Hedonic Price Modeling to Value Irrigated Agriculture Across a River Basin

Steven Shultz[1]

Introduction

The need to quantify the economic value of irrigation associated with production agriculture has become essential in evaluating the economic feasibility of various water management options in many areas of the Central and Western U.S. This paper summarizes two alternative approaches to value irrigation in an area such as Nebraska which relies on both ground and surface water resources: relying on existing surveys of real estate experts and hedonic price modeling.

The geographic focus of this research is the Niobrara River Basin which extends 486 miles across Nebraska from Wyoming in the West to the confluence of the Missouri River in the East (Figure 1) and encompasses 7.6 million acres of pasture/grazing/livestock production, wet meadows, and both dry and irrigated cropland production from both ground and surface water sources. The National Scenic River portion of the River is heavily used for recreational floating from June to August with flow levels being influenced by both overland (stream) and aquifer hydrologic connections meaning that recreational flow levels may be influenced by out-of-stream water uses, particularly irrigated agriculture across the Basin. The Nebraska Game and Parks Commission is studying irrigation values in the Basin as part of their evaluation of the merits of an in-stream flow request for recreation on the River. As well, several lawsuits are ongoing in the Basin that require an estimation of regarding the fair market value of irrigation associated with subjugated water rights. Finally, in other watersheds of Nebraska (such as the Platte and the Republican Basins), and in many other Western states, the need for accurate estimates of the value of irrigation is necessary to help both policy makers and landowners determine the highest and best use for scarce water resources and to determine fair market prices for the purchase and/or leasing of water rights, and/or to resolve compensation cases associated with damaged or lost water rights.

[1] Steven Shultz, PhD. Barigт Professor of Real Estate and Land Use Economics, Economics Department, College of Business Administration, University of Nebraska at Omaha (email: sshultz@unomha.edu).
This research was funded by the Nebraska Game and Parks Commission and the Nebraska Environmental Trust.

Figure 1 Location Map of the Niobrara Basin

Previous Studies and Approaches to Valuing Irrigation

In many western states that rely on surface water irrigation, and which have active markets for trading water surface water supplies, economists and appraisers simply report observed selling prices (usually auctions and exchanges) while adjusting for transaction costs (Landry, 1999; Pritchett, James, Thorvaldson, and Frasier, 2009; Basta and Colby, 2010). However, in other central and western states (such as Nebraska and Kansas) that rely either on groundwater or a mix of groundwater and surface water supplies for irrigation, and where there is often not a formal market for trading surface water rights, agricultural economists have generally relied on the 'Land Value Approach' to value irrigation.

The principal assumption underlying the 'Land Value' approach for determining the contributory value of irrigation is that buyers and sellers of agricultural land are able to differentiate the factors of production as they relate to future profits when agreeing to sale prices for agricultural land. Therefore, real estate prices reflect revealed preferences for particular land characteristics, including irrigation, while holding all other land condition factors constant.

There are three different ways to utilize the 'Land Value Approach' for valuing irrigation: All rely on real estate market transaction data but differ in relation to data specificity, sample sizes of market transactions, geographical scale, and level of analytical complexity. These alternatives are: 1) Pairwise/comparable sales analyses (the approach preferred and most utilized by fee appraisers); 2) Observed price differentials between aggregated and survey based land value data; and 3) The hedonic valuation method (HVM) which is a multiple regression based technique based on parcel specific data which is often collected through the use of geographic information system (GIS) based technologies and spatially related databases.

The pairwise/comparable sale based approach to valuing irrigation most often relies on comparing paired sales. In the case of valuing irrigation, price differentials would be calculated between irrigated and non-irrigated agricultural sale parcels which are otherwise very similar if not identical (Derbes, 2005). A limitation of this approach is that it is often difficult to identify identical agricultural sale parcels that differ only with respect to irrigation activity. Land which is developed for irrigation usually has superior bio-physical characteristics than nearby (i.e.

'comparable') non-irrigated land parcels which often have inferior soil characteristics, field slopes, and/or water supplies required for irrigation. These non-comparability issues are potentially remedied by individual appraisers making price adjustments for differences across parcels but these estimates are potentially subjective and/or subject to valuation errors, particularly when based on small samples of compared sales.

