Editorial

Agricultural Water and Groundwater Management: An Introduction to the Special Issue

Susanne M. Scheierling
Water Global Practice
The World Bank, Washington, DC

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This special issue presents selected contributions to the 11th Annual Meeting of the International Water and Resource Economics Consortium (IWREC). It was hosted by the World Bank in Washington, DC on 7–9 September 2014. IWREC has served as a platform for water economists worldwide to promote economic work on water resources and exchange information and research findings since the early 1990s. The 11th Annual Meeting, held under the theme “Efficiency and Water Conservation: Methodologies and Case Studies”, included 50 presentations in 12 sessions, and may have been the largest gathering of water economists to-date (<http://www.worldbank.org/water/iwrec2014>).

The seven papers in this special issue focus on a particularly challenging area in agricultural water management: the assessment of policy and investment options in irrigated agriculture for conserving water and adapting to increasing water scarcity — with a special consideration of the linkages to groundwater resources and their management. This is an increasingly important area of research for a number of reasons. First, irrigated agriculture accounts for about 70% of global freshwater withdrawals (Molden and Oweis 2007), and is a major contributing factor to the water scarcity situation in many countries (Scheierling and Treguer 2016a). Second, with almost a quarter of freshwater withdrawals for irrigated agriculture being made up of groundwater supplies (Siebert *et al.* 2010) — corresponding to 70% of total groundwater withdrawals (FAO 2013) —,

agricultural water use is also a major contributing factor to aquifer overexploitation. And, third, surface water and groundwater are closely linked in most parts of the world, with groundwater discharge contributing to the base flow of streams and surface water contributing to groundwater recharge, and these interactions are intensified by human action, in particular water withdrawals for irrigated agriculture (Groundwater Governance 2016). Even in cases where irrigated agriculture depends mostly on surface water, groundwater impacts therefore need to be accounted for when assessing water conservation efforts (and vice versa).

A range of water conservation options and their relations to groundwater resources are considered in the seven papers. Four papers examine the conversion to more capital-intensive irrigation technologies, a popular and often subsidized intervention that increases the “efficiency” of irrigation water use on a field by reducing evaporation and “losses” from surface runoff or subsurface drainage. The effect of the intervention on water scarcity depends on the local context and the relative importance of the return flows for downstream uses, and thus requires careful assessments (Scheierling and Treguer 2016b). This also applies to the lining of leaky canals to achieve a higher conveyance efficiency, an intervention studied in another paper. Further interventions considered in the papers include limiting the cropping area and restricting groundwater pumping. The last paper explores approaches for assessing whether such interventions, especially those aimed at increasing on-farm irrigation efficiency and/or conveyance efficiency, contribute to the widely emphasized need for improving agricultural water productivity.

The seven papers incorporate the linkages of the policy and investment options to groundwater resources and their management in different ways. They range from recognizing the importance of the linkages and emphasizing the need for offsetting any negative impacts, to integrating hydrologic models in the economic analysis for an estimation of likely impacts, and to specifying targets for groundwater levels or, in the case of a stream–aquifer system, standards for instream flows that need to be met by the interventions.

Wang *et al.* examine farmers’ decisions to adopt irrigation technologies with higher irrigation efficiencies in the South Saskatchewan River basin in the state of Alberta, Canada, where surface water is the major water source for irrigation. Based on a farm survey, they use three econometric models to examine the extent and intensity of the adoption process, and the factors influencing the adoption decisions. The results indicate that obtaining information on irrigation technologies from other farmers, or farmer associations, and from extension agencies significantly influenced farmers’ adoption decisions. Receiving support services following the adoption decision significantly increased adoption intensity. The extent

and intensity of adoption were also higher for irrigators with a corporate farm structure, larger households, longer period of farm ownership, and higher degrees of education. The authors note that when interventions are undertaken to promote the adoption of more efficient irrigation technologies, it is important to include measures for offsetting possible increases in net consumptive use, and preventing return flow reductions as well as third party impacts through changes in surface and groundwater flows.

Msangi and Cline use an integrated economic model of agricultural production and groundwater usage to explore different policy interventions for reducing groundwater overdraft in the state of Maharashtra, India. The model is applied to an empirical example based on data from village-level surveys. Its agricultural component is a multi-input and multi-output model that is calibrated with the positive mathematical programming approach, and its hydrological component consists of a three-cell model of the hard-rock aquifer underlying the case study area. The authors illustrate the divergence between current myopic groundwater usage patterns and a dynamically optimal path that includes better demand-side management for stabilizing groundwater levels. They then explore policy alternatives for attaining the latter path, including not only a reduction in groundwater withdrawals but a concomitant reduction in crop consumptive use, while taking into account the current context of smallholder agriculture with limited groundwater governance. The authors find that the most feasible and practically implementable approach would be the imposition of limits on the cropping area.

