Valuing Vegetation in an Urban Watershed[*]

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Abstract
This study uses the hedonic price method to examine if land cover types – trees, shrubs, water and impervious surface areas – affect the sale price of single-family residential properties in Multnomah County, Oregon. We combine detailed structural and location information for 42,722 single-family residential property sales from 2005-2007 with the percentage of trees, shrubs, water, and impervious surface area on each property and within 200 feet, ¼ mile, and ½ mile buffers of each property. Results using a semi-log functional form indicate that vegetation on a property and within each buffer contributes positively to a property's sale price when compared to impervious surface area. The percentage of a property covered by trees that is estimated to maximize a property's sale price (31.33%), is higher than the current average for the properties in our study (26.08%), but less than the goal established by policy makers (35-40%).

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I. Introduction

Oregon is known for its innovative land use planning, abundant natural resources and, for western Oregon, a rainy season that lasts for eight months. Oregon's nineteen statewide land use planning goals address issues such as urbanization, natural resource protection, and air, water and land resources quality (Oregon Department of Land Conservation and Development). Goal 14, urbanization, requires each city, county and regional government in the state to create and maintain an urban growth boundary (UGB). This has resulted in dense development and impervious surface areas inside UGBs often exceeding 10%, a widely accepted tipping point past which water quality diminishes rapidly (Booth et al. 2002; Metro 2008).

The Portland metropolitan area's UGB is managed by Metro, a regional government whose jurisdiction includes Portland and 24 other cities. The Willamette River flows north through the Portland metropolitan area before discharging into the Columbia River. Water quality in this section of the Willamette River is characterized as "poor" to "very poor" based on Oregon's Water Quality Index with mercury, temperature and bacteria listed as major pollutants under the Willamette Basin Total Maximum Daily Load program (Oregon Department of Environmental Quality).[1] Water quality is compromised, in part, by Portland's combined sewer system which discharges untreated sewage and stormwater into the river almost every time it rains. To address this problem, the City is spending an estimated $1.4 billion on an infrastructure project that is expected

[1] The Portland Harbor, a 5.5-mile section of the Willamette River that is north of downtown Portland was designated a Federal Superfund Site in 2000 (Oregon Department of Environmental Quality 2009)

to reduce discharges by more than 94% when completed in 2011 (Portland Bureau of Environmental Services).

In addition to investing in infrastructure, local and regional governments are seeking innovative ways to improve water quality. The Clean River Rewards program, for example, provides water bill discounts for commercial and residential property owners who take such actions as planting trees or installing ecoroofs to decrease stormwater runoff (Portland Bureau of Environmental Services). Other initiatives include regulations on development, local and regional bond measures to purchase ecologically important natural areas, and educational programs to promote natural landscaping.

The ecological benefits from protecting and enhancing vegetation in the study area are clear (Metro 2008, 2009). However, whether residential property owners will participate in incentive-based and/or voluntary programs to increase vegetation, or plant the type of vegetation at levels needed to have an impact on water quality is uncertain since the existing literature finds mixed results about the relationship between vegetation and property values.

The goal of this paper is to examine if land cover types – trees, shrubs, water and impervious surface areas – on single-family residential properties, and in the areas surrounding these properties, affect their sale price. Our method allows us to estimate the effect on a property's sale price from replacing impervious surface areas with vegetation and to compute the level of vegetation that maximizes a property's sale price. We test whether different kinds of vegetation on a property, and in the areas surrounding a property, have a different influence on sale prices and if the effects of vegetation vary with distance from a property. This paper is structured as follows. The next section reviews relevant literature on valuing vegetation using the hedonic price method. Section III provides an overview of the study area, and Section IV discusses and summarizes the data used in our analysis. Models and empirical results are described in Section V. The final section concludes with policy recommendations.

