Overcoming Water Scarcity:

A Collaborative and Systematic Approach to Addressing Water Scarcity in Agriculture

Background

The Foundation for Food and Agriculture Research (FFAR) believes that our food system must evolve. Sustainably nourishing the growing global community demands transformative discoveries from the best and brightest scientists. FFAR brings together leading experts to identify and investigate key research questions whose resolution have the potential to enhance the economic and environmental resilience of our food supply. One major area of this endeavor is water scarcity in agriculture. According to a recent report by the FAO, water scarcity is one of the greatest challenges of the 21st century (FAO, 2016). Water withdrawals grew at almost twice the rate of population increase in the twentieth century, and, furthermore, food demand is expected to grow by 60 percent by 2050. "There is an urgent need, therefore, to address water scarcity" (FAO, 2016).

Water of adequate quality and quantity is essential in agricultural production, fisheries, as well as the processing and preparation of foods and related products (Dankova, 2016). However, at approximately 70% of global freshwater withdrawals, agriculture is the largest industry water user globally, and is increasingly competing with other domestic, industrial, and environmental uses. It is also a major source of water pollution. Agricultural use of groundwater and surface water in the U.S. accounts for approximately 80% of the nation's diversions. Unsustainable agricultural water use practices threaten livelihoods dependent on water and agriculture.

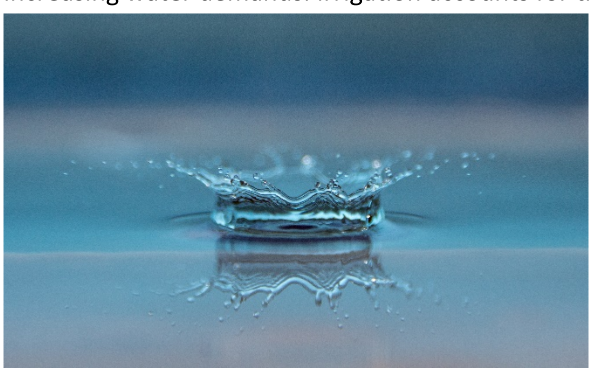
FFAR recognizes the importance of investing in research, technologies, training and best management practices that can address water scarcity issues, and has therefore prioritized Overcoming Water Scarcity as one of its seven strategic Challenge Areas. Specifically, FFAR aims to increase the efficiency of water use in agriculture, reduce agricultural water pollution, and develop water reuse technologies. This Challenge Area will target innovative research that includes, but is not limited to, developing water conservation and reuse technology throughout the production chain, improving crop and livestock varietals/breeds' ability to use water efficiently, creating improved agronomic practices, increasing the social and economic tractability of water-conserving technologies/practices, and enhancing the efficacy of extension services.

At FFAR, we recognize there are critical challenges and key scientific priority areas through which FFAR and other key stakeholders can partner to become change agents focused on advancing issues of water scarcity while meeting the critical challenge of increasing demand for food production. FFAR is uniquely positioned in a pre-competitive space and to work with a wide range of stakeholders to address these water scarcity challenges and opportunities through public/private partnerships. This can be done by funding projects that foster innovation in the areas that can result in positive changes in water resource management and use. We also recognize that it is important to identify areas where we can leverage resources to support transformative and innovative research with a targeted outcome of overcoming water scarcity related issues.

Transformative Spaces

Continued growth in agricultural productivity is essential not only to address future food, including protein, fiber and fuel demands, but also to preserve our natural environment. One of the key components required to increase productivity is optimizing our water use and addressing water scarcity challenges which impact our productivity and ability to meet the growing demand for nutritious foods.

A number of factors affect water scarcity: population and economic growth, water-right administration and adjudication, water quality/environmental priorities, and expansion of the U.S. energy sector contribute to increasing water demands. Irrigation accounts for the largest share of human water use in many regions, therefore emerging demands will have to be met through transfers in existing irrigation water supplies (USDA 2017). Factors such as warming temperatures and shifting precipitation patterns are projected to increase variability in water supplies in the face of increasing water demand. These trends place added pressure on existing water allocations, heightening the importance of water conservation for a sustainable irrigated agriculture sector (USDA 2017).



To address global food and environmental problems, a more interdisciplinary cooperation is needed (Nakashima & Suenaga, 2017). FFAR is poised to provide the support and public private partnerships to support that interdisciplinary cooperation.

