Estimating Value Contribution of Tree and Stand Condition[1]

R. Joss Hanna[2] **Richard P. Thompson[3]** **Douglas D. Piirto[4]**
Jay E. Noel[5]

Abstract: *Key issues in encouraging forest management at the interface level in the oak woodlands are fire abatement, stand improvement, infection reduction, and hazard tree removal. The development of effective management prescriptions for stand improvement and economic returns provide guidance for homeowners, appraisers, and realtors. The purpose of this research project was to determine the effects of stand characteristics (e.g., structure, density and health) on the value of urban/interface forested properties. In this study, the forest characteristic coefficients were statistically significant with an estimated value contribution of about $30,000 each, or over 22 percent of the median property's value ($262,079).*

El Dorado and Placer Counties are two of the fastest growing counties within California and have undergone continued urbanization since the 1800's. The population of El Dorado County has almost tripled in 20 years, from 43,833 in 1970 to 125,995 in 1990. In Placer County the population has more than doubled, from 77,632 in 1970 to 172,796 in 1990 (San Francisco Examiner 1995). This explosive growth has created an urbanization of "traditional" wildlands into suburban communities. California's forests are a desirable place in which to reside and will continue to succumb to urbanization far into the future. Objective recognition of the beneficial economic and ecological qualities of a property's forest character will encourage improved management that incorporates the necessities of the natural environment.

The forests of the Lake Tahoe Basin today are overstocked and contain heavy infection levels of parasitic higher plants as agents of tree diseases (Tahoe Daily Tribune 1994). The suppression of fire, coupled with an increasing population base, has further reduced the health, composition, structure, and stocking of the Lake Tahoe Basin forest (hereinafter referred to as LTB). Drought, disease, and beetles respect no property boundaries when a forest's natural defense mechanisms are weakened. These threats have changed a once unbridled vigorous forest into an infected urban forest on both public and private land in California.

The existing literature on the implicit price of trees and their presence on residential property summarizes either the interrelationships between condition and associated health of the forest or the economic contribution from the absolute presence of trees on residential property. Literature on the value contribution of trees on urban, suburban, and rural property includes work by Magill (1989), Anderson and Cordell (1985), Chadwick (1980), and Neely (1979). Studies by Standiford and others (1987), Anderson and Cordell (1985), and Colorado State Forest Service/Colorado State University (1979) have attempted to identify the optimum number of trees on a property to enhance the value. These studies utilized both realtors and appraisers to estimate the value contribution or reduction in varied stocking levels from photographs, if all other site conditions were held equal.

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[2]Economist in the Environmental and Natural Resources Group. Law and Economics Consulting Group, Inc., 2000 Powell St., Suite 600, Emeryville, CA 94608.

[3]Professor, Natural Resources Management Department, California Polytechnic State University, San Luis Obispo, CA 93407.

[4]Professor and Project director, Natural Resources Management Department, California Polytechnic State University, San Luis Obispo, CA 93407.

[5]Associate professor, Agribusiness Department, California Polytechnic State University, San Luis Obispo, CA 93407.

We attempted to design a more comprehensive model that reflects not only the esthetic value contribution of the number of trees per acre but also the effect of average tree size and the health of the trees. In this paper, a brief description of this model using sample data from the LTB will be presented. Finally, we will discuss the applicability of this modeling approach to other forested property markets, specifically the oak woodlands.

Methods

The approach used in this study rests upon hedonic theory wherein the value of any "property" is the cumulative result of the values of the characteristics which comprise the property. This study adds to the current body of knowledge by estimating the contribution to property value through a very comprehensive measure of tree and stand esthetic incorporating the size, infection level, and number of trees per acre.[6] The structural relationships of this model can be described as follows:

$$V_t = f(SQFT_{it}, VIEW_{i1994}, NS_{it}, LNDSCP_{it}, \mathbf{Z}_{i1994})$$

$$\text{where } \mathbf{Z} = f(SDI^*, INFECT_i^{\gamma}),$$

$$SDI_i^* = TPA_i^{\phi 2}\left[\frac{DBH^{\phi_1}}{10}\right]^{-1.6}$$

(see *table 1* for variable definitions)

Here, the value of any characteristic is imputed by the strength of the relationship between the property's value (V_t) and the quantity/quality of the characteristic, referred to as an implicit price of the non-market characteristic. The hypothesis was that tree condition, defined as structure, composition, density and health, in the LTB of California affect property value. In the above equation $\mathbf{Z}_{i1994}$ represents the forest vector, defined by the size and number of trees (SDI_i*) and their vigor ($INFECT_i$). In this hedonic model the estimated implicit price