II. Literature

Numerous studies use the hedonic price method to estimate the relationship between vegetation, both on and around a property, and a property's sale price. While most studies find a positive effect from trees (Anderson and Cordell 1988; Dombrow et al. 2000; Mansfield et al. 2005; Donovan and Butry 2009) and other green vegetation (Kestens et al. 2004), some find that dense vegetation and woodlands have a negative effect (Des Rosiers et al. 2002; Kestens et al. 2004; Netusil et al. forthcoming), especially when blocking a view (Mooney and Eisgruber 2001).

Anderson and Cordell (1988) were the first to investigate the impact of trees on a property's value. They find that trees in Athens, Georgia, increase the sale price of single-family residential properties by 3.5% to 4.5%. More recently, Dombrow et al. (2000) estimate that the existence of mature trees on a property increases its value by 1.9% and Mansfield et al. (2005) estimate that increasing tree cover on a property by 10% adds $800 to its value. Donovan and Butry's (2009) analysis of street trees in the east side of Portland finds that street trees in front of a house add $8,870 to its sale price (3% of the median sale price) and also have a positive effect on the value of surrounding properties.

In addition to using a survey of trees on each property, the Mansfield et al. study utilizes a normalized difference vegetation index (NDVI), which is monotonically related to the density of green leaves and frequently used to approximate vegetation density (Tucker 1979). Higher mean NDVI on a parcel has a statistically significant negative effect on sale price after controlling for many key variables, including the proportion of the lot that is forested, which has a positive effect on sale price. The authors also find evidence that property owners substitute between mean NDVI on their parcel and distance from a private forest.

Kestens et al. (2004) also use NDVI to approximate vegetation density by calculating the mean NDVI within a 40m radius of properties. Higher mean NDVI within 40m has a positive and significant effect on sale price, suggesting that people like vegetation immediately around their properties. However, the authors also determine that increasing woodlands within 1km and increasing concrete surfaces within 100m of a property decreases its sale price. Des Rosiers et al. (2002) similarly find that sale prices are lower for properties from which highly dense vegetation is visible. A possible explanation is that woodlands and dense vegetation block views. Mooney and Eisgruber (2001) estimate that although stream frontage increases the value of the mean property in western Oregon by 7%, a 50 foot treed riparian buffer decreases sale price by about 3%, probably due to diminished view.

Open space, a zoning classification that is generally densely vegetated, is commonly valued using the hedonic price method. Geoghegan et al. (2003) determine how permanent easements in Maryland, which create open space, affect property values. Their results suggest that open space increases the sale price of adjacent properties, but too much open space can diminish property values. Lutzenhiser and Netusil (2001) show the varying impacts on property sale prices of five different types of open space in Portland, Oregon. With the exception of cemeteries, all open spaces have a significant and positive effect on sale price. Holding other factors constant, natural area parks have the greatest impact on sale price, increasing sale price by $10,648 in 1990 dollars, on average.

