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The Impact of Saturated Thickness to Protect Farmers from Severe Drought in High Plains Aquifer

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Background

- The High Plains aquifer is the primary source of water supply for irrigating major crops in the region including corn and soybeans
- Climate change is expected to reduce groundwater availability in High Plains Aquifer and increase extreme climatic events such as droughts to cause severe damages to U.S crop yields
- Climate change is expected to cause significant yield loss in the future (Schlenker and Roberts, 2009)
- Aquifer depletion leads to lower well yields, which in turn diminish the effectiveness of irrigation against drought (Foster et al., 2014).

U.S Drought Monitor Categories

Category	Drought intensity level	Percentile chance	Possible impacts
D0	Abnormally dry	20 to 30	• Short-term dryness slowing planting, growth of crops or pastures
D1	Drought, moderate	11 to 20	• Some damage to crops, pastures • Streams, reservoirs, or wells low, some water shortages developing or imminent
D2	Drought, severe	6 to 10	• Crop or pasture losses likely • Water shortages common
D3	Drought, extreme	3 to 5	• Major crop/pasture losses • Widespread water shortages or restrictions
D4	Drought, exceptional	0 to 2	• Exceptional and widespread crop/pasture losses • Shortages of water in reservoirs, streams, and wells creating water emergences

Table 1: Categories defined by the U.S Drought Monitor

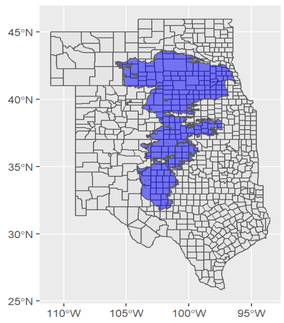

Figure 1: County-level map of High Plains Aquifer

Objectives

- Estimate the effect of saturated thickness to protect irrigated corn and soybeans production against severe drought in the High Plains Aquifer.
- Calculate the impact of aquifer depletion on farmers' ability to protect against severe droughts based on the regression results.

Data

Data:

- Irrigated corn and soybeans yields at the county level from 2000 to 2018 in the 8 states of high plains aquifer measured in bushels per acre
- County-level saturated thickness of High Plains Aquifer from the year 2000 to 2018 measured in feet
- Weekly drought index of the U.S Drought Monitor categories at the county-level in the High Plains Aquifer region

Methods

Empirical model:

$$Y = a + b_1\,Sat + b_2\,D0 + b_3 D1 + b_4\,D2 + b_5\,D3 + b_6\,D4 + b_7\,(D0*sat) + b_8\,(D1*Sat) + b_9\,(D2*Sat) + b_{10}\,(D3*Sat) + b_{11}\,(D4*Sat) + b_{12}\,(d5*Sat) + c + v$$

- Y: corn or soybean yields
- Sat: saturated thickness
- D0 through D4: drought categories defined in Table 1
- Dx*Sat: interactions of drought category variables and saturated thickness
- c: county fixed effect
- v: error term

Results & Implications

Corn yield

	Dependent variable: value	
	(1)	(2)
DO	0.010	0.119
	(0.127)	(0.120)
D1	-0.603***	-0.365***
	(0.127)	(0.122)
D2	-0.143	-0.260**
	(0.125)	(0.123)
D3	-0.804***	-0.772***
	(0.153)	(0.152)
D4	-2.305***	-2.175***
	(0.262)	(0.232)
sat	1.356***	1.372***
	(0.372)	(0.368)
I (sat * y_d0)	0.003*	0.003*
	(0.002)	(0.002)
I (sat * y_d1)	0.005**	0.004**
	(0.002)	(0.002)
I (sat * y_d2)	-0.0001	0.001
	(0.002)	(0.001)
I (sat * y_d3)	0.003	0.004*
	(0.002)	(0.002)
I (sat * y_d4)	0.015***	0.014***
	(0.004)	(0.003)
Observations	1,911	1,911
R^2	0.721	0.724
Adjusted R^2	0.687	0.691
Residual Std. Error (df = 1706)	13.735	13.644
Note:	*p<0.1;* ***p<0.05;*** p<0.01	

Soybean yield

	Dependent variable: value	
	(1)	(2)
D0	-0.110**	-0.098*
	(0.046)	(0.052)
D1	-0.060	-0.073
	(0.047)	(0.052)
D2	-0.003	0.001
	(0.052)	(0.061)
D3	-0.513***	-0.560***
	(0.087)	(0.095)
D4	-0.428***	-0.448***
	(0.163)	(0.165)
sat	-0.123	-0.119
	(0.165)	(0.165)
I (sat * D0)	0.002**	0.002**
	(0.001)	(0.001)
I (sat * D1)	0.0005	0.001
	(0.001)	(0.001)
I (sat * D2)	-0.001	-0.001
	(0.001)	(0.001)
I (sat * D3)	0.004**	0.005***
	(0.001)	(0.001)
I (sat * D4)	0.002	0.002
	(0.002)	(0.002)
Observations	1,158	1,158
R^2	0.790	0.789
Adjusted R^2	0.755	0.755
Residual Std. Error (df = 993)	3.914	3.917
Note:	*p<0.1;* ***p<0.05;*** p<0.01	

Summary of Results:

- Drought events have negative impacts on yield as expected
- Having higher saturated thickness negate more of the damages droughts incur on crop yield
- Having higher saturated thickness is particularly important when the severest kind of drought occurs

Policy Implications:

- The ability of irrigation to protect farmers from drought depends critically on saturated thickness
- Aquifer management is critical to ensure productive irrigated agriculture
- The importance of aquifer management only becomes more important in the future due to climate change that can make drought events more frequent and severe.

References & Acknowledgments

- Foster, T., Brozović, N., & Butler, A. P. (2014). Modeling irrigation behavior in groundwater systems. Water resources research, 50(8), 6370-6389.
- Schlenker, W., & Roberts, M. J. (2009). Nonlinear temperature effects indicate severe damages to US crop yields under climate change. *Proceedings of the National Academy of sciences*, *106*(37), 15594-15598.
- The U.S Drought Monitor. The National Drought Mitigation Center (NDMC), the U.S. Department of Agriculture (USDA) and the National Oceanic and Atmospheric Administration (NOAA).

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