Irrigation and Groundwater Depletion in the Ogallala Aquifer

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Introduction:

The Ogallala Aquifer is located in the Central High Plains region of the United States, a region with a semi-arid climate. It underlies eight states: South Dakota, Wyoming, Nebraska, Colorado, Kansas, Oklahoma, New Mexico and Texas. It is one of the world's largest aquifers, and home to much of the United States' farmland and livestock. It is also vulnerable to groundwater depletion. Consisting mainly of fossil water and therefore being slow to recharge, it can be considered a non-renewable resource. Some studies have found that depletion of groundwater will lead to changes in area of irrigated farmland (Harrington, et al., 2008; Qi, et al. 2002).

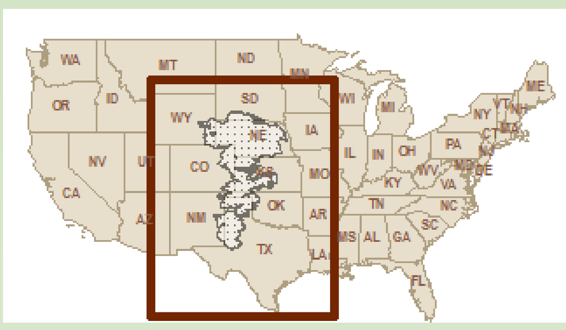

Fig. 1: Location of the Ogallala Aquifer

However, are the areas of highest irrigation also the ones where the water table drops are the most significant? Or do areas of high irrigation tend to be in places where groundwater levels are still relatively stable? **For this project, I examined if irrigation demand, as expressed by percentage of county devoted to irrigated farmland, is correlated with the areas of greater groundwater elevation changes.**

Data:

Data from the USGS (Qi et al., 2002)and Ozdogan and Gutman(2008) were used to calculate the percentage of each county that was irrigated in the states where the aquifer was located. The data from the USGS (Qi et al., 2002) represent the percentage of each county irrigated, calculated from a resolution of 1 km by 1 km in 1987. The data from Ozdogan and Gutman (2008) were originally a raster set of percentage of land irrigated calculated at a resolution of 500 m by 500m in 2001. Because of the differences in data collection between the two sources, as well as the scope of the area of concern, only counties that were directly over the aquifer were used in further calculations. Furthermore, data from Wyoming was excluded from further analysis on the basis it became apparent that mountainous areas were likely misidentified as irrigated farmland, particularly in the 1987 data.

Average groundwater depletion data per county is from the USGS study McGuire et al., 2012 . The data represent average water table elevation change per county. The periods of analysis used in this project are from 1980 to 1995, 1995 to 2000 and 2000 to 2001.

Methods:

The 2001 raster data was converted to a binary data set, where 10% irrigated land was set as the threshold for a pixel to be counted as "irrigated" . This threshold was determined by inspection in comparison to the aerial photography as reasonable cutoff. Zonal statistics were calculated on a county basis to determine the percentage of each county irrigated in order to make it more comparable to the 1987 data (see Figure 2).

Groundwater depletion data from the USGS report were converted to spatial data and joined with the irrigation data. Groundwater water data from the three previously mentioned time periods were graphed against irrigation data from 1987 and 2001, and a regression analysis was performed. 1987 irrigation data were used with groundwater data from 1980-1995 and 1995-2000, while 2001 data were used with 1995-2000 and 2000-2005 groundwater data. The period of 2000-2005 was repeated with both sets of irrigation data to see if a correlation from the earlier data set is a predictor of future trends.

Analysis:

1980-1995 Groundwater, 1987 Irrigation

Analyzing all counties over the aquifer yielded nearly no correlation between the percentage of the county irrigated and the rate of groundwater depletion (R^2= 0.07). However, the correlation becomes stronger once the state of Nebraska is removed from the analysis

