Spatio-temporal trend of irrigation water pumping and its response to water conservation policy (LEMA) in Kansas

Govinda Khanal*, Musabbir Turjo, Jeeban Panthi

K-State Geology Department, K-State Civil Engineering Department

*govindak@ksu.edu

1. BACKGROUND

Groundwater storage depletion across western Kansas has intensified over the past several decades due to persistent irrigation demands on the Ogallala Aquifer (McGuire, 2017). Spatial and temporal analyses of long-term pumping data shows widespread declines in groundwater availability, underscoring the need for local conservation strategies. Kansas has implemented Locally Enhanced Management Areas (LEMAs) to encourage voluntary, community-based reductions in groundwater use. Evaluating the effectiveness of these programs through statistical and spatial approaches helps identify where management actions are working and where additional interventions are needed to sustain agricultural productivity and groundwater resources.

Center Pivot irrigation system. Photo: US Geological Survey

2. OBJECTIVES

- Quantify long-term spatial and temporal trends in groundwater pumping across Kansas.
- Evaluate the effectiveness of LEMA implementation in reducing irrigation intensity.
- Examine the influence of growing-season precipitation and temperature on annual pumping variability.

3. METHOD

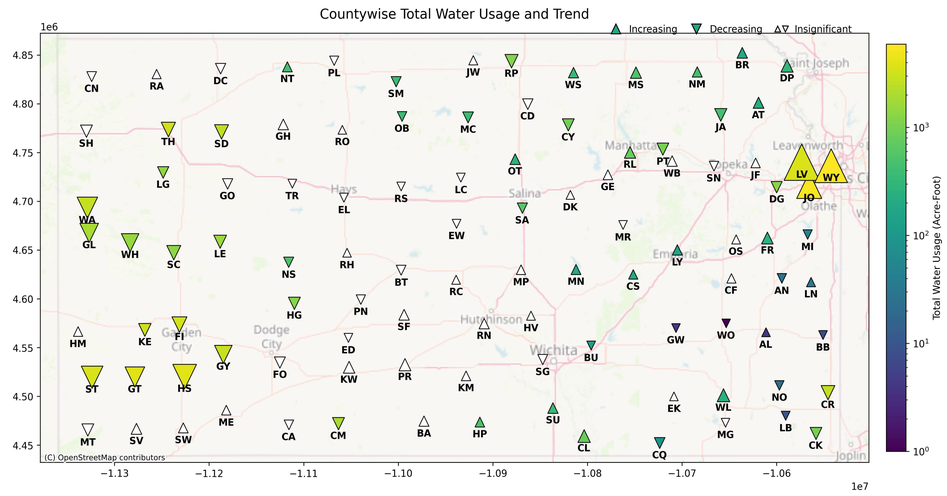
Sen's slope and Mann-Kandall test for trend analysis

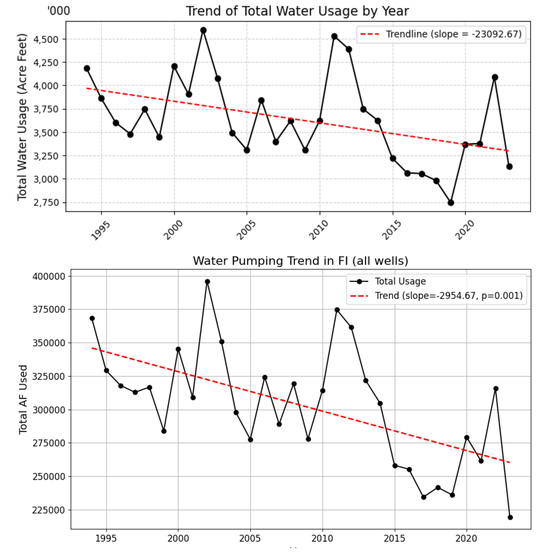
The Difference-in-Differences (DiD) model estimates the causal effect of LEMA implementation on irrigation intensity by comparing treatment (LEMA) and control (non-LEMA) areas before and after policy adoption.

$$Y_{it} = \alpha + \beta_1 \text{Treatment}_i + \beta_2 \text{Post}_t + \beta_3 (\text{Treatment}_i \times \text{Post}_t) + \beta_4 \text{Precip}_{it} + \beta_5 \text{Temp}_{it} + \varepsilon_{it}$$

