Journal of Agricultural and Resource Economics 36(2):395–415

How Do Homebuyers Value Different Types of Green Space?

Rosalind H. Bark, Daniel E. Osgood, Bonnie G. Colby, and Eve B. Halper

It is important to understand tradeoffs in preferences for natural and constructed green space in semi-arid urban areas because these lands compete for scarce water resources. We perform a hedonic study using high resolution, remotely-sensed vegetation indices and house sales records. We find that homebuyers in the study area prefer greener lots, greener neighborhoods, and greener nearby riparian corridors, and they pay premiums for proximity to green space amenities. The findings have fundamental implications for the efficient allocation of limited water supplies between different types of green space and for native vegetation conservation in semi-arid metropolitan areas.

Key words: hedonic model, locally weighted regression, spatial, open space, golf course, park, riparian

Introduction

In semi-arid regions, natural vegetated landscapes are limited because of human landscape alterations and because water is scarce. Large areas of semi-arid regions lack vegetative cover. This scarcity suggests that vegetated areas may be highly valued. In Tucson, Arizona surface water runs through washes (dry river beds) after rain events. Few washes have perennial flows. Riparian vegetation is concentrated in these natural waterways and along their banks. These "green spaces" provide stark visual contrasts to upland desert flora. Other highly vegetated green spaces occur in neighborhoods that tend to retain native desert plant varieties. Less natural green spaces occur in older neighborhoods with mature non-native landscaping, public parks, and golf courses. In this paper we examine whether adjacency and proximity to different types of green space commands premiums for nearby homeowners. The results are useful for open-space preservation initiatives that seek to preserve natural green space. Such results are also important for communities debating landscaping codes, allocation of treated wastewater for golf course and park turf irrigation, and riparian restoration.

Open space acquisition programs are common at local, county, and state government levels in the United States. Programs often start with ballot initiatives and rely upon funding from voter-approved increases in taxes. Public support is essential to such programs (ILG, 2005). Successful open space programs not only improve the quality of life for constituents, but may also yield notable positive externalities to homeowners through higher residential property values. In 2004, Tucson area voters approved a comprehensive conservation plan – the Sonoran Desert Conservation Plan (SDCP). This plan aims to integrate natural resource protection and land use planning to preserve natural green

Rosalind Bark is a Resource/Ecological Economist at CSIRO in Adelaide, Australia. Daniel Osgood is a Lead Scientist in the Financial Instruments Sector Team and Associate Research Scientist at the International Research Institute for Climate and Society, The Earth Institute at Columbia University. Bonnie Colby is a Professor in the Department of Agricultural and Resource Economics at the University of Arizona. Eve Halper, PhD, works for the US Bureau of Reclamation in Tucson, Arizona. This research was supported by Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA), a National Science Foundation, Science and Technology Center (Agreement No. EAR-9876800).
Review coordinated by Myles J. Watts.

space resources for future generations. Specifically, the plan includes elements to preserve desert landscapes, to protect remnant riparian habitat in the Tucson area, and to restore riparian vegetation. In much of the metropolitan region, riparian habitat has been degraded as a consequence of surface water diversions, groundwater decline, infrastructure development, and urbanization. The SDCP is financed by open space acquisition bonds. Open space acquisitions are occurring as over 200,000 acres have been purchased. These purchases ensure that a stock of natural green space will be preserved as a public good for current and future residents.

Under an Intergovernmental Agreement (IGA), City (Tucson) and County (Pima) officials can access up 10,000 acre feet of effluent (treated wastewater) per year to support riparian habitat programs in the Tucson area. This Conservation Effluent Pool (CEP) was authorized for establishing and/or maintaining riparian restoration projects, and a forthcoming City and County procedural agreement will enable the CEP to be used for riparian projects (Bark, forthcoming).

Green Space, Open Space and Hedonic Studies

A growing body of literature seeks to understand preferences for green space and open space resources. Nearby natural resources such as open space, green space, cropland open space, lakefront amenities, visibility, views, urban wetlands, coastal water quality, and ecological diversity and connectivity are often capitalized into property values (Irwin and Bockstael, 2001; Geoghegan, 2002; Shultz and King, 2001; Smith, Poulos, and Kim, 2002; Anderson and West, 2006; Cho, Bowker, and Park, 2006; Hatton MacDonald et al., 2010; Kuminoff, 2009; Spalatro and Provencher, 2001; Benson et al., 1998; Paterson and Boyle, 2002; Bin et al., 2008; Mahan, Polasky, and Adams, 2000; Acharya and Bennett, 2001; Leggett and Bockstael, 2000; Geoghegan, Wainger, and Bockstael, 1997). A motivation for this research is the desire to provide useful information on preferences for green space to natural resource managers and city planners in a policy environment of rapid growth and concerns about quality of life.

It is relatively straightforward to control for the presence or absence of green space, its size, and proximity to communities. However, measures of the quality of the green space are often absent from research. If people are indifferent to the quality of green space, then restoring a degraded riparian habitat might be a waste of public money. Few studies account for the variation in habitat quality (Cho, Poudyal, and Roberts, 2008; Payton et al., 2008; Bark et al., 2009; Hatton MacDonald et al., 2010). Perhaps the key constraint limiting these studies is the expense of collecting ecological survey data. This high cost makes it infeasible to perform this type of study on large scales or in many locations. High resolution remote sensed vegetation indices are a promising solution to help characterize heterogeneity in green space resources at much lower costs. These vegetative indices are constructed from ratios and differences of spectral bands for each location observed by satellites. The indices are normalized, continuous variables that proxy the level of vegetative extent, vigor, and health. Vegetation index maps are more commonly called "greenness" maps.[1]

A growing number of studies have combined remote sensing data with economic analyses. Remote sensing products have been used to inventory and map land uses and land use change (Millington, Douglas, and Critchley, 1994; Hatton MacDonald et al., 2010), measure the pace of urbanization, and determine the causes of sprawl (Burchfield et al., 2006). Remote sensing indices have been used to monitor regulatory compliance (Schweik and Thomas, 2002) and as a proxy for agricultural productivity (Nivens et al., 2002). They have also been used as a proxy to control for landscape amenities in hedonic property price studies (Sengupta and Osgood, 2003; Payton et al., 2008).

In Sengupta and Osgood (2003), the authors used the normalized difference vegetation index (NDVI) in a hedonic analysis of ranchette land value in Arizona. The authors used NDVI to control for otherwise unobserved confounding variation such as temperatures and the presence of water.

[1] See http://ivm.cr.usgs.gov/

Payton et al. (2008) examine the values of amenities proxied by NDVI and found that neighborhood greenness impacts dominated property level greenness impacts in Indianapolis/Marion County, Indiana. Homebuyers valued greener public green space more than more greenness on their individual property. In this paper we determine if green space at the parcel and neighborhood level is also of value in a semi-arid, metropolitan area.

Neighborhood amenity research was described in earlier work by Brueckner (1983). He noted that the amenities afforded by public green space areas in an apartment complex are jointly consumed by all residents. The analogue for single family homes is that homeowners in neighborhoods/subdivisions with large tracts of undeveloped desert vegetation and riparian corridors may benefit from positive externalities associated with these public good amenities. The distinction between private and community green space is important from a policy standpoint. The homebuyer has direct control (at least after some time lag) over vegetation amenities on personal property through landscaping and watering decisions. The same homebuyer has, at most, indirect control over community-based vegetation amenities by participating in the development or modification of homeowner association landscaping rules and voter initiatives that preserve green space.

In this paper, sales prices of single family residences (SFR) in north central and northeast Tucson, Arizona (see figure 1 for an overview of the study area) are estimated using a hedonic property price model with typical structural and neighborhood variables and three sets of high resolution, remotely-sensed vegetation index (VI) data. The greenness index value at each riparian corridor or wash, parcel and subdivision is used as a proxy for variations in: (1) natural habitat extent and quality; (2) neighborhood-level green space; and (3) landscaping at the lot-level. We explicitly measure the greenness of each type of green space at each parcel as was suggested in Mansfield et al. (2005). The addition of VI data allows us to better control for the amenity value of vegetation than could be achieved using other variables such as the distance to the nearest riparian corridor. The remotely-sensed vegetation data allows us to observe how homebuyers value different levels of greenness and different sources of greenness in addition to typical measures of proximity to these amenities.

