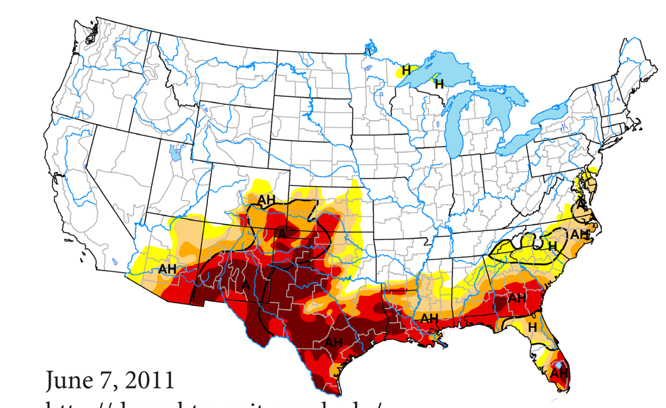
Preparing for Drought?

Crop Area Change in the Ogallala Aquifer, 2001-2011



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http://droughtmonitor.unl.edu/

Introduction

In the 1930's, the Dust Bowl hit areas of Colorado, Kansas, Texas, Oklahoma, and New Mexico, resulting in significant agricultural (and economic) losses. The causes of the Dust Bowl have been a subject of academic interest, and some researchers have argued that direct and indirect human actions made the impacts of the Dust Bowl much more severe than a similarly sized drought would have otherwise been. Specifically, Cook et al. found that farmers abandoning previously irrigated crop land contributed to the severity of the Dust Bowl.

The area previously hit by the Dust Bowl once again has significant amounts of agricultural activity going on. Cropland requires water, however, and the area is not known for receiving large amounts of precipitation. This has resulted in a reliance on irrigation, either from surface- or ground-water. According to the USDA, in the half-century since the Dust Bowl, the water levels of the Ogallala Aquifer (which underlies much of the area once hit by the Dust Bowl) have dropped from 240ft to 80ft. If another severe drought hits the area, how will the area be impacted this time? How are communities reacting to the increased likelihood of drought due to climate change? *What factors influence the amount of crop acreage in the area today?*

Methods

This analysis was done through a mixture of ArcGIS Pro and RStudio. The shapefile of the Ogallala Aquifer and water use data were retrieved from USGS. County outlines were retrieved from the US Census. Land use data for 2001 and 2011 was retrieved from NLCD, and climate data was taken from NOAA.

Land use values were reassigned in ArcGIS Pro with cropland receiving a value of 1, and all other land uses receiving a value of 0. I calculated the percent of each county that was covered in cropland in 2001 and in 2011 using zonal statistics, and then subtracted the 2011 raster from the 2001 raster to determine the increase or decrease in crop acreage in each county. *Map 1* shows the results from this calculation. I exported the results from this calculation into RStudio to develop a model of what variables are connected to land use.

Connected county-level water use data for 2000 and 2010 and region-level climate data to the crop data. Developed a model using the linear regression function in RStudio. The regression model went through multiple iterations and was built in a stepwise fashion. The results of the final model can be found in *Table 1*.

