Landscaping and House Values: An Empirical Investigation

Authors François Des Rosiers, Marius Thériault, Yan Kestens and Paul Villeneuve

Abstract

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This hedonic study investigates the effect of landscaping on house values, based on a detailed field survey of 760 single-family homes sold between 1993 and 2000 on the territory of the Quebec Urban Community. Environmental information includes thirty-one landscaping attributes of both houses and their immediate environment. By and large, a positive tree cover differential between the property and its immediate neighborhood, provided it is not excessive, translates into a higher house value. Findings also suggest that the positive price impact of a good tree cover in the visible surroundings is all the more enhanced in areas with a high proportion of retired persons. Finally, a high percentage of lawn cover as well as features such as flower arrangements, rock plants, the presence of a hedge, etc. all command a substantial market premium.

Objective and Context of Research

This study investigates the effect of landscaping on house values, based on a detailed field survey of 760 single-family home sales transacted between 1993 and 2000 in the territory of the Quebec Urban Community (CUQ). The hedonic approach is used for that purpose. While the impact of tree cover on residential prices has already been the object of several studies, little attention has been devoted to landscaping as such. It can be assumed that aging populations and the ensuing propensity for "cocooning" should result in homeowners spending an increasing portion of their income on landscaping. This article is an attempt to circumscribe the phenomenon and measure the increment in value associated with landscaping features.

Literature Review

Over the past two decades, increasing attention has been devoted in the economic and real estate literature to the study and measurement of the impact environmental externalities exert on property prices (Des Rosiers, Bolduc and Thériault, 1999). While topics encompass a wide range of issues, several authors have investigated the effect of trees and landscaping on values. Some, like Schmitz (1988) and Yee (1989), address that issue with respect to the office market, but most researchers still focus on residential properties. Payne (1973) was among the first to do so. Using traditional valuation techniques, he concludes that the market value of a single-family house receives a 7% premium on average (between 5% and 15%) due to arborescent vegetation, provided that there are less than thirty trees on the lot. Beyond that point, the impact on prices is detrimental. Payne and Strom (1975) estimate the value of seven simulated combinations of amount and distribution of tree cover for a twelve-acre parcel of unimproved residential land in Amherst, Massachusetts. Arrangements with trees are found to be valued 30% higher than arrangements without ones, land price being maximized with a 67% wooded cover.

Perception studies were also performed over the past decade. Using Multiple Listing Service-transacted suburban properties in Champaign-Urbana, Illinois, Orland, Vining and Ebreo (1992) conducted such a study based on digitized photographs taken from the street. Three different size-class trees were then superimposed via video-simulation techniques. While public groups' evaluations show that house attractiveness is highly correlated with MLS recorded sale prices, tree size has little effect on evaluations. While tree presence or size exerts no impact on less expensive properties, a slight increase in value is noted for more expensive houses when smaller trees are added, but a price decrease is associated with larger trees. As for Kuo, Bacaicoa and Sullivan (1998), they assess the preference pattern of 100 residents of high-rise buildings surrounding a public open space in a densely populated neighborhood in Chicago, Illinois. Both tree planting density and grass maintenance are tested. While the presence of trees has strong, positive effects on residents' preference ratings for the courtyard, grass maintenance also has a positive impact on sense of safety, particularly when there are fewer trees.

Finally, several hedonic analyses have been performed since the late seventies. Combining factor analysis and multiple linear regression techniques, Morales, Boyce and Favretti (1976) conducted a study on sixty residential sales in Manchester, Connecticut. Four factors are used as explanatory variables, reflecting location, house size, date of sale and tree cover, respectively. With 83% of price variations explained by the model, the authors conclude that a good tree cover could raise total sale price by as much as 6% to 9%. According to Seila and Anderson (1982), newly built houses command prices that are 7% higher when located on tree-planted lots rather than on bare ones.

Anderson and Cordell (1985) performed a first analysis on some 800 single-family houses sold over the 1978–1980 period in Athens, Georgia. The average house sold for about $47 000 and had five front-yard trees visible in its MLS photographs. The study led to the conclusion that the presence of trees adds a 3% to 5% premium to sale price, although other lot and building features associated with tree cover could explain part of this increment in value, add the authors. In a second study by Anderson and Cordell (1988) on a similar size sample involving cheaper properties (mean sale price at $38,100), the rise in market value associated with the presence of intermediate and large size trees stands within the 3.5% to 4.5% range, regardless of species. Broad-leaved trees contribute each roughly $376 in value, as opposed to $319 for conifers. In either study, the ensuing increase in the city's property tax revenues is estimated to lie between $100,000 (1988 study) and $200,000 (1985 study) a year.

In his recent hedonic analysis on house prices in the Netherlands, Luttik (2000) first isolates the influence of structural housing attributes on values. In a second step, residuals from the first model are regressed against location (accessibility to services, traffic noise, etc.) and environmental amenities (number of trees on lot, distance to nearest green area, water body and open space). While the positive effect of water bodies and open spaces could be demonstrated in almost every instance, the hypothesis that a green structure commands a premium had to be rejected in six cases out of eight. In the two cases where this variable emerges as significant, the increment in value associated with the presence of trees or the proximity to green areas ranges from 7% to 8%. Finally, Dombrow, Rodriguez and Sirmans (2000) conducted a study on a sample of 269 single-family house sales, with a mean price of $93,272. Using a semi-log functional form, a dummy variable is included in the equation to account for the presence of mature trees. The market-derived estimate suggests that mature trees contribute about 2% of home values in that specific market segment.