Methodology

Policymakers need to understand how the type and quality of green space influence nearby private property values when: (1) designing conservation programs to protect or rehabilitate public green space; (2) introducing ordinances to shape private green space; (3) allocating limited water supplies; and (4) implementing water restrictions that might adversely affect green space (Hatton MacDonald et al., 2010). To help understand green space amenities, we calculate a VI using high resolution, remotely-sensed data as a proxy for the extent and vigor of natural (riparian corridors and intact Sonoran desert landscapes) as well as constructed (lot-based, parks and golf courses[2]) vegetation amenities. These data allow us to test if greenness is a determinant of property values and the types of green space homebuyers value most highly.[3, 4]

[2] All the golf courses in the study area are privately owned and all are irrigated with reclaimed water.

[3] As per Payton et al. (2008) and Sengupta and Osgood (2003) we apply VI as a rough proxy for green space heterogeneity. We do not identify the many varied ecological processes it may represent. Research in other partially vegetated landscapes similar to Tucson, Arizona, has shown that vegetation indices are positively correlated with vegetation cover (Carlson and Ripley, 1997; Nagler, Glenn, and Huete, 2001). Furthermore, percent of ground cover is positively correlated with a biological measure of habitat health – the leaf area index (Nagler, Glenn, and Huete, 2001). This research provides evidence that vegetation indices can be used as meaningful measures of vegetation characteristics that are also easily assessed by homeowners – percent ground cover and vegetation vigor. Additionally, remotely-sensed data can be used to classify vegetation over a large area. Such an exercise is often excessively expensive if using fieldwork surveys. An exploratory discussion on the use of VI and hedonic models for amenities in Tucson, Arizona is presented in Bark-Hodgins, Osgood, and Colby (2006).

[4] Earlier work (Bark-Hodgins, Osgood, and Colby, 2006) uses lower resolution remote sensing data with a pixel size of 323 ft^2 (30 m^2). The results were similar in that homebuyers paid premiums for greener lots and to live near to greener riparian corridors. However, high resolution (pixel size 1 m^2) data better maps vegetation heterogeneity and greenness effects.

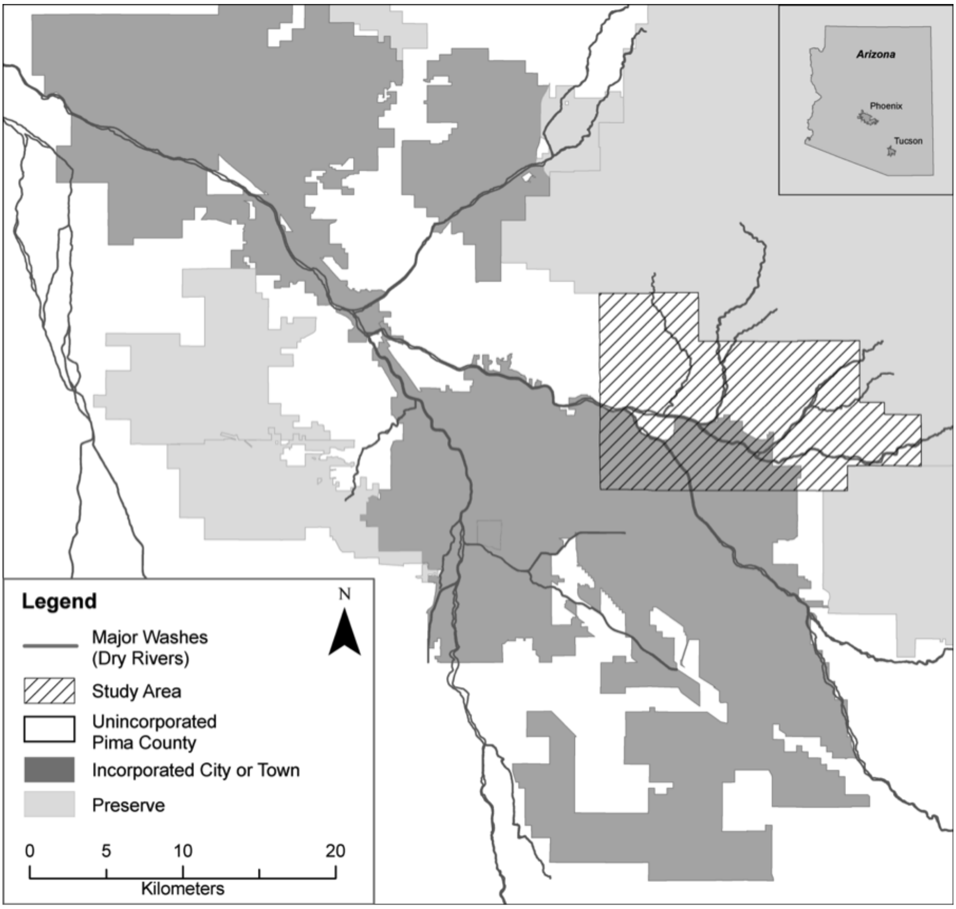

Figure 1. Overview of Study Area

A VI takes advantage of the spectral characteristics of vegetation. Chlorophyll absorbs wavelengths between 630 and 690 nm and scatters wavelengths between 740 and 1200 nm. VIs are derived from reflectance measurements in the red (600 - 700 nm) and near-infrared (800 - 1100 nm) bands of the spectrum. A high VI value indicates a greater amount of green leaf area and green biomass (Tucker, 1979). Many different VIs have been developed for specialized purposes. We selected the Soil Adjusted Vegetation Index, or SAVI, which was developed to reduce the distorting effect of soil brightness in areas with incomplete vegetation cover (Huete, 1988; Huete and Liu, 1994). SAVI is the most appropriate VI for measuring vegetation amenities in semi-arid regions such as Tucson, Arizona because of large expanses of bare (unvegetated) ground.[5] Figure 2 presents a SAVI image in which white denotes the greenest areas which are concentrated along riparian

[5] Two vegetation indices – the normalized-difference vegetation index (NDVI) and the soil-adjusted vegetation index (SAVI Huete, 1988) – were generated. SAVI was chosen as the most appropriate vegetation index for this study because it was explicitly modified from NDVI for remote sensing in areas where a vegetative groundcover is fragmented. The modification adjusts the index for brightness, or reflectivity, of background soils (Huete and Liu, 1994). The SAVI variable is incorporated into the model as an index ranging from 0, indicating no vegetation, to 1, indicating a saturated pixel. The actual range of greenness in our study area was narrower: 0.10-0.51 for the riparian corridors, 0.05-0.52 for the parcels, and between 0.08-0.47 for the subdivisions.

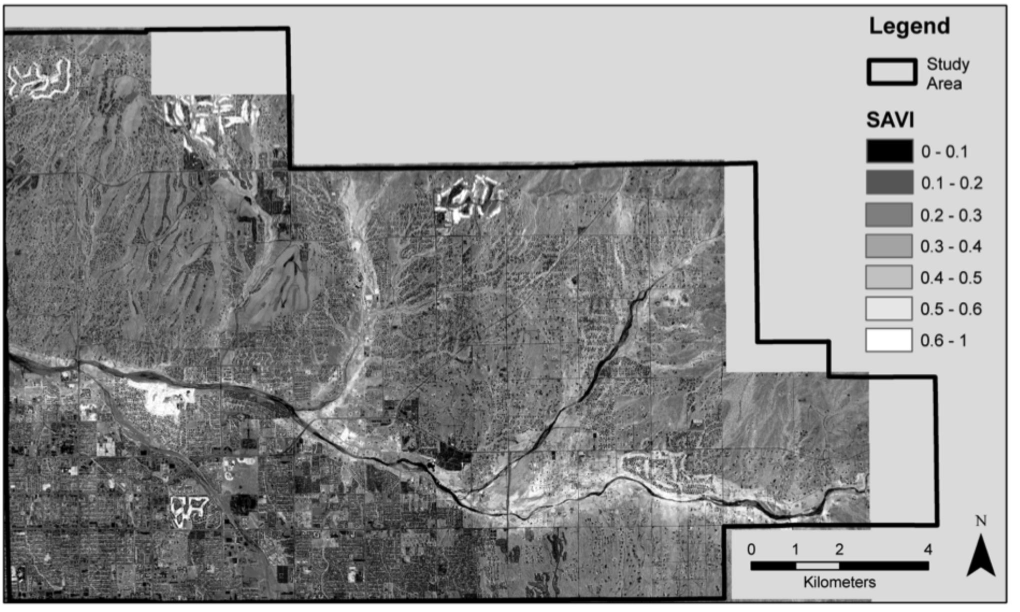

Figure 2. High Resolution SAVI Values

corridors and golf course fairways and greens. Black denotes non-vegetative areas such as structures, rock outcrops, dry sandy riparian corridors, and golf course water hazards and sand traps.

