Diffusion of Smart Irrigation Systems for Tackling Water-Energy-Food Nexus Challenges in the Indus Basin

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Abstract.

Irrigation is crucial for the well-being of an estimated 300 million people residing in the transboundary Indus River Basin (IRB) region of South Asia. At the same time, the IRB is severely water-stressed and irrigation is on average receiving 90-95% of total surface water allocations while depleting fossil groundwater reserves by more than 30 km^3 per year. Implementation of modern irrigation technologies such as sprinkler, drip, and canal lining and smart irrigation technologies such as soil moisture sensors, canal water monitoring meters and laser leveling demonstrated the huge potential for solving the water scarcity, access inequality problems, enhance resource efficiency, reduce inequalities and provide a backbone for accurate basin-wide water accounting. Yet, there is a lack of multi-sectoral analysis linking smart irrigation, regional cooperation and competing long-term sustainability objectives. Here, we apply an integrated model of the IRB's transboundary water, energy and agricultural sectors to assess how coordinated basin-wide water-energy management influences the multi-sector benefits of smart irrigation. Results indicate modern and smart irrigation technologies play an important role in improving upstream water availability by reducing the water application at the field level and how this interacts with energy and climate change targets aiming to reduce emissions together with improving energy access. The increased upstream water availability in the industrial and domestic sectors avoids expanded use of fossil groundwater and advanced water treatment, decrease the energy intensity in the agriculture sector, reduce the greenhouse gas emission, and can be utilized to produce more hydropower. Associated investment costs for the new irrigation technologies and approaches could pose a barrier to implementation for low-income farmers and local governments. The current study can play a vital role in understanding sustainable resources use investment costs, and the applied analytical methods can be adapted to other regions of the world with similar hydro-climatology.

Keywords: Smart Irrigation, Indus, Integrated Nexus Modeling.

Introduction

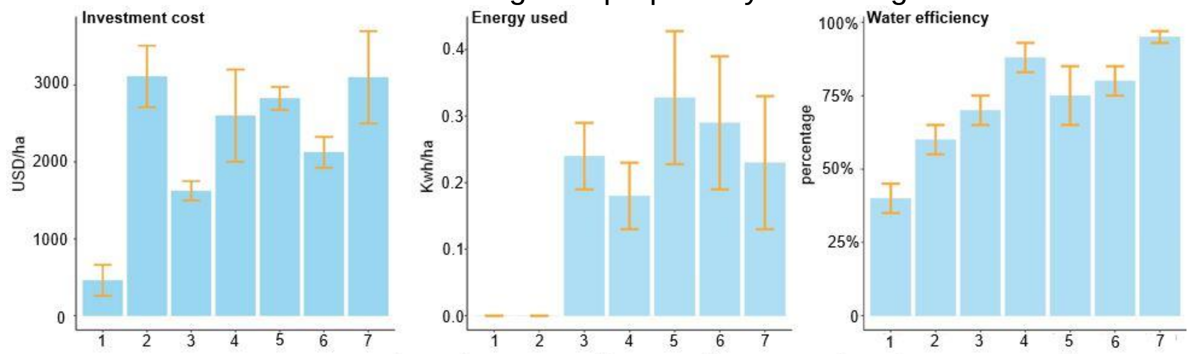
The Indus River is the twelfth largest river in the world and its basin area is about 1.13 million km^2 (Karki et al., 2011; Laghari et al., 2012) distributed among four countries including Pakistan, India, China, and Afghanistan. The IRB is home to about 300 million people and ranks among the largest basins in the world in terms of human dependence on irrigation diverted from the river water (Karki et al., 2011). The irrigation intensity of some part of the basin is more than 75 percent of the irrigated land under irrigation which ranks among the highest in the world (Mekonnen et al., 2016; Laghari et al., 2012). The Indus basin also has an unconfined and highly productive aquifer that augments the surface water supply by the pumped groundwater (Mekonnen et al., 2016; Qureshi, 2011). Despite implications for future water allocation, land-use and energy demands there are no pervious works assessing the impact of smart technology for agriculture water management in the IRB.

The focus of this study is to address the irrigation challenges by introducing modern and efficient irrigation technologies. This study contributes a new analysis of diffusion pathways for smart agriculture water technologies in the IRB using a nexus approach to map synergies and trade-offs for the water, energy and land sectors. Modernize irrigation technologies such as drip and sprinkler irrigation, improving leveling of the field, and canal lining considerably reduces the water application at the field level (Qureshi et al., 2010; Playa´n and Mateos, 2006). An increase in water use efficiency in irrigation sector actually saves some of the water from resources. This saved water can effectively solve the problems of domestic and industrial water use, will reduce groundwater extraction, decrease the energy, and reduce GHG emissions in the agriculture sector and can be utilized to produce more hydropower. The modeling framework is applied under alternative diffusion pathways to answer the following research questions: What are the potential impact of smart technologies and distributed policies on irrigation withdrawals and energy use in the IRB? How does the irrigation efficiency enable through smart technologies impact the cost of water supply for the downstream users in the IRB? What is the scale of investment needed to modernize the IRB's agriculture sector with smart technologies?

