Ogallala Aquifer
Funded by USDA ARS Research Initiative
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Project Plan from FY2015
(Fiscal Years 2016-2017)

Research Priority Area: 2015 Sub-Objective 1

1) Title: Mobile drip irrigation for water limited crop production in Southern High Plains

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3. Summary/Abstract:

Diminishing well capacities across the Southern High Plains, coupled with the desire to conserve water and extend the usable life of the Ogallala aquifer have stimulated development and adoption of efficient irrigation application technologies such as Low Elevation Spray Application (LESA), Low Energy Precision Application (LEPA), and Subsurface Drip Irrigation (SDI). All these technologies have been shown to have high application efficiencies in various studies. However, adoption of some of these technologies has been limited due to differences in cultural practices as well as cost. While LEPA has been adopted in Texas, it is not widely used in Kansas. Likewise, SDI adoption is higher in the Texas High Plains than in Kansas, but it has also been limited by high initial costs and problems such as poor germination and rodent damage. LESA is used by many producers both in Texas and Kansas. We propose to evaluate an irrigation application technology called Mobile Drip Irrigation (MDI) promoted to combine the efficiency of drip irrigation and economic advantages of center pivot irrigation systems. MDI will be evaluated in different cropping systems and under different well capacities in Texas and Kansas. By applying water along crop rows, it is hypothesized that this technology could increase irrigation application efficiency by eliminating water losses due to spray droplet evaporation, wind drift, and reduced soil and canopy evaporation.

The target audience for this technology will be producers who already own center pivots that have limited irrigation capacity associated with loss of well yield due to water level declines. For such producers, the cost of retrofitting a center pivot with sprinklers to MDI will be relatively low. The study will be conducted in Kansas and Texas. In Kansas the study will be conducted at KSU SWREC near Garden City. In Texas the study will be conducted at research sites at Halfway and Bushland.

Expected project outcomes include: improved water conservation through efficient irrigation water application, as irrigation application efficiency of MDI will be compared to that of other irrigation application technologies used in the region; effect of MDI on crop yield and water productivity at different well capacities will be determined; recommendations from economic analyses will help producers in deciding whether to invest in retrofitting their sprinkler systems to MDI. Specific project outputs will include: journal articles, extension bulletins and oral and poster presentations at various meetings including the annual OAP workshop.

4. Project Narrative

a) **Objectives:** This project will address OAP overall objective 1 related to the development of water management strategies and technologies that could reduce water withdrawals by 20% by 2020 compared to 2012 while sustaining economic viability of agriculture in the region. Specific project objectives are listed below:

1. Compare water application efficiency (Ea), and soil water storage efficiency (Es) of MDI versus LESA (at Garden City, KS).

2. Determine crop growth (LAI), crop yield and yield components, above ground biomass, crop water use efficiency (CWUE) and irrigation water use efficiency (IWUE) of MDI and LESA over a range of irrigation capacities (0.12, 0.16, and 0.20 inches/day corn at Garden City; limited irrigation by LEPA, LESA, SDI and MDI on corn, cotton in Texas, with irrigation rates, methods and crops determined by location at Halfway and Bushland).

3. Conduct a partial budget economic analysis to determine the marginal economic impact of producing corn (or cotton and/or sorghum) under MDI and LESA (as well as LEPA and/or SDI in Texas) at different irrigation capacities, and develop a spreadsheet template for estimating costs for retrofitting a center pivot to MDI.

4. Use field experiment data to calibrate an irrigation efficiency model and use the model to compare and analyze different irrigation management strategies specific to the MDI, SDI, LESA and LEPA systems. Use the simulation analyses to evaluate applicability of MDI to irrigation management constraints common to Texas and Kansas.

