Exploring the Potential for Using GIS to Measure Environmental and Visual Amenities When Valuing Agricultural Lands

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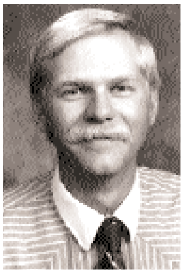

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Abstract

Geographic Information Systems (GIS) data are used to measure parcel specific environmental and visual amenities for 138 agricultural land sales in Wyoming. Land values are correlated with the environmental and visual amenity measurements as well as production attributes. This suggests there is potential for using GIS to measure attributes objectively that traditionally have been less quantifiable.

INTRODUCTION

The market for agricultural land is affected both by the demand for rents by agricultural producers and by households' demand for rural amenities. Agricultural land prices result from desired characteristics such as soil quality, water supply, location to markets, current and future development potential, recreation opportunity, access to public lands, wildlife habitat, and open space. Features beyond improvements and agricultural productivity are incorporated into land market prices and the appraisal process.

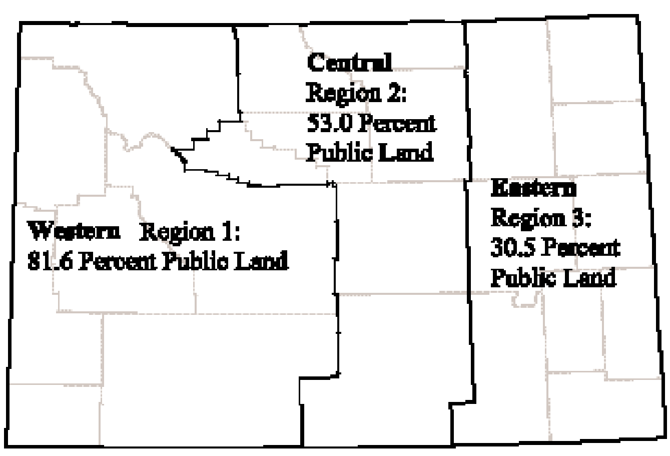
Appraisal forms used in the Wyoming Farm and Ranch Land Market study (see Bastian, Leishman and Hewlett; Bastian and Hewlett; Bastian, Foulke and Hewlett) often contain the following statements: "This property has excellent hunting and fishing," "..scenic ranch ..," or "buyer purchased land because of view of … mountains." Many properties may have unique features, other than those directly associated with agricultural productivity, that affect market values. Developing objective approaches for quantifying environmental and scenic amenities on land parcels could be useful in determining valued components of agricultural real estate. Rural appraisers and policy makers may need such tools when facing valuation of conservation easements, growth management initiatives and real estate taxation conflicts brought about by increasingly diverse demands for agricultural lands.

One tool that offers promise in quantifying traditionally non-measured land attributes is Geographic Information Systems (GIS). GIS permits a quantitative means of relating specific land characteristics to precise locations. This paper demonstrates how GIS data might be generated to measure scenic and environmental amenities on agricultural parcels. Agricultural productivity and GIS created variables designed to measure hunting and fishing potential, scenic amenities and distance to services for a sample of 138 appraised sales in Wyoming are provided. The results of an exploratory analysis assessing how well these GIS created variables and agricultural productivity measures from appraisals relate to land values in three regions of Wyoming are reported. Conclusions from this analysis are drawn regarding the land and policy implications of GIS measured environmental amenities. This application lends itself for use with agricultural parcels throughout the United States.

Hypothesized Relationships and Characteristics Influencing Wyoming Agricultural Land Values

The market for agricultural land in Wyoming includes actors that demand the land for agricultural production as well as for other amenities such as recreation potential or scenic value. Agriculturalists bid up land values based on the characteristics of the land that increase potential rents associated with agricultural production. Hunting and angling opportunities may provide rents from fee based recreation or provide the owner(s) with private recreation, both increasing land values. The presence of scenic amenities is expected to increase the purchase price of agricultural lands regardless of intended use. Regions across the state will vary significantly in agricultural productivity and amenity levels, and such variations should relate to regional differences in land prices. The GIS generated variables along with agricultural productivity characteristics are hypothesized to correlate with agricultural land values across the state.

