Data-driven crop yield forecasting in the Pannonian Basin and its skill in years of severe drought

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DryPan

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Background

In the last decades, droughts have heavily affected agricultural production in the Pannonian Basin, a lowland area in southeastern Europe, caused by a generally increasing frequency of heatwaves and dry conditions [1]. In addition, agriculture in this region is particularly vulnerable to droughts, as it receives relatively low levels of precipitation of around 550 mm y-1, while most agriculture is only rain-fed [1]. Yet, significant parts of the local population are dependent on agriculture [2,3]. The already challenging conditions for crop production are expected to worsen due to climate change [4,5]. The Pannonian Basin is even considered as the region with the most negative impacts of climate change on crop production in Europe [6]. A potential tool to support the adaption to these challenging circumstances is crop yield forecasting. This has proven a vital method to minimise socio-economic impacts of crop losses [7].

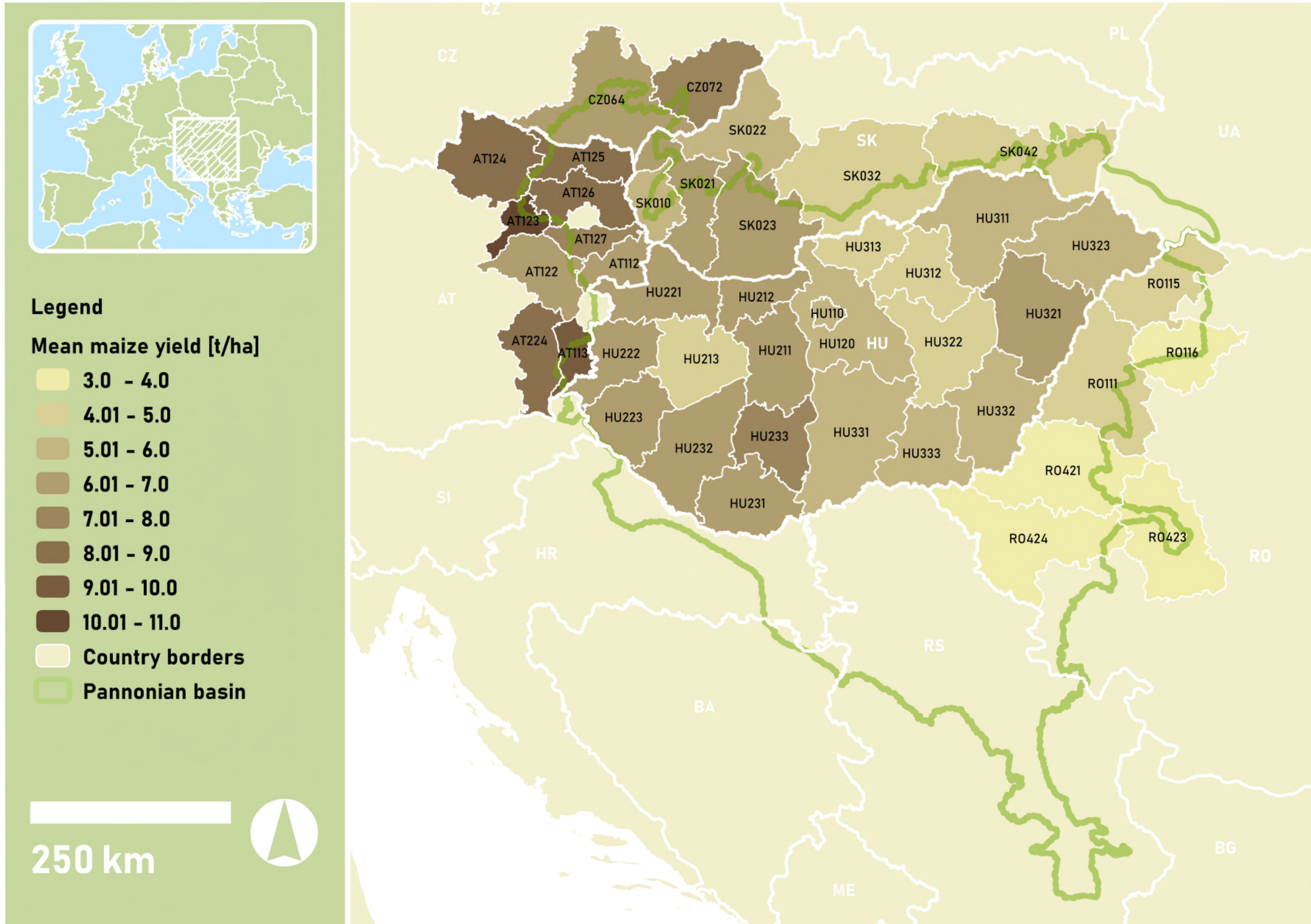

Fig. 1: Overview of the study area

Key Findings

- Wheat and maize crops can be forecasted around **two months before harvest** with a good performance (Fig. 6)
- Crop yield losses in years of **severe drought are underestimated by the forecasts** but the model correctly detects negative anomalies (Fig. 4)
- **Good** model performance **to predict interannual variabilities** of the yields for the districts (Fig. 6)
- **Bad model performance** to distinguish the crop yields **between the different regions** within individual years
- **Wheat yields** are mainly dependent on the **temperature** - **maize yields** on **water availability** (Fig. 3)

Methods

Yearly yield anomalies of maize and winter wheat are forecasted for various administrative districts in the Pannonian Basin (Fig. 1). The forecasts are calculated using machine learning (random forest) with 18 predictor datasets describing the state of the vegetation (estimated from satellite observations), weather, and soil moisture. In addition, seasonal weather forecasts of precipitation and air temperature are used. Monthly forecasts are made for each growing season, starting around four months before harvest.

