

Review comments 3

General Comments

This study presents a comprehensive assessment of the seasonal soil moisture prediction skill of the SEAS5 forecasting system, using ERA5 as the reference, and explores the agricultural relevance of these forecasts for winter wheat and maize across Europe and the Mediterranean. The work examines how the soil moisture anomalies relate to crop-yield variability at country and regional scales.

However, a number of scientific and methodological issues need to be addressed before the manuscript can be accepted for publication. These relate to the benchmarking and validation framework, the statistical robustness of the crop-yield analysis, and the transparency of the data reconstruction procedure, etc. The paper also contains several technical and presentation issues that should be corrected.

The manuscript addresses an important topic and presents a creative methodological approach, but the issues noted above need to be resolved before publication. With careful revision, the paper will be a valuable contribution to the seasonal forecasting and agricultural hydrology literature.

We sincerely thank the reviewer for the positive review. It's a great encouragement for us. We will work on the scientific, methodological, statistical and validation issues to be addressed before the manuscript is accepted for publication.

Specific Comments

1. The study uses ERA5 reanalysis as the sole reference for evaluating SEAS5 soil-moisture anomalies. While ERA5 is a state-of-the-art product, it is a model-based reanalysis with its own uncertainties (e.g., parametrizations, forcing, data assimilation). The authors should acknowledge more explicitly that ERA5 is not a direct observation and that some of the differences between SEAS5 and ERA5 may reflect errors in ERA5 rather than in the forecast system. A brief discussion of how the main conclusions might be affected if a different reference (e.g., ERA5-Land or in-situ data) were used would strengthen the manuscript. And

an acknowledgement of the possible influences on the conclusion if ERA5 is solely used is also recommended.

We agree that ERA5 is a reanalysis product rather than a direct observational dataset and therefore it may contain uncertainties. Consequently, some of the differences identified between SEAS5 and ERA5 may reflect uncertainties in the reference dataset itself rather than forecast errors alone. Therefore, as per your suggestion, we have added the analyses of ERA5-Land data. Figure S6 (below and in the revised manuscript) represents the EOFs of ERA5-Land soil moisture anomaly of layer1 (SWVL1). These are in very close agreement with the EOFs of ERA5 and SEAS5 anomaly EOFs. These results strengthen the analysis in the manuscript as indicated by the reviewer. Also, we would like to emphasize here (and in the revised manuscript) that the connection between SEAS5/ERA5 and yield data demonstrates that although SEAS5/ERA5 are relatively synthetic datasets, they show a relation to an independent yield dataset. This demonstrates their usability.