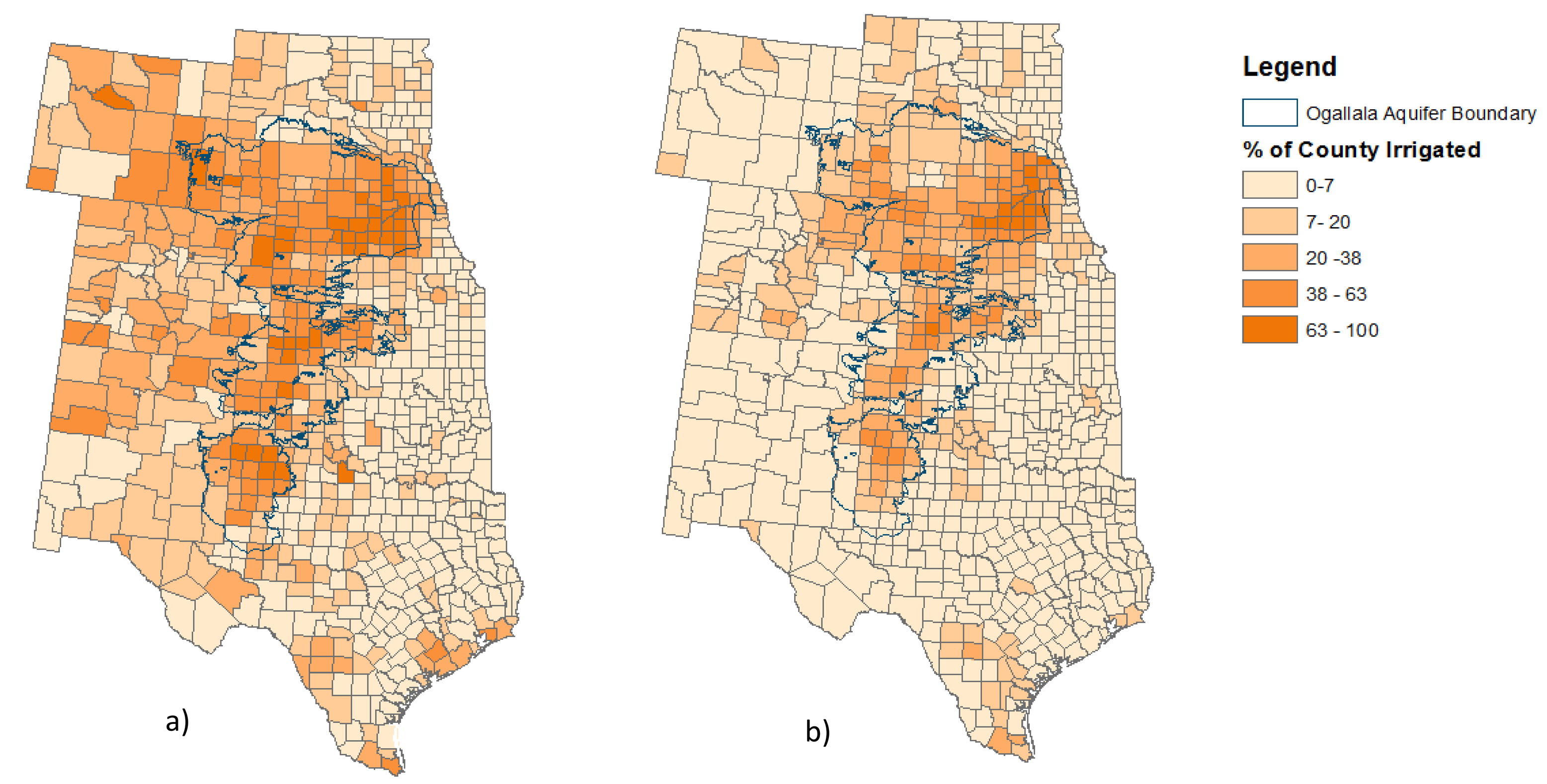

Fig. 2: Percentage of Irrigated land per county for a) 1987 (McGuire, 2012), and b) 2001 (calculated from Ozdogan and Gutman, 2008).

(R^2= 0.49). Nevada is the only state with a slight positive correlation between percentage of land irrigated and positive groundwater change.

1995-2000 Groundwater, 1987 Irrigation

As in the previous case, no correlation was shown between percentage of land irrigated and water depletion until Nebraska's data and its weak positive correlation between irrigation and positive groundwater change. The R^2 values for the region with and without Nebraska's data are R^2 = 0.05, and R^2= 0.419 , respectively.

