The Value of Groundwater in the High Plains Aquifer of Western Kansas

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Placing a value on water is difficult. Because water is essential for life, the last drop of water cannot be valued. On the other hand, when water is abundant, then a unit of water may have minimal value. The value of many goods and services are readily apparent because they are traded, so the market price gives a reliable estimate of their value. But the market for water is thin and has large frictions—both political and physical—that prevent trades. This lack of a market for water makes it a challenge to value groundwater in western Kansas. What we can observe though is the market value for irrigated versus nonirrigated land and this reveals some important information about the additional value created by groundwater used for irrigation. In this paper, we describe the results from a few different recent research studies that utilize this market information to value groundwater. We also report results from a research study that estimates how much more livestock and agribusiness activity occurs in western Kansas due to the High Plains Aquifer. Finally, we conclude by noting some limitations with these valuation estimates and other considerations that were beyond the scope of our research.

VALUING THE HIGH PLAINS AQUIFER USING LAND VALUES

In well-functioning land markets (i.e., many buyers and sellers), the price of farmland reflects the net present value of future economic returns from farming. The difference in land values between irrigated and nonirrigated parcels represents the value that landowners are willing to pay for the expected stream of additional returns from irrigated rather than nonirrigated production. Sampson, Hendricks, and Taylor (2019) use regression methods with parcel-level land transaction data from 1988 to 2015 to estimate the relative difference in value between irrigated and nonirrigated parcels that have similar climatic and soil characteristics.

Agricultural land values in Kansas are roughly $3.79 billion larger today because of the High Plains Aquifer. To get this estimate of the increase in land values, we assume a relative difference between nonirrigated and irrigated land values of 53% based on estimates by Sampson, Hendricks, and Taylor (2019). We assume an average price of nonirrigated land values of $1,662/acre and 2.57 million acres irrigated in Kansas from the Groundwater Management Districts overlying the aquifer. County-level nonirrigated land values in 2020 are obtained from Reid (2021) and acres irrigated in counties overlying the aquifer in 2017 are from the Division of Water Resources, Kansas Department of Agriculture.[1]

How sensitive are irrigated farmland values in Kansas to changes in groundwater stocks? The stock of groundwater under an irrigated parcel represents the present and future quantity of water available for irrigation on the parcel, subject to annual pumping limitations set forth in the water right. Groundwater stocks are commonly defined using the term saturated thickness, which is a measure of the vertical depth of the saturated zone (i.e., water table to aquifer base). A potential buyer of farmland observes the quality of the land and the expected quantity of water available for present and future irrigation. All else equal, a 1 foot change in saturated thickness beneath the parcel can be inferred by buyers as a change in the productive quality of the parcel. Differences in the price of farmland which differ only in the saturated thickness beneath their respective parcels reveals information on the market value of saturated thickness.

Sampson, Hendricks, and Taylor (2019) estimate that **an additional 1-foot of saturated thickness under a parcel increases that parcel's market value by between $3.42 and $15.86 per acre.** Extrapolating this estimate to the approximately 2.57 million irrigated acres overlying the High Plains Aquifer in Kansas implies **a total valuation of between $8.79 million and $40.76 million for a uniform 1 foot increase in saturated thickness**.

THE ANNUAL VALUE OF THE HIGH PLAINS AQUIFER USING RENTAL MARKET DATA

An alternative approach to value groundwater stocks is to utilize data on cash rental rates for irrigated versus nonirrigated land and the number of acres irrigated. As the aquifer depletes this causes a decrease in the well capacities (i.e., the rate that water can be pumped) and an increase in the depth to water. If well capacities decrease sufficiently, then farmers cannot pump the water fast enough from a single well to meet the full irrigation water demand of corn. To adjust, farmers can either reduce the number of acres irrigated, water corn less intensively, or switch to less water-intensive crops. The latter two adjustments will be reflected in farmers paying lower rental rates for irrigated land. Another effect of aquifer depletion is that that the depth to water increases which increases to cost of pumping the water and again will either cause farmers to reduce acres irrigated or pay less rent for remaining irrigated land. Perez-Quesada, Hendricks, and Steward (2022) value groundwater stocks using this approach. They use county-level irrigated acres data from the Census of Agriculture, county-level rental rate data from NASS (National Agricultural Statistics Service), and saturated thickness data from Steward and Allen (2016). Intuitively, they use an economic model that compares outcomes in counties with similar climate and soils that are in the same state and same year but have different groundwater stocks because of natural variability in groundwater stocks before

