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LINKING INNOVATIONS IN PRACTICES AND POLICIES FOR GROUNDWATER CONSERVATION ACROSS THE OGALLALA AQUIFER REGION

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THE OGALLALA WATER COORDINATED AGRICULTURAL PROJECT

The Ogallala Water Coordinated Agriculture Project, a multi-disciplinary collaborative effort funded by USDA-NIFA, is focused on developing and sharing practical, science-supported information relevant to best management practices for optimizing water use across the Ogallala region. Our team is engaged in research, outreach and cooperative partnerships with a diverse set of stakeholders, working to support current and future generations of producers in the region. The team of ~70 university researchers, Extension specialists, students and post-doctoral researchers is based at 9 institutions and 10 hub agricultural experiment stations in 6 Ogallala states (Figure 1). This paper provides a summary of some of team's work over the past four years, but is not a comprehensive overview as key accomplishments by our team. Additional team accomplishments are summarized elsewhere in these proceedings in papers by Rudnick, Warren, Lauer, Schneekloth, Chavez, and Aguilar.

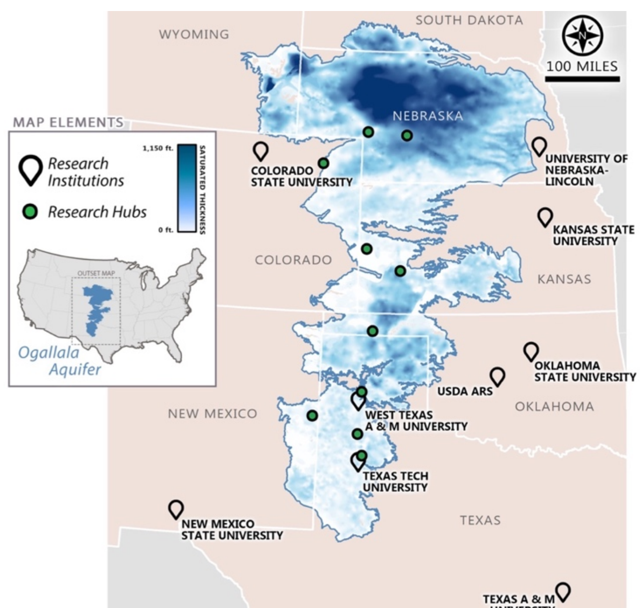

Figure 1. The OWCAP team includes 9 institutions (open symbols) and our field-based research and outreach is centered at 10 research and extension centers (filled circles) across 6 states and that range from higher to lower aquifer saturated thickness (gray shading). Image by L. Moore.

Part 1. Practices with potential improve conservation and profitability

Our team has conducted a wide range of field and modeling research to evaluate the potential of technologies that are available to producers today and emerging technologies for use in the future. We have also evaluated management practices with the potential to improve whole system water use efficiency. A key goal in our work in studying these technologies and practices has centered on how to improve groundwater conservation and water use efficiency while also supporting producer productivity and profitability within the contexts of fully irrigated, limited irrigated and/or dryland production systems.

For in-field irrigation management, our team's research is informing the use of new irrigation management technologies including sub-surface drip irrigation (SDI) systems, soil moisture sensors, and mobile drip irrigation (MDI) applications. Murley et al. (2018) evaluated the importance of precision planting above SDI systems. They found little overall effect on corn yields of different planting row offsets above SDI lines, which suggested that precision planting above SDI is not required to achieve optimum crop performance. Singh et al. (2018) evaluated different soil moisture sensors available on the marketplace to compare data in terms of absolute and relative values they provide to producers to inform irrigation management. They found that the relative values were highly consistent across sensors, but the factory calibrations varied substantially across sensors resulting in different absolute values reported. In particular, soil clay content had a large effect on soil moisture values from different sensors. A field study of eight electromagnetic soil moisture sensors Lo et al. (2019) identified strategies to mitigate the consequences of interreplicate variability and improve confidence in soil moisture data used to help schedule irrigation. Field evaluations of mobile drip irrigation systems demonstrated differences in soil profile moisture relative to a standard LEPA and LESA systems (Oker et al. 2018 & 2019). The MDI system provided a similar level of application efficiency and uniformity as the LEPA system, which were both greater than the LESA systems, suggesting that MDI has the potential to provide efficient water application without the large investment needed for an SDI system.

Dynamic irrigation scheduling based on crop phenology and modeled or measured soil moisture status has the potential improving irrigation water use efficiency. The team has worked to improve irrigation scheduling tools, such as the Water Irrigation Scheduler for Efficiency (WISE) developed by Colorado State University, the Dashboard for Irrigation Efficiency Management (DIEM) tool developed by Texas A&M, and KanSched developed by Kansas State University. In particular, we are evaluating the potential to integrate short-term weather forecast data and in-field variability to improve the precision of scheduling tools across time and space (Jones et al., 2019). In addition, our team has conducted field research and synthesized existing research to evaluate the most promising approaches to managing water with limited well capacity. A Texas High Plains study of cotton production found that in in most years, on heavy soils, that SDI productivity can be improved by limiting pre-plant and early-season irrigations as part of a deficit irrigation regime (Bordovsky, 2020). This has included syntheses of deficit irrigation effects on corn production and water use efficiency (Rudnick et al. 2019), evaluation of different rotation systems in Texas cotton-based systems (West and McCallister, *in review*), and a meta-analysis of water use efficiency in deficit irrigation systems in the Southern High Plains (McCallister et al. *in review*).