A variation of the comparable sales/pairwise appraisal approach is to compare the average values of large numbers irrigated versus non-irrigated land sales derived from annual surveys and/or local real estate expert opinions. Producer surveys that collect land value information include the June Agricultural survey by the National Agricultural Statistics Service (NASS), or the agricultural census (both by the U.S. Department of Agriculture). Both of these collect uniform data nationally, and it has been demonstrated in at least two studies that this data is relatively accurate (Gertel, 1995, Shultz, 2006). However, a major drawback associated with the Federal Land Value data is the level of analysis at which it is released (States or occasionally counties) or the infrequency in which more detailed data is released (e.g. County level land value data from the Agricultural Census which is only conducted every 10 years. As an alternative, numerous state-level land value surveys have been developed over the years to elicit agricultural market transaction values from bankers, appraisers, and other real estate experts. Often, they are conducted by faculty working in State Land Grant Universities and or staff of Federal Reserve Banks (particularly in Midwest States).

State land value surveys intended to gauge expert opinions are often aggregated within regions of a State intended to represent fairly generalized agricultural land market segments. For example the Nebraska annual land survey by the University of Nebraska-Lincoln (UNL) is conducted within eight unique regions (Johnson and Lukassen, 2009). However, these regions are often very large and in many cases do not accurately correspond to watershed boundaries which is often required for irrigation policy decision making, particular in a State like Nebraska where many irrigation management activities are undertaken by locally empowered Natural Resource Districts whose jurisdicti9ns are based on watershed boundaries.

Expert opinion surveys often have relatively low sample sizes which limits an evaluation of statistical significance of reported land values. Also, when used to estimate irrigation values by comparing irrigated and non-irrigated land values, this approach suffers from the same problem as pairwise analyses in that the bio-physical characteristics (aside from irrigation status) are not always similar. This is particularly a problem in dry areas where, due to insufficient rainfall, irrigation is required for corn and other cropland production. In these areas most land that has suitable characteristics for irrigation (i.e. relatively good soil productivity, level slopes, and water availability) has already been irrigated while non-irrigated land is usually unsuitable for irrigation anyway. Some of the state surveys, including the University of Nebraska-Lincoln survey, attempt to conduct such mismatched comparisons by comparing irrigated land values with 'dry land sales *that have the potential for irrigation'*. However, it is not clear whether there exist enough of the sales described as 'dry land with irrigation potential' in many surveyed markets. Thus, it is difficult for experts to provide accurate survey data on this type of land valuation.

For these reasons, the most reliable and widely accepted approach among economists to value irrigation is the multiple regression-based 'Hedonic Valuation Method' (HVM). The HVM is also known as a hedonic price model (the terminology used for the remainder of this present study), or a 'price attribute model' or a 'mass appraisal technique'. The hedonic approach was formerly established by Rosen (1974) and has been used to value a full range of factors influencing real estate prices. The approach was refined and applied specifically to agricultural land sale prices by Palmquist (1989 and 1991) and is based on the assumption that producers are able to differentiate factors of production as they relate to profits when purchasing agricultural land under the following conditions:

$$P(q,s,z,i) = \int_0^\infty R(q,s,z,i)e^{-rs}ds$$

where the price of agricultural land (P) is specified a function of agricultural rent *R* based on soil quality characteristics q, location *z*, time *s*, the ability to irrigate *i*, and the interest rate *r*.

The marginal price of irrigation (both rights and potential bundled together) on sale prices is indicated by the coefficient of a variable measuring the percentage of a sold parcel that is irrigated. This can be considered the price differential between an irrigated versus a non-irrigated parcel while taking into account (controlling) for other factors (productivity measures). This irrigation value represents buyers and sellers opinions regarding the discounted net value of irrigation over time. Therefore, to convert such irrigation values to an annual basis, it is necessary to multiply hedonic based irrigation values by a capitalization rate (the ratio of annual rental rates to sale prices).

Recent estimates of irrigation value tied to real estate almost always rely on hedonic price modeling. Crouter (1987) estimated a linear regression equation for 53 real property sales near Greeley, CO with the irrigation variable represented as acre-feet of surface water delivered to the parcel and a dummy indicating the presence of a well. An index of soil quality available from the NRCS was used to proxy for the physical characteristics of the parcel. Overall, the value of an acre-foot of delivered water was shown to be just under $100 depending on the model used. Crouter (1987) also notes that this relatively low irrigation value may be due to the absence of an explicit water market in the area which leads to higher transaction costs. Torell, Libbin, and Miller (1990) extend this research to the agricultural production in areas served by the Ogallala Aquifer and determined that irrigation was on average worth $545 per acre-foot.