[1] County-level irrigated acres in 2017 are available at https://agriculture.ks.gov/divisions-programs/dwr/water-appropriation/water-use-reporting.

irrigation development. Further details on the methodology are available in Perez-Quesada, Hendricks, and Steward (2022).

This study finds that if the saturated thickness is initially less than 70 feet, then a decrease in 1 foot of saturated thickness decreases the annual returns to land overlying the aquifer by $0.23 per acre. Note that this represents the impact averaged across all acres (e.g., cropland and pasture) overlying the aquifer and not just per acre of irrigated land. If the saturated thickness is initially greater than 70 feet, then the impact is an annual decrease of $0.05 per acre of land overlying the aquifer. The impact of aquifer depletion becomes significantly more severe when the saturated thickness is smaller. A key reason for this is the importance of well capacities. When saturated thickness is large, a decrease in saturated thickness may decrease well capacity but the well capacity remains sufficient to avoid large economic impacts. But once the saturated thickness declines below a certain level, then the well capacity becomes a major constraint to production and economic impacts of further aquifer depletion are large.

Consider, for example, the impact of aquifer depletion in Wichita County that has an average saturated thickness of less than 70 feet. The area in Wichita County overlying the aquifer is roughly 460,000 acres. Therefore, we predict that a 1 foot decrease in saturated thickness would lead to an annual decrease in the returns to land of roughly $104,400 in Wichita County.

This study also applies estimates of economic impacts of aquifer depletion to the scenarios of aquifer depletion under a business-as-usual scenario projected by Steward and Allen (2016). **Under a business-as-usual scenario, simulation results indicate that the annual present value of the returns to land are expected to decrease by $34.1 million between 2020 and 2050**. This is about a 5.3% decrease in the returns to cropland in the region and reflects a 13.5% decrease in irrigated acres. **By 2100, the annual present value of the returns to land are expected to decrease by $86.3 million**, reflecting a 13.4% decrease in returns to cropland and 32.7% decrease in irrigated acres.

An important caveat to these results is that they reflect the value of groundwater stocks valued in the returns to land. There are also likely additional returns to management and labor and broader economic spillovers that are not captured in these estimates.

ECONOMIC SPILLOVERS OF THE HIGH PLAINS AQUIFER TO OTHER AGRICULTURAL SECTORS

Next, we discuss these significant spillover effects of the High Plains Aquifer on the economic activity of related agricultural sectors. Estimates of the impact of the aquifer on livestock and agribusiness activities in table 1 are obtained through regression analysis. Intuitively, the regression compares outcomes in counties overlying the aquifer to those counties that are just outside the aquifer yet have similar climate and soil characteristics. The regression also adjusts for the fact that outcomes differ by the amount of saturated thickness in the respective county. Further details on the methodology are reported in Hendricks (2018).

Irrigation from the aquifer has increased animal feed production in western Kansas while groundwater provides water for animals. This has led to an increase in livestock production in western Kansas compared to what otherwise would exist. Total animal sales are 40.7% larger and the number of cattle on feed are 172% larger due to access to the aquifer in Kansas (see table 1). Greater crop production on irrigated land also increases the demand for fertilizer, chemicals, seeds, and other inputs that are sold by area agribusinesses. Fertilizer, chemical, and farm operating expenditures are 25.0%, 17.9%, and 25.3% larger in the counties overlying the aquifer in Kansas.

