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Annual Report for FY18

Sustaining rural communities through new water management technologies

Progress Report

The Ogallala Aquifer Program (OAP) is a research and education consortium seeking solutions to problems arising from declining water availability from the Ogallala Aquifer on the Southern High Plains. The consortium includes Kansas State University, Texas A&M AgriLife Research and Extension Service, Texas Tech University, West Texas A&M University, and the USDA ARS National Program 211 research projects at Bushland and Lubbock, TX. OAP funding is from the USDA ARS at Bushland, and OAP management is led by ARS at Bushland with cooperation of a management team composed of the principle investigators for the funding agreements with the four universities.

University and ARS collaborators in the OAP produced 24 publications in FY18 and in prior years that were not reported previously. These are listed in the publications for this research project. These publications support the 27 substantive accomplishments reported here.

Accomplishments

Canopy temperatures and weather data successfully schedule irrigation applications. Corn is an important crop for cattle feed on the Texas High Plains. However, water for agriculture in this area is limited. Therefore, ARS scientists in Bushland, Texas used canopy temperature and weather data (feedback) to determine whether areas within a corn field were water-stressed. If the crop was stressed, water was applied. These results were compared to corn that was scheduled manually using a very accurate soil water probe. In the feedback plots, grain and biomass yields, the amount of water that the crop used and yield per amount of water were similar to the manually scheduled plots. Farmers could use this system that will be available soon from Texas A&M AgriLife as a download to help improve irrigation management of corn by maintaining yields but preventing under-and over-watering.

APEX farm model underestimates crop water use. Freshwater resources are becoming scarce and subject to nutrient pollution from agricultural use. Modeling tools such as the Agricultural Policy Environmental eXtender (APEX) model are used to evaluate the effects of management practices on water quality. Meaningful evaluation is dependent on accurate simulation of water balance components. However, limited work has been done to assess the model's ability to estimate evapotranspiration (ET). In this study, researchers from Bushland, Texas compared simulated ET from five methods to measured ET values from Bushland, Texas. Results indicated that APEX generally underestimated ET for crops grown in the semi-arid Texas High Plains. These results are of interest to SWAT users and those that use model results for water planning and policy decisions.

Drought is more likely the further west on the Texas High Plains. Drought conditions are common in areas such as the Texas High Plains and can cause large agricultural losses. To minimize drought impacts, it is beneficial to understand how likely certain levels of drought can be. However, such data are not readily available for the Texas High Plains. Therefore, scientists from ARS in Bushland, Texas and El Reno, Oklahoma and researchers from Texas A&M AgriLife Research and Extension Service calculated the likelihood of drought conditions throughout the Texas High Plains, based on a standard index, and found that drought conditions are very likely throughout the summer months. Drought conditions decreased from West to East, possible in response to rainfall increasing from West to East. These data can provide useful information for managing water in this region.

Hand held device can detect virus infection in irrigated wheat. Approximately three million acres of winter wheat are grown in the Texas High Plains region, with one-third being irrigated. A critical issue for farmers is that wheat is susceptible to Wheat Streak Mosaic Virus (WSMV), which is transmitted by the wheat curl mite. If infected early in the season, the wheat will produce little to no yield although it remains green. ARS scientists /at Bushland, Texas, along with researchers at Texas A&M AgriLife, demonstrated that a hand held meter which detects different colors of light can be used to identify WSMV infection in a field in early spring. Wheat crops with high levels of infection should not be irrigated because the crop will not use the additional water. This is an important finding for producers as early detection with this sensor can limit water waste.

Critique of soil water sensors identifies accurate sensors. New and improved soil water sensor technologies are being promoted for the assessment of crop water use and to schedule irrigation. However, the accuracy of some of the sensors is questionable thereby requiring evaluation under field settings where they will be used. ARS scientists from Bushland and Lubbock, Texas critiqued several available soil water sensors and showed that some results can be misleading. This critique provides helpful guidance for better research practices in the future that will provide farmers, extension agents and crop consultants with better information for guiding the use of soil water sensors to schedule irrigation.

Narrow row cotton does not increase dryland cotton lint yields. Dryland farming may replace irrigated acres as water from the Ogallala Aquifer becomes scarce. Cotton is a good dryland crop if new farm practices can offset the yield limiting growing season on the southern High Plains. Scientists from Bushland, Texas and Texas A&M AgriLife Research and Extension Service tested row and plant spacing effects on cotton fiber quality and yield using field plots. Cotton grown in narrow, 25 to 50 cm row widths and 7.5 to 10 cm spacing along the row were shorter and had fewer bolls per plant than with common 76 cm (30 inch) row width. These results show farmers, extension agents and crop consultants that dryland cotton planted with narrow row and plant spacing did not yield higher.

