

**The Contribution of Environmental Amenities to Agricultural Land Values: Hedonic
Modelling Using Geographic Information Systems Data**

By

Donald M. McLeod

Chris T. Bastian

Matthew J. Germino

William A. Reiners

Benedict J. Blasko*

Presented at Western Agricultural Economics Association Annual Meeting
July 11-14, 1999
Fargo, ND

*** Senior Authorship is shared by the first two authors.** Authors are assistant professor and agricultural marketing specialist from the Department of Agricultural and Applied Economics; and doctoral candidate, professor and research assistant from the Department of Botany, all from the University of Wyoming, Laramie, WY. The authors acknowledge the support from USDA-NRI Rural Development for research funding, Farm Credit Services of Nebraska and Wyoming as well as the Wyoming Farm Loan Board for sales data and the Departments of Agricultural and Applied Economics as well as Botany, both at the University of Wyoming for general support.

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Abstract

Geographic Information Systems (GIS) data are used in a hedonic model to measure the impact of recreational and scenic amenities on agricultural land values. Results indicate agricultural land values are determined by environmental amenities as well as production attributes. Significant amenity variables included scenic view, elk habitat and fishery productivity.

Introduction

Agricultural land values can be estimated by summing the discounted productive rents. This approach may reflect soil quality, capital improvements, water supply and location to markets. Agricultural land also provides land for current and future development, recreation, access to public lands, wildlife habitat, and open space. Land, following Xu et al. (1993), can be viewed as an input to production; space for amenities (provision of public goods via place); fixed and taxable (provision of public goods via net revenue); and as an asset (capital good). Sale price should be the outcome of the total economic value of a parcel, given existing and efficient markets.

The demand for agricultural land results not only from the demand for additional productive land by agriculturalists, it is also affected by the households' demand for rural amenities. Agricultural land is being converted into nonagricultural uses across the U.S. (Vesterby et al., 1994) and the Rocky Mountain region. Population in Utah, Colorado and Idaho grew by 10 to 15 % from 1990 through 1995 (US Census, 1996). Mountain counties in western Wyoming grew by 7 to 18 % during the same period (Woods and Pole, 1996). All counties did not experience the same population growth. Rocky Mountain counties containing or bordering national forest wilderness areas experienced population gains from 1970 to 1985 (Rudzitis and Johansen, 1989). This region has abundant public lands, wildlife, and open spaces.

Growth affects agricultural land in terms of aggregate output and income, the viability of input suppliers and the economic base of rural counties. Rural land is competed

for in a range of input markets. It is important to understand what factors are driving land prices, prompting the conversion of agricultural land to other uses and putting agricultural lands at risk for development.

Theory of Land Value

Land can be viewed as having a bundle of property rights and related use values associated with ownership. The various sticks in the bundle may be sought after in different markets. Agricultural rents from production can be understood as follows:

$Q_i = f(L, X)$ where Q_i denotes output level of commodity i . L is the land input, and X is a vector of all other inputs.

$P_L = \sum_{i=1}^n [(P_i Q_i) - P_x X]$ denotes the rent to land at a given point in time, where P_i and P_x are output and input prices, respectively. The production function can be refined to account for soil fertility factors as well as climatic and locational factors affecting the contribution of the land input, L , to production of a given commodity. A more elegant and comprehensive discussion of land value theory is found in Randall and Castle (1985).

The above formulation does not account for the impact amenity values may have on land price. The presence of wildlife habitat, such as big game for hunting or viewing, provides opportunities for securing additional rents. The presence of water and angling opportunities on the parcel may lead to returns to fee fishing for the landowner.

If the market for land is driven by residential demand, wildlife enjoyment and fishing may be important household utility arguments. Aesthetic considerations, such as scenery and open space, are attributes of land that may provide homeowner satisfaction.

Household production theory provides a means of conceptualizing land as an input to the production of household satisfaction. It can be demonstrated as follows:

$Z_i = f(L, M, N, K)$ where Z_i is the output of concern i.e. place to live, N is the labor input, K is the capital input, L is the land input and M is a vector of other material inputs. Land may have many attributes that could contribute to the quality and contribution of L . The individual acts like a firm in minimizing cost subject to technical constraints in Z_i and K .

The individual then seeks to maximize utility subject to the cost constraint as

$U = v(Z_i)$ given $C = g(P_j, Z_i, K)$ where U is a utility function, C is the cost function consisting of a vector of prices, P_j one of which pertains to land; the output of interest, Z_i ; and the capital input, K . See Deaton and Muellbauer (1987) for a clearer and more rigorous treatment of household production theory.

