Trends of weather-related impacts on Austrian crop production under changing climate

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1. Objective of this study

Higher temperatures, changing precipitation patterns and more severe and frequent extreme weather events will significantly affect weather-sensitive sectors, especially agriculture. Weather-related risks can affect crop growth and yield potentials directly (e.g. heat, frost, drought) and indirectly (e.g. through biotic factors such as pests). Due to climate change, severe shifts of cropping risks may occur, where farmers need to adapt effectively and in time to increase the resilience of existing cropping systems. Therefore, the development of sound adaptation and mitigation strategies towards a "climate-intelligent agriculture" is crucial to improve the resilience of agricultural systems to climate change and increased climate variability. Within the project AGROFORECAST a set of weather-related risk indicators and tailored recommendations for optimizing crop management options are developed and tested for various forecast or prediction lead times (short term management: 10 days - 6 months; long term strategic planning: climate scenarios) to better inform farmers of upcoming weather and climate challenges. In this poster, the first results of long-term weather-related impacts on Austrian crop production under past (1980-2020) and future periods (2035-2065) are presented.

2. Material and methods

Various agro-climatic risk indicators and crop production indicators are analysed for two time periods in selected case study regions using two models. The calculation of the agro-climatic indicators (Tab 1) is carried out with the existing model AGRICLIM and the GIS-based software ARIS, which was developed to estimate the effects of adverse weather conditions on crops. The crop growth model AquaCrop is used for the analysis of soil-plant water balance parameters, crop yields and future crop water demand.

Models	Time period	Climate data	Soil data	Crops	Location
ARIS and AquaCrop	• present (1981-2010) • near future (2036-2065)	• INCA data (1981-2010) • 2 ÖKS15 projections: EC-Earth_RACMO and IPSL_WRF • 2 emission scenarios: RCP 4.5 and RCP8.5 (all simulations were carried out with the full extent of atmospheric CO_2 concentration, although large ranges can be observed in reality)	• available soil water capacity • AquaCrop: 3 soil classes: low- to medium- and high-value arable land (Fig 1)	• winter wheat and • spring barley	3 climatically different agricultural regions in Austria: a region in southern Styria (Illyrian climate zone), in Weinviertel (Pannonian climate zone) and in Upper Austria (Central European transition climate) Reference weather stations: Bad Gleichenberg, Kremsmünster and Poysdorf (Fig. 1)

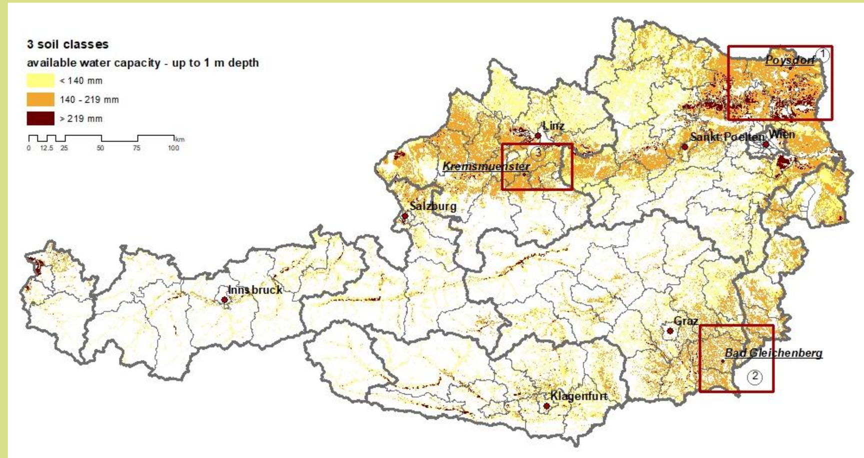

Fig 1. The location of the three study regions (rectangles) in Austria as well as the distribution of the applied three main soil classes (soil 1, soil 2, soil 3) over agricultural land (defined by the available water capacity in mm)

3. Results

ARIS (Agricultural Risk Information System)

The GIS-based agro model ARIS (**A**gricultural **R**isk **I**nformation **S**ystem) is an indicator model that calculates various abiotic and biotic weather-related agricultural risks for the whole of Austria. Various indicators are calculated on a daily basis for winter wheat, spring barley, grain maize, sugar beet and grassland:

- Drought Intensity indicator
- Water stress indicator
- Heat stress indicator
- Combined (water and heat) stess indicator
- Intensive water deficit (for two time periods) indicator
- Peronospora
- Late frost (apple) indicator
- Huglin index
- Effective global radiation indicator
- Field workdays (june, july) indicator
- Snow cover indicator
- Frost stress indicator
- Winter severity indicator
- Hibernation damage risk indicator
- Heat wave indicator
- Early heat stress indicator
- Potential water balance indicator (for two time periods)
- Potential yield reduction
- Vegetation summer indicator
- Effective temperature indicator
- Selected pest algorithms (e.g. grape berry moth)

Tab 1. The ARIS indicators, a combination of abiotic and biotic weather-related risks

Fig 2 shows for example the agro-climatic index "intensive drought" for winter wheat and its spatial distribution in the case study region Bad Gleichenberg ② (Fig 1) - EC-Earth_RACMO, RCP 8.5: 1981-2010 and 2036-2065. Here the number of days with intensive drought (ETa/ETo<0.3 for 5 days continuously) from sowing to maturity were calculated; the number of these days will increase up to 10 days in the near future.

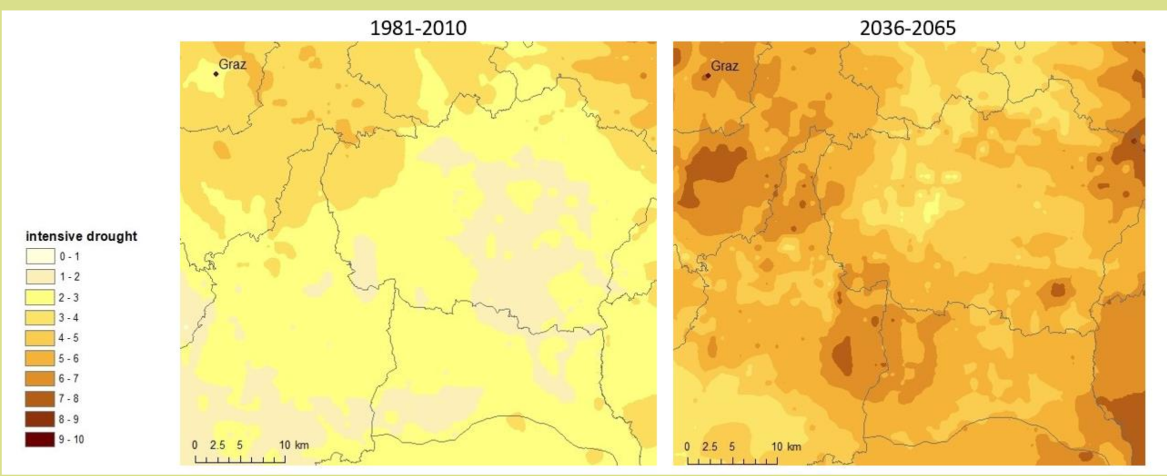

Fig 2. Number of "intensive drought days" in the case study region Bad Gleichenberg 1981-2010(left) and 2036-2065 (right) simulated with the EC-Earth_RACMO projektion, RCP 8.5.

The agro-climatic index "heat stress" (number of days with Tmax>=35°C and ETa/ETo<0.5) for winter wheat in the case study region Poysdorf ①(Fig 1) for IPSL_WRF, RCP 8.5 are presented in Fig 3. A clear increase in heat stress days in the near future can be expected.

