Detailed Project Plan

Title: Development of a GIS Model to Project and Map Future Water Availability

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Summary / Abstract

The purpose of this research is improve our understanding of the hydrologic and climatic factors that will affect future water availability, cropping and the profitability of farm operations on the southern High Plains in Texas. As the Ogallala Aquifer is drawn down over the next 50 years, there will be a significant decline in the acreage dedicated to large-volume irrigation and farm operations will transition to less water-intensive forms of crop production.

To better understand how this agricultural transition will play out in across the landscape over time, the main goal of this research is to develop a GIS-based model that can be used to map the projected useable lifetime of the aquifer based on current rates of water use. To estimate the time-to-depletion, the current saturated thickness (2013) will be divided by the rate of water level decline averaged over the last 10 years, from 2004-2013. Assuming these recent rates of water use continue into the future, the results from the baseline analysis will be used to map the areas where the saturated thickness of the Ogallala Aquifer is at below 30 feet in 2013, 2020, 2030, 2040 and 2050.

Once the baseline analysis is complete, the model can be run as a decision support tool to map and quantify water availability under any number of future scenarios – and for any defined geographic area. To demonstrate the utility of the model as a planning and analysis tool, the second goal of this research is to run the analysis assuming two different future scenarios. In the first scenario we will assume that future conservation efforts produce a 5, 10, 15 and 20 percent reduction in future rates of water use. In the second scenario we will assume that a drier climate with more frequent drought produces a 5, 10, 15 and 20 percent increase in future rates of water use. The results from both of these analyses will be presented as a series of maps, graphs and tables to illustrate the projected spatial and temporal changes in water availability. Once complete, the model should greatly improve our understanding of the hydrologic and climatic factors that affect water availability – and these future projections can serve as a basis for any economic analysis concerned with agricultural systems and the future profitability of farm operations.

Project Narrative

a) Objectives

The purpose of this research is to improve our understanding of the hydrologic and climatic factors that affect water use on the southern High Plains in Texas. The main objective of the research is to develop a GIS-based model to that can be used to project and map future water availability under different water conservation and/or climate change scenarios.

b) Rationale

As the Ogallala Aquifer is drawn down over the next 50 years, there will be a significant decline in the acreage dedicated to large-volume irrigation. As the groundwater resource is drawn down, farmers will be compelled to transition to some form of less water-intensive agriculture. Given this reality, access to reliable and current hydrologic data is central to making informed research and policy decisions concerning the future of crop production on the southern High Plains over the next 50 years.

In previous research supported by the OAP, we analyzed well data from the TWDB observation network to develop the GIS data layers necessary to quantify the spatial variability in the hydrologic characteristics of the aquifer and changes over time (Mulligan and Barbato, 2009). These layers include the base of aquifer, water table elevations, saturated thickness and annual rates of change for the period from 1990 through 2008.

With OAP funding last year, 1) we extended the 1990-2008 analysis to include the last five years of TWDB well data, 2) we refined the analysis procedures to include an assessment of the uncertainty in interpolated water table elevation surfaces, 3) we developed new water table, saturate thickness and saturate thickness change surfaces for each year in the entire 1990-2013 record and 4) we developed annual summary statistics by county for the Ogallala region in Texas.

While this previous research is paramount to understanding historical water use, changes in the hydrologic characteristics of the aquifer over the past 25 years, and current water availability – it also provides a spatial and temporal framework for projecting future changes in the aquifer. In this proposed research, the main goal is to develop a GIS-based model (that leverages the previous work) to project the future of the aquifer under different conservation and climate change scenarios.

c) Methods and Procedures

To quantify and map the future of the aquifer in Texas, the proposed research includes four specific tasks.

1) Analysis of the Texas Drought and Future Climate Change
With new water table elevation surfaces for each year from 1990-2013, the first task is to analyze the effects of the recent Texas drought (2011-2013) on rates of water use. Rates of saturated thickness decline (water use) measured for 2011, 2012, 2013 and the 2011-2013 average will be compared to the 10-year average (2004-2013) and 10-year prior record (2001-2010) to determine the impact of the drought and how it varies spatially across the landscape. In areas with sufficient available water, we expect to see a significant increase in rates of water use during the drought. In

areas with limited available water, we expect to see little change in the rates of water use. Overall, the main goal of this analysis is to use the Texas drought as a proxy for understanding the effects of climate change (severe drought) on water use.

