Dear Editor,

We would like to submit our revised manuscript entitled "***Monitoring the combined effects of drought and salinity stress on crops using remote sensing in the Netherlands***" ***(HESS-2022-50)***. This revision is based on the comments provided by the reviewers based on our earlier revised manuscript. Reviewer 1 was satisfied with our revisions and recommended acceptance. Reviewer 2 mostly provided comments for clarification. We appreciate these suggestions. Our itemised responses are attached below and the changes made have also been annotated in the revised manuscript. In order to facilitate the review, the reply is displayed in blue font, and the comment of the reviewer is displayed in black. All revisions have been marked with the "Track Changes" function in Microsoft Word.

We hope that this revised manuscript is acceptable for publication. We deeply appreciate your consideration of our manuscript and look forward to your response.

Yours sincerely,

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 # Response to Reviewer 2

Main comment

The revisions to the manuscript have mostly addressed my major comments. However, considering there is only 2018 case analyzed here, it is better to discuss the uncertainty of these conclusions and explain why other cases are not included in the study. What is more, comparisons this study with other researches about the 2018 case could also be used to verify your conclusions. I am still confused about the timescale of drought. Is it fixed from April 1st to October 30th ? Considering the drought may not persist over the whole growing period, it may not be suitable to use cumulative thresholds (-214, -312) to classify drought.

Response/Action: Thank you for your comments. We now discuss the limitations of this study and explain the reason for not considering case studies from other years in a new dedicated section 4.4. (Lines 345-366) We are not aware of other studies executed for the year 2018.

With respect to the time scale of the drought: The drought map was created based on SPEI with a 3-months sliding time scale. The onset of the 2018 drought was from March to May across the Netherlands according to the result of our team (Chen et al., 2022). Crops are usually planted between April to May, and harvested before the end of October in the Netherlands. So, to be consistent with the crop growing season, we evaluated the drought impacts from April to October. Exactly because the drought may be intermittent over the growing period, the cumulative SPEI can capture the overall impacts of these droughts. The cumulative nature of the metric also helps to evaluate impacts across multiple crops across large areas as different crops may respond more quickly or slowly to drought events. A cumulative SPEI captures all these responses. Moreover, the 2018 drought lasted up to the end of the growing season (October) as indicated by several other studies (Brakkee et al., 2022; Peters et al., 2020). In combination, we believe that using the cumulative SPEI gives reasonable insight to classifying drought and its impacts on crops.

Lines 345-366: 'The number of studies that evaluate the effects of drought and salinity stress on crops is limited (Wen et al., 2020). In general, studies focus on small-scale experimental studies under strictly control of all variables with only a limited number of crops (Hussain et al., 2020; Ors and Suarez, 2017). To our knowledge, this is the first study that uses satellite remote sensing to investigate drought and salinity impacts for a large area under real-life conditions necessary for constructing stress management policies.

In such real-life conditions, as investigated here, irrigation of crops is commonly applied as management practice during drought events to reduce the severity of drought impacts (Deb et al., 2022; Lu et al., 2020). In this study, however, we have evidence that irrigation did not play a major role in the patterns found since all croplands included in our research area were identified as rainfed cropland (according to the ESA/CCI land cover map in 2018; https://maps.elie.ucl.ac.be/CCI/viewer/). In addition, while farmers in the area are known to irrigate their cropland, the Dutch government announced a temporary national irrigation ban in 2018 (for various areas including our research area) to spare water (Perry de Louw, 2020). As a consequence, we could not analyze the impacts of irrigation management on the combined effects of drought and salinity. This might potentially be solved by investigating other drought historic events with moderate severity in Europe, such as the year of 2003 (Ciais et al., 2005) or 2015 (Ionita et al., 2017) in Europe, when such a ban was not executed. Unfortunately, satellite remote sensing observations with the required 20-30m resolutions of these events are limited, as Sentinel-2 was only launched in 2015 and the Landsat satellites provide a too coarse temporal resolution.

Likewise, impacts of salinity and drought are moderated by crop selection. Traditionally, farmers do not plant highly vulnerable crops in moderate/high salinity areas. In fact, we found crops sensitive to salinity such as apple (Ivanov, 1970) and broccoli (Bernstein and Ayers, 1949) to be abundant in non-saline areas but only little in saline areas. To ensure an accurate evaluation of salinity impacts, we only investigated those crops with a significant abundance in all available stress conditions. More sensitive crops might even respond more strongly.'

Specific comments:

Q1. L29: drought and salinity "stress".

