Do homebuyers care about the 'quality' of natural habitats?

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Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Providence, Rhode Island, July 24-27, 2005

Abstract

We study if homebuyers in Tucson, Arizona care about the condition of natural habitats and if they have preferences between natural and manmade habitats. Using field work data we examine whether homebuyers' willingness to pay is influenced by the biological condition of the neighboring riparian habitat and how homebuyers value alternative manmade green areas, specifically golf courses. We also explore the relationship between the field data and remote sensing vegetation indices. The results of a hedonic analysis of houses that sold within 0.2 miles of 51 stratified-random selected riparian survey sites in Tucson, Arizona reveals that homebuyers significantly value habitat quality and negatively value manmade park-like features. Homebuyers are willing to pay twenty percent more to live near a riparian corridor that is densely vegetated and contains more shrub and tree species, particularly species that are dependent on perennial water flow. These environmental premiums are significant, outweighing structural factors such as an additional garage or swimming pool. Likewise, proximity to a riparian habitat with low biological quality or to a golf course lowers property values.

Introduction

Although it is well established that urban populations value different types of natural amenities, such as parks, wetlands, and river corridors, it is not clear what elements of these amenities are valued. Much of the literature on economic valuation of urban amenities focuses on simple measures such as distance to the amenity (Smith, Poulos and Kim, 2002) and its size (e.g., the size of the urban wetland, Mahan, Polasky, and Adams, 2000). Hedonic studies may not provide a measure of the value of the natural environment if homebuyers are indifferent between manmade parks, degraded ecosystems, and vibrant natural habitat. In addition, if people do not value the natural features of environmental amenities, then manmade features could substitute for natural habitat. Since natural riparian habitats and irrigated manmade features often compete for water, it is worthwhile to understand their relative values.

In this study, we develop and utilize a rich set of data on amenity characteristics to identify which features contribute to value. Specifically, we ask if homebuyers care about the condition of the vegetation in their nearest riparian corridor, or if they are indifferent to natural environments, and how they value manmade recreation environments, such as golf courses.

Riparian corridors are species-diverse ecosystems (Naiman, Décamps, and Pollock, 1993). In the semi-arid southwest these green corridors of trees and shrubs are also aesthetic resources. In Tucson, Arizona there are few natural habitat substitutes with dense trees because rare natural water flows are channeled down these corridors. Riparian habitat in Tucson varies from densely vegetated deciduous forest to less dense shrubland to open bare areas. Such variation is likely the consequence of natural processes, including variance in watershed size and mean stream flow rate, but some loss, fragmentation, and simplification of the riparian ecosystem is a response to human modification of hydrologic fundamentals and extensive treatment to some sections of river beds and banks (Stromberg et al. 2004), as has occurred elsewhere in the southwest (e.g., Scott, Shafroth and Auble, 1999 and Patten, 1998).

Riparian habitats differ in tree species composition and density of vegetation and also in the wildlife habitat and aesthetic values they provide. We apply hedonic price methods to georeferenced biological survey and parcel level sales data to test whether the variation in habitat condition impacts human valuation of the riparian corridor.

Previous research reports that nearby natural resources: 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 and Smith, Poulos and Kim, 2002, Acharya and Bennett, 2001, Shultz and King, 2001; Spalatro and Provencher, 2001; Paterson and Boyle, 2002; Benson et al., 2000; Mahan, Polasky, and Adams, 2000; Leggett and Bockstael, 2000; and Geoghegan et al., 1997). This literature uses the proximity between residential parcels and environmental features, as well as land use patterns, in valuing amenities. It does not explicitly address the site-specific biological features or natural versus manmade qualities of sites.

Particularly relevant to our work are hedonic valuations of riparian ecosystems. King, White, and Shaw (1991) examined the effects of proximity to riparian habitat and other natural areas on the sale prices of single family residences (SFR) in the Tucson metropolitan area. This research identified a three to five percent ‘premium’ in the sales price of SFR located within one-half mile of riparian areas and other wildlife habitat. These results were confirmed in Colby and Wishart (2002). The authors found that by reducing the distance to the large central urban riparian corridor from 1.5 miles to 0.1 miles (as per the methodology Mahan, Polasky, and Adams, 2000) the sample mean house price rose by 6%. As with other research, these studies value amenities without measuring amenity specific features.

