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Effects of Irrigation and Climate on the High Plains Aquifer

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Market Report	Year Ago	4 Wks Ago	11-8-19
L0.ivestock and Products, Weekly Average			
Nebraska Slaughter Steers, 35-65% Choice, Live Weight.	114.00	110.00	115.00
Nebraska Feeder Steers, Med. & Large Frame, 550-600 lb.	169.61	159.39	158.53
Nebraska Feeder Steers, Med. & Large Frame 750-800 lb.	154.36	152.82	150.79
Choice Boxed Beef, 600-750 lb. Carcass.	217.37	214.12	237.08
Western Corn Belt Base Hog Price Carcass, Negotiated	51.07	*	*
Pork Carcass Cutout, 185 lb. Carcass 51-52% Lean.	70.34	76.74	81.04
Slaughter Lambs, wooled and shorn, 135-165 lb. National.	135.43	147.18	153.15
National Carcass Lamb Cutout FOB.	380.23	396.39	402.45
Crops, Daily Spot Prices			
Wheat, No. 1, H.W. Imperial, bu.	4.43	3.68	3.70
Corn, No. 2, Yellow **Columbus**, bu.	3.40	3.83	3.60
Soybeans, No. 1, Yellow **Columbus**, bu.	7.79	8.41	5.93
Grain Sorghum, No.2, Yellow Dorchester, cwt.	5.48	6.13	8.32
Oats, No. 2, Heavy Minneapolis, Mn, bu.	3.18	3.21	3.27
Feed			
Alfalfa, Large Square Bales, Good to Premium, RFV 160-185 Northeast Nebraska, ton.	*	*	127.13
Alfalfa, Large Rounds, Good Platte Valley, ton.	110.00	107.50	107.50
Grass Hay, Large Rounds, Good Nebraska, ton.	87.50	100.00	95.00
Dried Distillers Grains, 10% Moisture Nebraska Average.	137.50	14700	149.50
Wet Distillers Grains, 65-70% Moisture Nebraska Average.	49.00	50.00	51.50
* No Market			

The High Plains Aquifer (HPA), sometimes known in Nebraska as the Ogallala Aquifer, is an enormous resource underlying 112 million acres across parts of eight states, from South Dakota to Texas.

Our research has previously estimated that irrigation water drawn from the HPA adds at least $2 billion worth of additional crops per year in Nebraska alone, and $3.5 billion across the entire HPA[1].

In the years ahead, world population growth will surely increase the pressure for irrigation from the stock of water in the HPA. But pumping that water from the aquifer can increase the depth to groundwater which can cause a number of associated environmental and economic problems.

This raises the important social issue of *how much aquifer water should be withdrawn for irrigation.*

How much water should be withdrawn from the HPA?

That is a difficult issue to address in general and we do not propose to answer it in this report. But we cannot address that broad question if we do not know how the level of groundwater is

[1] Garcia, Federico, Lilyan Fulginiti and Richard Perrin. 2019. "What Is the Use Value of Irrigation Water from the High Plains Aquifer?" *American Journal of Agricultural Economics*, 101(2):455-466. https://doi.org/10.1093/ajae/aay062

affected by irrigation practices and by weather, which are the issues we do address in this research.

The structure of groundwater dynamics for the HPA as a whole has not been assessed because of the great variability of these dynamics across the HPA. The HPA is not a big bathtub under the surface. It consists of water in the interstices of rock, sand and soil particles in underground geological layers, layers that vary immensely across the landscape. Thus, while hydrogeologists can determine quite accurately the groundwater effects of irrigation from a given well or set of neighboring wells, those dynamics will differ greatly across the HPA.

How do HPA water levels respond to irrigation pumping and weather?

We have examined groundwater dynamics at the aquifer level by estimating county-level impacts of irrigation and weather on aquifer levels, across the 208 counties that lie at least in part above the HPA[2]. This allows us to estimate the average response to uniform changes in irrigation and weather across the HPA.

We constructed average data for each county for five different years between 1985 and 2005 (statistics reported in Table 1). We then estimated simple hydrological and economic relationships among these variables using statistical techniques.

We used the estimated equations to estimate the impact of uniform changes in irrigation and weather on the rate of subsidence of the groundwater level in each of the 208 counties, but we report here, in Table 2, only the average across counties.