Response/Action: We have revised this sentence according to your suggestion. (Lines 29-31)

Lines 29-31: 'Of these stresses, drought and salinity stress have been identified as the two main factors to limit crop growth, affecting respectively 40% and 11% of the global irrigated areas (Dunn et al., 2020; FAO, 2020).'

Q2. L33 Rank the references.

Response/Action: The references have been reranked. We have revised the citations sort order over the whole manuscript. (Lines 31-34)

Lines 31-34: ‘With drought and salinity forecasted to increase spatially and in severity (Rozema and Flowers, 2008; Schwalm et al., 2017; Trenberth et al., 2013), and with predictions of higher co-occurrence around the world (Corwin, 2020; Jones and van Vliet, 2018; Wang et al., 2013), food production will be more deeply challenged by both stresses.’

Q3. L36: Co-occurrence of drought and salinity stress is found to decrease… “more” compared the individual stress only.

Response/Action: We have revised this sentence according to your suggestion. (Lines 36-38)

Lines 36-38: ‘Co-occurrence of drought and salinity stress is found to decrease the yield of spinach (Ors and Suarez, 2017) and the forage grass *Panicum antidotale* (Hussain et al., 2020) more compared with the occurrence of one of these stresses only.’

Q4. L55-57: Please conclude the specific studies about the impact of drought/salinity stress on crops. It is better to put this study to the background of the research about assessing the impacts on crops using RS techniques.

Response/Action: We have added specific studies in background information. (Lines 55-60)

Lines 55-60: ‘Canopy chlorophyll content and mean leaf equivalent water thickness (EWT) of maize differed remarkably under drought stress using hyperspectral remote sensing data (Zhang and Zhou, 2015). Using a look-up-table approach, LAI and chlorophyll content of wheat obtained from a radiative transfer model showed potential to assess drought levels (Richter et al., 2008). However, while there have been several attempts to monitor the response of crop health with either a drought or salinity focus, not much research has taken these factors into account simultaneously (Wen et al., 2020).’

Q5. L114-115 & L211-213: Add “in 2018” to the figures’ captions.

Response/Action: We have revised the captions of the figures according to your suggestion. (Lines 117-118, Line 215, Line 239)

Lines 117-118: ‘Figure 2. Map of the Netherlands overlaying a) drought and b) salinity to show c) the co-occurrence of drought and salinity in 2018. The selected study area is indicated by black lines in panel c. d) The associated crop map of the study area in 2018.’

Line 215: ‘Figure 3. Expressions of LAI, FAPAR, and FVC under various stress conditions in May, June, July, and September 2018.’

Line 239: ‘Figure 4. Expressions of Cab and Cw under various stress conditions in May, June, July, and September 2018.’

Q6. L138-147: What are the spatial resolution and time scale of LAI, FAPAR, and etc?

Response/Action: All traits are at 10 m resolution and each monthly trait estimate was derived by the biophysical processor within SNAP. We have clarified the related information in section 2.3. (Lines 152-154)

Lines 152-154: 'The biophysical processor within the SNAP toolbox derives the five traits, namely LAI, FAPAR, FVC, canopy chlorophyll content (CCC), and canopy water content (CWC), for each pixel from the Sentinel-2 top of canopy reflectance data at a 10m-resolution for each month.'

Q7. L163: What is "hoc test"?

Response/Action: The post-hoc test is an integral part of an ANOVA. While the ANOVA identifies that significant differences occur among at least two of the groups, it does not indicate which groups differ significantly. A post-hoc test evaluates which groups differ significantly from each other within the ANOVA.

Q8. L164: As you mentioned "ANOVA" many times, explain the method more in details.

Response/Action: ANOVA refers to the analysis of variance. A two-way ANOVA is a test to compare the difference between groups based on two factors. In this study, we adopted a two-way ANOVA to evaluate the main effects of the factors 'stress' and 'date' as well as the interaction of stress and date. We have explained ANOVA in section 2.4. (Lines 164-166)

Lines 164-166: 'Instead, two-way analysis of variance (ANOVAs) was applied to test the main effects and the interactive effect between stress combinations (consisting of 6 levels) and time (5 months) on each individual crop trait.'

Q9. L347-348: Add "during 2018 over the Netherlands".

Response/Action: We have revised this sentence according to your suggestion. (Lines 368-369)

Lines 368-369: 'In this study, we present the first attempt to evaluate the real-life effects of drought, salinity, and their combination on crop health using multiple traits from remote sensing monitoring during 2018 over the Netherlands.'