5. Disseminate research findings through extension meetings, field days and social media. Targeted audiences will include agricultural producers, regional irrigation-focused agribusiness, and governmental agencies tasked with groundwater management and conservation (such as Ground Water Management Areas and Groundwater Conservation Districts in Kansas and Texas). In addition a survey of early adopters of MDI will be conducted to gain feedback on advantages, disadvantages, management/maintenance concerns, successes and failures of MDI

b) **Rationale/Literature Review/ Conceptual framework:** The Ogallala aquifer continues to decline despite a decrease in the number of irrigated acres (e.g., Kansas had 3.5 million acres in 1980 compared to approximately 3.0 million acres in 2012 [Rogers and Lamm, 2012]). There is uncertainty about the future of irrigation in major irrigated areas of western Kansas, e.g., in many parts of Kansas's Groundwater Management District 1, groundwater has already been depleted while other areas have only 25 to 50 years of the usable life of the aquifer (Buchanan et al., 2009). To cope with these limited water supplies, producers need innovative irrigation application technologies that can help them increase productivity per unit of water applied while extending the usable life of the aquifer. We propose to evaluate engineering performance and impact on agronomic production of MDI on major irrigated crops in the region (corn in Kansas; corn and/or cotton in Texas). MDI may be attractive to producers because it might allow them to harness the efficiency of drip irrigation.

The idea of replacing center pivot sprinkler nozzles with drip lines is not new (Olson and Rogers, 2007; Rawlins et al., 1974 and Phene et al., 1981). However, what is new is the advancement in the way the drip line is connected to the center pivots and drip line emitter technology e.g., pressure compensated emitters. Such emitters eliminate the need for pressure regulators, which reduces the weight being dragged by the center pivot. Another advantage of MDI is that in areas where this technology could prove very useful such as Southern High Plains, many producers already own center pivots, therefore the transition from sprinklers to MDI will be relative easy. This technology may also overcome some of the challenges that have slowed adoption of other microirrigation technologies such as SDI e.g., initial cost of the system, poor germination in dry years and need for intensive management.

By applying water along crop rows, it hypothesized that MDI could eliminate water losses due to spray droplet evaporation, wind drift, and reduce soil evaporation due to reduced surface wetting especially before canopy closure. The anticipated increase in irrigation application efficiency could result in increased crop yields, CWUE and IWUE by reducing the evaporation component of evapotranspiration (ET). This technology is also expected to keep wheel tracks of center pivots dry minimizing system down time resulting from stuck wheels. MDI will be compared to other efficient irrigation application technologies such as LESA, which is commonly used by producers with low well capacities in the region. Previous research comparing irrigation application technologies at Bushland by Colaizzi et al. (2004) showed that under deficit irrigation, SDI resulted in significantly higher sorghum yields compared to LEPA and LESA technologies but the trend reversed at 75% and 100% of full irrigation. Overall they concluded that under the climatic conditions and soil conditions of the Texas High Plains, SDI offered the greatest potential under low well capacities. MDI might help harness the high application efficiencies of drip irrigation without the problems associated with SDI discussed earlier.

However, there are questions that have been raised, as industry promotes this technology within the region. For example: How does MDI compare to in-canopy sprinklers or LEPA systems in terms of application efficiency? Is there a significant yield benefit to converting to MDI? At what well capacity should a producer change from spray to MDI? Can you get good germination with MDI in dry years? What is the cost of retrofitting center pivot to MDI? What is the effect of MDI on herbicide incorporation? What is the effect of dragging drip lines on their longevity? What are the risks associated with emitter clogging and rodent damage? This proposed project will answer some of the questions raised by the producers through experiments at various locations throughout the region. The ex post facto simulation analyses will extend applicability of research findings to the range of management scenarios and practices commonly found in Texas and Kansas. Research findings will be disseminated through extension programs in both Texas and Kansas.

c) Approach and Research Procedures: In Kansas, the study will be conducted at the KSU SWREC in Garden City. A new center pivot equipped with MDI and LESA with VRI capabilities has been installed at KSU SWREC. The new center pivot has four 135 feet spans nozzled for 200 gpm and will irrigate an area of 22 acres. Each span is split between LESA and MDI spaced at 5 ft. Objective 1 will be a one factor experiment with two levels, each span will represent a replication with two treatments: MDI (T1) and LESA (T2). The experimental design will be RCBD. The measurements for objective 1 will be repeated before and after canopy closure.