Table 1—Rating guide for near and far viewsheds

Rating	Meaning
Near Viewshed	
1	NO VIEW possibly along major road or heavy-use area.
2	VERY POOR, surrounding property has heavy overstocking and poor condition
3	POOR, characteristics of 1 and 2 but in a modest degree
4	BORDERLINE, more (3) attributes than (5)
5	FAIR, on side of overgrown or undermanaged
6	INDETERMINATE, mild effort necessary manage condition
7	IMPROVING, more (6) attributes than (8)
8	GOOD, possibly hilltop and well stocked forest adjacent
9	VERY GOOD, near lake with wide view or open space
10	EXCELLENT, surrounding property is possibly lake-front or park-like; Forest Service land adjacent
Far Viewshed	
1	NO VIEW, possibly along major road or heavy-use area
2	VERY POOR, surrounding property heavily overstocked and in poor condition
3	POOR, characteristics of (1) and (2) but in modest degree
4	BORDERLINE, more (3) attributes than (5)
5	FAIR, on side of overgrown or undermanaged
6	INDETERMINATE, mild effort necessary to manage condition
7	UNENCUMBERED, more(6) attributes than (8)
8	GOOD, possibly hilltop and well stocked forest in the distance
9	VERY GOOD, near lake with wide views near mountains or open space
10	EXCELLENT, outlying property is possibly lake-front or views of mountain ranges in the distance and/or ski slopes

[6]A complete description of the theoretical and empirical model presented in this paper is presented in a thesis by R. Joss Hanna (1995).

contribution of the stand characteristics to the value of a property was the primary research interest, and the phi (Φ) and gamma (γ) vectors are for transformation to functional form.

Field Data Collection

Time-series empirical data were collected and constructed for the hedonic model and applied to sample home sales from 1989 to 1994. In July 1994, exactly 100 transactions of improved sites (defined as improved property, owned in fee) were randomly selected through public records at the El Dorado and Placer County assessors' offices. Collection of transactions evidence was equally divided between El Dorado and Placer Counties, fulfilling a range of price stratum identified by realtors and appraisers from the area.

Upon selection, permission to enter the property was obtained, and data were collected and verified on site. The silvical characteristics evaluated were: (1) tree size, (2) number of trees, (3) species, (4) form class, (5) locational attributes to the home, (6) presence of pathogens and insect infestation, (7) tree mortality, and (8) evidence of previous tree management. Other variables that could significantly affect a property's sale price are those that reflect the condition of the neighborhood and community where it is located. In order to capture and separate those impacts from forest characteristic differences, near-view and far-view variables were evaluated, along with 31 cross-sectional data items from each sample property comprising the house and property characteristics, typically found in a multiple listing service's description.

The variables used to represent forest characteristics are size and density of trees; position in the crown; evidence of management; mortality and infection rating incorporating needle, top crown, twig, branch, trunk, and root condition, as well as lean of tree (*tables 1, 2*). These measures are proxies for the esthetic impact, physical setting, and health of the individual portion of the forest contained on the property. Along with the extensive recording of data, all sites and plant aggregates were photographed for confirmation of the particular evaluations to complete the refined range of variables for repeatability and documentation.

Econometric Analysis

Tests for the best functional form indicated that a log transformation of the price, power transformations of infection, and stand density using an autoregressive process best fit the data. The variable transformations and statistical procedures improved the model and increased the efficiency in estimating the value contribution from the tree and stand characteristics to property value. The dependent variable is the selling price of a single family residence, varying in size from one-third to five acres and covering sales from 1989 through 1994, while the impact of forest attributes on the property value is our principal interest.

In determination of the "best" model two primary goodness-of-fit criteria were employed, the log likelihood function and the adjusted R^2. Through the iterative process, we examined the adjusted R^2 and predicted beta's significance. Each iteration involves different values for the phi (Φ) and gamma (γ) vectors and will yield alternative functional forms in the estimation of contribution from forest characteristics to property value.

Detection of error problems were conducted through the model's specification. Respecification of the model may alter the error term conditions; therefore, finding an acceptable specification for the model involves simultaneously altering the functional form and remediating the error problems. If the empirical design is correct, then the iterative processes should converge on a model whose coefficients and error have the correct properties and for which there is a high degree of "goodness-of-fit" (Judge and others 1985).