Recent work is beginning to control for site-specific environmental characteristics without addressing quality, health, or how artificial the amenity is. Bark-Hodgins, Osgood and Colby (2005a) investigate not only proximity, but the impact of wash size, and "greenness", on the hedonic valuation of washes in Tucson, Arizona. The authors found that wash greenness, as measured by a remotely sensed vegetation index, was a large, significant and positive factor in determining house price. The research documents that a 10% increase in greenness at the nearest riparian corridor raises house prices by 5%. The greenness index they used is a proxy for site-specific plant vigor that does not disaggregate the range of qualities that could contribute to greenness, provide a measure of habitat health, or distinguish between natural and manmade features.

This paper adds to the literature by investigating whether the condition of the vegetation in the riparian corridor differentially impacts nearby house prices. A few terms will aid this discussion. Johnson, Carothers, and Simpson (1984) identified three main categories of riparian habitat: *hydroriparian* habitats require perennial stream flows and have the highest vegetation density and support some trees species are not found elsewhere, whilst *mesoriparian* and *xeroriparian* habitats respectively have intermittent to ephemeral stream flow. It is unlikely that many Tucson homebuyers would know this classification system; however, these same homebuyers may have preferences about characteristics of riparian habitats.

Study area

We study riparian habitats in the desert city of Tucson, Arizona. Tucson is a useful study area because of the intense competition between development and the relatively scarce riparian areas. The US Census Bureau estimated that in 2003 the Tucson metro area had a population of 893,000. Population growth is rapid in this sunbelt city averaging an annual 2.7% rate between 1990 and 2000 (US Census Bureau). The city is located in the Sonoran desert in southwest USA. The climate is generally hot and dry;[i] however, there are two distinct wet seasons. Summer precipitation coincides with the Mexican/North American monsoon and frontal systems produce winter rains. In the period 1868-2003 Tucson received an annual average 11.8 inches (289 mm) of precipitation.[ii]

The study area covers 77 square miles (200 km^2) in northeast metropolitan Tucson, Arizona. It contains a total of 236 miles (380 km) of washes, of which 89% are ephemeral river beds. Intermittent streams run for a total 25 miles (39 km) and perennial streams for 0.7 miles (1.2 km) in the study area.[iii]

Methods and data

Pima County provided residential sales data and their assessed structural characteristics for the period 1998-2003. After data cleaning there were about nine thousand[iv] SFR sales in study area over the study period. Riparian corridor and parcel GIS data was obtained from the Pima County Land Information System (PCLIS) which included topology, wash locations, and flow characteristics.[v] Sales were georeferenced to the GIS database using parcel identification numbers.[vi]

Washes are distinguished by their treatments and habitat condition. At one extreme some are straightened and completely concrete-lined[vii]. Other washes follow their 'natural' course and have an abundance of trees. Some of the watercourses have flowing water and support mesoriparian and hydroriparian tree species; others are dry (ephemeral) washes with xeroriparian trees. For those unfamiliar with Sonoran desert vegetation hydoriparian habitat is most differentiated from upland desert vegetation i.e. leafy green tall trees versus cactus and creosote.

In order to control for and thus determine the influence of habitat characteristics survey data was collected on the characteristics of riparian sites across the study area. This data was collected in late spring and early summer 2003 at 51 stratified-random sites[viii] and included measures of vegetation volume (m^3/m^2), woody species richness, and the proportion of hydro and mesoriparian woody species, and amenity data, such as a subjectively determined "use by walkers" variable[ix]. To integrate the georeferenced field work dataset, the wash 'arcs' or segments on which the survey sites were located were bounded in the GIS by a 1,056 ft (0.2 miles, 0.32 km) buffer zone. This distance was chosen as it is the distance used by the Pima County Assessor's Office in determining 'comparables' in the property tax dispute process. Those homes that had sold in the study period within these buffers were selected for a hedonic analysis. Of the 9,462 house sales in the study area in the study period 692 sales were within the buffer zones.[x] The buffering reduced the number of wash arcs used in the analysis to thirty four, because no sales were recorded in the study period within nine of the buffers and some survey sites were located on the same wash arc. The 51 survey sites and buffers are shown on Figure 1. House sales within these buffers are displayed as dots.