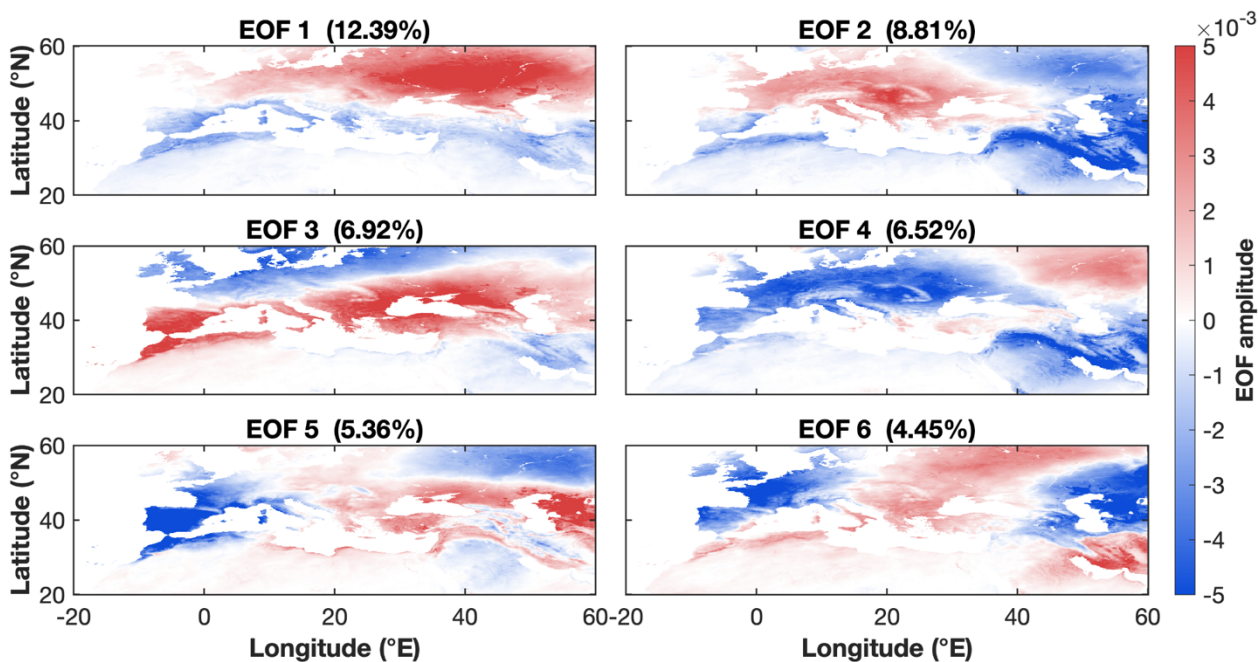


Figure S6: First six EOFs of ERA5-Land data with the percentage of variance corresponding to each EOF of soil moisture layer 1 (swvl1) from 1981 to 2024.

2. The authors identify non-physical discontinuities in PC1 of the deepest soil layer (swvl4). They then remove PC1 entirely from the reconstruction and base their main correlation improvements on PCs 2-10. This is a pragmatic solution, but the manuscript lacks a clear justification for why PC1 is discarded, a discussion of what effects of doing this, and a discussion of why the discontinuities happen. The authors should provide a more detailed analysis of the discontinuity. For instance, regarding the discussion of what effects of doing this, does excluding PC1 substantially alter the spatial patterns of forecast skill or crop-yield correlations? A brief sensitivity analysis could reinforce the robustness of the PC2–PC10 reconstruction approach.

The decision to exclude PC1 from the SWVL4 reconstruction was motivated by the presence of a pronounced discontinuity in this specific PC time series. EOF analysis identifies the dominant mode of variance, regardless of whether that variance originates from physically meaningful variability or from an artificial shift in the data. In the case of SWVL4, PC1 is dominated by an abrupt jump and long-term drift, present in both ERA5 and SEAS5, and it does not represent seasonal-to-interannual soil moisture variability that is the focus of this study.

To assess the impact of excluding PC1, we compared the correlations obtained between PC2–PC10 reconstruction and yield (Figure S5 in the main manuscript). The overall spatial structures and the main conclusions regarding forecast skill and crop-yield relationships remained largely unchanged. These results indicate that the improvements obtained from the PC2–PC10 reconstruction are not solely an artifact of removing PC1 but reflect a more robust representation of the physically meaningful variability contained in the soil-moisture fields. We will include an expanded discussion of the discontinuity, its possible origin, and the sensitivity of the results to the exclusion of PC1 in the revised manuscript.

3. The crop-yield analysis (Section 4.3 and Tables 4-5) reports correlation values but does not provide confidence intervals or significance tests for the reported coefficients. Many of the country-level correlations in Tables 4-5 are described as “positive” or “negative” without numerical values, and the significance is not assessed. The authors should include numerical correlation coefficients (and, where appropriate, p-values) for the country-level statistics. This

is particularly important for readers to interpret why some countries' relationships appear relatively weak (e.g., France, Italy).

We agree that including the correlation coefficients together with their corresponding p-values will provide a more rigorous assessment of the statistical significance of the reported relationships. We will therefore add the correlation coefficients and associated p-values in the revised manuscript. This addition will strengthen the robustness of the analysis and improve the overall quality and interpretability of the paper.

4. Where raw or reconstructed ERA5 soil moisture is used should be clearly specified. In most of the places the reconstructed ERA5 soil moisture is used, in this way, in the title or captions of the table and figures, and also in the main text, the "reconstructed" (if so) should be stated clearly.

We agree that the distinction between raw and reconstructed ERA5 soil moisture should be clearly stated throughout the manuscript. We will carefully review the text, figure captions, table captions, and corresponding discussions to ensure consistency.

5. The paper does not include any independent validation of whether the filtered SEAS5 fields are actually more accurate than the raw fields in predicting future soil moisture. The authors should comment on this limitation and, ideally, add a small cross-validation experiment.

Since both ERA5 and SEAS5 are affected by artificial discontinuities, we do not see an additional advantage in predicting ERA5 soil moisture with its artifacts. But this is part of the reason we added the correlation analysis of crop yield with ERA5, both original (Figure 9) and reconstructed soil moisture (Figure S5 in the sup). This part represents a kind of independent cross-validation analysis, demonstrating SEAS5 usability in predicting seasonal crop-yield. We will emphasize this point in the revised manuscript.