FFAR recognizes that in order to more effectively address water scarcity, it is important to leverage resources to drive collaborative thinking to accelerate innovative research that improves water use efficiency in agriculture. At this time, FFAR has identified several program priorities (below) and is in the process of assessing the research gaps within those priority areas and determining where our resources may be most effectively leveraged. The FFAR Overcoming Water Scarcity suite of programs will address these windows of opportunity for transformative impact.

About the Overcoming Water Scarcity Challenge Area

FFAR seeks to support collaborative research centered on addressing challenges in Water Scarcity, with an emphasis on integrated public-private partnerships. The Overcoming Water Scarcity Scientific Program will focus on identifying research that contributes to understanding and addressing issues of water scarcity, while addressing the social and economic realities that challenge farmers, ranchers, private businesses and other stakeholders in meeting the demand for increased productivity and limited resource availability. Through the development of a comprehensive program that supports water scarcity in agriculture, FFAR will address four priority areas that advance knowledge in this space through basic and applied research. The FFAR program is designed to foster the adoption of science, management strategies, technologies, training and outreach which not only support sustainable practices but also increase the tools available to farmers, ranchers and decision makers allowing them to make more informed management decisions.

Program Priorities Under Water Scarcity

Components of a comprehensive and strategic approach:

- Irrigation
- Plant Efficiency
- Water Reuse/Recovery
- Groundwater Recharge
- Systems in Agriculture

Irrigation

One of the key issues identified by FFAR stakeholders within the Challenge Area is irrigation. This is due to the significant role that irrigation plays in food production and agriculture production generally. Agricultural producers, as well as stakeholders from the industry, municipal, and environmental sectors have a number of interconnected vested interests surrounding water availability, agricultural water use and improved water use efficiency. The need is great as well for well-defined best management practices in high efficiency on-farm irrigation systems, regional water delivery infrastructure, control systems, and irrigation scheduling. Technology demonstrations and end user training could potentially have the opportunity to tackle an important research gap in addressing water scarcity and technology transfer. Demonstration and training can also dramatically improve the collective ability to transfer suitable technologies into use by growers.

The future of irrigated agriculture depends in part on producers' ability to improve on-farm water management for crop production. Upgrades in irrigation system technologies and improved water-management practices, such as decision support tools, can enhance on-farm water-use efficiency and reduce water pollution. However, advanced systems can also increase water consumption and can reduce water available to other sectors (particularly when advanced systems meet earlier crop water shortages). In addition, coordinating water management at the farm- and watershed-levels may help increase the efficiency of water allocation among competing users. Institutional measures—such as water rights administration, groundwater and surface-water withdrawal regulations, water banks, and option water markets—can encourage agricultural producers to optimize crop consumptive use while facilitating the reallocation of water to higher valued uses (USDA, 2017).

Potential areas of focus:

- Irrigation Technologies – Best management practices

- On Farm Demonstrations
- Modeling/Reporting
- Water Demand Management (metrics, crop monitoring and coefficients, soil and evapotranspiration-based decision support technologies)
- Governance mechanisms and training
- Water and Energy Efficiency
- System integration and management

Plant Efficiency

Water shortage is a limiting factor in crop production, which in turn increasingly affects food production and food security. For this reason, scientists have never stopped efforts to improve efficiency of water usage and reduce the effect of water shortages on crop production (Zhou et al. 2016). Achieving a sustainable yield increase in agricultural productivity is critical and to achieve this, there must be an increase in productivity without further increased pressure on agricultural inputs such as land and water. An added obstacle is changing weather patterns and climate which poses a serious threat to our food security.

The "increasing vulnerability of plants to a variety of stresses such as drought, salt and extreme temperatures" poses a global threat to sustained growth and productivity of major crops. Of these stresses, drought represents a considerable threat to plant growth and development" (Joshi et al. 2016). In view of this, developing crops with improved drought tolerance emerges as a sustainable solution toward improving crop productivity in a scenario of climate change.

FFAR recognizes that in order to more effectively and address water scarcity, it is important to leverage resources to drive innovation science resulting from collaborative thinking to accelerate research that improving plant efficiency. FFAR is seeking to fund transferrable research that can break new ground in water scarcity, specifically in plant efficiency and fund innovative science to ask the right questions, convene the best and brightest minds to answer those questions, and see research through to successful implementation.

