Identifying accurate climate indicators of extreme yield loss in Europe

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Research Questions

- How can we analyze the performance of various indicators in their ability to predict extreme yield loss?
- Do complex (*e.g.,* crop models) indicators perform better than simple ones?
- Can we improve the reliability of commonly used indicators?

Main Conclusions

- We obtain contrasting results for the performance of indicators (many do not perform significantly better than random classification depending on crop species/country combination)
- There is no obvious relationship between complexity and accuracy
- We show how to calculate the probability of extreme yield loss from indicators

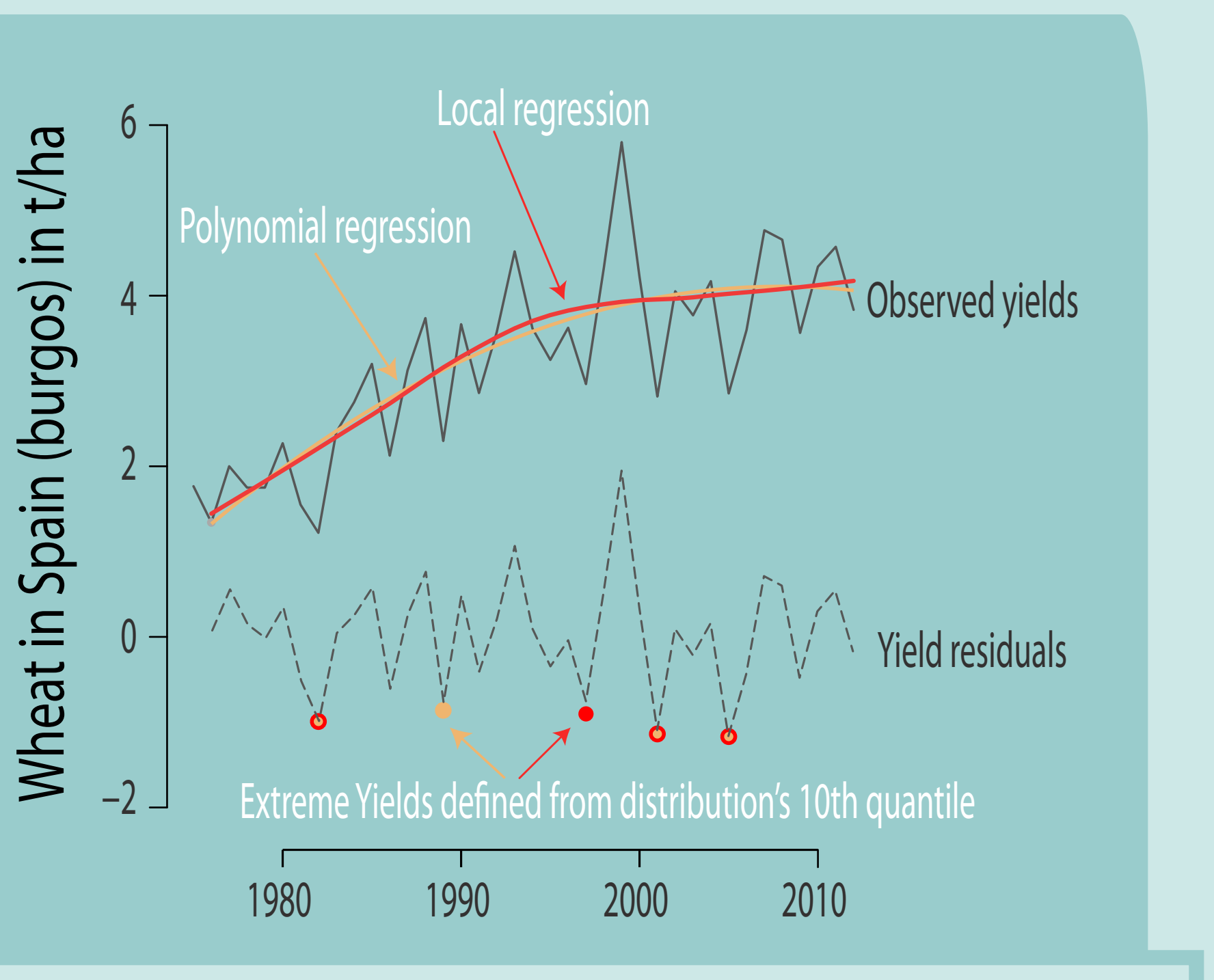
Data

- Yields (1)