Faux and Parry (1999) using hedonic pricing found that irrigation values in Oregon ranged from $514 to $2,551 per acre (or from $147 to $729 per acre foot of water) with the highest values being associated with the highest quality land. Petrie and Taylor (2007) used hedonic pricing to determine that irrigation well moratoriums and pumping restrictions had significant impacts on irrigation values in Georgia. Finally, Butsic and Netusil (2007) estimated a hedonic price model based on 113 land sale transactions in rural county in southwester Oregon which was used to determine that irrigation was on average worth $1,850 per acre (a 26% premium over dry land values) which corresponds to $261 per acre-foot of irrigation water. It should be noted that that none of the above summaries of hedonic based irrigation values have not been adjusted to present dollars.

Common shortcomings or limitation with many of these previous hedonic studies of irrigation value are that they are based on relatively small samples of sales and/or that they are missing key bio-physical information describing sold land parcels. Field slope, and water pumping capacity are frequently missing from these models and even more serious common omission is the inability to quantify the precise number of sold irrigated acres. That is, researchers have often had to assume that all of the land associated with an irrigated land sale was irrigated when in fact it is likely that only portions of sold parcels were actually irrigated.

A Summary of Irrigation Valuation Approaches of the Present Study

In this present study, the value of irrigation across the Niobrara Basin based on real estate transaction data will involve two alternative approaches and data sources. First readily available real estate transaction data and survey-based values associated with both irrigated and non-irrigated land are compared to land value survey data (a single Basin-wide value). Second, these irrigation value estimates are compared to irrigation values derived from hedonic price modeling within specific sub-regions (markets) in the Basin.

The land survey data is based on the annual University of Nebraska-Lincoln Agricultural Land Value Survey conducted by Bruce Johnson of the Department of Agricultural Economics and hereafter referred to as the 'UNL/Johnson Survey data'. Such information quantifies inherent (or implied) irrigation values by subtracting the value of irrigated versus non-irrigated land
The hedonic modeling approach relies on the use of multiple regression to estimate the marginal price of irrigation (defined as the contribution that irrigation makes to sale price on a per acre basis). But it first requires the time consuming and difficult process of mapping and analyzing the geo-spatial characteristics of all sold agricultural parcels (contained in the State of Nebraska agricultural sale transaction database known as the '521' database of the Department of Property Transaction).

Irrigation Values Based on Surveys of Real Estate Experts

Land value estimates based on the UNL/Johnson agricultural land value survey (administered to real estate experts segregated by eight regions statewide) are summarized in Figure 2 for the North and Central regions combined (which provide the best available geographical overlap with the Niobrara Basin). In particular the following categories of reported land values are represented and analyzed: Irrigated cropland, dry cropland, pasture land, and dry cropland with irrigation potential. Later the estimation of the contributory value of irrigation based on these reported land values will be made by calculating 'net irrigation values' as the value of irrigation land minus the value of dry land.

The Non-Irrigated cropland with irrigation development potential values are of particular interest as subtracting this value from reported irrigated land values would generate a much more realistic estimate of the contributory value of irrigation per se as it would not be based on comparing irrigated land with land with no potential for irrigation. However, a potential limitation of relying on this category of land value for estimating net irrigation values is that very few sales of dry cropland with irrigation potential may exist making it difficult for surveyed 'experts' to accurately report such values on an annual basis and/or for specific areas.

Figure 2 demonstrates irrigated cropland values are consistently higher than non-irrigated cropland values and pasture land values over time (on average 62%). This differential increased sharply between 2005 and 2010 when the value of pivot irrigation land increased by 11% per year while dry land increased 9% per year. Dry cropland and pasture land values are very similar, and, as expected, dry cropland values are higher than dry cropland without irrigation potential.

Net irrigation values shown in the graph are calculated by subtracting irrigated land values from the average of pasture and dry cropland and are therefore in between (the average) of these classes of land values. Over the 10-year period they are on average $655/acre.

The two most serious limitations or drawbacks associated with these survey based net irrigation values are that the elicited values are likely based on a relatively low number of sales of 'dry cropland with irrigation potential', and that the estimated values are not specific to different study areas throughout the Basin (i.e. NRDs and/or irrigation districts). In fact, there was no Basin-wide specific value reported (instead this study had to use average values across two distinct survey regions).