Table 1. The Relative Change in Livestock and Agribusiness Sectors in 2012 Compared to Prediction Without the Aquifer in Kansas

Animal Sales	Cattle on Feed	Fertilizer Expenditure	Chemical Expenditure	Farm Operating Expenditure
0.407**	1.721**	0.250**	0.179**	0.253**
[0.194, 0.718]	[0.447, 4.021]	[0.101, 0.391]	[0.053, 0.312]	[0.111, 0.450]

Note: This table is copied from table 6 of Hendricks (2018). ** indicates statistical significance at the 0.05 level. The numbers in brackets below the main estimate represent the 95% confidence interval.

In 2012, counties with greater than 50% of their area over the aquifer had $8.1 billion of animal sales, 3.8 million head of cattle on feed, $0.55 billion of fertilizer sales, $0.37 billion of chemical sales, and $11.2 billion of total farm operating expenditures. We then apply the estimates of the relative changes due to the aquifer to the 2012 Census of Agriculture statistics. This indicates that **the aquifer has led to an increase in animal sales of $2.4 billion annually and increased the number of cattle on feed by 2.4 million head. The aquifer has also increased fertilizer expenditures by $0.11 billion, chemical expenditures by $0.06 billion, and farm operating expenditures by $2.3 billion.**

There is an important caveat to the estimates of spillover effects on the livestock and agribusiness sectors. These estimates reflect how much more livestock and agribusiness activity occurs today due to the history of having access to the aquifer. However, these estimates may not reflect the impact of losing access to the aquifer—for example, due to aquifer depletion. Livestock processing plants and feed yards already have significant sunk costs in infrastructure in western Kansas. Even if local crop production decreased due to reduced irrigation, these businesses may not find it optimal to move to other locations. For example, it may be more profitable to remain located in western Kansas and import feed grains from other regions of the U.S.

OTHER CONSIDERATIONS IN VALUING GROUNDWATER

There are some other important factors to consider that are not mentioned in the discussion above. First, the valuation by the market for land does not account for the potential importance of inter-generational transfers. That is, when landowners bid on land, they are evaluating the value of the land as a discounted stream of returns where future returns are valued less than current returns from an investment perspective. Society may not discount these future returns and may place a value on the ability to irrigate in future generations simply for the fact that it preserves a certain way of life (known as "bequest value"). Considering this valuation for future generations leads to a larger value placed on preserving the stock of groundwater.

Second, extraction of water from the aquifer may be occurring at a rate faster than is economically optimal due to the common pool nature of the aquifer. This behavior is reflected in the sentiment, "if I don't pump it, someone else will" and is frequently referred to as a Tragedy of the Commons. To the extent that over-extraction of the aquifer occurs, the stream of returns to land could be increased by reducing current extraction. Optimal management of the aquifer could increase the value of the aquifer compared to what the land market currently reflects.

Third, our valuation reflects the value of the aquifer for irrigation, which is the dominant use of the groundwater. Other important uses of the water include municipal, livestock, and industrial uses. These alternative uses of the water likely generate higher value per unit of water than irrigation. Therefore, accounting for these alternative uses would increase the valuation of groundwater stocks.

SUMMARY

Water is a critical input to agricultural production in western Kansas and elsewhere. However, placing an economic value on water is made difficult by a general lack of markets where water is bought and sold. Water values can be inferred from land market transactions, where the quantity of water available for irrigation differentiates the productive qualities of land. In total, agricultural land values in Kansas are roughly $3.79 billion larger today because of the High Plains Aquifer. Utilizing farmland transaction data, we estimate that a uniform 1 foot increase in saturated thickness across the Kansas High Plains Aquifer would have a valuation of between $8.79 million and $40.76 million. Utilizing data on cash rental rates, we estimate that depletion of the High Plains Aquifer by 2050 will annually decrease farmland returns by $34.1 million. Access to water from the aquifer increases animal feed production and increases demand for agricultural inputs such as seeds, fertilizer, and chemical inputs, which benefits the agribusinesses supplying these inputs. Lastly, the aquifer provides municipal drinking water and inputs to non-agricultural industries, though we have not yet precisely quantified these valuations.

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