Figure 1. Percent public land by region of Wyoming,



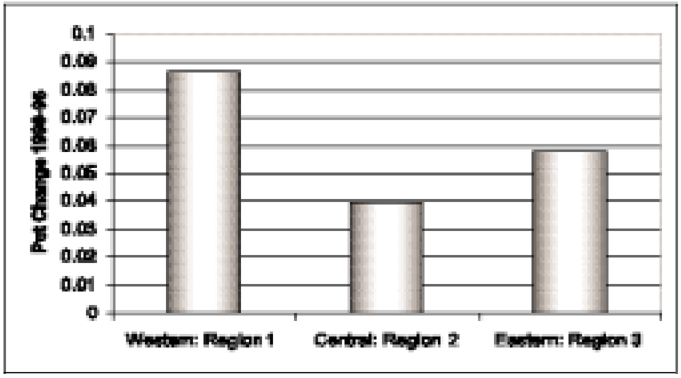
Wyoming Land Markets: Background

Wyoming is a sparsely populated state. It has diverse landscapes with irrigated basins and forested range in the north and west, desert and high plains in the central and east part of the state. The state is divided into three regions for this project. Region 1 (Figure 1) is the western part of the state. All counties in this region border or contain national parks and or wilderness areas. Region 2 (Figure 1) is in the central part of the state. Several, but not all, of these counties border or contain wilderness areas. Region 3 (Figure 1) is in the eastern part of the state. One county, Crook County, has a national monument (Devil's Tower) within its boundaries. Federal lands dominate in Regions 1 and 2 as seen in Figure 1.

Wyoming agriculture primarily consists of livestock and forage production followed by grain, dry bean and sugar beet production. Region 3 has the most crop acres. It has the highest value crop and livestock operations compared to the remainder of the state. It is the dominant agricultural region of the three as measured by agricultural receipts (Wyoming Agricultural Statistical Service).

Population change on unincorporated lands has not occurred uniformly across the state. Counties with more public lands tended to grow the fastest. The western portion of the state grew faster than the remainder from 1990 through 1995 as seen in Figure 2 (U.S. Department of Commerce, Bureau of Census). It is hypothesized that the higher population growth rates comes largely from in-migration of people seeking amenities rather than agricultural production opportunities. Mail surveys conducted in Sublette (McLeod, Kruse and Woirhaye) Uinta (McLeod et al 2002b) and Sheridan Counties (McLeod et al 2002a) indicate residential growth potential. Nonresident landowners would live full time in those counties, in which they owned property, based on their preferences for amenity values such as scenery, recreation, wildlife viewing and environmental quality. This potential for in-migration likely places pressure on agricultural lands as people try to purchase property with desired amenities.

Figure 2. Wyoming rural population change, 1990-1995, by region.



DATA

Agricultural Production Variables

Production characteristics of Wyoming agricultural parcels are taken from land sales between 1989-95. Farm Credit Services in Wyoming and Nebraska as well as the Wyoming Farm Loan Board and the Wyoming BLM provided the data. Data consist of a sample of 138 transacted sales selected statewide. Appraisals of these sales reported individual tract descriptions including values established by type of land, structural improvements and public and private grazing leases and permits. Land characteristics and the chosen measures of each used for this analysis follow Torell and Doll; Xu, Mittlehammer, and Barkley; and Xu, Mittlehammer, and Torell.

Agricultural productivity by land type (i.e., range, irrigated crop or meadow) is rated on animal unit months (AUMs) per acre as listed in each sale appraisal. Variables used in this exploratory analysis and their descriptions are summarized in Table 1. Land value is based on price per acre, **DOLACRE,** or average within parcel price. **DOLACRE** is calculated as total (nominal) sale price divided by deeded acres for the transaction.