Hedonic price models relate land attributes to the price of land. The land itself is an input that is being competed for in multiple markets. Hedonic price models, including GIS delineated variables, permit inferring the impact of land attributes on land values.

Theory of Hedonic Price Valuation

The hedonic technique is based on the premise that goods traded in the market are made up of different bundles of attributes or characteristics. These goods are not homogeneous and can differ in numerous characteristics (Palmquist, 1991). Market data can be used to analyze the effects that different characteristics have on the price of agricultural lands. Benefits of a change may be measured from the underlying demand for the characteristic or characteristics of interest.

Rosen (1974) indicates that the differentiated product (\mathbf{z}) can be represented by a vector $z = (z_1, z_2, \dots, z_n)$. The z vector is based on two sets of characteristics, agricultural production attributes, z_a , and amenities attributes, z_o . The observed price for z in the market will be defined as a hedonic function of its characteristics represented by $P = P(z_{a1}, \dots, z_{an}, z_{o1}, \dots, z_{on})$. The marginal price of z_o can be estimated from this function.

The underlying demand function for z_o needs to be correctly specified. The demand for agricultural land can be considered as a factor demand model associated with a production function which includes agricultural outputs, consumptive value outputs and residential sites. The price a prospective buyer will be willing to pay is a function of output prices, non-land input prices, production skills and site characteristics. This specification of the demand for land provides guidance for the hedonic price function specification.

Selective Review of Literature

A farmland price model was devised by Gertel and Atkinson (1993). They found that a multivariate state space approach was superior to other price forecasting models. Their model sets average farmland price per acre as a function of lagged farmland prices, returns to assets and real interest rates. No consideration is given to farmland attributes.

The literature examined reveals various components of land values. Garrod and Willis (1992) examined neighborhood or environmental characteristics of countryside parcels in the UK using a hedonic property model. Measured attributes were compared to perceived attributes. The view, and the presence of water were important. McLeod (1982) used a bid-price approach to determine marginal willingness-to-pay for urban residential properties in Perth, Australia. River view as well as water and park access were important.

Elad et al., (1994) estimated a hedonic model for rural Georgia land. They found that residential, agricultural and locational factors were significant determinants of land price. They used mean hedonic estimates as variables in a bid-price function. Residential use per acre values exceeded those for agriculture use.

Spahr and Sunderman (1995) used Wyoming ranchland sales data to model the contribution of scenic and recreational quality to land price. Low, medium and high quality, based on the judgement of area appraisers, were represented by dummy variables in their statistical model. These variables were statistically significant with high scenic quality contributing to higher sale price. Sunderman and Spahr (1998) examined agricultural land prices in the west using a hedonic approach. They found that taxes on agricultural lands encouraged speculation where nonscenic subsidized scenic via taxes. The scenic value variables were dummy variables multiplied by the deeded acres across little, good, or great scenic levels. Scenery was significant in explaining land values.

A hedonic rural land study using GIS is provided by Kennedy et al., (1996). The analysis identifies rural land markets in Louisiana based on economic, topographic and spatial variables. GIS was used for building distance to market and soil type variables. No nonagricultural amenities or open space variables were included in the estimation.

Conceptual Model

Let $P = f(Zag_i, Zam_i)$ where P is the total price of the land parcel, Zag_i is a vector of agricultural production related variables, Zam_i is a vector of amenity related variables and i is either **PA** or **HH** where **PA** is production agricultural demander and **HH** is

household demander. It is hypothesized that $\partial P / \partial AG_{PA} > 0$; $\partial P / \partial AG_{HH} \leq 0$;

$\partial P / \partial AM_{PA} \geq 0$; and $\partial P / \partial AM_{HH} > 0$.

Any given rural land parcel is being competed for in alternate markets defined by intended land use. The attributes are preferred by demanders of land except in the case of some Zag_i attributes not adding to utility of **HH** demander. The presence of agricultural production characteristics may have a mixed effect depending on the demander profile. Some of the agricultural production factors will be inconsequential in household demand. It is expected that the presence of amenities raise land price in all cases. This is due to the land purchaser's opportunity to capitalize on rents from fee hunting and fishing as well as some recreation access and activities.