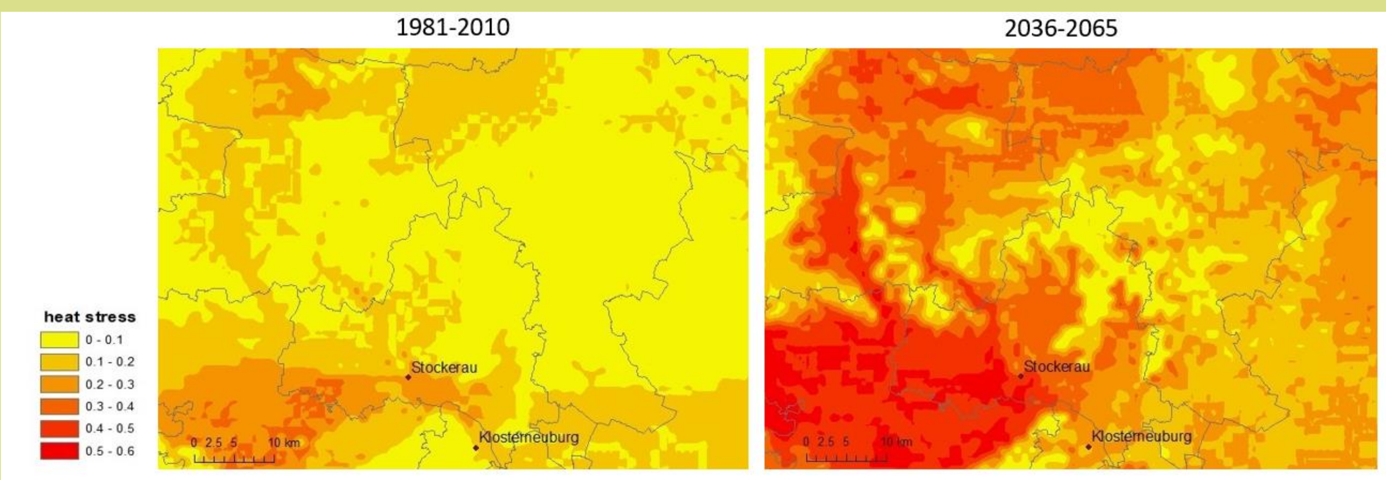

Fig 3. Number of "heat stress days" in the case study region Poysdorf 1981-2010(left) and 2036-2065 (right) simulated with the IPSL_WRF projection, RCP 8.5.

AquaCrop

The crop growth model AquaCrop (v 6.1), developed by FAO's Land and Water Division, is used to analyse soil-plant water balance parameters, crop yields and future crop water requirements based on different weather conditions and soil classes. Spring barley and winter wheat are simulated.

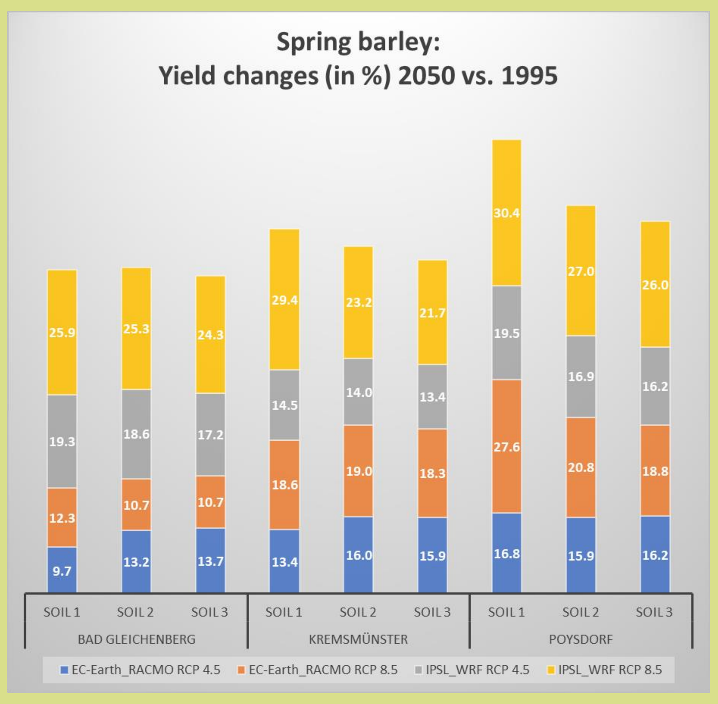

Fig 4. Yield change (in %) of spring barley in Bad Gleichenberg, Kremsmünster and Poysdorf in comparison 2050 to 1995, analysing three different soil classes, 2 projections (EC-Earth_RACMO and IPSL_WRF) and 2 emission scenarios (RCP 4.5 and RCP8.5).

Looking at the yield changes of spring barley and winter wheat in the near future compared to today, a clear growth trend can be observed in the two ÖKS15 projections (Fig 4 - example spring barley). This is mainly due to higher precipitation in May and June in the period 2036-2065. In RCP 8.5, these increases are more pronounced due to higher atmospheric CO_2 concentrations.

To determine the water stress, the division of actual evapotranspiration (ETa) with potential evapotranspiration (ETo) was calculated for spring barley. In Fig 5 this stress indicator has been determined for soil class 2. The three study regions as well as the periods 1981-2010 and 2036-2065 for the two projections and emission scenarios were considered in more detail. The lowest water stress can be observed in Kremsmünster (ETa/ETo ≈ 0.9), then in Bad Gleichenberg (≈ 0.8) and finally in Poysdorf (≈ 0.7). While the stress indicator is similar between the two periods or even slightly decreases in some areas, the standard deviation increases. Thus, a stronger variability between the individual years is to be expected. This can be observed especially for RCP 4.5 in Poysdorf, the driest site. RCP 8.5 shows less water stress, which is due to the higher CO_2 concentration in the model assumption.

