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Overview of Ogallala Aquifer Program

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Abstract. *Irrigation increased markedly on the southern High Plains during the second half of the 20th century, drawing water primarily from the Ogallala Aquifer. During this time, irrigation sustained regional farm incomes and rural economies. Withdrawals from the aquifer, however, have exceeded recharge, resulting in declining water availability. In order to sustain future agricultural activities, new water conservation technologies and practices are needed. To pursue such an objective, funding was secured in 2003 for the Ogallala Aquifer Program (OAP), a research and education consortium including ARS-USDA (Lubbock and Bushland TX), Kansas State University, Texas AgriLife Research and Extension Service, Texas Tech University and West Texas A&M University. Research successes to date include: 1) economic assessment of various water conservation strategies; 2) improved management strategies for subsurface drip and deficit irrigation; 3) improved irrigation scheduling techniques; 4) improved practices for dryland farming; and 5) technologies for water conservation in confined animal feeding operations and animal processing plants.*

Keywords. Irrigation technology, irrigation scheduling, water conservation, economic impacts, Ogallala Aquifer.

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Introduction

The objective of this chapter is to provide an overview of the Ogallala Aquifer Program and to summarize the main contributions that will be presented in this symposium. In the simplest explanation, the Ogallala Aquifer Program was initiated to address problems resulting from declining water levels in the Ogallala Aquifer. The program is a research consortium consisting of the Agricultural Research Service-U.S. Department of Agriculture (USDA-ARS) locations at Bushland and Lubbock, Texas, and four universities, Kansas State University, Texas A&M University, Texas Tech University and West Texas A&M University. The alternative title of the Ogallala Aquifer Program is “Sustaining rural communities through new water technologies”. The remainder of this paper will provide details of the problems that the Ogallala Aquifer Program is addressing and the research results achieved to date that provide potential solutions to declining water levels.

Background

The Ogallala Aquifer is located in the U.S. Great Plains and extends from the southern portion of the Texas High Plains and eastern New Mexico, northward through the panhandle areas of Texas and Oklahoma, into western Kansas and eastern Colorado, to Nebraska and southern South Dakota, covering 173,000 square miles (Zwingle, 1993). The water bearing formation of the Ogallala Aquifer was deposited 10,000 to 25,000 years ago and is essentially “fossil water”, meaning that current recharge to most of the aquifer is minimal. The saturated thickness of the aquifer, which represents the interval between the water table of the aquifer and the base of the aquifer, ranges from 0 to 1200 feet and averages 200 feet. The thickest portions of the saturated zone of the aquifer are located in Nebraska, and in the panhandle areas of Texas and Oklahoma into southwestern Kansas.

Water from the Ogallala Aquifer has contributed greatly to the agricultural output of the Great Plains. A great increase in irrigation in the Great Plains occurred during the post-World War II era. By 1959, total irrigated cropland acreage was approximately 7 million acres. By 1978, irrigated cropland had increased to approximately 13 million acres. Irrigated acreage declined by approximately 20% by the late 1980s (Kromm and White, 1992). Despite declines in irrigated acres, irrigation use still accounts for nearly 90% of the groundwater withdrawals in many areas over the Ogallala Aquifer. Aquifer depletion rates of 1 to 3 feet annually are commonplace in areas of irrigated agriculture. In many areas of the aquifer, especially in the southern portion of the Texas High Plains, eastern New Mexico, northwestern Kansas and eastern Colorado, the saturated thickness has been reduced by as much as 40% of pre-development levels (National Research Council, 1996). Withdrawals greatly exceeding rates of recharge have resulted in lower well yields, deeper water tables, and reduced saturated thickness.

The current state of ground water utilization in the Great Plains is a reflection of the economic, social, and political factors. The primary reason that the underground water resources in the Great Plains are being used at a high rate is that the revenues stemming from their current use are greater than the associated cost of extraction. Current withdrawals also increase farm and regional economic stability and reduce producer risks. However, current rates of withdrawals from the aquifer can not be sustained in many areas of the Great Plains. For this reason, the sustainability of this resource and its associated economic consequences need to be better understood.

