Nahid Jafari , Najmeh Mahjouri and Elahe Dartomi, 2026, A novel framework for robust seasonal groundwater banking in agricultural regions under deep uncertainty, *Agricultural Water Management*, 332, art. no. 110483.

Abstract Unregulated groundwater extraction in arid regions threatens environmental sustainability and food security. Groundwater banking has emerged as a key market-based tool to manage demand and mitigate seasonal water variability. However, existing planning frameworks often do not adequately address the deep uncertainties inherent in climate and market systems, particularly over seasonal timescales. To bridge this gap, this study develops a novel, integrated framework for designing robust seasonal groundwater banks under such deep uncertainty. First, a core hydro-economic market model is developed. This involves feasibility assessment, hydrogeological simulation, the establishment of sustainable and equitable seasonal water rights, and the estimation of user bid packages based on agricultural economics. This deterministic model provides the baseline optimal allocation and a benchmark objective function value. Then, robustness analysis based on Info-Gap Decision Theory (IGDT) is integrated with a seasonal hydro-economic market model to derive robust water allocation policies against deep uncertainties in water availability and crop prices. Following a socio-economic analysis that confirmed local farmers' risk-averse behavior, applying the framework for the Nough Plain in Iran generates a robust front of decision alternatives in the objectives' space. These alternatives are subsequently ranked using a multi-criteria method, namely, Measurement of Alternatives and Ranking according to Compromise Solution (MARCOS), systematically incorporating stakeholder preferences from farmers, environmental agencies, and water authorities. The optimal robust policy maintains system performance across seasons despite a 14.5% reduction in water availability and a 16.5% decrease in crop profit. Under this policy, farmers' profits remain 41% higher than those in the non-banking scenario. The proposed integrated framework provides a critical decision-support tool for establishing seasonal robust groundwater banks that are economically efficient, environmentally sustainable, and resilient to deep uncertainties.

Keywords Groundwater market, Robust optimization, Risk-informed strategies, Information Gap Decision Theory (IGDT), Agricultural-economic modeling