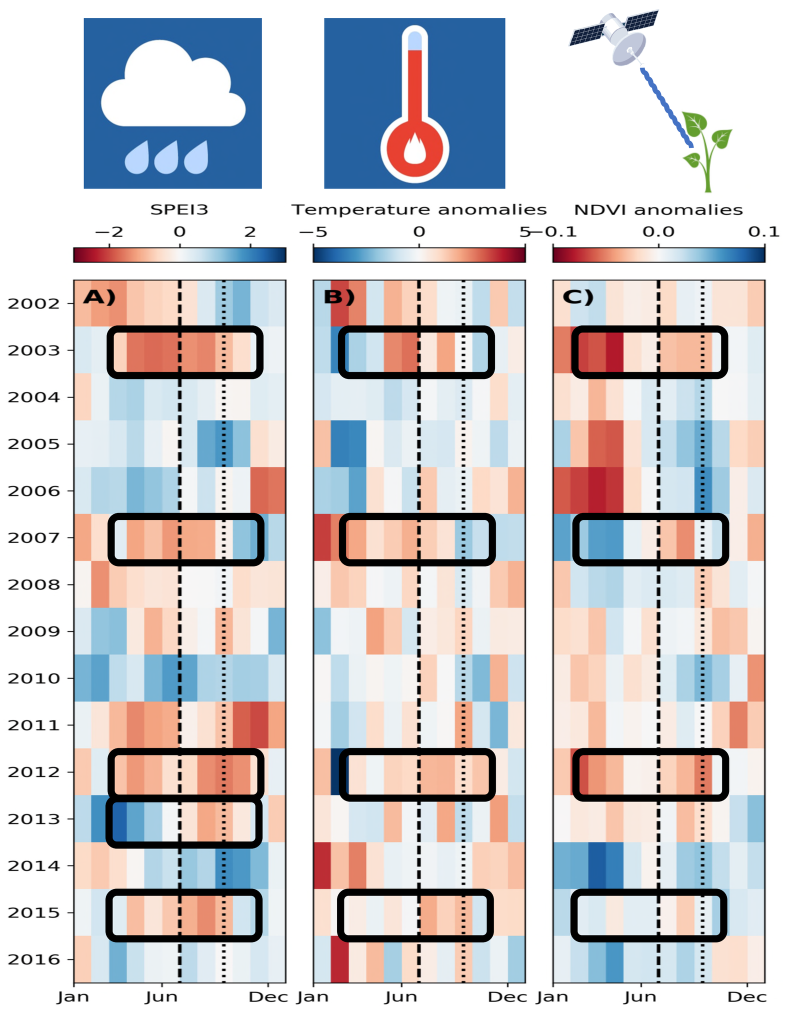

Fig. 2: Anomalies of three important explanatory variables

Machine Learning

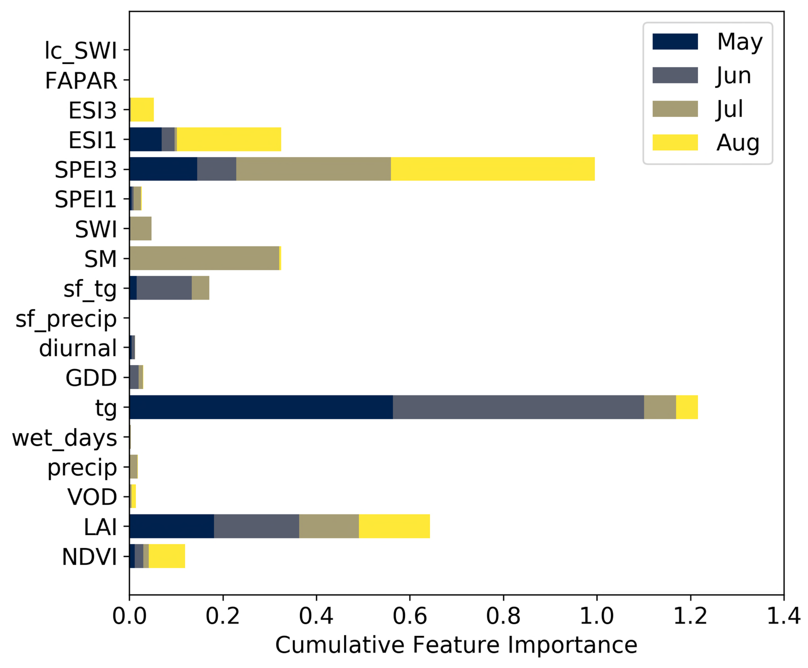

Fig. 3: Cumulative feature importances of the predictors

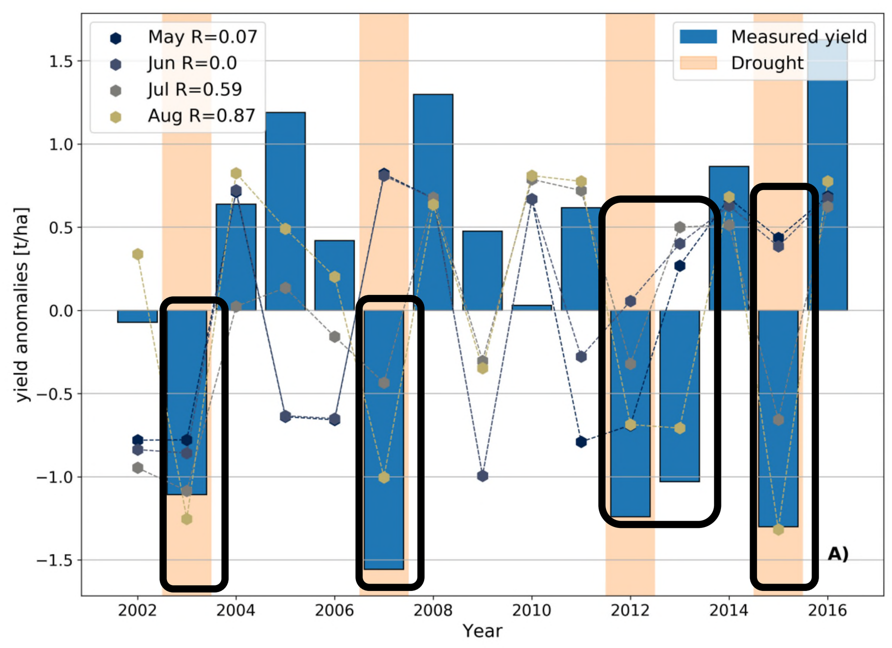

Fig. 4: Forecasted and observed mean maize yield anomalies over the Pannonian Basin

Results

- Correlations of explanatory variables and crop yields are increasing over the months (Fig. 5)
    - All relatively high in July and August, except precipitation