Detrended NUTS3 yields for wheat and non-irrigated maize in Spain and in France (1976 - 2013)

- Climate(2)

Gridded (5°) climate data (JRC)



Basic climate indicators

Radiation
Tmax & Tmin
Precipitation
Evapotranspiration
Vapor pressure deficit

Phenology-based indicators

ARID: defined as a ratio of actual to potential transpiration
critical Tmax & Tmin : defined with crop-specific thresholds
critical ARID :defined with crop-specific thresholds
FU : a drought index defined from precipitation sums and reference evapotranspiration

Large-scale climate Mode

North Atlantic Oscillation (NAO) monthy values

Crop model simulations

Simulations from the WOFOST model (Mars Monitoring system - CGMS) :
Potential Yield
Water-limited Yield

Methods

Classification Rule(3)

"Yield is lower than a percentile (5th or 10th) if an indicator takes a value below/ablove a threshold"

Error rates

Sensitivity = 1- rate of false negative
Specificity = 1 - rate of false positive

Overall Accuracy of Indicators

ROC analysis : AUC (Area Under the Curve) is calculated for every possible climate threshold
AUC= 0.5 corresponds to random classification
AUC = 1 corresponds to perfect classification

Significance of AUC

A p-value is calculated for each AUC
AUC non-significantly different from 0.5 (p<0.001) are greyed (Fig. 2)

Probability of Extreme Yield Loss

The probability of observing an extreme yield loss given that an indicator value is below/above a threshold