In 2003, the U.S. Congress provided ARS-USDA with funding for research into the complex nature of water availability, potential uses, and costs which will help determine future water

policy in the Ogallala Aquifer region, and thus, the Ogallala Aquifer Program was started. The two major objectives of the program are: 1) develop, evaluate and disseminate information and technologies for water uses; and 2) provide scientifically sound data to water use planners and policymakers. To meet these objectives, the annual budget has increased from 2003 through 2006 to its current level of approximately $3.6 million in 2010. The number of participating scientists and educators has increased from 40 in 2004 to approximately 90 in 2010.

To meet the program's objective, seven research priority areas were developed in consultation with stakeholders: 1) Develop methodologies for assessing groundwater resource of the Ogallala Aquifer; 2) Improve water management, both irrigation and precipitation; 3) Improve irrigation practices/systems; 4) Reduce the dependence on groundwater resources by developing integrated cropping systems; 5) Evaluate water use by concentrated animal feeding operations (CAFOs) and agricultural processing industries; 6) Estimate the economic impacts of water management activities; and 7) Develop information programs. By 2010, numerous research and technology transfer projects have been completed in each of these areas. A sampling of research results from each priority area is presented herein.

Results

Within the Groundwater Resource Assessment Area, substantial progress has been achieved in gathering data related to recent changes in saturated thickness in the Ogallala Aquifer in Kansas, Oklahoma and Texas. Maps depicting water levels from 1994 to 2004 in Texas are available on the internet at http://www.gis.ttu.edu/OgallalaAquiferMaps/. Data regarding recharge developed from the distribution of chloride in soils indicates that recharge rates are small, less than a few inches annually, even in areas with higher levels of saturated thickness like Roberts County, Texas. Other data indicate that no-till dryland farming promotes rainfall infiltration to greater depths in the soil, thus possibly encouraging an increase in recharge to the aquifer. Studying the effects of climate change on irrigation demands indicates that a drought of the magnitude experienced in the early 1950's in the Texas Panhandle may increase the demand for irrigation beyond what the aquifer and wells can deliver. Another set of researchers asked the question: What could farmers do to reduce the effects of a forecasted drought? Their results indicated that the effects of drought could be significantly reduced by a combination of management decisions including: 1) selecting crops requiring less water; 2) planting earlier maturing cultivars; and 3) altering the planting date.

The research effort in the Water Management Area has been broad-based and has focused on the use of precipitation and irrigation water. The Ogallala Aquifer Program has facilitated further developments in the use of evapotranspiration (ET) data to schedule irrigations. Results from these efforts are available through the Texas High Plains ET Network, an internet site (http://txhighplainset.tamu.edu/) that provides weather data for irrigators. These efforts regarding the use of ET data have been investigated at both the field and county levels. At the field level, crop coefficients have been either developed or refined for use in the southern High Plains. The presentation entitled "Crop Coefficient Development and the Application to an Evapotranspiration Network" by Dr. T. Marek later in this symposium will provide further details on the accomplishments in this area. Research on the use of remote sensing and various energy balance equations/models has proceeded with the notion that ET estimates could be provided for regions currently not served by the Texas High Plains ET Network and other weather station based networks.

Other research efforts identified crop residues as an important management tool in supporting crop yields under dryland farming conditions. Recent efforts have extended these concepts to deficit irrigation systems with similar results, that is, more residues promote water infiltration,

reduce evaporative losses and thus increase crop yields. Planting geometries that are alternatives to the typical uniform row spacing have been investigated. With several crops including corn and sorghum, it appears that skip row planting geometries (plant 1 or 2 rows, leave 1 or 2 rows unplanted) or planting seeds in cluster or clumps can produce higher grain yields under conditions of moderate water stress. The potential of alternative or new crops that can sustain farm income with less water have been researched. Specifically, substantial data have been acquired that indicate cotton can be grown successfully in the Texas panhandle and southwest Kansas, areas in which cotton has not be thought of as a traditional crop in the past.

