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A decomposition approach for optimal management of groundwater resources and irrigated agriculture in arid coastal regions

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For ensuring an optimal sustainable water resources management in arid coastal environments, we develop a new simulation based integrated water management system. It aims at achieving best possible solutions for groundwater withdrawals for agricultural and municipal water use including saline water management together with a substantial increase of the water use efficiency in irrigated agriculture. To achieve a robust and fast operation of the management system, it unites process modelling with artificial intelligence tools and evolutionary optimisation techniques for managing both, water quality and water quantity of a strongly coupled groundwater-agriculture system. However, such systems are characterized by a large number of decision variables if abstraction schemes, cropping patterns and cultivated acreages are optimised simultaneously for multiple years. Therefore, we apply the principle of decomposition to separate the original large optimisation problem into smaller, independent optimisation problems which finally allow for a faster and more reliable solution. At first, within an inner optimisation loop, cropping patterns and cultivated acreages are optimised to achieve a most profitable agricultural production for a given amount of water. Thereby, the behaviour of farms is described by crop-water-production functions which can be derived analytically. Secondly, within an outer optimisation loop, a simulation based optimisation is performed to find optimal groundwater abstraction pattern by coupling an evolutionary optimisation algorithm with an artificial neural network for modelling the aquifer response, inclusive the seawater interface. We demonstrate the decomposition approach by an exemplary application of the south Batinah region in the Sultanate of Oman which is affected by saltwater intrusion into a coastal aquifer system due to excessive groundwater withdrawal for irrigated agriculture. We show the effectiveness of our methodology for the evaluation and optimisation of different irrigation practices, crop pattern and abstraction scenarios in order to achieve sustainable solutions for the agricultural management at farm and regional level in respect of the water resources. Due to contradicting objectives like profit-oriented agriculture vs. aquifer sustainability a multi-criteria optimisation is performed.