6. The manuscript reports negative correlations between soil moisture and winter wheat yields in several regions (e.g., Italy, parts of France). These are interpreted as reflecting energy limitation (e.g., radiation deficits) or irrigation effects. While plausible, the interpretation remains speculative without additional supporting analyses (e.g., correlation with temperature

or radiation, or a breakdown of areas with different irrigation levels. The discussion would be strengthened by a more explicit analysis of energy balance and a distinction between areas with different irrigation levels using dataset such as irrigation maps. A brief introduction for calculating anomalies of soil moisture or crop-yield data should be added.

The negative correlations between soil moisture and winter wheat yields observed in some regions of Europe were interpreted as potential signatures of temperature/radiation-limited conditions and/or irrigation effects based on previous studies. Several studies have shown that, in humid and energy-limited environments, above-normal soil moisture is often associated with increased cloud cover, reduced incoming solar radiation, and lower temperatures, which can adversely affect crop growth despite favorable water availability (Lobell and Field, 2007; Zampieri et al., 2017; Ceglar et al., 2019). In addition, irrigation can weaken or even reverse the expected positive relationship between soil moisture and crop yields because crop productivity becomes less dependent on natural soil moisture variability (Siebert et al., 2015).

At the request of the reviewer, we added our own analysis of correlations between yield and radiation, together with correlations between yield and temperature, in the supplementary information (also below Figures S7 and S8). In addition, we added maps of irrigated regions (Figures S9 and S10). This analysis, together with the new citations, supports our claims in the original manuscript. Specifically, as we suggested, we find that regions with negative correlations between soil moisture and yield are generally controlled by radiation and temperature. For example, northern Europe shows a positive correlation between wheat yield and temperature/radiation, particularly at the end of the season (Jan-Apr). Italy and parts of France seem to be controlled by a mixture of irrigation/raditaion/temperature together with soil moisture. Overall, these results suggest that, along with the soil moisture variability, radiation and temperature anomalies are significantly impacting the crop yield growth regionally and seasonally over Europe and Mediterranean regions. It will be discussed more clearly in the revised manuscript.