Study Area and Data

The study area covers 77 square miles and contains a total 236 miles of riparian corridors (figure 3). Riparian vegetation is concentrated in and on the banks of perennially and intermittently flowing washes. These green corridors provide startling visual contrast to an otherwise semi-arid landscape. They are also accessible to nearby residents, so they can provide both passive use values and active recreational opportunities.

Historic development in the Tucson Basin (the large arid basin in which the Tucson metropolitan area is located) depleted regional groundwater aquifers. As groundwater levels declined, the perennial streams and rivers that once supported riparian habitats dried up. Today only a small stretch of the river in the basin flows perennially. A number of remnant riparian habitats are present in the study area and have been earmarked for preservation or rehabilitation under the SDCP. The consequence of water development in the Tucson Basin is that any plan to protect or restore riparian vegetation will require supplemental water supplies, most likely from CEP treated effluent. It is important to understand homebuyers' preferences for different types of green space amenities because treated effluent supplies are finite and have competing uses and restoration is expensive.

Other green space resources include lot- and subdivision-based vegetation amenities. Most houses in Tucson have xeriscaped yards. These yards consist of rock, gravel, cactus and other low-water use plants, and a small number of desert-adapted tree species or citrus trees. However, some homes have little or no vegetation, some have turf, and some exist in golf-course communities. Some neighborhoods landscapes, including many in the study area, consist of natural desert vegetation such as creosote bushes, cactus, Saguaro cactus, and endemic trees. Trees are important amenities in Tucson as elsewhere (Anderson and Cordell, 1985; Morales, 1980; Morales, Micha, and Weber,

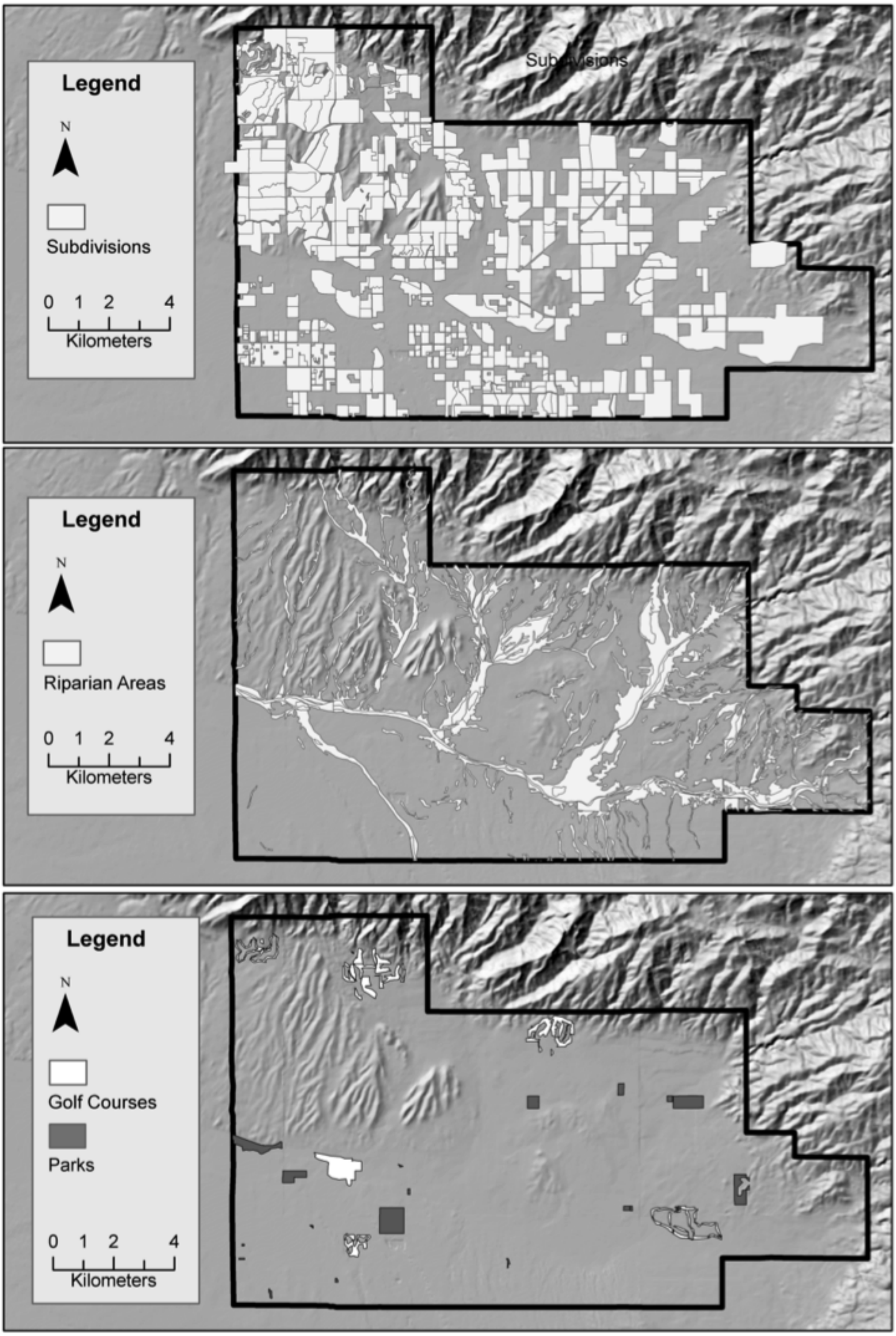

Figure 3. Study Area with Subdivision, Riparian Corridor, Park and Golf Course Polygons

1983) because they provide shade for understory vegetation, houses and sidewalks, and provide leafy visual contrast to cactus, creosote and agaves.

Several different data sets were collected or generated for this research: 1) SFR sales in Pima County and associated tax-assessed housing characteristics, 2) geographic information system GIS) riparian corridor data, 3) U.S. Census block-level statistics, and 4) remotely sensed vegetation indices. The residential sales data and assessed structural characteristics were for Pima County. The data set consists of 6,676 SFR sales data for the period 1998-2003 (**P**). These were coupled with Tax Assessor data on structural housing characteristics (**S**) by unique parcel identification numbers to account for home additions. These data sets provided the variables comprising the vectors of structural (**P**), neighborhood (**N**) and environmental (**E**) characteristics.[6]

The ***N*** vector is built from Census block level data and two levels of geographic data, school districts, and zip codes (zip codes are a much finer scale than school districts). A separate model was run for the Schools Specification and the ZIP Specification (figure 4).

The vector ***E*** incorporates remotely sensed VI data and information on the proximity of each house to different types of green amenities. The vegetation index data used in the regressions were derived from 10.8 ft^2 ($1m^2$) high resolution multi-spectral orthophotography acquired by Pima Association of Governments (PAG) in May, 1998.[7] This is very high resolution data compared to the 323 ft^2 ($30m^2$) resolution data used by Payton et al. (2008). This late spring date coincides with full leafing out of desert trees and the dry, pre-summer monsoon period in the Sonoran Desert – a period in which weeds are sparse. Thus, it is likely that the greenness data reflect native desert vegetation, landscaped lots, and turf. The SAVI image was overlaid with the polygon coverages for riparian corridors, household parcels, and subdivisions, and the mean SAVI value for riparian corridor polygon (WASHSAVI), household parcel (lot) polygon (LOTSAVI), and neighborhood polygon (SUBDNSAVI).[8] Note that the variable SUBDNSAVI incorporates greenness from lots, golf courses, and riparian corridors as well as vegetation on commercial and public tracts of land.

Estimation

Following Rosen (1974) we use a hedonic regression model to estimate coefficients for structural, neighborhood, time and environmental variables. The regressions are semi-log, as specified in equation 1.[9]

$$ln(P_i) = [S_i, N_i, E_i, T_i]'\beta + \varepsilon_i. \qquad (1)$$

The ordinary least squares regression results were obtained Stata with robust standard errors. ***P*** is a vector of house sales prices. The structural vector ***S*** consists of typical hedonic variables, lot size 10,000 ft^2 (LOT), living area 100 ft^2 (LIVING), number of bath fixtures (BATH),[10] age in years (AGE). ***S*** also includes less familiar features used in hedonic analysis that are particularly important

[6] SAS 9.1 for Windows, Stata 7.1 and GeoDa 0.9.5-I (Beta) were used. The geographically-referenced data was processed in ArcView 3.3 and ArcInfo Desktop 9.2.