We follow the standard hedonic price analysis introduced by Rosen (1974). Let P be the price of housing and x the numeraire good, a composite commodity representing all other goods. Housing prices are a function of the typical housing characteristics: defined by a vector of structural attributes, **S**; neighborhood attributes, **N**; and environmental attributes, **E**; which describes the biological characteristics of the nearest riparian corridor. Household utility is a function of these characteristics, $u(x, \mathbf{S}, \mathbf{N}, \mathbf{E})$. Agents maximize utility subject to the normalized budget constraint $Y - P - x = 0$. Assuming that house prices are in equilibrium, and that preferences are weakly separable, the hedonic price function can be specified as $P = P(\mathbf{S}, \mathbf{N}, \mathbf{E})$ (Freeman, 1997).

Model

The observed cross-sectional sales prices of SFR are modeled as a function of structural, neighborhood and environmental characteristics. The sample is treated as single cross section because all of the houses sold only once in the study period.

The choice of variables to include in the hedonic model was guided by the goal to estimate the ‘net’ value of the riparian corridor characteristics to nearby homebuyers (Chao *et al.*, 1998). For example, enhanced flood risk associated with proximity to the wash might depress house prices and therefore should be tested for significance in the model. However, we found that the Federal Emergency Management Agency’s 100-year flood zone/flood risk parameter was insignificant in this model. This might be because all the SFR sales used in this model are located within a maximum distance of 1,056 ft of the wash centerline and therefore most of the sample is subject to some flood risk. Elevation another factor we had a priori thought might be a significant determinant of house prices in the study area was also insignificant in the model.[xi]

Following other researchers (Shultz and King, 2001; Acharya and Bennett, 2001; Mahan et al., 2001) a semi-log model was used for the benchmark regression.[xii] The econometric model is specified below, where, $\boldsymbol{\varepsilon}$ is assumed to be independent and normally distributed.

$$\ln(\mathbf{P}_i)=[\mathbf{S}_i, \mathbf{N}_i, \mathbf{E}_i, \mathbf{T}_i]'\boldsymbol{\beta} + \boldsymbol{\varepsilon}_i \qquad (1)$$

Where, **E** represents the vector of riparian characteristics, comprising vegetation volume, (m^3/m^2) (VEGVOL), overall woody plant species richness (DIVERSITY), hydro and mesoriparian species richness (HMRICH) measures at each survey site and a "use by walkers" (WALKERS) variable[xiii]. The structural vector **S** consists of typical housing value variables, lot size sq. ft. (LOT), living area sq. ft. (LIVING), number of bath fixtures[xiv] (BATH), age in years (AGE), and also less familiar features that are important in the desert heat: number of covered garage spaces (GARAGE), and pool area sq. ft. (POOL). The neighborhood vector, **N**, comprised a distance to the nearest golf course in feet (DISTGOLF) variable[xv]. In order to account for SFR property appreciation, following Mooney (2001), the number of years of the sale before 2003 (APPREC) was calculated, **T**.

Results

Ordinary least squares (OLS) was used to estimate the parameters in Equation (1). The regression results are shown in Table 2. The mean house price in the study area is \$196,481. The model explained 86% of house price variation in the field area. The parameters in the model were all significant at the five percent level. People are willing to pay more for new[xvi], larger houses, on larger lots, with more bathrooms, and covered garage spaces. House price appreciation in the study area is rapid. The parameters for the environmental characteristics indicate that homebuyers are willing to pay more to be near a densely vegetated, woody plant species-rich washes, and those with a greater number of hydro/mesoriparian plant species. But, the use of riparian corridors by walkers had a negative effect on house prices. The distance to golf variable is positive meaning that a location nearer a golf course negatively impacts house prices in this area.

Several diagnostic tests were run to investigate the robustness of the OLS results. To test for heteroscedasticity, White's (1980) and Breusch-Pagan (1979) tests were applied. Both detected heteroscedasticity beyond the 99% confidence level. White's heteroscedasticity-consistent covariance matrix of the parameter estimates was calculated and used to correct the OLS standard errors (see Table 3). After correction for heteroscedasticity all the variables remain significant at the tenth of one percent level.