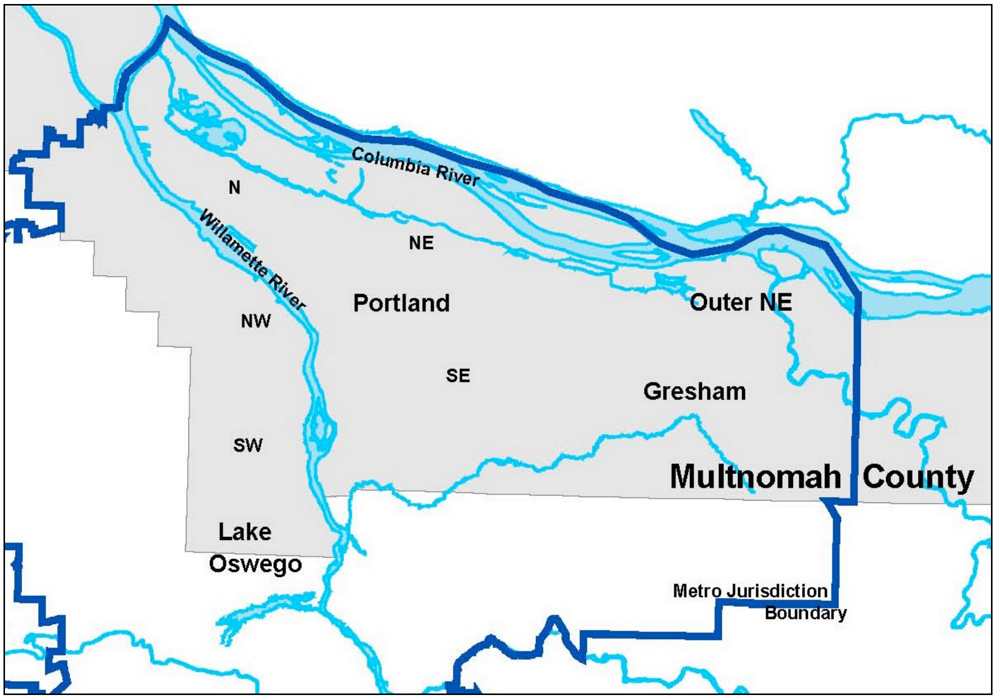
Another study focusing on the Portland area is Mahan et al. (2000), which estimates the value of wetlands. Wetlands provide important water filtration services and are generally home to diverse and ecologically important flora and fauna. The authors find in their first stage analysis that increasing the size of the nearest wetland by one acre increases sale price by $24, and moving a property 1,000 feet closer to the nearest wetland increases sale price by $436; a second stage hedonic price function was estimated, but the results were unreliable. Netusil et al. (forthcoming) successfully estimate the benefits of large patches of tree canopy in Portland, Oregon by combining results from a first stage hedonic model with a survey of property owners' preferences and socioeconomic characteristics in a second stage model. The first stage provides evidence of diminishing returns to tree canopy with some parts of the study area experiencing negative marginal implicit prices. Per-property benefit estimates in the second stage decline in one specification once tree canopy exceeds 35% of the area within 1/4 mile of a property.

While the literature on the relationship between vegetation and property values is extensive, and several studies using the hedonic price technique exist for the study area, no study to date has explicitly looked at how individual property owners in an urban area value high structure vegetation, such as trees, and low structure vegetation, such as shrubs and lawns, in comparison to impervious surface areas, such as driveways, patios and rooftops. Additionally, the quality of the vegetation layer and the number of buffers used in the analysis – 200 feet, 1/4 mile and 1/2 mile – represent an improvement over previous research.

III. Study Area

The study area includes the part of Multnomah County, Oregon within Metro's jurisdiction – an area of approximately 140,687 acres. The majority of the study area, 34.78%, is classified as impervious surface, followed by 29.87% high structure vegetation, 25.57% low structure vegetation, and 9.78% open water. As shown in Figure 1, the study area includes the majority of the city of Portland, which is divided into five quadrants (North, Northeast, Northwest, Southwest and Southeast) and parts of six other cities: Gresham, Lake Oswego, Milwaukie, Troutdale, Wood Village, and Fairview. Transactions in the last three cities, which are located in the northeastern part of the study area, were grouped together as the Outer Northeast category for our analysis. Our data set includes only one observation in Milwaukie, which was grouped with SE Portland.

Figure 1: Study Area



IV. Data Set

The data set includes sale price, property characteristics, location, and land cover information for 42,722 single-family residential properties sold between January 1, 2005 and December 31, 2007. Sale prices and property characteristics were obtained from the Multnomah County Assessor. Sale prices were deflated to 2007 dollars using the CPI-U and transactions were screened to make sure they occurred at arms length and were free of recording errors. Land cover information was obtained from Metro (Metro Data Resource Center). Table 1 contains a list of explanatory variables used in the analysis.[2]

[2] Quadratic terms were used for variables such as Lotsqft, Age, etc. and are denoted by variablename2 in the regression results.

