# Research Plan for the Ogallala Aquifer Program - 2015

1. **Title:** Development and evaluation of efficient irrigation management strategies for grain sorghum production in the Texas High Plains under current and future climate scenarios

2. **Investigators**


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3. **Summary/Abstract**


The Texas High Plains is one of the important agricultural regions in the U.S. Water from the Ogallala aquifer in this region has been extracted for irrigation at a much faster rate than it is being replenished, resulting in a rapid depletion of available groundwater. In addition, climate change studies predict warmer and drier summers in this region in the future, requiring larger groundwater withdrawals to meet higher evapotranspiration demands of crops. In view of depleting groundwater resources, the Groundwater Conservation Districts (GCDs) in this region proposed restrictions on annual allowable groundwater pumping rates in order to ensure that certain percentage (varies among GCDs) of the currently available water will still be available after 50 years. The popularity of grain sorghum continues to grow in this region in view of its lesser water requirement, drought tolerance, lower input costs and increasing demand. Studying the effects of soil moisture at planting and the soil moisture threshold for initiating irrigation during the growing season on grain sorghum yields, and assessing the impacts of historic and future weather patterns on grain sorghum production in the Texas High Plains enable development and evaluation of irrigation strategies for efficient use of groundwater resources in this region. The CERES-Sorghum plant growth module within the Decision Support System for Agrotechnology Transfer (DSSAT) Cropping System Model (CSM) will be evaluated for this region using observed data from the long-term field experiments conducted at the Helms Farm near Halfway, TX, and then the evaluated model will be used to suggest efficient irrigation management strategies that are aimed at conserving valuable groundwater resources under the current and future weather patterns.


4. **Project Narrative**

**a. Objectives:**

The proposed study is aimed at addressing sub-objectives 1 and 3 of the 2015 OAP solicitation, and is focused on developing and evaluating climate change adaptation/ mitigation strategies for sustainable grain sorghum production in the Texas High Plains. The specific objectives are to:

i) Evaluate the CSM CERES-Sorghum model for the Texas High Plains region using measured data from long-term grain sorghum experiments at the Helms Farm.
ii) Use the evaluated CSM CERES-Sorghum model to:
   a) Determine optimum soil moisture content at planting and optimum soil moisture threshold for initiating irrigation during the growing season under different weather patterns.
   b) Develop irrigation management strategies to efficiently utilize allowed annual groundwater pumping rates set up by the GCDs under the current and future climate scenarios.
   c) Assess the environmental impacts (warmer and drier vs cooler and wetter growing seasons) on grain sorghum water use and yield, and define irrigation scheduling approaches that maintain crop production while reducing irrigation water applied.

d) Define the value of an irrigation or rainfall event as crop yield increase for an amount of water applied at various times during growing seasons of differing environmental conditions.

iii) Provide educational opportunities to increase awareness and improve adoption of evaluated efficient grain sorghum irrigation strategies.

**b. Rationale/Literature Review/ Conceptual Framework**

Grain sorghum is one of the important irrigated crops in the Texas High Plains region. The underlying Ogallala aquifer is the major source of irrigation water in this region and more than 90% of the groundwater pumped from this aquifer is used for agriculture. However, irrigated agriculture in this region faces severe challenges from rapidly declining groundwater levels in the Ogallala aquifer, increasing groundwater pumping costs, and recurring droughts. In addition, climate change studies suggest that environmental variability could result in warmer summers and reductions in annual precipitation in the future (Nielsen-Gammon, 2011; Modala et al., 2015). Such trends would lead to larger groundwater withdrawals to meet the higher evapotranspiration demand of most crops including grain sorghum. In order to reduce the groundwater use and prolong the usable lifetime of the aquifer, the GCDs in this region have enacted restrictions on groundwater pumping. Proposed restrictions on groundwater use and projected future weather patterns make it imperative that producers in this region adopt effective irrigation management plans to efficiently use groundwater resources. A critical understanding of the interactions of climate variables on crop growth and yield is of utmost importance in order to develop efficient irrigation strategies for grain sorghum production. The CERES-Sorghum model available within the DSSAT CSM is very useful for this purpose.

DSSAT is a platform that integrates the database management system (soil, climate, and management practices) and crop models with various application programs (Tsuji et al., 2002; Jones et al., 2003). It brings together different individually developed crop models to a single platform. The latest DSSAT 4.6 version is equipped with over 28 crop growth simulation models including CERES-Sorghum (Hoogenboom et al., 2012). Each crop growth model incorporated in DSSAT predicts crop growth and yield as well as soil water, carbon and nitrogen processes over time based on weather, soils, crop management, and crop cultivar information. The DSSAT CSMs are important computational tools, which can be used for developing efficient irrigation and crop management strategies that can mitigate the effects of (or better adapt to) climate change. The CSMs can rapidly and inexpensively simulate crop growth, development and yield in response to variability in weather conditions, soil properties and management practices. The CSMs can also perform economic analyses such as estimation of net returns and risk analysis. After proper evaluation using field measurements, CSMs can be used to understand field-scale water and nutrient balances, test the yield outcome of alternative irrigation and crop management practices, and determine strategies for sustainable crop production. Simulation results from these models can be incorporated into decision support systems to help producers in the Texas High Plains region make informed decisions about irrigated grain sorghum production in the future.

