Responses to RC #3:

Summary of comments:

This manuscript (MS herein) developed a downscaled monthly soil moisture (SM) dataset at 0.05° resolution by combining spato-temporal gap-filling algorithms and machine learning downscaling approach. The MS used the downscaled SM product to compute the standardised soil moisture drought index (SSI) in z-scores and applied SSI to assess the spatio-temporal dynamics of agricultural drought across China. The downscaled SM product achieved improved accuracy against benchmarking SM products. The MS then analysed spatial patterns, interannual variability and seasonal variations of agricultural drought derived from the SSI metric.

The topic of this MS is suitable to the science scope of HESS. The SM downscaling approach was sophisticated and logically sound, and the derived high-resolution products showed potential for agricultural drought assessments. However, a much more in-depth engagement with the relevant literature is needed in Introduction and Discussion sections to articulate the scientific context and evaluate the novelty of this research. Moreover, the drought index definition needs to be revisited, which may lead to changes in the drought assessment findings and conclusions.

After considering my major and specific comments below, I recommend a reject with invitation to resubmit.

Reply: Thank you for giving us the opportunity to revise and resubmit our manuscript. Your thorough and insightful comments have been invaluable in improving the quality of our work. Following your guidance, we have substantially revised the entire manuscript and have now completed all modifications. Once the editor notifies us to upload the revised version, we will perform a final check and submit it promptly. Our major revisions focus on three aspects:

1. Optimized the Introduction and improved method description

We have optimized the writing of the Introduction by replacing generic or imprecise statements with specific clarifications and adding relevant references, thereby more clearly articulating the research gap and the novelty of our work. Moreover, following your suggestion, we have revised the language of the methodology section to avoid a "technical note" style (e.g., removing note-taking expressions like "Stage 1: …") and to present the workflow in a more natural, narrative academic style.

2. Improved drought identification accuracy based on recalculated SSI and dynamic threshold development

✧ Recalculated SSI

We revised the SSI calculation scheme according to your suggestion by recalculating all SSI values using monthly mean and monthly standard deviation instead of annual statistics. Based on the revised SSI dataset, the coefficient of determination (R^2) between the extracted drought area and observed drought area reached 0.746 (Fig.1 (b)). The observed drought-affected area used in this study was constructed through the following steps. First, we used the daily agricultural drought comprehensive monitoring spatial distribution data from the Open Laboratory of the National Meteorological Center Forecast System as the baseline spatial dataset. Second, we validated the accuracy of this daily drought distribution dataset against the China Agricultural Meteorological Disaster Dataset compiled by the China Meteorological Administration, which contains detailed records of disaster name, occurrence date, intensity, affected area, and damage percentage. Third, from the validated daily drought distribution data, we extracted annual drought-affected areas at different severity levels. Finally, we cross-compared these extracted areas with two official statistical sources—the government-published annual crop drought-affected areas and the China Flood and Drought Disaster Bulletin—and integrated them to derive the final observed drought-affected area used for validation in this study.

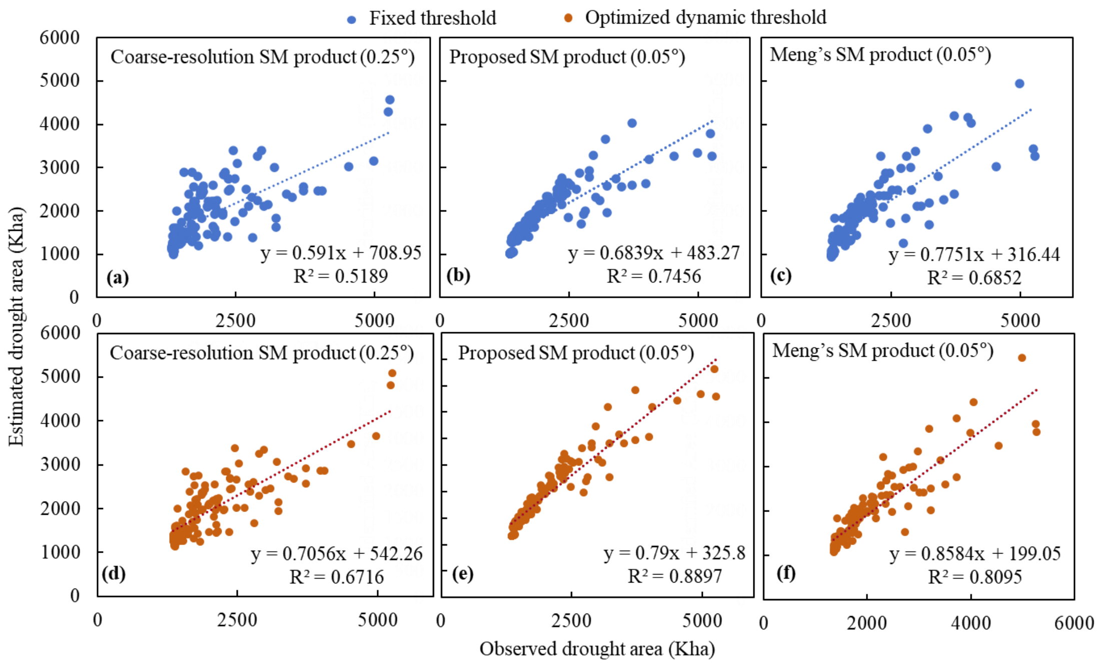

Fig.1 Validation of drought area identification using different SSI thresholds across three soil moisture products with varying resolutions. The top row (a-c) shows results from the fixed threshold SSI method (blue points), and the bottom row (d-f) shows results from the KDE-based optimized dynamic threshold SSI method (orange points). Linear fitting equations and coefficients of determination (R^2) are provided in each subplot.