[7] Note that 1998 was the last time PAG acquired high resolution, pre-processed data with all the bands necessary to calculate SAVI.

[8] ESRI Polygon shape files of parcels and subdivisions were overlaid on the SAVI image. Summary statistics were generated for each polygon using the "Zonal Statistics as Table" tool in ArcInfo Desktop 9.2. Each parcel was then matched with SAVI values for its subdivision (if applicable. Determining SAVI statistics for the wash polygons was slightly more complex. Some of these polygons were very large and extended far from the parcels and subdivisions. We hypothesized that a parcel's residents would be primarily influenced by the characteristics of the wash area closest to them. GIS analysis showed that the maximum distance from a parcel to a wash was 6,492 ft. Therefore a buffer of 6,600 ft was created, and the wash shape file was clipped with this buffer. We then generated summary statistics for each wash polygon and each parcel was matched with its nearest wash polygon.

[9] Box-Cox procedures generated transformation parameters of 0.045 and -3.649, for the ZIPS Specification. In general, the results suggest log-linear specifications.

[10] Three bath fixtures is equivalent to a full or a half-bath with a shower, toilet and sink.

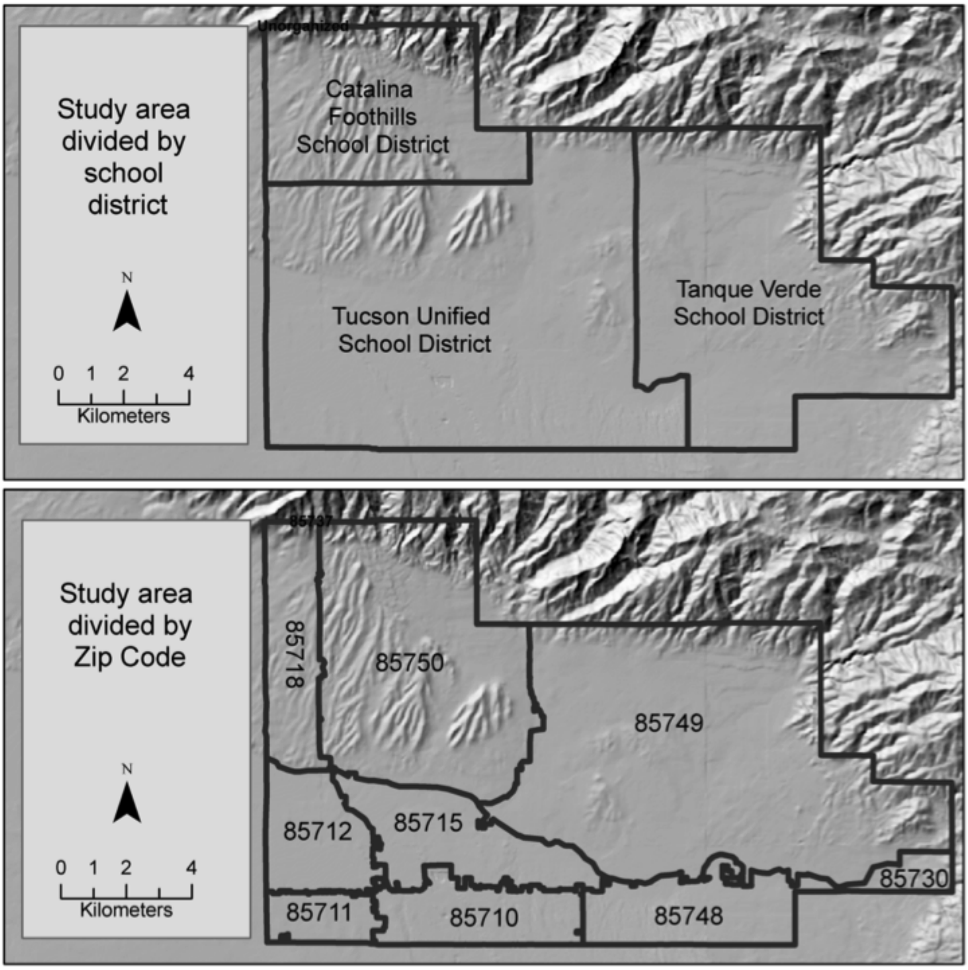

Figure 4. Study Area with School Districts and ZIP Codes

in the desert heat such as the number of garage spaces (GARAGE) and pool area 100 ft^2 (POOL). A final variable ELEV measures the elevation of each property in meters above sea level. ELEV may proxy construction costs and views. The study area encompasses both the valley floor and the foothills: elevation ranges from around 2,460 ft to 3,510 ft m above sea level.

Three Census variables were chosen to characterize neighborhoods: 1) the average age of the Census Block (AVGAGE), 2) the percent of Caucasians (% WHITE), and 3) the percent of single person households (% 1 PERSON). To account for SFR property appreciation, a vector of binary variables for year of sale (D99-D03) was generated (T). We compare this to sales in 1998.

Two variables control for non-vegetation based variations in riparian corridor amenities – wash size (CFS_NO) and wash treatment (BANKPROT). We use six categories of wash size, CFS1-CFS6, with CFS6 indicating the largest, widest wash in the data set. A binary variable BANKPROT, equals one if the wash is concrete-lined and reinforced, and zero otherwise. Finally, to account for flood risks associated with proximity to riparian amenities (Bin et al., 2008), a binary variable (FLOOD) was set equal to one if the property is within the Federal Emergency Management Agency flood zone, and equal to zero otherwise. Owners of such properties are eligible to purchase supplemental homeowners' federally-backed flood insurance.

The ***E*** vector consists of environmental variables chosen to characterize the heterogeneity of green space resources, and proximity to these amenities in the study area. We investigate two (household and subdivision) spatial scales of green space. The high resolution greenness variables represent mean parcel level (LOTSAVI) and mean subdivision level (SUBDNSAVI). The SUBDNSAVI variable allows us to test if neighborhood amenities/ greenness are important determinants of house price variation after controlling for lot-level greenness (Brueckner, 1983; Payton et al., 2008). The mean SAVI value at the nearest riparian corridor to each property (WASHSAVI) is also included in the regression.

Other variables are used to investigate the role of green space as a bundled amenity. Following Kuminoff (2009), green space is allowed to exhibit positive or negative externalities depending on house location. For this study, we include six variables that represent adjacency and proximity to green space. We create a binary variable that tests homebuyers' preferences for a property that is adjacent to, and therefore has a view of and direct access to, a riparian corridor (ADJTWASH). This variable may also incorporate privacy and wildlife viewing benefits resulting from county regulations that forbid building in a floodway. The second is a binary variable set equal to one if a home is within a 1,056 ft buffer, but not adjacent to a wash, and zero otherwise (WASHBUFF).[11] The third is a binary variable that equals one if a property is located either on or immediately adjacent to a golf course and zero otherwise (ADJTGOLF). This variable is important as golf courses have been identified as a significant amenity for explaining house prices. There are six golf courses in the study area (Do and Grudnitski, 1995; Shultz and Schmitz, 2009). The fourth binary variable is set to one if a home is nearby (within 1,056 ft) but not adjacent to a golf course (GOLFBUFF). The fifth and sixth variables, ADJTPARK and PARKBUFF, reflect adjacency and nearness to public parks.

Neighborhood-level geography may also be important in explaining house prices in the study area. To account for this possibility, we specify two different levels of geography in the neighborhood vector, ***N***. The first specification uses school districts (Schools Specification), which have been found to be a source of price variation in housing markets (Black, 1999; Downes and Zabel, 2002). Three binary variables identify: 1) the Catalina Foothill School District (CFSD), the elite school district in the area; 2) the Tanque Verde School District (TVSD); and 3) the lower-achieving Tucson Unified School District (TUSD). Our Benchmark regression is the Schools Specification with the 1998-2003 SFR sales data. An alternative specification uses the smallest geographical unit – zip codes (ZIP Specification). Binary variables were created for eight zip codes 85710, 85711, 85712, 85715, 85748, 85749 and 85750 (ZIP10-ZIP50). The base (85718) is located in the northwest corner of the study area.

The mean house sales price was $213,892. Table 1 reports variable descriptions and table 2 provides summary statistics for the regression variables.

Regression Results

In this section we report OLS regression results for the two geographic specifications: our Benchmark regression (Schools Specification) and a diagnostic regression (ZIP Specification). We also explore other diagnostic spatial regressions to test the robustness of the SAVI, adjacency and proximity to green space results.

[11] The 1,056 ft. buffer was chosen with the advice of property assessors at the Pima County Assessor's Office (personal communication September 4, 2007).

