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Using stochastic dynamic programming to support catchment-scale water resources management in China

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A hydro-economic modelling approach is used to optimize reservoir management at river basin level. We demonstrate the potential of this integrated approach on the Ziya River basin, a complex basin on the North China Plain south-east of Beijing. The area is subject to severe water scarcity due to low and extremely seasonal precipitation, and the intense agricultural production is highly dependent on irrigation. Large reservoirs provide water storage for dry months while groundwater and the external South-to-North Water Transfer Project are alternative sources of water.

An optimization model based on stochastic dynamic programming has been developed. The objective function is to minimize the total cost of supplying water to the users, while satisfying minimum ecosystem flow constraints. Each user group (agriculture, domestic and industry) is characterized by fixed demands, fixed water allocation costs for the different water sources (surface water, groundwater and external water) and fixed costs of water supply curtailment. The multiple reservoirs in the basin are aggregated into a single reservoir to reduce the dimensions of decisions. Water availability is estimated using a hydrological model. The hydrological model is based on the Budyko framework and is forced with 51 years of observed daily rainfall and temperature data. 23 years of observed discharge from an in-situ station located downstream a remote mountainous catchment is used for model calibration. Runoff serial correlation is described by a Markov chain that is used to generate monthly runoff scenarios to the reservoir. The optimal costs at a given reservoir state and stage were calculated as the minimum sum of immediate and future costs.

Based on the total costs for all states and stages, water value tables were generated which contain the marginal value of stored water as a function of the month, the inflow state and the reservoir state. The water value tables are used to guide allocation decisions in simulation mode. The performance of the operation rules based on water value tables was evaluated. The approach was used to assess the performance of alternative development scenarios and infrastructure projects successfully in the case study region.