Impact of heat stress, drought and wetness on crop yield anomalies in Germany

Stefan Siebert and Frank Ewert
Institute of Crop Science and Resource Conservation (INRES), University of Bonn

universitätbonn

Crop Science Bonn

Background and Methodology

Introduction

- In well managed environments, with sufficient nutrient supply and control of pests, diseases and weeds, crop yield anomalies are often caused by unsuitable weather conditions during the growing period which are likely to increase in the future.
- Here we analyze the impact of three stressors (heat, drought and wetness) on yield anomalies of four crops (winter wheat, winter rapeseed, sugar beet and silage maize) grown in Germany between 1950 and 2010.

Data and methods

- Observed crop yields averaged over the whole of Germany (Figure 1) and over the German federal states were derived from annual statistical yearbooks.
- Crop yield anomalies were calculated as deviation from the 11-year moving average crop yields in both, absolute (t ha^{-1}) and relative (%) terms.
- Ranking of years according to largest negative crop yield anomalies.

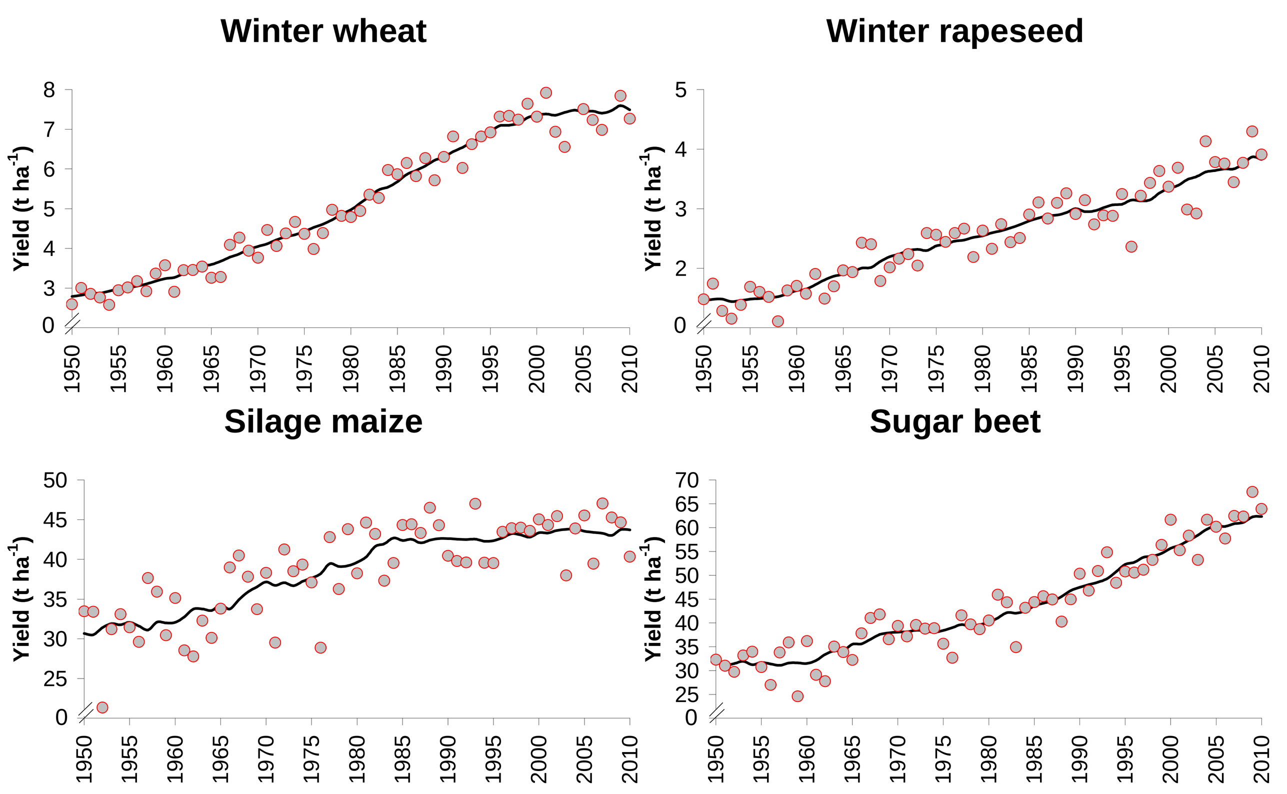

Figure 1. Crop yields in the period 1950 – 2010 averaged over Germany, black lines indicate 11-year moving average crop yields.