Data Bank and Analytical Approach

The Data Bank

As mentioned earlier, this study is based on a detailed field survey of 760 single-family homes sold between 1993 and 2000 in the urbanized area of the QUC territory. These include bungalows (one-story, detached), cottages (multi-story, detached or semi-detached) and row houses. Conducted during the summer of 2000, the survey focuses on landscaping characteristics of homes and their immediate environment, that is the neighborhood visible from the properties.

The overall, initial data bank includes 215 variables and factors, of which eighty-eight physical descriptors, thirty census attributes plus twelve census factors, forty-six location and access attributes plus two accessibility factors as well as six time and cyclical variables. Factors are derived from previous work by Des Rosiers, Thériault and Villeneuve (2000) whereby principal component analysis (PCA) is performed on both 1991 census data and car travel distances and times computed via the TransCAD transportation-oriented GIS software (Caliper Corp). In addition, thirty-one environmental and landscaping attributes derived from the field survey are added to the data bank. These are captured from the front and side of houses and namely include trees as well as ground cover with trees—classified by size class and type of species—flower arrangements and rock plants, hedges, landscaped curbs, density of visible vegetation as well as roof, patio and balcony arrangements.

The operational definition of all the variables actually used in this study—twenty-three physical, census and access descriptors as well as eleven landscaping attributes—is displayed in Exhibit 1. As for descriptive statistics relative to physical, census, access and landscaping attributes, they are presented in Exhibits 2–6. While average sale price stands at around $112,000, one property sold for $900,000 and was therefore deleted from the analysis. This results in the price distribution being confined within the $50,000–$435,000 range. Accounting for improvements in the housing stock, properties are, on average, sixteen years old (apparent age), with a mean living area of roughly 120 square meters (1,300 sq. feet). Bungalows and detached town-cottages account respectively for 42% and 40% of sales while semi-detached cottages represent 11% of the sample. As for row houses, they account for the remaining 7%. Turning to landscaping attributes, the average percentage of the tree cover in the neighborhood and on the property stands at roughly 46% and 44% respectively, with the percentage of ground cover making up for the difference. By and large, the discrepancy in the percentage of the tree cover between the property and its neighborhood is a slight one. Quite clearly, broad-leaved trees largely dominate in the immediate neighborhood. Finally, 41% of houses have a hedge while landscaped curbs are present in 90% of cases.

Analytical Approach and Regression Procedures

The analysis is performed in two steps. In the first place, a basic model (Model 1) is set up using only the physical, census and access attributes of the houses. Variable selection is done using the standard ''enter'' procedure, which was validated via a stepwise approach. With respect to census and access attributes, both individual variables and PCA-derived factors are successively tested. While the latter allow for a more qualified interpretation of the urban dynamics underlying the price determination process than the former do, they do not lead to better model performances. In this article therefore, individual census and access variables are used instead of factors.

Once Model 1 parameters are stabilized, they are forced into Models 2 and 3, which also include landscaping attributes. Again, both standard and stepwise regression procedures are successively applied to the latter for final variable selection. Several combinations of landscaping arrangements were tested and various mathematical transformations performed on variables. By and large,

Exhibit 1 | Operational Definition of Variables

Variable	Attributes	Type
BUNGALOW	One-story, single-family detached house	D
COTTAGE	More than one-story, single-family detached townhouse	D
SEMIDET	More than one-story, single-family semi-detached townhouse	D
ROW	Row house	D
APPAGE	Apparent age of the property, in years	M
LIVAREA	Living area of the property, in square meters	M
LNLOTSIZ	Natural logarithm of the lot size, expressed in square meters	M
QUALINF	Indicates a below-average overall building quality	D
QUALSUP	Indicates an above-average overall building quality	D
SUPFLOOR	Superior quality, hardwood floor	D
ATTGARAG	Attached garage	D
DETGARAG	Detached garage	D
EXCAPOOL	Excavated pool	D
BASEFINH	Finished basement	D
OVEN	Built-in oven in the kitchen (modern kitchen)	D
%AGE45_64	% of individuals aged 45-64	M
%AGE65_UP	% of individuals aged 65 and over	M
%WOMEN	% of women	M
%SGLHLD	% of one-person households	M
%DW46_60	% of buildings built between 1946 and 1960	M
%UNIVDEGR	% of individuals with a university degree	M
ULAVLCTM	Car travel time from property to Laval University, in minutes	M
HIGHW1KM	The property is within one km. from a highway exit	D
%Tree Prop	Percentage of tree cover on the property	M
%Tree Nbhd	Percentage of tree cover in the neighborhood	M
%Grnd Prop	Percentage of ground cover on the property	M
%Grnd Nbhd	Percentage of ground cover in the neighborhood	M
Prop-Nbhd %Tree	Difference in the % of tree cover between the property and the neighborhood	M
Prop_Nbhd %Tree Ratio	Property vs. neighborhood % tree cover ratio	M
%Brdlvd Nbhd	Percentage of broad-leaved trees in the neighborhood	M
Density Visible Veg	Density of vegetation visible from the property	R
Hedge	Presence of a landscaped hedge/wall	D
Patio	Presence of a landscaped patio	D
Curbs	Presence of landscaped curbs	D

Notes: N.B.: M = Metric; D = Dummy; R = Rank.