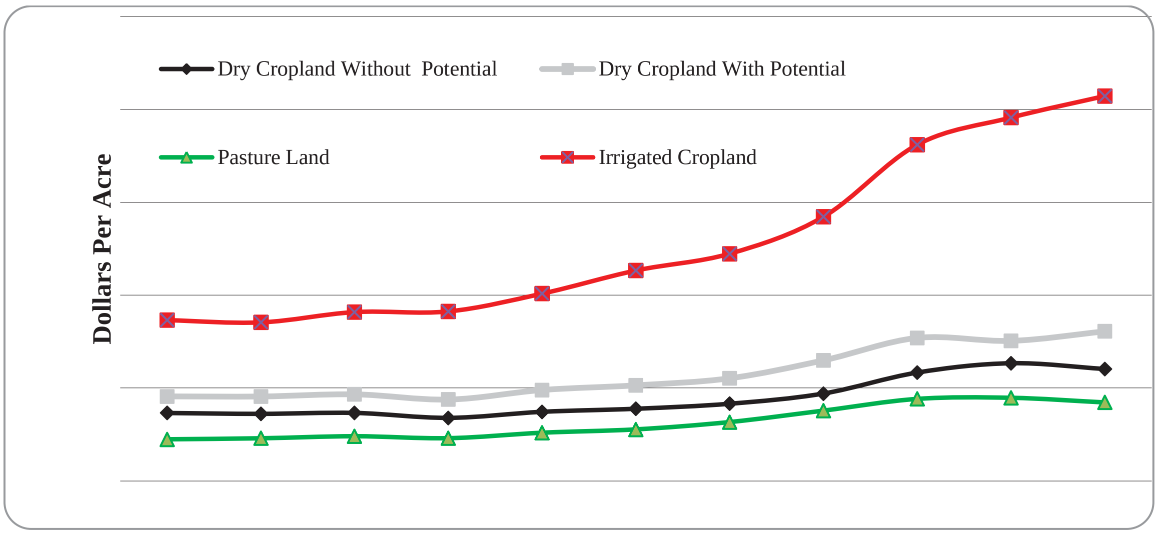

Figure 2. Land Values in the 'North' and 'Central' Regions: 2000-2010 (Based on UNL/Johnson Land Value Surveys of Real Estate 'Experts)

GIS-Based Hedonic Analyses of Irrigation Values

The data source for the estimation of hedonic models to quantify irrigation values in the Basin are recorded agricultural land sales transaction data contained in the 'Form 521' database maintained by the Nebraska Department of Revenue (Property Taxation Division). The '521 Sales' data is compiled by County Assessors and provided to the State for the purposes of evaluating the accuracy and fairness (equity) of tax assessments. A major advantage of these sales is that they include all arms-length transactions, and they account for non-land assets included in sales such as irrigation pivots or other farm equipment included with sales.

These sales were geo-spatially referenced (digitized within a GIS) using available legal descriptions of sold parcels along with National Agricultural Aerial Imagery Program (NAIP) field imagery and common land unit (CLU) boundaries of farm parcels as compiled by the Farm Service Agency of the U.S. Department of Agriculture. This was required to estimate irrigation values in specific sub-regions of the Basin in this case Natural Resource Districts, and to accurately quantify the extent of irrigation within sold parcels and measure the bio-physical characteristics of irrigated acreage.

Most (94%) of all sales were successfully digitized into a GIS database. Some (around 4%) of the sales were excluded as a result of the inability to digitize some sale parcel boundaries due to confusing, missing and/or incorrect legal descriptions, or because key sales transaction data were missing or incorrect. And approximately 1% of the digitized sales were classified as being uncharacteristic outliers and excluded based on comments made by local appraisers and/or assessors related to their a-typical nature. In most cases these were lands purchased for recreational activities by non-agricultural producers.

Digitized parcel boundaries of 94% of all arms-length sales (916 sales over the 2000 to 2008 time period), were spatially overlaid with a year 2005 land use database for the region (CALMIT 2005 and Dappen et al., 2007) in order to quantify both the irrigation status and crop type (cropland versus pasture) of all sold acres. The sale parcels were also spatially overlaid with a variety of other GIS databases including stream and well data from the U.S Geological Society (USGS) and the Nebraska Department of Natural Resources (NE DNR), a soil rating for plant growth (SRPG) measure USGS digital soils (SSURGO) data project (USGS 2010), and finally mean field slopes calculated from USGS digital elevation maps (USGS, 2009).

The frequency of sales across the Basin from 2000 to 2008 are shown in Figure 3 and summarized by land cover type in Table 2. Dry cropland sales are less than 5% of all sales, and additional inquiries indicated that only about 10% (i.e. five) of these sales had the potential to be irrigated (with similar characteristics as nearby irrigated sales). This shortage of dry cropland sales with irrigation potential may limit the accuracy of the earlier discussed UNL/Survey based estimates of net irrigation values which are based on comparing irrigated sale prices with cropland with irrigation potential prices. In other worlds if such sales are extremely infrequent it is not clear how experts can accurately relate their opinions about the value of such sales.