- Heat stress was computed as accumulated temperature sum of daily maximum temperatures (Siebert and Ewert, 2012) above a threshold temperature of 30 °C (Figure 2) and averaged over cropland in Germany or German federal states.
- Three precipitation anomaly indicators were calculated for periods between 1 and 5 months based on deviations from long-term mean precipitation (Figure 3): (i) accumulated relative monthly precipitation deficit [-], (ii) accumulated relative monthly precipitation surplus [-], and (iii) deviation of precipitation sum [mm].
- A overall precipitation indicator on a scale from -6 (to wet) to +6 (to dry) was computed based on correlation coefficients of crop yield anomalies (absolute and relative) and the three precipitation anomaly indicators.
- Correlation between heat stress and crop yield anomalies was analyzed to detect crop specific sensitivity of yields to heat stress.
- Combined effects of heat and drought on crop yields were analyzed by comparing regression coefficients of single or multivariate (heat + drought) regressions.

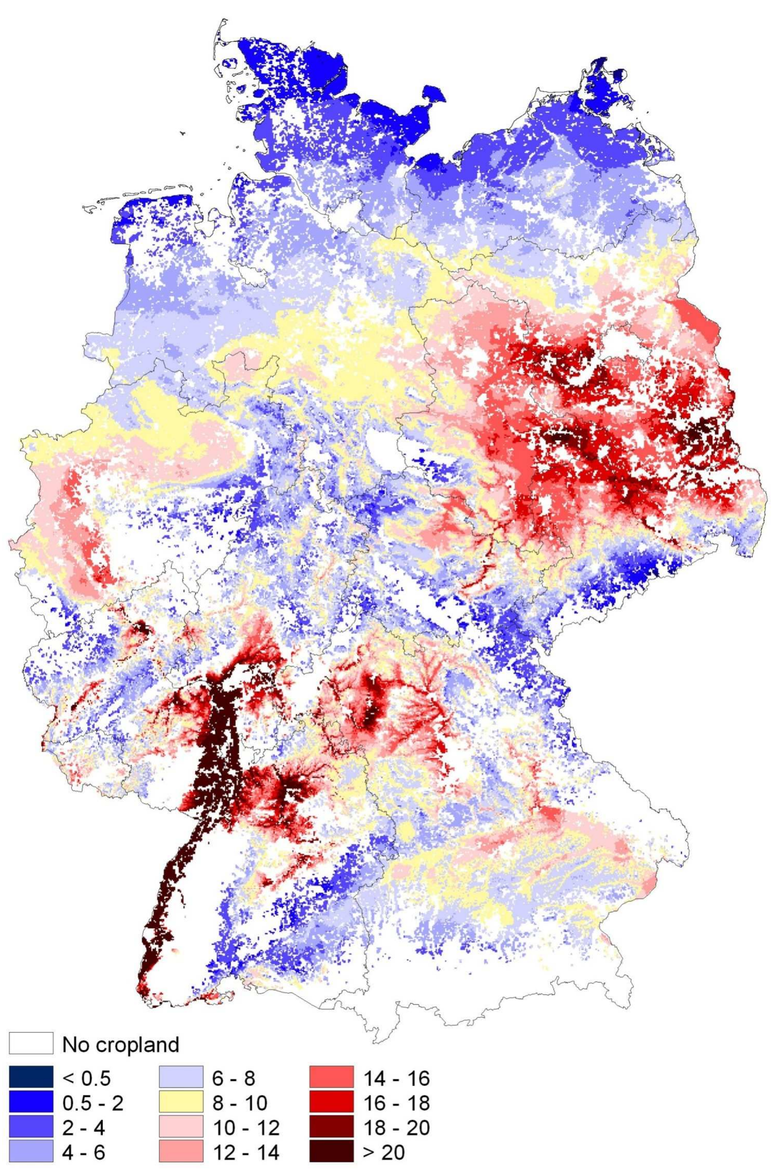

Figure 2. Mean annual heat stress (temperature sum of daily maximum temperatures above 30 °C, °Cd) in period 1950 – 2010 on cropland in Germany.