Results

Probability distribution of indicators associated with (non)-extreme yields

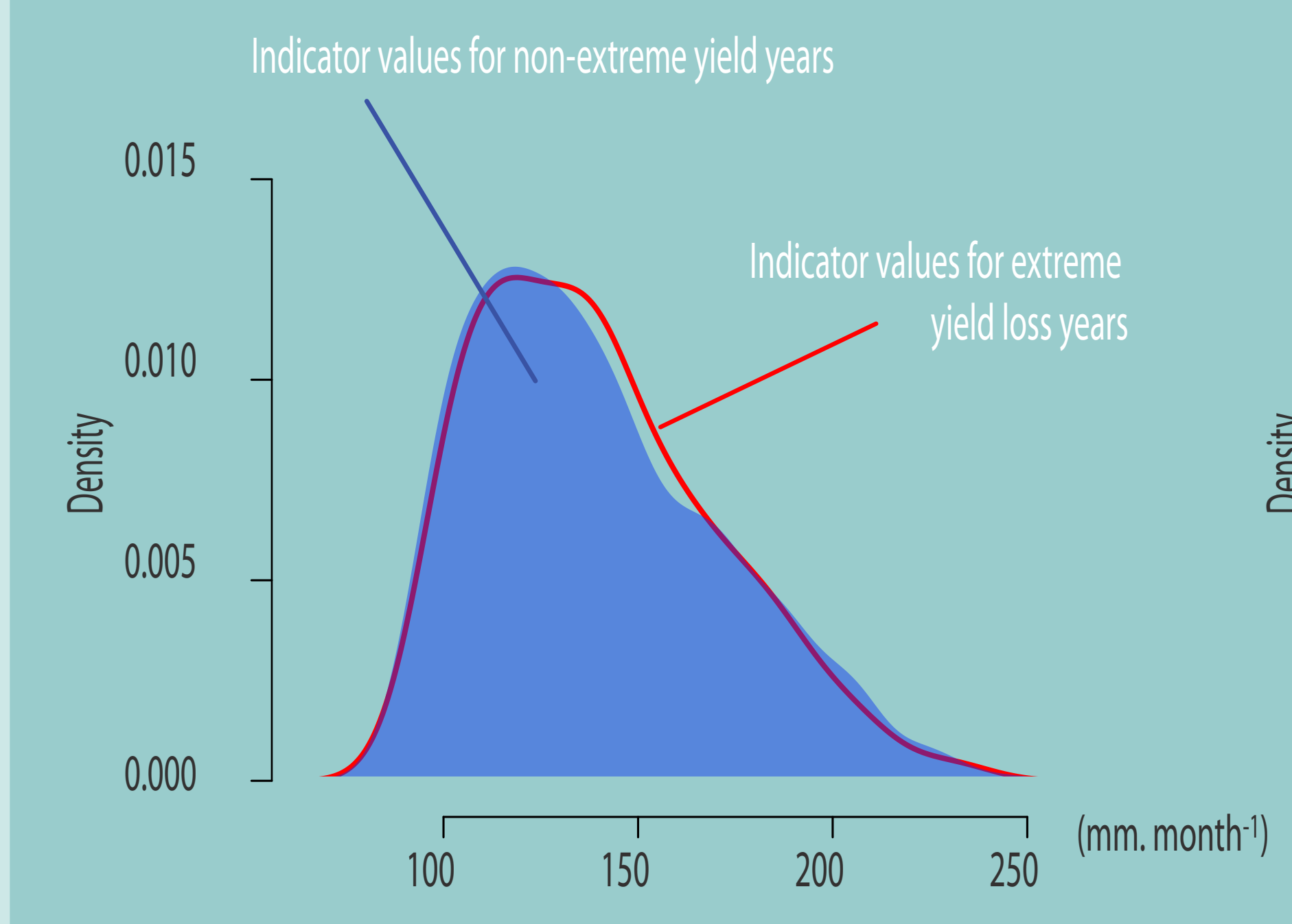


Fig. 1a The distribution of non-extreme versus extreme autumn **Evapotranspiration** for wheat in Spain. The similarity in the indicator's distribution is associated with a poor accuracy: AUC=0.52

