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Impact of data quality and quantity and the calibration procedure on crop growth model calibration

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Crop growth models are a commonly used tool for impact assessment of climate variability and climate change on crop yields and water use. Process-based crop models rely on algorithms that approximate the main physiological plant processes by a set of equations containing several calibration parameters as well as basic underlying assumptions. It is well recognized that model calibration is essential to improve the accuracy and reliability of model predictions. However, model calibration and validation is often hindered by a limited quantity and quality of available data. Recent studies suggest that crop model parameters can only be derived from field experiments in which plant growth and development processes have been measured. To be able to achieve a reliable prediction of crop growth under irrigation or drought stress, the correct characterization of the whole soil-plant-atmosphere system is essential. In this context is the accurate simulation of crop development, yield and the soil water dynamics plays an important role.

In this study we aim to investigate the importance of a site and cultivar-specific model calibration based on experimental data using the SVAT model Daisy. We investigate to which extent different data sets and different parameter estimation procedures affect particularly yield estimates, irrigation water demand and the soil water dynamics. The comprehensive experimental data has been derived from an experiment conducted in Germany where five irrigation regimes were imposed on cabbage. Data collection included continuous measurements of soil tension and soil water content in two plots at three depths, weekly measurements of LAI, plant heights, leaf-N-content, stomatal conductivity, biomass partitioning, rooting depth as well as harvested yields and duration of growing period.

Three crop growth calibration strategies were compared: (1) manual calibration based on yield and duration of growing period, (2) manual calibration based on yield, biomass partitioning, LAI, plant height, rooting depth and duration of growing period, as well as an (3) automated calibration using the AMALGAM optimization algorithm and Pareto front analysis based on the data listed in (2). Three different calibration strategies have been applied for the estimation of the parameters of the soil hydraulic property functions: (1) using pedotransfer functions based on soil texture data derived from soil sampling (2) using a laboratory evaporation method for the determination of pF-curves and unsaturated hydraulic conductivity (HYPROP), and (3) inverse estimation by multiobjective optimization and Pareto front analysis using the AMALGAM algorithm based on time series of soil moisture in three soil depths.

The results show that simulations of yield and soil water dynamics can simultaneously be improved if the data quantity used for calibration increases (from strategy 1 to 3). The study quantifies the impacts of different model calibration procedures and data input on the modeling results. Even though parameter estimation using an multi-objective optimization algorithm is computationally demanding, it enhances the accuracy of model predictions and thus the overall reliability of the modeling results. To estimate climate change impacts based on crop growth modeling, we suggest a proper model calibration based on the simultaneous estimation of soil hydraulic parameters, crop phenology, growth and yield-related parameters using comprehensive experimental data.