Data

Agricultural Production Determinants of Value

Production characteristics of Wyoming agricultural land are taken from land sales between 1989-95. Farm Credit Services in Wyoming and Nebraska as well as the Wyoming Farm Loan Board provided the data. Data consist of appraisals for transacted sales. Appraisals reported individual tract descriptions including values established by type of land, structural improvements and public and private grazing leases and permits. Land characteristics and chosen measures of each used in the hedonic property model follow Torrell and Doll (1991); Xu et al. (1993) and Xu et al. (1994).

Nonagricultural (Amenity) Determinants of Value

Integrating GIS data into a hedonic framework permits modeling the presence of amenities on agricultural land prices more accurately. GIS protocols for quantifying

amenity resources, including measurement of view quality, trout fishing, wildlife habitat, and accessibility. Numerous studies have used these resources to measure amenity values, though none have done so in a hedonic model.

A GIS approach will be used to quantify the abundance and quality of each amenity resource represented in the hedonic model. The selected resources are 1) wildlife habitat, 2) trout habitat, 3) accessibility, and 4) scenery.

The consumptive and non-consumptive values of wildlife habitat for each land sale will be estimated by the area of select habitat types for elk. Elk were chosen due to their popularity in wildlife hunting and viewing. Measurements will be based on GIS coverages created by the State Game and Fish Departments.

Trout were chosen as a desirable fish to represent availability of water-related recreation. Stream coverages available from the USGS are combined with information on trout fishing quality, available from the Game and Fish Department, for each state.

Accessibility to towns is important in that it provides cultural and shopping opportunities to rural residents. Proximity to incorporated towns with greater than 2,500 individuals will be measured to represent the accessibility of the purchased land. The town size was chosen due to size thresholds as related to the provision of various retail trade and service opportunities (Taylor, 1998). Road coverages come from the US Census Bureau TIGER files and will be used to identify the roads travelled and town boundaries.

The development of a protocol for estimating scenic value, or view quality, using GIS, is an important component of the proposed work. The view variables are based on view cognition and preference studies (e.g. Kaplan et. al. 1989, Hammit et. al. 1994).

Photograph-like simulations of the view seen by an observer standing at the centroid of a parcel are used for measurements of the composition of the view. Digital Elevation Models (DEM) were adjusted for vegetation heights. This adjustment was based on the Wyoming Land Cover coverages (Driese & Reiners 1998) and expert opinion for average vegetation heights (WA Reiners and DH Knight, University of Wyoming).

A measure of diversity is used to indicate the quality of view. Simpson's Index is taken from the ecology literature and applied to views of landscapes. The composition of the view rather than types of species are used in the calculation. Simpson's Index (Barbour et al. 1980) is calculated as follows: $D = 1 - \sum_{i=1}^l (p_i)^2$ where D is the diversity index ranging from 0 to 1 (0 being no diversity and 1 being maximum diversity), l is land coverage type, and p_i is the proportion of land area coverage type which can be seen from the centroid of the parcel in a 360° panoramic view. The total area of land which can be viewed from the centroid in all directions was estimated. The GIS coverage for each of ten different land coverage types was overlaid on that area. The area of each land coverage type was then divided by the total potential view area from the centroid to estimate p_i . Land coverage types or categories included coniferous, deciduous, shrubland, riparian, prairie, water, incorporated, alpine, barren and disturbed.

The following variables were used in estimating the hedonic property model: The dependent variable of the model was PRICE, which was the total sale price in dollars for each observation. TREND is a number ranging from 1 to 6, where 1 represented sales occurring in 1989 and 6 represented sales occurring in 1995; RANGACRS is the sum of acres from all land categories which produced forage harvested by grazing only for each

parcel; IRRIGACRS is the sum of acres from all land categories which were irrigated by gravity or sprinkler irrigation for each parcel; PUBACRS is the sum of all leased state or federal acres which had permits that transferred with the sale of each parcel; IMPDOLR is the value of capital improvements capitalized into the sale price; TOWNND is the total road miles from edge of parcel to nearest incorporated town having at least 2500 people; TOTELKAC is the total acres of habitat classified by the Game and Fish departments as either Winter Year Long or Spring Summer Fall elk habitat for each parcel; FISHPROD is an index ranging from 1 to 4 of trout productivity for streams contained in parcel according to Wyoming Game and Fish department, the higher the index number the more productive; and SIMPCENT is Simpson's diversity index calculation applied to view.