Table 1
Names and Definitions of Explanatory Variables

Variable Name	Description
	Property Variables
Lotsqft	Lot square footage
Bldgsqft	Total house square footage
Fullbaths	Number of full bathrooms
Halfbaths	Number of half bathrooms
Fireplaces	Number of fireplaces
Age	Year house was sold minus year house was built
	Location Variables
	Quadrant and City Dummy Variables (*North is the excluded quadrant*)
N, NW, NE, SE, SW	North, Northwest, Northeast, Southeast, Southwest Portland
ONE	Troutdale, Wood Village and Fairview
GR	Gresham
LO	Lake Oswego
Ndist, NWdist, NEdist, SEdist,…	Interactive variables: quadrant and cities * distance to Portland central business district
	Land Cover Variables
	On Property Variables (*Impervious is the excluded cover type*)
Property_High	Proportion High Structure Vegetation
Property_Low	Proportion Low Structure Vegetation
Property_Water	Proportion Water
Property_Impervious	Proportion Impervious Surface
	200 Feet buffer (*Impervious is the excluded cover type*)
200_High	Proportion High Structure Vegetation within 200 feet
200_Low	Proportion Low Structure Vegetation within 200 feet
200_Water	Proportion Water within 200 feet
200_Impervious	Proportion Impervious Surface within 200 feet
	200 Feet to 1/4 Mile buffer (*Impervious is the excluded cover type*)
1-4_High	Proportion High Structure Vegetation between 200 feet and 1/4 Mile
1-4_Low	Proportion Low Structure Vegetation between 200 feet and 1/4 Mile
1-4_Water	Proportion Water between 200 feet and 1/4 Mile
1-4_Impervious	Proportion Impervious Surface between 200 feet and 1/4 Mile
	1/4 Mile to 1/2 Mile buffer (*Impervious is the excluded cover type*)
1-2_High	Proportion High Structure Vegetation between 1/4 Mile and 1/2 Mile
1-2_Low	Proportion Low Structure Vegetation between 1/4 Mile and 1/2 Mile
1-2_Water	Proportion Water between 1/4 Mile and 1/2 Mile
1-2_Impervious	Proportion Impervious Surface between 1/4 Mile and 1/2 Mile

The vegetation layer is limited to Metro's jurisdiction, so transactions in the part of Multnomah County outside of Metro's jurisdiction were dropped. The majority of the remaining transactions occurred in SE Portland (35.69%), followed by NE Portland

(26.90%), North Portland (11.88%), SW Portland (9.94%), Gresham (9.03%), Outer NE Portland (4.02%), NW Portland (2.24%), and Lake Oswego (0.29%).[3]

Table 2 provides summary statistics for the real sale price and structural variables in our data set. Real sale price varies by a factor of three with the highest average price in NW Portland ($745,262) and the lowest in North Portland ($247,006). Average building size and lot size are small averaging 1,933 square feet and 7,718 square feet, respectively.

Table 2
Summary Statistics for Real Sale Price and Structural Variables

Variable Name	Mean	Standard Deviation	Minimum	Maximum
REALSALEPRICE (study area)	310,121	190,816	53,135	4,349,733
REALSALEPRICE (N Portland)	247,006	84,569	64,795	1,322,614
REALSALEPRICE (NE Portland)	305,192	146,037	53,135	1,572,030
REALSALEPRICE (NW Portland)	745,262	318,141	107,527	2,750,809
REALSALEPRICE (SE Portland)	266,461	120,470	58,921	1,903,024
REALSALEPRICE (SW Portland)	493,187	339,412	93,618	4,349,733
REALSALEPRICE (Outer Northeast)	270,508	84,962	84,092	855,809
REALSALEPRICE (Gresham)	280,019	114,488	82,609	1,602,485
REALSALEPRICE (Lake Oswego)	570,142	358,213	247,678	3,559,783
Lotsqft	7,718	19,378	808	1,751,131
Bldgsqft	1,933	869	360	35,680
Age	53.40	31.77	0	137
Fullbaths	1.65	0.69	0	7
Halfbaths	0.32	0.51	0	6
Fireplaces	0.85	0.69	0	6

Metro's Data Resource Center collects and maintains extensive GIS layers of the Portland metropolitan area. A high resolution landcover layer was created in 2007 to support *State of the Watersheds,* which is an initiative to track changes in the region's vegetation and water quality over time (Metro 2008, 2009).