The data used in this study is of a spatial nature and therefore the Moran's I (Moran, 1948) and Geary's C (Geary, 1954) t-statistics were used to test for the existence of spatial error processes. Both statistics were calculated using an inverse squared distance weights matrix. In building the spatial weights matrix we used a cut off distance of 1,000 ft., approximately equal to the distance used to buffer the sites. The Moran's I statistic calculated was estimated at 0.27 (t-value 7.2, p-value <0.001). Thus positive significant spatial error processes were detected. The Geary's C test was estimated at 0.44 (t-value -4.0, p-value 0.00005), also revealing positive significant spatial error processes. Maximum likelihood and GMM two step and iterative approaches were attempted to estimate a spatial autocorrelation model. However, we were unable to find a spatial autocorrelation model that would converge, perhaps because of the highly clustered dataset resulting from sampling the parcels surrounding our field sites.

Marginal implicit prices (MIP) or hedonic prices and elasticities were calculated for the recovered parameters.[xvii] LIVING is the single most important determinant of house prices in the study. A one percent increase in LIVING raises house prices by 0.65 percent. Other structural factors are important determinants of house prices in this area. For example, GARAGE's implicit value is $7,649 and AGE is -$1,580. The environmental variables are highly important. For example the elasticity data show that a one percent increase in DIVERSITY raises house prices by 0.21 percent. Homebuyers are willing to pay $47,000 or 24% of the total average house value for DIVERSITY, HMRICH, and VEGVOL. However, WALKERS has a negative sign meaning that sales prices of houses located near a wash with high walker use are discounted. It may be that homeowners neighboring washes prefer private, more inaccessible riparian corridors. The neighborhood variable, DISTGOLF, is positive this means that proximity is negatively valued by homebuyers. For example, reducing DISTGOLF from the sample average 9,537 ft, to the sample minimum 1,370 ft, reduces the sample mean house price by $4,574. This result is contrary to what we might expect *a priori* if greenness alone was important to homebuyers, and specifically greenness that the homeowner does not have to pay to water. In summary, although homebuyers are willing to pay more to live near a denser, species rich riparian corridor they are not willing to pay more to live near a golf course. Either homeowners do not value such manmade green space or any such premium is outweighed by the negative impacts associated with proximity to a golf course, such as traffic, privacy, and safety issues.

Habitat characteristics and vegetation indices

Because remotely sensed proxies for vegetation are widely available and becoming increasingly common in hedonic analyses (Nivens *et al*, 2002; Sengupta and Osgood, 2003; Bark-Hodgins, Osgood and Colby, 2005a) it is worthwhile to investigate the meaning of these proxies in terms of habitat characteristics. Using a single Landsat ETM+ image, with 30m^2 resolution[xviii], we generated two vegetation indices for our study area.[xix] The vegetation indices were the normalized vegetation index (NDVI) and the soil-adjusted vegetation index (SAVI). SAVI (Huete, 1988) is explicitly modified for remote sensing in arid and semi-arid areas where a vegetative groundcover is fragmented or largely absent, it does this by adjusting the index for the brightness, or reflectivity, of the background soil. A high NDVI or SAVI value indicates vigorous, healthy vegetation; in contrast a low NDVI or SAVI value indicates little vegetation or dead vegetation (perhaps as a result of drought). A low NDVI or SAVI value may also indicate that the wash is extremely large with large expanses of non-vegetated river sand and a small stand of highly attractive deciduous cottonwoods[xx], or mesquites, or alternatively a stand of invasive salt cedar. The index falls in the range 0-255 but the actual range of greenness in the study area was much smaller: from 100-198 for the parcels and from 101-221 for the washes.[xxi]

We tested whether two remotely sensed greenness indices, NDVI or SAVI, could predict our detailed field survey data, specifically, woody vegetation volume and species richness. The regressions run were:

$$\text{DIVERSITY} = \beta_0 + \beta_1 \text{ Veg INDEX (at the survey site or wash arc)} + \varepsilon \quad (2a)$$

$$\text{VEGVOL} = \beta_0 + \beta_1 \text{ Veg. INDEX (at the survey site or wash arc)} + \varepsilon \quad (2b)$$