Exhibit 2 | Descriptive Statistics—Continuous Descriptors

	SPRICE ($)	*LOTSIZE*	*APPAGE*	*AGE*	*LIVAREA*	*%AGE45_64*	*%AGE65_UP*	*%PERSHLD*	*%WOMEN*	*%SGLHLD*	*%UNIVDEGF*
Mean	112,096	659	16	19	123	20.3	6.7	2.8	50.9	14.8	23.1
Median	92,500	572	15	15	109	20.1	4.6	3.0	50.5	11.6	18.7
Mode	82,000	372	0	0	86	20.1	3.8	3.0	50.2	6.0	14.7
Std. Dev.	61,488	816	13	20	49	7.8	6.7	0.4	2.4	11.0	13.9
Min.	50,000	125	0	0	39	6.9	0	1.3	37.5	0	2.1
Max.	900,000	18,767	54	164	627	37.9	53.7	3.5	65.4	78.0	65.1

Note: N = 76.

Exhibit 3 | Descriptive Statistics—Dummy Variables

	BUNGALOW	*COTTAGE*	*SEMIDET*	*ROW*	*QUALINF*	*QUALINF*	*QUALSUP*	*EXCAPOOL*	*ATTGARAG*	*DETGARAG*
N Valid	760	760	760	760	760	760	760	760	760	760
N Missing	0	0	0	0	0	0	0	0	0	0
Mean	0.42	0.40	0.11	0.07	0.07	0.01	0.05	0.07	0.10	0.15

Exhibit 4 | Descriptive Statistics—Landscaping Variables

	Density Visible Veg	*%Tree Nbhd*	*%Tree Prop*	*%Grnd Prop*	*%Grnd Nbhd*	*Prop_Nbhd %Tree*	*Prop_Nbhd %Tree Ratio*	*Hedge*	*Patio*	*Curbs*	*%Brdlvd Nbhd*
Mean	2.24	45.6	43.6	55.4	53.7	−2.0	0.97	0.41	0.01	0.90	84.7
Median	2.00	40.0	40.0	60.0	60.0	0	0.97	0	0	1.00	90.0
Mode	2	40.0	30.0	70.0	60.0	0	0.97	0	0	1.00	90.0
Std. Dev.	0.53	21.9	25.8	26.1	22.0	19.1	0.58	0.49	0.11	0.30	15.5
Min.	0	0	0	0	0	−80.0	0	0	0	0	0
Max.	4	90.0	100.0	100.0	100.0	70.0	6.4	1.0	1.0	1.0	100.0

Note: $N = 76$.

Exhibit 5 | Descriptive Statistics—Interactive Variables

	%Tree Nbhd%Age65_up*	*%Grnd Prop*Cottage*	*%Grnd Prop*Bungalow*	*Prop–Nbhd%Tree ctd*%age45_65*	*%Grnd Prop ctd*Cottage*	*%Tree Nbhd ctd*%Women ctd*
Mean	3.44	0.21	0.25	−0.03	−0.87	0.13
Median	1.60	0	0	0	0	0.05
Mode	0.26[a]	0	0	0	0	0.11
Std. Dev.	4.45	0.31	0.33	1.51	15.97	0.58
Min.	0	0	0	−8.95	−55.37	−1.78
Max.	35.82	1.00	1.00	9.30	44.63	6.10

Notes: $N = 76$.

[a] Multiple modes exist. The smallest value is shown.

Exhibit 6 | ANOVA Results

Model		Sum of Squares	df	Mean Square	*F*	Sig.
1	Regression	93.451	18	5.192	264.601	0.000
	Residual	14.520	740	1.962E-02		
	Total	107.971	758			
2	Regression	93.846	19	4.939	258.425	0.000
	Residual	14.125	739	1.911E-02		
	Total	107.971	758			
3	Regression	93.215	24	3.884	193.206	0.000
	Residual	14.755	734	0.020		
	Total	107.971	758			

Note: The dependent variable = *LNSPRICE*.

interactive variables (Jaccard, Turrisis and Wan, 1990) proved to be particularly efficient at capturing household behavior with respect to landscaping. While *absolute* interactions are resorted to in Model 2, *relative* interaction variables are also used in Model 3, each continuous component of the resulting descriptors being first centered, thereby reflecting its departure from the mean.

Both the linear and semi-log functional forms were tested, with the latter yielding much better overall performances and, by and large, higher "*t*" values. Moreover, regression coefficients derived from the semi-log form are expressed as relative—rather than absolute—implicit prices, thereby allowing for a more flexible interpretation of the contribution of housing attributes to property value. The general formulation of the final hedonic equation underlying the current empirical investigation can thus be expressed as follows:

$$Y = e^{B_0} * e^{B_{1i}\,Phys} * e^{B_{2i}\,Census} * e^{B_{3i}.Access} * e^{B_{4i}\,Landsc} * e^{\varepsilon}, \quad (1)$$

Where Y is the sale price while *Phys*, *Census*, *Access* and *Landsc* represent the four series of descriptors used in the analysis. This, in turn, can be put as:

$$\mathrm{Ln}Y = B_0 + B_{1i} * Phys + B_{2i} * Census + B_{3i} * Access + B_{4i} * Landsc + \varepsilon. \quad (2)$$

Finally, no extreme outliers were filtered out from the study since nothing could lead to the conclusion that these were not representative of the residential market under analysis.

