

EGU21-15524

<https://doi.org/10.5194/egusphere-egu21-15524>

EGU General Assembly 2021

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Identifying meteorological drivers of extreme impacts: an application to simulated crop yields

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Compound weather events may lead to extreme impacts that can affect many aspects of society including agriculture. Identifying the underlying mechanisms that cause extreme impacts, such as crop failure, is of crucial importance to improve their understanding and forecasting. In this study we investigate whether key meteorological drivers of extreme impacts can be identified using Least Absolute Shrinkage and Selection Operator (Lasso) in a model environment, a method that allows for automated variable selection and is able to handle collinearity between variables. As an example of an extreme impact, we investigate crop failure using annual wheat yield as simulated by the APSIM crop model driven by 1600 years of daily weather data from a global climate model (EC-Earth) under present-day conditions for the Northern Hemisphere. We then apply Lasso logistic regression to determine which weather conditions during the growing season lead to crop failure.

We obtain good model performance in Central Europe and the eastern half of the United States, while crop failure years in regions in Asia and the western half of the United States are less accurately predicted. Model performance correlates strongly with annual mean and variability of crop yields, that is, model performance is highest in regions with relatively large annual crop yield mean and variability. Overall, for nearly all grid points the inclusion of temperature, precipitation and vapour pressure deficit is key to predict crop failure. In addition, meteorological predictors during all seasons are required for a good prediction. These results illustrate the omnipresence of compounding effects of both meteorological drivers and different periods of the growing season for creating crop failure events. Especially vapour pressure deficit and climate extreme indicators such as diurnal temperature range and the number of frost days are selected by the statistical model as relevant predictors for crop failure at most grid points, underlining their overarching relevance.

We conclude that the Lasso regression model is a useful tool to automatically detect compound drivers of extreme impacts, and could be applied to other weather impacts such as wildfires or floods. As the detected relationships are of purely correlative nature, more detailed analyses are required to establish the causal structure between drivers and impacts.