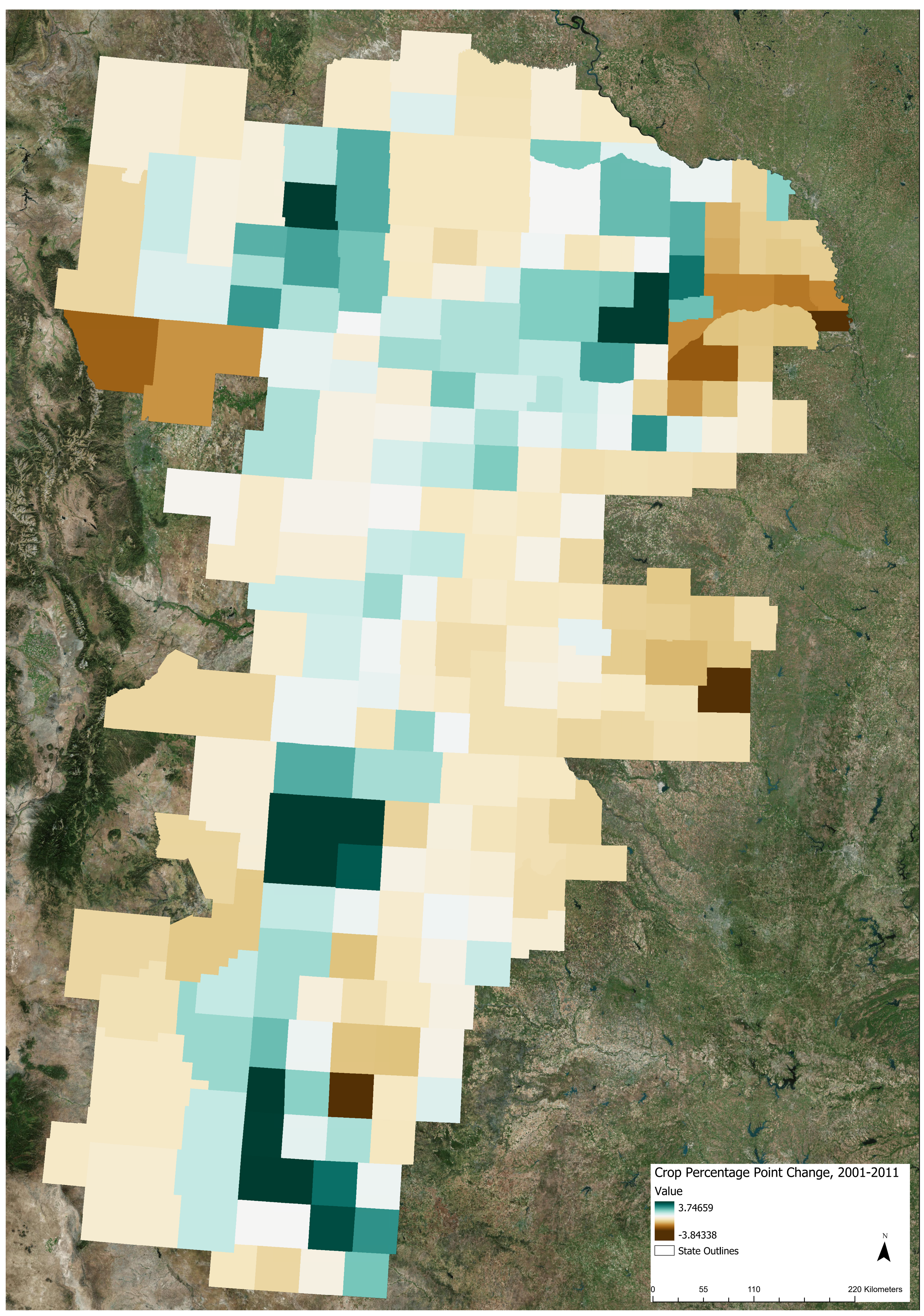
Limitations

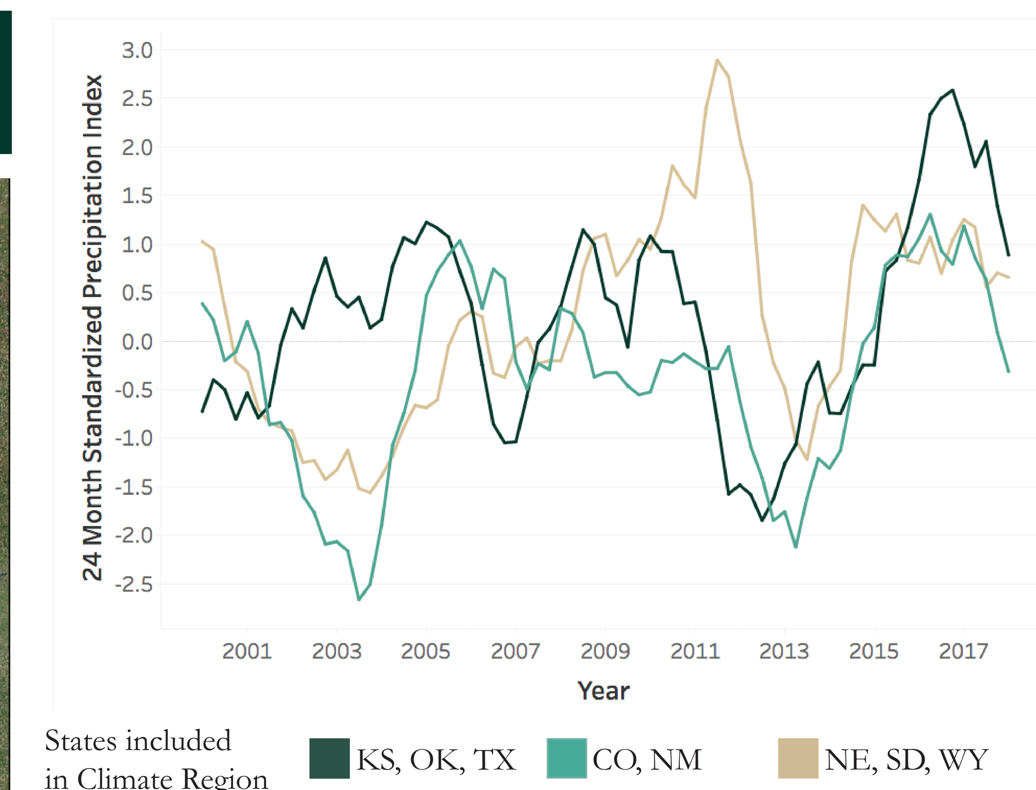
This model does not include an assortment of variables that one would expect to be correlated to crop acreage because they were found to not be significant. This may be due to the different years that data was collected in, the differences in spatial scale, or to some other reason.