Table 1. The Frequency of Agricultural Sales by Type* (2000-2008)

	Number	Proportion of All Sales
Dry Cropland	45	5%
Irrigated Cropland	213	23%
Pasture	418	46%
Mixed Sales	240	26%
Total	916	100

** Derived from spatial overlays of sale parcels with a land use cover database for 2005*

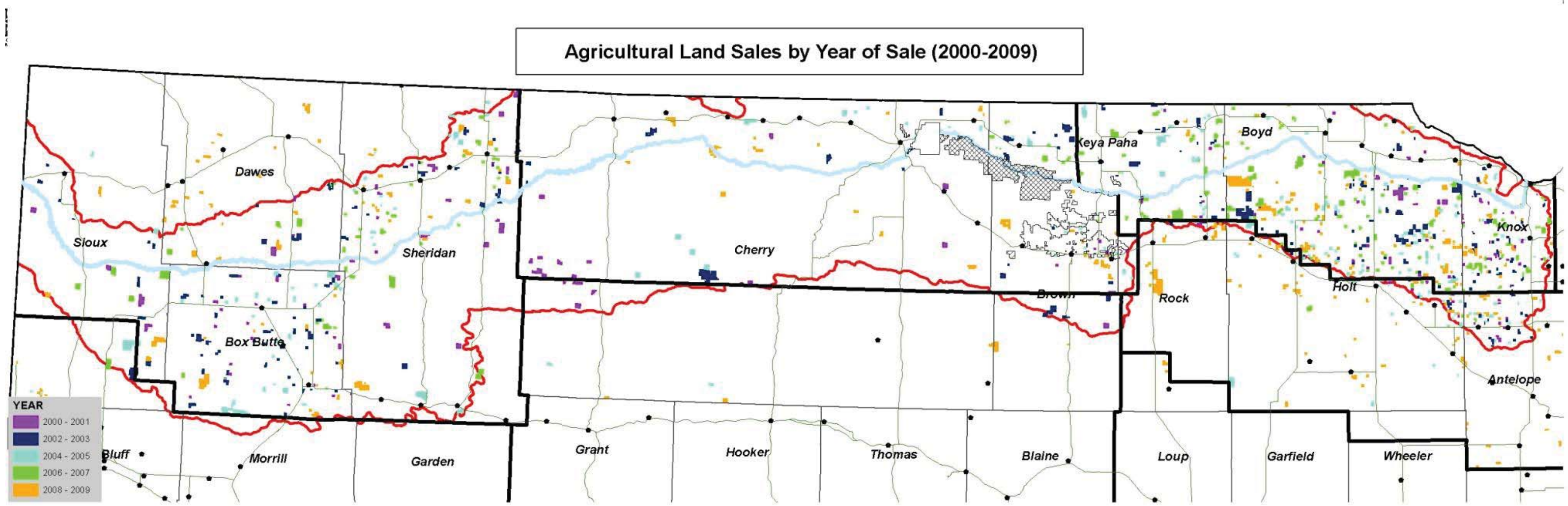

Figure 3. The Location of Agricultural Land Sales Across the Niobrara Basin (2000 to 2008*)
**** including 8 sales which occurred in early 2009***

The mean price of irrigated land sales across the Basin was $1,333/acre whereas the mean sale price for non-irrigated land was $375/acre. Based on this agricultural land sales information classified by irrigation status it is possible to conduct a quick and simple calculation of net irrigation values by subtracting non-irrigated (dry) land values from irrigated values. The caveat here is that the non-irrigated land parcels evaluated may not actually have any irrigation potential so these resulting net irrigation values should be considered an exaggerated (or high end) range of actual (likely) irrigation values. In this case they average $928/acre across the entire Basin with a range of value by NRD from $418/acre to $1027/acre

The general form of the hedonic price model to more accurately estimate irrigation values is:

$$(Price\,/\,Acre)_i = \beta_0 + \sum_{i=1}^{n} \beta_q Q_{ij} + \beta_s S_{ij} + \beta_z Z_{ij} + \beta_c I_i + u$$

where the of price per acre is a function of a vector of physical characteristics **Q**, a time trend matrix of dummy variables **S**, location dummies **Z**, a vector representing the presence of a irrigation rights and ability **I**, and a random error term u.

