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

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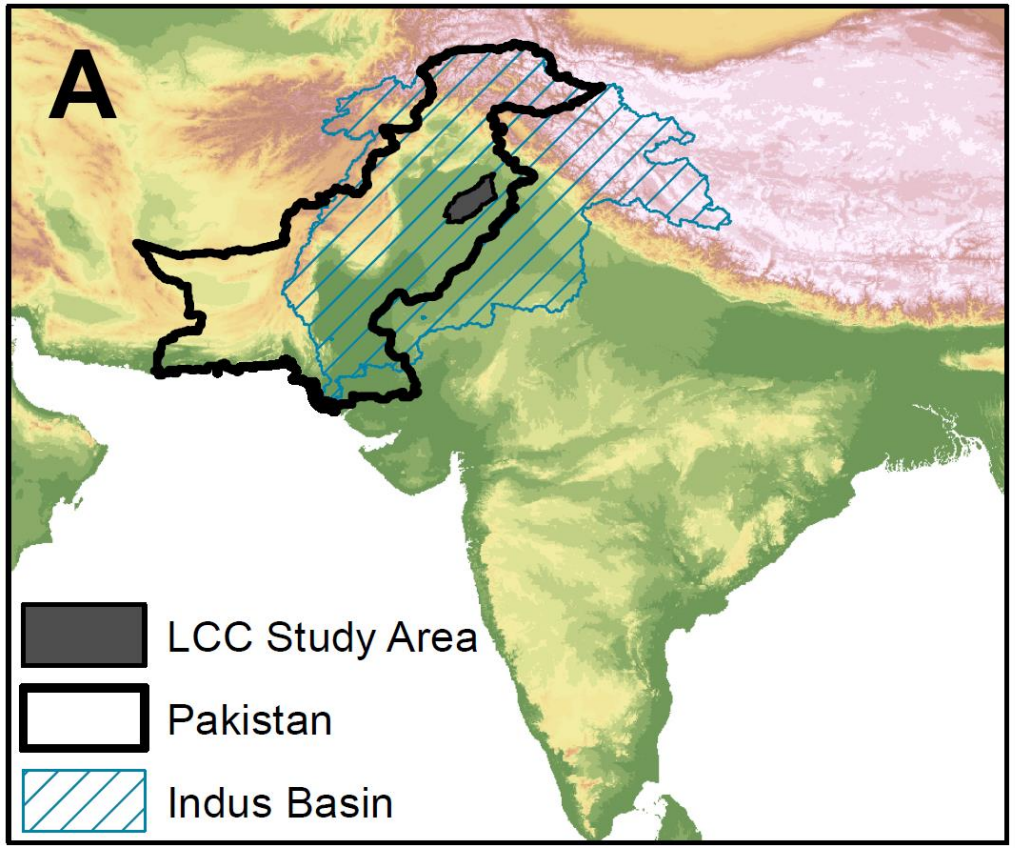
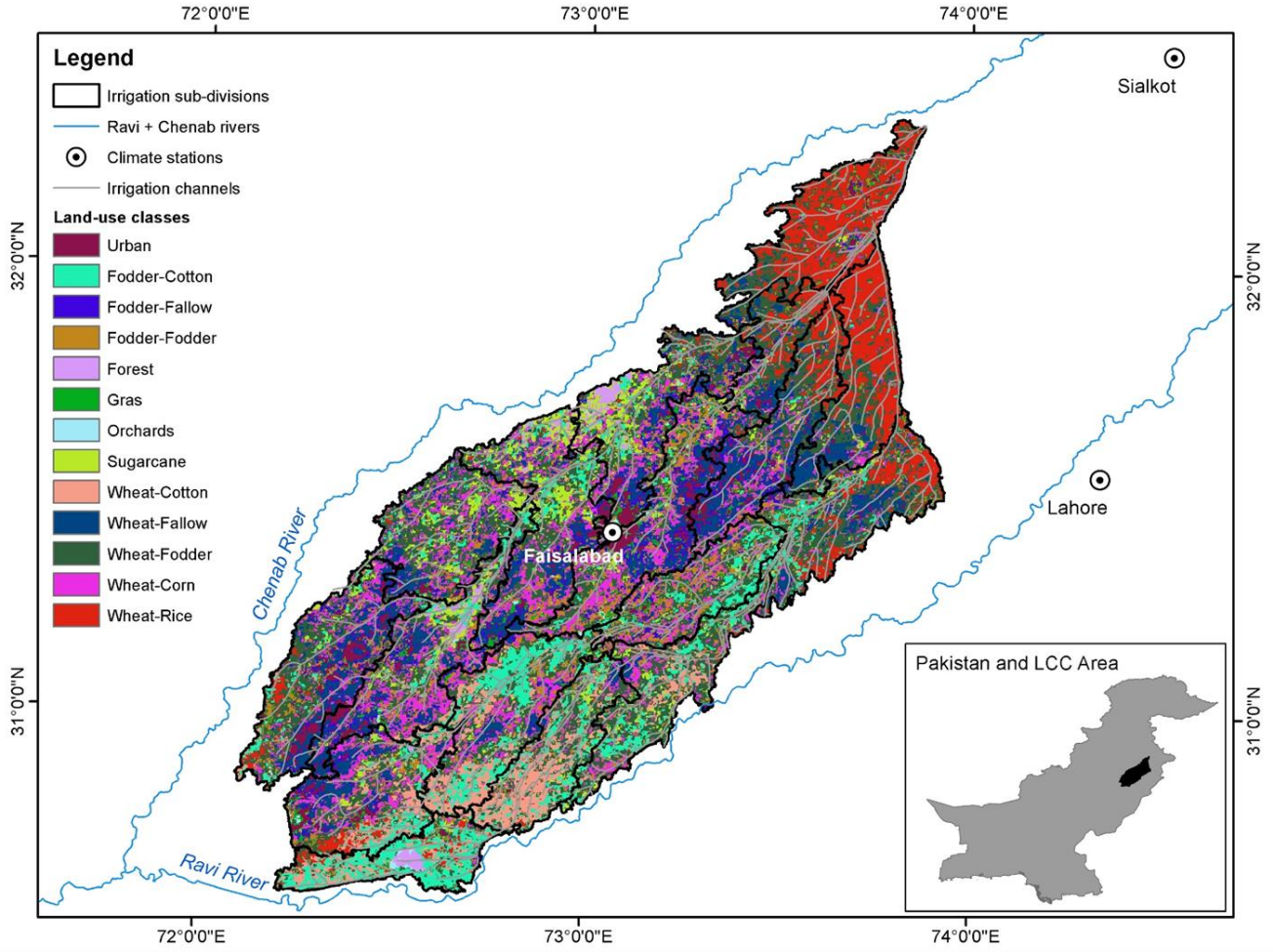
Background