Table 1. Variable Names and Definitions

Variables	Description
Dependent variable	
LNSALESP	Log of unadjusted sales price
Environmental variables	
LOTSAVI	Mean SAVI value for parcel
WASHSAVI	Mean SAVI value at nearest riparian corridor
SUBDNSAVI	Mean SAVI value in subdivision
Home structure variables	
LOT	Lot size, 10,000 ft^2
LIVING	Living area, 100 ft^2
AGE	Age of house in years
BATH	Number of bath fixtures
GARAGE	Number of garage spaces
POOL	Pool size, 100 ft^2
ELEV	Elevation of property in 100 ft above sea level
Neighborhood variables	
CFSD	Binary variable equal to one if school district is Catalina Foothills and equal to zero otherwise. Compared to Tucson Unified SD
TVSD	Binary variable equal to one if school district is Tanque Verde and equal to zero otherwise. Compared to Tucson Unified SD
ZIP10/11/12/15/48/49/50	Binary variable equal to one if house is in zip code 85710, 85711, 85712, 85715, 85748, 85749, 85750. All compared to 85718
FLOOD	Binary variable equal to one if house is in the Federal Emergency Management Agency flood zone and equal to zero otherwise
BANKPROT	Binary variable equal to one if the nearest wash is bank protected and equal to zero otherwise
WASH SIZE	Measure of riparian corridor size, from CFS1 through CFS6.
Census variables	
AVG AGE	Average age in Census Block in 2000
% WHITE	% of households in Census Block 2000 identified as white
% 1 PERSON	% of single person households in Census Block 2000
Amenity access variables	
ADJTWASH	Binary variable equal to one if house is adjacent to a riparian corridor and equal to zero otherwise
WASHBUFF	Binary variable equal to one if a house is not adjacent to, but within 1056 ft of a riparian corridor, and equal to zero otherwise
ADJTGOLF	Binary variable equal to one if house is adjacent to a golf course and equal to zero otherwise
GOLFBUFF	Binary variable equal to one if a house is not adjacent to, but within 1056 ft of a golf course, and equal to zero otherwise
ADJTPARK	Binary variable equal to one if house is adjacent to a public park and equal to zero otherwise
PARKBUFF	Binary variable equal to one if a house is not adjacent to, but within 1056 ft of a public park, and equal to zero otherwise
Appreciation variables	
D99-D03	Binary variable for year of sale, 1999-2003 compared to a sale in 1998

Table 2. Summary Statistics

Variable	Mean	St. Dev.	Min	Max
N	6,676			
SALESP	213,891	149,903	34,000	4,500,000
Environmental variables				
WASHSAVI	0.26	0.05	0.10	0.51
LOTSAVI	0.20	0.06	0.05	0.52
SUBDIVSAVI	0.21	0.05	0.08	0.47
Home structure variables				
LOT	216.45	255.90	20.24	397.57
LIVING	20.57	6.83	4.52	109.04
AGE	22.90	12.72	2	76
BATH	7.63	2.51	3	23
GARAGE	1.28	1.15	0	5
POOL	188.59	235.94	0	1,237.85
ELEV	86.83	3.48	80.94	105.59
Neighborhood variables				
CFSD	0.18	0.38	0	1
TVSD	0.09	0.28	0	1
ZIP10	0.13	0.34	0	1
ZIP11	0.05	0.21	0	1
ZIP12	0.09	0.28	0	1
ZIP15	0.14	0.35	0	1
ZIP48	0.10	0.29	0	1
ZIP49	0.18	0.39	0	1
ZIP50	0.27	0.44	0	1
FLOOD	0.03	0.16	0	1
BANKPROT	0.09	0.28	0	1
WASH SIZE	3.11	1.45	1	6
Census variables				
AVG AGE	40.69	4.30	31	60
% WHITE	83.44	6.90	52	100
% 1 PERSON	25.93	11.76	7	64
Amenity access variables				
ADJTWASH	0.16	0.37	0	1
WASHBUFF	0.49	0.50	0	1
ADJTGOLF	0.02	0.14	0	1
GOLFBUFF	0.03	0.18	0	1
ADJTPARK	0.02	0.18	0	1
PARKBUFF	0.07	0.25	0	1
Appreciation variables				
D99	0.17	0.38	0	1
D00	0.17	0.37	0	1
D01	0.16	0.39	0	1
D02	0.16	0.37	0	1
D03	0.17	0.37	0	1

OLS Results

The OLS results with robust standard errors for the Benchmark and ZIP Specification are provided in table 3. The adjusted R-squared statistics indicate that both specifications explain the data well. Given the spatial nature of the housing and greenness data and the importance of 'neighborhood' in housing markets, many of the parameters of interest are smaller and some are insignificant as compared to the Benchmark. The table also displays the estimated marginal implicit prices for each of the regression variables evaluated at the mean house price.

The regression results show that the estimated coefficients meet a priori expectations. Homebuyers in the study area prefer newer, larger houses on larger lots with more garage spaces and larger swimming pools. The coefficient for ELEV is also positive and significant. Higher elevation may proxy both higher construction costs and also a premium view. The positive and significant coefficients for the high-achieving school district, CFSD, are consistent with claims by realtors that locations in this school district add to property values. Discounted home values for FLOOD was expected.

The coefficient for BANKPROT is significant and positive in the Benchmark and ZIP regression. This was somewhat unexpected as these riparian corridors have been enhanced with which diminishes their natural amenities. However, concrete construction of bank protection in urban Tucson simulates natural river banks. Further, such treatments may create a perception of reduced flood risk.

The Census variables behaved as expected. Homebuyers are willing to pay more to live in an area with a larger portion of senior residents, and in some specifications, with more white households. Housing prices in areas with more single person households (fewer families) are generally discounted. The year binary variables also behaved as expected - house prices appreciated considerably in Tucson between 1998 and 2003.

The combination of the adjacency and proximity variables provide interesting findings that capture the bundled component of green spaces (Kuminoff, 2009). In the Benchmark regression, homebuyers pay a significant premium to live adjacent to a golf course (ADJTGOLF). The size of this premium is consistent with other studies (Do and Grudnitski, 1995; Shultz and Schmitz, 2009). Homebuyers are also willing to pay a small premium to live adjacent to a wash. The coefficient for GOLFBUFF is insignificant as expected as there appears to be little value in living near to, but not on, a golf course. Homebuyers in the study area are, however, willing to pay small premiums for proximity to washes (WASHBUFF). This may reflect a key characteristic of riparian corridors because they are community, open space recreation resources that can be accessed by nearby homeowners for jogging, dog walking, etc. This is quite different from than golf courses, which restrict access to members and paying golfers.

The ADJTPARK and PARKBUFF variables are negative and significant. These results may seem surprising. However, the public parks in the study area are mostly large municipal parks which might be associated with nuisances such as traffic, noise, and safety concerns (Cho, Bowker, and Park, 2006). In many cases, large public parks are not well irrigated which often results in an aesthetically unappealing (brown and dry) areas during parts of the year (Hatton MacDonald et al., 2010). Fierro, Fullerton, and Donjuan-Callejo (2009) also find evidence that proximity to parks is inversely related to housing values in Ciudad Juarez, Mexico and suggest this may be related to crime and poor maintenance. Hatton MacDonald et al. (2010) also find evidence in Adelaide, Australia that the type of park (playgrounds vs. large public park) determines whether proximity is a positive or negative externality to nearby homeowners. Mansfield et al. (2005) also find that adjacency to what they termed "institutional forest" in the Research Triangle, North Carolina did not confer a premium on nearby homeowners. In our study area, many households have relatively large lots and, therefore, may place lower values on additional space provided by public parks (Cho, Bowker, and Park, 2006; Anderson and West, 2006; Hatton MacDonald et al., 2010).