Advances in the irrigation systems and practices have greatly reduced the per acre water consumption in irrigation. Since the 1970's, water use per acre has decreased by at least 25% as furrow irrigation was replaced by other more water use efficient systems. Data from the U.S. Agricultural Censuses indicate that water use on a per acre basis decreased by 5% from 2003 to 2008. Research in the Ogallala Aquifer Program's Irrigation Systems Area has supported research into the design and best management practices for sub-surface drip irrigation (SDI), as a means of enhancing the adoption of water efficient delivery systems. Two presentations in this symposium, "Can Subsurface Drip Irrigation (SDI) be a Competitive Irrigation System in the Great Plains for Commodity Crops" by Dr. Lamm and "Crop Production comparison with spray, low energy precision application (LEPA) and subsurface drip irrigation in the Texas High Plains" by Dr. Colaizzi, will provide additional results regarding use of SDI. Further, the development of means to automate irrigation applications has been another area of focus. Dr. O'Shaughnessy's presentation entitled "Automatic Irrigation Scheduling of Grain Sorghum Based on a Crop Water Stress Index (CWSI) and Time Threshold" will expand on these accomplishments. Funds from the Ogallala Aquifer Program were helpful in the commercialization of a previously developed technology, Biological Identified Optimal Temperature Interactive Console (BIOTIC), or irrigation scheduling. The BIOTIC system detects differences in leaf and air temperatures and after a certain differential is accumulated, the system starts to irrigate. A major Great Plains consulting company demonstrated great interest in the technology during the 2010 growing season. Other research has been examining both the hardware and theory for the development of accurate and reliable soil sensors that may have a role in irrigation scheduling.

Research in the Integrated Cropping Systems Area has identified the value of adding a livestock component to dryland farming operations. Grazing of winter wheat by stocker cattle can increase the income of wheat production by $45 per acre under current prices without affecting grain yields. However, under no-till farming practices, a post grazing conservation tillage operation (sweep tillage for example) may be necessary to offset the effects of animal trampling on soil compaction. Additions of Austrian peas or cowpeas to small grain pastures had little, if any, positive effects on livestock grazing. An area of growing interest is the use of different types of sorghums as a feedstock for biofuel production or use by the growing dairy industry in the Southern High Plains. Data indicate that there is a great potential for growing sorghum for these various uses in the region and the production of sorghum requires less irrigation water than corn.

Water use by beef feedyards, dairies and beef packing plants has been determined. Although these industries use less than 5% of the water withdrawn from the Ogallala Aquifer, efficient water use by these operations is necessary for profitability. Water use by beef and dairy cattle was estimated to be 7 to 13 gallons and 60 to 80 gallons per head, respectively. Beef carcass processing is water intensive, using approximately 500 gallons per head. There appears to be opportunities to reduce water consumption in beef processing plants. For example, research sponsored by Ogallala Aquifer Program demonstrated that water use by head washing could be reduced by 75% from 20 to 5 gallons each. Reductions in water use, however, must be acceptable to health inspectors. Therefore, research has been conducted on the use of digital

photography techniques to provide unbiased evidence of product cleanliness after various washing treatments.

Within the Economic Impact Area, assessments of the current value of Ogallala Aquifer water in supporting current agriculture and the consequences of various water use policies have been conducted. This team estimated that irrigated agriculture creates billions of dollars of economic opportunity within the region. The U.S. Geological Service estimated in 2007 that only 10% of the pre-development water resource in the Ogallala Aquifer has been used (McGuire, 2007). However, the data regarding the entire Ogallala Aquifer may not be relevant or reflect regional conditions, because a lot of the water in the Ogallala Aquifer is located in places where irrigation does not occur, like western Nebraska. In the next 50 years, many counties in which irrigation currently occurs will have decreases in saturated thickness that exceed 50% without changes in present water use (Panhandle Water Planning Group, 2006). As water available for irrigation from the Ogallala Aquifer decreases, the amount of acres in dryland farming will increase.

Other assessments made by the Economic Impact Area team indicate that permanent or temporary conversion of current irrigated acreage to dryland will not result in more water being left in the aquifer in 50 years. This occurs because water not used on those acreages will be used elsewhere to help maintain farm income. The projected outcome changes if landowners are not allowed to shift the water use between acres. Furthermore, researchers have shown that removing irrigated acreages through programs like Conservation Reserve Program (CRP) or Conservation Reserve Enhancement Program (CREP) can have negative effects on rural economies because acreages removed from farming do not require inputs and there is less of a demand for local companies supplying products and services. Assessment of the returns from various irrigation systems have been calculated and results indicate that conversion to low energy application systems like LEPA or SDI reduce pumping costs and thus increase producers' net profits.