More specifically, this hedonic price model involves regressing sale prices on a per acre basis against the size of sold parcels, the percentage of a parcel that is wetlands or wet meadows which are incompatible with irrigated agriculture, the proportion of a parcel that is irrigated, the average soil productivity of a parcel (SRPG), the reciprocal of the average slope of a parcel[2], the distance from sold parcels to towns containing a population of 2000 persons or greater, time trend variables representing the year in which sales occurred, and finally dummy variables (yes/no) indicating the NRD in which a sale was located and whether or not it was in an fully appropriated area. These variables along with their summary statistics (means and standard deviations) are summarized in Table 2.

Alternative functional forms including semi-log, log-log, and quadratic specifications were experimented with and estimated. The hedonic models were first estimated basin-wide and then separately for unique market segments (NRDs and NRDs north and south of the Niobrara River) to evaluate the extent to which whether irrigation values vary spatially across the Basin. It is hypothesized that such market segment variables are important for accurate estimates of irrigation values this hedonic price model because Niobrara Basin covers such a large area with heterogeneous bio-physical conditions and land use practices. That is, the market segments are expected help account for variations in land characteristics across the study area as well as omitted variables within particular areas. As well, such NRD specific irrigation valuation estimates are considered relevant to policy makers and land owners as irrigation activities (development policies and water allocations) are managed autonomously in each of these NRD based market segments.

The estimated coefficient of most interest is the proportion of a sold parcel that is irrigated because this represents the marginal price of irrigation (both rights and potential bundled together). Again, this is considered the effect of changing irrigation status on an acre of land.

---

[2] Reciprocal function forms for explanatory and variable B_1 are represented by $Y = B_o + B_1 \; 1/X_1$. Such a functional form is commonly used for modeling variables with a satiation or a minimum acceptable level (such as the slope of a field at which the use of a pivot irrigation is infeasible. The marginal effect of a reciprocal variable (X) is interpreted as $- B_1 \; 1/X_1$ (that is, the sign of estimated coefficient needs to be reversed for interpreting its effect on Y).

Conceptually this can be considered to be equivalent to the price differential between an irrigated versus a non-irrigated parcel while taking into account (controlling) for other factors (productivity measures) and hence the marginal implicit price of irrigation on a per acre basis.

Table 2. Variables in the Basin-Wide Hedonic Price Model

Variable	Description	Mean	Std. Dev.
Price_Acre	Sale Price Per Acre (the dependent variable)	$693	$538
Totalac	Sold Acres	339	549
P_Wet_Meadows	Proportion (%)of the Sold Parcel Comprised of Wet Meadows and/or Wetlands (considered non-irrigatable)	2%	7%
P_Irrigated	Proportion (%) of the Sold Parcel Irrigated	26%	36%
SRPG	Soil Rating For Plant Growth	35.1	11.6
rSlope	Parcel Slope	3.5	3.1
d_u_nrd	If in the Upper Niobrara-White NRD	27%	0.44
d_m_nrd	If in the Middle Niobrara NRD	13%	0.33
d_l_nrd	If in the Lower Niobrara NRD	47%	0.50
d_2001	If sold in 2001	8%	
d_2002	If sold in 2002	11%	
d_2003	If sold in 2003	14%	
d_2004	If sold in 2004	13%	
d_2005	If sold in 2005	6%	
d_2006	If sold in 2006	12%	
d_2007	If sold in 2007	5%	
d_2008	If sold in 2008 or early 2009	22%	
Dist_Town_2000	Distance from Sold Parcel to Nearest Town of 2000 persons or more (Miles)	29	15
d_Fully_App	If in a Fully appropriated Area	56%	

The baseline hedonic model that specified sale prices ($/acre) to be a function of bio-physical characteristics of sold parcels, the year of the sale and the NRD in which the sale is located had a R^2 value of 0.67 meaning that 67% of the variation in sale prices are explained by the variables in the model. This is reflected in a statistically significant F-value and most of the explanatory variables having t-values that are statistically significant and with expected signs (positive or negative impacts on sale prices).
The estimated coefficients for this model are summarized in Table 3.

Estimating the hedonic model using alternative functional forms (semi-log, log-log and quadratic) did not result in any significant improvements to the explanatory powers of the model nor did they substantially change the direction, statistical significance, or magnitude of any of the estimated coefficients, particularly the coefficient representing irrigation value.

The variable measuring the percentage of a sold parcel that was irrigated has a statistically significant and positive impact on sales prices at the 99% confidence level. Each additional acre of irrigation adds $827 to total sale prices which is $273/acre or 26% higher than net irrigation value estimates based on expert surveys, but $101/acre (11%) lower than non-hedonic based net irrigation estimates calculated through comparisons of GIS-confirmed irrigated and dry land sale values.