- Study area is a semi-arid, meso-scale irrigation system in Punjab, Pakistan.
- The Soil & Water Assessment Tool (SWAT) was used to simulate potential future water balance and yield changes.
- As Climate Change data we used CORDEX (CMIP5) for RCP 4.5 and RCP 8.5 to study short (until 2030) and medium term (until 2050) impacts.

Study Area

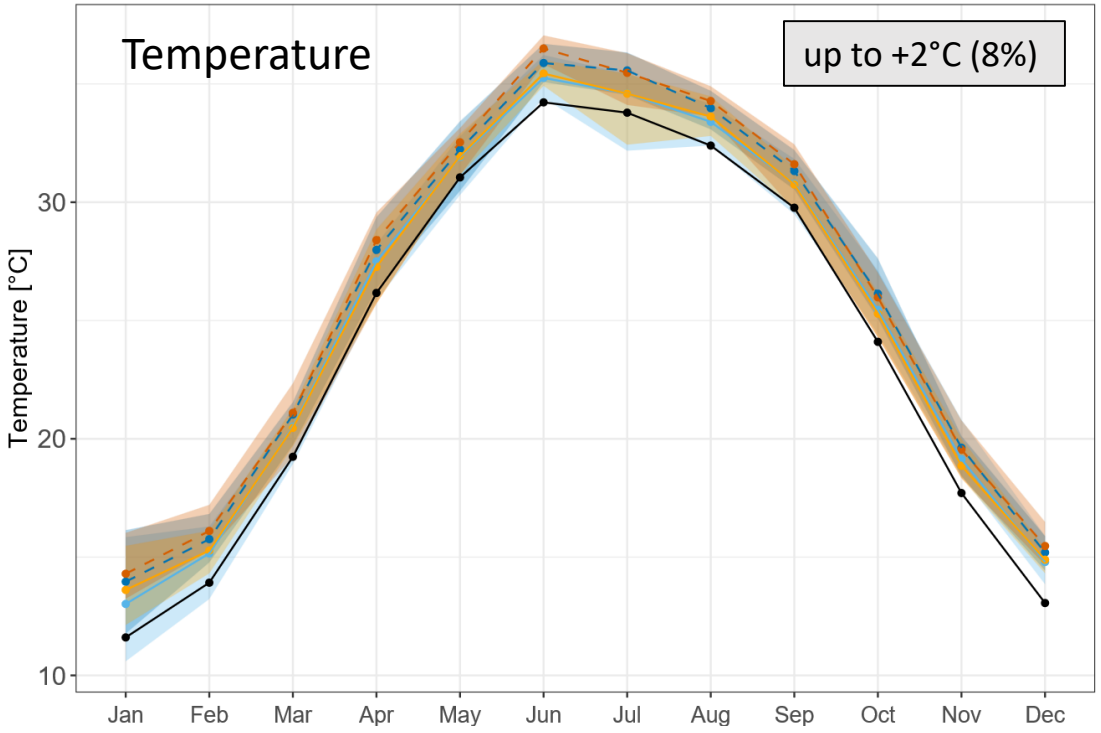

A
LCC Study Area
Pakistan
Indus Basin

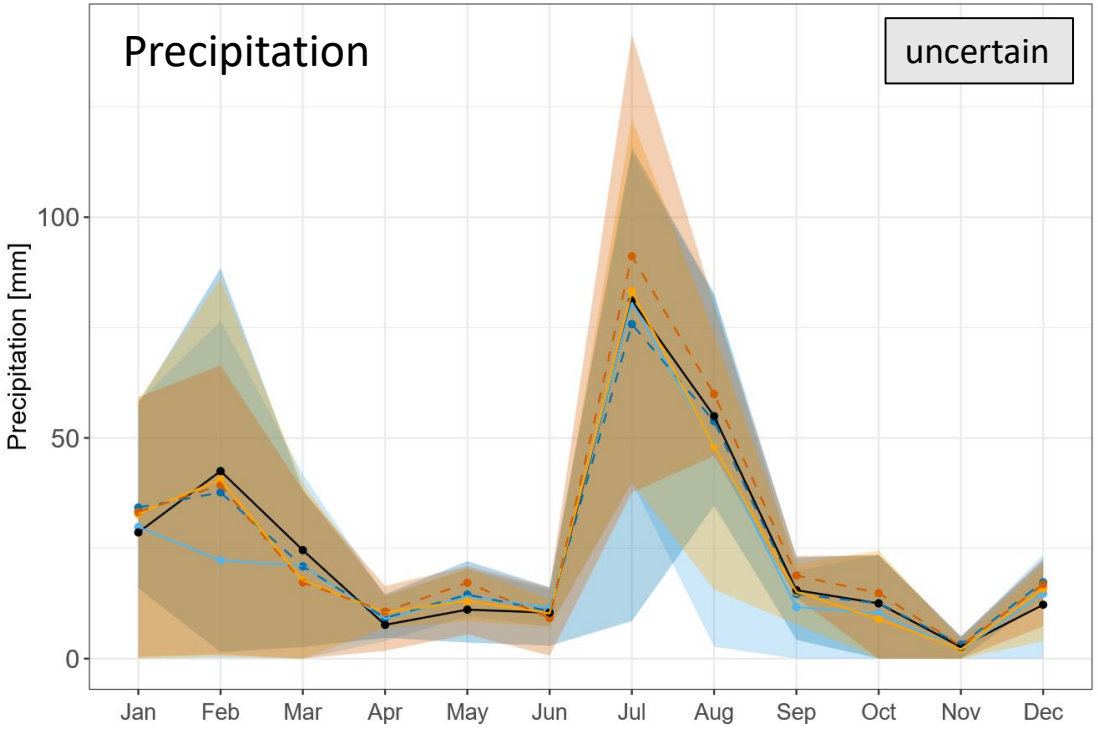

72°0'0"E
73°0'0"E
74°0'0"E
32°0'0"N
31°0'0"N
Legend
Irrigation sub-divisions
Ravi + Chenab rivers
Climate stations
Irrigation channels
Land-use classes
Urban
Fodder-Cotton
Fodder-Fallow
Fodder-Fodder
Forest
Gras
Orchards
Sugarcane
Wheat-Cotton
Wheat-Fallow
Wheat-Fodder
Wheat-Corn
Wheat-Rice
Sialkot
Lahore
Faisalabad
Chenab River
Ravi River
Pakistan and LCC Area

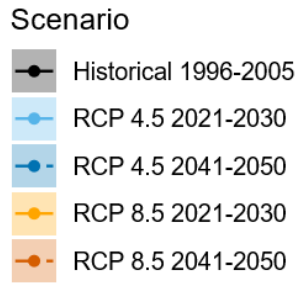
Research questions

- Q1: How are temperature and water stress controlling future water demand in agriculture (in our study area) ?
- Q2: What are counter-acting effects of temperature and water stress?
- Q3: How can we use the results for better adaption strategies to Climate Change?