References

Bernstein, L., and Ayers, A.: Salt tolerance of cabbage and broccoli, United States Salinity Laboratory Report to Collaborators, Riverside, CA, 39, 1949.
Ciais, P., Reichstein, M., Viovy, N., Granier, A., Ogée, J., Allard, V., Aubinet, M., Buchmann, N., Bernhofer, C., Carrara, A., Chevallier, F., De Noblet, N., Friend, A. D., Friedlingstein, P., Grünwald, T., Heinesch, B., Keronen, P., Knohl, A., Krinner, G., Loustau, D., Manca, G., Matteucci, G., Miglietta, F., Ourcival, J. M., Papale, D., Pilegaard, K., Rambal, S., Seufert, G., Soussana, J. F., Sanz, M. J., Schulze, E. D., Vesala, T., and Valentini, R.: Europe-wide reduction in primary productivity caused by the heat and drought in 2003, Nature, 437, 529-533, https://doi.org/10.1038/nature03972, 2005.
Corwin, D. L.: Climate change impacts on soil salinity in agricultural areas, Eur. J. Soil Sci., 72, 842-862, https://doi.org/10.1111/ejss.13010, 2020.
Deb, P., Moradkhani, H., Han, X., Abbaszadeh, P., and Xu, L.: Assessing irrigation mitigating drought impacts on crop yields with an integrated modeling framework, J. Hydrol., 609, 127760, https://doi.org/10.1016/j.jhydrol.2022.127760, 2022.
Dunn, R. J. H., Stanitski, D. M., Gobron, N., Willett, K. M., Ades, M., Adler, R., Allan, R., Allan, R. P., Anderson, J., Argüez, A., Arosio, C., Augustine, J. A., Azorin-Molina, C., Barichivich, J., Barnes, J., Beck, H. E., Becker, A., Bellouin, N., Benedetti, A., Berry, D. I., Blenkinsop, S., Bock, O., Bosilovich, M. G., Boucher, O., Buehler, S. A., Carrea, L., Christiansen, H. H., Chouza, F., Christy, J. R., Chung, E. S., Coldewey-Egbers, M., Compo, G. P., Cooper, O. R., Covey, C., Crotwell, A., Davis, S. M., de

Eyto, E., de Jeu, R. A. M., VanderSat, B. V., DeGasperi, C. L., Degenstein, D., Di Girolamo, L., Dokulil, M. T., Donat, M. G., Dorigo, W. A., Durre, I., Dutton, G. S., Duveiller, G., Elkins, J. W., Fioletov, V. E., Flemming, J., Foster, M. J., Frey, R. A., Frith, S. M., Froidevaux, L., Garforth, J., Gupta, S. K., Haimberger, L., Hall, B. D., Harris, I., Heidinger, A. K., Hemming, D. L., Ho, S.-p., Hubert, D., Hurst, D. F., Hüser, I., Inness, A., Isaksen, K., John, V., Jones, P. D., Kaiser, J. W., Kelly, S., Khaykin, S., Kidd, R., Kim, H., Kipling, Z., Kraemer, B. M., Kratz, D. P., La Fuente, R. S., Lan, X., Lantz, K. O., Leblanc, T., Li, B., Loeb, N. G., Long, C. S., Loyola, D., Marszelewski, W., Martens, B., May, L., Mayer, M., McCabe, M. F., McVicar, T. R., Mears, C. A., Menzel, W. P., Merchant, C. J., Miller, B. R., Miralles, D. G., Montzka, S. A., Morice, C., Mühle, J., Myneni, R., Nicolas, J. P., Noetzli, J., Osborn, T. J., Park, T., Pasik, A., Paterson, A. M., Pelto, M. S., Perkins-Kirkpatrick, S., Pétron, G., Phillips, C., Pinty, B., Po-Chedley, S., Polvani, L., Preimesberger, W., Pulkkanen, M., Randel, W. J., Rémy, S., Ricciardulli, L., Richardson, A. D., Rieger, L., Robinson, D. A., Rodell, M., Rosenlof, K. H., Roth, C., Rozanov, A., Rusak, J. A., Rusanovskaya, O., Rutishäuser, T., Sánchez-Lugo, A., Sawaengphokhai, P., Scanlon, T., Schenzinger, V., Schladow, S. G., Schlegel, R. W., Schmid, M. E., Selkirk, H. B., Sharma, S., Shi, L., Shimaraeva, S. V., Silow, E. A., Simmons, A. J., Smith, C. A., Smith, S. L., Soden, B. J., Sofieva, V., Sparks, T. H., Stackhouse, P. W., Steinbrecht, W., Streletskiy, D. A., Taha, G., Telg, H., Thackeray, S. J., Timofeyev, M. A., Tourpali, K., Tye, M. R., van der A, R. J., van der Schalie, R. V. B. V., van der SchrierW. Paul, G., van der Werf, G. R., Verburg, P., Vernier, J.-P., Vömel, H., Vose, R. S., Wang, R., Watanabe, S. G., Weber, M., Weyhenmeyer, G. A., Wiese, D., Wilber, A. C., Wild, J. D., Wong, T., Woolway, R. I., Yin, X., Zhao, L., Zhao, G., Zhou, X., Ziemke, J. R., and Ziese, M.: Global climate-state of the climate in 2019, State of the climate in 2019, 101, S9-S128, https://doi.org/10.1175/bams-d-20-0104.1, 2020.

