Economic costs of reducing unsustainable groundwater use: Application of IIASA global hydro-economic modeling framework

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Global water withdrawals for beneficial purposes have been increasing substantially in the last century, driven by the growth in population, food production, and income. The ensuing damages have been building up rapidly during recent years, with many basins around the world undergoing pervasive water scarcity conditions and progressive depletion of groundwater. Moreover, impacts of future climatic and socio-economic changes are projected to further exacerbate supply deficit in those basins. Therefore, the development of adaptation strategies to address growing water scarcity is needed. Groundwater resources are expected to play an important role and groundwater pumping will likely increase in the future to offset the declines in surface water availability and to provide a buffer against extreme drought events. However, groundwater resources are vulnerable to human activities and climatic conditions. For instance, aquifer systems in numerous regions around the world have been suffering considerable pressures during recent years, with extraction rates well above recharge. Intensive extractions have been brought about mainly by the adoption of low-cost pumping technologies and the supply of subsidized energy.

The damages from groundwater depletion on water and food security and ecosystem wellbeing could be substantial and irreversible, which call for the design of sustainable groundwater management policies. The design of policies requires quantitative tools for planning and policy evaluation that integrate biophysical, institutional, environmental, and economic metrics, reflecting decision-making objectives and processes. This study presents a global hydro-economic modeling framework developed at IIASA that represents water resource systems, infrastructure, management options and associated economic values in an integrated manner. The model is able to interact with existing global integrated assessment tools or global hydrological models. The model includes an economic-hydrologic optimization procedure that aims to balance water demand and supply at the level of large-scale river basins worldwide. The objective of the optimization is to minimize total costs of meeting water demands from agricultural, industrial and domestic sectors, subject to various technical and resource constraints. The optimization includes capacity expansion and is solved over a multi-decadal horizon. Sub-annual variability is incorporated at a monthly time-scale. The model can be used to simulate a variety of basin management decisions including resource extractions, inter-basin transfers, reservoir operation regimes, and water infrastructure investment. The model uses information on water demand and availability provided by existing global integrated assessment models and global hydrological models.

In this study, the model is used to evaluate the effects of different groundwater management policies (unlimited pumping vs. sustainable pumping) under future socio-economic and climatic scenarios (combinations of Shared Socio-economic Pathways (SSPs) and Representative Concentration Pathways (RCPs)). The model is applied to basins in the Middle East and North Africa (MENA) region which provides a challenging case study. However, the modeling framework is designed to be adaptable for any basin elsewhere. Model results show the economic and environmental tradeoffs among the different policy choices and the hurdles facing policies aimed at reducing unsustainable groundwater use. Specifically, our results suggest that addressing the redoubled challenge of adaptation to growing water scarcity and sustainable use of groundwater resources in the MENA region will require major investments in more efficient water use technologies and unconventional freshwater supply options, such as wastewater

recycling and desalination, with potential consequences on water supply costs, energy use and carbon emissions.

Keywords: Hydro-economic modeling, Water scarcity, Groundwater resources, Sustainable management, Policy tradeoffs