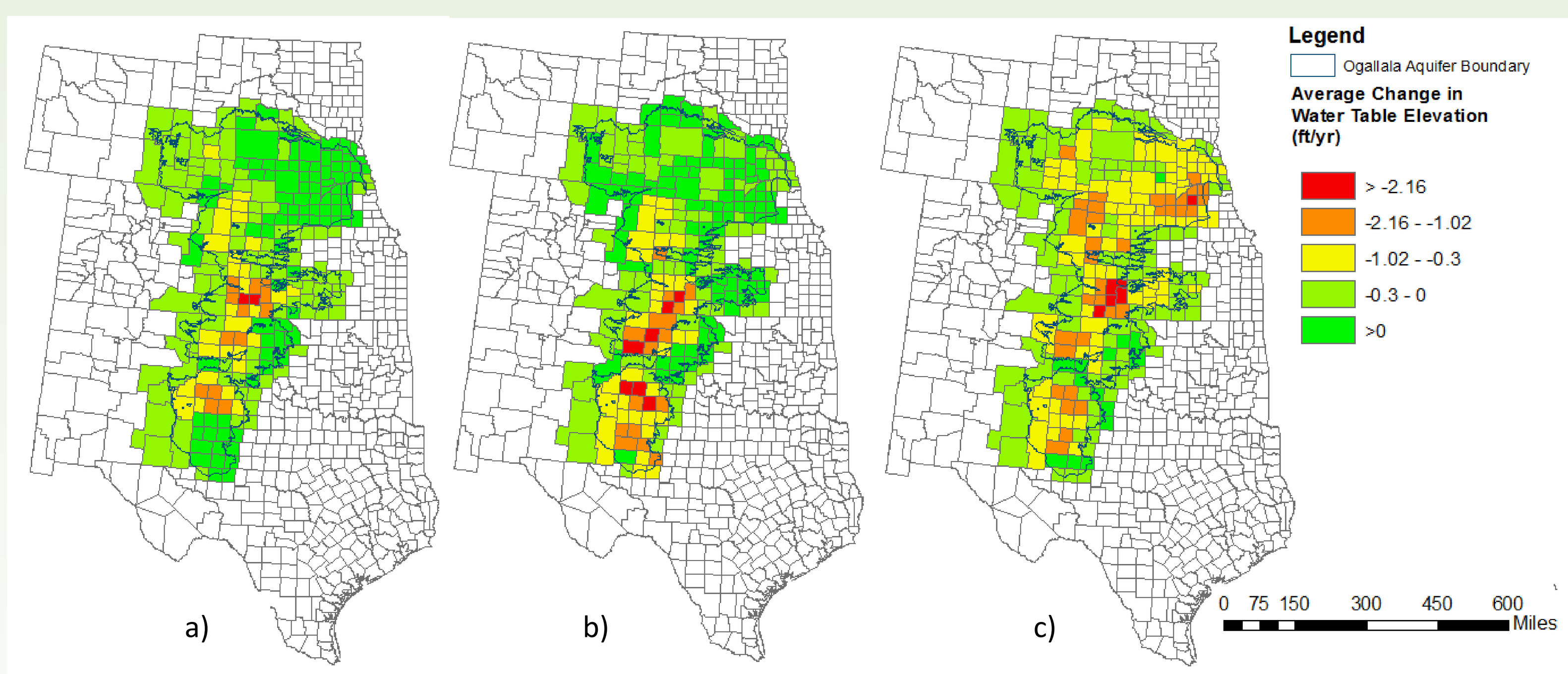

Fig. 3: Average water table elevation changes per county in ft/per year for a) 1980 – 1995, b) 1995 – 2000, and c) 2000—2005. Values calculated from McGuire, et al (2012) data.

1995-2000 Groundwater, 2001 Irrigation

The 2001 data do not confirm a correlation between percentage of irrigated land and groundwater depletion (R^2= 0.00), . Removing Nebraska from the analysis yields a weak correlation (R^2= 0.28) . Again, in Nebraska, there is a weak positive correlation between percent of a county that is irrigated and positive change in groundwater.

2000-2005 Groundwater, 2001 Irrigation

From this data, we do see a correlation between increased irrigation within a county and amount of groundwater depletion (R^2= 0.51). Nebraska in this case also has a similar correlation between irrigation and groundwater depletion. There is more groundwater depletion in this time period, but we see similar trends as in the other two cases.

