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EDITORIAL

Highlights of special issue on 'Agriculture in Water-Limited Areas'

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Agriculture in water-limited areas is an integral part of regional and global food security. Indeed, food production has increased dramatically in the arid and semiarid areas thanks to the advances in agronomy, genetics and engineering. Irrigation technology, fertilizers and pesticides, and soil management have revolutionized agriculture in water-limited areas. However, water scarcity remains the greatest challenge for agriculture and usually is also the cause for other socioeconomic and environmental problems. Moreover, water scarcity in an area often coexists with low water use efficiency (WUE). This problem is further exacerbated by unprecedented climate change, population explosion and competing demands of the limited water supply from other industrial sectors in the region. Altogether, this threatens the sustainability of regional and global food security, and calls for improving WUE, through integrated science and engineering approaches. As such, collected in this special issue are some important endeavors in this increasingly vital area of research.

Soil is inherently heterogeneous, and to improve resource efficiency and minimize the environmental impact (or footprint) requires precision water and chemical application. However, characterizing soil heterogeneity is often costly and time consuming. In this special issue, Abdu et al. present a non-invasive method to characterize the spatial variability of soil properties. They utilized electromagnetic induction mapping in well-leached soil, so the measured electrical conductivity (EC) is largely determined by soil water content. Furthermore, they categorized the persistent spatial patterns of EC occurring over time to divide a field into three distinct regions: consistently high-medium-low EC areas. These regions were confirmed by ground-truthing to corresponding soil texture. Their methodology has the potential to be extended to areas of low salinity and remote sensing applications.

The quest to reduce soil water evaporation through soil management, which can be traced back to early civilizations, continues unabated. Pi et al. investigated the straw, and white and black plastic film mulching for improving soil water storage in a wheat-maize rotation. They showed that mulching treatments increased soil water storage, but lead to a significant decline in soil organic carbon and nitrogen. Therefore, mulching will no doubt improve soil WUE; however, it brings a new challenge; preventing any consequent decline in soil carbon and nitrogen.

While evaporation is generally considered as nonproductive, transpiration at different growth stages and times is not equally productive, and this relatively less productive transpiration is considered to be excessive. Through chemicals produced inside various organs, plants are able to regulate their evapotranspiration in response to environmental stresses. Ji et al. tested an externally-applied chemical, an antitranspirant, to reduce excessive transpiration. They found that foliar application of a new antitranspirant on soybean under a low-irrigation rate was physiologically effective, but did not significantly improve biomass and grain yield. However, under the higher locally-used irrigation rate, foliar application of the antitranspirant increased soybean physiologic activities, grain yield and WUE.

It is well known that irrigation intensity, droplet size and kinetic energy of the droplet per unit mass (specific power) from sprinklers can damage soil structure, and cause soil erosion. However, little is known about how sprinkler settings can cause damage to plant organs. The paper by Zhang and Zhu presents an important study on how sprinkler irrigation droplet diameter, application intensity and specific power cause damage to flowers being grown for the fresh-cut flower trade. These results provide important parameters for designing proper sprinkler for limiting damage to flowers and other plant organs.

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One fundamental question of irrigation in water-limited areas is how to distribute the limited available irrigation water at the right time and at the right amount to maximize grain yield and WUE. Fang et al. used a process-based agricultural system model and long-term weather data to quantify irrigation requirements, maize grain yield and WUE. They examined the effect of crop water use restriction during vegetative and reproductive growth and concluded that irrigation should be reduced during vegetative growth to save water for the reproductive stage. Since their evapotranspiration-based irrigation method takes into account local weather variation, their optimized irrigation practices and the relationship between targeted ET levels and crop yield should be applicable to other areas with different weather conditions.

To evaluate and measure WUE, many indicators of crop WUE are available. Zhuo and Hoekstra compared several WUE indicators in response to varying agricultural management practices under full and deficit irrigation. When replacing full sprinkler irrigation without mulching to deficit subsurface drip irrigation with organic mulching, all indicators improved significantly. In some cases, increasing irrigation efficiency does not necessarily reduce the blue water footprint, suggesting that multiple indicators be used for guiding irrigation and evaluating soil management practices.

In addition to irrigation, crop production in water-limited areas also requires supplementary chemicals application. To optimize resource use across areas is essential to improving overall resource use efficiency. To this end, Wang et al. took a data driven approach to comprehensively evaluate the geographical differences in agricultural production efficiency in the arid region of northwestern China and explored opportunity for input reduction. They employed data envelope analysis of inputs and were able to identify irrigation districts with low total technical efficiency. Generally, the larger the irrigation districts, the more effective the allocation of resources, and the more technically efficient, suggesting centralized management is an option for improving allocation of agricultural inputs and reducing the impact of agriculture on the environment.