If the rate of irrigation water applied were to increase everywhere by 10% (i.e., from the overall average of 1.12 ft to 1.23 ft), other things including area irrigated held equal, we estimate that the average groundwater level across the HPA would recede by an additional -0.088 feet per year, that is, from an average of -0.49 feet per year to -0.578 feet per year.

On the other hand, if the area irrigated everywhere increased by 10% (i.e., from 32% of area to 35% of -area), other things equal we estimate that the annual rate of subsidence of the groundwater level would increase by 0.1271 feet per year, from -0.49 feet per year to -0.6271 feet per year.

Our measure of the temperature component of weather is the amount of time the crop is exposed to temperatures above 35°C, recorded as "degree 0.3days" (number of hours divided by 24), a variable which we refer to as DD35. On average, an additional day of exposure to these extreme temperatures results in a net increase in subsidence of .056 feet per year (Table 2, row 4).

Climate change?

It happens that models of climate change tend to provide inconsistent and relatively small changes in the climate in the HPA area, with it being in a transition area with hotter and drier predictions to the west and cooler, wetter conditions to the east. Bathke, et al., (2014) do suggest that for Nebraska, plausible changes might consist of as much as a 50% increase in hot temperatures and 25% less precipitation. We estimate the individual and combined impact of these levels of change in the last rows of Table 2. The estimated increase in the average annual rate of subsidence is 0.222 feet per year, only about a third of the impact of a 10% increase in irrigation. In this estimate we have included expected adjustments in irrigation due to the weather changes.

What is the take-away?

Increasing pressure in the future for food production will almost certainly create economic incentives to increase extractions of irrigation water from the HPA. But increases in both area and rate will be highly regulated in most counties in the future (regulatory constraints were very light during the 1985-2005 period we examined). So we expect responses in the future to be smaller than those we have observed in the past.

However, the relationships we have estimated will provide broad guidance for regulatory constraints on irrigation acreage and application rates that would be necessary to achieve desirable rates of aquifer subsidence in the future.

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[2] Silva, F., L. Fulginiti, R. Perrin, and K. Schoengold. 2019. "The Effects of Irrigation and Climate on the High Plains Aquifer: A County-Level Econometric Analysis." *Journal of the American Water Resources Association* 55 (5): 1085–1101. https://doi.org/10.1111/1752-1688.12781

Table 1. Overall mean, minimum and maximum of the county-level variables observed for years 1985, 1990, 1995, 2000, and 2005.

Variable	Units	Mean	Min	Max
Annual Groundwater Change	Feet	-0.49	-9.17	8.83
Application Rate	Feet	1.12	0.00	3.87
Fraction of Land Irrigated	Proportion	0.32	0.00	0.91
Water Price	$/Acre-foot	6.20	2.43	22.24
Fertilizer Price	Price Index	117.40	97.00	162.00
Output Price	$/Ton	58.54	29.89	147.06
Chemical Price	Price Index	108.80	90.00	123.00
Annual Precipitation	Inches	21.25	2.04	40.41
Precipitation Quarter 1	Inches	3.12	0.15	11.17
Precipitation Quarter 2	Inches	8.48	0.09	23.57
Precipitation Quarter 3	Inches	6.74	0.06	18.86
Degree Days >36° C	24-hour days	0.61	0.00	2.89

Table 2. Estimated average net effects of changes in irrigation, precipitation and time above 36℃ (DD36) on the *net annual change in groundwater levels* (in feet) in the HPA.

Cause	Estimated net effect (in feet per year)
Irrigation:	
10% increase in application rate	-0.088
10% increase in area irrigated	-1.271
Precipitation - one inch less	-0.041
Temperature - one extra DD36	-0.056
Climate change:	
50% increase in DD36	-0.017
50% increase in DD36 plus 25% less precipitation	-0.222

Reference

Bathke, D. J., R. J. Oglesby, C. M. Rowe, and D. A. Wilhite. 2014. "Understanding and assessing climate change University of Nebraska–Lincoln implications for Nebraska." In: *A synthesis report to support decision making and natural resource management in a changing climate.* University of Nebraska-Lincoln. http://snr.unl.edu/download/ research/projects/ climateimpacts/2014ClimateChange. pdf

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