataset that identified the footprints and locations of buildings provided by Dakota County GIS, and, to identify the land-cover composition of each property's viewshed, a land-cover map, Twin Cities Metro Hybrid Land Cover (HYBLC) 2000, available from the MNDNR, which we updated to 2005 conditions using parcel-level land-use data. To calculate viewsheds, we first modified the bare earth DEM to include buildings, then used this DEM, along with footprints for sample buildings as observer locations, to calculate each property's viewshed using techniques established in previous studies (Sander and Manson, 2007; Sander and Polasky, 2009). The views calculated in this manner are based on estimated building heights and actual locations and approximate the views from top-story windows of each building in the study. Because minimal information regarding tree locations and heights is currently available in the study area, it was not possible to include trees as view obstructions in the DEM. To quantify viewshed characteristics, we next calculated the areal extent of each viewshed as well as the area of each land-cover class in each view.

To provide a further measure of the local aesthetic environment around each sample parcel as well as a measure of local climate regulation, we calculated additional variables related to tree cover. To do so, we utilized the National Land Cover Database (NLCD) 2001 Tree Canopy dataset available from the MNDNR. This dataset identifies per pixel percent tree canopy cover at a 30-m resolution based upon Landsat Thematic Mapper imagery (Homer et al., 2004; Huang et al., 2003). A temporal mismatch of four years exists between this dataset and the parcel data. However, tree cover in the study area changes little in the short-term since most land-cover change is from treeless agricultural land to built land covers and tree canopy cover changes little in the short space of four years. Additionally, no other tree cover data were available. Thus, this dataset, although not ideal, was the best available dataset for our purposes. To quantify tree cover as well as to identify the sphere of influence of tree cover on home sale prices, we calculated the mean percent tree cover within a series of neighborhoods around each sample parcel (parcel level, parcel to 100-m, 100- to 250-m, 250- to 500-m, 500- to 750-m, and 750- to 1000-m). We expected that tree cover in the closer neighborhoods would contribute positively to home sale prices and that tree cover at the parcel level as well as in more distant neighborhoods would not significantly impact home sale prices. Although this is counter to some previous studies (e.g., Anderson and Cordell, 1988; Dombrow et al., 2000; Donovan and Butry, 2010), these studies examined only parcel-level tree cover and did not include variables to control for neighborhood tree cover. More recent studies that considered both neighborhood and parcel tree cover found that tree cover in local neighborhoods around homes impacts home sale prices while tree cover on the parcel itself does not (Holmes et al., 2006; Sander et al., 2010). We consider these studies to more accurately capture the relationship between tree cover and home sale prices as they control for tree cover at both levels.

The above-described variables were used to construct a hedonic pricing model as detailed in the previous section after first verifying that variables were not correlated with one another. Based upon this model, we estimated the marginal implicit prices for significant environmental variables.

4. Results

The results of the hedonic pricing model for Dakota County as well as the marginal implicit prices for the ecosystems services variables are presented in Tables 1 and 4. The adjusted R^2 value for the OLS model (0.8265) was highly significant ($p < 0.001$). However, because our Moran's I estimate was significant ($p < 0.001$) and robust Lagrangian multiplier tests, used because simple Lagrangian lag and error tests were significant, indicated the presence of significant spatial autocorrelation in the error term (RLMerr = 743.86, $p < 0.001$; RLMlag = 0.35, $p = 0.56$), we estimated a SAR error model using 2-km weights to address spatial autocorrelation. We selected these weights carefully after examining a variety of spatial weight matrices. This model represented an improvement over the OLS model as indicated by the significant value for the coefficient lambda ($\lambda = 0.7587$, $p < 0.001$), the spatial autoregression coefficient, and by its reduced Akaike's information criterion value (−5460) as compared to that of the OLS model (−5167.5). Because a Breusch–Pagan test designed for use with SAR models indicated the presence of significant heteroscedasticity, we also calculated White's standard errors (White, 1980) using a modified method for use with SAR models (R. Bivand *personal communication*).

Most coefficients for structural variables were significant and of the expected sign. The acreage of a home's lot as well as its finished square footage both were positively related to home sale prices, indicating that homes with higher acreage or finished square footage sold for more than homes with less, while tax rate was negatively related, indicating that homes with higher property tax rates sell for less than other homes. Home age was negatively related to home sale price to the age of approximately 145-years, after which it was positively related. Most sale month dummy variables, with the exception of March, had a significant or nearly significant and positive relationship to home sale prices as compared to February, indicating that sale prices are significantly higher in most other months than in February.