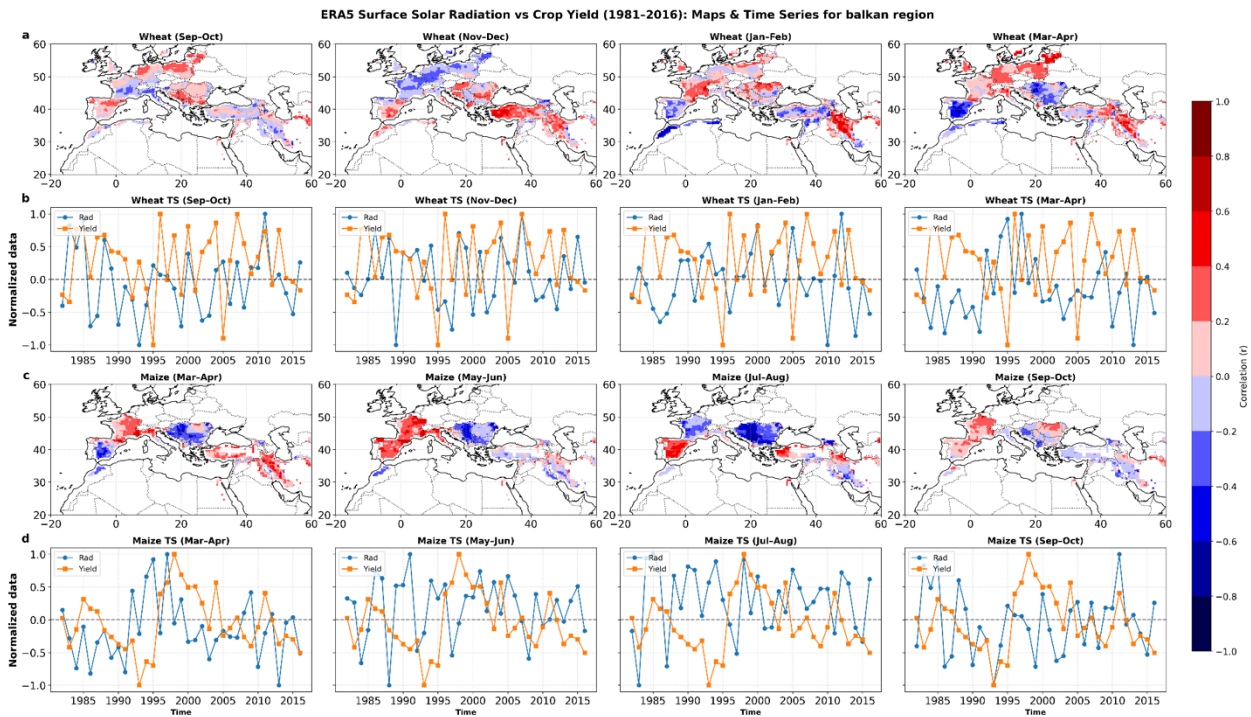


Figure S7: Panels a and c represent the pixel-wise correlation between the shortwave net solar radiation (Rad) and the crop-yield anomalies (Winter wheat and Maize). Panels b and d represent the normalized time series of crop yield (Winter wheat and Maize) for the Balkan region for the period of 1981 to 2016.

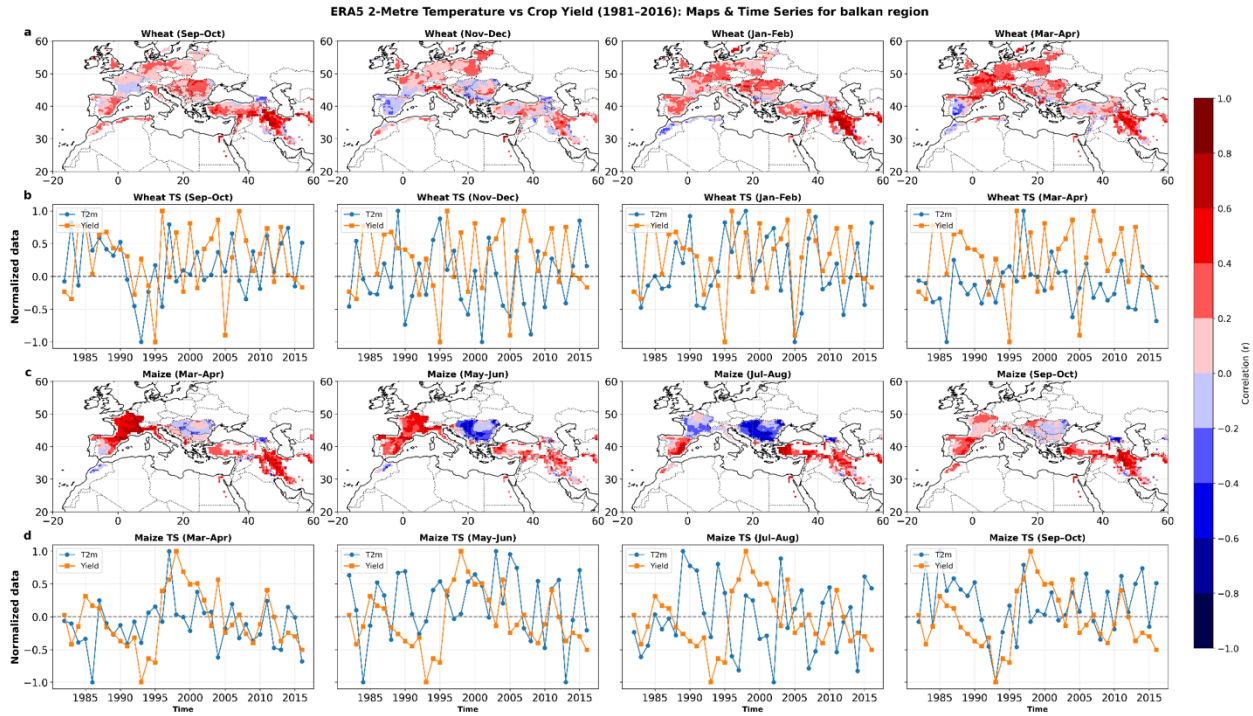


Figure S8: Panels a and c represent the pixel-wise correlation between the 2m temperature and the crop-yield anomalies (Winter wheat and Maize). Panel b and d represent the normalized time series of crop yield (Winter wheat and Maize) for the Balkan region for the period of 1981 to 2016.