Measures of agricultural productivity are calculated as either AUMs per acre or a percent with the exception of operation size, which is estimated as total AUMs. These measures (AUMs per acre or percent of total) are meant to address scaling issues associated with parcel size (see Parsons). Those agricultural production attributes hypothesized to affect price are **RNGACPER** (range acres); **IRMACPER** (irrigated meadowlands); **IRIGAUAC** (irrigated croplands); **DEED** (operation size); **IMPDOLAC** (on-

Table 1. Variable identification and description.

DOLACRE	Total ranch price in dollars divided by deeded acres.
DEED	Total deeded acres in sale.
RNGACPER	Total deeded acres classified as range divided by deeded acres and multiplied by 100.
IRGACPER	Total deeded acres classified as irrigated cropland divided by deeded acres and multiplied by 100.
IRMACPER	Total deeded acres classified as irrigated meadow divided by deeded acres and multiplied by 100.
PUBACPER	Total acres classified as public range which are an assured lease with the sale of the property divided by deeded acres and multiplied by 100. Note: This percentage can be more than 100.
SIMPINDX	Simpson's diversity index multiplied by 100. This number can range between 0 and 100.
STRMAC	Meters of stream on the property divided by deeded acres.
FISHPROD	Fish productivity average index on the property. The index comes from a Wyoming Game and Fish coverage.
FISHVALU	STRMAC multiplied by FISHPROD, providing a measure of fishing density per acre.
IMPDOLAC	Total dollar of improvements divided by deeded acres.
ELKACPER	Acres of spring-summer-fall and winter yearlong elk habitat / deeded acres.
TOWND	Distance from edge of property to nearest incorporated town of 2,000 inhabitants by road.

parcel improvements); and leased land (PUBACPER). The former is railroad land interspersed with private, state, and federal lands. The average value of railroad grazing leases in Wyoming tends to be greater than those found on public lands from 1990-1995 (Bastian, Foulke and Hewlett; Bastian and Hewlett).

GIS Generated Amenity Variables

GIS is used to quantify the abundance and quality of the following attributes: wildlife habitat, trout habitat, scenery and accessibility. The first step in measuring parcel specific characteristics required determining the precise boundaries of each land parcel sold, as described by legal descriptions in the appraisals, and then depicting those boundaries on a GIS generated map of Wyoming. This map depicting parcel boundaries could then be overlaid with other GIS coverages or maps containing the information desired for amenity measurements.

Wildlife Habitat

Elk habitat contained within each land parcel was estimated. Elk were chosen as an indicator species due to their popularity in wildlife hunting and viewing. Estimated expenditures for all elk hunters in Wyoming grew by 22.6% from 1990 through 1995, with 1995 hunter expenditures exceeding $29 million (Wyoming Game and Fish Department 1996). Total expenditures on elk hunting exceed expenditures for hunting any other species in the state (Wyoming Game and Fish Department 1996).

Area of elk habitat within a parcel was based on GIS coverages created by the Wyoming Game and Fish Department depicting elk habitat in Wyoming. Each land parcel was overlaid with a GIS coverage containing both Winter-Year-Long (WYL) and Spring-summer-Fall (SSF) elk habitat. Descriptions of the two habitat types used are listed below (taken from the WY Game and Fish 1998 coverage metadata):

> Winter/Yearlong Habitat: A population or portion of a population of animals makes general use of the documented suitable habitat within this range on a year-round basis. But during the winter months (between 12/1 and 4/30), there is a significant influx of additional animals into the area from other seasonal ranges.
>
> Spring/Summer/Fall Habitat: A population

or portion of a population of animals use the documented habitats within this range from the end of the previous winter to the onset of persistent winter conditions (variable period, but commonly from May through November).

These two types of habitat were chosen as they were thought to maximize hunting and/or viewing opportunities for elk (Lutz). Land area within the parcel boundaries, which met these criteria were then measured and recorded. These areas were used to create the variable used in this analysis called **ELKACPER.** This variable is the percent of deeded acres in the transacted parcel that was classified as one or both of the two habitat types described above.