Future Climate Patterns



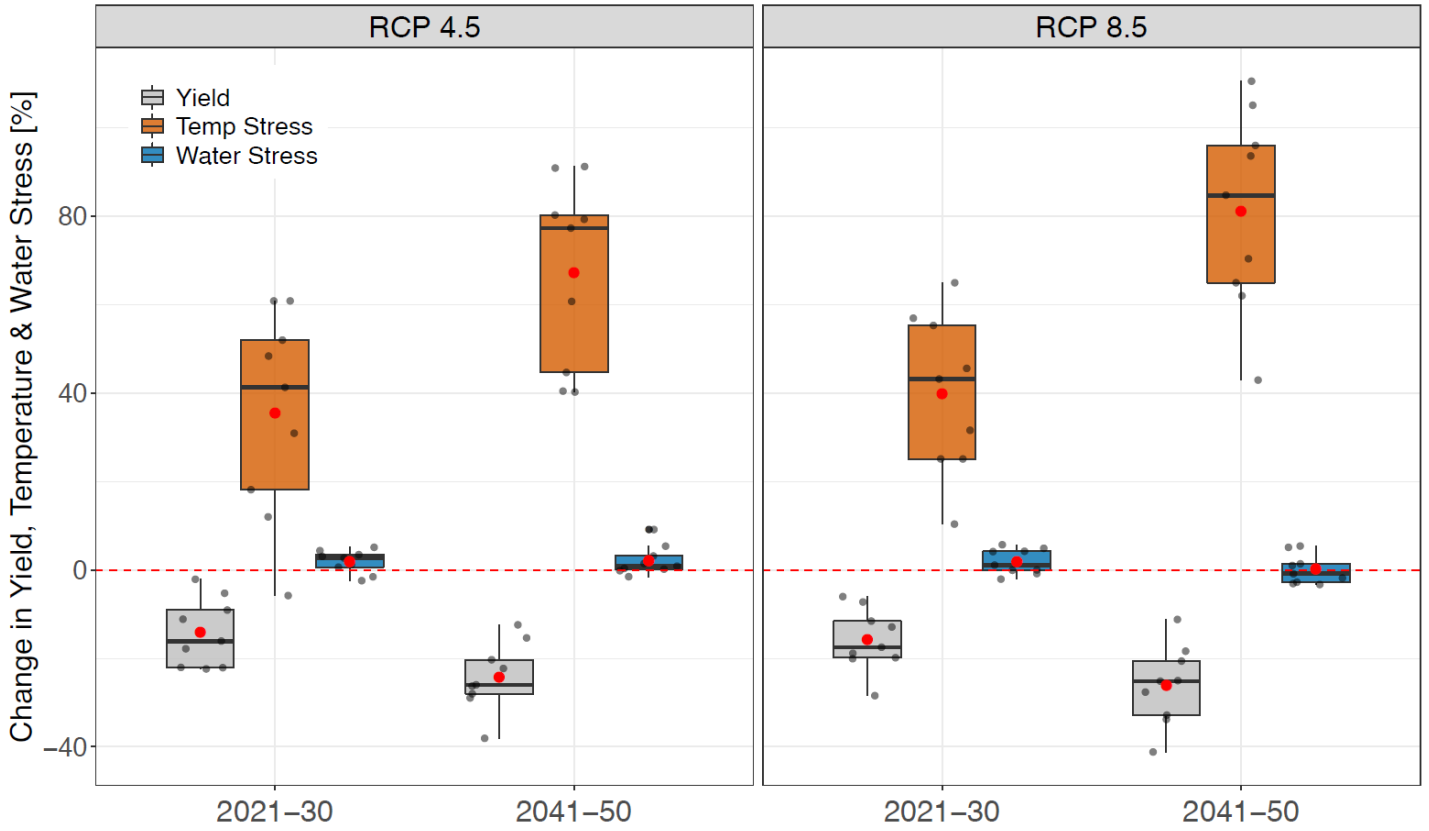




- Significant ***increase in temperature***
- Strongest increase under RCP 8.5 (2041-2050)

- ***Uncertain precipitation*** signals

Agricultural Productivity



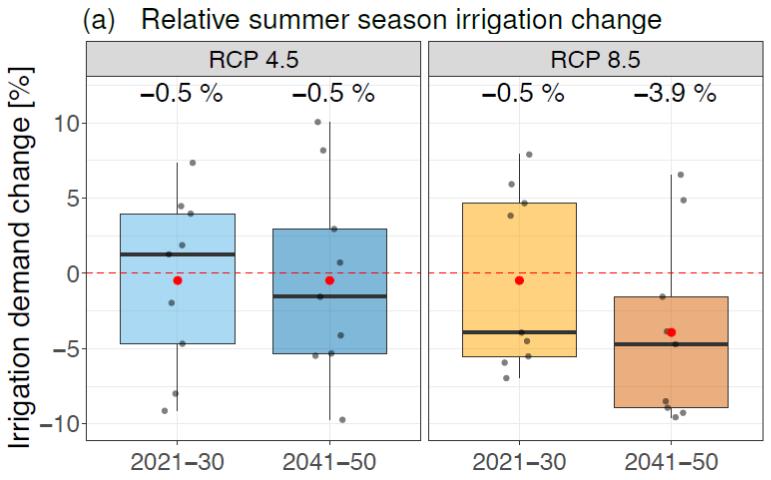
