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Simulation-Optimization Model of a Multi-Purpose Reservoir for Water Allocation and Irrigation Scheduling Under Diverse Hydrological Conditions

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The sustainable utilization of water resources entails an exhaustive perception of its components and complex interactions between them. Accordingly, applying suitable simulation techniques in order to achieve a more realistic analysis of water resources system is an unavoidable necessity in the modeling process. The overall aim of this study is to optimize water allocation to agricultural, municipal and environmental sectors under various weather conditions. So, the simulation-optimization model for a multi-purpose reservoir in southern Iran was developed. The model was broken down into the meteorological, hydrological, demand and optimization sub-models. In the meteorological sub-model, using daily time series of climatic data and FAO Penman-Monteith equation, reference evapotranspiration is computed. With respect to uncertainty in the hydrological parameters, rainfall, evapotranspiration, and inflow were considered to be stochastic. Hence, the hydrological sub-model selects the appropriate probability distribution function for aforementioned parameters. Then, by combining diverse probability levels of rainfall, evapotranspiration, and inflow, three hydrological conditions (dry, normal and wet) were specified. The demand sub-model contains agricultural, municipal, and environmental branches. In Iran's agricultural sector, more than 90% of the total water resources are consumed for irrigating farmlands, with usually low efficiency. Thus, by applying the hydrodynamic method and an accurate soil water balance equation, the farmland system was simulated. In order to assess the irrigation water productivity (IWP), full irrigation (FI) and deficit Irrigation (DI) scenarios were designed. In this investigation supplying municipal and environmental demands were put as the first priority. The optimization sub-model consists of the objective functions, the constraints, and the optimization algorithm. The first objective function evaluates the FI scenario that is an economic function based on crop-water production functions, production cost, and crop prices. The second objective function analyzes the DI scenario, which makes an equilibrium between the economic considerations and reservoir storage by applying relative net benefit (RNB) index. The proposed model is solved using co-evolutionary particle swarm optimization (CPSO) algorithm. Decision variables are cultivated area and deficit irrigation percentage for each crop. The results showed, under DI scenario by adopting each operational policy with RNB $\geq$1, all of the main factors such as annual net profit, the area under cultivation, and reservoir storage at the end of the water year increased in comparison to FI scenario. However, under dry hydrological condition due to the initial storage of the reservoir, storage enhancement approach must be intensified by choosing RNB$\leq$1. With decrement in RNB index that includes an uneconomical approach of reservoir operation, the model tends to maximize IWP at farmland level (on average 30% increase in comparison to FI scenario), minimize the total area under cultivation and consequently, reservoir storage will be increased. Finally, the model presents an optimal rule curve and irrigation scheduling, which can be used by reservoir operators and irrigation managers, respectively. The main advantage of the proposed model is that the input data are entered in a user-friendly Excel database and the outputs will be available in a separate file; therefore, it can be easily applied for different case studies.