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Advancing Agricultural Water Security and Resilience Under Nonstationarity and Uncertainty: Evolving Roles of Blue, Green, and Grey Water

Paula L.S. Rees

College of Engineering, University of Massachusetts, Amherst, MA

With population expected to rise to close to 10 billion by the year 2050 (UN Department of Economic and Social Affairs 2017), the world faces an extraordinary agricultural and water management challenge. Food security, however, is a current as well as future problem. The World Health Organization estimates that today nearly 821 million people (~10.9%) are undernourished, and in Sub-Saharan Africa 29.5 to 48.5% of the population, depending on region, faced severe food insecurity from 2014-2017 (FAO et al. 2018). The most critical food shortages tend to correspond with areas under water stress, and the poor are most susceptible (FAO et al. 2018). Meeting the nutritional and caloric needs of the world population will require a combination of increased food production, food waste reduction, and improved food storage and delivery infrastructure systems. Effective management of water resources will be key to success.

In 2004, Falkenmark and Rockström introduced the green-blue water paradigm, which has since gained widespread acceptance in the international and U.S. water management communities. This framework has been expanded to include reclaimed and/or grey water (Dobrowolski et al. 2008; Waskom and Kallenger 2009). Blue water is the water storage in streams, lakes, wetlands, glaciers, snowpack, and saturated groundwater. Green water is soil moisture in the unsaturated zone. Grey water is classically defined as wastewater from domestic activities such as laundry, dishwashing, and bathing which can be recycled and used, but of greater significance in terms of volume is reclaimed water from municipal wastewater. Reclaimed water is an important commodity in many areas of the world including areas of the U.S. The blue/green/grey framework has the potential to significantly improve water management within the agricultural domain.

With this in mind, in 2013, the United States Department of Agriculture (USDA) National Institute of Food and Agriculture (NIFA) issued a request for applications to "provide a global view of the challenges and the opportunities for future research, education and extension via presentation of a wide range of forward-looking perspectives on blue, green and grey water issues related to agriculture." USDA award number 2013-51130-21485 supported a special track at the 2014 joint annual conference of the Universities Council on Water Resources (UCOWR), National Institutes for Water Resources (NIWR), and the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) entitled *Advancing agricultural water security and resilience under nonstationarity and uncertainty: Evolving roles of blue, green and grey water*. The conference track summarized the state of our knowledge and provided a global view of the challenges and the opportunities for future research, education, and extension via presentation of a wide range of forward-looking perspectives on blue, green, and grey water issues related to agriculture. Proceedings from the conference as well as abstracts and videos of the presentations are available on the Massachusetts Water Resources Research website: http://wrrc.umass.edu/events/blue-green-grey-water-agriculture. A special session was subsequently held at the 2017 conference. This special issue of the Journal of Contemporary Water Research and Education (JCWRE) is the final deliverable of the USDA grant.

The issue begins with the paper *Blue, Green, and Grey Water Quantification Approaches: A Bibliometric and Literature Review* by Stanley Mubako, which provides an overview of methodologies for quantifying blue, green, and grey water in studies published from 2000 – 2018, including the most popular publications and most cited authors, an assessment of the spatial scale analyzed, and which components of the blue, green and grey paradigm were included in each study. Insight on approaches taken in the literature can lead to a better understanding of how production and consumption decisions impact freshwater resources.

In *Agricultural Use of Reclaimed Water in Florida: Food for Thought*, Lawrence Parsons examines the use of reclaimed water for agriculture irrigation in Florida over the last 50 years. Florida provides an example of how clear regulations and high quality research examining the impact of its use have enabled reclaimed water to become an important water source for agriculture. While agricultural producers and the public were initially opposed to its use, reclaimed water application to crops now has wide support and acceptance. Reclaimed water is currently utilized in 118 systems that irrigate agricultural crops, including 17 that irrigate edible crops. While reclaimed water supplies continue to grow in Florida, competition from public access and industrial users has increased and citrus production and acreage have declined, decreasing the percent of agricultural reuse. This may change if growers ask for a variance on the prohibition on direct contact of reclaimed water with crops eaten raw, as has been allowed in California for more than 30 years. Such a variance could reduce demand on groundwater for freeze protection of strawberries and blueberries.

In their paper entitled *Grey Water: Agricultural Use of Reclaimed Water in California*, Sheikh, Nelson, Haddad and Thebo provide an overview of how impediments, incentives, and competing demands contribute to wide variability in agricultural water reuse practices across the U.S. and around the world using California as a case study. Drivers for and against water recycling can generally be classified into social, policy, technical, natural, and economic categories. While attitudes can be changed with proper outreach, demonstration, and education, most successful projects require "the persistence of a visionary champion" to bring stakeholders together in order to overcome barriers. Increased understanding of these factors will ideally lead to increased use of reclaimed water for agricultural production.