4. RESULTS

4.1 Spatio-temporal trend of groundwater pumping

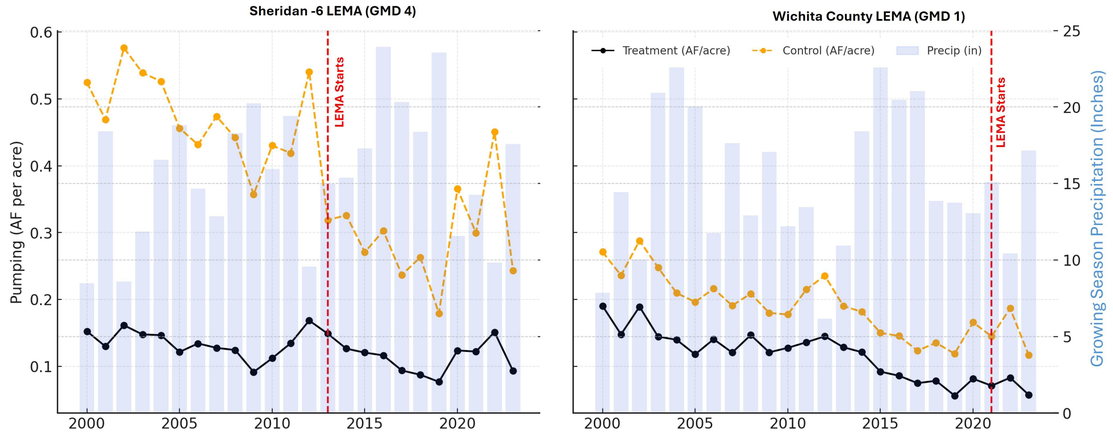




The figure illustrate long-term groundwater pumping trends across Kansas from 1994 to 2023 based on the data from KGS. The statewide county-level map highlights spatial variations, showing that most western Kansas counties experience decreasing water use while the eastern and northern counties display increasing or insignificant trend. Overall, the results indicate a reduction in groundwater pumping in major agricultural regions.

4.2 LEMA impacts on irrigation water pumping

LEMA (GMD / Area)	Counties	Term Start	Term End
Sheridan-6 – First Term	***Sheridan County and small portion of Thomas County***	***Jan 1, 2013***	***Dec 31, 2017***
Sheridan – Second Term	Sheridan County and small portion of Thomas County	Jan 1, 2018	Dec 31, 2022
Sheridan-6 – Third Term	Sheridan County and small portion of Thomas County	Jan 1, 2023	Dec 31, 2027
Greater GMD 4 LEMA (District-wide)	Entire Groundwater Management District No. 4 – Sheridan, Thomas, Sherman, Wallace, Logan, Cheyenne, Rawlins counties	Jan 1, 2018	Dec 31, 2022
Greater GMD 4 LEMA (Renewal)	Same GMD 4 counties	Jan 1, 2023	Dec 31, 2027
Wichita County LEMA (GMD 1)	***Wichita County (western Kansas)***	***Jan 1, 2021***	***Dec 31, 2025***
GMD 1 Four-County LEMA	Greeley, Lane, Scott, and Wallace counties	Jan 1, 2023	Dec 31, 2027



- The Sheridan County LEMA reduced pumping by ~0.09 AF/acre/yr (p = 0.04), confirming measurable water savings attributable to the policyintervention.
- Preliminary results from the Wichita county LEMA show a downward pumping trend (−0.05 AF/acre/yr) but the short record limits statisticalsignificance.
- Weather variability (particularly growing-season precipitation) remains the strongest short-term control on irrigation demand.

5. PRILIMINARY INSIGHTS

There is general decline in groundwater pumping overall. LEMA is effective in reducing groundwater pumping rate, however, we need more data and time to analyze the impacts in a full scale.

Acknowledgements

Kansas Geological Survey (KGS) for groundwater pumping records
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References

McGuire (2017), Water-level and recoverable water in storage changes, High Plains aquifer, predevelopment to 2015 and 2013–15. US Geological Survey Scientific Investigations Report 2017-5040, https://doi.org/10.3133/sir20175040

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