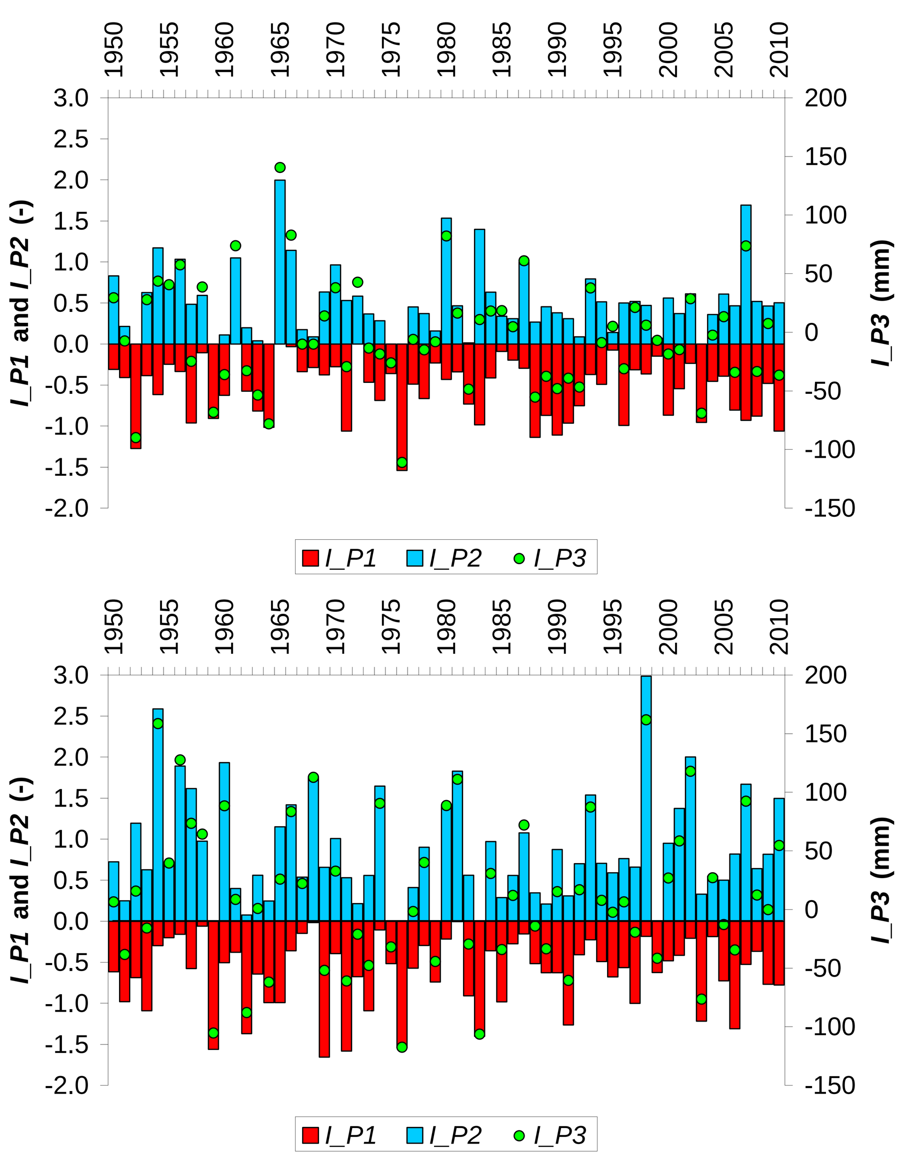

Figure 3. Three precipitation anomaly indicators between 1950 and 2010 in Germany. Indicators refer to accumulated relative monthly precipitation deficit (*I_P1*), accumulated relative monthly precipitation surplus (*I_P2*) and deviation of precipitation sum (*I_P3*) in period April to July (top) or June to October (bottom) averaged over Germany.

Results

Spatial patterns in crop yield anomalies

- Distinct spatial pattern in crop yield anomalies; differences among crops and years; even in years with the largest negative crop yield anomalies yields in some federal states were less or even not affected (Figure 4).