2) Analysis of the Projected Useable Lifetime of the Aquifer
The second task in this research is to analyze the projected usable lifetime of the aquifer based on the ten year period of record, from 2004-2013. In our previous analysis of the usable lifetime of the aquifer, the maps of "time-to-depletion" were based on an analysis of well data from 1994-2004. With a decade of new observation well data (2004-2013), the new analysis will be based on a projection that incorporates more recent trends in land use, crop selection and water use. The main goal here is to produce a more accurate and updated series of maps showing the areas where the saturated thickness is 30 feet or less in 2013, and those areas that are projected to be 30 feet or less in 2020, 2030, 2040 and 2050.

3) Analysis of Future Water Availability
To demonstrate the utility of the model as a planning and analysis tool, the third task in this research is to run the time-to-depletion analysis assuming two different future scenarios. In the first scenario we will assume that future conservation efforts produce a 5, 10, 15 and 20 percent reduction in future rates of water use. In the second scenario we will assume that a drier climate with more frequent drought produces a 5, 10, 15 and 20 percent increase in future rates of water use. The results from both of these analyses will be presented as a series of maps, graphs and tables to illustrate the projected spatial and temporal changes in water availability. Once complete, the model should greatly improve our understanding of the hydrologic and climatic factors that affect water availability – and these future projections can serve as a basis for any economic analysis concerned with cropping systems and the future profitability of farm operations.

4) Update and Re-Design Ogallala Aquifer Web Site
The last task is in this study is to develop a more efficient and user-friendly web site to disseminate aquifer data and maps. In our previous research we developed the Ogallala Aquifer interactive map using the Esri Flex viewer (Mulligan, *et al.*, 2011). With advances in mapping technology, we will develop the new interactive map using the Esri JavaScript application user interface. Using this approach, the interactive maps on the new Ogallala Aquifer web site will operate and perform in a manner similar to the maps of the Playa Wetlands web site (http:gis.ttu.edu/pwd). Moreover, this change will accommodate the future integration of the playa and aquifer data into a seamless interface.

Schedule

The proposed research is expected to be completed in one year. The project will extend from September 2015 to August 2016, covering fiscal year 2016.

Task	Q1	Q2	Q3	Q4
1. Analysis of the Texas drought	■			
2. Analysis of projected useable lifetime	■	■		
3. Analysis of future water availability		■	■	
4. Update and redesign Ogallala web site			■	■

d) Expected Outcomes

The results of this research on the hydrologic and climatic factors affecting past, present and future water availability are of interest to the general public, scientists, and decision makers. In particular, we expect the future projections of water availability under different scenarios of conservation and climate change to be particularly useful in any analysis of cropping systems and the future profitability of farm operations. In this regard, the research team has sought the input of collaborators whose research includes drought tolerant plant genetics (J. Mahan), climate change (S. Mauget), agricultural economics (P. Johnson) and the development of new cropping strategies (C. West).

Relevant Publications

The PIs have a proven record of delivering GIS products to the research community and extensive experience making the maps available through hosted websites and dynamic web mapping applications.

Cao, G., Wang, S., Hwang, M., Padmanabhan, A., Zhang, Z., and Soltani, K. 2015. "A Scalable Framework for Spatiotemporal Analysis of Location-based Social Media Data". *Computers, Environment and Urban Systems*, 51: 70-82, DOI:10.1016/j.compenvurbsys.2015.01.002

Cao, G., Yoo, E.H., Wang, S. (2014): A Statistical Framework of Data Fusion for Spatial Prediction of Categorical Variables. Stochastic Environmental Research and Risk Assessment, 28: 1785-1799.

Cao, G., Kyriakidis, P.C. and Goodchild, M.F. (2011): A multinomial logistic mixed model for prediction of categorical spatial data, International Journal of Geographical Information Science, 25(12), pp.2071-2086.

Cao, G., Kyriakidis, P.C. and Goodchild, M.F. (2011): Combining spatial transition probabilities for stochastic simulation of categorical fields, International Journal of Geographical Information Science, 25(11), pp.1773-1791.

Mulligan, K., Barbato, L., Seshadri, S. (2014) Geography of the Ogallala Aquifer in Texas. http://www.gis.ttu.edu/center/Ogallala/Storymap/Index.html

Mulligan, K., Barbato, L., Seshadri, S. (2014) Ogallala Aquifer PDF Maps. http://www.gis.ttu.edu/center/Ogallala/OgallalaPDFMaps.html

Mulligan, K., Barbato, L., Seshadri, S. (2011) Ogallala Aquifer Interactive Map Viewer. http://mapserver.gis.ttu.edu/OgallalaOAP

Mulligan, K., Barbato, L. (2009, revised 2014) Ogallala Aquifer County Data, 1990 to 2008. http://www.gis.ttu.edu/center/Ogallala/OgallalaData.html

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Mulligan, K., Barbato, L. (2009) Ogallala Aquifer County Data, 1990 to 2008. http://www.gis.ttu.edu/center/Ogallala/OgallalaData.html

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