The experimental design for objective 2 will be a split-plot design with two factors namely irrigation capacity (0.12, 0.16, and 0.20 inches/day) and irrigation application method (MDI and LESA) replicated four times. Irrigation capacity will be the main plot factor while irrigation application method will be the subplot factor. Irrigation will be triggered based soil moisture (MAD>50%) but limited by irrigation capacity. Soil water monitoring using neutron probe will be made weekly to provide feedback on adequacy of the irrigation management. Soil water sensors will be installed to provide information on temporal soil water dynamics. Corn will be planted in circles to prevent drag lines from tangling over corn rows. Fertility and herbicide applications will follow standard cultural practices for corn in the region. Statistics analysis will be performed using Proc. GLIMMIX in SAS (SAS Institute, Cary NC).

Specific Procedures:

Garden City, Kansas:

Methodology for achieving objective 1: Application efficiency (Ea) and soil water storage efficiency will be quantified using procedures described in Irmak et al. (2011). Volume of water stored in the soil will be quantified using neutron probe measurements made at 2 feet intervals up to 8 feet. The volume of water reaching each span will be measured using a water meter installed at the manifold supplying each zone. Temporal soil water dynamics will be measured using Acclima TDR 315 soil water sensors installed in the top 3 feet.

Methodology for achieving objective 2: The effect of irrigation application method (i.e., MDI and LESA) and irrigation capacity (0.12, 0.16, and 0.20 inches/day) on LAI, grain yield, yield components, above ground biomass, CWUE and IWUE will be quantified using a split-plot experimental design. The main plot factor will be irrigation capacity while irrigation application method will be a sub-plot factor. The study will be replicated four times. Corn yield (bu/ac) and above ground biomass (tons/ac) will be hand harvested from representative plot areas. Seasonal ET (inches) will be estimated as the residual of a seasonal soil water balance. Statistical analysis will be performed as described earlier.

Methodology for achieving objective 3: The economic analysis will follow a partial budgeting framework. The marginal economic return received from applying irrigation water using MDI and LESA at different well capacities will be quantified using grain yield data from objective 2 and prevailing corn prices. Prevailing corn prices, as well as operational and production costs for the region will be used. Costs associated with converting an old center pivot to MDI or LESA will be packaged in an Excel template.

Methodology for achieving objective 4: Data collected from field trials will be used to calibrate the Irrigation Management Online simulation tool (Hillyer and Sayde, 2010). Sensitivity analyses will be conducted based on a range of expected irrigation regimes, system capacities, and soil types. The expected range of values will be based on surveys of county extension agents and recent USDA Farm and Ranch Irrigation Survey data. These simulation analyses will be transformed into materials suitable for dissemination in support of objective 5.

Methodology for achieving objective 5: Technology dissemination will be conducted through established Texas and Kansas extension programs. An online survey will be conducted to obtain feedback from early adopters of MDI.

Texas Locations:

Methodologies described for the Garden City site will be adapted at the Texas locations according to local infrastructure available. Objective 1: Application efficiencies (Ea) and volume of stored soil water will be estimated using water application depth and soil moisture sensor information. For objective 2, effects of irrigation application method (MDI, LESA, LEPA, SDI) on crop performance (yield, biomass, quality, as appropriate, water use efficiency) will be determined for corn, cotton, and/or sorghum, according to research rotation sequence at the site(s). Appropriate statistical analyses will be used to assess results, and these results will be reported with - and complement – Garden City, Kansas information. Locally appropriate crop management practices and range of irrigation levels will be used to facilitate interpretation of research results in context with other research at the site and to adapt recommendations for local/regional stakeholders. For objective 3, economic analysis will parallel that of the Kansas-based work, using locally applicable input budgets, value (yield and quality information applied with prevailing market prices), and irrigation equipment and operation values. Finally, objective 5 will be accomplished through leveraging of existing extension / outreach networks and venues, including local/regional agricultural and irrigation conferences.