Equally important as water scarcity, is the environmental impact of agriculture in arid zones. Mann et al. examined the effect of biochar amendment on the retention of estrogenic hormones from poultry manure treatment. A previous study had shown that sandy soil with first-year biochar application had a significant retention of estrogenic hormone. However, this study showed that in the second year, there were significant biotic and abiotic changes on the surface of the biochar, resulting in release of dissolved organic carbon, which, in turn, facilitated greater leaching of hormones from poultry manures in soil profile.

Ecosystems in arid and semiarid zones are fragile and vulnerable to soil and wind erosion, and human disturbance. Therefore, ecorestoration in arid and semiarid zones is more challenging than in humid areas. Screening for vegetation that favors fast establishment is important for ecorestoration success. Switchgrass is a useful plant for ecorestoration, livestock forage feed and bioenergy, but due to drought-induced seed dormancy planting on the loess plateau can lead to habitat destruction. Wang et al. investigated prechilling stratification and sulfuric acid scarification on seed germination of three switchgrass ecotypes. They found that germination percentage was improved by both treatments, but reduced by increased drought stress. The three ecotypes differed in response to treatments and one of the three is recommended as being suitable for semiarid areas.

Weed control in agricultural field is important for reducing nonproductive water consumption and nutrient uptake. Efficient and economical control of some weeds, particularly parasitic weed such as the broomrapes, is extremely difficult because infested soil usually contain high seed reservoir densities. Lang et al. examined the effect of using trap crops to induce germination of a broomrape species and deplete its seed reservoir. They found that extracts of cotton, a non-host, induced germination of the broomrape, but with significant variation associated with the cotton cultivar used. This demonstrate that biological control of broomrape is possible in a crop field.

There has been considerable progress in understanding genetics of drought resistance of plants. Yan and Zhang conducted a timely review on how *Rht* genes reduce plant height, and affect root and coleoptile length, and consequently influence grain yields and WUE. Clearly, two of the dwarfing genes, *GAR* and *GAI* can be used in breeding and may help boost WUE and yields in water-limited areas.

To minimize seepage under riverbeds or irrigation channels is critical for reducing water loss during delivery. Most riverbeds are multi-layered in soil texture and often consist of one or more clay layers, especially in riverbeds that are engineered. Li et al. adopted the minimum flux at saturation to evaluate the seepage and resorted GIS tools to upscale the seepage values to large areas. They compared their method with infiltration tests and numerical simulations, and confirmed its usefulness in a case study.

One solution to combat climate change is to maximize carbon sequestration, and agriculture has much to contribute to this solution, especially in the water-limited areas. Zhou and Zou compared carbon sequestration between agriculture and ecological plantings and suggest that agriculture sequesters more carbon than ecological plantations.

Agriculture in water-limited areas encompasses a wide range disciplines. Although the work presented in this special issue does not cover the full range of issues and solutions, we hope that readers will enjoy reading this collection and find that the contributions made represent a significant improvement in the understanding of frontiers of agriculture in water-limited areas. Lastly, this special issue would not have been possible without the support from the China 111 Project, through which solid international collaborations on dryland agriculture have been fostered between Northwest A&F University and institutions around the world.

Pute Wu, guest editor of this special issue, is a professor of agriculture engineering in Northwest A&F University. As one of the experts in water-saving irrigation engineering and technology, he is also working as a professor in Innovation Base of Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Conservancy. He has been dedicated to research, engineering practice and scientific training in the field of agricultural engineering in northwestern China. He has contributed many creative and important advancements in rainwater utilization in farmland and water-saving irrigation engineering, which have been widely applied to production with remarkable benefits. He has won two Second Prize for National Science and Technology Progress Awards, one Second Prize for National Technology Invention Awards, four other first prizes at ministerial and provincial level. He holds 36 patents and published 310 papers (101 Science Citation Index) and eight books. He has supervised 49 Masters and 45 PhD graduates. He works as the leader of expert panel for national water-saving agricultural project of Ministry of Science and Technology, Vice Chairman of the Board of Directors of the Chinese Society of Agricultural Engineering, and a member of the Seventh Session of the Science and Technology Committee and Vice Director of Agriculture and Forestry Division, Ministry of Education. He was selected as a National Excellent Agricultural Scientist, National New Century Hundred, Thousand and Ten Thousand Talents Project, and Excellent Talent of Ministry of Agriculture and Innovation Team. He also won the China Agricultural Engineering Science and Technology Contribution Award, National Contribution Award for Excellent Execution of The Eleventh Five-Year Plan and National May 1 Labor Medal.