Assessment of climate change impact on mid-century wheat production in Germany using multi-model-ensembles

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Process-based crop simulation models (CSM) serve as valuable tools to assess potential crop production under future climate conditions. They support the development and evaluation of suitable adaptation strategies in crop management to address future risk factors like increased temperature and altered precipitation patterns. The use of a multi-model-ensemble (MME) approach in crop modelling can increase simulation robustness compared to single model outputs. This study aims to assess mid-century mean yield development and yield stability of winter wheat (*Triticum aestivum*) under different climate scenarios for important wheat production regions in Germany.

We use the three wheat crop models CERES, CROPSIM and Nwheat embedded in the Decision Support System for Agrotechnology Transfer (DSSAT). This enables depiction of the CSM-specific uncertainties in addition to the climate model-related uncertainties allowing a more robust evaluation of potential future wheat yields. After cultivar-specific calibration and evaluation of the three models to fitting observed and simulated phenology, growth and yield parameters, we simulate yields in 2031-2060 and the reference period 1971-2000 using daily weather data of the 17 climate scenarios of the core ensemble of the German weather service. In addition, the simulations for 2031-2060 are performed with constant mean CO_2-level of 1971-2000 in order to quantify and evaluate the CO_2 fertilization effect on future yield development. These virtual experiments are executed for a range of representative wheat production sites that cover the multitude of soil types and climate conditions present in Germany.

We see that for all sites and climate scenarios the multi-model-ensemble projects higher yields in the future than in the past, with a mean yield increase of around 12% for RCP2.6 and RCP4.5 up to 15% for RCP8.5. Most of the projected yield increase is driven by the increasing atmospheric CO_2 concentrations, which are highest under RCP8.5 and lowest under RCP2.6. The results show that the yield advances due to the CO_2 fertilization effect are likely going to decrease in future. This indicates that other, non CO_2-related climatic changes (i.e., temperature, precipitation) are going to excerpt an increasingly negative impact on future yield formation of winter wheat. The study demonstrates the potential and necessity of using MME both, with regard to climate change scenarios and crop models, especially when intended for policy advice.