A commonly used crop model overestimates crop growth and water use. Water scarcity due to drought and groundwater depletion has led to an increased number of modeling studies aimed at evaluating crop response to limited irrigation. The Decision Support System for Agrotechnology Transfer (DSSAT) is a widely used crop growth model. However, the ability of this model to simulate crop response and water balance under limited irrigation has not been well studied. Therefore, scientists from ARS, Bushland, Texas and Texas A&M AgriLife compared simulated and measured plant growth values for corn grown in the Texas Panhandle under full and limited irrigation. Results showed that this model overestimated corn growth, yield, and crop water use under limited irrigation. These results are of interest to agronomists, plant physiologists and crop modelers because they demonstrate the weakness of the current model to simulate corn growth under less than ideal growing conditions.

Design for sub-surface drip irrigation for a large lysimeter. Conservation of scarce water supplies has motivated farmers on the Southern High Plains to adopt new irrigation technologies with the hope that groundwater withdrawals can be reduced while maintaining or increasing crop yields. The large weighing lysimeters at the ARS research location in Bushland, Texas provide important information on crop water use that can be used for scheduling irrigation applications. These results have been limited to those farms using sprinklers such as center pivots as the application method. However, the occurrence of subsurface drip irrigation (SDI) has increased substantially in the past 10 to 15 years in part because of cost share on installation from NRCS-USDA. Therefore, ARS scientists at Bushland, Texas devised a method to install and use SDI on two of the four large weighing lysimeters located in Bushland, Texas. These installations will allow for precise comparison of crop water use between crops grown under sprinklers and SDI in the future.

Managed deficit irrigation can save 6 inches of irrigation per acre and boost yields. Development of sustainable and efficient irrigation strategies is a priority for agricultural producers faced with water shortages. A promising management strategy for reducing water use is managed deficit irrigation, in which the crop is not fully irrigated but greater irrigation is applied during grain set and early fill. However, experimental results are lacking for this irrigation strategy. Thus, ARS scientists from Bushland, Texas collaborated with Texas A&M AgriLife Research and Extension Service to study managed deficit irrigation with grain sorghum. Managed deficit irrigation averaged 25 bushel per acre more than deficit irrigated sorghum using only 1.5 inches of additional irrigation as compared to nearly 8 inches with fully irrigated sorghum. If irrigation water is limiting, managed deficit irrigation has significant advantages over deficit irrigation.

The auto-irrigation part of a commonly used hydrologic model cannot simulate irrigation practices. Water scarcity due to drought and groundwater depletion has led to an increased emphasis on irrigation strategies for extending limited water resources. Models are commonly used to assess the impacts of such strategies. The Soil and Water Assessment Tool (SWAT), a widely used hydrologic model, is increasingly being used to evaluate the impacts of irrigation strategies at both field and watershed scales. However, concerns about the ability of the auto-irrigate function in SWAT to simulate actual irrigation practices have tempered results. Scientists from Bushland, Texas and Texas A&M AgriLife compared simulated irrigation, crop water use, plant growth, and yield to measured values for crops grown in the Texas

High Plains. Results showed that the auto-irrigate function was unable to represent irrigation practices of the region, prompting the need for revision of the auto-irrigation algorithm in SWAT. Although users of SWAT have expressed dissatisfaction with the auto-irrigation regime, this is the first report establishing the inability of the routine to simulate current irrigation practices.

Low wheat yields are unlikely with El Nino on the Texas High Plains. Decades of pumping with minimal recharge has resulted in declining levels of the Ogallala Aquifer in the Texas High Plains. A gradual transition to more dryland management systems including winter wheat cropping rotations is expected. Precipitation forecasting approaches may help producers manage crops accordingly. However, the use of these forecasting approaches has not been fully investigated. It is now known that temperatures in the Pacific Ocean affect the climate in North America, especially the southwestern region of the U.S. These Pacific Ocean temperature trends were used to separate years into relatively wet (El Nino) and dry (La Nina) phases using historical measured precipitation data from the ARS laboratory at Bushland, Texas. Analyses of simulated wheat yield values revealed a reduced likelihood of lower grain yields for El Nino phases. Therefore, predictions of El Nino or La Nina may be a useful tool to determine the level of inputs for dryland crop production on the Texas High Plains.