Location in a FEMA flood zone was positively related to home sale price such that homes in flood zones experienced higher sale prices than other homes. This is likely a function of both the desirability of living near water and a lack of awareness of flood risk on the part of the general public in this region. Previous studies suggest that this lack of significance may result from a lack of information related to and a lack of understanding regarding the degree of flood risk or insurance costs for properties in flood zones on the part of home purchasers (Chivers and Flores, 2002; Pope, 2008). These home buyers thus lack sufficient information to adequately consider this information when negotiating purchase price. The results of an additional study suggest that recent experience with flooding increases home purchasers' awareness of the risks and costs associated with flooding and ensures that they are better-reflected in home sale prices (Bin and Polasky, 2004). As the study area

Table 4
Results of the SAR error hedonic pricing model for Dakota County with White's standard errors.

Variable	Coefficient	Std. error	*t*-value	
(Intercept)	10.28700000	0.19082000	53.91	***
Structural variables				
Ln_acres	0.14003000	0.00520090	26.92	***
Ln_finsqft	0.50105000	0.00811970	61.71	***
Home_age	−0.01077600	0.00029348	−36.72	***
Age_sq	0.00007356	0.00000264	27.82	***
Tax_rate	−0.10109000	0.00895870	−11.28	***
Flood	0.08327400	0.01341900	6.21	***
Sale month dummy variables (ref. month is February; 1 for sale in month, 0 otherwise)				
Jan	0.02610700	0.01136800	2.30	*
Mar	0.01240100	0.01167400	1.06	
Apr	0.02224900	0.01144000	1.94	
May	0.02363600	0.01133100	2.09	*
June	0.03064500	0.01088400	2.82	**
July	0.03810400	0.01094100	3.48	**
Aug	0.04712700	0.01105400	4.26	***
Sept	0.04049500	0.01137400	3.56	***
Oct	0.03536400	0.01183800	2.99	**
Nov	0.03351100	0.01199200	2.79	**
Dec	0.02666800	0.01235300	2.16	*
Neighborhood variables				
Impervious	0.00038039	0.00014732	2.58	*
LN_CBD	−0.12675000	0.01894700	−6.69	***
Submarket dummy variables (ref. location is Simley HSD; 1 in district, 0 otherwise)				
Applevalley	0.15034000	0.03353800	4.48	***
Burnsville	0.09444800	0.03228000	2.93	**
Eagan	0.13177000	0.03162900	4.17	***
Eastview	0.13064000	0.03166800	4.13	***
Farmington	0.11641000	0.03608700	3.23	**
Hastings	0.07867500	0.04358500	1.81	
Lakeville	0.18074000	0.03508900	5.15	***
Rosemount	0.10153000	0.03230800	3.14	**
S_Stpaul	0.06496300	0.02492000	2.61	*
W_Stpaul	0.06102800	0.02832800	2.15	*
Nfld_Rndlph	0.12062000	0.05843700	2.06	*
Ecosystem service and amenity variables				
Access to outdoor recreation areas				
Ln_park	−0.00042724	0.00021280	−2.01	*
LN_lake	−0.00405820	0.00062261	−6.52	***
Tree cover				
Mean_tree	0.00012471	0.00011822	1.05	
Tree_100	0.00058086	0.00018516	3.14	**
Tree_250	0.00032274	0.00016329	1.98	*
Tree_500	0.00061027	0.00016913	3.61	***
Tree_750	0.00034537	0.00016138	2.14	*
Tree_1000	−0.00007851	0.00014685	−0.53	
View				
View_area	0.00056791	0.00009884	5.75	***
IMP5_10	−0.00000010	0.00000018	−0.56	
IMP11_25	−0.00000026	0.00000014	−1.81	
IMP26_50	−0.00000026	0.00000008	−3.42	**
IMP51_75	−0.00000032	0.00000013	−2.54	*
IMP76_100	−0.00000024	0.00000017	−1.44	
Lawn	0.00000055	0.00000019	2.89	**
Mtd_tallgr	0.00000026	0.00000016	1.65	
Forest	0.00000009	0.00000011	0.76	
Shrub	−0.00000100	0.00000126	−0.79	
Grassland	−0.00000007	0.00000013	−0.57	
Emer_veg	−0.00000007	0.00000016	−0.41	
VW_H20	0.00000025	0.00000007	3.48	**
Wood_wet	0.00000005	0.00000010	0.52	
AG	−0.00000004	0.00000003	−1.70	