We were unable to detect a statistically significant link between the remotely sensed variables and the biological survey data perhaps due to the low number of observations (51) and the relatively coarse resolution of the image. The strongest predictor was SAVI, which was still insignificant for both vegetation volume (parameter estimate 0.002, t-value 0.55, p-value 0.587) and species richness (parameter estimate 0.083, t-value 1.04, p-value 0.304). Thus, given the data we have available, it is difficult to directly link remotely sensed vegetative proxies to particular habitat qualities. Nagler *et al.,* (2001) found similar results; they also could not identify different species or vegetation volume in a riparian ecosystem. However, in their study they found that vegetation indices were positively related to percent vegetation cover. It may be worthwhile to improve the remote sensing protocol, for example, by using multiple images concurrent with known leafing-out times of the main deciduous woody species or using higher resolution images (see Bark-Hodgins, Osgood and Colby, 2005b). Note that greenness data as measured by SAVI was not used in our hedonic regression. If we had included SAVI in this regression, there would have potentially been redundant measures for species diversity and vegetation volume, making the results difficult to interpret.

Discussion

The variables chosen for the modeling differ from similar research in this area by Bark-Hodgins, Osgood and Colby (2005a). In this current paper the FEMA flood zone variable was insignificant however it was a significant negative variable in the aforementioned paper. An explanation is that all the house sales in this clustered sample are subject to some flood risk as they are located with a maximum 0.2 miles of the wash centerline. Another variable significant in this other work but not in this paper is the top-rated Catalina Foothills School District. In the clustered model this school district variable is significantly correlated with three variables used in the model: DIVERSITY, DISTGOLF and WALKERS (Pearson coefficients and prob.>|rho|: 0.475 (<.0001), -0.144 (0.0001) and -0.109 (0.0040), respectively). We found that if we removed these three correlated variables from the model, that the Catalina Foothills School District parameter was significant at the tenth of one percent level and the marginal implicit price was calculated to be $31,060, which is very close to the $30,448 estimated in Bark-Hodgins, Osgood and Colby (2005a).

Unmodeled spatial autocorrelation may lead to inefficiency in the parameter estimation and bias the standard errors recovered in our estimation. However, concerns have been raised in the literature that autocorrelation corrections may impose substantial, and perhaps undesirable, structure on the causal model (Nivens *et al.,* 2002, p472) and that detecting autocorrelation does not necessarily imply it is appropriate to correct at all for spatial autocorrelation (Greene, p.577). Given the extremely low standard errors we have recovered, bias in the recovery of the standard errors would have to be quite dramatic (orders of magnitudes in terms of p-values) in order to lead to spurious detections of significance for the parameters important to our study. Nevertheless, the reader should be mindful that spatial processes may have biased the recovered errors and led to exaggerated measures of quality of fit.

Conclusion

The results of this research provide evidence that Tucson homebuyers located within 0.2 miles of a riparian corridor value natural habitat more than manmade green areas, specifically golf courses. It seems that, at least for these homebuyers, manmade environments are not a substitute for natural habitat. This is an interesting finding because in semi-arid environments where water is scarce golf course irrigation is a competitor for instream water flows. Moreover, the environmental premiums for riparian corridors with high density, overall species diversity, and hydro and mesoriparian species richness outweigh structural variables (variables that can be influenced by the homeowner) such as a covered garage or a swimming pool.

Specific characteristics of riparian corridors associated with the endangered Sonoran cottonwood-willow forest type, appear to have considerable value to property owners in Tucson. For those readers unfamiliar with the Sonoran desert, it is these sections of the riparian corridor that provide the greatest visual contrast with the typical upland desert vegetation. It is an interesting coincidence that those sections of the riparian corridor that might be considered to have higher ecological 'quality' are valued more highly than those sections of the riparian corridor that are either naturally dry or degraded. However, we cannot say whether such willingness to pay is a function of a concern for wildlife habitat or the result of aesthetics or some other factor.