Cover crops in western Kansas may decrease wheat yields by decreasing soil water. Recently there has been a great interest in the use of cover crops to promote soil health and reduce erosion. However, there is a debate whether planting cover crops will be beneficial in areas where crop production is limited by rainfall because the cover crop may deplete soil water for crops that produce farm income. Therefore, scientists from Kansas State University in the ARS led Ogallala Aquifer Program at Bushland, Texas studied replacing fallow in no-till winter wheat–fallow rotation with cover, forage, or grain crops. Plant available water at wheat planting was reduced the most when the fallow period was replaced with a summer grain crop. For every inch of saved soil water at planting, wheat yields increased by 2.5 bushels per acre (about $12.5 per acre). Wheat yields were depressed least when the summer fallow was replaced with a short season annual forage.

No-till promotes higher yields of dryland wheat and sorghum in western Kansas. As available water for irrigation from the Ogallala Aquifer decreases, more land owners are likely to farm more dryland (rain-fed) acres. Tillage is an important cropping practice that affects yield, profitability, and environmental quality, especially with dryland farming. However, the responses of crops to different tillage practices are site specific and vary with crop rotations. Therefore, scientists from Kansas State University in the ARS led Ogallala Aquifer Program at Bushland, Texas conducted a long term investigation (26 years) of the effects of different tillage practices on a dryland wheat-grain sorghum-fallow rotation in western Kansas. On average, there was a 31% wheat yield advantage for no till over stubble much tillage, and 120% sorghum yield advantage for no till over stubble mulch tillage. Farmers interested in greater crop yields should consider no-till over stubble mulch tillage.

Water requirement for optimum grain yields less with modern corn hybrids. Corn is the major irrigated crop on the Texas High Plains (THP) using over 50% of the total irrigation water. Currently, high level corn production is challenged because of the declining water in the Ogallala Aquifer and water policies of regional groundwater conservation districts. However, management practices for sustainable high corn yields with less irrigation water needs are to be refined. Scientists from Texas A&M University in the ARS led Ogallala Aquifer Program at Bushland, Texas evaluated corn management practices on the THP with reduced or limited levels of irrigation over the last forty years. With recent advances in corn breeding and genetics, irrigation requirements can be reduced by up to 25% in some years with grain yields comparable to full irrigation. Among management practices, irrigation remains the single-most important factor affecting corn yields, with some effects from planting date, and seeding rate.

Drought tolerance in dryland wheat related to its ability to use soil water from deeper depths. Drought is the most important factor limiting wheat yields on the U.S. southern High Plains (SHP). Adoption of suitable cultivars and crop management practices are crucial to reducing yield loss from drought, however, the parameters associated with tolerance to drought are not fully known. Therefore, scientists from Bushland, Texas, Texas A&M University and North Dakota State University conducted a 5-yr study to investigate soil water extraction by four wheat cultivars. There were large variations in grain yields (474 to 3,685 kg per ha) in dryland wheat across years and cultivars. Yield was largely determined by plant available soil water at planting and seasonal precipitation. More recent cultivars (TAM 110, TAM 111, and TAM 112) were able to extract more water from deeper in the soil profile than the legacy wheat cultivar, TAM 105, especially during the dry year seasons. This study demonstrated that effective use of soil water from greater soil depths is important for wheat yields on the Southern High Plains.

Heavy early season irrigation is wasteful for cotton production on the Texas High Plains. Decreased groundwater under the Texas High Plains has increased the risks associated with irrigation. However, timing application of irrigation boosts crop yields significantly in most years. Therefore, scientists from Texas Tech University, and Texas A&M University in the ARS led Ogallala Aquifer Program at Bushland, Texas investigated 27 irrigation treatments combining time of application and amount of applied water using cotton as the crop. Heavy irrigation early in the growing season used more water, did not increase boll number, and was often detrimental to yield. Mid- and late-season irrigation improved yield and fiber quality. These results provide insight into optimizing cotton water use in a region with declining crop water availability, increased pumping restrictions, and a challenging climate.

