Detailed Project Plan

Title: Development of current hydrologic data and analysis of water availability in the Ogallala Aquifer over the next 50 years

Investigators

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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 agriculture.

To better understand how this agricultural transition will play out in across the landscape over time, the first 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 show the areas where the saturated thickness of the Ogallala Aquifer is at below 30 feet in 2013, 2020, 2030, 2040 and 2050. These regional maps will then serve as the basis for calculating future water availability by county (again, assuming current rates of water use continue unchanged).

Once the baseline analysis is complete, the model can be run as a decision support tool to map and quantify water availability under any 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 then 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, most 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 agriculture 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, 2008). These layers include the base of aquifer, water table elevations, saturated thickness and annual rates of change for the period from 1990 through 2008. Using these data we mapped the projected useable lifetime of the aquifer and time to depletion based upon the spatial variability in saturated thickness and past trends of water use. In this proposed research, the main goals are to update the previous analysis to include the last 5 years, refine the analysis procedures, and further develop a model that can be used to project future of the aquifer under different conservation and climate change scenarios.

c) Methods and Procedures

To develop the data and analysis procedures necessary to quantify and understand the future of the Ogallala Aquifer in Texas, the proposed research includes seven specific tasks.

1) Update the Ogallala Aquifer Geodatabase
The first task in this research to extract and process the TWDB well data for the Ogallala Aquifer for the period that covers the last five years, from 2009 through 2013. The main objective here is to update the existing geodatabase of observation wells for Texas.

2) Analysis of the Uncertainty in Interpolated Water Table Elevation Surfaces
The second task is to create new and refined annual water table elevation surfaces for the entire 25 year record (1990-2013). In our previous research, we used a spline interpolation to create water table elevation surfaces. While this deterministic method forces the interpolated surface through each well point, there is no way to evaluate the error or uncertainty in interpolated values – which will vary depending upon the density and distribution of wells and the consistency of change over time. In this new research we will use a spatial-temporal interpolation technique that incorporates both the spatial variability in the distribution of points and the spatial variability in temporal trends (Cao, *et al*., 2012). More importantly, the spatial-temporal analysis is a stochastic approach that allows us to evaluate the uncertainty in interpolated water table elevation surface values and allows us to create a confidence

layer. Preliminary testing suggests that most of the water table elevation surfaces created in our previous analysis will be similar to those created during this analysis – except in areas with a sparse distribution of wells and areas with erratic well-depth measurements. The added value of this analysis will be the ability to provide scientists and decision makers with a measure of confidence in the interpolated surface and subsequent water availability and water use calculations.

3) Analysis of Spatial and Temporal Trends in Water Availability and Water Use
With new water table elevation surfaces for each year (1990-2013), the third task is to develop new saturated thickness and annual change rasters for the 25 year period of record. The main goal here is to map the spatial and temporal trends in water availability and water use. To compare these hydrologic characteristics, summary statistics will be generated by county for the Ogallala region in Texas.

4) Analysis of the Texas Drought and Future Climate Change
Once the hydrologic geodatabase is complete, the fourth 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 2011-2013 will be compared to the 10-year average and 10-year prior record 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 on water use.

5) Analysis of the Projected Useable Lifetime of the Aquifer
The fifth 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.

6) Analysis of Future Water Availability
To demonstrate the utility of the model as a planning and analysis tool, the sixth 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 then 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.

7) 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 advancements in mapping technology, we will develop the new interactive map using the Esri JavaScript application user interface. Using this technology, 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 one seamless interface.

Schedule

The proposed research represents a major undertaking that is expected to be completed over a two year period. The project will extend from September 2014 to August 2016, covering fiscal years 2015 and 2016.

	FY 15				FY 16			
Task	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. Extract, evaluate and process TWDB data.	■							
2. Interpolate water table elevation surfaces		■	■					
3. Analysis of trends in water availability/use			■	■				
4. Analysis of the Texas drought				■	■			
5. Analysis of projected useable lifetime					■	■		
6. Analysis of future water availability						■	■	
7. Update and redesign Ogallala web site							■	■

d) Expected Outcomes

The expected outcome of this research will produce measures of water availability (mean saturated thickness) and water use (rates of saturated thickness change) for more than 40 counties for each year over the 25 year period of record (approximately 2,000 maps). These results will also be presented as graphs and tabular data summarized by county. In addition, the interactive web map will allow users to explore the data and trends for any particular location and the GIS data layers will be available for download.

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 the 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 research community and public and making the maps available through hosted websites and dynamic web mapping applications.

Cao, G.,Wang, S., and Guan, Q. (2012) A state-space model for understanding spatial dynamics represented by areal data. *Proceedings of the Seventh International Conference, GIScience 2012*, Columbus, Ohio, September 2012.

Cao, G., Kyriakidis, P.C. and Goodchild, M.F. (2011) A geostatistical framework for categorical spatial data modeling, *The SIGSPATIAL Special*, 2011, 3(3), pp.4-9.

Mulligan, K., Barbato, L., Seshadri, S. (2012) Ogallala Aquifer Map Series 1990 to 2008 (includes Time to Depletion map). http://www.gis.ttu.edu/ OgallalaAquiferMaps/MapSeries.aspx.

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

Mulligan, K., Barbato, L. (2009) Ogallala Aquifer Map Series 1990 to 2004. http://www.gis.ttu.edu/ OgallalaAquiferMaps/ MapSeries.aspx.

Mulligan, K., Barbato, L, (2008) Texas County Map Series of Water Information. http://www.gis.ttu.edu/OgallalaAquiferMaps/TXCounties.aspx.

7) References

Cao, G.,Wang, S., and Guan, Q. (2012) A state-space model for understanding spatial dynamics represented by areal data. *Proceedings of the Seventh International Conference, GIScience 2012*, Columbus, Ohio, September 2012.

Mulligan, K., Barbato, L, (2008) Texas County Map Series of Water Information. http://www.gis.ttu.edu/OgallalaAquiferMaps/TXCounties.aspx.

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