Potential areas of focus:

- New genetic pathways to increasing water use efficiency
- Multiple Stressors
- Impact of Water Scarcity on Crop Quality
- Alternative Crops and Systematic Approach to Abiotic Stress

Water Reuse/Recovery

The amount of water on the earth is quasi-fixed. Water is constantly used and reused through the hydrologic cycle, withdrawn from aquifers and streams, and placed back into the hydrologic system.

Reclaimed water is valued as a resource and the trend has shifted toward discovering innovative ways to incorporate more effective water reuse strategies and utilize nontraditional irrigation water sources.

As droughts and population increases continue to stress the availability and demands of fresh water supplies, reuse of municipal water will play an increasing role in meeting water demands associated with increased agricultural production. Reclaimed water is used for many purposes from pasture irrigation to potable water supply augmentation. However, there is a need for a greater understanding of the public health impacts of reclaimed water quality (Crook & Surampalli, 2005).

The safe use of nontraditional waters such as treated or mixed saline waters or treated wastewaters for agricultural production is an important component of improving agricultural water use efficiency. Growers are increasingly looking to recycled water as a way to consistently meet their irrigation demands in the face of growing water scarcity and pollution concerns (Schulte, 2016). The biggest concern regarding the use of recycled water on farms is the impact on human and environmental health and regulations governing food safety issues. As traditional technologies for reclamation have high energy requirement (i.e. reverse osmosis), the opportunities to reduce financial, in addition to, environmental costs, are significant.

Potential areas of focus:

- Quantification of the nonmonetized costs and benefits of potable and non-potable water reuse compared with other water supply sources to enhance water management decision making
- Examination of the public acceptability of engineered multiple barriers compared with environmental buffers for potable reuse, Examination of impact of reclaimed water quality on public health
- Development of rapid screening methodologies., Research related to purposeful ecological enhancement with reclaimed water

Groundwater: Recharge Research

Freshwater resources are vulnerable and have the potential to be strongly impacted by climate change (IPCC, 2008). Groundwater supplies nearly half the world's drinking water and much of the world's irrigation water supply. Population growth, overexploitation, salinization, nonpoint source pollution from agricultural activities (including animal farming, ranching, and forestry activities), impacts to surface water, and groundwater quality and quantity conflicts at the urban-rural interface have reached global dimensions and threaten the health and livelihood of this planet.

The ability to quantify future changes in hydrological variables, and their impacts on systems and sectors, is limited by uncertainty at all stages of the assessment process.

Improved observational data and data access are necessary to improve understanding of ongoing changes, to better constrain model projections, and are a prerequisite for adaptive management required under conditions of climate change (IPCC, 2008). Greater insight is also needed into emissions from decentralized treatment processes and into uncontrolled wastewater discharge. The impact of properly reusing water on mitigation and adaption strategies needs to be understood and quantified (IPCC, 2008).

Potential Areas of Focus:

- Development of 3–D capabilities for geologic modeling to a level that can be integrated routinely with hydrologic models
- Improvement of estimations of recharge for groundwater modeling and other hydrologic applications, development of more sophisticated flow and transport processes in variably saturated flow models
- Improvement of expertise in bridging soil, vegetation, and atmospheric modeling with hydrologic modeling to create a broader understanding of the groundwater component of the hydrologic cycle (Sanford et al., 2006).

Systems in Agriculture

American agricultural producers are expected to play an active role in meeting growing global needs for food, feed, and fiber while land, water, and soils decline in availability and quality. Meeting this challenge necessitates attaining the four goals that support sustainability of agriculture: perpetuating the economic viability of agriculture; satisfying human needs for food, feed, and fiber; protecting and improving environmental quality and the resource base; and enhancing quality of life of producers and consumers of agricultural output. The robustness of sustainability is the ability "to continue to meet the goals in the face of stresses and fluctuating conditions." (NRC, 2010)

A systems approach to fostering agricultural sustainability is the most effective means of achieving the above goals because connectivity among goals ensures robustness and resilience. The pursuit of sustainability risks trade-offs between the goals; for example, building soil health through no-tillage can complicate pest control and fertilizer placement, and thus compromise productivity. Systems research entails understanding the interactions and feedbacks among components so that one may optimize the whole, even if no single component is maximized. Optimizing the whole reduces risk and enhances resilience across variations of environmental and economic conditions. The continued availability of high-quality water for agricultural production is an imperative that demands a systems approach to research, management, and policy, especially as supplies decline and competition among human uses intensifies. Optimization of water use merits deeper study at all system scales, including the farm enterprise, watershed, aquifer, policy region, and climatic zone. Decision-makers at each level need metrics and information that help optimize the sustainability goals.