There are portions of the aquifer that are facing groundwater depletion to an extent that transitions to lower water use crops or reduction in irrigated acreage are occurring. Our team's research has evaluated crop performance across a range of well capacities through field research and modeling. This research indicates that sorghum can be more profitable than corn and that rotations with lower water use crops, such as wheat, sorghum and soybean in some regions, can improve overall system productivity as compared to continuous corn at lower well capacities (Warren et al. 2016; Araya et al. 2017, 2019; Sharda et al. 2019).

As groundwater declines, soil health management practices become increasingly important as they can influence water infiltration rates and water holding capacity (Cano et al. 2018; Ghimire et al. 2019). Irrigation enhances productivity and, in turn, can increase soil organic matter and soil health indicators. We are evaluating different management strategies to maintain soil health when transitioning land from full to limited to dryland management (Ghimire et al. 2018). A recent analysis by Deines et al. (*in review*) found that about 13% of the land across the aquifer facing depletion by 2100 is not suitable for the production of dryland crops due to land suitability concerns (soil texture, climate, erosion susceptibility) and is more likely to transition to pastureland with large variations in land suitability across the case study counties evaluated. These different land use trajectories have major implications for regional economies.

Part 2. Sharing successful strategies across state lines

In 2018, we partnered with the Kansas Water Office to organize the Ogallala Aquifer Summit in Garden City, Kansas. This event drew over 200 participants representing a broad range of stakeholder groups involved in water management from all 8 states overlying the aquifer. This highly interactive meeting provided participants an opportunity to learn about successful approaches and programs from different states. As an outcome of the summit, several of these programs have been expanded and adapted to new regions, including a new Colorado Master Irrigator program that launched in February 2020 which was designed using the Texas North Plains Groundwater Conservation District Master's Irrigator program as inspiration and template. Master Irrigator offers a 4-day curriculum covering pros, cons, costs, and scientific understanding related to irrigation management and technologies, including economic data. Through a partnership with NRCS, program participants receive priority ranking for financial assistance through conservation incentive programs. Master Irrigator program development is now underway in Oklahoma and there are plans for potential expansion of the program in Kansas and the Delta region. After the summit, the Testing Ag Performance Solutions (taps.unl.edu) program originally initiated in Nebraska in 2017 has since expanded to include an offshoot program now active in the Oklahoma Panhandle, with work underway to expand participation by farmers in Colorado and Kansas in these TAPS programs.

Key take-homes from the social science survey data from Lauer and Sanderson (2019), Lauer et al. (2018) and Shepler et al. (2019), summit feedback, and successful voluntary water conservation initiatives, such as the Sheridan 6 Locally Enhanced Management Area (Golden and Liebsch 2018), are that: 1) irrigators are concerned about groundwater declines and there is a shared desire to conserve this resource for future generations; 2) establishing pumping limits can lead to water conservation without impairing producer profitability; 3) older producers and renters place a lower value on maintaining groundwater levels, have lower levels of concern for future groundwater availability, are less likely to adopt practices that decrease groundwater pumping, and are less supportive of coordinated conservation efforts, and 4) policies need to provide flexibility and educational opportunities to support producers in choosing from a wide range of management practices to achieve conservation targets that may take biogeophysical factors, like soil type and saturated thickness or well capacity, into account.

Part 3. Integrating practices with policies to improve conservation and profitability

To evaluate the potential economic and groundwater impacts of different policy and management options, our team has worked collaboratively to develop an integrated agronomic-hydrologic-economic model. This model, MOD$$AT, integrates the crop model DSSAT with the groundwater model MODFLOW and an economic optimization model (Haacker et al. 2019a; Rouhi Rad et al. *in review)*. The DSSAT model has been calibrated and validated for the major crops across different climate regions within the aquifer region. Detailed hydrologic and well log data has been integrated into MODFLOW to improve the model's ability to better simulate the bedrock topography and to estimate aquifer properties such as hydraulic conductivity and specific yield. The MOD$$AT model will be used in collaboration with groundwater management districts in Nebraska, Kansas, Colorado and Texas to evaluate future policy and management options under current and future climates. Segmented regression is a promising tool for groundwater managers to evaluate change thresholds and the effectiveness of management strategies on groundwater storage and decline, using readily available water table data (Haacker et al. 2019b). Meanwhile, our team also investigated the spatio-temporal structures of regional historical drought variability within the Great Plains, finding that there has been an increase in growing season maximum and minimum temperatures across many areas of the Great Plains between 1901 and 2015, with less frequent but more intense drought incurring short-term and large water deficits occur that may affect critical stages of crop growth. In contrast, the number of total wet events has risen in recent years, indicating an increased risk of excess moisture that may have major impacts on agriculture in the future (Zambreski et al. 2018). Relatedly, a study of weather and climate-driven causes of crop loss in the Ogallala region, using Risk Management Data for indemnities paid from 1989-2017 found that drought and excess moisture showed significant increasing loss cost trends in western Ogallala region counties of the Ogallala (Reyes et al., *in press*). In contrast, hail showed significant decreasing trends in the northern and eastern portions. These results suggest the northern counties of the Ogallala may perceive hail as a greater risk, and may be better equipped to handle drought losses as compared with the southern Ogallala. Crop insurance loss data play a role in integrating long-term trends with near-term management practices, and providing relevant risk information in producers' operational to tactical decision making processes.

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