As expected, wet meadows and parcel slope have statistically significant and negative impacts on sale price. Similarly, as expected, soil productivity (SRPG) has a statistically significant positive impact on sales price. Finally, as expected, proximity to towns of greater than 2000 people (i.e. only relatively large towns in the Basin) had a positive and statistically significant impact on sale price.

Somewhat unexpectedly, sale parcel size does not have a statistically significant impact on price per acre meaning that prices on per acre basis are not lower for large sales as has been demonstrated in other hedonic price studies of agricultural land sales. This may be a result of most sales in the Niobrara Basin being relatively large (i.e. a mean sale size of 339 acres).

Whether or not a sale was located in a fully appropriated area (where no new irrigation developments are permitted) had a statistically significant and negative ($91/acre) impact on sale price which is about tenth of the magnitude of the impact of irrigation itself on sale prices.

Each of the four market segment variables (NRD's) had a statistically significant impact on sale prices which reinforces the hypothesis that distinct market segments exist and are not accounted for only with the other explanatory variables in the model. Finally, time trend values only from 2005 to 2008 have a statistical significant impact on sale prices.

Table 3. Estimated Coefficients for the Basin-Wide Hedonic Price Model

	Coef.	Std. Err.	T	P>t
Totalac	0.00	0.02	-0.21	0.83
P_Wet_Meadows	-235.12	143.01	-1.64	0.10
P_Irrigated	827.36	35.16	23.53	0.00
SRPG	3.20	1.05	3.03	0.00
recip_Slope	62.69	14.77	4.24	0.00
d_u_nrd	-354.37	47.26	-7.5	0.00
d_m_nrd	-211.92	49.93	-4.24	0.00
d_l_nrd	-93.95	32.88	-2.86	0.00
d_2001	-2.92	51.15	-0.06	0.96
d_2002	9.31	47.95	0.19	0.85
d_2003	25.41	46.14	0.55	0.58
d_2004	74.49	46.86	1.59	0.11
d_2005	345.19	54.47	6.34	0.00
d_2006	360.54	47.68	7.56	0.00
d_2007	478.16	57.17	8.36	0.00
d_2008	232.43	43.94	5.29	0.00
Dist_Town_2000	-2.91	0.92	-3.16	0.00
d_Fully_App	-91.08	33.68	-2.7	0.01
_cons	473.05	66.83	7.08	0.00

Hedonic-based estimates of the marginal value irrigation estimated separately for specific sub-markets of the Niobrara Basin are summarized in Table 4. Marginal irrigation prices were successfully estimated for each of the NRDs in the Basin (i.e. all models having statistically F-tests, relatively high R^2 values and statistically significant irrigation coefficients). The resulting irrigation values range from $596/acre in the Upper Niobrara NRD to $909/acre in the Lower Niobrara NRD.

Within even more specific market segments (NRD segments classified by whether they are north or south of the Niobrara River), marginal irrigation prices were again successfully in all cases and the resulting irrigation values display an even wider range, from $412/acre in the Middle Niobrara/North of River NRD market segment to $985/acre in the middle Niobrara/South of River NRD market segment. This is a result of marked geological variations in land north and south of the River which directly impacts the biophysical characteristics and productivity of agricultural lands. The marked variation in irrigation values in different market segments of the Basin demonstrated the dangers of using a single (Basin-wide) irrigation value to policy making activities.

Table 4. Hedonic Marginal Irrigation Values by Market Segments (2000-2008)

	Sales	R^2 Value (hedonic model)	Marginal Value of Irrigation
Entire Basin	916	.68	$827*
By NRD Market Segments			
Upper Niobrara	247	.62	$596
Middle Niobrara & Upper Loup	114	.54	$909
Lower Niobrara	409	.74	$911
Upper Elkhorn	125	.49	$807
By Detailed NRD Market Segments			
Upper Niobrara-White North	104	.57	$701
Upper Niobrara-White South	141	.70	$578
Middle Niobrara North	37	.66	$412
Middle Niobrara South	77	.61	$985
Lower Niobrara North	70	.61	$496
Lower Niobrara South	342	.73	$916

** In contrast the value of irrigation based on expert surveys was $655/acre*

Conclusions

This study has compared two alternative approaches to valuing irrigation across a large river basin where irrigators rely on a mix of both ground and surface water supplies and where there is not an active surface water exchange market. These included relying irrigation value estimates derived from surveys of local real estate experts, and the estimation of a parcel level hedonic price model.