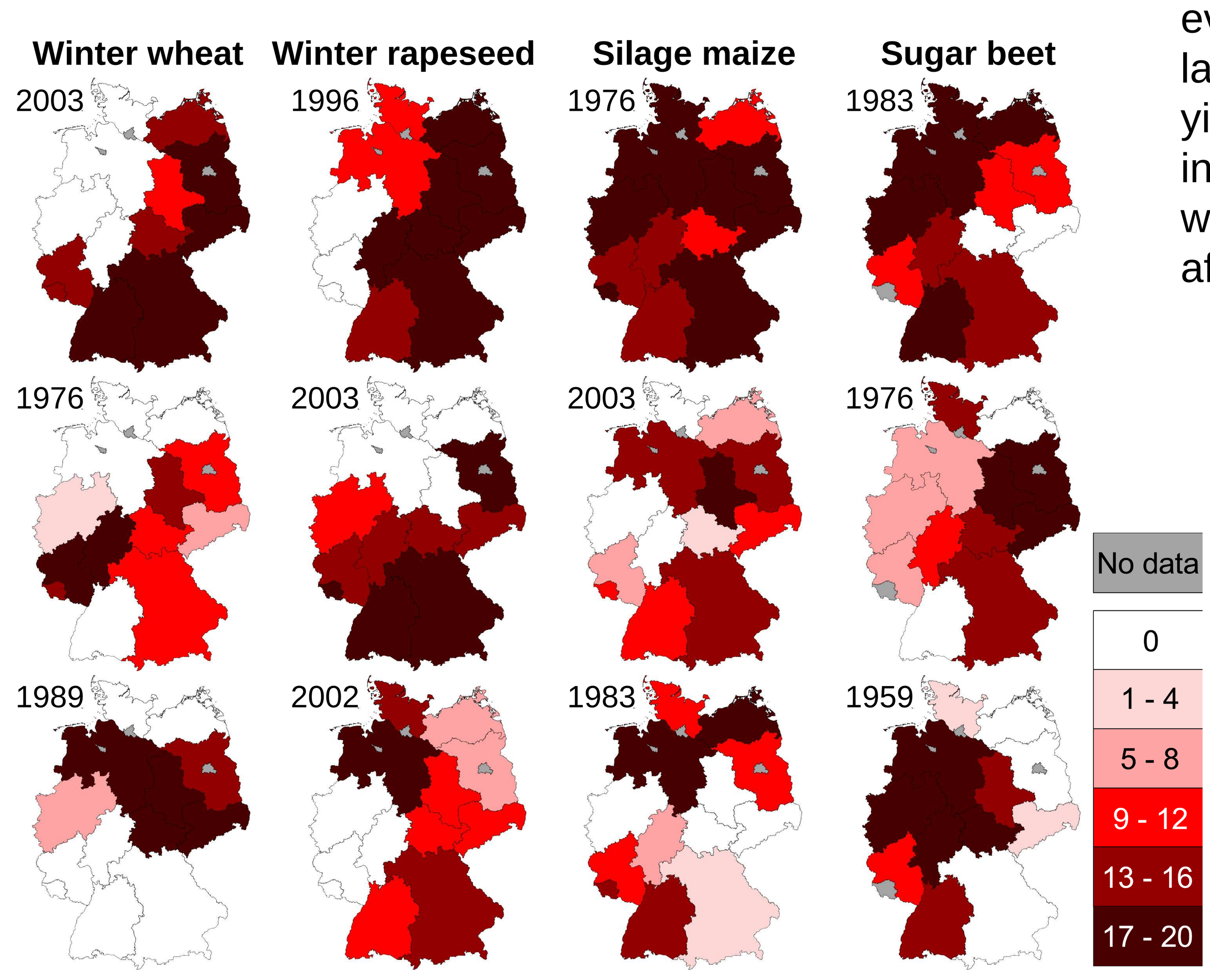

Figure 4. Ranking of years according to largest negative yield anomalies, a value of 20 means that the year showed largest negative yield anomalies in both, absolute (t ha^{-1}) and relative (%) terms, a value of 0 means that the year was not among the 10 years with the largest negative crop yield anomalies.

Impact of the stressors heat, drought and wetness

- Positive precipitation anomalies (wetness) resulted in negative yield anomalies of winter crops in western Germany (Figure 5).
- Negative precipitation anomalies (drought) resulted in negative yield anomalies of summer crops in almost all federal states (Figure 5).
- Negative correlation between heat stress and crop yield anomalies in almost all federal states, but at different magnitudes depending on crop and state (Figure 6).

