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Addressing the Chinese water challenges with hydroeconomic modelling

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Population growth and rapid development of the Chinese economy have increased water scarcity and put the natural water resources and aquatic ecosystems in the North China Plain under pressure. Dry rivers, decreasing groundwater tables and strongly polluted surface water are some of the consequences of this development. As a response, the Chinese authorities have launched 2011 No. 1 Central Policy Document, with the Three Red Lines setting strict targets related to water scarcity and water quality. These policy documents mark an important step towards sustainable management of the Chinese water resources. The targets are, however, highly coupled and attempts to meet all targets with uncoordinated regulation will therefore likely fail. Water allocation, groundwater pumping, hydropower production, wastewater treatment, river water quality, water for ecosystems and water diversion are all elements of one large coupled management problem, which underlines the need for decision support tools that can deal with water management in an integrated manner. A traditional stochastic dynamic programming (SDP) approach was used to minimize the basin-wide total costs arising from water allocation, water curtailment and water treatment. One-step-ahead sub-problems were solved for all combinations of discrete reservoir storage, Markov Chain inflow classes and monthly time steps. A water quality module to handle conservative pollutants, first order depletion and non-linear reactions was introduced. This compromised linearity of the objective function which was handled by outsourcing complicating decision variables to a genetic algorithm, which calls a linear program to determine the remainder of the decision variables. This hybrid formulation keeps the optimization problem computationally feasible and represents a flexible and customizable method. The proposed hydroeconomic optimization modelling approach has been applied to the Ziya River Basin, a part of Hai River in North China. The model provided valuable decision support, such as long-term optimal reservoir operation and optimal allocations to the water users. Finally, the model can also be used to assess costs of meeting constraints such as minimum water quality or to economically prioritize investments in waste water treatment facilities based on economic criteria. While the SDP-based model provides important decision support for the Ziya River Basin, the method scales poorly to more complex management problems with multiple state variables, e.g., reservoirs and aquifers. Future research will target this computational limitation by switching to a Model Predictive Control-based approach. This will allow inclusion of a more realistic representation of the system, e.g. delayed yield in agriculture along with multiple reservoirs, aquifers and water quality aspects.