Table 3. OLS Model Results and Hedonic Values

Variable	**SCHOOL** Parameter Estimates	**SCHOOL** Hedonic Price	**ZIP** Parameter Estimates	**ZIP** Hedonic Price
Environmental variables				
WASHSAVI	0.23***		(0.03)	
	(0.05)	12,446	(0.05)	*-1,475*
LOTSAVI	0.26***		0.17***	
	(0.05)	17,860	(0.05)	11,634
SUBDNSAVI	0.82***		0.34***	
	(0.09)	45,729	(0.10)	19,011
Home structure variables				
LOT	0.03***		0.03***	
	(0.00)	6,975	(0.00)	6,061
LIVING	0.04***		0.04***	
	(0.00)	7,610	(0.00)	7,350
AGE	−0.01***		−0.01***	
	(0.00)	-1,559	(0.00)	-1,510
BATH	0.01***		0.01***	
	(0.00)	2,731	(0.00)	2,433
GARAGE	0.02***		0.02***	
	(0.00)	4,669	(0.00)	3,514
POOL	0.02**		0.01***	
	(0.00)	3,260	(0.00)	3,105
ELEV	0.02***		0.04***	
	(0.00)	3,809	(0.00)	8,496
Neighborhood variables				
CFSD	0.10***			
	(0.01)	20,410		
TVSD	−0.08***			
	(0.01)	-17,364		
ZIP10			−0.22***	
			(0.01)	-47,489
ZIP11			−0.06***	
			(0.02)	-13,138
ZIP12			−0.18***	
			(0.02)	-37,666
ZIP15			−0.18***	
			(0.01)	-37,475
ZIP48			−0.25***	
			(0.01)	-52,347
ZIP49			−0.10***	
			(0.01)	-20,961
ZIP50			−0.03***	
			(0.01)	-6,682

(continued on next page…)

Variable	SCHOOL Parameter Estimates	SCHOOL Hedonic Price	ZIP Parameter Estimates	ZIP Hedonic Price
Neighborhood variables (continued)				
FLOOD	−0.04***		−0.03***	
	(0.02)	-8,168	(0.02)	-6,898
BANKPROT	0.03***		0.05***	
	(0.01)	6,150	(0.01)	11,471
WASH SIZE	−0.01***		0.00	
	(0.00)	1,046	(0.00)	*207*
Census variables				
AVG AGE	0.01***		0.01***	
	(0.00)	1,283	(0.00)	1,145
% WHITE	0.02***		−0.00	
	(0.00)	3,418	(0.00)	*-651*
% 1 PERSON	−0.02***		−0.01***	
	(0.00)	-3,591	(0.00)	-2,513
Amenity access variables				
ADJTWASH	0.01*		0.02***	
	(0.01)	2,881	(0.01)	3,259
WASHBUFF	0.01**		0.01***	
	(0.01)	2,602	(0.01)	2,869
ADJTGOLF	0.08***		0.13***	
	(0.02)	17,043	(0.02)	27,247
GOLFBUFF	0.01		0.02	
	(0.02)	2,756	(0.02)	*3914*
ADJTPARK	−0.04***		−0.03***	
	(0.01)	-8,028	(0.01)	-6,980
PARKBUFF	−0.05***		−0.02***	
	(0.01)	-10,550	(0.01)	-4,968
Appreciation variables				
D99	0.07***		0.07***	
	(0.01)	12,446	(0.01)	*-1475*
D00	0.13***		0.127***	
	(0.01)	45,729	(0.01)	19,011
D01	0.19***		0.19***	
	(0.01)	17,043	(0.01)	27,247
D02	0.26***		0.26***	
	(0.01)	2,881	(0.01)	3,259
D03	0.34***		0.34***	
	(0.01)	-8,028	(0.01)	-6,980
CONSTANT	10.09***		10.03***	
	(0.12)	*2,756*	(0.10)	*3,914*
R^2	0.88		0.89	
N	6,676		6,676	

Notes: Numbers in parentheses report heteroskedastic-consistent standard errors. * = .10 level (10%) ** = .05 level (5%) *** = .01 level (1%). Hedonic values for LOTSAVI, WASHSAVI and SUBDNSAVI are the implied premium between average and maximum recorded SAVI values for each type of open space and for each data set. Numbers in italics are not significant at the 10% level.

The Benchmark regression results for the three SAVI variables indicate that homebuyers have preferences for more greenness, i.e., more vegetation at the lot-level, neighborhood-level, and in their nearest riparian corridor. In the Benchmark regression, premiums for WASHSAVI are less than LOTSAVI (but are of the same order of magnitude). WASHSAVI premiums are a little less than a one-third of the premium associated with SUBDNSAVI. The SUBDNSAVI coefficient estimates suggest that neighborhood level greenness is an important determinant of house price variation. These results are similar to those of Payton et al. (2008) and Hatton MacDonald et al. (2010). In the diagnostic ZIP code regression, WASHSAVI is insignificant and the other SAVI-based parameter estimates are smaller. The ZIP code dummies provide spatial fixed effects to control for unobserved spatial characteristics. But because the SAVI data are only for one point in time, we cannot distinguish if the inclusion of finer scale spatial dummy variables captures variation driven by our variables of interest, or by unobserved variables at the same spatial scales.

The geographic variables behaved as expected. Homebuyers are willing to pay to a premium to live in the high-achieving Catalina Foothills School District (CFSD). For the diagnostic regression, the coefficients for ZIP10-ZIP49 are negative and significant as compared to the highly desirable ZIP18. Smaller discounts apply to ZIP50, and ZIP11 (both located adjacent to ZIP18) and ZIP49 which is located in the northeast corner of the study area and is adjacent to extensive public lands.

The estimated hedonic prices for housing characteristics are in line with expectations. For example, in the Benchmark regression the estimated value of 100 ft^2 of living space is \$7,610 and a home 100 ft higher in elevation than the average home commands a \$3,809 premium. Homebuyers are willing to pay almost \$18,000 more for the greenest lot compared to the average, and a premium of over \$12,000 to live near the greenest riparian corridor compared to the average. A location on a golf course yields an 8 % premium while a location adjacent to a wash offers a 1.3 % premium.

Spatial Regression Diagnostics

The spatial nature of home sales and amenity data provides a possible source of concern. Spatial dependence in the variable and error terms would violate OLS assumptions of uncorrelated error terms and independent observations, leading to inefficient estimations and biased error estimates. Spatial dependence between house sales can be diagnosed and corrected. Although OLS parameter estimates may be inefficient when spatial processes are detected, these differences may not be "large enough to meaningfully affect the benefit-cost ratio or policy decision in project evaluation or regulatory impact analyses" (Mueller and Loomis, 2008, p. 229). We test for spatial processes, correct for spatial auto correlation, and compare the results of the spatial dependence model with our benchmark analysis. We use *GeoDa* to detect spatial dependence processes in the data. Distance spatial weight matrices were created for each specification using threshold distance as a criterion. Spatial diagnostics indicated the presence spatial error processes. After identifying the type of spatial dependence, maximum likelihood (ML) spatial error models were estimated in *GeoDa*.

The Moran's I (Moran, 1948) statistic was found to be positive and significant in each case indicating strong positive spatial autocorrelation in the residuals. For each model, an additional variable (LAMBDA) is reported that is used to identify spatially correlated errors. In all cases, LAMBDA is positive and significant at the 1% level. Table 4 reports the parameter estimates and hedonic values. In addition, the likelihood ratio test of spatial error dependence results are significant across the models providing further evidence that the introduction of the spatial error term improved the model fit from the OLS results. However, in all cases heteroskedasticity remained in the model suggesting that some spatial effects remained.

The spatial error model controls for unobserved spatial correlation. Therefore, our expectation is that the SAVI coefficients will be smaller in absolute value compared to the OLS results. We find this to be true. For example, the SAVI coefficient estimates in the Benchmark regression spatial error model are positive and significant but smaller in absolute terms that the OLS results. The difference

Table 4. Spatial Error Model Results and Hedonic Prices

	SCHOOL		ZIP	
Variable	**Parameter Estimates**	**Hedonic Price**	**Parameter Estimates**	**Hedonic Price**
Environmental variables				
WASHSAVI	0.00*		−0.02	
	−0.06	132	(0.06)	*-825*
LOTSAVI	0.09**		0.09**	
	−0.04	6,239	(0.04)	5,830
SUBDNSAVI	0.20**		0.16*	
	−0.08	10,947	(0.08)	8,765
Home structure variables				
LOT	0.03***		0.03***	
	(0.00)	6,027	(0.00)	6,106
LIVING	0.03***		0.03***	
	(0.01)	6,398	(0.01)	6,406
AGE	−0.01***		−0.01***	
	(0.00)	-1,728	(0.00)	-1,712
BATH	0.01***		0.01***	
	(0.00)	1,790	(0.00)	1,836
GARAGE	0.01***		0.01***	
	(0.00)	2,965	(0.00)	2,893
POOL	0.01***		0.01***	
	(0.00)	3,111	(0.00)	3,083
ELEV	0.03***		0.03***	
	(0.03)	7,187	(0.03)	5,659
Neighborhood variables				
CFSD	0.03			
	(0.02)	*7,224*		
TVSD	0.04			
	(0.04)	*8,095*		
ZIP10			−0.15***	
			(0.05)	-31,104
ZIP11			−0.20***	
			(0.06)	-43,722
ZIP12			−0.15***	
			(0.06)	-32,695
ZIP15			−0.09**	
			(0.05)	-19,011
ZIP48			−0.15***	
			(0.05)	-31,971
ZIP49			−0.08	
			(0.05)	*-16,218*
ZIP50			−0.07*	
			(0.04)	14,618

(continued on next page...)

