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Holistic irrigation water management approach based on stochastic soil water dynamics

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Appreciating the essential gap between fundamental unsaturated zone transport processes and soil and water management due to low effectiveness of some of monitoring and modeling approaches, this study presents a mathematical programming model for irrigation management optimization based on stochastic soil water dynamics. The model is a nonlinear non-convex program with an economic objective function to address water productivity and profitability aspects in irrigation management through optimizing irrigation policy.
Utilizing an optimization-simulation method, the model includes an eco-hydrological integrated simulation model consisting of an explicit stochastic module of soil moisture dynamics in the crop-root zone with shallow water table effects, a conceptual root-zone salt balance module, and the FAO crop yield module. Interdependent hydrology of soil unsaturated and saturated zones is treated in a semi-analytical approach in two steps. At first step analytical expressions are derived for the expected values of crop yield, total water requirement and soil water balance components assuming fixed level for shallow water table, while numerical Newton-Raphson procedure is employed at the second step to modify value of shallow water table level.
Particle Swarm Optimization (PSO) algorithm, combined with the eco-hydrological simulation model, has been used to solve the non-convex program. Benefiting from semi-analytical framework of the simulation model, the optimization-simulation method with significantly better computational performance compared to a numerical Mote-Carlo simulation-based technique has led to an effective irrigation management tool that can contribute to bridging the gap between vadose zone theory and water management practice.
In addition to precisely assessing the most influential processes at a growing season time scale, one can use the developed model in large scale systems such as irrigation districts and agricultural catchments. Accordingly, the model has been applied in Dasht-e-Abbas and Ein-khosh Fakkeh Irrigation Districts (DAID and EFID) of the Karkheh Basin in southwest of Iran. The area suffers from the water scarcity problem and therefore the trade-off between the level of deficit and economical profit should be assessed. Based on the results, while the maximum net benefit has been obtained for the stress-avoidance (SA) irrigation policy, the highest water profitability, defined by economical net benefit gained from unit irrigation water volume application, has been resulted when only about 60% of water used in the SA policy is applied.