Summary of Major Findings

The Basic Model

As can be seen from Exhibit 7, the overall performances of Model 1 are quite good. With thirteen physical, three census and two access variables in the equation,

Exhibit 7 | Regression Results—Model 1/Basic Attributes

	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics
	B	Std. Error	Beta	*t*	Sig.	VIF
Constant	10.546	0.089		117.83	0.000	
LIVAREA	0.004	0.000	0.447	22.84	0.000	2.11
LNLOTSIZ	0.106	0.014	0.130	7.54	0.000	1.64
ROW	−0.158	0.024	−0.105	−6.64	0.000	1.37
SEMIDET	−0.104	0.018	−0.085	−5.72	0.000	1.23
QUALINF	−0.224	0.045	−0.071	−4.98	0.000	1.12
QUALSUP	0.012	0.029	0.066	4.03	0.000	1.46
APPAGE	0.042	0.001	−0.394	−19.32	0.000	2.29
SUPFLOOR	0.042	0.011	0.055	3.73	0.000	1.20
ATTGARAG	0.116	0.019	0.090	5.98	0.000	1.26
SETGARAG	0.072	0.016	0.069	4.48	0.000	1.30
EXCAPOOL	0.069	0.023	0.045	3.01	0.003	1.26
BASEFINH	0.055	0.011	0.072	5.01	0.000	1.15
OVEN	0.066	0.015	0.067	4.52	0.000	1.19
%AGE65_UP	0.006	0.001	0.108	5.37	0.000	2.24
%DW46_60	0.002	0.000	0.059	3.07	0.002	2.04
%UNIVDEGR	0.007	0.000	0.245	13.47	0.000	1.83
HIGHW1KM	−0.039	0.013	−0.050	−3.12	0.002	1.42
ULAVLCTM	−0.017	0.002	−0.209	−9.10	0.000	2.90

Notes: The dependent variable is *LNSPRICE*. R^2 = .866; Adj. R^2 = .862; *F*-value = 264.6 (.000); and the std. error of the estimate = 0.1401 (15.04%).

Exhibit 8 | Regression Results—Model 2/Landscaping Absolute Interaction Variables

	Unstandardized Coefficients		Unit Adjustment Factors			Collinearity Statistics
	B	Std. Error	Exp (B)	*t*	Sig.	VIF
Constant	10.369	0.076		135.99	0.000	
LIVAREA	0.004	0.000	1.004	20.88	0.000	2.56
LNLOTSIZ	0.105	0.013		7.94	0.000	1.48
QUALINF	−0.245	0.045	0.783	−5.49	0.000	1.13
QUALSUP	0.131	0.028	1.140	4.60	0.000	1.49
APPAGE	−0.011	0.001	0.989	−18.43	0.000	2.26
SUPFLOOR	0.039	0.011	1.040	3.49	0.001	1.22
ATTGARAG	0.109	0.019	1.116	5.63	0.000	1.30
SETGARAG	0.072	0.016	1.074	4.46	0.000	1.32
EXCAPOOL	0.081	0.023	1.084	3.56	0.000	1.25
BASEFINH	0.050	0.011	1.051	4.54	0.000	1.18
OVEN	0.068	0.014	1.070	4.69	0.000	1.20
%UNIVDEGR	0.007	0.000	1.007	14.64	0.000	1.79
ULAVLCTM	−0.141	0.002	0.986	−8.48	0.000	2.37
%DW46_60	0.001	0.000	1.001	2.88	0.004	2.03
%Tree Nbhd%Age65_up*	0.011	0.002	1.011	6.74	0.000	2.17
*%Grnd Prop*Bungalow*	0.002	0.000	1.002	8.73	0.000	2.19
*%Grnd Prop*Cottagep*	0.002	0.000	1.002	7.54	0.000	2.43
Prop – Nbhd%Tree	0.002	0.000	1.002	5.50	0.000	1.40
Hedge	0.039	0.111	1.039	3.51	0.000	1.16

Notes: The dependent variable is *LNSPRICE*. R^2 = .869; Adj. R^2 = .866; *F*-value = 258.4 (.000); and the std. error of the estimate = 0.1382 (14.82%).

the adjusted R^2 is .86 while the *F*-value reaches 265. In spite of a relatively high prediction error (15%), which stems from both the regional scope of the model and the wide range of sale prices, all regression coefficients are consistent in sign and magnitude with theoretical expectations and statistically significant at the .01 level. Particularly noteworthy is the marginal contribution of the education/income variable (*%UNIVDEGR*) that comes next to property age (*APPAGE*) in terms of *t*-value as well as that of the main access descriptor (*ULAVALCTM*), which confirms the strategic role played by Laval University as a regional activity center. While transactions spread over an eight-year period, the model retains no time or cyclical variable, as prices remained relatively stable until late 1997 and recovered only slightly thereafter. Finally, multicollinearity remains within very acceptable limits, with the highest VIF standing at 2.90.

Landscaping Features—Absolute Interactions

While inserting landscaping variables in the hedonic equation only slightly improves overall explanatory and predictive model performances (Adj. R^2 up to .87 and SEE down to 14.8%), it does not modify substantially the implicit prices of the basic housing attributes remaining in the equation—although four of these (*ROW*, *SEMIDET*, *‰AGE65_UP* and *HIGHW1KM*) are rejected from the initial model. Most of all, Model 2 (Exhibit 8) provides a clear indication that landscaping features do exert a significant impact on property prices. While all five related descriptors that enter the model emerge as highly significant without causing undue collinearity, three of these—showing the strongest *t* values—are actually interactive variables that bring out *absolute* interactions between landscaping features on the one hand and property type or demographic structure on the other. Such a device proves very useful in that it allows for a better qualified interpretation of landscaping influence on values.