*Table 2—Variable definitions and source**

Variable	Definition	Unit /Example	Source
PRICE:	Full transaction amount recorded	Real price	MS
Date:	Date the transaction was consummated	Day/Mo./Yr	MS
Size:	Acreage or portion thereof	Acres	MS
Year built:	Year home was built	Year	MS
SQFT:	Square footage of heated living area	Actual	MS
Bedroom:	Number of bedrooms	Actual	MS
Bathroom:	Number of bathrooms	Actual	MS
Stories:	Number of stories of home	Actual	OS
Garage:	Presence of garage	0 = none 1 = 1 car 2 = 2 car	OS
Location:	Access variable will measure nearest tenth of a mile distance from main arterial road.	1 = 0-.5 mi. 2 = >.5-1 mi. 3 = >1-1.5 mi. 4 = > 1.5-2 mi. 5 = > 2 mi.	OS
VIEW:	Average of the Near and Far View value	0 -15	OS
NS	County dummy variable (also a proxy for forest type: Jeffrey Pine, Mixed Conifer, respectively).	1 = El Dorado 2 = Placer	
Stand Data			
DBH	Avg. measured in each plant aggregate	measured	OS
Height	Avg. measured in each plant aggregate	measured	OS
TPA	Trees/acre in each plant aggregate	measured	OS
P.A.	Size of plant aggregate (PA) in relation to the total property	1 = 0 -10 pct 2 = >10-20 pct 3 = >20-30 pct 4 = >30-40 pct 5 = >50 pct	OS
P.A. weight:	Size of plant aggregate in relation to the other aggregates	1 = 0-20 pct 2 = >20-40 pct 3 = >40-60 pct 4 = >60-80 pct 5 = >80 pct	OS
Pathogens*:	Pathogens detected that are presenting problems to stand and affecting health of trees	1 = none 2 = moderate 3 = definite 4 = heavy	OS
Insects*:	Insects detected that are presenting problems to stand and affecting health of trees	1 = none 2 = moderate 3 = definite	OS
INFECT	Risk Class based on Tahoe Regional Planning Agency Hazard Guide (source: M. D. Hansen, TRPA)	1 = no risk 2 = 1 -4.5 3 = 5 - 7.5 4 = 8 +	OS
LNDSCP:	Effort in managing to natural surroundings	1 = no 2 = yes	OS
SPCS:	Species present on property	Actual	OS
LAYER:	Layers present in canopy (D, CD, I, S/S, & Sup.)	Actual	OS

* Other data were collected but not described in this table. For a full listing of all data and variables constructed, contact the authors.

OS = Data collected on site. MS = Data provided through metro scan.

Stand Density Index and Value Contribution

Reineke (1933) found that a consistent relationship existed between log(TPA) and average DBH. The slope of the stand density index was approximately -1.6 for many species. The stand density index value is not strongly correlated with age or site and therefore can be used as a comprehensive measure of stand density condition. This quality of independence of age or site makes the stand density index an additional valuable parameter in describing a stand (Husch and others 1982); thus a composite variable is formed using Reineke's definition of stand density.

$$SDI = TPA \bullet \left(\overline{DBH}/10\right)^{-1.6}$$

It was further hypothesized that **Z** variables of tree size, density, condition, height, diversity, and species would significantly influence forest property values. These are typical stand measures and as such have well-established methods of data collection. Reliance upon "tried and true" sampling measures promotes the applicability of this modeling approach.

The **Z** vector is a composite term that contains forest characteristics of the property that have been hypothesized to influence value. The specification of **Z** is the primary interest in the identification of the hedonic model. Alternative specifications for **Z** range from a very specific representation to a general composite variable representing several tree and stand attributes. The two expressions for **Z** presented below represent the final two competing specifications:

$\mathbf{Z}_1 = f$(DBH, TPA, SPECIES, LAYERS, HEIGHT, INFECT, LANDSCAPE, NS)

$\mathbf{Z}_2 = f$(SDI, INFECT, LDSCP, NS), where SDI = f(DBH, TPA)

The correlation matrix in *table 3* is composed of Pearson correlations between all candidate independent variables. The first data column shows the relationship between all the independent variables and the dependent variable (P log). It was hypothesized that the relationship between a property's characteristics and its price is positive. The correlations between P log and the independent variables (SPECIES, LAYER, SDI, INFECT , NS, VIEW, LNDSCP, SQFT, TPA, DBH) appear to be frequently highly correlated, a positive sign for further empirical analysis.

