Economic implications of Equus Beds Chloride Plume

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1. Background

This report serves as a preliminary investigation into the effects of the chloride plume on agricultural production in Groundwater Management District 2 (GMD2) near Burrton, Kansas. To determine the extent of the area affected by the chloride plume, I rely on data produced as part of a 2024 report by the Burns & McDonnell Engineering Company for the Kansas Department of Health and Environment (Burns & McDonnell Engineering Company, Inc., 2024). More specifically, I combine the lower, middle, and upper areas of the plume modeled in the referenced report to create a single affected area. I then use the latitude and longitude values for points of diversion (ie. wells) from the Water Information Management and Analysis System (Wilson et al., 2005). The affected points of diversion are plotted in figure 1 by the Use Made of Water (UMW) code. In this report, I focus on the 153 points of diversion within the plume that are used for irrigation.

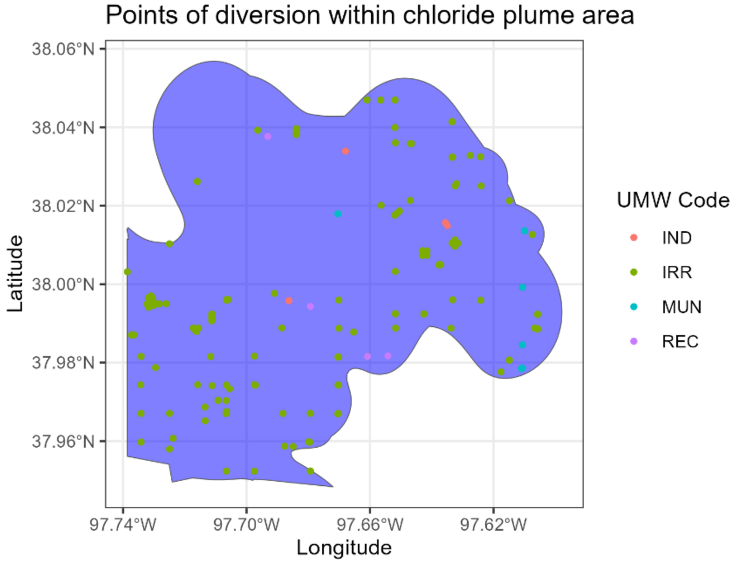

Figure 1: Location of points of diversion within the area of GMD2 affected by the chloride plume. Points of diversion are labelled according to the Use of Water code listed in the WIMAS database.

Chloride is a naturally occurring ion that serves as the plant available form of chlorine, one of 16 essential micronutrients for plant growth. In addition to its functions in photosynthesis and as an osmotic regulator, there is also evidence that chloride helps suppress a variety of wheat pathogens present in Kansas (Ruiz Diaz, 2019). However, at higher concentrations, excessive chloride salts exacerbate water stress and reduce nutrient availability by inhibiting plant's ability to regulate osmotic pressure (Munns, 2002). The chloride concentrations recorded in groundwater samples from the Equus Beds Plume (200-1,300 mg/L) are orders of magnitude greater than the recommended level for crop production (4-6 mg/L) and often exceed known thresholds at which the growth of major cereal crops is adversely affected. For example, the threshold electrical conductivity (EC) value at which corn begins to experience negative yield effects is 1.7 dS/m, around 600 mg/L for chloride (Wallender et al., 2012).

If the Equus Beds Plume is significantly impacting crop production, there are two main adaptation strategies producers are likely using to mitigate the detrimental effects of salt stress. First, producers can adjust crop rotations, cultivating salt-sensitive crops like corn less frequently and instead planting more salt-tolerant crops such as wheat or sorghum (Alkharabsheh et al., 2021). For example, a study on the long-term effects of salinity on crop production found no evidence of yield impacts for a corn-wheat system routinely irrigated from a water source with salinity comparable to the highest values found in the Equus Beds Plume (Wang et al., 2023). Second, producers may reduce the total quantity of water applied per acre to limit salt accumulation or cease irrigation during critical growth stages when high salinity levels are especially detrimental (Minhas et al., 2020; Munns, 2002).