The HMRICH habitat condition variable is correlated to water availability. Shallow and stable groundwater levels are necessary to support hydro-mesoriparian tree species (Horton, Kolb and Hart, 2001 and Scott, Shafroth and Auble, 1999). The results of the hedonic analysis indicate that homebuyers place most value on those sections of the riparian corridor where water still flows perennially or intermittently. But, such habitats are particularly threatened by continued groundwater over-drafting. Research by Lite and Stromberg (2005) shows that as streams are dewatered and groundwater levels decline riparian tree communities shift from higher human valued hydro and mesoriparian species to more mesic species, which have lower human value.

Because homebuyers seem to value habitat quality, other hedonic work that has used aggregate measures such as remotely sensed greenness indices or 'open space' may, to some extent, be measuring the value of natural habitats. However, it is important to remember that these aggregate proxies are implicitly valuing a mix of natural habitats and manmade parks/golf courses that homebuyers may value differently. For our 51 survey sites, we were unable to detect a significant link between remotely sensed indices and measured habitat quality, so we cannot make a strong statement as to what a remotely sensed proxy represents in terms of habitat.

Our results have implications for those concerned with water management and riparian habitat preservation and restoration. We show that there are sound economic reasons to limit groundwater pumping, stream diversions and new flood control infrastructure whilst supporting public purchases and re-watering of riparian habitat. In Pima County, the Floodprone Land Acquisition Program (FLAP is limited to buying those properties that can be assessed for development, thus excluding the fraction of any parcel that is in the floodway and floodplain fringe.[xxii] A partial estimate of the 'value' of the riparian zone is the property price premium accruing to nearby property owners. This research documents large premiums and could provide a basis for alternative valuation procedures that support the purchase (and conservation) of hydro and mesoriparian habitat. However, the outright purchase of parcels that contain significant riparian habitat is not a guarantee to this ecosystems survival if groundwater overdrafting continues.

The hedonic analysis also demonstrates an economic justification for the restoration of the riparian corridor by guaranteeing the hydrologic conditions necessary to support hydro and mesoriparian habitat, which in turn benefits private property values and boosts property tax revenue. Without such changes, future population growth and consequent increased water demand in Tucson, including for golf course irrigation, are likely to negatively affect riparian habitat and nearby property values.

Acknowledgements

This research was supported by Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA), a National Science Foundation, Science and Technology Center. Thanks also to Jason S. Schuminski for his hard work with the spatial data and spatial statistics.

Notes

[i] Average high temperatures from May to September are 90ºF (32.2ºC) or higher, National Weather Service, NOAA.

[ii] Data from the National Climatic Data Center, NOAA.

[iii] This data was calculated in the Geographic Information System (GIS).

[iv] The authors excluded 414 'non-market' sales from the database, for example sales classified as "sales under duress" and "sales between related parties". Other sales were excluded because assessor characteristics were not available or the data recorded seemed problematic. Sales price or assessor characteristics that seemed unreasonable were double-checked against the Pima County's on-line sales and assessor files.

[v] In the PCLIS GIS each wash 'arc' or segment of the riparian corridor is classified by size. The classification is based on the volume of flood water a wash can carry in cubic feet per second (cfs). There are six classes with 'very small' wash (CFS1, <500 cfs) designating the smallest washes and 'extremely large' wash the largest (CFS6, >25,000 cfs). Such size classifications are hard to visualize, so for illustration, our field research found that a 'very small' classified wash typically had a narrow channel (3-6 ft), with steep, often densely vegetated, banks, whilst an 'extremely large' classification describes a wash with a wide channel (60-165ft) where river sand not vegetation dominates. The size classification is partly determined by elevation: almost all of the 'very small and 'small wash arcs are located in the foothills in the north and eastern parts of the study area and these form larger washes downstream until they join the main Rillito Creek which is 'extremely large. Significant is the absence of smaller, tributary washes in the urban-south portion of the study area (see Figure 1). All wash segments in this area are

all classified as ‘large’ or ‘very large’; this is a consequence of elevation and urbanization; many smaller washes have been filled in and paved over, however, they often reveal their former wash status by flooding after rain.

[vi] Three statistical packages were used in the data analysis: SAS 9.0 for Windows, Stata Intercooled 7.0, and for the spatial econometrics, SpaceStat 1.91. The geographically-referenced data was processed mostly in the more powerful ArcInfo program but the resulting data was imported into ArcView 3.3 for mapping and to export data to SpaceStat.