ARS' Ogallala Aquifer Program is helping to train the next generation of agricultural engineers. Advances in farming across the U.S. and the High Plains will require the development of a capable and skilled labor force. However, many students are "booked learned" and gain little practical experience in the design and production of farm equipment. Therefore, professors from West Texas A&M University and University of New Haven in the ARS led Ogallala Aquifer Program at Bushland, Texas had students in the mechanical and civil engineering programs work on a variety of engineering projects. This specific project designed, built and evaluated a solar distillation apparatus that can "clean up" wastewater from livestock production systems on farms. Students gain practical experience in engineering design and equipment production that should prepare them better for future agricultural related jobs.

Water policies need to take into account crop prices, input costs and discount rate. Agriculture plays a vital role in the sustainability of the economy of the High Plains Region of the United States. With the development and adoption of irrigation technology, this region was transformed into one of the most agriculturally productive regions in the world. The primary source of irrigation in this region is the Ogallala Aquifer. Currently, water from the aquifer is being used at a much faster rate than natural recharge can occur, resulting in a high rate of depletion. Not enough is known about how this depletion of groundwater will affect regional economic sustainability. Scientists from West Texas A&M University and Kansas State University in the ARS led Ogallala Aquifer Program at Bushland, Texas evaluated the impact of alternative prices and discount rates on groundwater policy recommendations. The study showed that crop prices, input costs, and discount rates have an impact on the effectiveness of water policies that encourage fewer irrigated acres. These results are of interest to water policy makers when estimating changes in farm economy with changes in groundwater policy.

A coupled natural-human model can help guide water policy decisions. As water from the Ogallala Aquifer decreases, water policy makers need information on the impact of future water policies on socio-economic impacts. However, the tools for developing such information to guide water policy formulation are still under development. Scientists from Kansas State University, Pennsylvania State University, Auburn University and University of Minnesota in the ARS led Ogallala Aquifer Program at Bushland, Texas studied the impact of water policy on conserving the Ogallala Aquifer in Groundwater Management District 3 in southwestern Kansas using a model that simulates a coupled natural–human system. The findings corroborate previous studies showing that conservation often leads to an initial expansion in irrigation. This study supports the use of a-coupled-natural-human model to understand the effects of changes in groundwater policy.

Wastewater can be "cleaned up" by solar distillation. As water availability from the Ogallala Aquifer decreases, other sources of fresh water will need to be pursued to make up from lost supply. However, there is substantial waste water of low quality on the Texas High Plains from electricity production, livestock processing, oil and gas mining, towns and cities, etc. Therefore, processes to produce usable water from waste streams need to be developed and tested. Scientists from West Texas A&M University and the University of New Haven in the ARS led Ogallala Aquifer Program at Bushland, Texas tested the ability of a solar distillation system to treat wastewater. Analyses demonstrated that such a process is feasible for reclaiming water on farms.

Contaminants in wastewater from beef feedlots can be removed. Other sources of high quality water will need to be identified and developed as available water from the Ogallala Aquifer decreases. Cattle feedlot runoff and waste water contains substantial concentrations of salts, nutrients, pathogens, and organic matter, which limits its reuse. However, processes that can separate these contaminants from the water need to be developed. Therefore, scientists from West Texas A&M University and Cleveland State University in the ARS led Ogallala Aquifer Program at Bushland, Texas studied the efficiency of treating feedlot wastewater with an electrocoagulation process. The results demonstrated that most contaminants could be removed. These findings are vital for the development of methods to generate "clean" water from feedlot wastewater.

Cotton drought tolerance increased with a gene that decreases sensitivity to a plant hormone. As available water from the Ogallala Aquifer for irrigation decreases, farmers will need to reduce withdrawals from the aquifer. The use of varieties that use less irrigation water per unit of yield is one way that farmers can reduce withdrawals and maintain farm sales. However, basic knowledge of the physiological processes that contribute to efficient water use must be identified. In previous studies, cotton that was insensitive to the plant hormone abscisic acid (ABA) tended to be drought tolerant. However, the exact mechanism for this drought tolerance has not been identified. Therefore, scientists from Texas Tech University, Texas A&M University and University of California-Davis in the ARS led Ogallala Aquifer Program at Bushland, Texas investigated transgenic cotton lines with genes that impart insensitivity to ABA. Results substantiate the potential for engineering drought tolerance in agricultural crops such as cotton by over-expression of these genes. This information is of value to other crop breeders and plant physiologists working towards enhanced drought tolerance in major crops for the southern High Plains.