**c. How the objectives will be met**

The CSM CERES-Sorghum model will be calibrated and validated using the observed crop yield and phenology data collected from four grain sorghum experiments conducted in 1992-1994 (irrigation level x irrigation interval); 2001-2008 (multiple irrigation capacities, sorghum rotated with cotton); 2004-2008 (irrigation limited to 5 ac-in/ac each year, sorghum rotated with cotton); and 2007-2015 (irrigation levels in field scale evaluations, sorghum rotated with cotton every 3rd year) growing seasons. These studies were conducted at the Research Center at Halfway and at the Helms Research Farm near Halfway, TX (Bordovsky et al, 1996; Bordovsky et al, 2011). The historic weather data required for model calibrations will be obtained from the TXHPET network (Porter et al., 2005) weather station at Halfway, TX. The soil input data will be taken from previous measurements at the study site as well as from the published soil survey reports.

The calibrated CERES-Sorghum model will be used to study the effects of soil moisture content at planting (0%, 20%, 40%, 60% and 80% depletion) and initiating irrigation at 80%, 70%, 60%, 50%, 40% and 30% plant available water on grain sorghum yield and water use, and recommendations on optimum deficit irrigation strategies for the Texas High Plains region will be made. In addition, a number of hypothetical experiments will be conducted by applying various combinations of irrigation amounts in specific crop growth stages, and the best irrigation strategies that maximize grain sorghum yield while keeping the total amount of irrigation water applied within the allowable groundwater pumping, will be suggested.

Finally, the impacts of projected future climate variability and change on grain sorghum production in the Texas High Plains will be assessed. The future weather data (daily precipitation, maximum and minimum daily temperature, and daily solar radiation) for the Texas High Plains region that was recently acquired and processed by Dr. Ale, PI and his research team (Modala et al., 2015) will be used in this study. This data were downloaded from the North American Regional Climate Change Assessment Program (NARCCAP) (Mearns et al., 2007). The future weather data from the NARCCAP is available as spatially downscaled high resolution (50 sq. km) daily average projections. The IPCC (Intergovernmental Panel on Climate Change) Special Report on Emission Scenarios (SRES) A2 climate datasets developed by three Regional Climate Models (RCMs) for both historic (1971-2000) and future (2041-2070) time periods were downloaded from the NARCCAP and bias-corrected based on the historic (1971-2000) observed data. The projected future climate data for Halfway, TX will be taken from this processed dataset and used in the DSSAT simulations in this study. The interactions between different climate variables (temperature, $CO_2$ concentration, precipitation) and their effects on grain sorghum water use, growth and yield will be studied, and potential strategies for adapting to future environmental modifications will be suggested.

Technology transfer for this study will leverage existing networks, resources, recurring events and extension/outreach venues. These may include: Irrigation conferences (such as the High Plains Irrigation Conference, held annually in the Amarillo area); presentations in local/regional agricultural conferences; subject matter professional development training and CEU workshops for county extension agents, crop consultants and other technical advisors; and articles in audience targeted electronic (Internet-based) and print media outlets (including agency newsletters and commercial publications to maximize readership with little/no publication costs).

### d. Expected outcomes, economic assessments and technology transfer activities

***Expected outcomes:***

i. Evaluated DSSAT CSM CERES-Sorghum model for the Texas High Plains region.
ii. Enhanced awareness of climate change impacts on grain sorghum production.
iii. Recommendations for adaptive and efficient irrigation management strategies for projected future climate scenarios and for meeting restrictions on groundwater use.
iv. A research report, graduate student/Post-Doc training, and at least two peer reviewed journal articles that will document the results of the analysis.

***Economic Assessment Plan:*** An economic assessment of simulated hypothetical scenarios will be made using the economic analysis functionalities available in the DSSAT CSMs. A thorough evaluation of strategies that maximize net returns from grain sorghum production in comparison to the strategies that maximize yields under different weather patterns will be made.

***Technology Transfer:*** The results from this study will be presented in agricultural and water related conferences, field days and producer trainings to enhance the awareness of farmers, researchers and policy makers about climate change impacts and adaptation/mitigation strategies for grain sorghum production in the Texas High Plains region. Pending the results of this study, an educational video will also be subsequently proposed for inclusion on the Ogallala Aquifer Program (OAP) and Lubbock/Vernon/Amarillo AgriLife Research and Extension Center websites for educational purposes.