[vii] During fieldwork it was observed that many nearby residents built walls to exclude these washes from their view.

[viii] The stratified random procedure was conducted as follows. The research team decided to select an equal number of sites from the ‘small’ (CFS1-3), ‘medium’ (CFS4) and ‘large’ (CFS5 and CFS6) size categories and in each of four sub-sections related to somewhat distinct markets: exurban-east, urban-south, Foothills-north and along the main central urban Rillito Creek/Tanque Verde wash. Wash arcs were randomly selected for biological sampling based on those criteria. A primary and backup site were drawn in the random sampling to address sites that were inaccessible either because the wash segment was located in a gated community or required traversing private land. Results of this random selection are shown in Table 1. The stratification was restricted somewhat by regional homogeneity: most of the washes within the urban-south sub-area were CFS4.

[ix] This variable was subjectively determined by the field researcher. The coding system was 0 for no visible use, 1 for low use, 2 for moderate use, and 3 for high use. The range in the field area was 1 to 3 with the average approximately 2.

[x] The breakdown of the size of the nearest riparian corridor to all 692 sales is: very small wash 33, small wash 59, medium wash 71, large wash 518, very large wash 10, and extremely large wash 1.

[xi] The breakdown of the house sales by year are: 1998, 110 sales; 1999, 121 sales; 2000, 120 sales, 2001 115 sales; 2002, 111 sales and 2003, 115 sales. The study area encompasses lower lying suburban neighborhoods as well as more exclusive, higher elevation 'Foothills' neighborhoods. *A priori* we had expected elevation to be a significant and positive parameter in the model.

[xii] The log-log specification yielded the same significant parameters and the same signs as the benchmark, with many similar elasticities. The log-log model specification does generate what we consider unreasonably high marginal implicit prices for both HMRICH and GARAGE. The linear model performed very badly, with few significant variables, and parameters that make little sense. For example, in the linear model the hedonic price for BATH (a single bath fixture) was $12,159 or $36,000 for a full bath, or four times more than GARAGE.

The more general Box-Cox transformation was performed allowing for separate parameters for the left hand and right hand side variables and the inclusion or exclusion of each individual right hand side variable in the transformation. The results had the same signs as the log-linear results and all variables were still significant except for

WALKERS and BATH. Because this functional form is difficult to interpret, the semi-log form is presented, as is common in the hedonic literature.

[xiii] The river park system consists of pathways for bicyclists, walkers and horse-riders. To date nearly 30 miles of river park trails and pathways have been constructed. The river park facilities provide a system of connected pathways as well as numerous park amenities including picnic facilities, playground equipment, staging areas, habitat restoration projects, and much more. See http://www.dot.co.pima.az.us/flood/cip/index.htm.

[xiv] Three bath fixtures is equivalent to a full or half bath and two bath fixtures to a half bath.

[xv] See Figure 1 to locate golf courses in the study area. Note that three of the seven golf courses in the study area are located in the exclusive Foothills neighborhoods, three in the urban southwestern section, and one in the exclusive far eastern sector.

[xvi] The field area includes only one Historic District, the Fort Lowell Multiple Resource Area, as per the National Register of Historic Districts. The mean house age in the field area was relatively low at 27.08 years.

[xvii] The MIP calculation used was $MIP_k = \beta_k . P$ where β_k is the estimated coefficient for independent variable k and P_k is the average value for a home sale in the sample. The elasticity calculation for all continuous variables was as per Franklin and Waddell (2002) $E_k = \beta_k X_k$ where β_k is the estimated coefficient for independent variable k and X_k is the average value for the independent variable, k.

[xviii] Note that the 30 m^2 resolution is wider than many of the riparian corridors in the area. See endnote V.

[xix] The vegetation indices were calculated using the reflectances, ρ, recorded for the following remote sensing bands and formula: NDVI = $(\rho_{near\ infrared\ (NIR)} - \rho_{red}) / (\rho_{NIR} + \rho_{red})$ and SAVI = $(1 + L) (\rho_{NIR} - \rho_{red}) / (\rho_{NIR} + \rho_{red} + L)$. The L value chosen was 0.5. An L value of 0.5 minimizes soil brightness and eliminates the need for additional calibration for different soils (Huete and Liu, 1994).

