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Economic valuation of inter-annual reservoir storage in water resource systems

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Inter-annual reservoir operation in large-scale water resource systems has long been a challenge. Excessive release will threaten future supplies while unnecessary hedging creates economic hardship downstream. What's the appropriate amount of carry-over storage in reservoirs? The present study answers this question for complex large-scale water resource systems using economic valuation of end-of-year carry-over storage. The use of economic carry-over storage value functions (COSVFs) helps represent inter-annual inflow uncertainty within water resource optimization models. The proposed approach discretizes the full planning horizon to shorter periods (often a hydrological year) and performs sequential runs. The final state from the previous year provides the initial condition to each year-long problem and COSVF acts as a boundary condition representing the value of stored water for future use (beyond each optimized period). These COSVFs are quadratic to reflect the fact that the value of water increases when it is scarce and reservoir levels are low. COSVF parameters that maximize the inter-annual benefits from river basin operations (release/extraction and allocation) are optimally determined using an external multi-objective evolutionary algorithm (EA). Maximizing operated benefits is the main objective, but another objective is added to guarantee that the EA's outputs can be interpreted as COSVFs. This generalizable approach allows for determining the inter-annual release decisions, and it introduces a method for valuation of carry-over storage in water resources systems with non-convexity. The approach is applied to the California Central Valley water system with 30 reservoirs, 10 power plants, 22 aquifers, and 51 urban and agricultural demand sites. Head-dependent pumping costs make the optimization problem non-convex. Results show an improved scarcity management evidenced by a reduction of scarcity (80% in scarcity volume and 98% in scarcity costs) compared to a historical approximation. Groundwater results show how considering non-linear groundwater pumping costs in management models leads to reduced recommended overdrafting of aquifers. Obtained economic valuation of storage is helpful in informing water storage management decisions. Employing a multi-objective search algorithm provides the flexibility to consider more objectives.