Ogallala Aquifer
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**Project Plan from FY2014**
(Fiscal Years 2015-2016)

## 1) Title: Optimizing land/water allocations for irrigated corn production

## 2) Investigators:

Freddie Lamm, Irrigation Engineer, KSU Northwest Research Extension Center, Colby Kansas
Robert Schwartz, Soil Scientist, USDA-ARS CPRL, Bushland, Texas
Alan Schlegel, Soil Scientist, KSU Southwest Research Extension Center, Tribune, Kansas
Isaya Kisekka, Water Resources Engineer KSU Southwest Research Extension Center, Garden City, Kansas
Jourdan Bell, Agronomist, Texas AgriLife, Amarillo, Texas
Dan O'Brien, Agricultural Economist, KSU Northwest Area Office, Colby Kansas
Paul Colaizzi, Agricultural Engineer, USDA-ARS CPRL, Bushland, Texas

### Collaborators/Cooperators

Judy Tolk, Crop Physiologist, USDA-ARS CPRL, Bushland, Texas
R. Louis Baumhardt, Soil Scientist, USDA-ARS CPRL, Bushland, Texas
Thomas Marek, Irrigation Engineer, Texas A&M AgriLife, Amarillo, Texas
Bridget Guerrero, Economist, West Texas A&M University, Canyon, Texas

**Research Location:** Kansas State University sites at Colby, Garden City, and Tribune, Ks.
USDA-ARS-CPRL at Bushland, Texas

**Summary-Abstract:** The severity of the recent drought in the Southern Ogallala Aquifer region has caused crop failure or severe yield reductions in irrigated corn production for irrigation systems with marginal capacity (e.g., gpm/acre or inches/day). Primarily, this is a problem exacerbated by too much irrigated land area for the given pumping capacity that can be greatly remediated by more closely matching land area and water supply. Although, the time period of the current drought cannot be ascertained, the problems of too many acres for marginal water supplies occurs periodically and may increase if climate change results in more evaporative demand and less summer precipitation for the region. While the optimal irrigation capacity varies with respect to location, institutional restrictions being imposed or contemplated by regional water districts may limit seasonal applications and could affect production land/water allocation strategies. The Investigators propose to develop irrigated corn yield production functions for several locations North to South in the Southern High Plains Ogallala region (NW Kansas to Texas Panhandle) and then normalize them according to differences in vapor pressure deficit (VPD). This will allow the production functions to have a more general regional application. Producers will be able to plan their land/water allocations according to their region, water availability, anticipated precipitation, and $ET_c$ to maximize water use efficiency at an acceptable production risk. As a result of this proposed research, the OAP economist's group will have a much more technically sound and robust method to work with in adjusting their yield functions within their economic impact-oriented models. Once, this technique is validated for this major crop in the region, similar studies could be conducted for other crops that are not as widely grown across this large region.

## Project Narrative

### Objectives:

1. Determine grain and biomass yield response to 5 different irrigation capacities limited to 1 inch every 4, 6, 8, 10 or 12 days at Colby and Garden City, Kansas for two corn hybrids (drought tolerant corn, DKC 62-27 DGVT2PRO and a standard hybrid Non DT: DKC 62-98 VT2PRO) planted at a plant density of 32,000 plants/acre.

2. Determine grain and biomass yield response to 3 different irrigation capacities (see specific procedures for the locations) at Bushland, Texas and Tribune, Kansas, for three corn hybrids (drought tolerant corn hybrids, DKC 62-27 DGVT2PRO and P1151HR and a standard hybrid Non DT: DKC 62-98 VT2PRO) planted at various (2 or 3, see specific procedures) plant population densities .
3. Normalize the yield production functions across the region according to VPD differences and yield partitioning in response to water stress. This work will be augmented with preliminary calibration of existing datasets of corn production functions at Colby and Bushland.
4. Evaluate the economics of corn production for the various irrigation capacities, hybrids and plant population for the regional sites. These analyses will follow a partial economic budgeting approach, and will be framed within regionalized probabilities of irrigation demand based on seasonal precipitation minus estimated corn ETc (Allen et al., 1998), design irrigation capacities, and the yield production function.

These objectives address OAP Subobjective 1 by providing information about corn production as affected by the amount of applied water. The results will help to balance land/water allocations so that any proposed reduction in irrigation can be economically justified. Specifically, the project will provide sound and robust corn yield production functions that are appropriate for the region and provide a methodology for making the results more generic across the region. The investigators have purposely adjusted this Plan's Objectives 1 and 2 to more closely meet the local research needs, environments and capabilities of the various sites, while still maintaining sufficient commonality of treatments for a robust analysis.