The results show substantially decreasing yield levels (-26% ± 9%) under future climate scenarios and significantly increasing temperature stress, while water stress is kept low. Nutrient stress is also kept minimal.

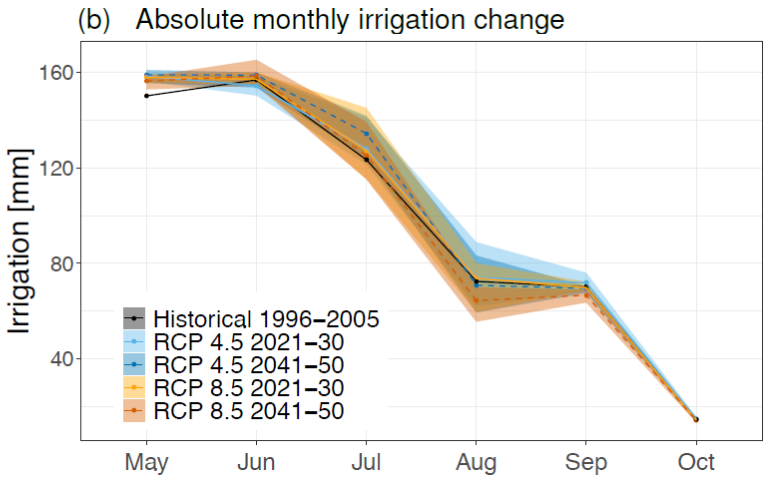
Heat stress is in this intensively irrigated study area the main driver of yield decline