The findings can be summarized as follows:

- A positive differential in the percentage of tree cover between the property and its immediate neighborhood (*Prop-Nbhd %Tree*) raises house value by roughly 0.2% for each percentage point, which could be interpreted as a ‘‘scarcity’’ premium;
- The higher the proportion of retired people in the neighborhood, the more beneficial to the market value of a given property the presence of trees in its vicinity is (*%Tree Nbhd * %Age65_up*);
- For bungalows and cottages though, the higher the percentage of ground cover (lawn, flower arrangements, rock plants, etc.) on the property, the higher the value (*%GrndProp * Bungalow*, *%GrndProp * Cottage*), each percentage point adding some 0.2% to the price; and
- Finally, the presence of a hedge or landscaped wall (*Hedge*) raises a property’s value by nearly 4%, which can be assumed to mirror both the enhanced visual appearance from the home and the increased intimacy it provides.

By and large, the results obtained with Model 2 are in line with the literature. Applying the mean value for each landscaping-related variable and assuming the presence of a hedge results in a 7.7% market premium for either a typical bungalow or cottage. This is quite similar to findings by Morales, Boyce and Favretti (1976—6% to 9%), Seila and Anderson (1982—7%) and, more recently, Luttik (2000—7% to 8%).

Landscaping Features—Relative Interactions

Model 3 (Exhibit 9) mainly differs from Model 2 in that several of the landscaping interactions tested are based on centered, rather than original, variables. Performed on continuous descriptors only, this procedure generates complex implicit prices reflecting the impact of a departure from the local standard. *Relative* interactions between landscaping features and other price determinants are thus measured. At first glance, Model 3 displays slightly lower overall performances compared to Model 2, mainly with respect to the *F*-value, which drops to 193.2, from 258.4 previously. With twenty-four descriptors emerging as significant (*ROW*, *SEMIDET* and *‰AGE65_UP* re-enter the model while *ULAVLCTM* is rejected), several landscaping features—used as single characteristics or in interaction—are shown to affect prices.

Thus:

- With a *t*-value in excess of 5 and a positively signed coefficient, the property vs. neighborhood percentage-of-tree-cover ratio (*Prop_Nbhd %Tree Ratio*) corroborates Model 2 findings with regard to the ‘‘scarcity’’ premium (in this case, 7.3% per measurement unit) assigned to houses with more trees than surrounding properties.
- In contrast, a negative adjustment is required in neighborhoods where early boomers (*i.e.*, people aged 45–64) dominate (*Prop-Nbhd %Tree * Age45_64*).
- An increment is also added to house value wherever the proportion of women in the residential area and the tree cover in the immediate vicinity of the property are both either above or below the local average; in contrast, prices drop if the two components evolve in opposite directions (*%Tree Nbhd ctd * %Women ctd*).
- As with Model 2, cottages experience a rise in their market value (0.1%) for each additional positive departure-from-mean percentage point of ground cover on the property, and a drop if the departure is negative (*%GrndProp ctd * Cottage*).
- Quite interestingly, the density of the vegetation visible from the property (*Density Visible Veg*) impacts negatively on prices, each rank unit resulting in a loss of roughly 2.2% of value.
- Considering the distribution of this variable, such a finding can be interpreted as a confirmation of Payne’s (1973) conclusions regarding excessive tree cover.

Finally, a landscaped patio, a hedge as well as landscaped curbs add respectively 12.4%, 3.6% and 4.4% to the market value of a house, respectively.

While Model 3 provides a great variety of landscaping influences on property values, pertaining regression coefficients display, by and large, lower *t*-values than

Exhibit 9 | Regression Results—Model 3/Landscaping Relative Interaction Variables

	Unstandardized Coefficients		Unit Adjustment Factors			Collinearity Statistics
	B	Std. Error	Exp (B)	*t*	Sig.	VIF
Constant	10.316	0.091		113.52	0.000	
LIVAREA	0.004	0.000	1.004	21.56	0.000	2.25
LNLOTSIZ	0.081	0.015		5.52	0.000	1.75
ROW	−0.141	0.025	0.868	−5.76	0.000	1.42
SEMIDET	−0.121	0.019	0.886	−6.47	0.000	1.26
QUALINF	−0.238	0.046	0.788	−5.18	0.000	1.14
QUALSUP	0.157	0.029	1.170	5.43	0.000	1.47
APPAGE	−0.010	0.001	0.990	−16.64	0.000	2.34
SUPFLOOR	0.026	0.011	1.027	2.29	0.022	1.24
ATTGARAG	0.117	0.020	1.124	5.93	0.000	1.28
SETGARAG	0.080	0.016	1.083	4.88	0.000	1.31
EXCAPOOL	0.093	0.023	1.097	3.98	0.000	1.27
BASEFINH	0.048	0.011	1.050	4.33	0.000	1.17
OVEN	0.079	0.015	1.082	5.33	0.000	1.21
%AGE65_up	0.008	0.001	1.008	6.76	0.000	2.20
%DW46_60	0.002	0.000	1.002	3.61	0.000	2.11
%UNIVDEGR	0.009	0.000	1.009	20.81	0.000	1.36
Prop − Nbhd%Tree Ratio	0.071	0.014	1.073	5.11	0.000	2.43
Prop − Nbhd %Tree%Age45_64*	−0.006	0.002	0.994	−3.46	0.001	2.45
*%Grnd Prop ctd*Cottage*	0.001	0.000	1.001	2.93	0.003	1.31
%Tree Nbhd ctd%Women ctd*	0.036	0.010	1.036	3.56	0.000	1.25
Density visible veg	−0.023	0.010	0.978	−2.30	0.022	1.20
Hedge	0.036	0.011	1.036	3.16	0.002	1.15
Patio	0.117	0.048	1.124	2.41	0.016	1.04
Curbs	0.043	0.018	1.044	2.36	0.019	1.13