## Rationale/Literature Review/ Conceptual Framework:

Although corn yield production functions have been used for many years to predict the response of corn to water, they continue to be a topic of investigation. Part of the rationale for continued investigation is the improvements in hybrids and agronomic cultural practices, but differences in regional soil and environmental conditions can make the functions quite site specific. In the proposed study, the investigators will leverage specific studies needed at their specific sites for local needs to extend the yield production functions by normalizing them according to VPD differences. A methodology for adjusting crop water productivity or water use efficiency according to VPD has been discussed in detail by Tanner and Sinclair (1983) and its application is discussed further in Sinclair and Weiss (2010) and Stöckle et al. (2008). The biomass transpiration ratio (essentially the inverse of biomass water productivity) for a $C_4$ crop such as corn was reported to be 160, 220 and 280 g water per g of biomass produced for VPD levels of 1.5, 2 and 2.5 kPa (Sinclair and Weiss, 2010). Recent articles in Science (Ort and Long, 2014 and Lobell et al., 2014) have also suggested that changes in VPD are and will be important in yield response to corn, though there work was confined to the Corn Belt. The major corn seed companies have extensive hybrid development work underway in the western Corn Belt to develop hybrids that are drought tolerant. The overall goal is to develop hybrids that will not incur a yield reduction under ideal conditions, yet stabilize yield under water-stressed conditions. A major secondary trait associated with drought tolerance in corn is the shortening of the anthesis to silk interval (ASI) which has a strong influence on biomass partitioning (Bolaños and Edmeades, 1996). In the Texas High Plains, the flowering period of corn often coincides with the period of greatest irrigation demand and consequently a limited irrigation capacity during this critical stage can markedly affect the ASI, biomass partitioning and grain yield. In the proposed study, the investigators will evaluate drought tolerant hybrids against a stand hybrid and determine how yield components (ears/plant, kernels/ear or kernel mass), harvest index and ASI are affected for these hybrids under water stress. Increases in plant density for corn are generally beneficial in increasing yield provided plant water stress does not affect ear or kernel set. The effect of plant density on the yield production functions will be examined at Bushland and Tribune, Kansas. Although corn yields have increased greatly during the last 30 years, much of the increase can be attributed to achieving greater final kernel set at higher plant densities (i.e., greater number of kernels/unit area). However, Lobel et al. (2014) suggest that greater plant densities result in greater sensitivity to drought. The results of the proposed study should help to indicate the significance of plant density to yield as affected by VPD.

# Approach and Research Procedures:

## General procedures:

Corn will be planted in the spring at an appropriate timing under lateral move sprinkler systems at all locations. Irrigation will be scheduled as needed according to weather- or soil- based water budgets, but will be limited to irrigation capacities (i.e., gpm/acre or inches/day) as indicated in the specific site procedures. Soil water will be measured in the complete root zone periodically throughout the season to help quantify periods of water stress and to determine crop water use. Weather data will be measured using automated weather stations that exist on all of the sites and phenological and growth stages data will be recorded throughout the growing season. Corn grain yield will be determined by hand harvesting a representative sample at physiological maturity which will enable the determination of all corn yield components, (grain yield, plant density, ears/plant, kernels/ear, and kernel mass) as well as the important intermediate yield component, kernels/area. Dry aboveground biomass will be determined periodically (every 3 weeks) through destructive sampling of 5 adjacent plants and drying the samples and weighing the resultant samples. Existing data sets for corn production from Colby, Kansas and Bushland, Texas will be leveraged to examine yield functions in relation to VPD to help normalize the newly acquired yield production functions. The availability of periodic biomass values in the new studies will be valuable in assessing how coefficients vary with crop growth stage and period VPD. Since existing normalization methods are based on biomass and transpiration, efforts will be required to translate these differences to grain yield through means of the different harvest indexes and to evapotranspiration through canopy interception or canopy cover. Alternatively, soil water evaporation (E) can be estimated by determining the intercept of the cumulative biomass – cumulative ET relationship (Tanner and Sinclair, 1983).

It is more important that the corn yield functions be developed over a range of conditions than that the actual treatments be identical at all sites. Thus, the Investigators may utilize a slight amount of flexibility in treatments should weather conditions be excessively atypical (e.g., if treatments are collapsing into each other because of excessive drought or wet conditions, the investigators may alter treatments to provide a better range of water stress levels).