2. Trends in irrigation behavior over time

The ideal method for providing causal estimates of the chloride plume's impact on irrigated agriculture in GMD2 would be a difference-in-differences approach. Such an approach would compare the change irrigators' behavior before and after the plume migrated into their wells' area of influence with similar irrigators' behavior during the same time frame. However, this approach would require data on the movement of the plume over time, and the data available at present only depicts the spatial extent of the plume circa 2023. In the absence of such data, I instead present data comparing water use over time for irrigators with wells inside the affected area to the remaining irrigators in GMD2 over time using data drawn from the Water Information Management and Analysis System

(Wilson et al., 2005). The data displayed in the following figures are aggregated to the water right group level at which authorized quantities and acreage are recorded.

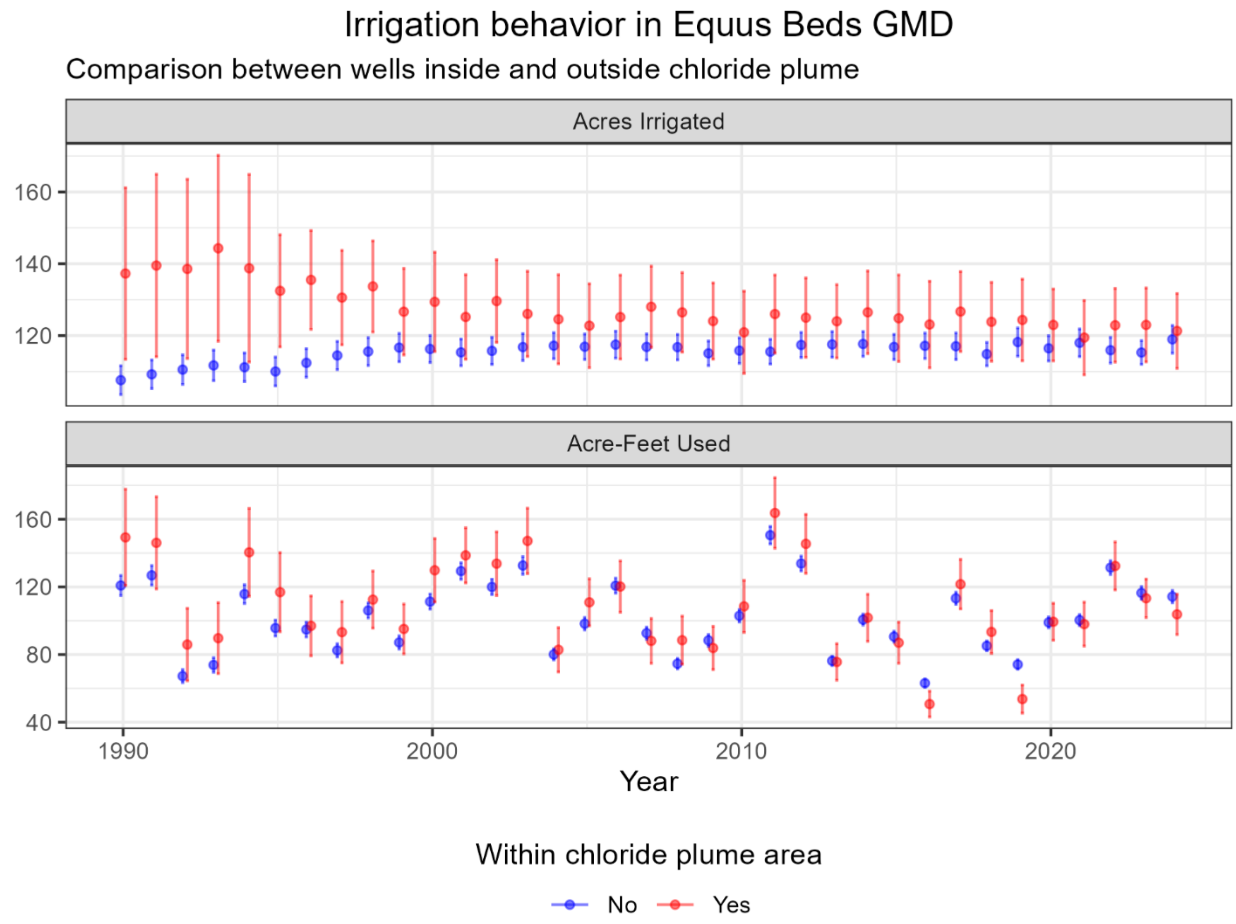

Figure 2: Change in the mean irrigated acreage and groundwater withdrawals for irrigators inside and outside the area affected by the chloride plume over time. The bars on either side of each point encompass the 95% confidence interval for the mean.

In figure 2, I display the mean irrigated acreage and groundwater withdrawals for wells inside and outside the area affected by the plume from 1991 to 2024. The mean acreage for wells within the plume shows some evidence of a decrease over time in the top graph of figure 2. In contrast, mean acreage for wells outside the plume is more stable around 120 acres which is typical for quarter sections irrigated with a center-pivot system. This decrease could be the result of changes in irrigation systems. For