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Coupling agricultural and hydrological models for improved management of groundwater irrigation under climate change

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The agriculture in tropical arid and semi-arid regions mainly depends upon the irrigation, especially in the non-monsoon season. In case of upland areas groundwater is the major source of irrigation. To meet the food demand for growing population, the stress on the groundwater reservoir is increasing, which is resulting in the depletion of groundwater level. The increase in the irrigation will increase the crop production, but will deplete the groundwater levels. There is a need to find optimal irrigation which can produce maximum crop production with an irrigation in equilibrium with the mean recharge. Climate change is expected to rise temperature and bring more intense spells of rain, and decrease the number of rainy days, which results in changes in the groundwater irrigation needed for the optimal crop production and sustainable groundwater level.

To understand the effect of the irrigation on the crop yield and groundwater level an integrated modelling of crop and groundwater levels is developed. This study presents one such approach by one way coupling between STICS crop model and a lumped groundwater model applicable at the plot scale. A multi-objective optimization is formulated to optimize the crop yield and to find sustainable groundwater level. This formulation allows a comprehensive evaluation of the trade-off between different crop yields and sustainable groundwater levels. The concept of Pareto dominance is used to solve the multi-objective optimization problem and derive Pareto-optimal irrigation. The uncertainty in the parameters of crop and groundwater model results in the uncertainty in the optimal Pareto front. The uncertainty in the optimal Pareto is derived using the concept of Generalized Likelihood Uncertainty Estimate (GLUE). The effect of climate change on the Pareto front is evaluated by considering three scenarios: (i) rise in temperature, (ii) increase in intensity of rain, and (iii) decrease in number of rainy days.

The proposed modelling framework is illustrated by applying it to non-monsoon Maize (Zea mays L.) crop in a plot (approximately one hectare) in AMBHAS site (www.ambhas.com) during 1992-2007. The study area lies in a gneissic aquifer and has semi-arid climate settings. The coupled model is calibrated using the observed data of maize yield and ground water levels. These estimated parameters along with their uncertainty are used to simulate the effects of irrigation on the crop yield and on the groundwater levels. Then the analysis is carried out by considering the three scenarios of climate change. Though the method is applied on a plot scale, it is generic enough to be applied at catchment scale by distributing STICS model and coupling it with a groundwater model such as MODFLOW.