Notes: The dependent variable is *LNSPRICE*. R^2 = .863; Adj. R^2 = .859; *F*-value = 193.2 (.000); and the std. error of the estimate = 0.1418 (15.23%).

is the case with Model 2 and are therefore less reliable. Having said that, no inconsistency can be detected between the two models, each of which throwing a different shade on the phenomenon under analysis and complementing the other.

Testing for Spatial Autocorrelation and Heteroscedasticity of Residuals

Implicit prices derived from hedonic modeling may not be considered as reliable unless it can be shown that model residuals are both exempt from any significant spatial autocorrelation and homoscedastic (Dubin, 1988; Anselin and Rey, 1991; Ord and Getis, 1995; Can and Megbolugbe, 1997; Basu and Thibodeau, 1998; Pace, Barry and Sirmans, 1998; and Des Rosiers and Thériault, 1999). Indeed, either phenomenon is highly detrimental to the efficiency of the statistical tests used to assess the statistical significance of ordinary least squares regression coefficients (Anselin 1990). It is worth mentioning that while structural heteroscedasticity can occur in the absence of any spatial autocorrelation, the reverse is not true, the latter causing the former.

Measuring Spatial Autocorrelation Using Moran's I

Named after Moran (1950), the Moran's I is used to measure spatial autocorrelation in the models residuals. Considering (x_i, y_i, z_i), a data triad, where x and y are projected Euclidean co-ordinates of a point location (i), and z is any numerical value associated to that location, one can define indexed vectors containing values measured at n locations. The Euclidean distance (d_{ij}) between any pair of data at locations i and j is computed using their Cartesian co-ordinates (x_i, y_i) and (x_j, y_j):

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}. \quad (3)$$

The mathematical average of the n values of vector z is noted:

$$\bar{z} = \sum_{i=1}^{n} z_i / n. \quad (4)$$

The Moran's I index measures autocorrelation between values of the z vector, considering some weight (w_{ij}) that is a function of spatial proximity between any (i and j) pair of observations:

$$I = \frac{n}{\sum_{i=1}^{n} \sum_{j=1}^{n,j\neq 1} w_{ij}} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n,j\neq i} w_{ij}(z_i - \bar{z})(z_j - \bar{z})}{\sum_{i=1}^{n} (z_i - \bar{z})^2}, \text{ and} \tag{5}$$

$$w_{ij} = \frac{p_{ij}^a}{d_{ij}^2}, \tag{6}$$

where p_{ij} measures some degree of interaction between i and j. The exponent (a) is chosen to express the relative importance of the interaction links between the n by $n - 1$ pairs of observations. For the purpose of this article, p_{ij}^a was kept equal to one, meaning that interaction between each property was weighted only by the squared inverse distance between them. This clearly expresses the decrease in influence under gravitational effect.

The sampling distribution of the mean $E(I)$ and variance $Var(I)$ expectations of Moran's I are known. They form the basis of a parametric test for confirming the significance of experimental results. Knowing that the theoretical distribution of Moran's I is gaussian, the standard normal deviate $Z(I)$ between the measure and its expectation is used in order to reject the null hypothesis that the observed autocorrelation occur by chance only (Odland, 1988). We thus have:

$$Z(I) = \frac{I - E(I)}{\sqrt{VAR(I)}}, \text{ where} \tag{7}$$

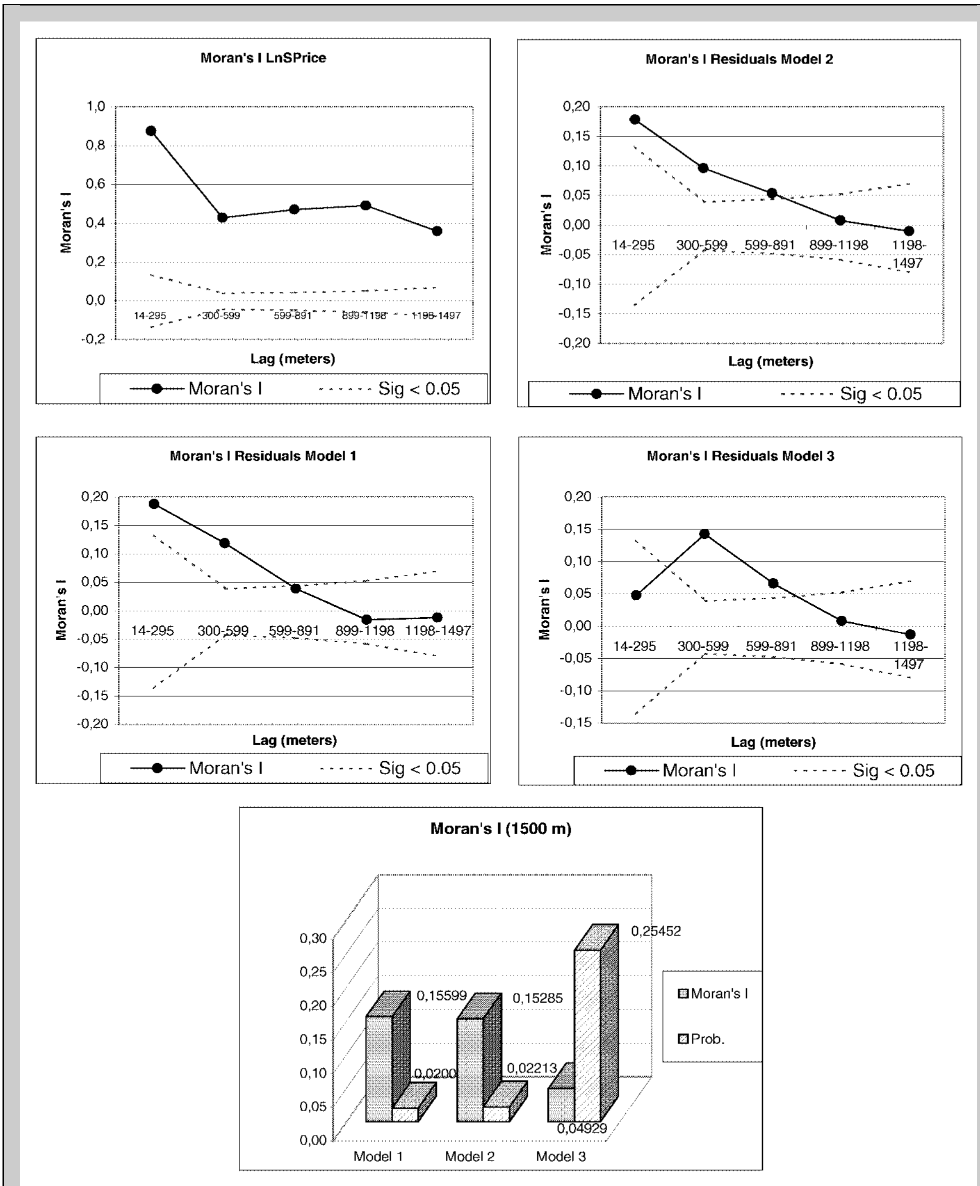
$$E(I) = \frac{-1}{(n - 1)}, \text{ and} \tag{8}$$

$$VAR(I) = \frac{n_2 S_{1-n} S_2 + 3\left(\sum_{i=1}^{n} \sum_{j=1}^{n,j\neq i} w_{ij}\right)^2}{\left(\sum_{i=1}^{n} \sum_{j=1}^{n,j\neq i} w_{ij}\right)^2 (n_2 - 1)}, \text{ with} \tag{9}$$

$$S_1 = \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n,j\neq i} (w_{ij} + w_{ji})^2 \text{ and } S_2 = \sum_{i=1}^{n} \left(\sum_{j=1}^{n,j\neq i} w_{ij} + \sum_{j=1}^{n,j\neq i} w_{ji}\right)^2. \tag{10}$$

Spatial autocorrelation indexes reported in this article are computed using the *MapStat* software developed by Thériault and take into account all pairs of

Exhibit 10 | Testing for Spatial Autocorrelation of Models Residuals



transactions linking homes located within a radius of 1,500 meters (roughly one mile) from one another (Euclidean distances). Moran's I are computed on both sale price and Models 1 to 3 residuals. Resulting correlograms as well as the overall autocorrelation index for properties located within a 1,500 meters radius are shown in Exhibit 10. As expected, sale prices display a high degree (0.9) of spatial dependence in the immediate vicinity of a residence, with the Moran's I tending to fall rapidly with distance and stabilizing at around 0.5 beyond 450 meters. While models 1 and 2 residuals are still flawed by a significant degree of spatial autocorrelation within a 750 meters radius, even after socio-economic, access and landscaping *absolute* interaction variables are introduced, resorting to *relative* interactions between landscaping features and other price determinants greatly improves the picture. Indeed, nearby autocorrelation, which is most detrimental to the stability of implicit prices of housing attributes, is no more significant. As can be seen from the lower portion of Exhibit 10, the overall index measured over a 1,500 meters radius sharply falls from roughly 0.16 and 0.15 in Models 1 and 2 respectively to 0.05 in Model 3 (prob. 0.2545).

Measuring Heteroscedasticity Using Glejser's Test

With spatial autocorrelation under control, it is now relevant to test for the presence of heteroscedastic residuals. The heteroscedasticity issue was dealt with several decades ago by Goldfeld and Quandt (1965) and Glejser (1969) who have designed statistical tests for its detection. According to the former, G-Q test, the global sales sample is first split into a lower and an upper portion segmented along one or several criteria (sale price, age, living area, etc.), the middle 20% segment of the distribution being left aside. Either submarket is then applied the initial model's parameters and the resulting squared residuals are summed up. A higher and a lower value are thus derived and their ratio, which follows a Fisher distribution, is finally computed: where statistically significant, this ratio indicates that model residuals are not homoscedastic. As for the latter, Glejser test, it simply consists in successively regressing selected variables against the absolute value of model residuals, using various functional forms. Heteroscedasticity is said to be present in the residuals if any b_i coefficient emerges as statistically significant.

