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An integrated modeling framework for assessing water-energy-land nexus solutions: Application to the Zambezi transboundary river basin

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Water demands for agricultural, domestic and industrial uses in many areas around the world are expected to increase substantially in the coming decades as countries attempt to sustain a larger population and more prosperous economy. At the same time, available surface and ground water resources are projected to remain at the present level or could even decline because of the climate change impacts, water quality degradation, and the increasing environmental flow requirements. As such, policymakers in vulnerable areas need to anticipate on how to adapt management practices to secure reliable future water supply that can meet the demands from different sectors. However, the choice of water management options is often associated with trade-offs across multiple water-related systems such as drinking water supply, food production, energy generation, and ecosystem services. An appropriate choice of these options requires the development of a system approach, depicting the biophysical and socioeconomic factors that determine the future dynamics of river basins, including the key interactions among water, energy, and agricultural systems.

As part of the Integrated Solutions for Water, Energy, and Land (ISWEL) project, this study presents an innovative integrated modeling framework that combines, in a consistent way, various sectoral models including a high-resolution global hydrological model (CWATM), a global land use model (GLOBIOM), a water quality model (MARINA), and a hydro-economic model (ECHO). The consistent linkage among the individual models, in terms of input data and processes, facilitates a more effective integrated optimization of water-energy-land nexus management solutions. This innovative modeling framework has been applied to the Zambezi basin, one of the largest river basins in Africa, covering an area of 1.4 million km2 spanning over eight countries. A set of socioeconomic and climate change scenarios based on combinations of the Shared Socioeconomic Pathways (SSPs), Representative Concentration Pathways (RCPs), and co-developed bottom-up policy scenarios, through stakeholders' engagement with the Basin Commission (ZAMCOM), have been utilized to simulate the integrated modeling framework. Results of this study show the effects of future climatic, socio-economic and policy changes on water supply, food production, and hydropower generation in the Zambezi basin. Moreover, the study identifies a broader solution space, which could help to achieve a more efficient utilization of water-energy-land resources, by taking advantage of synergies and overcoming tradeoffs. Overall, this study demonstrates the capacity of the proposed modeling framework as a system approach to address challenging issues related to the water-energy-land nexus.

Keywords: water-energy-land nexus, integrated modeling, scenarios, stakeholders' engagement, Zambezi basin