For example, despite climate likely influencing the amount of crop acreage, it was not found to be significant. This may be because the Ogallala Aquifer spans multiple climatic regions resulting in heterogeneity within the variable, making it hard to clearly correlate land use with climate. While this climate data was included in an early version of the regression, none of the variables used (i.e., precipitation and four versions of the Palmer drought index) were found to be significant. Therefore no climate variables were included in the final results.

(At right) Map 1: Map of counties overlapping the Ogallala Aquifer and the change in percent of county area covered by crops between 2001 and 2011. Green shows an increase in the amount of cropland in a county, and brown shows a decrease. Created in ArcGIS Pro using data from the US Census, USGS, NLCD and an ArcGIS base map.

Map of Crop Change by County, 2001-2011





(Above) Graph 1: Trend in 24-month Standardized Precipitation Index (SPI) between 2000 and 2018 for the three NOAA climate regions that intersect with the Ogallala Aquifer. It shows long-term precipitation patterns that are likely to affect stream flows, reservoir levels, and possibly groundwater levels. Positive values indicate wet trends, and negative values indicate dry trends. Values between -1.0 and 1.0 are considered normal; values below -2.0 or above 2.0 are considered to be extremes. Visit World Meteorological Organization SPI User Guide for more information.

(Below) Table 1: Table of final linear regression model results. Intercept represents the change in crop acreage. To remove time from the equation, all variables represent the change over the course of a decade. Crop acreage change is between 2001 and 2011, and water use change is between 2000 and 2010.

Variable	Estimate	Standard Error	P-value	Significance
Intercept	0.291	0.0365	6.54E-14	***
Total Population	-0.0357	0.00469	7.39E-13	***
Fresh surface-water withdrawls for irrigation	0.00283	0.00116	0.0151	*
Fresh ground-water withdrawls for irrigation	-0.000535	0.000813	0.511	
Interaction between fresh surface- and ground-water withdrawls for irrigation	0.0000522	0.0000143	0.000321	***

Significance Codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.001 ' ' 0.001

(Below) Map 2: Context map for Ogallala Aquifer. Outline of Aquifer overlaying map of United States with states labeled. Aquifer intersects Nebraska, Kansas, Texas, Oklahoma, New Mexico, Colorado, Wyoming, and South Dakota. Created in ArcGIS Pro using data from the US Census and USGS and an ArcGIS base map.

Conclusion & Recommendations

The results suggest that further increases in cropland may not impact the levels of the Ogallala Aquifer as much as might be expected. However, the general trend of increasing the amount of crop acreage in the area is somewhat concerning considering that climate change and global warming will likely increase the severity of future droughts.

The results of this study suggest that more research needs to be done. The lack of a strong relationship between water use, land use, and climate found in this study suggests that there are other factors at play that influence decisions about whether or not to use land for agriculture. One missing factor may be the influence of federal policies on decisions about agricultural land use. One question raised by this research is the impact of different agricultural policies on land use change. Another next step could be to conduct a sensitivity analysis, which would identify the optimal model based on the data included in this model.

Results

The independent variable most strongly correlated with crop acreage was the total population of a county, which had a correlation value of -0.424. A linear regression model including only total population as a predictor variable resulted in a model with an adjusted R-squared value of 0.147 and a p-value of 6.35e-10. When variables for fresh surface- and ground-water withdrawals (in million gallons/day) for irrigation purposes and a variable for the interaction between those two variables were included, the adjusted R-squared value increased to 0.192 and the p-value increased to 6.78e-11. Clearly population is a major predictor of—and has an inverse relationship with—crop area. The data suggests that as a county increases their cropland area, they begin to depend more on surface water for irrigation, rather than on ground water.

Charlotte Leis, Fall 2018
ENVS 170: Environmental Data Visualization

Map projection: Albers 1983
Data Sources: US Census, NOAA, USGS, NLCD