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Hydro-economic modeling of conjunctive ground and surface water use to guide sustainable basin management

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Water demands for irrigation, urban and environmental uses in arid and semiarid regions continue to grow, while freshwater supplies from surface and groundwater resources are becoming scarce and are expected to decline with climate change. Policymakers in these regions face hard choices on water management and policies. Hydro-economic modeling is the state-of-the art tool that could be used to guide the design and implementation of sustainable water management policies in basins. The strength of hydro-economic modeling lies in its capacity to integrate key biophysical and socio-economic components within a unified framework. A major gap in developments on hydro-economic modeling to date has been the weak integration of surface and groundwater flows, based on the theoretically correct Darcy equations used by the hydrogeological community.

The modeling approach taken here is integrated, avoiding the single-tank aquifer assumption, avoiding simplified assumptions on aquifer-river linkages, and bypassing iterations among separate hydrological and economic models. The groundwater flow formulation used in this paper harnesses the standard finite difference expressions for groundwater flow and groundwater-surface water exchange developed in the USGS MODFLOW groundwater model. The methodological contribution to previous modeling efforts is the explicit specification of aquifer-river interactions, important when aquifer systems make a sizable contribution to basin resources. The modeling framework is solved completely, and information among the economic and hydrological components over all periods and locations are jointly and simultaneously determined.

This novel framework is applied to the Jucar basin (Spain), which is a good experimental region for an integrated basin scale analysis. The framework is used for assessing the impacts of a range of climate change scenarios and policy choices, especially the hydrologic, land use, and economic outcomes. The modeling framework integrates the multiple dimensions of water resources, allowing scenario results to provide reliable information to guide basin scale climate change adaptation policies. Sustainable water management requires policy analysis based on sound science, integrating the hydrologic, economic and environmental dimensions of basins.