The advantage using survey data is that at least in States where it is collected, it is readily available thanks to the hard-work of the persons who conduct and report these surveys (and the experts who answer them). The limitations of relying on surveys to value for irrigation is whether there are enough sales of dry cropland with irrigation potential for direct comparisons to irrigated sale values. Also the statistical significance of the results cannot be tested, and the results are usually just available as a single value Basin or region wide.

In contrast, the use of hedonic price modeling to value irrigation is considerably more time consuming as sale parcels need to be digitized into a GIS, parcel level data collected, and hedonic models estimated. But the advantages of such hedonic based estimates of irrigation values are many. First they are based on actual market transactions and the statistical validity of irrigation estimates can be tested. More importantly such irrigation values based on this approach take into account the different characteristics of sold parcels to ensure that irrigation itself is being valued. In this case hedonic price estimates generated slightly higher irrigation value estimates than values derived from expert opinion surveys.
A final advantage of the hedonic approach is that allows irrigation values to be estimated within specific sub-markets of the Basin in this case NRDs that are based on sub-watershed boundaries and where bio-physical conditions vary markedly and where irrigation activities are managed autonomously. Such NRD specific irrigation values are expected to useful in ongoing and future efforts that will compare the relative values and tradeoffs between in and out-of-stream water uses in specific areas of the Niobrara Basin.

Such parcel level hedonic studies require that county and/or state authorities carefully track and disseminate information regarding agricultural land sales. It also requires that legal descriptions of land sales be accurately recorded, and that researchers make significant efforts to digitize such sales so that they can be integrated with other spatially related data using GIS technologies. These are costly and time consuming endeavors but as demonstrated by this study, they are deemed necessary for making accurate estimates of irrigation values.

References

Basta, E. and B. Colby. 2010. Water Market Trends: Transactions, Quantities, and Prices. The Appraisal Journal, 78(1).

Butsic, V. and N. Netusil. 2007. Valuing Water Rights in Douglas County Oregon, Using the Hedonic Price Method. *Journal of the American Water Resources Association*, 43(1): 622-629.

Crouter, J.P. 1987."Hedonic Estimation Applied to a Water Rights Market." *Land Economics.* 63(3) 259-271.

Dappen, P., Merchant, J., Ratcliffe, I., and Robbins, C. 2007. Delineation of 2005 land use patterns for the state of Nebraska department of natural resources. Final Report. (online: http://www.calmit.unl.edu/2005landuse/data/2005_NE_landuse_finalreport.pdf).

Derbes, M.. 2005. *The Appraisal of Land*. Publication of the International Right of Way Association. 2005.

Faux, J. and G.M. Perry. 1999. "Estimating Irrigation Water Value using Hedonic Price Analysis: A Case Study in Malheur County, Oregon." *Land Economics.* 75(3) 440-452.

Gertel, K. 1995. Farmland Values from Opinion Surveys and Sales Data: How they Differ and Why. Journal of the American Society of Farm Managers and Rural Appraisers: 89-100.

Landry, C. 1999. “Market Transfers of Water for Environmental Protection in the Western United States” *Water Policy,* Vol. 1 457-469.

Johnson, B. and R. Lukassen, 2009. Nebraska Farm Real Estate Market Developments (2008-2009). Report # 186. Department of Agricultural Economics, University of Nebraska-Lincoln. June 2009.

Palmquist, R.B.1989. “Land as a Differentiated Factor of Production: A Hedonic Model and Its Implications for Welfare Measurement.” *Land Economics* 65(1) 23-28.

Petrie, R.A. and L.O. Taylor. 2007. “Estimating the Value of Water Use Permits: A Hedonic Approach Applied to Farmland in the Southeastern United States.” *Land Economics.* 83(3) 302-318.

Pritchett, J., J. Thorvaldson, and M. Frasier. 2009. “Water as a Crop: Limited Irrigation and Water Leasing in Colorado” *Review of Agricultural Economics,* Vol. 30 No. 3 435-444.

Rosen, S. 1974. “Hedonic Prices and Implicit Prices: Product Differentiation in Pure Competition.” *Journal of Political Economy.* 82(Jan-Feb 1974) 34-55.

Shultz. S.2006. Differences between agricultural land value surveys and market sales*. Journal of the American Society of Farm Managers and Rural Appraisers*, 69(1): 8-16.

Torell, A., J. Libben, and M., Miller (1990). The Market Value of Water in the Ogallala Aquifer. *Land Economics*, 66:163-175

USGS, 2009. Digital Elevation Models. http://eros.usgs.gov/#/Guides/dem

USGS. 2010. Soil Survey Geographic (SSURGO) Database. http://soils.usda.gov/survey/geography/ssurgo/