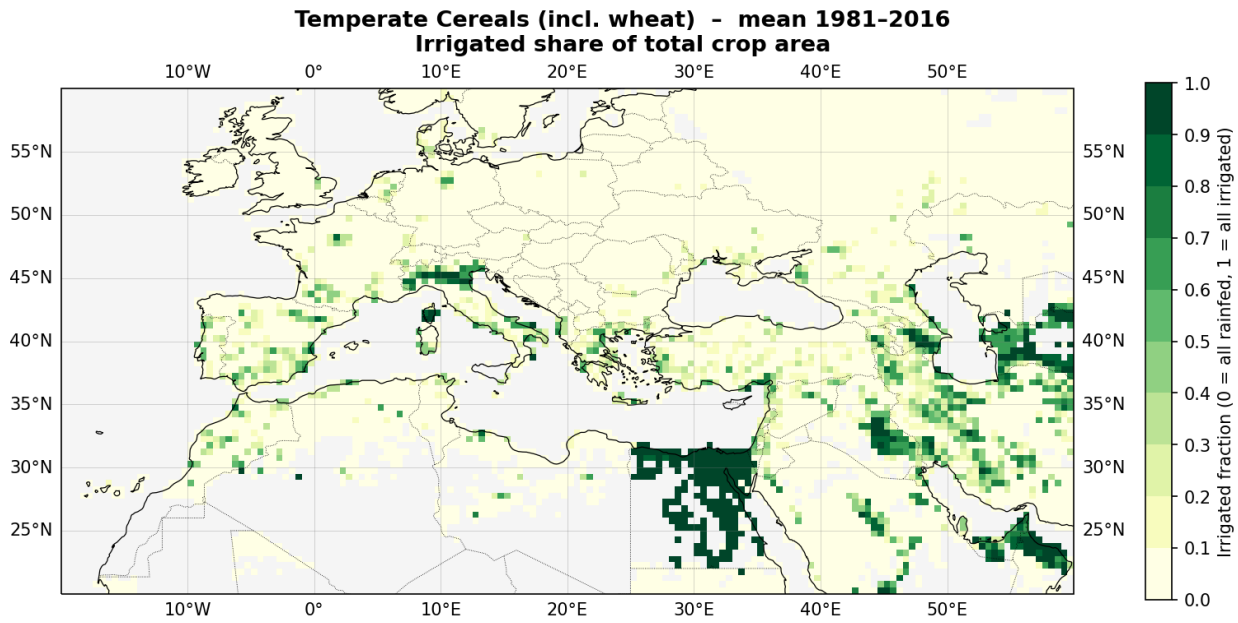
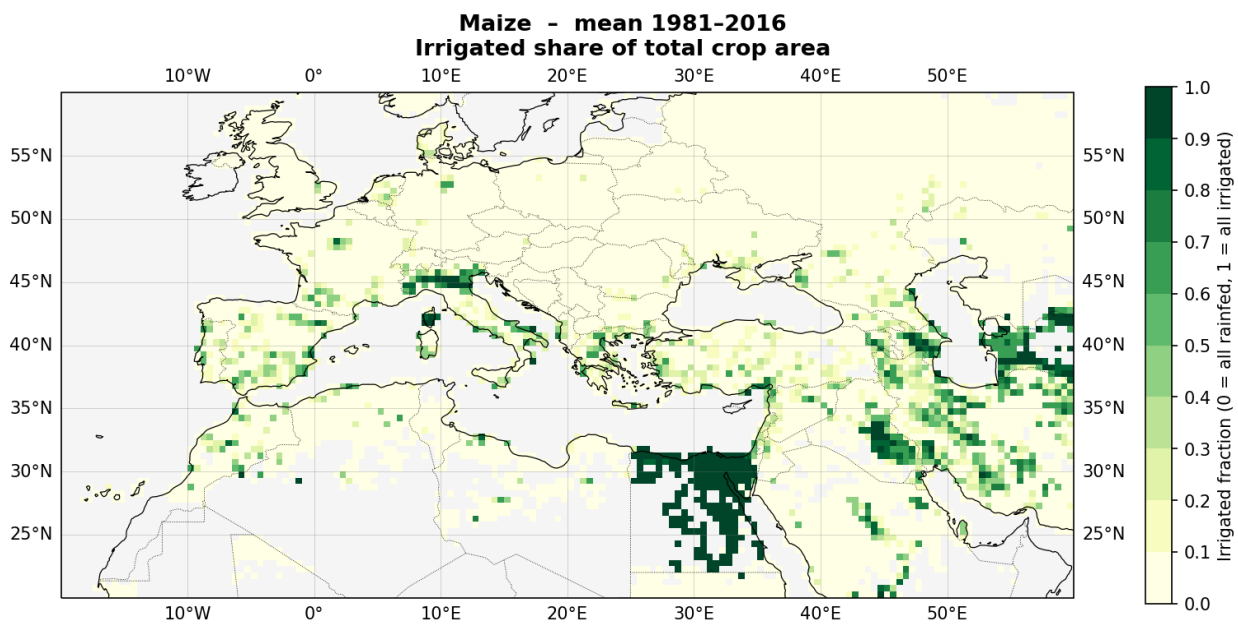


Figure S9: Irrigated share of the wheat crop area over Europe and the Mediterranean region for the mean of 1980 to 2016.