$\lambda = 0.75867$ LR test value: 294.5 $p < 0.001$.
Significance codes: ***$p = 0.001$, **$p = 0.01$, *$p = 0.05$, $p = 0.1$.
Log likelihood: 2785.984 for error model.
ML residual variance (sigma squared): 0.019367 (sigma: 0.13916).
Number of observations: 5094.
AIC: -5460, (AIC for OLS: -5167.5).

examined in the present study has little recent experience with flooding, it is likely that homeowners were unaware of or unclear on the risks associated with purchasing a home in a flood zone and thus that sale prices may not accurately capture the true value associated with this variable. Future studies might tease out a portion of this by including variables that identify distances to rivers and streams in addition to the distances to lakes included in this study. We attempted to include such variables in the present study, but were obliged to remove them because of multicollinearity.

The coefficients for nearly all neighborhood variables were significant and of the expected sign. Distance to the central business districts of Minneapolis and St. Paul was negatively related to home sale price such that homes located closer to a central business district sold for more than comparable homes located further away. The mean area of impervious surface within 500 m of a home was also positively related to home sale price, indicating that homes in areas with more impervious surface and thus higher development intensities sold for more than homes with lower levels. This result is surprising and may indicate a preference for living in more developed areas which might incorporate more amenities (e.g., restaurants, shopping and fitness centers, day care providers, schools) or simply may be a function of the tendency of homes to be located in more intensively-developed areas in Dakota County. This might be perceived as indicating that increasing development is valued, but this study did not consider very high-density forms of residential development (e.g., townhomes, apartment buildings), so it is difficult to comment upon this. However, as the values of these properties tend to be lower than those of single-family housing, one might speculate that higher intensity development is valued only to a certain point, after which it may become a disamenity. All dummy variables for submarkets with the exception of the dummy variable for location in the Hastings High School district were significant and positive as compared to the Simley High School district, indicating that homes in these submarkets experience higher sale prices than those in the Simley submarket.

Both variables indicating a property's access to outdoor recreation areas significantly impacted home sale prices. Road distance to parks greater than 1-ha in area had a significant and negative relationship to home sale price, such that the marginal implicit price of a 100-m decrease in distance to such a park evaluated at the mean home sale price of $319,073 from an initial distance of 1-km was $13.16 (0.040%). Euclidean distance to lakes also was significantly and negatively related to home sale price, although the impact of lakes was greater than that of parks, with a marginal implicit price for a 100-m decrease in distance calculated as above of $129 (0.041%). Thus, the owners of single-family properties in Dakota County pay more to live near to these outdoor recreation areas.

The results of the hedonic pricing model also indicate that some aspects of views significantly influence home sale prices in Dakota County (Table 4). View area, for example, significantly and positively impacts home sale prices such that a 1-ha (10,000-m^2) increase in view area from the mean view area (33.26-ha) calculated at the mean home sale price corresponds to a home sale price increase of $181 (0.057%). The areas of two built land-cover types in views, 26–50 percent impervious surface and 51–75 percent impervious surface, had significant and negative relationships to home sale price, such that a 1-ha increase in each of these land-cover types from their mean values (0.44 and 2.98-ha, respectively) resulted in a decrease in home sale price of $831 (−0.260%) and $1035 (−0.324%) respectively. The coefficients for other built land-cover types (i.e., 5–10 percent impervious, 11–25 percent impervious, and 76–100 percent impervious) were also negative, but were generally smaller and not significant. This indicates that the owners of single-family homes may prefer homes with views that include lower levels of impervious surface, below the 26 percent level. The failure of views with very high (76–100 percent impervious) levels of impervious surface to significantly impact home prices may indicate that the owners of homes in highly developed areas value something else about these areas, for instance, their urban character, and that this offsets the negative value of highly-developed views under other circumstances. However, the coefficient for this variable was relatively high and negative (−0.00000024, $p = 0.15$), suggesting a tendency on the part of home buyers to pay less for homes with high levels of impervious surface in their views. Additionally, in combination with the positive values placed on increased levels of neighborhood impervious surface described above, the negative values for many impervious land-cover types in views may indicate a preference for living in more intensely-developed areas, but not actually being able to see them, for example, in situations where barriers such as slopes obstruct views of local impervious surfaces. It may also indicate that homeowners make a trade-off between the level of development in their neighborhood which may provide them with access to amenities and the level of impervious surfaces in their views.