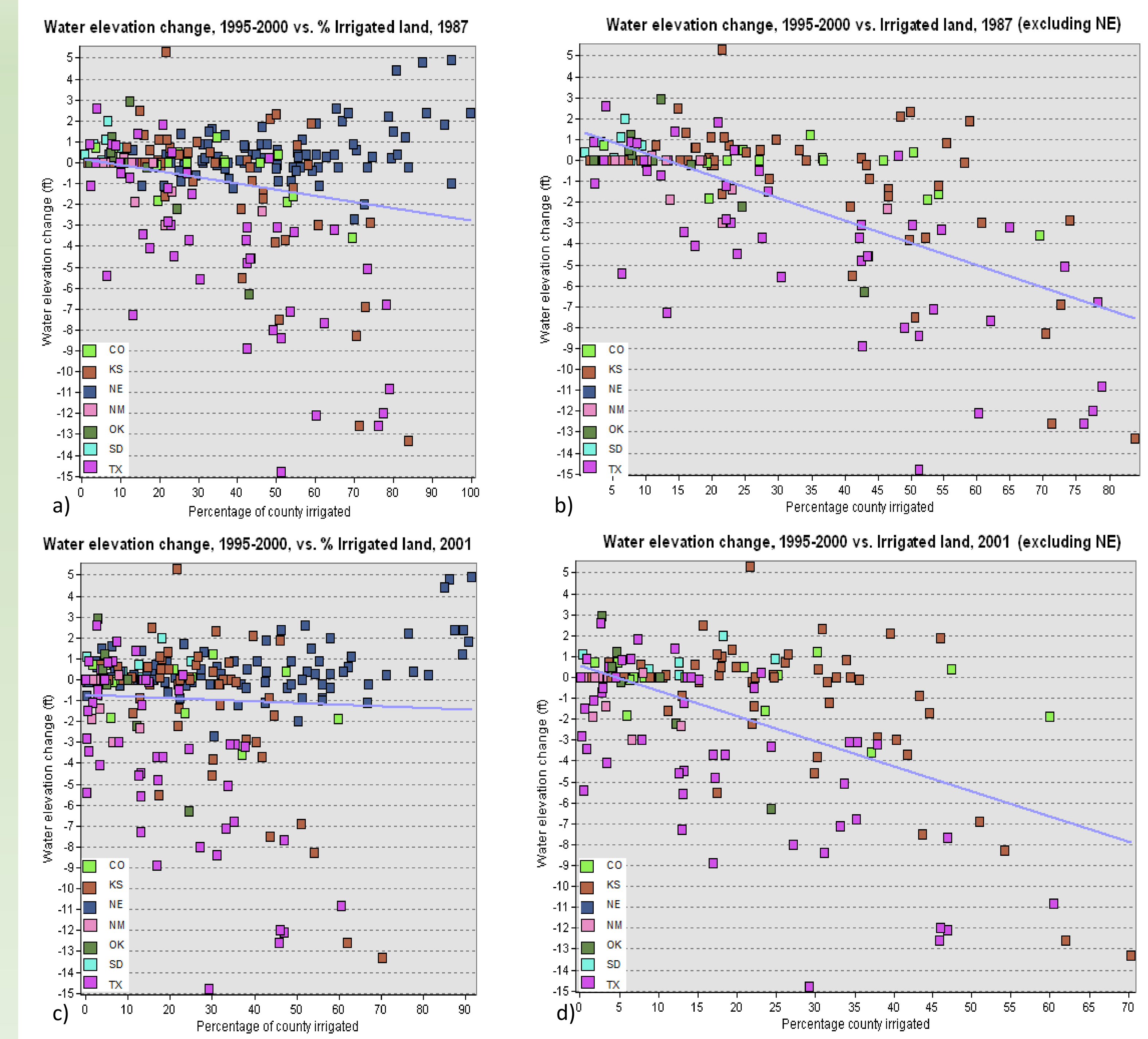

Fig. 4: Example analysis of a) 2000-2005 groundwater change vs. 1987 irrigation data, b) the previous case, excluding Nevada, c) 2000-2005 groundwater change vs. 2001 irrigation data, and d) previous case, excluding Nevada.

Conclusions:

There is some preliminary evidence that there is a small local correlation between irrigated farmland and groundwater depletion for most areas in the Ogallala Aquifer, although there is considerable spread to the data indicating other factors are at play. Nebraska's trends are noticeably different from other states, particularly for the 1995-2000 groundwater data. This perhaps can be partially attributed to the slope of the aquifer to the east, or other factors unique to Nebraska such as possible differences in precipitation or surface water sources , or different farm or water management practices. Further study is needed to determine which factors are relevant.

References and Data Sources:

Harrington, Lisa et al. 2008. Groundwater depletion and agricultural land use change in high plains: a case study from Wichita County, Kansas. *The Professional Geographer* 59(2): 221-235.

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Ozdogan, Mutulu and G. Gutman. 2008. A new methodology to map irrigated areas using multi-temporal MODIS and ancillary data: An application example in the continental US. *Remote Sensing of the Environment* 112: 3520-3537. Suporting data: Irrigated Lands from Remote Sensing: Continental US, circa 2001. http://www.sage.wisc.edu/mapsdatamodels.html

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