The layer was created using high resolution color infrared orthophotos to classify

[3] Outer Northeast includes transactions in Troutdale, Wood Village and Fairview.

each 3x3 feet cell as one of four landcover types: high structure vegetation, low structure vegetation, impervious surface and open water (Metro Data Resource Center). Classification was performed using radiometric (specifically NDVI), texture, and geometric based methods. High structure vegetation includes tree canopy and woodlands, while low structure vegetation includes grassy vegetation and small woody vegetation such as shrubs and small trees.[4] Impervious surface includes built and scarified land such as concrete and rooftops. Open water includes rivers, streams, lakes, and other water bodies (Metro Data Resource Center 1988). The overall accuracy of the layer was calculated at 88% (Metro Data Resource Center).

Ringed buffers were created around each property in the data set. The first buffer spans from the edge of the property out 200 feet, the second from the boundary of the first buffer out ¼ mile, and the third from the boundary of the second buffer out ½ mile. Buffer distances were chosen to reflect both visual and walking area in the surrounding neighborhood, as well as to match buffer sizes used in the literature.

Table 3 provides detailed summary statistics for the land cover variables. The average proportion of high structure vegetation, low structure vegetation and impervious surface area remains fairly constant across areas. On average, land cover on properties in the study area is 26.08% high structure vegetation and 29.67% low structure vegetation. Impervious surface has the largest average value at 44.24% with open water having the lowest average coverage at 0.01%.

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[4] Metro's high resolution landcover layer is based on aerial photographs. Low structure vegetation and impervious surface areas may be under high structure vegetation, so these variables should be interpreted as measuring the amount of these land cover types not blocked by high structure vegetation.

Table 3
Summary Statistics for Land Cover Variables

Variable Name	Mean	Standard Deviation	Minimum	Maximum
On the Property				
High Structure Vegetation	0.2608	0.2213	0	1
Low Structure Vegetation	0.2967	0.1918	0	1
Impervious Surface	0.4424	0.1960	0	1
Open Water	0.0001	0.0057	0	0.7261
Within 200 Feet of the Property				
High Structure Vegetation	0.2559	0.1458	0	0.9991
Low Structure Vegetation	0.2823	0.1033	0	0.9019
Impervious Surface	0.4609	0.1323	0	0.9664
Open Water	0.0009	0.0153	0	0.6771
Between 200 Feet and 1/4 Mile				
High Structure Vegetation	0.2614	0.1305	0.0243	0.9699
Low Structure Vegetation	0.2816	0.0837	0.0107	0.7289
Impervious Surface	0.4534	0.1222	0.0057	0.9384
Open Water	0.0036	0.0270	0	0.7082
Between 1/4 Mile and 1/2 Mile				
High Structure Vegetation	0.2628	0.1267	0.0562	0.9842
Low Structure Vegetation	0.2773	0.0779	0.0054	0.6538
Impervious Surface	0.4508	0.1229	0.0042	0.8658
Open Water	0.0091	0.0364	0	0.5962

V. Results

The models used to estimate the effects of different land cover types on the sale price of properties in the study area include linear and squared terms of the high and low structure vegetation variables. Our a priori expectation, informed by recent research in the study area (Netusil et al. forthcoming) is that there is a point past which increasing vegetation will reduce a property's sale price. This is attributable to vegetation blocking views and sunlight, the small lot sizes in the study area, and the cost associated with maintaining vegetation. In contrast, no squared term is included for the water variables since our expectation is that increasing the amount of water on a property will reduce a property's sale price, while increasing the amount of water in the buffer areas will increase a property's sale price over the range of values in our data set. The impervious surface variable is excluded, so coefficients are interpreted relative to this variable.