Variable	SCHOOL		ZIP	
	Parameter Estimates	**Hedonic Price**	**Parameter Estimates**	**Hedonic Price**
Neighborhood variables (continued)				
FLOOD	0.01		0.01	
	(0.02)	*1,373*	(0.02)	1,545
BANKPROT	0.00		0.01	
	(0.01)	*945*	(0.01)	1,512
WASH SIZE	0.00*		0.00	
	(0.00)	857	(0.00)	*668*
Census variables				
AVG AGE	0.00**		0.00***	
	(0.00)	399	(0.00)	456
% WHITE	−0.01**		−0.01**	
	(0.01)	-3,014	(0.01)	-2,890
% 1 PERSON	−0.01***		−0.01***	
	(0.00)	-2,737	(0.00)	-2,428
Amenity access variables				
ADJTWASH	0.03***		0.03***	
	(0.01)	6,593	(0.01)	6,135
WASHBUFF	0.02***		0.02***	
	(0.01)	5,020	(0.01)	4,694
ADJTGOLF	0.11***		0.12***	
	(0.02)	24,456	(0.02)	26,431
GOLFBUFF	0.01		0.01	
	(0.01)	1,649	(0.01)	*1,831*
ADJTPARK	−0.03*		−0.03*	
	(0.02)	-6,132	(0.02)	-5,937
PARKBUFF	−0.01		−0.01	
	(0.01)	*-3,085*	(0.01)	*-1,976*
Appreciation variables				
D99	0.07***		0.07***	
	(0.01)	14,992	(0.01)	14,909
D00	0.13***		0.13***	
	(0.01)	27,814	(0.01)	27,752
D01	0.20***		0.19***	
	(0.01)	41,660	(0.01)	41,571
D02	0.26***		0.26***	
	(0.01)	55,989	(0.01)	55,955
D03	0.33***		0.33***	
	(0.01)	70,532	(0.01)	70,569
CONSTANT	10.47***		10.72***	
	(0.27)		(0.26)	
Lambda	0.91***		0.88***	
	(0.01)		(0.01)	

(continued on next page. . .)

	SCHOOL		ZIP	
Variable	Parameter Estimates	Hedonic Price	Parameter Estimates	Hedonic Price
R^2	0.91		0.91	
Moran's I	85.0***		69.4***	
LR Test	1794.2***		1,153.1***	
N	6,676		6,676	

Notes: Numbers in brackets report standard errors. * = .10 level (10%) ** = .05 level (5%) *** = .01 level (1%). Hedonic values for LOTSAVI, WASHSAVI and SUBDNSAVI are the implied premium between average and maximum recorded SAVI values for each type of open space and for each data set. Numbers in italics are not significant at the 10% level.

between the models may help identify sources of neighborhood spatial dependence. That is, the ADJTWASH parameter value is three times larger and the WASHBUFF parameter two times larger in the spatial error model. This may indicate the presence of omitted variable bias in our OLS estimates.

Concluding Remarks

This study finds that homebuyers have consistent preferences for green space in the semi-arid urban area of Tucson. They value not only greenness that they have control over, but also overall neighborhood greenness which they cannot directly control. Neighborhood-level greenness had the largest marginal effect on home values relative to other greenness measures even after controlling for greenness of homeowner's lots. Our results indicate that neighborhood-level greenness has important external benefits and support the findings of Brueckner (1983). We also confirm similar results from an Indiana study which used lower resolution remote-sensing data (Payton et al., 2008). Our work extends their research to include natural habitat, parks and golf courses within urban areas.

Although the implicit value for green space amenities varies throughout metropolitan regions (Anderson and West, 2006), our study suggests that developers who preserve native vegetation within developments will be able to sell units at a premium. Further research could determine if this premium offsets the opportunity costs of preserving the greenspace. Furthermore, landscaping ordinances and open space bonds that protect native desert landscapes and riparian restoration programs likely have associated positive externalities for nearby residents, in addition to raising property values. This, in turn, increases local property tax revenues. The direct and administrative costs associated with such programs are funded by taxes. There are tradeoffs between conservation programs and other programs, or no program and lower taxes, our study does not address these issues, rather it provides information on some of the positive externalities attributable to greenspace.

Our econometric modeling and results indicates that it is worthwhile to control for the heterogeneity of each type of green space in the study area, the explicit location of the amenity with respect to each home, and spatial dependence in the housing market. The results have an interesting policy implication because riparian commons lack explicit water rights. Therefore, it is likely that shared riparian corridors are under-watered. Privately-owned parcels are more likely to be optimally irrigated and green.[12] This greenness is influenced by homeowners through landscaping

[12] It could be that they are less green than optimal because of externalities. Neighbor A might benefit from Neighbor B's watering and landscaping but is unable to influence Neighbor B's behavior. It could also be that homeowners over-water their property.

and watering.[13] Nevertheless, it may be efficient[14] to dedicate some portion of treated wastewater supplies to the washes and improve this public green space, not only for nearby homebuyers (some may even pay for a connection to an extended wastewater pipeline for their own landscape watering), but also for other Tucson residents who recreate in the riparian corridors. Thus, public good proposals such as the Pima County's SDCP that advocate returning flows (treated effluent, the CEP) to some portion of the riparian network to conserve and rehabilitate riparian habitat, may be particularly effective. The value of riparian corridors, which are by their nature elongated and narrow, might benefit more nearby residents than a large park (Cho, Bowker, and Park, 2006) because of the multiple nearby homeowners (and renters) who benefit from such green space. In the study area, public green space is capitalized into private property values and higher property tax revenues. These incremental property tax revenues may be sufficient to pay for open space preservation and riparian conservation and rehabilitation Bark-Hodgins and Colby (2006). Alternatively, mill levies could be reduced and homeowners could spend this money on other items, including saving.

These arguments could assist policymakers in responding to challenges by developers who object to dedicating scarce water (treated effluent) to riparian projects. Their argument is that the replacement cost of water is high and, therefore, it should be put to a higher value use. However, our results indicate that the greenness in riparian corridors is capitalized into nearby homes and generates positive externalities. Thus restoring natural habitats may be an efficient use of water (treated effluent) because of the positive private and public good benefits of these green spaces.

Our research has shown that residences located on or adjacent to a golf course enjoy property price premiums, but that homes that are only close to golf courses do not. Meanwhile, homes located adjacent to and nearby riparian corridors enjoy property price premiums. Both types of green space confer private property benefits to homeowners and also contribute to greener subdivisions. Our research demonstrates that homebuyers have preferences for this type of regional greenness. Given that the greenness in riparian corridors is capitalized into nearby home values and that these public green spaces provide positive externality benefits, restoring natural habitats may be an economically sound use of water.

[Received July 2009; final revision received June 2011.]

References

Acharya, G. and L. L. Bennett. "Valuing Open Space and Land-Use Patterns in Urban Watersheds." *Journal of Real Estate Finance & Economics* 22(2001):221–237.

Anderson, L. M. and H. K. Cordell. "Residential Property Values Improve by Landscaping with Trees." *Southern Journal of Applied Forestry* 9(1985):162–166.

Anderson, S. T. and S. E. West. "Open Space, Residential Property Values, and Spatial Context." *Regional Science and Urban Economics* 36(2006):773–789.

Bark, R. H. "Levelling the Playing Field – Can Non-Market Values Compete in Policy Debates? A Case Study of Wastewater Allocation in Tucson, Arizona, USA." *Policy and Society* (forthcoming).

Bark, R. H., D. E. Osgood, B. G. Colby, G. Katz, and J. Stromberg. "Habitat Preservation and Restoration: Do Homebuyers Have Preferences for Quality Habitat?" *Ecological Economics* 68(2009):1465–1475.