a rectangular quarter section field, conversion from flood or furrow irrigation to a center-pivot system will invariably decrease the number of acres that can be irrigated. This is an area where additional investigating is warranted if time varying geospatial data on the extent of the plume becomes available.

In the bottom graph of figure 2, withdrawals vary similarly over time for those inside and outside of the plume as I would expect due to annual variation in precipitation. It appears that differences in mean withdrawals between the two groups may also be weather driven because the greatest differences occur in years with relatively high or low withdrawals. For example, mean acre-feet used is around 20 acre-feet lower for irrigators with wells in the plume affected area in 2019, a year when there was above average precipitation. Differences in average withdrawals could also be the result of changes in irrigation systems over time. Increasing adoption of more efficient irrigation systems could explain why withdrawals tend to be greater for wells inside the plume earlier in the time series (Cameron-Harp & Hendricks, 2025).

To investigate whether differences in irrigation systems are contributing to the differences in irrigated acreage and acre-feet applied in figure 3, I separate the wells in GMD2 by irrigation system and display the irrigation intensity over time in figure 3. The depth-applied values in figure 3 represent the groundwater applied per acre and provide further evidence that groundwater use for irrigation, both inside and outside the affected area in GMD2, is predominantly dictated by annual precipitation. While there are individual years when irrigation intensity differs between the two groups, the trends over time are largely consistent.