Because the functional form of a hedonic equation is uncertain (Freeman 2003; Cropper et al. 1988), we used a Box-Cox model to inform our specification. Results reject the linear, semi-log and inverse functional forms, but the test-statistic value is smallest for the semi-log model. Researchers frequently use the semi-log model for the hedonic price function (Taylor 2003), and the semi-log model provides a better fit than the linear model (R^2 of 76.2% versus 70.4%). Although there are a few differences in the sign and significance of estimated coefficients reported in Table 4, the vast majority of coefficients are consistent across specifications. Therefore, the semi-log is our preferred model and is discussed below.

Table 4

Regression Results - Robust Standard Errors in Parentheses

	Linear	Semi-Log
<u>Property Variables</u>		
Lotsqft	2.025***	3.07e-06***
	(0.231)	(2.64e-07)
Lotsqft2	-1.33e-06***	-2.17e-12***
	(1.67e-07)	(2.15e-13)
Bldgsqft	89.59***	0.000245***
	(10.77)	(3.34e-06)
Bldgsqft2	-0.000420	-6.50e-09***
	(0.00204)	(3.51e-10)
Fullbaths	40411***	0.0878***
	(2069)	(0.00265)
Halfbaths	30131***	0.0575***
	(1965)	(0.00307)
Fireplaces	8021***	0.0338***
	(1800)	(0.00213)
Age	15.66	-0.00160***
	(104.3)	(0.000181)
Age2	-1.071	9.06e-06***
	(0.892)	(1.56e-06)
<u>Location Variables</u>		
N	*Excluded*	*Excluded*
NW	271606***	0.345***
	(31272)	(0.0563)
NE	117942***	0.351***
	(16474)	(0.0506)
SW	454424***	0.353***
	(37371)	(0.0550)
SE	29287*	0.303***
	(15690)	(0.0499)
ONE	-3.723e+06***	-6.651***
	(485215)	(0.825)
GR	262816**	-0.188
	(126159)	(0.301)
LO	-3.357e+07***	-33.56***
	(1.177e+07)	(10.53)
Ndist	-11.42***	-3.14e-05***
	(1.223)	(4.00e-06)
Ndist2	0.000190***	4.05e-10***
	(2.40e-05)	(8.00e-11)
NEdist	-16.27***	-4.85e-05***
	(0.458)	(1.03e-06)

NEdist2	0.000197***	5.83e-10***
	(6.69e-06)	(0)
NWdist	-8.529***	-2.15e-05***
	(2.655)	(3.45e-06)
NWdist2	-4.84e-05	-0
	(5.81e-05)	(7.85e-11)
Swdist	-54.74***	-6.47e-05***
	(3.305)	(3.18e-06)
SWdist2	0.00120***	1.24e-09***
	(8.10e-05)	(7.84e-11)
Sedist	-10.78***	-4.79e-05***
	(0.407)	(8.65e-07)
SEdist2	0.000118***	5.74e-10***
	(5.97e-06)	(0)
ONEdist	103.5***	0.000182***
	(13.94)	(2.40e-05)
ONEdist2	-0.000758***	-1.36e-09***
	(1.00e-04)	(1.74e-10)
GRdist	-15.63***	-1.55e-05*
	(3.900)	(9.18e-06)
GRdist2	0.000126***	1.33e-10*
	(2.96e-05)	(6.97e-11)
LOdist	2081***	0.00204***
	(735.6)	(0.000663)
LOdist2	-0.0323***	-3.14e-08***
	(0.0115)	(1.04e-08)
Land Cover Variables		
Property_High	74434***	0.0896***
	(8898)	(0.0169)
Property_High2	-104641***	-0.143***
	(13395)	(0.0224)
Property_Low	16831*	0.0422*
	(9312)	(0.0224)
Property_Low2	-3646	-0.105***
	(12691)	(0.0332)
Property_Water	247043	-0.333
	(264079)	(0.316)
Property_Impervious	*Excluded*	*Excluded*
200_High	41636*	0.138***
	(21990)	(0.0332)
200_High2	41568	0.0224
	(39579)	(0.0509)
200_Low	166336***	0.350***
	(27653)	(0.0576)
200_Low2	-209423***	-0.342***
	(42156)	(0.0872)
200_Water	466548***	0.932***
	(134923)	(0.148)

