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Addressing Irrigation Aquifer Depletion: Introduction

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The Food and Agriculture Organization of the United Nations (FAO) estimates that food production must be increased 70% (from 2009 levels) in order to feed an additional 2.3 billion people by 2050 (FAO 2009). Irrigated cropland is extremely important to global food security. According to FAO (2016), although irrigated cropland currently occupies only about 20% of the total agricultural area worldwide, it supplies roughly 40% of the total yield (i.e. 3.6 times that of dryland). Groundwater is an extremely important source of irrigation water. An estimated 38% of irrigated areas depend on groundwater (Siebert et al. 2010) and in the U.S., groundwater supplies 43% of the irrigation water (Maupin et al. 2014). At the same time, an increasing number of countries and regions are reaching alarming levels of water scarcity. According to NASA satellite data, 13 of the largest 37 aquifers in the world are considered significantly distressed (Richey et al. 2015). Severe aquifer depletion evident in the Ogallala Aquifer, California's Central Valley, the Mississippi Delta, and Arizona's alluvial basins (Konikow 2013) threaten food production in the U.S. How will we meet growing food demands and the water needs of growing populations in these regions with declining aquifers? How do we prolong, sustain, or restore these aquifers? When restoration is not possible, how do we best support the conversion to dryland or grazing systems? This JCWRE special issue examines new technologies, cropping system management practices, decision support tools, incentives and policies to sustain food production, rural communities, and ecosystem services in these critical regions. In particular, recent research advances from the decades long USDA-ARS funded Ogallala Aquifer Program, recently funded USDA-NIFA Ogallala Water Coordinated Agricultural Project, and regional efforts in California and the Mississippi Delta are discussed.

Brauer et al. describe the research and education efforts of the Ogallala Aquifer Program conducted over the last decade and a half. USDA-ARS laboratories in Bushland and Lubbock TX, with university partners at Kansas State University, Texas A&M AgriLife Research and Extension Service, Texas Tech University and West Texas A&M University are developing and evaluating water management strategies and technologies to reduce water withdrawals for irrigation by 20% in 2020 (compared to 2012) and increase the productivity and profitability of dryland cropping systems, including developing best management practices for production of high value and alternative crops for both dryland and irrigated systems. This consortium is also working to improve the understanding of hydrological and climatic factors affecting water use and agricultural profitability and determining the impacts of alternative water withdrawal/use policies on the economic viability of the agriculture industry of the Southern Ogallala Aquifer region.

These efforts are extremely important, particularly with the warming trends documented by Lin et al. resulting in increased evapotranspiration loss, soil moisture stress, and associated management challenges in Kansas. This, coupled with declining water levels in the Ogallala Aquifer and increasing restrictions on pumping are challenging the production of corn and other crops. Xue et al. found in their review of long-term production and corn management practices that yields and water use efficiency have increased due to advances in corn genetics and irrigation technologies, and recommended continued research to improve grain quality, crop drought tolerance, and adoption of new technologies to sustain production in the High Plains.

Water use-yield relationships are important for efficient water management (Siahpoosh et al. 2012) and models such as the Kansas Water Budget (KSWB) and Decision Support System for Agrotechnology Transfer (DSSAT) Cropping System Model (CSM) are important tools to assess these relationships. Moberly et al. evaluated the predictive accuracy of the KSWB model for crop water use and grain sorghum and winter wheat productivity, grown in a range of crop sequences. They found that the Kansas Water Budget model provided a useful analytic framework for predicting water supply constraints to grain production, but poorly predicted yield response for either grain sorghum or winter wheat. Adhikari et al. used the DSSAT-CSM model to simulate the long term cotton lint yield and seasonal crop ET and found it useful for scheduling ET-based irrigation management practices in the Texas High Plains and estimating future ET for other modeling experiments.

In addition to these models, groundwater models that not only capture regional hydrogeologic characteristics but also human-hydrologic-climate interactions are crucial for guiding future water management and policy planning endeavors. A conceptual modeling framework built on this premise was applied by Uddameri et al. to a current regional-scale groundwater modeling study in the Southern High Plains where the lack of groundwater production data is a major limiting factor. To identify alternative approaches to fill this critical data gap and properly parameterize the model, they evaluate the importance of surface water groundwater interactions, determine whether explicit coupling of watershed and groundwater models is warranted, and assess limitations in simulating human-aquifer interactions. The study demonstrated the utility of several simple "first-cut" analysis techniques to evaluate groundwater interactions with other interconnected systems.

Golden and Guerrero evaluate the likely economic impacts associated with the implementation of LEMAs, Local Enhanced Management Areas authorized by the 2012 Kansas Legislature. Under this Kansas water law, groundwater management districts have the authority to initiate a voluntary process to develop a conservation plan meeting local goals. Results suggest that the LEMA framework of groundwater management will provide benefits to both the agricultural producer and rural communities. However, Golden and Guerrero note that LEMA adoption may only result in short-lived reductions in groundwater consumption with water saved today eventually being used and the water resource exhausted.

Similarly, in 2014, the Sustainable Groundwater Management Act was enacted in California to reform groundwater management and ensure groundwater is managed sustainably. To help groundwater managers create some of the baseline measures needed to develop a groundwater sustainability plan required by this Act for medium and high priority basins, Flores Marquez et al. introduce a novel method for development of a water budget and present the implementation of this method in the Ukiah Valley Groundwater Basin. Results indicate that because the groundwater basin is not experiencing a decrease in groundwater storage or a lowering of the water table, the groundwater sustainability agency is uniquely positioned to focus on proactive maintenance of current conditions when constructing their sustainability plan.

In the final paper, Reba et al. describe key research efforts in the Lower Mississippi River Basin, an internationally-important region of intensive crop production heavily reliant on the Mississippi River Valley Alluvial Aquifer for irrigation. This region too is facing aquifer depletion and exploring innovative methods to address this issue. Reba et al. investigated innovations in rice irrigation, on-farm water storage, and managed aquifer recharge as means to reduce the on-going decline of this economically and ecologically important alluvial aquifer. They found that collaborative efforts to improve rice irrigation management as part of the Rice Stewardship Partnership effectively reduced the amount of water applied on nearly 30,000 hectares. Their inventory of on-farm reservoir tailwater recovery systems showed that significant investments have been made as part of efforts and supports the potential for surface water storage in critical groundwater areas. Finally, the novel test of managed aquifer recharge described will be used as the basis for further testing in areas where large-scale surface water projects are unlikely.

As this special issue demonstrates, significant efforts and advances are ongoing throughout the U.S. and globe to ensure food and water needs are met into the future. However, continued research is needed to improve irrigation efficiency, crop genetics, cropping systems, and our understanding of the climate, hydrology, water use, and policy impacts. As noted by Golden and Guerrero, adoption may only result in short-lived reductions in groundwater consumption with water saved today eventually being used and production ultimately converted to dryland. Efforts today to improve dryland production will go a long way to ensuring food for future generations.

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