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Simulation of operating rules and discretional decisions using a fuzzy rule-based system integrated into a water resources management model

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Water resources systems are operated, mostly, using a set of pre-defined rules not regarding, usually, to an optimal allocation in terms of water use or economic benefits, but to historical and institutional reasons. These operating policies are reproduced, commonly, as hedging rules, pack rules or zone-based operations, and simulation models can be used to test their performance under a wide range of hydrological and/or socio-economic hypothesis. Despite the high degree of acceptation and testing that these models have achieved, the actual operation of water resources systems hardly follows all the time the pre-defined rules with the consequent uncertainty on the system performance. Real-world reservoir operation is very complex, affected by input uncertainty (imprecision in forecast inflow, seepage and evaporation losses, etc.), filtered by the reservoir operator's experience and natural risk-aversion, while considering the different physical and legal/institutional constraints in order to meet the different demands and system requirements.

The aim of this work is to expose a fuzzy logic approach to derive and assess the historical operation of a system. This framework uses a fuzzy rule-based system to reproduce pre-defined rules and also to match as close as possible the actual decisions made by managers. After built up, the fuzzy rule-based system can be integrated in a water resources management model, making possible to assess the system performance at the basin scale. The case study of the Mijares basin (eastern Spain) is used to illustrate the method. A reservoir operating curve regulates the two main reservoir releases (operated in a conjunctive way) with the purpose of guaranteeing a high realiability of supply to the traditional irrigation districts with higher priority (more senior demands that funded the reservoir construction). A fuzzy rule-based system has been created to reproduce the operating curve's performance, defining the system state (total water stored in the reservoirs) and the month of the year as inputs; and the demand deliveries as outputs. The developed simulation management model integrates the fuzzy-ruled system of the operation of the two main reservoirs of the basin with the corresponding mass balance equations, the physical or boundary conditions and the water allocation rules among the competing demands. Historical information on inflow time series is used as inputs to the model simulation, being trained and validated using historical information on reservoir storage level and flow in several streams of the Mijares river. This methodology provides a more flexible and close to real policies approach. The model is easy to develop and to understand due to its rule-based structure, which mimics the human way of thinking. This can improve cooperation and negotiation between managers, decision-makers and stakeholders. The approach can be also applied to analyze the historical operation of the reservoir (what we have called a reservoir operation "audit").