

## Referee #1

In this work, the authors investigated the joint probability of soil moisture and precipitation over Europe in order to derive meaningful insights on the combined usage of these variables for the detection of agricultural droughts within a probabilistic modelling framework. The in-depth analysis of the tail-dependence especially reveals clear spatial patterns, such as identification of regions which may benefit more from the joint use of the two variables due to the observed strong low tail-dependence, over others. The authors also showed that the spatial patterns are significant using a random forest classification. The scientific goal and the findings of the manuscript are of high relevance and are presented in a clear, concise and well structured way. There are only but a few grammatical errors and typos which could be corrected upon a thorough reading of the manuscript.

We would like to thank the reviewer for the positive feedback on our manuscript. We carefully revised the text to remove errors and typos.

## Referee #2

General Overview:

The manuscript deals with the investigation of the joint probability of precipitation and soil moisture by using different copula functions and a large dataset over Europe. The analysis of the tail-dependence shows clear spatial patterns in non-parametric and parametric approaches. The manuscript is an interesting approach that could be valuable to drought studies and, presented the approach in a clear and well-structured way. However, I have a few concerns which should be resolved before recommending the paper for publication.

Major remarks:

1) The independence is questionable between the 3-month accumulated precipitation and soil moisture which is a requirement in copula-based analysis, but it can be checked using some statistical tests.

We tested the temporal dependence of each standardized time series by analysing the partial auto correlation function (PACF). The PACF suggests the presence of statistically significant auto correlation only for lag = 1, as somewhat expected for both 3-month accumulated values and soil moisture data. Overall, we did not consider any additional correction necessary as the sample size is good enough, but we added a paragraph describing the results in the revised version of the manuscript.

2) Is this study looking at the joint probability of precipitation and soil moisture or SPI-3 and SMA? This is not clear to me, and I could not see consistency in the manuscript.

We agree that the variables analysed in this study were not clearly introduced in the manuscript. We analysed SPI-3 and SMA, calculated non-parametrically, using empirical frequencies of 3-month precipitation and soil moisture. This was done to avoid any artifact that may be introduced by performing theoretical fittings ahead of the copula analysis.

We better clarified this procedure in the revised version of the manuscript, and we introduced the terms "standardized" precipitation and soil moisture, which is now used consistently through the text.

3) I would suggest authors to add some explanations with the justification for the practical use of the results in agriculture drought studies and drought characterization.

We revised the discussion section and included an example (Fig. 9) on how the tail-dependence may affect drought detection and characterization in practical cases.

### **Comments from the community**

We revised the text to clarify how we referred to drought indicators when discussing the lack of focus of the scientific literature on tail dependence. We also added some additional references on the analysis of tail dependence in multivariate studies in hydrology.

We added the outcome of the pairwise binary correlation to further stress on the differences between the areas with upper- and lower- tail dependence, as detected by the combination of parametric and non-parametric methods. This result also has the goal to highlight operational effects of the tail-dependence on the drought detection.