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Effects of temperature and water stress on agricultural productivity in a semi-arid irrigation system under changing climate

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The study focuses on the assessment of climate change impacts on the water balance and agricultural productivity in a semi-arid, meso-scale irrigation system, in Punjab, Pakistan.

To simulate potential future water balance changes in our intensively irrigated agricultural study area, we chose the widely used Soil & Water Assessment Tool (SWAT) model software. Using the SWAT model, we were able to incorporate detailed irrigation management strategies into the analysis, and to account for spatially distributed plant physiognomic dynamics and their effects on the local water balance.

Climate change data is taken from the Coordinated Regional Climate Downscaling Experiment (CORDEX; www.cordex.org), which provides a suite of regional climate projections based on Global Climate Models of the Coupled Model Intercomparison Project, Phase 5 (CMIP5). We take into account medium (RCP 4.5) and high (RCP 8.5) greenhouse gas emission scenarios from the IPCC - Fifth Assessment Record (AR5) and study their short (until 2030) and medium term (until 2050) impacts.

The assessment shows the following interesting results regarding climate change impacts on future agricultural productivity in our study area:

- Temperature stress on plant growth will increase significantly
- A substantial reduction in future summer crop yields can be expected
- Temperature stress induces the reduction of biomass production, which causes a decrease in transpiration and hence a decrease in actual evapotranspiration
- Reduced transpiration counteracts the temperature-induced increase in potential evapotranspiration, which leads to surprisingly low increases in future irrigation water demand despite the significant warming
- Temperature stress related adaption strategies (e.g. more heat tolerant crops) are under these circumstances more important than increasing irrigation efficiency
- Even though overall changes in water demand are surprisingly low, higher pressures on surface water and groundwater resources can be expected due to changes in plant growing cycles: Future temperature patterns are expected to speed up the plant growing cycle and increase

irrigation demands during the early growing stages. In our study area, this alters the share of irrigation water supply sources (i.e. rain, surface water and groundwater) and leads to higher demands of surface water and particularly groundwater resources, while rainfall contributions decrease.

The study discusses the above mentioned climate change impacts and their interaction. It focuses on the importance of temperature vs. water stress, and elaborates on their implications for potential climate adaption strategies.