FigureS10: Irrigated share of the Maize crop area over Europe and the Mediterranean region for the mean of 1980 to 2016.

7. The novelty of this paper should be more clearly articulated in relation to recent studies that have also evaluated SEAS5 soil moisture over the Mediterranean, such as Silvestri et al. (2025, *Hydrology and Earth System Sciences*). The authors should explicitly discuss how their work goes beyond these previous assessments.

As per the reviewer's suggestion, we would like to more clearly articulate the novelty of our study in relation to the recent work of Silvestri et al. (2025). Although both studies focus on the evaluation of soil moisture datasets, our work differs substantially in several important aspects.

First, our study extends both the temporal and spatial coverage of the analysis. While the study by Silvestri et al. (2025) focused on a limited domain and period, our analysis covers the broader Mediterranean region (20°W–60°E, 20°–60°N) and spans the period from 1980 to 2024.

Second, we employ a range of additional analyses to investigate the differences and inconsistencies between ERA5 and SEAS5 soil moisture datasets. These analyses provide deeper insights into the spatial and temporal variability of soil moisture and help identify the sources of mismatch between the two products.

Finally, and most importantly, our study extends beyond dataset evaluation by examining the relationship between soil moisture and crop yield across the Mediterranean region. This application demonstrates the practical value of the soil moisture datasets for agricultural monitoring and planning, an aspect that was not addressed in Silvestri et al. (2025).

We will revise the manuscript accordingly to better highlight these distinctions and clarify the unique contributions of our study.

8. The 25-member ensemble used in the analysis is not described fully, for example, are the anomalies based on the ensemble mean, median, or each member separately?

We have used the Mean of 25 ensemble members. The anomalies are with respect to the climatology of the ensemble mean.

9. "All datasets were regridded to a common spatial resolution," but the target resolution and interpolation method (e.g., bilinear, conservative) are not specified.

Sure, it will be added to the revised manuscript

10. Figure 7: The caption is incomplete ("Which shows a significant difference" is not a proper caption)

Sure, we will check it.

Technical Corrections:

11. Line 59: shouldn't the bracket contain anything?

There should be a reference, we will check it. Thank you.

12. Line 207: "More complex modes, however, vary widely, either due to structural", this sentence is incomplete.

13. Sure, we will take care of these king of miss alignments in the revised manuscript.

Reference list: Several cited references are incomplete or have minor formatting issues (e.g., missing page ranges, inconsistent use of DOI formatting). Please check carefully against the HESS reference style.

14. Thank you for the detailed revision. We will take care of these details in the revised manuscript.

References:

1. Silvestri, L., Saraceni, M., Brunone, B., Meniconi, S., Passadore, G., and Bongioannini Cerlini, P.: Assessment of seasonal soil moisture forecasts over the Central Mediterranean, *Hydrol. Earth Syst. Sci.*, 29, 925–946, <https://doi.org/10.5194/hess-29-925-2025>, 2025.
2. Zampieri, M., Ceglar, A., Dentener, F., & Toreti, A. J. E. R. L. (2017). Wheat yield loss attributable to heat waves, drought and water excess at the global, national and subnational scales. *Environmental Research Letters*, 12(6), 064008.

3. Ceglar, A., Toreti, A. Seasonal climate forecast can inform the European agricultural sector well in advance of harvesting. *npj Clim Atmos Sci* **4**, 42 (2021). <https://doi.org/10.1038/s41612-021-00198-3>
4. Lobell, D. B., & Field, C. B. (2007). Global scale climate–crop yield relationships and the impacts of recent warming. *Environmental research letters*, *2*(1), 014002.
5. Siebert, S., Kummu, M., Porkka, M., Döll, P., Ramankutty, N., and Scanlon, B. R.: A global data set of the extent of irrigated land from 1900 to 2005, *Hydrol. Earth Syst. Sci.*, *19*, 1521–1545, <https://doi.org/10.5194/hess-19-1521-2015>, 2015.