Results obtained with both tests are displayed in Exhibits 11 and 12. Both tests are conclusive and clearly indicate the presence of heteroscedasticity in the residuals with respect to sale price, apparent age and living area. Considering that

Exhibit 11 | Goldfeld-Quandt Test: Ratio of Upper to Lower Segment

Ranking Variable	Group 1	Group 2	*F*	Prob.
LnSPRICE	1,876	4,148	2,211	0,000
dl	228	227		
APPAGE	2,752	5,522	2,007	0,000
dl	227	226		
LIVAREA	3,052	6,133	2,010	0,000
dl	227	226		

Exhibit 12 | Glejser Test: Regression on Absolute Value of Residuals

Reference Variable	Functional Form	Coefficient	t	Prob.	Adj. R^2
LnSPRICE	Linear	b1	4.06	0.0001	0.020
	Inverse	b1	−3.81	0.0002	0.018
	Quadratic	b1	−4.96	0.0000	0.051
		b2	5.06	0.0000	
APPAGE	Linear	b1	4.38	0.0000	0.023
	Quadratic	b1	1.88	0.0608	0.023
		b2	−0.54	0.5892	
LIVAREA	Linear	b1	5.19	0.0000	0.033
	Inverse	b1	−4.11	0.0000	0.206
	Quadratic	b1	2.06	0.0396	0.033
		b2	−0.81	0.4158	

several spatial dimensions are already accounted for in the modeling process, it can be assumed that a-spatial, structural heteroscedasticity is at stake. Furthermore, the very wide range of sale prices ($50,000–$435,000) on which this study is based may largely explain the scope of the problem encountered.

Conclusion

This study investigated the effect of landscaping on house values, based on a detailed field survey of 760 single-family home sales transacted between 1993 and 2000 in the territory of the Quebec Urban Community, using for that purpose the hedonic approach. Conducted during the summer of 2000, this survey focuses on landscaping characteristics of homes and their immediate environment that is the adjacent neighborhood visible from the transacted properties. Environmental information was captured from the front and side of houses and includes thirty-one attributes dealing with tree as well as ground cover—with trees being classified by size class and type of species—, flower arrangements and rock plants, hedges, landscaped curbs, density of visible vegetation as well as roof, patio and balcony arrangements. Landscaping features are added to an array of physical, census and access attributes. Sale prices range from a minimum of $50,000 to a maximum of $435,000, with the mean price standing at $112,000. Property types include bungalows—one-story, detached (42% of sample)—, cottages—multi-story, detached (40%)or semi-detached (40%)—and row houses (7%).

Once the basic model (Model 1) is calibrated using the physical, census and access characteristics of properties, landscaping features are added to the hedonic equation, with both individual attributes and interactive variables being used. While *absolute* interactions are resorted to in Model 2, *relative* interactions based on centered variables are used in Model 3. As fewer significant landscaping-related coefficients are derived from the former model, they in turn display greater stability than those generated by the latter. Having said that, each model brings complementary information and remains consistent with one another.

By and large, a positive tree cover differential—or a more-than-unity ratio—between the property and its immediate neighborhood translates into a higher house value, although a negative adjustment is required where early boomers—aged 45-64—dominate (Model 3). While the relative importance of tree cover in the visible surroundings also exerts a positive impact on property prices, the effect is all the more enhanced in areas with a high proportion of retired persons (Model 2). If trees seem to be valued by most homeowners, a high percentage of ground cover (lawn, flower arrangements, rock plants, etc.) also commands a market premium in the case of bungalows and cottages (Model 2); moreover, the price of cottages benefits from an above-average ground cover whereas a below-average one is detrimental (Model 3). Quite interestingly, an above-average density of the vegetation visible from the property impacts negatively on prices (Model 3), in line with Payne's (1973) conclusions regarding excessive tree cover. Finally, a hedge, a landscaped patio as well as landscaped curbs all command a substantial market premium: while it amounts to between 3.6% (Model 3) and 3.9% (Model 2) of property value for a hedge, it reaches 12.4% in the case of a patio and 4.4% for landscaped curbs (Model 3). Applying Model 2 using the mean value for each landscaping-related variable and assuming the presence of a hedge results in a 7.7% market premium for either a typical bungalow or a cottage.

In conclusion, research findings are in line with the literature on the subject. They suggest that using a parametric estimation technique can yield reliable, space-specific hedonic prices if landscaping interactive variables are resorted to. Furthermore, using *relative* interaction variables substantially reduces the detrimental effects spatial autocorrelation exerts on the stability of regression parameters.

Conclusive though it might be, the current study has some limitations that deserve further research. First, it does not account for possible landscaping improvements carried out between the transaction date and the survey period (Summer 2000), which could distort hedonic prices. Second, the current data bank does not allow an investigation into the links between, on the one hand, homeowners' preferences for landscaping features and, on the other hand, their socio-demographic and economic profile. An extensive phone survey is presently underway, which should soon palliate these informational flaws and lead to an even more reliable assessment of how landscaping shapes house values.

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François Des Rosiers, Laval University, Canada or Francois.Desrosiers@fsa.ulaval.ca.

Marius Thériault, Laval University, Canada or Marius.Theriault@crad.ulaval.ca.

Yan Kestens, Laval University, Canada or Yan.Kestens@crad.ulaval.ca.

Paul Villeneuve, Laval University, Canada or Paul.Villeneuve@crad.ulaval.ca.