1. Motivation

Drought and heat events are a stress factor to agricultural systems and may threaten food security [1]. Compound drought and heat events are assessed regarding how much they enhance crop (wheat and barley) losses in comparison with the individual hazards. This work will contribute to design supporting tools and provide guidance in the decision-making process in agricultural practices to minimize crop losses related to climate hazards.

3. Statistical methods

The three conditional cumulative distribution functions (CDFs) are estimated and compared, representing the agricultural impacts under dry (Eq. 1), hot (Eq. 2) and compound dry and hot conditions (Eq. 3):

\[ F_{X_1X_2}(x_1, x_2 | y) = P(Y \leq y | X_1 \leq x_1, X_2 \leq x_2) \]  
\[ F_{X_1X_2X_3}(x_1, x_2, x_3 | y) = P(Y \leq y | X_1 \leq x_1, X_2 \leq x_2, X_3 \leq x_3) \]  
\[ F_{X_1X_2X_3}(x_1, x_2 | y) = P(Y \leq y | X_1 \leq x_1, X_2 \leq x_2) \]  

Where \( Y \) is crop yield annual anomalies, \( X_1 = \text{Tmax}_{\text{MAM}}, X_2 = \text{Tmax}_{\text{MAM}} \) for wheat and \( X_1 = \text{Tmax}_{\text{MAM}}, X_2 = \text{Tmax}_{\text{MAM}} \) for barley and the dry and hot thresholds (Table 1).

Copula theory [3,4,5] was used to model the trivariate dependence between \( \text{Tmax}_{\text{MAM}}, \text{P}_{\text{MAM}} \) for wheat and barley yields using Nested Archimedean Copulas (NAC) [6], where two of the margins are coupled by their bivariate copula:

\[ C_{(u_1, u_2, u_3)} = C_1(u_1, u_2; \theta_1)C_2(u_3; \theta_2) \]  

Once the best NAC model is known, uniformly distributed data is sampled allowing the estimation of Eq. 1-3.

4. Results

Crop loss increases with the severity of the compound event in both cereals and crops (Fig. 3).

Higher chances of crop loss in cluster 2 (Fig. 3 and 4) namely for barley.

Crop loss due to compound dry and hot conditions is driven primarily by drought than by heat, suggesting that drought causes more damage to crop yields than heat stress, even for lower values of stress (Fig. 4).

5. Conclusions

- A dependence between crop yield, drought and hot conditions is suggested based on Nested Archimedean Copulas (NAC).
- The probability of crop-loss increases with the severity of the compound event and increases when drought or heat aggravate to compound dry and hot conditions in both regions and cereals.
- Drought plays the major role in crop loss due to compound event.
- The likelihood of crop-loss is slightly higher in the southern cluster for both cereals, particularly in the case of barley.