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Multi-objective optimisation for a sustainable groundwater resources and agricultural management in arid coastal regions

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The scarcity of freshwater in coastal arid regions, coupled with an ongoing population growth, makes optimal water management crucial. Excessive use of groundwater for irrigation in agriculture puts those regions at risk of saltwater intrusion which limits the agricultural opportunities. To solve these problems, a simulation based integrated water management system has been developed to ensure a long-term profitable and sustainable water resources and agricultural management. Within the system, a groundwater module, assessing the water resources availability, and an agricultural module, controlling irrigation and cultivation, are connected in an optimisation module, optimising the water management. To reduce the computational complexity of the optimisation procedure, surrogate models are applied which describe the behaviour of the groundwater and agriculture process models regarding the most relevant variables for management. Furthermore, the optimisation problem is decomposed into a two-step optimisation. An analytical inner optimisation estimates irrigation practices and crop patterns, while an outer evolutionary optimisation algorithm determines the overall water abstraction scenarios, based on results of the inner optimisation. By these two features, consequent surrogate model application and decomposition of optimisation, the computational complexity of the optimisation problem is reduced considerably, allowing the consideration of specific regional and temporal aspects in the management tool.
The methodology is demonstrated 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. Due to contradicting objectives like profit-oriented agriculture vs. aquifer sustainability, multi-objective optimisation is performed. Optimisation runs for different simulation periods and management strategies show that a primarily profit oriented water management leads to financial losses in the long run. For long-term sustainability, especially in regions close to the coast, a conservative abstraction of water is essential, otherwise salt water intrusion leads to decreasing profits at a long run.