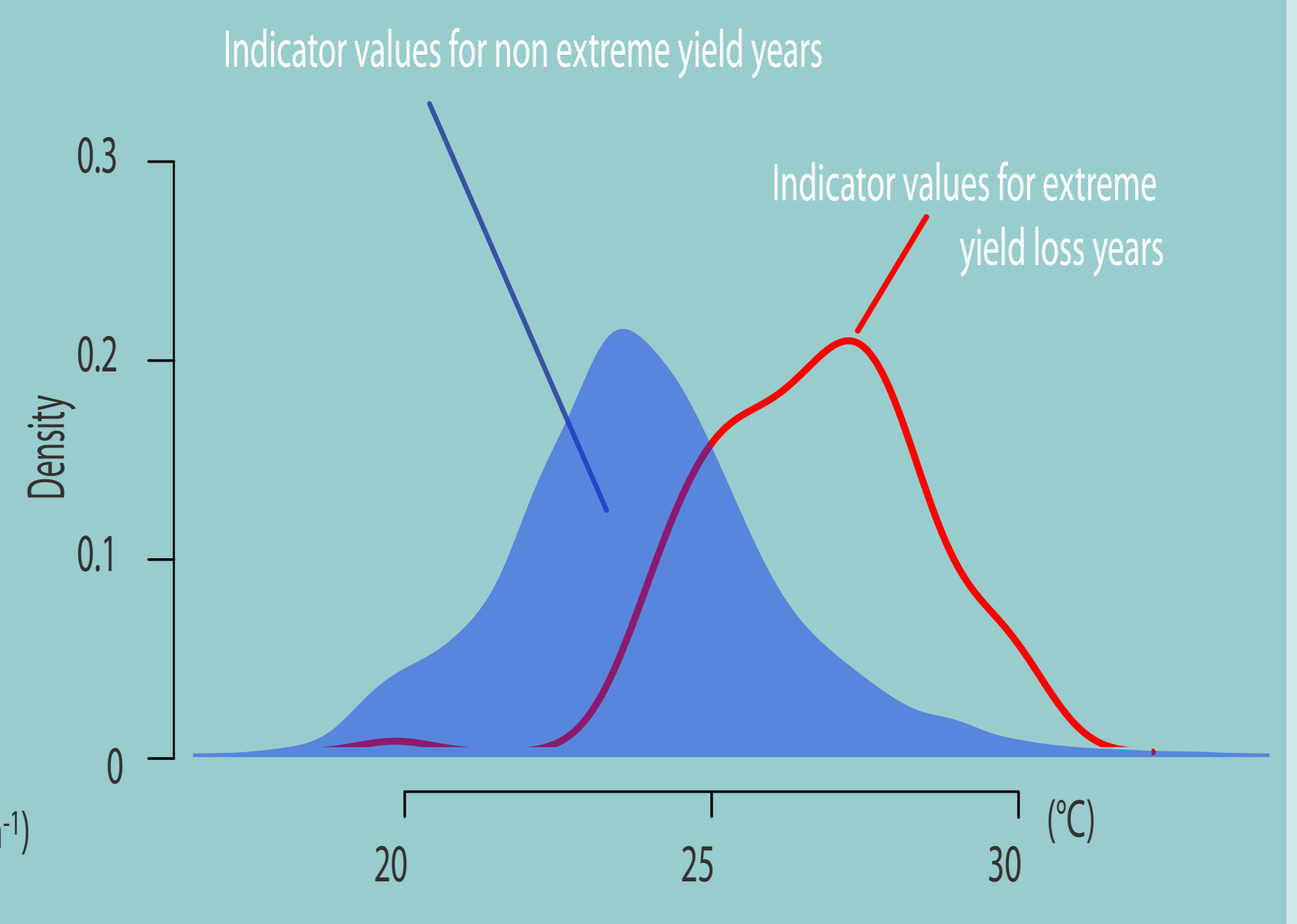
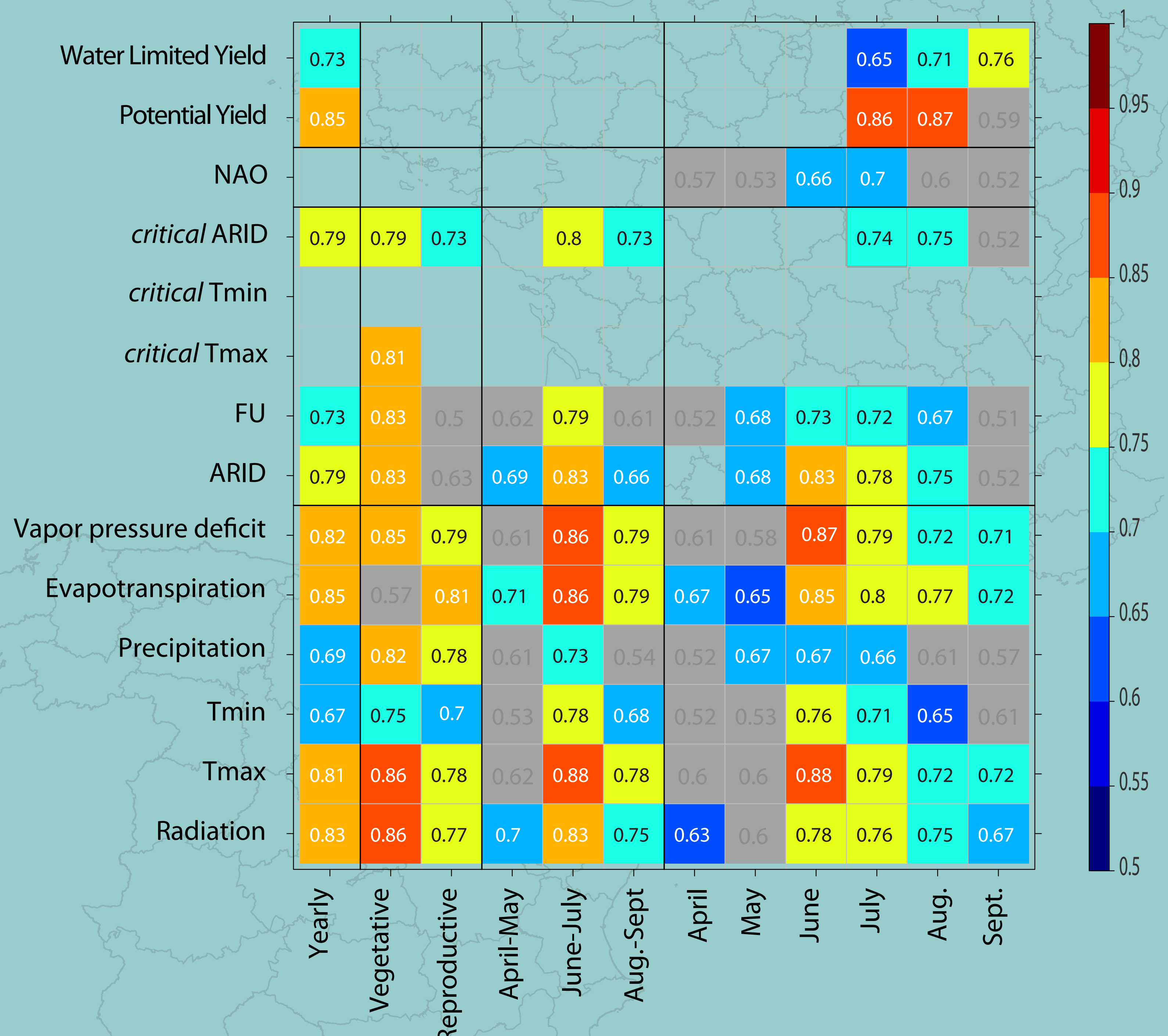


