

# Drought risk management in agriculture: A copula perspective on crop diversification

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## 1. Introduction

- Crop diversification is a well-known on-farm risk management instrument.
- However, extreme droughts in 2003 or 2018 caused yield losses of more than 20% for a wide range of different crops across Europe.<sup>[1],[2],[3]</sup>
- It is unclear to what extent the risk-reducing effectiveness of crop diversification varies by crop composition, drought severity, and environmental conditions such as soil quality.

## 2. Method

- A copula is a function that links marginal distribution functions together to form a joint distribution.
- We model the probability of simultaneous losses of two different crops (X and Y) on a farm conditional on different levels of drought severity (CR):

$$F_{X,Y|CR}(x,y|CR \leq cr) = P(X \leq x, Y \leq y | CR \leq cr)$$

- Work steps: (1) goodness-of-fit testing, (2) copula estimation of probabilities, (3) bootstrapping to generate confidence intervals.

## 3. Data

- 249,756 observations of regionally pooled farm-level crop-yield pairs for winter wheat, winter barley, winter rapeseed, sugar beet and grain maize over the period 1995-2019.
- We match the farm-level yield data with cumulative rainfall data (1<sup>st</sup> April to 30<sup>th</sup> of June) at the municipality level.

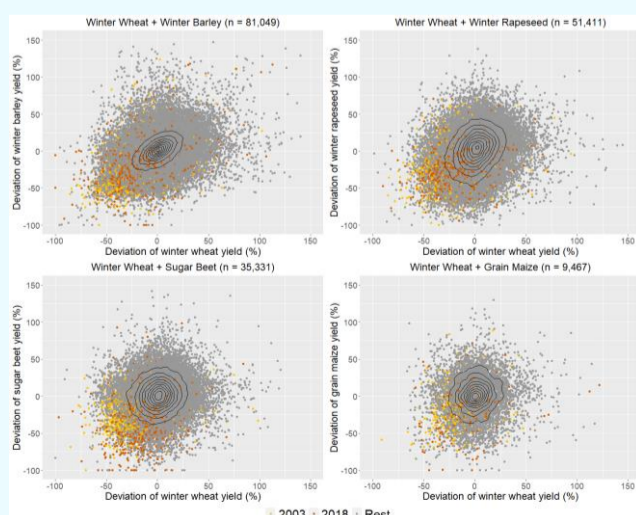


Figure 1. Simultaneous farm-level yield deviations of different crop-pairs with highlighted drought years in 2003 and 2018.

## 4. Results

- The risk-reducing effectiveness of crop diversification varies across regions, crop pairs, and drought severity.

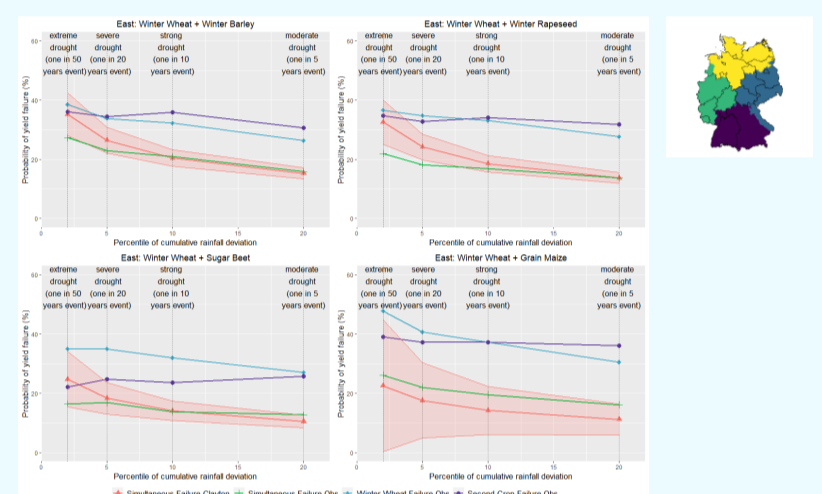


Figure 2. Sub-sample of eastern Germany (blue area on the map) – probability of simultaneous yield losses of ≥ 20% conditional on different drought severity levels.

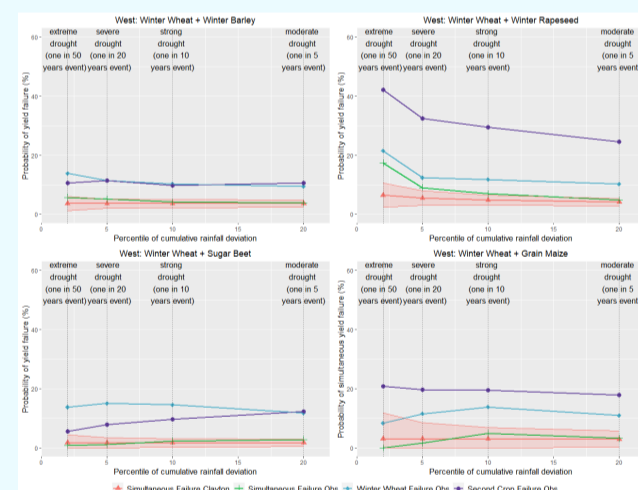


Figure 3. Sub-sample of western Germany (blue area on the map) – probability of simultaneous yield losses of ≥ 20% conditional on different drought severity levels.

## 5. Conclusion

- Diversification is an effective risk management instrument in most drought situations.
- However, extreme drought events can regionally decrease the risk-reducing effectiveness of diversification.
- Farmers and policy makers should implement and promote diversification that includes crops with different phenological requirements throughout the year.

## References

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- [3] Webber, H., Lischeid, G., Sommer, M., Finger, R., Nendel, C., Gaiser, T., & Ewert, F. (2020). No perfect storm for crop yield failure in Germany. *Environmental Research Letters*, 15(10), 104012.

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