---

[13] Although washes are for the most part private property as property lines typically extend to the wash centerline, the vegetation supported in the riparian corridors is a common good because of the water rights system in Arizona. Beginning in the 1870s surface water rights in the state were allocated by the prior appropriation doctrine (first in line first in right). Later a requirement of beneficial use was added. However, instream flows were not viewed as a beneficial use. Groundwater pumping rights are appurtenant to land and there are few controls to restrict groundwater pumping. Finally, surface and ground waters are managed separately in Arizona meaning that hydrologic connections between groundwater and surface waters is not recognized in law or water management. One outcome of Arizona's water rights and water management rules is that once flowing rivers in Tucson now run dry, except after heavy rain, because the water tables of the aquifers that used to support surface flows are now several hundred feet below the surface level.

[14] Approximately four times more land is in private yards than in riparian corridors in the study area.

Bark-Hodgins, R. H. and B. G. Colby. "An Economic Assessment of the Sonoran Desert Conservation Plan." *Natural Resources Journal* 46(2006):709–725.

Bark-Hodgins, R. H., D. E. Osgood, and B. G. Colby. "Remotely Sensed Proxies for Environmental Amenities in Hedonic Analysis: What does Green Mean?" In J. I. Carruthers and B. Mundy, eds., *Environmental Valuation: Intraregional and Interregional Perspectives,* London: Ashgate, 2006, 191–210.

Benson, E. D., J. L. Hansen, A. L. Schwartz, and G. T. Smersh. "Pricing Residential Amenities: The Value of a View." *Journal of Real Estate Finance & Economics* 16(1998):55–73.

Bin, O., T. W. Crawford, J. B. Kruse, and C. E. Landry. "Viewscapes and Flood Hazard: Coastal Housing Market Response to Amenities and Risk." *Land Economics* 84(2008):434–448.

Black, S. E. "Do Better Schools Matter? Parental Valuation of Elementary Education." *Quarterly Journal of Economics* 114(1999):577–599.

Brueckner, J. K. "The Economics of Urban Yard Space: An 'Implicit-Market' Model for Housing Attributes." *Journal of Urban Economics* 13(1983):216–234.

Burchfield, M., H. G. Overman, D. Puga, and M. A. Turner. "Causes of Sprawl: A Portrait from Space." *Quarterly Journal of Economics* 121(2006):587–633.

Carlson, T. N. and D. A. Ripley. "On the Relation Between NDVI, Fractional Vegetation Cover, and Leaf Area Index." *Remote Sensing of Environment* 62(1997):241–252.

Cho, S., N. C. Poudyal, and R. K. Roberts. "Spatial Analysis of the Amenity Value of Green Open Space." *Ecological Economics* 66(2008):403–416.

Cho, S. H., J. M. Bowker, and W. M. Park. "Measuring the Contribution of Water and Green Space Amenities to Housing Values: An Application and Comparison of Spatially Weighted Hedonic Models." *Journal of Agricultural and Resource Economics* 31(2006):485–507.

Do, A. Q. and G. Grudnitski. "Golf Courses and Residential House Prices: An Empirical Examination." *Journal of Real Estate Finance and Economics* 10(1995):261–270.

Downes, T. A. and J. E. Zabel. "The Impact of School Characteristics on House Prices: Chicago 1987-1991." *Journal of Urban Economics* 52(2002):1–25.

Fierro, K. P., T. M. Fullerton, and K. E. Donjuan-Callejo. "Housing Attribute Preferences in a Northern Mexico Metropolitan Economy." *Atlantic Economic Journal* 37(2009):159–172.

Geoghegan, J. "The Value of Open Spaces in Residential Land Use." *Land Use Policy* 19(2002):91–98.

Geoghegan, J., L. A. Wainger, and N. E. Bockstael. "Spatial Landscape Indices in a Hedonic Framework: An Ecological Economics Analysis using GIS." *Ecological Economics* 23(1997):251–264.

Hatton MacDonald, D., N. D. Crossman, P. Mahmoudi, L. O. Taylor, D. M. Summers, and P. C. Boxall. "The Value of Public and Private Green Spaces under Water Restrictions." *Landscape and Urban Planning* 95(2010):192–200.

Huete, A. R. "A Soil-Adjusted Vegetation Index (SAVI)." *Remote Sensing of Environment* 25(1988):295–309.

Huete, A. R. and H. Q. Liu. "An Error and Sensitivity Analysis of the Atmospheric- and Soil-Correcting Variants of the NDVI for the MODIS-EOS." *IEEE Transactions on Geoscience and Remote Sensing* 32(1994):897–905.

ILG. *Funding Open Space Acquisition Programs: a Guide for Local Agencies in California*. Sacramento, CA: Institute for Local Government, 2005.

Irwin, E. G. and N. E. Bockstael. "The Problem of Identifying Land Use Spillovers: Measuring the Effects of Open Space on Residential Property Values." *American Journal of Agricultural Economics* 83(2001):698–704.

Kuminoff, N. V. "Using a Bundled Amenity Model to Estimate the Value of Cropland Open Space and Determine an Optimal Buffer Zone." *Journal of Agricultural and Resource Economics* 34(2009):68–90.

Leggett, C. G. and N. E. Bockstael. "Evidence of the Effects of Water Quality on Residential Land Prices." *Journal of Environmental Economics and Management* 39(2000):121–144.

Mahan, B. L., S. Polasky, and R. M. Adams. "Valuing Urban Wetlands: A Property Price Approach." *Land Economics* 76(2000):100–113.

Mansfield, C., S. K. Pattanayak, W. McDow, R. McDonald, and P. Halpin. "Shades of Green: Measuring the Value of Urban Forests in the Housing Market." *Journal of Forest Economics* 11(2005):177–199.

Millington, A. C., T. D. Douglas, and R. W. Critchley. *Estimating Woody Biomass in Sub-Saharan Africa*. World Bank Publications, 1994.

Morales, D. J. "The Contribution of Trees to Residential Property Value." *Journal of Arboriculture* 7(1980):109–112.

Morales, D. J., F. R. Micha, and R. L. Weber. “Two Methods of Valuating Trees on Residential Sites.” *Journal of Arboriculture* 9(1983):21–4.

Moran, P. A. P. “The Interpretation of Statistical Maps.” *Journal of the Royal Statistical Society. Series B* 10(1948):243–251.

Mueller, J. and J. Loomis. “Spatial Dependence in Hedonic Property Models: Do Different Corrections for Spatial Dependence Result in Economically Significant Differences in Estimated Implicit Prices?” *Journal of Agricultural and Resource Economics* 33(2008):212–231.

Nagler, P. L., E. P. Glenn, and A. R. Huete. “Assessment of Spectral Vegetation Indices for Riparian Vegetation in the Colorado River Delta, Mexico.” *Journal of Arid Environments* 49(2001):91–110.

Nivens, H. D., T. L. Kastens, K. C. Dhuyvetter, and A. M. Featherstone. “Using Satellite Imagery in Predicting Kansas Farmland Values.” *Journal of Agricultural and Resource Economics* 27(2002):464–480.

Paterson, R. W. and K. J. Boyle. “Out of Sight, Out of Mind? Using GIS to Incorporate Visibility in Hedonic Property Value Models.” *Land Economics* 78(2002):417–425.

Payton, S., G. Lindsey, J. Wilson, J. R. Ottensmann, and J. Man. “Valuing the Benefits of the Urban Forest: A Spatial Hedonic Approach.” *Journal of Environmental Planning and Management* 51(2008):717–736.

Rosen, S. “Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition.” *Journal of Political Economy* 82(1974):34–55.

Schweik, C. M. and C. W. Thomas. “Using Remote Sensing to Evaluate Environmental Institutional Designs: A Habitat Conservation Planning Example.” *Social Science Quarterly* 83(2002):244–262.

Sengupta, S. and D. E. Osgood. “The Value of Remoteness: A Hedonic Estimation of Ranchette Prices.” *Ecological Economics* 44(2003):91–103.

Shultz, S. D. and D. A. King. “The Use of Census Data for Hedonic Price Estimates of Open-Space Amenities and Land Use.” *Journal of Real Estate Finance & Economics* 22(2001):239–252.

Shultz, S. D. and N. J. Schmitz. “Augmenting Housing Sales Data to Improve Hedonic Estimates of Golf Course Frontage.” *Journal of Real Estate Research* 31(2009):63–79.

Smith, V. K., C. Poulos, and H. Kim. “Treating Open Space as an Urban Amenity.” *Resource and Energy Economics* 24(2002):107–129.

Spalatro, F. and B. Provencher. “An Analysis of Minimum Frontage Zoning to Preserve Lakefront Amenities.” *Land Economics* 77(2001):469–481.

Tucker, C. J. “Red and Photographic Infrared Linear Combinations for Monitoring Vegetation.” *Remote Sensing of Environment* 8(1979):127–150.