Knowledge and technologies from the Ogallala Aquifer Program are already being transferred to end users. Water use planning groups in Texas have benefited greatly from estimates of water use by various agricultural production enterprises and the water resource in the aquifer. Information from the research has been applied to various decision support tools like Texas High Plains ET network, Crop Water Allocator, Crop Yield Predictor, etc. Dr. Klocke will provide additional details on the development of decision support tools in his presentations entitled "Irrigation Management Decisions Tools". Workshops and field days featuring Ogallala Aquifer Program research results have been held. Dr. Porter's presentation entitled "Technology Transfer: Promoting Irrigation Best Management Practices" will provide additional details regarding the program's sponsored efforts in technology transfer. In 2009 and 2010, a regional effort to transfer information related to SDI was conducted by Ogallala Aquifer Program participants. The Ogallala Aquifer Program also built and maintains a web site: http://www.ogallala.ars.usda.gov/. The web site has links to reports from individual completed research projects, annual accomplishment statements, news items related to the Ogallala Aquifer or Ogallala Aquifer Program participants, etc.

In addition to supporting research in the seven emphasis areas, the Ogallala Aquifer Program has also funded three large multi-year, multi-location, interdisciplinary projects since its inception: 1) management practices for deficit irrigation; 2) economic assessment at scales less than a county; and 3) plant physiology and genetics related to drought tolerance. The deficit irrigation project will be completed in 2010 while the other two are scheduled to be completed in 2011. Results from the deficit irrigation project indicate that the water use efficiency of preplant irrigation can be high if the soil is dry, planting populations need to be adjusted for intended water applications, and with limited water availability, crop yields tend to be higher if water is concentrated and applied at specific critical times during the growing season. Dr. Schlegel will

expand on results related to this project in his presentation entitled “Optimal Corn Management with Diminished Well Capacity”. In the economic assessment project, tools are being developed which will assess the effects of water conservation strategies on farm income and saturated thickness in the aquifer at the farm level. Physiological and biomolecular characteristics of genotypes differing in apparent drought tolerance are being compared for five of the major crops grown over the Ogallala Aquifer (corn, cotton, sorghum, peanuts and wheat). These studies have identified genotypes of sorghum with unique transpiration efficiency, heat and drought tolerance in peanuts, drought tolerance in corn and genes related to drought tolerance in wheat.

Research and technology developed with support from the Ogallala Aquifer Program is projected to conserve water in the future. Senate Bill 1 passed in 1997 created a regional water planning system in the state of Texas. The state was divided into 16 regions with Regions A and O encompassing the area above the Ogallala Aquifer. These regional water plans examine the supply and uses for water 50 years into the future and are revised every five years. Region A, which includes the Panhandle region, has drafted its water plan for 2011-2016 (Panhandle Water Planning Group, 2010). The water plan has identified the demand for water from the Ogallala Aquifer for irrigation will greatly exceed supply for 5 of the 21 counties in Region A. The Panhandle Water Planning Group has proposed implementation of various water conservation practices that will help alleviate the difference between water demand for irrigation and supply (Table 1). Eighty percent of regional farmers already use water efficient irrigation system as of 2010, and the percentage of such systems is expected to increase to 95% by 2040 (Table 1). Continued adoption of conservation tillage practices between 2010 and 2020 is also expected to reduce the demand for irrigation water slightly. Significant decreases in the demand for irrigation water is expected between 2010 and 2020 as farmers change from crop species with higher water demands to those with lower water demand and switch to crop varieties with lower water demands. After 2020, the availability and use of drought tolerant crops created through biotechnology is expected to further decrease irrigation demands. Widespread adoption of irrigation scheduling based on crop water needs is expected to reduce the demand for irrigation water. Finally, conversion of a small percentage of irrigated acreage to dryland farming is also anticipated over the 50 year planning horizon. All of these conservation practices either have been investigated or being investigated by scientists participating in the Ogallala Aquifer Program.