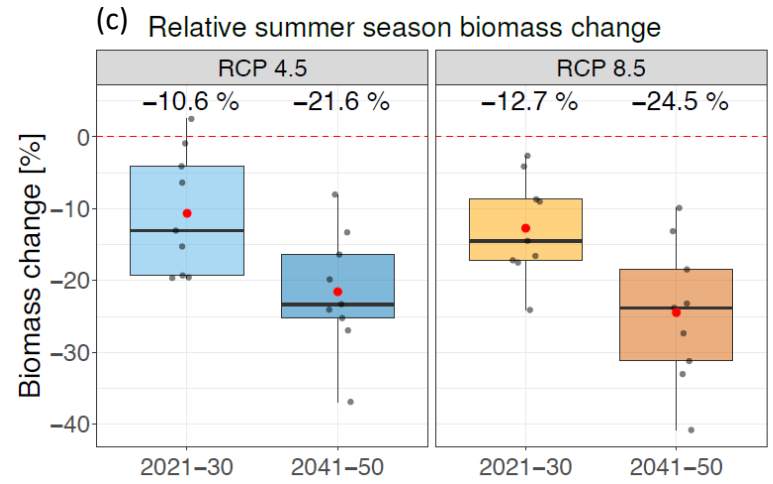
Water Demand and Plant Growth

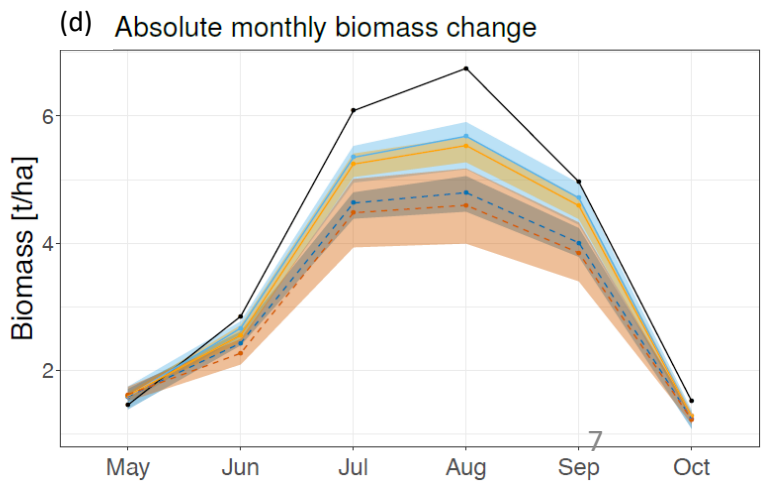
The simulations show surprisingly low changes in irrigation water demand and significant decreases in biomass production, as well as Leaf Area Indices (not shown here)

Temperature stress leads to a reduction in biomass production which is strong enough to reduce irrigation demand









Key findings:

- Temperature stress on plant growth will increase significantly
- A substantial reduction in yield can be expected
- ***Temperature stress induces the reduction of biomass production (and LAI), which is strong enough to cause a decrease in transpiration and hence a decrease in plant water demand***
- Temperature stress related adaption strategies (e.g. more heat tolerant crops) are under these circumstances more important than increasing irrigation efficiency

Research questions answered

- **Q1: How are temperature and water stress controlling future water demand in agriculture (in our study area) ?**
  - Temperature stress is the dominating stress factor which controls plant growth and therefore water demand
  - Increasing temperatures will not lead to expected increase in water demand
- **Q2: What are counter-acting effects of temperature and water stress?**
  - A strong decrease of plant growth due to temperature stress will counteract the increase in water demand due to temperature stress
- **Q3: How can we use the results for better adaption strategies to Climate Change?**
  - The separation of temperature stress and water stress is important to define optimal adaption strategies
  - Increasing irrigation intensities cannot mitigate the yield reduction due to Climate Change
  - Temperature stress related adaption strategies (e.g. more heat tolerant crops) are under these circumstances more important than higher irrigation intensities

Thank you for reading!

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