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Interactive comment on "Risk of crop failure due to compound dry and hot extremes estimated with nested copulas" *by* Andreia Filipa Silva Ribeiro et al.

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Reviewer: This study evaluated the risk of crop failure due to compound dry and hot extremes. A copula model is fitted to estimate the response of crop yield with respect to different dry and hot conditions. This manuscript is well crafted with clear structure.

Author's Reply: Thank you for this positive assessment.

Reviewer: A few issues need to be addressed before the potential publication of this study. (1) Selection of the periods Line 92-93: "We used 3-monthly means of Tmax and 3- monthly means of P during spring". Here the selection is based on the correlation

analysis, but not the whole growing season, right? Please justify this period. It is easy to understand this from a statistical perspective. Is this selection still valid from a physical perspective?

Author's Reply (1): Thank you for the question. Given the importance of assessing crop's water and temperature requirements at different moments of the vegetative cycle we conducted a correlation analysis between the yield and the 3-monthly means of precipitation and 3-monthly means of maximum temperature during the whole growing season (approximately from September of year n-1 to June of the year n), as shown in Fig. 2. The identification of the moment of the vegetative cycle of the highest crop's water and temperature requirements was assessed based on the strongest statistically significant correlation value. Fig. 2 suggests that the greatest influence of P and Tmax in crop yields is observed during spring (in both regions and cereals) corresponding to the moments in which the vegetation is photosynthetically more active. The effects of water content and high temperatures during middle growth stages of the crop life cycle are in accordance with previous studies (Ferrise et al., 2011; García del Moral et al., 2003; Iglesias and Quiroga, 2007; Ribeiro et al., 2019). Hence, this selection is valid both from the statistical and biophysical point of view.

We will clarify this aspect in the revised manuscript to the following in the Weather data section: "The vegetative cycle of the winter crops in Spain is mainly driven by precipitation and temperature: sowing occurs around autumn, followed by the vegetative phase in winter, reproductive phase (more photosynthetically active phase) in spring and crop harvest occurs in the early summer. Therefore, monthly precipitation (P) and monthly maximum temperature (Tmax) were extracted from the Climate Research Unit (CRU) TS4.01 dataset (Harris et al., 2014) spanning the same time period. Given the importance of assessing crop's water and temperature requirements at different moments of the vegetative cycle we conducted a correlation analysis between the annual yields and the 3-monthly means of P and 3-monthly means of Tmax during the whole growing season, as shown in Fig. 2. The identification of the moment of the vegetative cycle of the highest crop's water and temperature requirements was assessed based on the strongest statistically significant correlation value (denoted by filled circles in Fig. 2). Figure 2 suggests that the greatest influence of P and Tmax in crop yields is observed during spring (MAM in both regions and cereals) corresponding to the reproductive phase of plant development, when vegetation is photosynthetically more active. In this way, we used 3-monthly means of Tmax and 3-monthly means of P during spring (PMAM and TmaxMAM, respectively), which has also been identified in previous studies as a growth stage sensitive to the effects of water content and high temperatures (Ferrise et al., 2011; García del Moral et al., 2003; Iglesias and Quiroga, 2007; Ribeiro et al., 2019). This selection of climate variables allows to maximize the dependence between climate conditions and yields as also shown by previous work based on the same data (Ribeiro et al., 2019c)."

References:

Ferrise, R., Moriondo, M. and Bindi, M.: Probabilistic assessments of climate change impacts on durum wheat in the Mediterranean region, Nat. Hazards Earth Syst. Sci., 11(5), 1293–1302, doi:10.5194/nhess-11-1293-2011, 2011.

García del Moral, L. F., Rharrabti, Y., Villegas, D. and Royo, C.: Evaluation of Grain Yield and Its Components in Durum Wheat under Mediterranean Conditions: An Ontogenic Approach, Agron. J., 95, 266–274, 2003.

Iglesias, A. and Quiroga, S.: Measuring the risk of climate variability to cereal production at five sites in Spain, Clim. Res., 34(1), 47–57, doi:10.3354/cr034047, 2007.

Reviewer: (2) Copula implementation Line 161: "Due to the negative dependence between TmaxMAM and both crop yields", The clayton copula does not permit the negative dependence. Is this the reason to "invert the margins of TmaxMAM for copula modelling"? The rationale of this transformation needs to be clarified. Suggest to make it clear to aid the understanding.