    - Temperatures negative, rest positive
- Crop yield of maize and wheat are highly dependent on the conditions in the last two months before the harvest (Fig. 2 and 4)
    - Highest performance of forecast in those months
    - Mainly temperature for wheat and moisture avaliablity for maize (Fig. 3)
    - Seasonal forecast does not add enough value to improve that
- The model underestimates extremes for both, high and low, crop yields
- Forecast in drought years early detects crop yield losses
- Satellite derived variables of the state of the vegetation (green in Fig. 5) and of soil moisture (purple in Fig. 5) have among the highest correlations

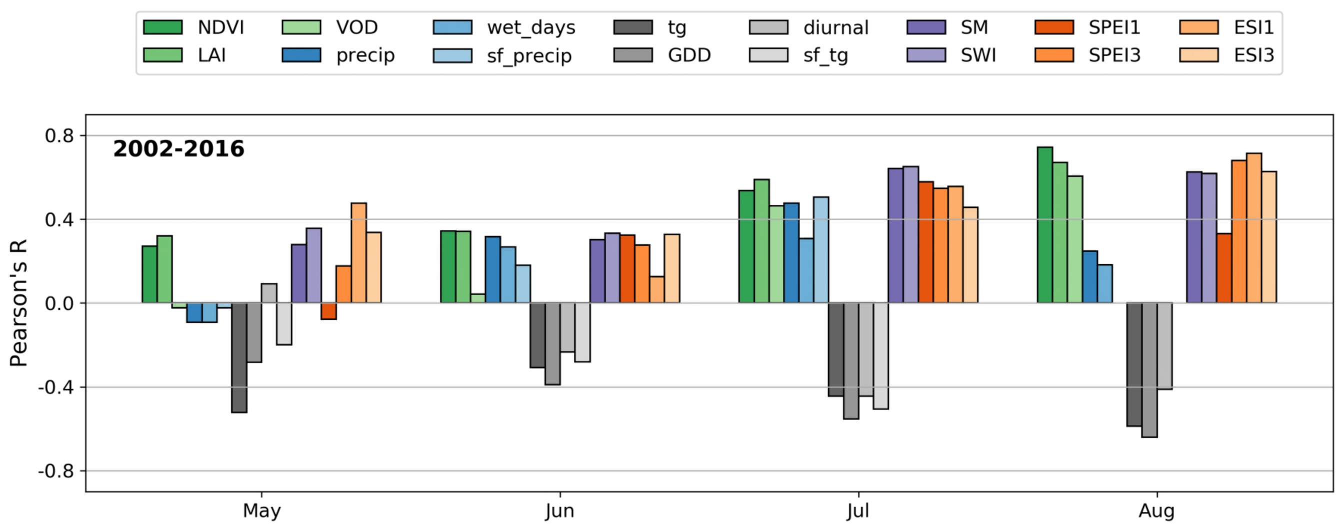

Fig. 5: Correlations of explanatory variables and maize yield anomalies. Green bars show the canopy status, blue precipitation-related variables, grey temperature-related variables, purple soil moisture, and orange drought indices. Sf_precip and sf_tg are the seasonal forecasts of temperature and precipitation