Fig. 1b The distributions of non-extreme versus extreme **Tmax** for the June-July period for wheat in France. The difference between the two distributions is associated with a good accuracy : AUC=0.88 *(See Fig. 2 below)*

Accuracy (AUC) of all indicators



	Yearly	Vegetative	Reproductive	April-May	June-July	Aug.-Sept	April	May	June	July	Aug.	Sept.
Water Limited Yield	0.73									0.65	0.71	0.76
Potential Yield	0.85									0.86	0.87	0.59
NAO							0.57	0.53	0.66	0.7	0.6	0.52
critical ARID	0.79	0.79	0.73		0.8	0.73				0.74	0.75	0.52
critical Tmin												
critical Tmax		0.81										
FU	0.73	0.83	0.5	0.62	0.79	0.61	0.52	0.68	0.73	0.72	0.67	0.51
ARID	0.79	0.83	0.63	0.69	0.83	0.66		0.68	0.83	0.78	0.75	0.52
Vapor pressure deficit	0.82	0.85	0.79	0.61	0.86	0.79	0.61	0.58	0.87	0.79	0.72	0.71
Evapotranspiration	0.85	0.57	0.81	0.71	0.86	0.79	0.67	0.65	0.85	0.8	0.77	0.72
Precipitation	0.69	0.82	0.78	0.61	0.73	0.54	0.52	0.67	0.67	0.66	0.61	0.57
Tmin	0.67	0.75	0.7	0.53	0.78	0.68	0.52	0.53	0.76	0.71	0.65	0.61
Tmax	0.81	0.86	0.78	0.62	0.88	0.78	0.6	0.6	0.88	0.79	0.72	0.72
Radiation	0.83	0.86	0.77	0.7	0.83	0.75	0.63	0.6	0.78	0.76	0.75	0.67

Fig. 2 **AUC values for all studied indicators of extreme yield loss in France** departements (i.e., NUTS2 counties) for non-irrigated maize. Higher values indicate good accuracy of each indicator over all departements. Only values significantly different from 0.5 (random classification) are coloured, non-significant values are presented in grey squares. Note that a similar matrix can be computed for winter wheat and irrigated maize in France and for wheat and non-irrigated maize in Spain.