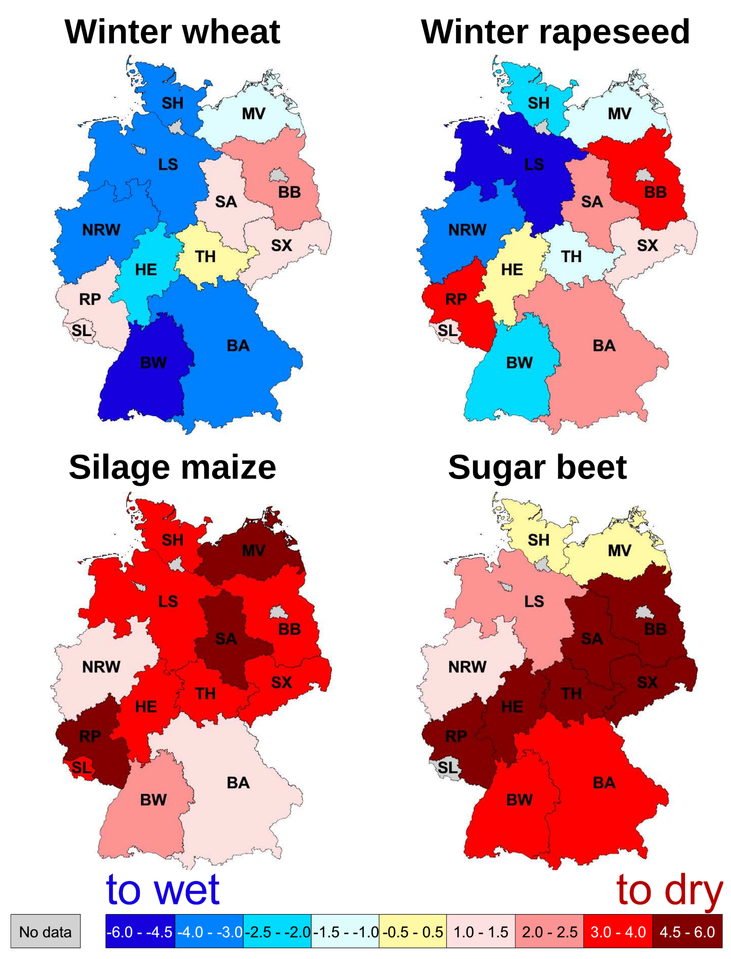

Figure 5. Relation between precipitation anomalies and crop yield anomalies to classify long-term mean precipitation effects on crops in federal states of Germany on a scale between -6 (to wet) to +6 (to dry).

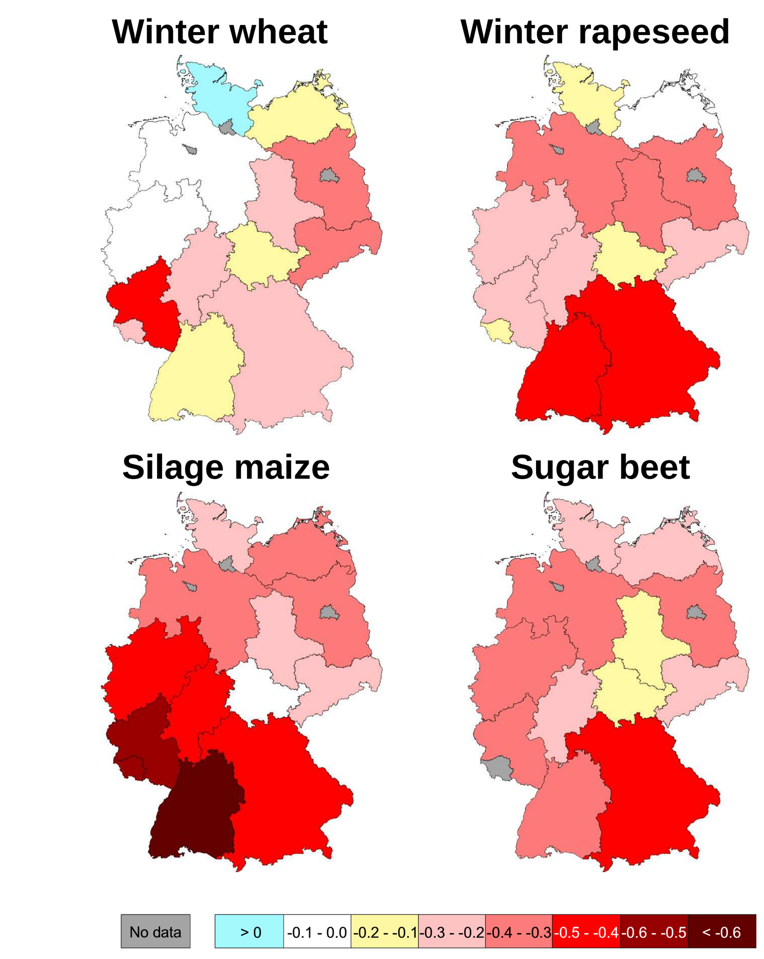

Figure 6. Correlation coefficient between heat stress in June (winter crops) or July (summer crops) and crop yield anomalies in federal states of Germany.