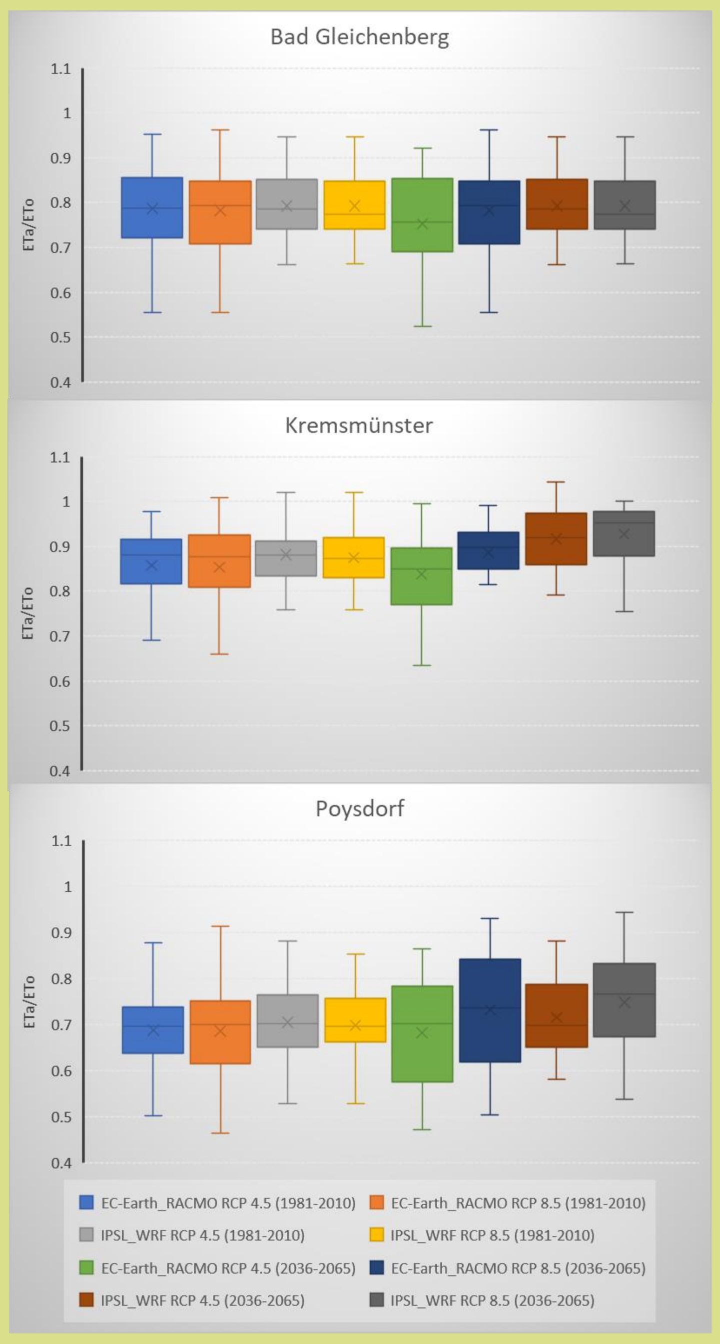

Fig 5. Water stress (ETa/ETo) of spring barley in Bad Gleichenberg, Kremsmünster and Poysdorf for soil class 2, analysing for the time periods 1981-2010 and 2036-2065, 2 projections (EC-Earth_RACMO and IPSL_WRF) and 2 emission scenarios (RCP 4.5 and RCP8.5).

4. Conclusions

Due to climate change, there may be serious shifts in cropping risks, which farmers need to adapt to in a timely and effective manner in order to increase the resilience of existing cropping systems. In this study, long-term weather-related impacts on Austrian crop production in the past (1980-2020) and in the future (2035-2065) were examined in more detail. The trend shows an increase in yields for winter wheat and spring barley, but at the same time a stronger variability within years. Indicators such as heat stress and intensive drought days will also increase in the future. In order to better identify regional differences, it is now necessary to compare and combine the different indicators. It is also important to simulate further projections to ensure a better long-term forecast.

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