200_Impervious	*Excluded*	*Excluded*
1-4_High	18604	0.374***
	(31641)	(0.0536)
1-4_High2	147772***	-0.0329
	(55573)	(0.0792)
1-4_Low	272280***	0.392***
	(51398)	(0.104)
1-4_Low2	-340701***	-0.399**
	(75596)	(0.156)
1-4_Water	263223***	0.315***
	(67685)	(0.0885)
1-4_Impervious	*Excluded*	*Excluded*
1-2_High	43678	0.556***
	(37103)	(0.0584)
1-2_High2	74481	-0.298***
	(62175)	(0.0846)
1-2_Low	444652***	0.812***
	(55397)	(0.112)
1-2_Low2	-596198***	-0.683***
	(85512)	(0.173)
1-2_Water	175909***	0.479***
	(32682)	(0.0460)
1-2_Impervious	*Excluded*	*Excluded*
Constant	-63095***	11.66***
	(21073)	(0.0497)
Observations	42722	42722
R-squared	0.704	0.762

Note: The excluded variables are in italics. Regressions also include dummy variables for each month. Full results are available from the authors.
*Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.

Estimated coefficients for the on property and location variables conform to expectations and are consistent with past research in the study area (Mahan et al. 2000; Lutzenhiser and Netusil 2001; Netusil et al. forthcoming). On the property, the high and low structure vegetation variables have positive and significant coefficients while their squared terms are negative and significant. For both variables, there is an "optimal" amount of on property vegetation, where the effect on sale price is maximized. This optimum is 31.33% for high structure vegetation, which is 5.25

percentage points higher than the average high structure vegetation on properties in the study area, and 20.10% for low structure vegetation, which is 9.57 percentage points lower than the average low structure vegetation on properties in the study area. To put this in context, 5.25% of the average sized lot is 406 square feet, which is the crown area of a 10-15 year-old tree (McPherson et al. 2002). If we replaced impervious surface areas with high structure vegetation at the optimal amount, we estimate a property's sale price will increase by 0.04%, or approximately $122 when evaluated at the mean sale price for properties in the study area. The water variable is negative, as expected, but is not significant. This is probably because there are only 85 transactions with water on the property and no variables controlling for water type (stream, river, or lake), water quality, or risk of flooding.

Within 200 feet of the property and between 200 feet and ¼ mile, the linear terms for high structure vegetation are both positive and significant, while the squared terms are insignificant. A joint F-test to examine whether the effects of high structure vegetation on sale price within these two buffers are equal was rejected at the 1% level (F (2, 42634) = 23.27). Increasing high structure vegetation relative to impervious surface within either of these buffers is estimated to continually increase sale price, unlike increases in on property vegetation which eventually reduce sale price. Increasing the existing high structure vegetation within 200 feet of a property by 5.25 percentage points, an amount computed above to be the difference between the current study average and the optimal amount of high structure vegetation on a property, is estimated to increase a property's sale price by 0.72%, or $2,247 when evaluated at the mean sale price for properties in the study area. The same increase between 200 feet and ¼ mile is estimated to increase the property's sale price by 1.96%, or $6,089.

The proportion low structure vegetation variables within 200 feet of the property, and between 200 feet and ¼ mile, have positive and significant coefficients on the linear terms and negative and significant coefficients on the squared terms. A joint F-test fails to reject the null hypothesis that the effects of low structure vegetation on sale price within these two buffers are equal to each other (F (2, 42634) = 0.05). The optimal amount of low structure vegetation within these buffers is 51.27% and 49.12%, respectively, which is approximately 2.5 times higher than the level of low structure vegetation on a property that is estimated to maximize its sale price.