[xx] Cottonwoods are beautiful large trees that leaf out early in spring, whilst in the fall the leaves turn golden yellow.

[xxi] The SAVI image was smoothed using a spatial filtering procedure. The blurring algorithm assigns a smoothed SAVI value to each center pixel in a 5x5 pixel neighborhood. The algorithm weighs the center pixel the most, that is it does not just average the values in the 5x5 grid. The rational for this procedure is that we did not have accurately georeferenced pixels and thus there was a slight offset between the GIS and the remote sensing image which this blurring technique minimized. The SAVI value was linked to each survey site, parcel and stretch of the riparian corridor in the GIS database. The distance from each parcel to the nearest stretch of riparian corridor was calculated in the GIS.

[xxii] No new housing development is allowed in floodways as per Pima County Code, Chapter 16.24 Floodways, Section 16.24.010, subsection D lists the types of uses allowed: accessory residential uses, including lawns, gardens, parking areas and play areas. (Ord. 1999-FC-1 § 1 (part) 1999; Ord. 1988-FC2 Art. 8 (A) 1988). The floodplain fringe, the area beyond the actual floodway, has different restrictions. Manufactured

homes and subdivisions might be permitted by the county engineer in the floodplain fringe if, and only if, developers met rigorous requirements, such as building design and construction, anchoring, and setbacks. (Chapter 16.28 Floodway Fringe Area Requirements).

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Table 1: Washes selected for vegetation data collection

Sub-area	**Sites selected**	**CFS size**	**Number selected**
		CFS 1	5
		CFS 2	5
East	13	CFS 3	7
Foothills-north	12	CFS 4	22
Urban-south	14	CFS 5	6
Large-CFS5/6	12	CFS 6	6
Total	**51**	**Total**	**51**

Table 2: Log linear OLS results, Adjusted R^2 = 0.8583

Variable	Parameter estimate	Standard Error	t Value	Pr > |t|	Mean Value
INTERCEPT	11.2509000	0.0682100	164.93	<.0001	
LOT	0.0000033	0.0000004	9.14	<.0001	21057.52
LIVING	0.0003453	0.0000219	15.80	<.0001	1877.27
AGE	-0.0080400	0.0009746	-8.25	<.0001	27.08
BATH	0.0153400	0.0061900	2.48	0.0134	6.91
GARAGE	0.0389300	0.0104800	3.71	0.0002	0.40
POOL	0.0001492	0.0000365	4.09	<.0001	177.66
DISTGOLF	0.0000029	0.0000009	3.07	0.0022	9536.73
WALKERS	-0.0273000	0.0086200	-3.17	0.0016	1.93
VEGVOL	0.1437200	0.0344300	4.17	<.0001	0.53
DIVERSITY	0.0205000	0.0020100	10.18	<.0001	10.36
HMRICH	0.0731200	0.0280000	2.61	0.0092	0.04
APPREC	-0.0754300	0.0047800	-15.77	<.0001	2.51

Table 3: Log linear heteroscedasticity corrected errors, MIP and elasticities

Variable	Error	χ^2-value	Pr > χ^2	MIP	Elasticity
INTERCEPT	0.069777	25998.3	<.0001		
LOT	0	51.65	<.0001	0.64	0.06844
LIVING	0.00003	130.86	<.0001	67.85	0.64824
AGE	0.001098	53.57	<.0001	(1,579.71)	-0.21770
BATH	0.008383	3.35	0.0672	3,014.02	0.10598
GARAGE	0.01085	12.87	0.0003	7,649.02	0.01553
POOL	0.000001	7.54	0.006	29.31	0.02650
DISTGOLF	0.035615	16.28	<.0001	0.56	0.02718
WALKERS	0.011924	5.24	0.0221	(5,363.94)	-0.05263
VEGVOL	0.002829	52.50	<.0001	28,238.30	0.07622
DIVERSITY	0.031301	5.46	0.0195	4,027.87	0.21247
HMRICH	0.000041	13.05	0.0003	14,366.72	0.00296
APPREC	0.005297	202.73	<.0001	(14,820.59)	-0.18912

Figure 1: Study area