Two other land-cover types in views, lawn and water, significantly and positively influenced home sale prices. Evaluated at the mean home sale price, a 1-ha increase in the area of lawn from the mean value (2584-m^2) in a home's viewshed corresponded to a sale price increase of $1742 (0.55%) while an equal increase in the area of water from its mean value (4904-m^2) corresponded to a sale price increase of $81 (0.03%). This indicates a preference on the part of single-family homeowners for views of grassy areas such as golf courses, parks, or large-lot residential housing and a lower preference for views of water. The areas of all other land-cover types in views (i.e., agriculture, maintained tall grassland, forest, shrubs, grassland, emergent vegetation, and woody wetlands) did not significantly impact home sale prices in the study area. It should be noted that forest land cover includes areas explicitly identified as forest (i.e., areas of contiguous trees with no interruption by other land cover types) and does not include, for example, urbanized land covers with high percentages of tree cover. Thus, the lack of a significant impact on homes sale prices for the area of forest in viewsheds does not imply a lack of value for tree cover.

The mean percentage of tree cover in most neighborhood areas significantly and positively influenced home prices. Notably, the mean percentage of tree cover on the parcel itself was not significantly related to home sale price, indicating that homeowners are not concerned about the level of tree cover on their parcel itself. However, the mean tree cover percentages within the 100-m, 250-m, 500-m, and 750-m neighborhoods showed significant and positive relationships to home sale price such that homes with more tree cover in these areas experienced higher sale prices. The marginal implicit prices for a 10-percent increase in tree cover within each of these four neighborhoods from their mean values (13.60%, 13.40%, 14.00%, and 14.57%, respectively) evaluated at the mean home sale price were $1853 (0.581%), $1030 (0.323%), $1947 (0.610%), and $1102 (0.345%), respectively. The level of tree cover in the 1000-m neighborhood was not significantly related to home sale price. This indicates that, while home purchasers are not particularly influenced by tree cover on their own parcel, they are influenced by tree cover in its surrounding neighborhood to a distance of approximately 750-m.

5. Discussion and conclusion

Our results clearly illustrate the utility of hedonic pricing in eliciting the values of multiple ecosystem services. The services examined in this study were valued by the owners of single-family residential properties. Positive price impacts were associated with increased view area and views of water and lawn, higher degrees of access to outdoor recreation areas, and higher levels of neighborhood tree cover. This clearly illustrates the importance of these services to local residents who will pay more to experience greater levels of service delivery in their neighborhoods. Land-use plans and policies that disregard impacts on these services not only may adversely affect them, but also are likely to negatively impact property values and the quality-of-life of local residents.

The values estimated in this and other studies in the region for the same time period (Sander and Polasky, 2009; Sander et al., 2010) can help us to better understand the values of ecosystem services and amenities in the TCMA as well as how they vary with locational context (Table 1). All three studies indicate that decreasing the distance between homes and lakes that suitable for outdoor recreation increases home sale prices. The benefit is highest ($216/100 m closer, 0.084%) in the most highly urbanized area (Ramsey County) and is lowest ($129/100 m closer, 0.0041%) in less heavily-developed Dakota County. This may be due to the higher relative difficulty of accessing these features by driving in more urban areas which makes proximity to them more valuable as it increases walkability. The value associated with decreasing the distance between homes and large parks differs greatly between the two counties (by $123), indicating that urban residents value these recreational open space features much more highly, likely due to their scarcity and the desirability of accessing them on foot in urban areas. Distances to trails and streams were omitted from the current study due to multicollinearity, so we cannot draw conclusions regarding the values of these features in the region.

The values associated with tree cover are somewhat higher ($482/10% increase in the 100-m buffer and $194/10% increase in the 250-m buffer) in the present study than in the other study that examined them in both Dakota and Ramsey Counties (Sander et al., 2010) and extend to a larger neighborhood area (750-m as opposed to 250-m). This may result from higher overall scarcity of tree cover in more agricultural Dakota County (mean tree cover is 11.87%) as compared to Ramsey County where mean tree cover is somewhat higher (18.58%). This scarcity could cause tree cover to be more highly valued in Dakota County.

Viewshed variables are difficult to compare among these studies because of the different means used for quantifying them (i.e., percent versus area increase), although all studies indicate that properties with higher overall view areas experience higher sale prices. The two studies that examined the impacts of different land-cover compositions in views on home sale price (Sander and Polasky, 2009 and the present study) both found that grassy surfaces in views were positively related to home sale prices as was the area of water. The value of water views appears to be somewhat lower in Dakota County than in Ramsey County, but this is difficult to assess for the reason stated above. Both studies indicate that forest views do not significantly influence home sale prices and may indicate that views of more impervious surfaces (downtown St. Paul and views of 26–75% impervious surface types) may negatively impact home sale prices, although this clearly requires further exploration.