Between ¼ mile and ½ mile, high and low structure vegetation have positive and significant coefficients on the linear terms and negative and significant coefficients on the squared terms. The maximum positive effect on sale price occurs at 93.15% for high structure vegetation and 59.40% for low structure vegetation. Within this buffer, increasing high structure vegetation above the current study mean by 5.25 percentage points is estimated to increase a property's sale price by 2.09%, or $6,482.

Joint F-tests were conducted to examine whether the two classifications of vegetation have a similar effect on a property's sale price. On a property, within 200 feet, and between 200 feet and ¼ mile, the null hypothesis of an equal effect of high and low structure vegetation is rejected at the 1% level (F (2,42634) = 6.01; F (2, 42634) = 5.53; F (2, 42634) = 35.62). Increasing high structure vegetation within any of these zones has a larger impact on a property's sale price than increasing low structure vegetation. For example, the 1.96% increase in a property's sale price that results from raising existing average high structure vegetation by 5.25 percentage points between 200 feet and ¼ mile is 2.3 times greater than the impact of a similar increase in low structure vegetation. In contrast, a joint F-test fails to reject the null hypothesis of an equal effect of high and low structure vegetation within the ¼ to ½ mile buffer (F (2, 42634) = 1.77).

The 5.25 percentage point increase in high structure vegetation discussed above is approximately a 20% increase in high structure vegetation on the average property. We also model this increase for each buffer because if each property owner in a neighborhood raised high structure vegetation by that amount, then the average high structure vegetation in buffers would increase accordingly. But the amount of land within a buffer increases with buffer size, so in order to compare the effect of a 5.25 percentage point increase in high structure vegetation we weigh the impact on a property's sale price by buffer size on a per-acre basis. These estimates are $687 (on a property), $499 (within 200 feet), $46 (between 200 feet and ¼ mile) and $17 (between ¼ mile and ½ mile).

For all three buffers, the water variable is positive and significant. This result suggests that overall proximity to water is desirable, probably because it indicates proximity to recreation opportunities and views.

VI. Conclusions and Suggestions for Future Research

The city of Portland's Urban Forest Action Plan establishes a target tree canopy goal of 35-40% for residential properties (Portland Parks & Recreation 2007). While our research estimates that increasing the existing amount of high structure vegetation will, on average, increase the sale price of single-family residential properties in our study, the city's goal exceeds the amount estimated to maximize a property's sale price.

Increasing high structure vegetation on a property by 5.25 percentage points, the amount found to maximize the sale price of properties in our study area compared to the current average amount, is estimated to raise the average property's sale price by $122. The present discounted value of average annual costs reported by McPherson et al. (2002) range from $230-$435 for a small tree; $307-$512 for a medium tree; and $359-$589 for a large tree assuming a 4.5% discount rate and adjusted to 2007 dollars. This makes the decision to plant a tree uneconomical for the properties in our study.

Although changing vegetation on a property has only a small impact on sale price, we find that increasing both high and low structure vegetation within ½ mile of a property has a larger effect on price. Therefore, even if planting an addition tree is not the optimal decision for an individual property owner, it may be socially optimal for everyone in a neighborhood to plant additional vegetation because benefits will accrue to all nearby property owners. This suggests that it may be efficient for governments in the study area to provide incentives for property owners to increase vegetation and/or to take direct action to protect vegetation by expanding natural areas.

How cities should construct incentive-based programs for maintaining and enhancing vegetation is an important question and a natural extension of our research. For example, the varied topography of the study area means that vegetation is more ecologically beneficial in certain areas, so it may be appropriate to target policies to overcome the conflict between private incentives and social benefits identified by our research. This could be investigated using spatial landscape indices to determine owners' preferences regarding the diversity and fragmentation of landcover types around their properties. Future work should also address some limitations of this study, such as more specific classifications for impervious areas and types of water as well as tests for spatial correlation.

Urban vegetation has environmental, social, and economic benefits. The statistical technique we use in our analysis, the hedonic price method, captures only one component of these benefits – the relationship between vegetation and property values. Our estimates, therefore, are a reflection of what motivates private property owners' decisions about the amount and type of vegetation on their properties and should be considered a lower bound of overall benefits.

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