Dallam County is one of the 5 counties identified in the water plan that demand for irrigation will exceed supply (Panhandle Water Planning Group, 2010). Dallam county had 130,000 acres of corn in 2009, nearly all of it irrigated (NASS, 2009a). Corn from Dallam County accounts for over 10% of the corn grain production in the state of Texas (NASS, 2009b). Under the baseline scenario, that is, no change in farming practices and water conservation measures, the difference between irrigation demand and water supply is expected to grow between 2010 and 2040 in Dallam County (Fig. 1). Projected decreases in this deficit between 2040 and 2060 are related to conversion of irrigated corn to dryland crops due to the inability to pump water economically from the Ogallala Aquifer. Adoption of the water conservation practices as in Table 1 are project to reduce the difference in the water demand for irrigation and water supply in Dallam County to the extent that supply will exceed demand in 2050 through 2060 (Fig. 1).

Table 1. Water conservation practices, their projected annual savings of irrigation water and rate of adoption by farmers in the Panhandle of Texas from 2010 to 2060. Adapted from Panhandle Water Planning Group (2010).

Conservation Practice	Annual Irrigation Savings	Year					
		2010	2020	2030	2040	2050	2060
	$m^3\ ha^{-1}$	% Adoption					
Use of water efficient irrigation systems	1630	80	85	90	95	95	95
Adoption of conservation tillage practices	470	60	70	70	70	70	70
Change to crop species with lower water demand	2160	20	40	40	40	40	40
Change to crop varieties with lower water demand	1065	40	70	70	70	70	70
Use of drought tolerant crops created via biotechnology	15-30%	0	50	90	100	100	100
Irrigation scheduling based on crop water need	250	20	27.5	35	42.5	50	50
Conversion from irrigated to dryland farming	2790	5	10	15	15	15	15

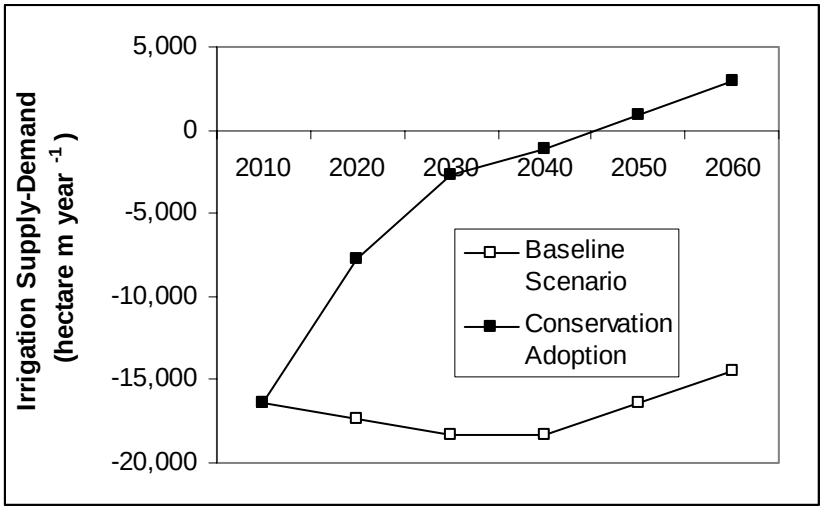

Fig. 1. Changes in the difference between irrigation demand and water supply for Dallam County, Texas from 2010 to 2060 under current farming practices (baseline scenario, open symbol) or after adoption of water conservation practices as described in Table 1 (solid symbols). Adapted from Panhandle Water Planning Group (2010).

Conclusion

Through continued research and technology transfer activities the Ogallala Aquifer Program has been successful in providing knowledge that will sustain rural economies in the Southern Great Plains as water available for irrigation from the Ogallala Aquifer decreases. In accomplishing this mission, Ogallala Aquifer Program researchers have contributed significantly to the research and technology transfer activities related to irrigation technology and irrigation best management practices. Participants in the Ogallala Aquifer Program will continue to be major contributors to the science and technology of irrigation science. In addition, the Ogallala Aquifer Program addresses knowledge and technology related to subjects other than irrigation including dryland farming, hydrology, climatology, etc. Research results related to irrigation and other emphasis areas will facilitate efficient use of the Ogallala Aquifer and provide water use planners and policymakers with valuable knowledge and tools.

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