Effective nutrient management will be important for meeting global food needs, particularly in terms of protecting downstream ecosystems. In the paper *Water Chemistry During Base Flow Helps Inform Watershed Management: A Case Study of the Lake Wister Watershed, Oklahoma*, Austin, Patterson, and Haggard examine the effectiveness of a simple human development index as a framework for prioritizing installation of best management practices to reduce nonpoint sources of nutrients. Post-implementation monitoring must be conducted at the appropriate spatial and temporal scale to evaluate the effectiveness of management plans.

In his paper *Food Security as a Water Grand Challenge*, Courage Bangira describes the challenges posed by population growth, climate change, land degradation, and water stress on food security. Some experts suggest that by mid-century, food production must double to meet the caloric needs of the global population. However a large percent of current global food production is supported either by rain-fed agriculture or unsustainable water use, making water a limiting factor in agricultural production. In addition, food security is about more than just availability. Issues of access to a balanced and nutrient-rich diet and proper storage and preparation of food in its utilization must also be addressed. Investment in irrigation, resource-efficient agricultural technologies, development of new crop varieties, and the application of appropriate regional, national, and international policies will be necessary to meet global food security needs.

In *The Value of Green Water Management in Sub Saharan Africa: A Review*, Clever Mafuta discusses the importance of integrated soil and water management for meeting the food needs of Sub-Saharan Africa. In comparison to irrigation, which is costly in terms of infrastructure and requires access to water sources, green water management can benefit communities across Sub-Saharan Africa. Green water, or water available to the root zone of plants from precipitation, has historically not been included in water accounting and management decisions. This failure to account for an important component of the water footprint in sub-humid and semi-arid regions has perhaps limited management options for improving agricultural productivity. More productive use of green water for agriculture, however, may have unintended impacts to other ecosystems.

The journal concludes with a paper by Colby and Isaaks, *Water Trading: Innovations, Modeling Prices, Data Concerns*, which examines recent Colorado policy innovations related to water trading. Their study highlights the importance of transparent water trading information for making effective water management decisions in real-time as well as the development of economic models to improve evaluation of water trading and its effects. They also note the effectiveness of piloting new water transaction initiatives for shifting policy paradigms. Pilot programs, with their specific end date, can broaden support for permanent policy changes by reassuring those initially opposed, while providing sufficient time to evaluate effectiveness. This paper is of broader relevance for understanding the data and policy innovations that may help address water management challenges in other arid regions.

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Author Bio and Contact Information

Paula Rees is Assistant Dean for Diversity in the College of Engineering at UMass Amherst. From 2007 – 2017 she served as director of the Massachusetts Water Resources Research Center. Her expertise and focal interests are in the areas of hydrology and hydrometeorology, sediment transport, water resource sustainability, watershed water quality and quantity modeling, and watershed dynamics and management. As a past-president and member of the board of directors of UCOWR, a former CUAHSI university representative, and a NIWR member, she deeply values the synergies and collaborative opportunities across these organizations. She may be contacted at 128 Marcus Hall – CEI Hub, 130 Natural Resources Rd, University of Massachusetts, Amherst, MA 01003; by phone: (413) 545-6324; or by email at rees@umass.edu.

References

United Nations, Department of Economic and Social Affairs, Population Division. 2017. *World Population Prospects: The 2017 Revision*. New York: United Nations. Available at: https://esa.un.org/unpd/wpp/publications/files/wpp2017_keyfindings.pdf. Accessed December 11, 2018.

Food and Agriculture Organization of the United Nations (FAO), the International Fund for Agricultural Development (IFAD), the United Nations Children's Fund (UNICEF), the World Food Programme (WFP) or the World Health Organization (WHO). 2018. *The State of Food Security and Nutrition in the World 2018. Building climate resilience for food security and nutrition.* Rome, FAO. License: CC BY-NC-SA 3.0 IGO. Available at http://www.fao.org/3/I9553EN/i9553en.pdf. Accessed December 11, 2018.

Falkenmark, M. and J. Rockström. 2004. *Balancing water for humans and nature: The new approach in ecohydrology*. Earthscan Publications, London, UK.

Dobrowolski, J., O'Neill, M., Duriancik, L., and J. Throwe, eds. 2008. *Opportunities and challenges in agricultural water reuse: Final report*. Washington, DC: USDA Cooperative State Research, Education, and Extension Service.

Waskom, R. and J. Kallenger. 2009. *Graywater Reuse and Rainwater Harvesting*. Colorado State Extension Fact Sheet. Fort Collins, CO: Colorado State University Extension.