Trout Habitat

Trout are chosen as a common and desirable fish to represent availability of water-related recreation and water quality. Estimated expenditures on sport fishing in Wyoming grew by 11.7% from 1990 through 1995 with 1995 angler expenditures being over $225 million (Wyoming Game and Fish Department 1996). Additional evidence on the importance of trout fishing in the Rocky Mountain region include willingness-to-pay estimates by Dalton et al. as well as Duffield and Allen, indicating the value of regional trout fisheries.

Stream coverages from the USGS were combined with information on trout fishing quality, available from the Wyoming Game and Fish Department. Stream coverages were intersected with each land parcel to calculate on-parcel trout productivity. This stream coverage is a subset containing perennial streams of the Wyoming Gap Analysis 1:100,000-scale hydrography coverage (HYDRO) for Wyoming (Spatial Data and Visualization Center (1996b)). No digital coverage that contains stream names or trout productivity for Wyoming is currently available. The Wyoming Game and Fish Trout Stream Classification Map was used to assign stream names and class to each stream for each intersected coverage. Wyoming Game and Fish provided a database containing trout productivity, stream name, and township and range information and this was used to manually assign productivity to each stream segment. Given these GIS coverages trout habitat is estimated by calculating the meters of perennial stream per acre on each parcel (**STRMAC** in Table 1.) The trout productivity database was then used to estimate the average trout productivity classification for that stream (**FISHPROD** in Table 1). These measurements were used to create the **FISHVALU** variable used in this analysis. **FISHVALU** is **STRMAC** multiplied by **FISHPROD**, providing a measure of average fishing density per acre for the transacted parcel.

Scenic Amenity Variable

Simulations of the view, as seen from an observation point two meters above the center of each parcel, were generated via GIS and used to measure characteristics of the view composition. View characteristics examined in this analysis include total view, relief, diversity and the amount of edge between land cover classes (Germino et al). These view variables include those related to view preference (Gobster and Chenoweth; Kaplan, Kaplan and Brown; Steinitz; Baldwin, et al.; Hammit, Patterson and Noe; and Bishop) and that could be calculated with the available data.

Land cover diversity, (measured by a modified form of Simpson's Index, see Barbour, Burk and Pitts), is used to indicate view composition. Preliminary work suggested that land cover diversity was the most significant view characteristic for predicting land prices. Simpson's Index values are driven by the more abundant land classes. It is assumed that some self-selection for view composition occurs based on the dominant land cover classes. Those who prefer forestland views choose views that have an abundance of forestlands, for example. The index is calculated as follows:

$$D = 1 - \sum_{i=1}^{1} (p_i)\ 2 \text{ where}$$

D is the diversity index ranging from 0 to 1 (0 being no diversity and 1 being maximum diversity), **1** is land coverage type, and **pi** is the proportion of view area occupied by each land type which can be seen from the center of the parcel.

The total area of land which can be viewed in all directions from each parcel from the center at a 2 meter height is approximated using Digital Elevations Models (DEMs) that have been adjusted for vegetation height. Simplified digital land cover data derived from Driese et al. is then digitally draped on the DEM and the area of each visible land cover type determined. This procedure creates a digital image, which estimates a 360(panoramic view at a 2 meter height in the center of the parcel. The GIS protocol then estimates the area bound-

Table 2. Pearson correlation coefficient between dollars per acre for agricultural land versus agricultural production and GIS amenity variables for Wyoming and the three regions (Coefficient: Prob > |R| under Ho: Rho=0).

Variables	Wyoming N=138	Region 1 N=60	Region 2 N=39	Region 3 N=39
DEED	-0.271 0.001	-0.336 0.009	-0.378 0.018	-0.299 0.064
RNGACPER	-0.590 0.000	-0.445 0.000	-0.607 0.000	-0.566 0.000
IRGACPER	0.452 0.000	0.427 0.001	0.604 0.000	0.270 0.096
IRMACPER	0.338 0.000	0.165 0.209	-0.0163 0.922	-------- --------
PUBACPER	-0.114 0.182	-0.211 0.106	-0.332 0.039	-0.014 0.931
SIMPINDX	0.387 0.000	0.260 0.045	0.217 0.185	0.447 0.004
STRMAC	0.312 0.000	0.317 0.014	-0.015 0.926	0.271 0.095
FISHPROD	0.207 0.015	0.060 0.649	0.073 0.661	0.365 0.022
FISHVALU	0.381 0.000	0.393 0.002	0.004 0.983	0.271 0.095
IMPDOLAC	0.278 0.001	0.084 0.522	0.668 0.000	0.406 0.010
ELKACPER	-0.096 0.261	-0.305 0.018	-0.129 0.433	0.235 0.150
TOWND	0.093 0.276	0.163 0.213	-0.383 0.016	0.340 0.034