Table 3—Pearson correlation matrix

Variable	Log P	SPCS	LAYER	SDI	INFCT	N/S	VIEW	LDSCP	SQFT	TPA
SPCS	**0.326**									
LAYER	0.173	**0.515**								
SDI	0.255	**0.315**	**0.342**							
INFECT	**-0.652**	-0.031	0.032	0.05						
N/S	0.152	-0.023	0.075	-0.06	0.065					
VIEW	**0.786**	**0.343**	**0.331**	0.22	**-0.536**	-0.091				
LDSCP	**0.265**	0.242	-0.037	-0.11	-0.209	0.002	0.134			
SQFT	**0.577**	0.168	0.088	0.14	**-0.43**	0.096	**0.335**	**0.302**		
TPA	**0.358**	**0.429**	**0.408**	**0.631**	-0.076	0.140	0.233	-0.017	**0.287**	
DBH	-0.094	0.047	0.117	**0.620**	0.231	-0.204	0.013	-0.115	-0.13	-0.1

Correlations in bold are considered to be sufficiently high to be relevant, using the following t-test at $\alpha = 0.05$ and $n = 76$, $t = r\,((n-2)/(1-r^2))^{0.5}$ (Snedecor 1957). See *table 1, 2* for explanation of variables.

In *table 3*, the correlation between SDI and DBH, and between SDI and TPA, are important to note for the development of Reineke's stand density index. Analysis of the correlation matrix and initial ordinary least squares (OLS) linear regressions point to a clear weakness in the $\mathbf{Z}_1$ specification relative to $\mathbf{Z}_2$. Poor model fit and little significance of the independent variables were due, at least in part, to loss of degrees of freedom, high multicollinearity, and probably serial correlation. Therefore, evidence exists to reject the $\mathbf{Z}_1$ specification and to aggregate or design instrumental variables as in the $\mathbf{Z}_2$ specification.

The variables SPECIES and LAYER appear to be highly related to other independent variables, particularly the composite measure, SDI. Important correlations are between LAYER and TPA, SPECIES and TPA, VIEW and SQFT and LDSCP. Clearly, some of the intercorrelations may be unintelligible, such as INFECT with VIEW and TPA with SQFT, and such spurious correlations can still create degrading multicollinearity.

Throughout the analysis and development to the final model, many alternative forms for the specification of $\mathbf{Z}_2$ were conducted. When all of the aforementioned forest variables were regressed together at the plant aggregate level, against the log of the final transaction price, the adjusted R^2 was 76 percent. Trees per acre and the diameter at breast height variables were on the borderline of significance. However, when the transformed stand density index value (SDI*) was employed in the final model, the adjusted R^2 increased to 83 percent and the tree and stand coefficients had a higher significance (*table 4*). It is important to note that the predicted beta ($\hat{\beta}$) remained quite stable as various forms of $\mathbf{Z}_2$ were tested by iterating values of the parameters (d, F_1, F_2). This stability is indicative of the absence of multicollinearity and gives confidence in our well behaved model and in the specification of our model.

Table 4—Results of the hedonic price generalized least squares model

Variable	Coefficient estimate	| *t*-value |	Confidence interval @ 90 pct	Marginal implicit price
	Log(PRICE)			
constant	11.556**	51.270		
SQFT	0.00014**	2.2785	\$221,299-\$317,924	\$ 34
LDSCP	0.13974**	2.2584	\$250,727-\$280,609	\$36,860
VIEW	0.06224**	6.2964	\$232,296-\$302,873	\$23,784
NS	0.20289	1.0253	\$225,376-\$312,173	\$53,979
SDI*	0.02235*	1.8004	\$234,055-\$300,598	\$ 5,804
INFECT	0.07985*	1.7961	\$234,103-\$300,656	\$20,745
rho	0.71152**	8.9289		
F-value	70.089			
Adj. R^2	0.8336			
Log L.F.	15.616			
n 76				

Notes: Mean property price was \$262,079.
Confidence Intervals were calculated at the mean of each variable and then evaluated at the mean property price.
Marginal Implicit Prices were calculated as the change in predicted prices for the lowest and highest values of the variable divided by the range of that variable.
** indicates 1-tailed *t*-value significant at the $\alpha = 0.01$ level
* indicates 1-tailed *t*-value significant at the $\alpha = 0.05$ level

Results

The generalized least squares results for the following final functional form of the empirical hedonic model are presented in *table 4*:

$$\log(P_i) = \beta_0 + \beta_1 \mathrm{SQFT}_{it} + \beta_2 \mathrm{VIEW}_{i1994} + \beta_3 \mathrm{LDSCP}_{i1994} + \beta_4 \mathrm{NS}_{it} + \beta_5 \mathrm{SDI}^*_{i1994} - \beta_6 \mathrm{INFECT}_{i1994}{}^{1.3} + e_i$$

where: i = 1, 2, . . ., 76 sample properties, and each argument is potentially a vector characteristic.

t = years 1989–1994

$$\mathrm{SDI}^* = \mathrm{TPA}^{0.7} \left[\frac{\mathrm{DBH}^{0.6}}{10} \right]^{1.6}$$

(The signs of the β coefficients represent the hypothesized relationships.)