FAO, I., UNICEF, WFP and WHO: The state of food security and nutrition in the world 2020, FAO, Rome978-92-5-132901-6, 2020.

Hussain, T., Koyro, H. W., Zhang, W., Liu, X., Gul, B., and Liu, X.: Low salinity improves photosynthetic performance in panicum antidotale under drought stress, Front. Plant Sci., 11, 481, https://doi.org/10.3389/fpls.2020.00481, 2020.

Ionita, M., Tallaksen, L. M., Kingston, D. G., Stagge, J. H., Laaha, G., Van Lanen, H. A. J., Scholz, P., Chelcea, S. M., and Haslinger, K.: The european 2015 drought from a climatological perspective, Hydrol. Earth Syst. Sci., 21, 1397-1419, https://doi.org/10.5194/hess-21-1397-2017, 2017.

Ivanov, V.: Main principles of fruit crop salt resistance determination, Pochvovedenie, 4, 78-85, 1970.

Jones, E., and van Vliet, M. T. H.: Drought impacts on river salinity in the southern us: Implications for water scarcity, Sci. Total Environ., 644, 844-853, https://doi.org/10.1016/j.scitotenv.2018.06.373, 2018.

Lu, J., Carbone, G. J., Huang, X., Lackstrom, K., and Gao, P.: Mapping the sensitivity of agriculture to drought and estimating the effect of irrigation in the united states, 1950–2016, Agric. For. Meteorol., 292-293, 108124, https://doi.org/10.1016/j.agrformet.2020.108124, 2020.

Ors, S., and Suarez, D. L.: Spinach biomass yield and physiological response to interactive salinity and water stress, Agric. Water Manag., 190, 31-41, https://doi.org/10.1016/j.agwat.2017.05.003, 2017.

Perry de Louw, V. K., Harry Massop, Ab Veldhuizen Beregening: Deltafact, Alterra - Soil, water and land use, Amersfoort 2020.

Richter, K., Rischbeck, P., Eitzinger, J., Schneider, W., Suppan, F., and Weihs, P.: Plant growth monitoring and potential drought risk assessment by means of earth observation data, Int. J. Remote Sens., 29, 4943-4960, https://doi.org/10.1080/01431160802036268, 2008.

Rozema, J., and Flowers, T.: Ecology. Crops for a salinized world, Science, 322, 1478-1480, https://doi.org/10.1126/science.1168572, 2008.

Schwalm, C. R., Anderegg, W. R. L., Michalak, A. M., Fisher, J. B., Biondi, F., Koch, G., Litvak, M., Ogle, K., Shaw, J. D., Wolf, A., Huntzinger, D. N., Schaefer, K., Cook, R., Wei, Y., Fang, Y., Hayes, D., Huang, M., Jain, A., and Tian, H.: Global patterns of drought recovery, Nature, 548, 202-205, https://doi.org/10.1038/nature23021, 2017.

Trenberth, K. E., Dai, A., van der Schrier, G., Jones, P. D., Barichivich, J., Briffa, K. R., and Sheffield, J.: Global warming and changes in drought, Nat. Clim. Chang., 4, 17-22, https://doi.org/10.1038/nclimate2067, 2013.

Wang, J. L., Huang, X. J., Zhong, T. Y., and Chen, Z. G.: Climate change impacts and adaptation for saline agriculture in north jiangsu province, china, Environ. Sci. Policy, 25, 83-93, https://doi.org/10.1016/j.envsci.2012.07.011, 2013.

Wen, W., Timmermans, J., Chen, Q., and van Bodegom, P. M.: A review of remote sensing challenges for food security with respect to salinity and drought threats, Remote Sens., 13, https://doi.org/10.3390/rs13010006, 2020.
Zhang, F., and Zhou, G.: Estimation of canopy water content by means of hyperspectral indices based on drought stress gradient experiments of maize in the north plain china, Remote Sens., 7, 15203-15223, https://doi.org/10.3390/rs71115203, 2015.