## 5. Relevant publications

i) Modala, N.R., S. Ale, N. Rajan, C. Munster, P.B. DeLaune, K. R. Thorp, S. Nair and E. Barnes. 2015. Evaluation of the CSM-CROPGRO-Cotton model for the Texas Rolling Plains region and simulation of deficit irrigation strategies for increasing water use efficiency. Transactions of the ASABE. In Press.

ii) Adhikari, P., S. Ale, J. Bordovsky, K. Thorp, N. Modala, N. Rajan, and E. Barnes. 2015. Simulating future climate change impacts on seed cotton yield in the Texas High Plains using the CSM-CROPGRO-Cotton model. Agricultural Water Management. In Review.

iii) Thorp, K. R., S. Ale, M. P. Bange, E. M. Barnes, G. Hoogenboom, R. J. Lascano, A. C. McCarthy, S. Nair, J. O. Paz, N. Rajan, K. R. Reddy, G. W. Wall, and J. W. White. 2014. Development and application of process-based simulation models for cotton production: A review of past, present, and future directions. Journal of Cotton Science. 18: 10-47.

iv) Modala, N.R., S. Ale, N. Rajan, K. R. Thorp and C. Munster. 2015. Simulating the impacts of future climate variability and change on cotton production in the Texas Rolling Plains. Beltwide Cotton Conferences. 5-7 January, 2015. San Antonio, TX.

v) Modala, N.R., S. Ale, N. Rajan, K.R. Thorp and C. L. Munster. 2013. Studying the effects of climate change on cotton production in Texas High Plains using the DSSAT-CROPGRO-Cotton model. ASABE Annual Meeting Paper No. 131612145. St. Joseph, MI: ASABE.

vi) Bordovsky, J., J. Mustian, A. Cranmer, C. Emerson. 2011. Cotton-grain sorghum rotation under extreme deficit irrigation conditions. Applied Engineering in Agriculture. 27:359-371.

vii) Bordovsky, J.P. and W.M. Lyle. 1996. LEPA irrigation of grain sorghum with varying water supplies. Transactions of the ASAE 39(6):2033-2038.

viii) Chaudhuri, S. and S. Ale. 2014. Long-term (1930-2010) trends in groundwater levels in Texas: Influences of soils, landcover and water use. Science of the Total Environment. 490:379-390.

ix) Chaudhuri, S. and S. Ale. 2014. Lon-term (1960-2010) trends in groundwater contamination and salinization in the Ogallala aquifer in Texas, USA. Journal of Hydrology. 513: 376-390.

x) Porter, D., D. Rogers, T. Marek, F. Lamm, T. Howell, M. Alam, N. Klocke. 2010. Technology transfer: promoting irrigation progress and Best Management Practices. ASABE Paper No. IRR10-9641. Proceedings of the 5th Decennial Irrigation Symposium. The Irrigation Association and ASABE, Phoenix, AZ. December 4-8, 2010.

## 6. Literature Cited/ References

Bordovsky, J., J. Mustian, A. Cranmer, C. Emerson. 2011. Cotton-grain sorghum rotation under extreme deficit irrigation conditions. Applied Engineering in Agriculture. 27:359-371.

Bordovsky, J.P. and W.M. Lyle. 1996. LEPA irrigation of grain sorghum with varying water supplies. Transactions of the ASAE 39(6):2033-2038.

Hoogenboom, G., J.W. Jones, P.W. Wilkens, C.H. Porter, K.J. Boote, L.A. Hunt, U. Singh, J.L. Lizaso, J.W. White, O. Uryasev, F.S. Royce, R. Ogoshi, A.J. Gijsman, G.Y. Tsuji, and J. Koo. 2012. Decision Support System for Agrotechnology Transfer (DSSAT) Version 4.5 [CD-ROM]. University of Hawaii, Honolulu, Hawaii.

Jones, J.W., G. Hoogenboom, C.H. Porter, K.J. Boote, W.D. Batchelor, L.A. Hunt, P.W. Wilkens, U. Singh, A.J. Gijsman, and J.T. Ritchie. 2003. The DSSAT cropping system model. European J. of Agron. 18 (3–4) (1): 235-65.

Mearns, L.O., et al., 2007, updated 2011. The North American Regional Climate Change Assessment Program dataset, National Center for Atmospheric Research Earth System Grid data portal, Boulder, CO. Data downloaded 2012-11-28.

Modala, N.R., S. Ale, D. Goldberg, M. Olivares, C. Munster, N. Rajan and R. Feagin. 2015. Climate change assessment in the Texas High Plains and Rolling Plains. Journal of Theoretical and Applied Climatology. In Review.

Nielsen-Gammon, J., 2011. The changing climate of Texas. The impact of global warming on Texas. University of Texas Press, Austin.

Porter, D., Marek, T., Howell, T., New, L., 2005. Texas High Plains Evapotranspiration Network (TXHPET) User Manual.

Tsuji, G.Y., A. du Toit, A. Jintrawet, J.W. Jones, W.T. Bowen, R.M. Ogoshi, and G. Uehara. 2002. Benefits of models in research and decision support: The IBSNAT experience. Agricultural System Models in Field Research and Technology Transfer: 71-89.