aries seen in the image and measures land area covered within those boundaries by each land cover type. The area of each land cover type was divided by the total view area to find **pi**. Land cover types included coniferous, deciduous, shrubland, riparian, prairie, water, incorporated, alpine, barren and disturbed lands (Spatial Data and Visualization Center (1996c)). **SIMPINDX** as described in Table 1 was used to measure diversity in view and to represent scenic value of a parcel.

Accessibility

Accessibility to towns is important in that it provides cultural and shopping opportunities to rural residents. Proximity to incorporated towns with greater than 2,000 individuals was measured to represent the accessibility of the transacted land parcel. The town size was chosen due to size thresholds as related to the provision of various retail trade and service opportunities (Taylor and Held). Road coverages came from the US Census Bureau TIGER files. They were used to identify the roads traveled and town boundaries. The distance to the closest town meeting the specified population requirement was calculated by GIS software as the shortest road access from each parcel's closest boundary to the closest town boundary (Spatial Data and Visualization Center

(1996a)). Digital road data (Spatial Data and Visualization Center (1997)) and the GIS created map of parcel boundaries were used to calculate the shortest path from parcel to town.

ANALYSIS AND RESULTS

Simple statistical analyses were conducted to evaluate the potential of the measured variables in explaining land prices. Table 2 reports correlation statistics for the regions and the state. Table 3 reports means for each of the variables on a regional and statewide basis. Table 3 also indicates regions for which that mean is different based on t-statistics used to test the difference in mean values for each of the variables between regions.

RNGACPER consists of low value native range explaining its negative and significant correlation with price per acre (Table 2). The higher the percentage of range in the parcel, the lower the dollar per acre paid for it. Conversely, irrigated acres add to productive value and property price as reflected in the positive sign on **IRGACPER.**

Public grazing leases (**PUBACPER**) tend to have no relation to price except in Region 2. This may specifically indicate the preponderance of the dependence on public land gazing in the BLM lands in Region 2. It may indicate the uncertainty associated with public grazing for producers and the lack of perceived value to residential demanders in other regions of Wyoming. Torell and Fowler 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 those 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 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 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 in Wyoming. This outcome follows the findings of Vanvig and Hewlett. Capital improvements (IMPDOLR) are related to sale price, except in Region 1 perhaps indicating less improvements than in the other regions.

View quality (**SIMPINDX**) adds to agricultural property value except for Region 2. The view is something that may improve owner utility as well as result in future gains should the land be developed residentially. The presence of on-parcel fishing (**FISHVALU**) and wildlife habitat (**ELKACPER**) are significantly related to price in Region 1 and nearly so in Region 3. This indicates the probable value associated with potential rents from fishing and the utility associated with recreational benefits on those agricultural lands. **ELKACPER** is negatively related to price because of the correlation it has with parcel size, i.e., the bigger the parcel (**DEED**), the larger the opportunity for elk habitat, and the larger the parcel the lower the price per acre.

Distance from the parcel to a town is negatively related to price in Region 2 as expected. **TOWND** is positively correlated with price in Region 3. This may be due to the remote location of the parcels used in Region 3. Moreover, receipts in region 3 comprise the largest percentage of the state's total agricultural receipts indicating the potential for a higher incidence of agricultural demanders for land. Agricultural demanders may very well prefer seclusion over shorter distances to services.