Materials and methods

We explore the interaction between long-term energy transformation, water conservation, crop yield to food production, land use, and climate change mitigation objectives with a linear systems-engineering optimization model: The NExus Solution Tool (NEST). The mathematical details and salient features of the model given in (Vinca et al., 2019; Wada et al., 2019). In order to incorporate the uncertainty in the investment decision, demand projection and model parameters the optimization framework applied across the number of scenarios.

All Irrigation technologies options incorporated in NEST model for analyzing the basin-wide impact shown in Figure 1. The data shown in Figure 1, collected from literature (Perry, 2011; Israelsen, 1932; Qureshi, 2011; Rizwan et al., 2018; Kahil et al., 2018; Bank, 2006). The model is consists of different commodities levels, the model boundaries define according to the historical freshwater supply data. The historical data of upstream outflow and surface runoff provide the water in rivers or canals that further diverted to the irrigation purpose by an average conversion factor.



Irrigation technologies options: [1]Flood, [2]Canal Lining, [3]Sprinkler, [5]Flood smart, [4]Drip, [6]Sprinkler smart, [7]Drip smart.

Figure 1. The irrigation technologies and parameters.

Preliminary results

We run a baseline (business as usual) versus a scenario with a basin wide reduction in freshwater availability. In reduction scenario, we implemented the constraint that reduced 25% of available freshwater as compare to water availability in the baseline scenario. As a result of the reduction in water the model finds a solution to use much less water in agriculture, this solution is largely deploying sprinkler and smart irrigation which shown in Figure 2. The Crop shift and smart irrigation technology penetrations scenarios also explored and will present in the future draft.

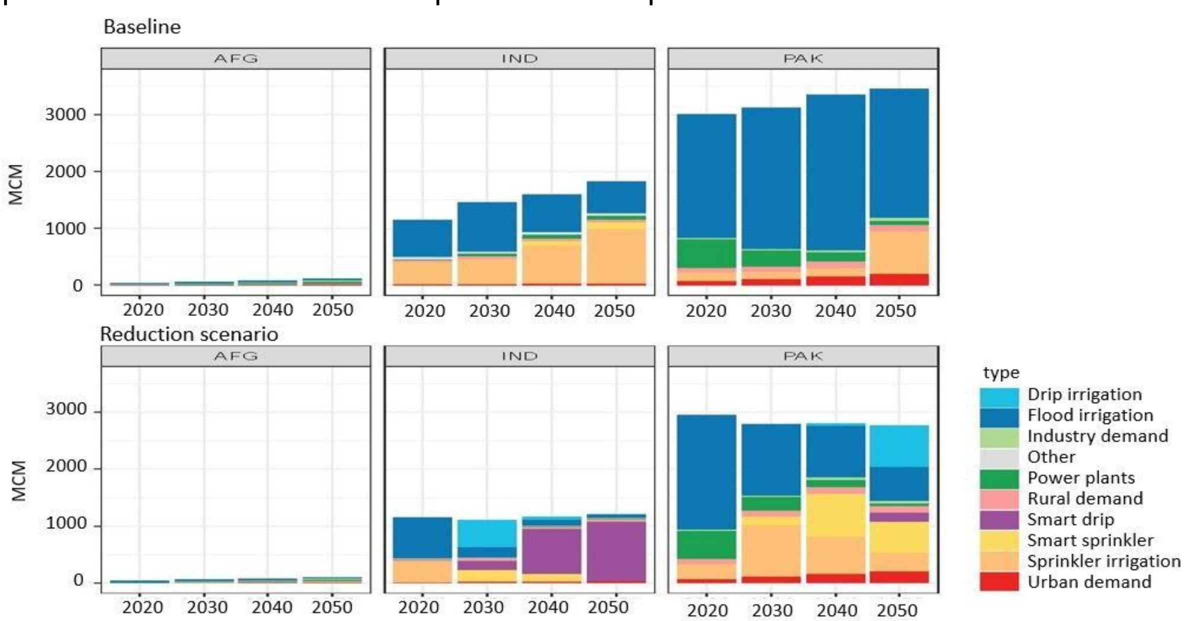


Figure 2. The water use by different technologies set under baseline and reduction scenario.

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