In an effort to improve upon the conventional cost-benefit analysis of the US Bureau of Reclamation for water conservation infrastructure such as canal lining, Schmidt and Taylor develop an approach that recognizes and accounts for the resulting changes in hydrologic interactions between surface water and groundwater at the basin-wide level. The authors point out that seepage losses from Reclamation projects involving surface water have created or sustained aquifers extending over vast areas of western states, and allowed the issuance of many groundwater rights for private groundwater irrigation districts. Yet, canal lining is promoted and federally financed to deal with water shortages brought about by climate change, ignoring the value of canal seepage as a positive externality. Integrated hydrologic and partial equilibrium models with conjunctive use externalities are employed to show that, in the case of the Reclamation Boise Project in the state of Idaho, the foregone net benefit to non-Project groundwater irrigation resulting from the elimination of the canal seepage externalities would outweigh the increase in net benefit to Boise Project irrigation by canal lining.

Quintana Ashwell and Peterson explore the role of subsidies for more capital-intensive irrigation technologies in addressing the externalities arising from

common pool groundwater use. This includes a stock externality arising from pumping being constrained by the stock of groundwater, and a pumping externality arising from the groundwater stock affecting the cost of pumping at the margin. The effects of these externalities are found by comparing the optimal control solution to the myopic solution with competitive pumping. The authors develop a model of inter-temporal groundwater use with substitutable technology and apply it to a county in the state of Kansas, United States, overlying the Ogallala aquifers. They find that, without subsidies, the myopic solution yields an early period with underinvestment in efficiency-improving irrigation technology relative to the socially efficient solution, which is followed by a period of overinvestment. This suggests a potential role for subsidies to improve welfare over certain ranges of the state variables. The results also suggest that excessively efficient irrigation technologies may lead to increased use rather than the conservation of water, at least in certain periods of the resource's life cycle.

In order to help policy makers assess the effects of improvements to irrigation efficiency, Contor and Taylor combine existing concepts in a framework that allows the quantification of the resulting change in water flows at the basin-level — a necessary first step to evaluate impacts on ecosystem services, private user benefits and social equity, and to balance competing uses. The framework involves four sequential assessments: assessing the irrigator response, closing the water budget on the change in flows precipitated by the irrigator response, considering the economic rivalry relationships surrounding the change in flows, and quantifying changes in supply to all affected water users and uses. The authors discuss the conceptual relationships and provide an illustration. A basic finding is that an increase in consumptive use must be anticipated if irrigation efficiency is improved, even if water spreading and double cropping can be eliminated. Furthermore, a reduction in gross withdrawal does not of itself provide a supply of “new water”. Effects of improvements need to be evaluated to secondary levels and beyond to fully understand implications of a proposed change.

Speir, Han and Brozovic study alternative restrictions in irrigators' groundwater pumping in a stream-aquifer system in order to meet standards for instream flow on a daily basis. The authors present an optimization model with a hydrologic model of stream-aquifer interactions that allows the effects of groundwater pumping on streamflow to vary across space and over time. The optimization model includes two groundwater wells located at different distances to the stream, and minimizes lost profit to irrigators from imposing limits on groundwater quantity for each day over an irrigation season. Simulation results show that the more distant well has a smaller, but longer lived impact on streamflow. Incorporating this spatially variable time lag reveals that the optimal spatial and temporal distribution of groundwater

pumping differs depending on the specification of the streamflow constraints. More generally, the results show the importance of space and time lags in designing groundwater policy.

Finally, Scheierling, Treguer and Booker point out that while improving agricultural water productivity is widely seen as a critical response to address increasing water scarcity, and significant public and private investments are being made with this goal in mind, much of the public debate is vague on the meaning of agricultural water productivity — often emphasizing “more crop per drop” as if water were the only input that mattered — and on what should be done to improve it. The authors discuss conceptual issues that should be kept in mind when assessing agricultural water productivity, and present findings from what may be the first survey of the agricultural productivity and efficiency literature with regard to the explicit inclusion of water aspects in productivity and efficiency measurements. The survey includes studies applying single-factor productivity measures, total factor productivity indices and frontier models. A key finding is that the studies tend to either incorporate field- and basin-level aspects but focus only on a single input (water), or they apply multi-factor approaches but do not tackle the basin-level aspects. However, deductive methods may provide the flexibility to overcome some of the limitations of the other methods.

Research on the economics of agricultural water conservation, especially with the incorporation of linkages between conservation options and groundwater resources and their management, is an evolving field, and this special issues makes important contributions. As the papers suggest, growing availability of data — such as on the responses of irrigators to changes in water conditions or in the policy environment, and on the basin-wide interactions between surface water and groundwater — will allow the application of more advanced methods and improve the understanding of policy and investment options for conserving agricultural water and increasing its productivity. More efforts will have to be undertaken to carry out context-specific assessments of potential interventions that go beyond the field- or project level, not least to avoid interventions with counterproductive effects that increase agricultural water use and negatively affect downstream uses. Given the worsening water situation in many parts of the world, policy makers will need sound advice on policies and investments related to water use in irrigated agriculture.

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