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Multi-objective analysis of the conjunctive use of surface water and groundwater in a multisource water supply system

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A multi-objective decision model has been developed to identify the Pareto-optimal set of management alternatives for the conjunctive use of surface water and groundwater of a multisource urban water supply system. A multi-objective evolutionary algorithm, Borg MOEA, is used to solve the multi-objective decision model. The multiple solutions can be shown to stakeholders allowing them to choose their own solutions depending on their preferences.

The multisource urban water supply system studied here is dependent on surface water and groundwater and located in the Algarve region, southernmost province of Portugal, with a typical warm Mediterranean climate. The rainfall is low, intermittent and concentrated in a short winter, followed by a long and dry period. A base population of 450 000 inhabitants and visits by more than 13 million tourists per year, mostly in summertime, turns water management critical and challenging. Previous studies on single objective optimization after aggregating multiple objectives together have already concluded that only an integrated and interannual water resources management perspective can be efficient for water resource allocation in this drought prone region.

A simulation model of the multisource urban water supply system using mathematical functions to represent the water balance in the surface reservoirs, the groundwater flow in the aquifers, and the water transport in the distribution network with explicit representation of water quality is coupled with Borg MOEA. The multi-objective problem formulation includes five objectives. Two objective evaluate separately the water quantity and the water quality supplied for the urban use in a finite time horizon, one objective calculates the operating costs, and two objectives appraise the state of the two water sources – the storage in the surface reservoir and the piezometric levels in aquifer – at the end of the time horizon. The decision variables are the volume of withdrawals from each water source in each time step (i.e. reservoir diversion and groundwater pumping).

The results provide valuable information for analysing the impacts of the conjunctive use of surface water and groundwater. For example, considering a drought scenario, the results show how the same level of total water supplied can be achieved by different management alternatives with different impact on the water quality, costs, and the state of the water sources at the end of the time horizon. The results allow also the clear understanding of the potential benefits from the conjunctive use of surface water and groundwater thorough the mitigation of the variation in the availability of surface water, improving the water quantity and/or water quality delivered to the users, or the better adaptation of such systems to a changing world.