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Using multi-objective robust decision making to support seasonal water management in the Chao Phraya River basin, Thailand

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A multi-objective robust decision making approach is demonstrated that supports seasonal water management in the Chao Phraya River basin in Thailand. The approach uses multi-objective optimization to identify a Pareto-optimal set of management alternatives. Ensemble simulation is used to evaluate how each member of the Pareto set performs under a range of uncertain future conditions, and a robustness criterion is used to select a preferred alternative. Data mining tools are then used to identify ranges of uncertain factor values that lead to unacceptable performance for the preferred alternative. The approach is compared to a multi-criteria scenario analysis approach to estimate whether the introduction of additional complexity has the potential to improve decision making.

Dry season irrigation in Thailand is managed through non-binding recommendations about the maximum extent of rice cultivation along with incentives for less water-intensive crops. Management authorities lack authority to prevent river withdrawals for irrigation when rice cultivation exceeds recommendations. In practice, this means that water must be provided to irrigate the actual planted area because of downstream municipal water supply requirements and water quality constraints. This results in dry season reservoir withdrawals that exceed planned withdrawals, reducing carryover storage to hedge against insufficient wet season runoff.

The dry season planning problem in Thailand can therefore be framed in terms of decisions, objectives, constraints, and uncertainties. Decisions include recommendations about the maximum extent of rice cultivation and incentives for growing less water-intensive crops. Objectives are to maximize benefits to farmers, minimize the risk of inadequate carryover storage, and minimize incentives. Constraints include downstream municipal demands and water quality requirements. Uncertainties include the actual extent of rice cultivation, dry season precipitation, and precipitation in the following wet season.

The multi-objective robust decision making approach is implemented as follows. First, three baseline simulation models are developed, including a crop water demand model, a river basin simulation model, and model of the impact of incentives on cropping patterns. The crop water demand model estimates irrigation water demands; the river basin simulation model estimates reservoir drawdown required to meet demands given forecasts of precipitation, evaporation, and runoff; the model of incentive impacts estimates the cost of incentives as function of marginal changes in rice yields. Optimization is used to find a set of non-dominated alternatives as a function of rice area and incentive decisions. An ensemble of uncertain model inputs is generated to represent uncertain hydrological and crop area forecasts. An ensemble of indicator values is then generated for each of the decision objectives: farmer benefits, end-of-wet-season reservoir storage, and the cost of incentives. A single alternative is selected from the Pareto set using a robustness criterion. Threshold values are defined for each of the objectives to identify ensemble members for which objective values are unacceptable, and the PRIM data mining algorithm is then used to identify input values associated with unacceptable model outcomes.