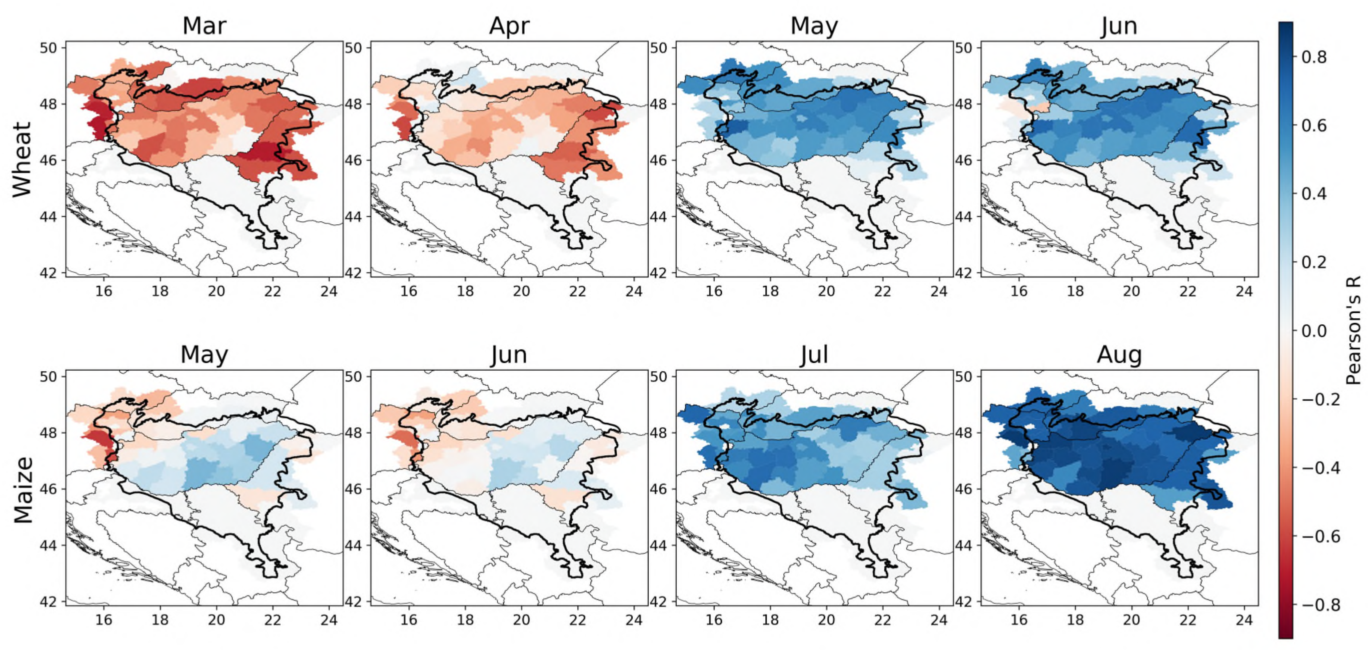

Fig. 6: Correlations of forecasted and observed crop yield anomalies

Conclusion

The Pannonian Basin has experienced several droughts recently. To support the local population, a random forest-based crop yield forecast system using EO and climate data is established for 44 regions in the Pannonian Basin. The results affirm earlier findings of the large dependency on the water availability for maize and the temperature for wheat, respectively, in the last weeks before the harvest. Future work should focus on how these conditions can be better represented for the modelling, by either considering other input datasets or increasing the temporal and spatial resolutions. A finer spatial resolution could, in addition, help to better distinguish the yields between the different regions. . Yield forecasts during the impact of severe droughts will require further improvement in the Pannonian Basin. There is potential which needs to be exploited to achieve this. A more thorough analysis of the seasonal forecast and potentially other machine learning techniques can help to do so.

Acknowledgement

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References

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