The economic analysis section of this study will follow a partial budgeting framework. This study will focus on the differential, marginal economic impacts of varying amounts of irrigation water applications, varying plant populations, differing corn hybrids, and locational effects on estimated net returns for irrigated corn production enterprises in the Ogallala Aquifer region. Estimates of production costs associated with the key factors in this study will be taken from project-related commercial seed cost expenses, university estimates of per unit irrigation water application costs, and other relevant expenditure information sources. Representative corn selling prices for the regional locations in the study will be used to calculate a uniform selling price for the purpose of placing an economic value on varying corn yield outcomes across treatments. In this type of marginal return-oriented partial budgeting analysis, the focus is on determining the marginal economic return received from varying amounts used and associated expenditures made on key crop production factors to the exclusion of those factors that will be held fixed across treatments.

## Specific Procedures:

<u>Colby and Garden City, Kansas:</u>

Whole-plot treatment sprinkler irrigation capacities of 1 inch every 4, 6, 8, 10, or 12 d limited by ET-based water budget irrigation scheduling will be examined in randomized complete block designs at Colby and Garden City, Kansas. The Garden City site will have one additional treatment and will have 4 replications while the Colby site will have 6 replications. Two corn hybrids DKC 62-

27 DGVT2PRO and DKC 62-98 VT2PRO will be superimposed as split plot treatments for a total of 48 and 60 subplots at Garden city and Colby, respectively.  Long term data sets for irrigated corn production at Colby will be examined to help calibrate coefficients in the VPD normalization procedure for water productivity.

Bushland, Texas

Whole-plot sprinkler irrigation capacities of 1 inch every 3, 4, or 6 d limited by ET-based water budget irrigation scheduling will be examined in a split plot design in Bushland, TX. Within split-plots, three corn hybrids (DKC 62-27 DGVT2PRO, DKC62-98 VT2PRO, and P1151HR) and two populations (24,000 and 32,000 plants/acre) will be examined in randomized experimental plots with three replications per treatment combination. Historical data sets for irrigated corn production at Bushland will be examined to calibrate coefficients in the VPD yield normalization procedure for water productivity.

Tribune, Kansas

Whole-plot sprinkler irrigation capacities equivalent to  1 inch every  4, 8, or 12 d limited by ET-based water budget irrigation scheduling will be examined in a split plot design in Tribune, KS. Plots will be irrigated on a weekly basis to provide the designated irrigation amounts.   Within split-plots, three corn hybrids (DKC 62-27 DGVT2PRO, DKC62-98 VT2PRO, and P1151HR) and three populations (24,000, 32,000 and 42,000 plants/acre) will be examined in randomized experimental plots with four replications per treatment combination.

## Schedule and Timelines:

October 1, 2014 through April 30, 2015:

Examine existing data sets for stability of coefficients.  Develop plan for dealing with anomalies.

Prepare field sites and acquire materials and supplies.

May 2015:

Establish field plots, plant corn and install neutron access tubes.

Read initial soil water.

June 2015 through September 2015:

Irrigate plots according to procedures.

Periodically measure biomass, green leaf area, and soil water.

Collect and evaluate weather data for reliability.

September-October 2015

Harvest samples at physiological maturity for yield components and biomass.

Measure soil water at physiological maturity to aid in determination of seasonal water use.

October 2015 through April 30, 2015

Analyze and summarize first year’s field results.

Compare normalized yield functions to results from past data sets. Develop plan to handle anomalies.

Prepare field sites

May 2016:

Establish field plots, plant corn and install neutron access tubes.

Read initial soil water.

June 2016 through September 2016:

Irrigate plots according to procedures.

Periodically measure biomass, green leaf area, and soil water.

Collect and evaluate weather data for reliability.

September-October 2016

Harvest samples at physiological maturity for yield components and biomass.

Measure soil water at physiological maturity to aid in determination of seasonal water use.

October 2016 through March 1, 2016

Analyze second year's results and compare to first year's results.
Analyze combine results and prepare reports.
Add economic analysis to combine both years results
Make presentations at regional or national meetings.
Complete project with journal publications and with presentations

## Expected Outcomes:

A calibrated model for corn suitable for predicting grain yield under water stressed conditions across a range of locations Texas panhandle and Western Kansas.

Economic analyses of alternative irrigation capacities for each location.

Recommendations of irrigation capacity required for corn production in each of the growing regions (associated with a given level of production risk).

Results will be disseminated through regional Texas A&M AgriLife Extension programs to assist local producers with agronomic decisions directly affecting production economics and resource management. In addition to established Extension programs, social media will be used to expand the customer base and influence. Similarly, the results in Kansas will be disseminated through local and regional meetings. Kansas helps to plan and coordinate the three state Central Plains Irrigation Conference held annually in mid to late February and the results of this study would be appropriate for this forum as well.

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