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Simulation–optimization model for optimum water allocation between environmental and agricultural demand using a coupled WEAP-MODFLOW model: Application in Miyandoab plain, Urmia basin, Iran

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In this study, we developed a simulation-optimization model for optimum water allocation to meet environmental flow requirements and agricultural demand. The simulation model consists of three modules: a hydrologic module, an agronomic module, and an economic module. The hydrologic module is based on a dynamic coupling of WEAP and MODFLOW, and includes water balances for the crop root zone, the surface water system, and the underlying aquifer. The agronomic module simulates the effect of deficit irrigation on crop yield response in each growth stage, while the economic module calculates the net benefit of crop production. The optimization model contains two objective functions, one related to agricultural production and the other related to environmental flows. These conflicting objective functions are maximized using the Multi-Objective Particle Swarm Optimization algorithm. Decision variables include crop acreages, minimum environmental flow requirements in the river, and the degree of deficit irrigation. We applied the simulation-optimization model to the irrigated Miyandoab plain in the semi-arid northwest of Iran, for the historical period 1984 to 2013. There is competition between irrigation demands in the plain and environmental flow requirements to downstream Lake Urmia, which has been shrinking in recent years due to decreased inflows. Our results quantify what the (Pareto) trade-off looks like between meeting environmental and agricultural water demand in the region. We find that historical water allocations were suboptimal and that both agricultural and environmental benefits can be increased by better management of cropping decisions, deficit irrigation, and environmental flow requirements. We further show that increased groundwater use for irrigation can partly alleviate the trade-off, but that it leads to significant declines in groundwater levels due to the relatively small specific yield of the aquifer.