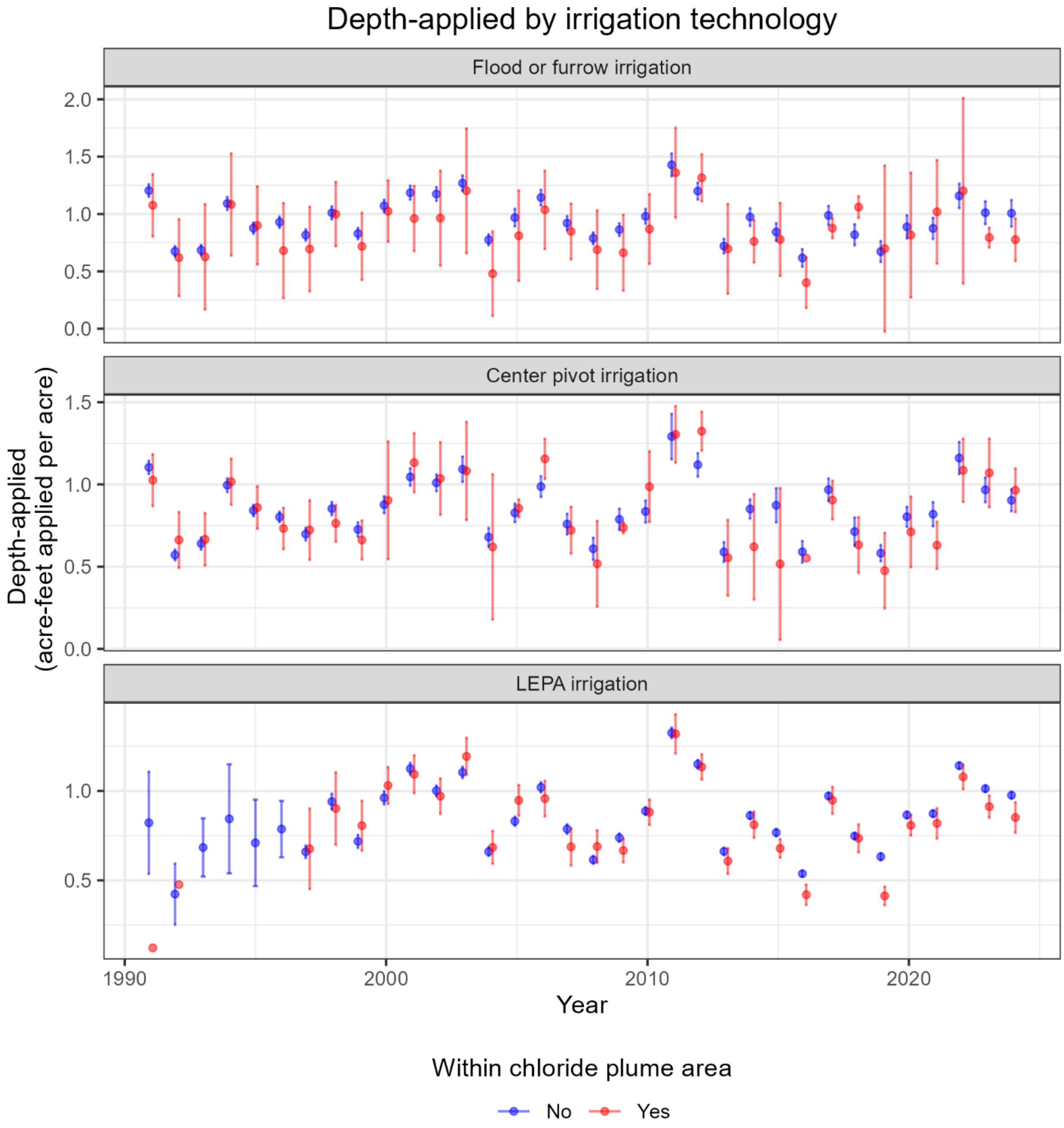

Figure 3: Average depth-applied—acre-feet used per acre—over time by irrigation system for irrigators inside and outside the area affected by the chloride plume in GMD2.

Given the differences in salt tolerance between crops, I also examine how crop choice varies over time between the affected area and the rest of GMD2. In figure 4, I plot the percent of each group's annual total irrigated acres planted to corn, sorghum, soy, and wheat over time for irrigators within the affected area and all other irrigators in GMD2. The main differences between the two graphs in figure 4 are the gradual increase in corn planting and the intermittent wheat planting for the area affected by the plume.