Bushland, Texas: Crop yield, ET, crop coefficients, and crop water productivity will be compared for different irrigation application methods and different irrigation application rates in small plot studies described in Colaizzi et al. (2004). Crops will include alternating years of corn and cotton. ET and crop coefficients (including the soil water stress coefficient; Allen et al., 1998) will be determined by a soil water balance, where changes in the soil water profile to 2.4 m will be measured by a field-calibrated neutron probe. Irrigation application methods will include LESA, MDI, LEPA, and SDI. Irrigation application rates will include 0, 25, 50, 75, and 100% of full crop ET measured by neutron probe. All treatments will be replicated three times in a strip-plot block design.

Halfway, Texas: Crop yield, seasonal irrigation water use efficiency, and cotton fiber quality will be determined for cotton and sorghum grown under MDI and LEPA irrigation at an irrigation rate up to 0.17 in/day, with the irrigation schedule based upon evapotranspiration. The experimental layout will include four replicates (3 drops per replicate, for a total of 12 irrigation drops).

Economic Analysis: MDI will be compared with other irrigation application technologies (LESA, LEPA, SDI, as appropriate by location) applied in the studies. A partial budget cost/benefit analysis will provide pertinent information needed to compare fixed costs (equipment, hardware, installation) and operating costs (energy, labor) and economic benefits (yield, quality, as applicable by crop). The results of this analysis will be summarized for ease of comparing the different irrigation options.

Schedule and Timelines:

October 1, 2015 through April 30, 2016:

- Conduct literature review on irrigation application technologies.
- Prepare field sites and acquire materials and supplies and design survey
- Identify and establish testing site(s) in Texas. Install irrigation application equipment on the center pivot(s).

May 2016:

- Establish field plots, plant corn and install neutron access tubes.
- Read initial soil water.
- Measure irrigation application efficiency and soil water storage efficiency before and after canopy closure. (Kansas)

June 2016 through September 2016:

- Irrigate plots according to procedures (irrigation methods and application rates).
- Periodically measure LAI, biomass, and soil water.
- Conduct MDI field day(s).

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 April 30, 2017

- Analyze and summarize first year's field results.
- Compare application and soil water storage efficiency of MDI and LESA (as well as SDI and LEPA, in Texas). Compare grain yield, above ground biomass, CWUE, IWUE, soil moisture and seasonal water use of MDI versus LESA.
- Publish results on irrigation application efficiencies of MDI versus LESA.
- Analyze results from survey of producers using MDI.
- Present initial results (progress report) in agricultural and irrigation conferences.

May 2017:

- Establish field plots, plant corn and install neutron access tubes.
- Read initial soil water.

June 2017 through September 2017:

- Irrigate plots according to procedures.
- Measure LAI, biomass, and soil water using soil water sensors and neutron probe.
- Conduct MDI field day.

September-October 2017

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 2017 through March 1, 2018

Analyze second year's results and compare to first year's results.

Use first and second year data to perform economic analysis.

Make presentations to crop producers, agribusiness, and regulatory agencies at regional or national meetings.

Write and publish journal article for objectives 2 and 3.

Write extension bulletin on important considerations for managing MDI

d) Expected Outcomes:

Improved water conservation through efficient irrigation water application, irrigation application efficiency of MDI will be quantified and compared to that of other irrigation application technologies widely used in the region.

Effect of MDI on crop growth, yield, yield components and water productivity at different well capacities will be determined; this information will help producers decide at what irrigation capacities changing from sprinkler to drip makes the most economic benefit.

Recommendations from economic analyses will aid producers in deciding whether to invest in retrofitting their sprinklers systems to MDI.

At least two peer reviewed manuscripts and one extension bulletin and one poster presentation at the annual OAP workshop.

Results will be proactively disseminated through Texas and K-State extension programs to targeted audiences. Professional conferences, field days and county extension events will be used for dissemination of findings. Research findings will be proactively presented directly to agribusinesses and groundwater management agencies and organizations where

5. Relevant publications

- Colaizzi, P. D., A. D. Schneider, S. R. Evett, T. A. Howell. 2004. Comparison of SDI, LEPA, and Spray Irrigation Performance for Grain Sorghum. Transactions of the ASAE 47(5): 1477−1492.
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