Similar variation in the values of ecosystem services in urbanized versus suburban and rural environments may exist in other locations. It seems likely that, as in this study, access to outdoor recreation areas, for example, may be more highly valued in urban areas compared to more rural areas due to the relatively higher scarcity of open space in urban areas. Likewise, in areas like Dakota County that are converting from predominantly agricultural to urban land uses, tree cover is likely to be relatively scarce due to the treeless condition of agriculture and more valuable than in more urban locations like Ramsey County. Comparison of values among urban, suburban, and rural environments thus warrants further study in additional locations.

This research provides valuable information that may be used in regional land-use planning. The values reported here are partial economic values for these services (i.e., the portion accrues to single-family homeowners). Full values are likely to be considerably higher. Nonetheless, these partial values provide incentives to consider these services in planning and policy making. Notably the values calculated here, because they represent impacts on property values and thus on community tax bases, could influence local and regional planning and policy making and improve the consideration of ecosystem services in setting such plans and policy. The relatively low percentage impacts of these variables translate to large values when considered for all properties within a community and thus may dramatically impact community tax bases.

At the local and regional level, policy makers could utilize the values calculated here and additional ecosystem service values calculated using hedonic pricing to identify the potential economic impacts of land-use policies. For example, they might compare the mean distances between homes and open space areas under present and planned land use and utilize values derived from hedonic pricing models to identify how these changes might impact home sale prices and tax dollars collected in their area. Additionally, the values of these services might be used directly in policy making aimed at maximizing property values while encouraging sustainable land-use practices as communities urbanize, for instance, in identifying land-use configurations that maximize the values of these services. Here, policies aimed at protecting services as development occurs could be supported by these economic values. In Dakota County, for example, the values calculated in this study might be used to support clustered development practices which would reduce mean lot acreage (and thus property values), but would preserve open space which in turn would increase property values, offsetting these negative impacts. This is supported by similar studies that found that clustered development, while causing somewhat lower home sale prices, would yield a higher profit to developers via reduced construction costs (Williams and Wise, 2008). These values might also be used to identify potential drops in home values associated with the development of existing open space areas. There is thus great potential to use economic values for ecosystem services calculated using hedonic pricing models to encourage more sustainable development.

Although hedonic pricing can elicit the values of ecosystem services for use in land-use planning and policy, it is not a panacea and should be used with caution. As stated above, this method elicits the values of ecosystem services as they accrue to the owners of single-family properties. Thus, it underestimates the values of ecosystem services and, for services that provide value over larger extents, these values are likely to be considerable underestimates. As such, using estimates from hedonic pricing models may make services appear less valuable than they are, causing these services to be underrepresented in policies that rely upon them. As such, while estimates of ecosystem service values generated using hedonic pricing are clearly useful to planning and policy, they should not be seen as comprehensive and should be augmented using additional measures of value. These might include estimates of value from tourism, the production of marketed goods, or estimates related to health impacts. In incorporating such estimates, care should be taken to avoid double-counting which would inflate the values of double-counted services. Future studies should explore the use of these and additional measures to generate a more comprehensive picture of ecosystem service value and means for incorporating value into planning and policy making at local to regional scales.

An additional word of caution related to the use of hedonic modeling in calculating values for ecosystem services involves the potential for omitted variable bias. In this and most hedonic pricing studies it is impossible to account for all factors that influence home sale prices. The fitted model may over or underestimate the influence of factors included in the model to compensate for the omitted factors. As a result the values calculated for factors included in the model may be larger or smaller than they are in reality. For example in this study we were unable to include variables related to home condition and to numbers of bathrooms and bedrooms. This may have influenced estimates for other variables included in the model. The inclusion of fixed effects as well as the use of a SAR error model may reduce this bias, but is unlikely to eliminate it. Policy-making based upon value estimates like those generated in this study should bear in mind that these values are estimates based on the best available data, but may, as a result of omitted variable bias, be somewhat too high or low.

Ecosystem services are valuable to us as humans and are integral to maintaining our health and well-being. The lack of recognized values for these services has facilitated their omission from planning and policy making, however, with negative consequences for their delivery. Hedonic pricing, as illustrated in this study, provides a means for eliciting these values in a manner that is highly relevant to planning and policy making. As such values estimated using this methodology have high potential to influence the sustainability of future landscapes if used in setting land-use policy.

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