Interaction of heat and drought

- In most regions and for most crops drought (precipitation sum) explained the variability in crop yield anomalies much better than heat stress, even when the analysis was performed only for years with heat stress (Figure 7).
- High regression coefficients of heat stress and crop yield anomalies were only obtained in regions that were classified as to wet (Figures 5, 7).

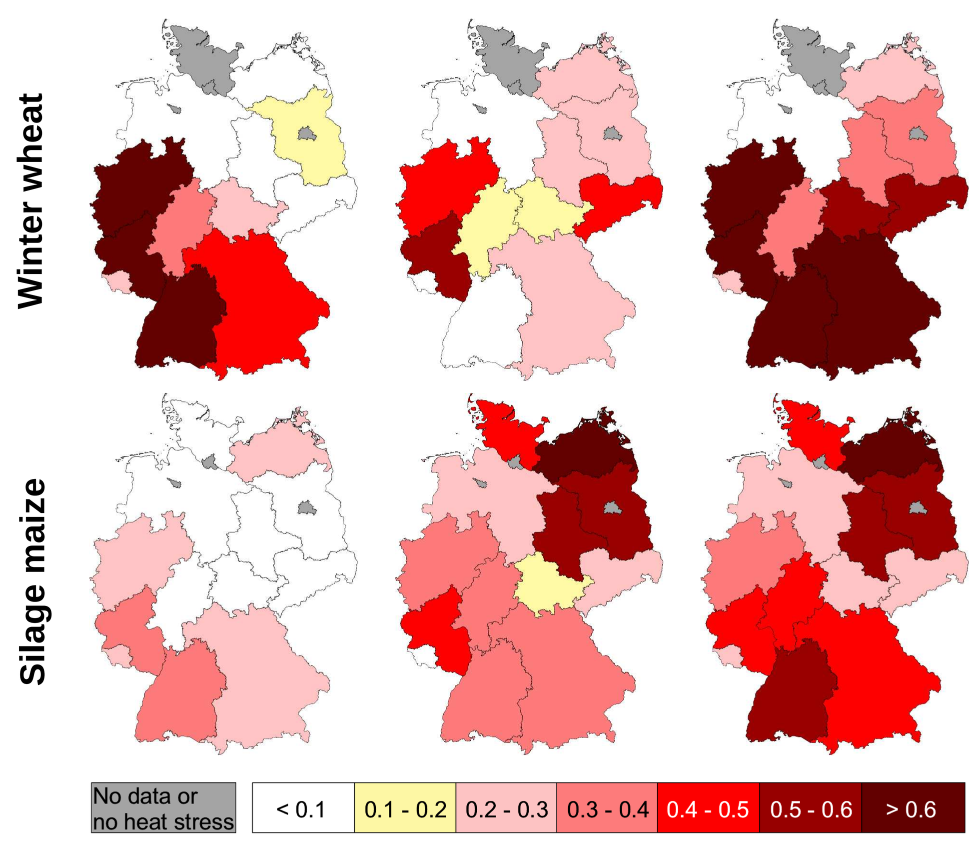

Figure 7. Regression coefficient r^2 of single variable regressions of heat stress (left) or precipitation sum (center) and multivariate regression of both variables (right) on crop yield anomalies. Regressions were performed for years with heat stress only.

Conclusion

Analyses of crop yield anomalies need to be crop specific, have to consider distinct spatial patterns even in small countries like Germany and have to account for interactions between different stressors.

References

Siebert, S. and Ewert, F., 2012. Spatio-temporal patterns of phenological development in Germany in relation to temperature and day length. Agricultural and Forest Meteorology 152, 44-57, DOI:10.1016/j.agrformet.2011.08.007

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Contact

Stefan Siebert (s.siebert@uni-bonn.de)
Institute of Crop Science and Resource Conservation
University of Bonn; Katzenburgweg 5, D 53115 Bonn, Germany.

Phone: +49 228 73 3262
Fax: +49 228 73 2870
http://www.lap.uni-bonn.de/