A gene from fruit flies may aid in the development of drought tolerant crops. As available water from the Ogallala Aquifer for irrigation decreases, farmers will seek crop varieties that are more water efficient. Conventional plant breeding methods have increased the yield potential of many commonly grown crops including cotton, wheat and corn. Traditional breeding methods tend to increase crop yields in a progressive, incremental manner. However, transgenetic technologies may increase crop yield by a rapid leap forward. A gene from fruit flies may increase the expression of introduced genes in transgenetic plants. Therefore, scientists from Texas Tech University, Chengdu Institute of Biological Products Co. (China), Henan Academy of Agricultural Sciences (China), Recep Tayyip Erdogan University (Turkey) and Sichuan University (China) in the ARS led Ogallala Aquifer Program at Bushland, Texas examined the effects of this fruit fly gene on the expression of two plant genes introduced into a model plant. The results showed that the fruit fly gene does promote the expression of two plant genes introduced into plants without the gene. These results are of interest to plant molecular biologists and crop breeders trying to increase the expression of desired traits.

A biochemical factor that promotes drought gene expression identified in cotton. Drought is a key limiting factor for cotton production, with more than half of the global cotton supply being grown in regions in which water supply is limited. The use of drought resistant cotton varieties is one way farmers can continue to grow cotton in such areas. However, the underlying mechanism of the response of cotton to drought stress remains elusive. Scientists from Texas A&M University and China Agricultural University along with ARS researchers at Bushland, Texas identified a protein factor that interacts with genes to regulate the drought stress response in cotton. This is an important step forward in understanding the drought response in crops and may aid in the development of improved varieties in the future.

Corn under mobile drip irrigation requires less irrigation water for similar yields. Since water availability for irrigation from the Ogallala Aquifer is declining; farmers in the Texas High Plains region are interested in mobile drip irrigation as a means to reduce groundwater withdrawals while maintaining crop yields. However, there is limited information on the performance of the mobile drip irrigation MDI system and its benefits. ARS scientists at Bushland, Texas with support from the High Plains Water District conducted a two-year study to compare corn production with mobile drip irrigation to low elevation sprinkler application (LESA) and low energy precision application (LEPA) drag socks. Results indicated that in a year with above average summer rainfall, there was little difference in yields among the three application methods. Corn under the mobile drip irrigation required about one inch less to produce optimum yields. However, during a year with less than average summer rainfall, corn irrigated with the mobile drip irrigation system required at least three inches less water to produce similar grain yields. These results could help sustain irrigated agriculture on farms that have limited well capacity.

Kansas Water Budget adequately predicts sorghum and wheat yields for the Southern High Plains. As water available for irrigation from the Ogallala Aquifer decreases, dryland farming will become more common place on the Southern High Plains. Farmers will need information on dryland yield potential based on weather forecasts to determine the optimum levels of inputs. However, currently the ability to predict wheat and sorghum yields is rather limited. Therefore, ARS scientists from Bushland, Texas worked with researchers in the Ogallala Aquifer Program at Kansas State University to better forecast dryland sorghum and wheat grain yields using weather variables and water use. Crop production functions relating water use and grain yield were developed based on the Kansas Water Budget (KSWB). The KSWB model was found to be a useful decision support tool for relating water supply to grain yield. In the future, farmers may be able to combine short term weather forecasts (30-90 days) with KSWB to determine yield potentials and the optimum levels of inputs including irrigation applications.

Tillage is required to sustain grazing of dryland wheat and sorghum. Water availability for irrigation from the Ogallala Aquifer is declining on the southern High Plains, and to maintain farm income with reduced water withdrawals, dryland row crop agriculture will need to intensify. The current three-year dryland wheat-sorghum-fallow rotation has stabilized crop production except under extended drought. Inclusion of grazing cattle at various stages of the rotation can increase income potential; however, the sustainable management protocols that preserve the infiltration of rain have not been adequately identified. Therefore, grazing and no-till (NT) or stubble-mulch (SM) tillage effects on rain infiltration and soil loss and stability were compared by ARS scientists from Bushland, Texas. Infiltration did not differ significantly with grazing. Soil loss from sorghum fallow increased with grazing and SM tillage. With good residue, SM tillage after grazed wheat increased infiltration greater than 100 % over NT. Occasional SM tillage is recommended to wheat farmers that combine grazing and NT. These results apply to grazing wheat throughout the southern Great Plains.

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USDA ARS United States Department of Agriculture Agricultural Research Service

Kansas State University

Texas Tech University

West Texas A&M University