The estimated coefficients were derived through the regression equation, and their *t* values were tested for significance. The SQFT, VIEW, and LNDSCP coefficients were statistically significant at $\alpha = 0.01$ (given that the alternative hypothesis indicated the direction of the relationship, a 1-tailed *t*-test was applied). The coefficient with the highest *t*-value was VIEW at 6.2964. The coefficients of the forest characteristics, INFECT and SDI*, were also statistically significant at $\alpha = 0.05$. The only variable deemed as having an insignificant relationship to log(P) was the locational proxy for forest type (NS).

It is more informative to interpret these statistical relationships in more meaningful terms, i.e., dollars. For the forested properties within the LTB, the estimated mean contribution of altering stand density (SDI*) is between $234,055 to $300,598, about the mean of $262,079, with 95 percent confidence. It is further concluded that with 95 percent confidence the mean value contribution from the INFECT variable to property value is $20,745 to the average home price of $262,079. As hypothesized, the infection rating had a significant inverse relationship to price.

Discussion

The development of an empirical hedonic model permits the valuation of forest and stand esthetics. The most striking outcome of this analysis was that easily measured stand condition variables accounted for a significant property value contribution. In our analysis we developed an *ex-post* model that effectively estimates forestland esthetics' economic contribution to property value.

As the traditional "wildland" forests succumb to urbanization, more information will be needed regarding the value contribution of the remaining forest stands to the new home sites. The results of this study should be helpful in understanding which forest characteristics create value and in quantifying these relationships. The following points summarize the results of our study:

- The specification presented here is only one of a multitude of possibilities based upon the current forest condition and other socio-economic factors.
- A significant portion of the variation (83 percent) in property sales price is explained by our independent variable set in the empirical model.
- All but one of the variables in the final empirical model are significant at $\alpha = 0.05$.
- All selected variables behave in a manner to be expected in their relationship to the dependent variable.
- Coefficients appeared to be quite stable in magnitude in all models tested, providing confidence in our data items.

It must be recognized that a higher SDI* does not imply an increase in TPA. In reference to the LTB, a rise from increasing average DBH while holding constant or increasing TPA will likely yield a higher value. The fastest and most proven method for increasing the average stand diameter for a given site is to thin out the weakest trees. This could be consistent with Anderson and Cordell (1985) because TPA alone was used to derive value and SDI was not tested. However, the final empirical hedonic model, not functional form, should be applicable to similar urban interface issues in other regions.

On the basis of our findings, the private landowners in the LTB will recognize that the present value of the gains in expected property value would clearly justify current out-of-pocket costs to improve stand health and esthetics. Implications from the empirical analysis led to the following statements relating to the primary objective of the study:

- Empirical results support the hypothesis that forest condition does influence property price in the LTB of California.
- Increasing SDI leads to gains in property value through increasing DBH by thinning.
- Unhealthy or dead trees diminish property value.
- Stagnated stands not only pose a hazardous threat but are also a value deflator.

These results should encourage landowners in the LTB to invest in the management of the stands. Because the majority of the urban forest is privately owned, the benefits must outweigh the costs for the small non-industrial private landowners to maintain their portions of the interface forest in a sound manner. With findings such as ours, there is significant support for the sustained management of the forest through economic returns in property values. Silvical prescriptions need to incorporate existing characteristics of the specific groups of vegetation. Because of the diversity of the composition and structure, it is not possible to identify one single best approach to meet management objectives.

Implications for Oak Woodlands

Just as with the Lake Tahoe area, the esthetic created from the current forested environment in the oak woodlands of California can be characterized as in decline because of urbanization. The multiple uses of the oak woodlands for ranches and suburban development have fragmented the forest cover type to a point that serious efforts in forest management are needed to rectify these problems and to promote improved property values. The fundamental approach to valuing the urban interface forest through this type of econometric analysis is sound. It is anticipated that as the forest types under inspection change, so will the significant property and stand characteristics.

Adjustments to the hedonic model might include the stocking, view, efforts in management, infection, and mortality in a different relationship to the property value than in the Sierra Nevada mixed conifer and Jeffrey pine forest types. Multiple uses would also be able to be modeled into the hedonic equation, incorporating uses for cattle and horse pastures. Another potentially important influence is the general forest condition in a particular forest property market, i.e., the cumulative effect of individual property stand conditions. To incorporate these influences, use of geographic information systems (GIS) and geo-statistical modeling techniques may help. Such research will help us to better understand and describe the value of the urban forest and assist policy makers direct land use.

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