Table 3 contains the average values for the set of variables analyzed. Most of the average variable values decline from the western (Region 1) to the eastern part (Region 3) of the state. Table 3 exhibits the test results for significant difference by average values between regions. Property values decline on average from west to east (Table 3). There are significant differences concerning land characteristics between regions in the state. Per acre parcel price and percent range acres differ as expected. Percent irrigated acres differs relative to Region 3. Both Region 1 and 2 are significantly different than Region 3 with respect to percent public acres as Region 3 parcels rely little on public land in comparison. Region 1 has more parcels with irrigated meadows relative to Region 2; commands better scenery than the other regions; has better elk habitat than the other regions; and provides quality on parcel fishing opportunities relative to the other regions. Region 1 tends to have more amenities, smaller parcels, although not significantly different from average parcel size in Region 3, and less of the agricultural production attributes than the other regions and concomitantly higher per acre parcel prices. These results meet with the authors' expectations based on

Table 3. Means for dollars per acre for agricultural land and agricultural production and GIS amenity variables in Wyoming and the three regions.[a]

Variables	Wyoming N=138	Region 1 N=60	Region 2 N=39	Region 3 N=39
DOLACRE	430.65	$635.32_{2,3}$[b]	$358.58_{1,3}$	$187.86_{1,2}$
DEED	1275.00	965.00_{2}	1952.00_{1}	1074.00
RNGACPER	77.20	$61.15_{2,3}$	$84.55_{1,3}$	$94.53_{1,2}$
IRGACPER	8.54	9.65_{3}	14.19_{3}	$1.18_{1,2}$
IRMACPER	12.74	28.47_{2}	1.25_{1}	0.00--
PUBACPER	36.36	59.59_{3}	32.97_{3}	$4.01_{1,2}$
SIMPINDX	45.43	$52.51_{2,3}$	$44.51_{1,3}$	$35.46_{1,2}$
STRMAC	1.06	1.63_{3}	0.88	0.37_{1}
FISHPROD	0.70	$1.08_{2,3}$	$0.59_{1,3}$	0.231,2
FISHVALU	2.25	3.69_{3}	1.93_{3}	0.371,2
IMPDOLAC	36.32	46.36_{3}	39.92	17.26_{1}
ELKACPER	14.63	$24.38_{2,3}$	9.22_{1}	5.02_{1}
TOWND	34.48	39.08_{2}	$18.94_{1,3}$	42.95_{2}

[a/] Numbers rounded to nearest hundredths.
[b/] Subscript numbers indicate region for which that mean is statistically different at the µ = 0.10 level based on PROC TTEST in SAS. For example, in row 1: Region 1's mean DOLACRE is significantly different from the means in regions 2 and 3; Region 2's mean DOLACRE is significantly different from the means in regions 1 and 3; and, Region 3's mean DOLACRE is significantly different from the means in regions 1 and 2.

knowledge of the state. Overall, these results point toward the potential for using GIS to generate relevant measurements for environmental and scenic amenity variables on agricultural land parcels.

CONCLUSIONS

Traditional economic approaches to assessing 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 rural growth points to the demand for agricultural lands being significantly affected by non-agricultural interests. The potential to use GIS data offers a richer set of tools that may be available in the future to rural appraisers and policy makers as they deal with an increasingly diverse set of demands for agricultural lands.

The demand for rural housing with access to amenities such as outdoor recreation, scenery and open space will continue to grow. The growing demands for such amenities will place pressures on rural appraisers and policy makers to quantify amenities and their contributions to land prices. This may become increasingly important in the policy arena, particularly in the western region. Land use and planning issues such as valuing conservation easements, developing growth management initiatives and addressing real estate taxation conflicts are apt applications of GIS driven assessment.

The objective of this paper was to provide an initial exploration into developing approaches for quantifying environmental and scenic amenities on agricultural land parcels. The contribution of this study is that it generated GIS estimated variables, the values of which were uniquely specific to individual land parcels. These results point to the potential of GIS as an analytical tool, which may be useful in the future to rural appraisers and policy makers. While these results are based on Wyoming land sales, the application of GIS to quantify amenities is not limited to Wyoming. As GIS data and software become more readily available to the public, rural appraisers likely will be able to utilize this technology in the future.

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