Results

The model described above was initially estimated using OLS regression techniques in *SAS*. Multicollinearity diagnostics from the COLLIN option in *SAS* were estimated. The conditional index scores indicated no significant multicollinearity problems with the model. It was hypothesized that serial correlation could be a major source of heteroscedasticity in the model given that the sales data sample was drawn from multiple years coupled with a price discovery mechanism for land which is often heavily influenced by past sales information. The Durbin-Watson statistic estimated for the OLS regression in the AUTOREG procedure indicated significant serial correlation with an estimated order of lagged covariance being 1. The AUTOREG procedure in *SAS* corrects for serial correlation using the Yule-Walker method. The Durbin-Watson statistic

indicated serial correlation was no longer significant in the Yule-Walker corrected model.

Thus, only the Yule-Walker estimates for the model are reported in Table 1.

Table 1. Yule-Walker estimates for hedonic land value model.

Variable	b - Value	t-statistic	Prob.
Intercept	-255642	-2.329	0.0210
TREND	17313	1.507	0.1336
RANGACRS	92.571188	6.251	0.0001
IRRIGACRS	1477.260469	5.901	0.0001
PUBACRS	-5.447908	-0.891	0.3743
IMPDOLR	1.243063	4.934	0.0001
TOWND	820.161799	1.220	0.2241
TOTELKAC	95.325333	3.110	0.0022
FISHPROD	109247	6.057	0.0001
SIMPCENT	387803	2.391	0.0179
R²	0.6721	N = 183	
F-statistic	39.1722	d.f. = 172	
Durbin-Watson	1.9530		

The R² estimate and F-statistic both indicate a statistically significant proportion of the variation in PRICE is explained by the regression. The signs on the significant variables meet apriori expectations. The number of acres associated with grazing (RANGACRS) and irrigated crop production (IRRIGACRS) are positively related to sale price. Both RANGACRS and IRRIGACRS are significant at the $\alpha=0.01$ level. Capital improvements (IMPDOLR) are positively related and significant in explaining sale price.

The significance of three of the variables designed to capture the effect of recreational and scenic amenities is an interesting result. Wildlife habitat as measured by TOTELKAC and fishing potential (FISHPROD) are both positively related to sale price. Both parameter estimates are significant at $\alpha=0.01$. This indicates the value associated with either or both the potential rents and utility associated with recreational benefits on agricultural lands. The most interesting result of these three amenity variables is the significant and positive relationship associated with scenic amenities (SIMPCENT) and agricultural land values. The view is something that could improve owner utility as well as result in future gains should the land be developed residentially.

The trend variable was not significant but did have the correct sign. The distance to town was also not significant in explaining price. While the variable associated with public forage (PUBACRS) was not significant, it is interesting to note that the sign is negative. This result is not without merit given the findings of past research. Torell and Fowler (1986) found that proposals for increasing grazing fees on federal lands and increased grazing fees on New Mexico state trust lands caused a substantially faster percentage decline in ranch values for ranches highly dependent upon public land forage. These estimates were for a period when ranch land values were declining overall in the 1980s. Torell and Doll (1991) concluded that public land grazing permits fell in value relative to deeded land given increased grazing fees and waning public support for public land grazing. Bastian and Hewlett (1997) concluded that as the public originated percentage of total forage for a ranch increased beyond 24% the price per animal unit

declined for ranchlands sold during 1993 through 1995. This outcome follows the findings of Vanvig and Hewlett (1990).

Conclusions

Traditional economic approaches to estimating agricultural land values have been related to the sum of the discounted rents over time, which could be captured through agricultural production activities and capital improvements. Recent trends point to the demand for agricultural lands being significantly affected by non-agricultural interests. Household production theory and hedonic modelling techniques offer a richer set of testable hypotheses regarding agricultural land values.

As population migration to less urban areas continues, the demand for amenities such as outdoor recreation, scenery and open space will continue to grow. These growing pressures will increase the competition for owning agricultural lands. It is important to understand what factors are driving land prices, prompting the conversion of agricultural land to other uses and putting agricultural lands at risk for development. Results of this study indicate agricultural lands which have a diverse set of attributes that include wildlife habitat, angling opportunities and scenic vistas command higher prices than parcels comparable in size offering primarily agricultural production opportunities.

While other studies have concluded attributes other than agricultural productivity are related to land values, this study utilized GIS estimated variables, the values of which were uniquely specific to individual land parcels. This result alone, points to the potential impacts GIS data can have on agricultural economics research beyond qualitative appraisal or measuring distance on a map.

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