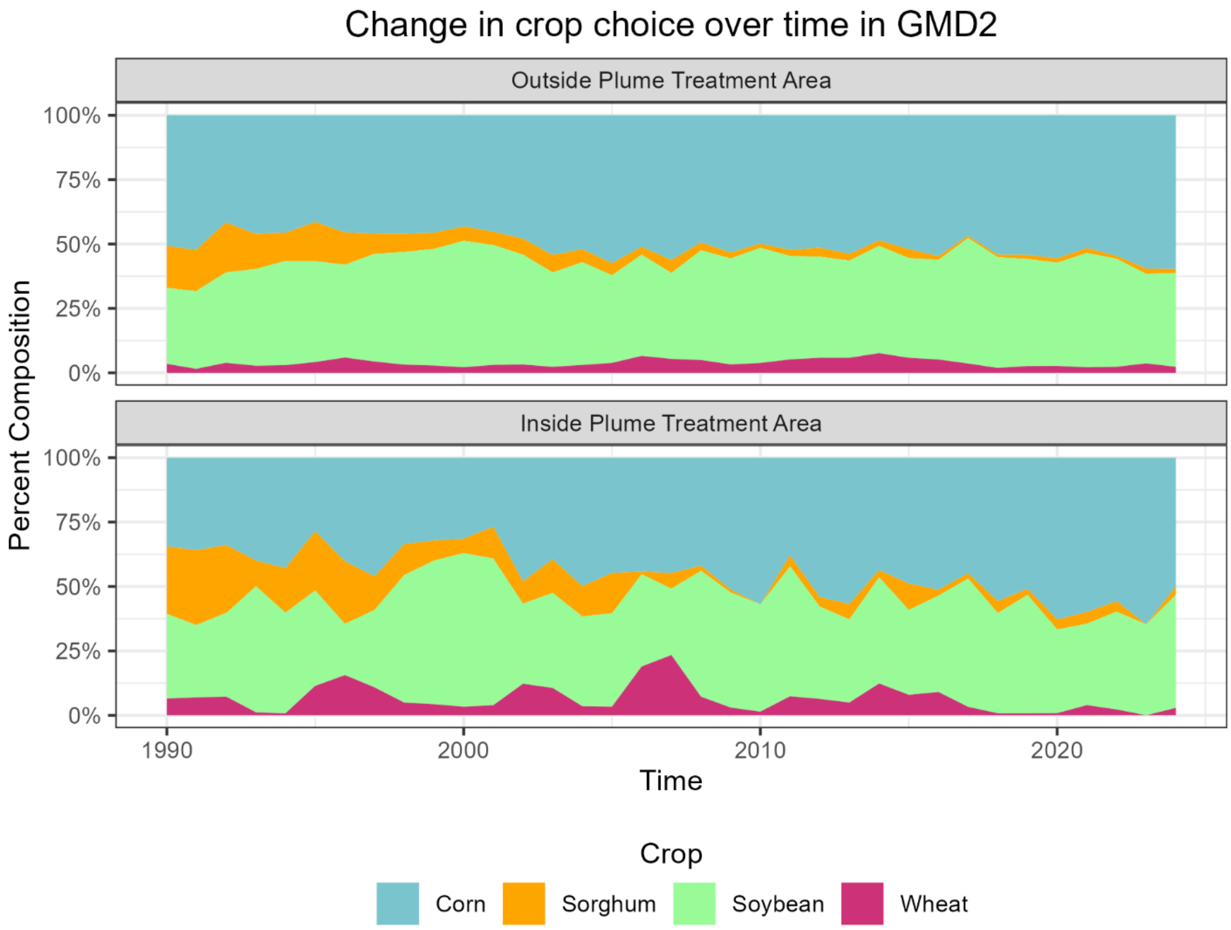

Figure 4: Change in crop choice over time by whether wells are inside or outside of plume affected area.

3. Summary and recommendations

My principal recommendation is to devote resources toward understanding the movement of the chloride plume over time so that a rigorous approach to generating causal estimates is possible. If the plume caused producers to alter cropping decisions or irrigation intensity, the economic ramifications for wells in areas where the plume is migrating could be significant. Consider the following illustration created using data on current production costs compiled by the Department of Agricultural Economics at Kansas State University (Ibendahl et al, 2025). For this example, we will consider a hypothetical producer in GMD2 growing 120 acres of irrigated corn under a center-pivot and the well feeding the center-pivot has recently been affected by the chloride plume. The producer decides to mitigate the risk of applying saline groundwater by reducing irrigation from 14.5 to 12.5 acres-inches of water applied. Using current estimates of production costs and a price of $4.42 per bushel of corn, we would expect a decrease in returns over total costs (income – direct and fixed expenses) from around $32/acre to -$60/acre. The 2-inch reduction in depth-applied, or acre-feet applied per acre, could decrease expected earnings for the entire 120-acre field from a $3,840 profit to a $7,200 loss.

4. References

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