Author's Reply (2): Thank you for the comment. The reason for inverting the margins is that the required complete monotonicity of the ACs generators to construct NAC following Okhrin and Ristig (2014) implies (i) that the same single-parameter generator function is used on each level of NAC (i.e. same family), but potentially with a different value of θ (as we discuss in lines 53-56, 135-40 and 263-264 in other words) and (ii) positively dependent AC models, hence the pairwise rank correlations are required to be non-negative. Therefore, in order to model positive dependencies among all possible pairs, we considered the inverted values of Tmax (i.e. multiplication by -1). For more details on complete monotonicity of the ACs generators and NAC constructions see e.g. Górecki et al. (2017).

We will clarify this in the revised manuscript by moving the referred information in line 161 (as the required complete monotonicity of the AC generators implies both conditions) and improving to: "Using the same single-parameter generator function on each level of NAC (but with a potentially different value of θ) satisfies the required complete monotonicity of the ACs generators to construct NAC following Okhrin and Ristig (2014), which also implies that the possible pairs are positively dependent. Therefore, due to the negative dependence between TmaxMAM and both crop yields and PMAM, we inverted the margins of TmaxMAM for copula modelling (i.e. multiplication by -1). For more details on complete monotonicity of the ACs generators and NAC constructions see e.g. Górecki et al. (2017)."

References:

Górecki, J., Hofert, M. and Holeňa, M.: On structure, family and parameter estimation of hierarchical Archimedean copulas, J. Stat. Comput. Simul., 87(17), 3261–3324, doi:10.1080/00949655.2017.1365148, 2017.

Reviewer: (3) Figure presentation Figure 7: "y-axis indicates the TmaxMAM percentile (Heat)". For heat, should you use the axis with the range like 0.5-0.95? Since for heat, we are interested in high percentile, right? Or if this is related to the aforementioned “inversion of the margins”, please clarity this and make it clear.

Author’s Reply (3): You are correct. By inverting the Tmax the highest values correspond to the lower quantiles. We will change the Figure y-axis to 0.5 - 0.95 to avoid confusion.

Reviewer: (4) Figure discussion Regarding Figure 7, “When PMAM/TmaxMAM are below/above the median, the probability of crop loss is always higher than 40%.” How could you tell this (i.e., above the median?) from the figure? The y-axis for heat stress is below median. Please make it clear.

Author’s Reply (4): We agree that this point is not clear. In the text we refer to the Tmax values, rather than the inverted Tmax values as it was supposed to. In other words, when referring to Tmax in the text we keep the concept of exceeding the highest percentiles. As mentioned above in comment (3), we will change the Figure y-axis to 0.5 - 0.95 to avoid this confusion.

Reviewer: (5) Minor comments: Check the bracket in the caption of Figure 5.

Author’s Reply (5): Thank you, we will delete the extra brackets in Fig. 5 caption

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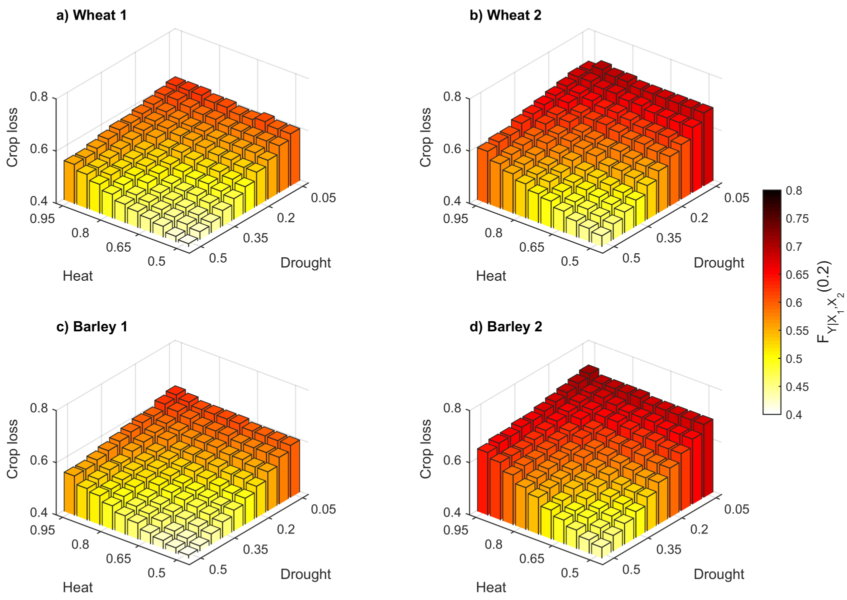

Fig. 1. Updated Figure 7