Probability *P* of extreme yield loss

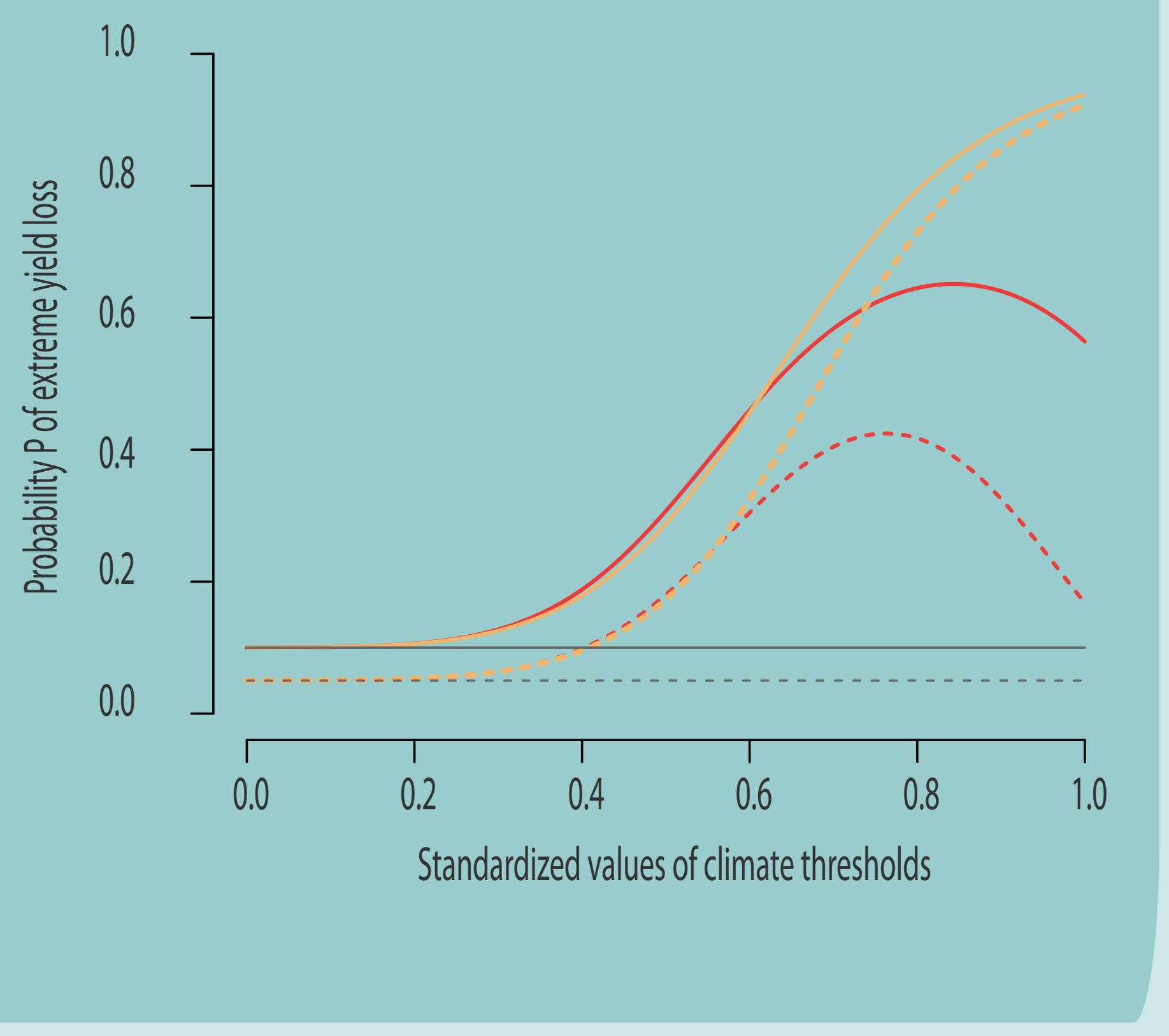
Rate of true positive obtained for one given climatic threshold

Proportion of extreme yield loss (i.e. equal to chosen quantile)

$$P = \frac{\text{Sensitivity . Frequency of Extreme yield loss events}}{\text{Sensitivity . Frequency of Extreme yield loss events} + (1\text{- Specificity})\ (1\text{- Frequency of Extreme yield loss events})}$$

Rate of true negative obtained for one given climatic threshold

Fig. 3 **Probability of extreme loss event for Tmax in the June-July period** (for non-irrigated maize in France, see also Fig. 1b). To assess the robustness of our calculations to methodological choices we plot P for polynomial (red) or local (orange) detrending methods and for extreme yield loss defined by 10th (bold) or 5th (dotted) percentiles. As a benchmark, a low performing indicator (evapotranspiration in autumn for wheat growing season - Fig. 1b) in plotted in grey.



Notes / Sources

(1) Time series length differ according to crops: 1976 to 2013 for wheat in France and in Spain / 1989-2000 to 2012 for non-irrigated maize in France and in Spain
(2) See also T. Klein, P. Calanca, T. Ben-Ari, D. Makowski & G. bellochi (2015) Increasing proportion of European wheat producing areas under extreme heat and drought for the 5th AgMIP workshop.
(3) See for example Makowski *et al*, (2006) Measuring the accuracy of agro-environmental indicators. Journal of environmental managment.

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