Potential Areas of Focus:

- Farming System Planning
- Monitoring Water Quality

Conclusions

These identified scientific priority areas represent the areas of focus for the Foundation for Food and Agriculture Research Overcoming Water Scarcity Challenge Area, and while these priorities are by no means exhaustive, they do represent FFAR's commitment to the needs expressed by our stakeholders and the spaces in the precompetitive space where our impact may be the most substantial.

Citations

Alexandratos N, Bruinsma J. World agriculture towards 2030/2050: the 2012 revision. Rome: FAO; 2012.

British Geological Service (2009). Groundwater Information Sheet. The Impact of Agriculture. Retrieved from https://www.bgs.ac.uk/downloads/start.cfm?id=1295 on May 3, 2017.

Comprehensive Assessment of Water Management in Agriculture. 2007. Water for Food, Water for Life, A Comprehensive Assessment of Water Management in Agriculture.

Crook, J., & Surampalli, R. Y. (2005). Water reuse criteria in the United States. Water Science and Technology: Water Supply, 5(3-4), 1-7.

Dankova, R. (2016). Agriculture holds the key to tackling water scarcity. [Blogpost] Retrieved from http://blogs.worldbank.org/water/psd/water/agriculture-holds-key-tackling-water-scarcity on June 1, 2017.

Food and Agriculture Organization of the United Nations. (2016) Coping with water scarcity in agriculture: a global framework for action in a changing climate. Paper presented at the Marrakech COP22- CMP12. UN Conference on Climate Change.

Intergovernmental Panel on Climate Change (2008). Gaps in knowledge and suggestions for further work. Climate Change in Water. Retrieved from https://www.ipcc.ch/pdf/technical-papers/ccw/chapter8.pdf.

Joshi, R., Wani, S. H., Singh, B., Bohra, A., Dar, Z. A., Lone, A. A., … Singla-Pareek, S. L. (2016). Transcription Factors and Plants Response to Drought Stress: Current Understanding and Future Directions. Frontiers in Plant Science, 7, 1029. http://doi.org/10.3389/fpls.2016.01029

Kansas Water Office (2014). Non-Traditional Sources and Uses of Water-Reuse. SECTION 2: Statewide Water Assessment - Water Supply. Retrieved from http://www.kwo.org/Water%20Plan/KWP2014/Water_Supply_Water_Reuse_drfat.pdf. On May 25, 2017.

Nakashima, K., & Suenaga, K. (2017). Toward the Genetic Improvement of Drought Tolerance in Crops. Japan Agricultural Research Quarterly: JARQ, 51(1), 1-10.

National Research Council. 2010. Toward sustainable agricultural systems in the 21st century. In P.T. Whitacre (ed.). The National Academies Press, Washington, D.C.

Pennisi, E. (2008). The blue revolution, drop by drop, gene by gene. Science, 320(5873), 171-173.

Sanford, W. E., Caine, J. S., Wilcox, D. A., McWreath, H. C., & Nicholas, J. R. (2006). Research opportunities in interdisciplinary ground-water science in the US Geological Survey. *US Geological Survey Circular*, *1293*, 21.

Schulte, P. (2016). Pacific Institute Farm Water Success Stories: Recycled Water and Agriculture. Pacific Institute.

Tilman D, Balzer C, Hill J, Befort BL. Global food demand and the sustainable intensification of agriculture. Proc Natl Academies of Science USA. 2011;108(50):20260–20264. pmid:22106295

United Stated Department of Agriculture. (2017). Irrigation and Water Use. Retrieved June 7, 2017, from https://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use/background/

Zhou, L., Liu, Z., Liu, Y., Kong, D., Li, T., Yu, S., ... & Luo, L. (2016). A novel gene OsAHL1 improves both drought avoidance and drought tolerance in rice. *Scientific Reports*, *6*.