✧ Dynamic threshold development

We replaced the original fixed threshold (SSI < 0) with a dynamic threshold method based on kernel density estimation (KDE) and historical drought records. Specifically, we divided China into four climatic zones (arid, semi-arid, sub-humid, humid). For each zone and each calendar month, we extracted all valid SSI values (2003–2023), removed outliers (values beyond ±3 standard deviations), and applied KDE to obtain a smoothed probability density curve. Using the three complementary reference datasets mentioned above – (i) government-published annual crop drought-affected area statistics (from the China Statistical Yearbook and China Flood and Drought Disaster Bulletin), (ii) the China Agricultural Meteorological Disaster Dataset, and (iii) the daily agricultural drought comprehensive monitoring spatial distribution data – we identified the SSI intervals corresponding to agricultural drought. This yielded a set of dynamic drought thresholds that vary spatially (by climate zone) and temporally (by month). Subsequently, we extracted drought areas using both the original fixed threshold and our newly constructed dynamic threshold across three soil moisture products: the coarse-resolution SM product, the SM dataset proposed in this study, and the SM product developed by Meng et al. (2021). Validation results demonstrate that the proposed dynamic threshold method effectively improved drought identification accuracy across all three datasets (Fig. 1). Quantitatively, compared with the fixed threshold, the dynamic threshold achieved relative improvements in R^2 between estimated and observed drought areas of 23% for the coarse-resolution product, 19% for our proposed product, and 22% for Meng's product.

We have recalculated the SSI and applied the above dynamic thresholds to re-extract agricultural drought areas across China. All related figures and conclusions (spatial patterns, interannual variability, seasonal characteristics, drought frequency across river basins, etc.) have been fully updated in the revised manuscript.

3. Enhanced discussion of added value

We have added a dedicated Discussion subsection that elaborates on the gains in drought area identification achieved by improved spatial resolution and accuracy of SM data, as well as the accuracy improvements brought by the optimized dynamic threshold method. Together, these methodological enhancements and the newly developed high-resolution SM dataset provide a more reliable scientific basis for national-scale agricultural drought monitoring in China, clearly demonstrating the necessity and value of our research.

Once again, we deeply appreciate your thorough and rigorous guidance, which has substantially enhanced the scientific quality and clarity of our work. Below is our point-by-point response to your comments.

Major comments:

1. The novelty of this research was unclear. There was limited literature review for existing downscaled SM-based drought studies in the Introduction to justify the research gap. Moreover, the authors reported the key interpretation of the results without critical discussion against existing literature, partly due to the lack of a standalone Discussion section. The authors partly showed the improvement by their downscaled SM product in the validation statistics, but did not demonstrate how such high-resolution SM data adds to agricultural drought monitoring. Think critically on this question: findings in this MS on drought patterns can also be obtained using the existing SM products – why do we need a new downscaled SM product to achieve this objective?

Reply: We sincerely thank the reviewer for this insightful and constructive comment, which has helped us significantly strengthen the novelty and scientific depth of our manuscript. We fully acknowledge the limitations in the original manuscript, including insufficient literature review in the Introduction section and the lack of a standalone Discussion section, which led to inadequate elaboration on the unique value of high-resolution soil moisture products for agricultural drought monitoring. We have comprehensively revised the manuscript to address these issues, as detailed below.

First, we have substantially revised the Introduction to better articulate the research gap. Specifically, we have systematically reviewed existing downscaled soil moisture products and their applications in agricultural drought monitoring, highlighting three key limitations of current studies: (1) Most global downscaled soil moisture products exhibit limited accuracy over China, particularly in regions with complex terrain, high vegetation cover, and intensive agricultural activities; (2) Existing regional downscaled products for China either have short time series, coarse spatial resolution (≥0.1°), or extensive missing data, which hinders long-term fine-scale drought trend analysis; (3) Previous drought studies based on downscaled soil moisture data have mostly focused on large-scale drought patterns, while the fine-scale spatial heterogeneity of agricultural drought in fragmented agricultural landscapes remains poorly understood. This expanded literature review clearly justifies the necessity of our study, which aims to produce a long-term, seamless, high-accuracy 0.05° soil moisture dataset covering China and reveal previously undocumented fine-scale agricultural drought patterns.

Second, we have added a standalone Discussion section in the revised manuscript. We now discuss the improvements of our downscaled product over coarse-resolution and low-precision products in terms of spatial resolution, temporal continuity, and drought detection accuracy, as well as the remaining uncertainties. For example, we recalculated the monthly Standardized Soil Moisture Index (SSI) using both our 0.05° data and coarser-resolution (0.25°) soil moisture data. Based on these two datasets, we estimated the drought-affected areas across different regions of China and compared the results with observed drought area (Fig.2 a–b). The comparison shows that the drought-affected areas derived from our high-resolution data are considerably more consistent with the observed statistics than those derived from the coarser data, demonstrating that higher spatial resolution enables more accurate extraction of drought-affected areas. We also calculated the SSI and drought-affected areas using a benchmark dataset (e.g., the 0.05° product from Meng et al., 2021) for comparison, and our data achieved higher accuracy in identifying drought-affected areas (Fig.2 b–c). The case of May 2009 clearly illustrates this advantage. During this period, the drought-affected cropland area in Heilongjiang Province reached 6.17 million hectares, accounting for 53% of the province's total cultivated land, of which 2.49 million hectares were severely drought-stricken. Our data detected that approximately 49.48% of the pixels in Heilongjiang experienced drought in that month, including severe drought. In contrast, Meng et al.'s data only showed 32.79% of pixels with mild drought.

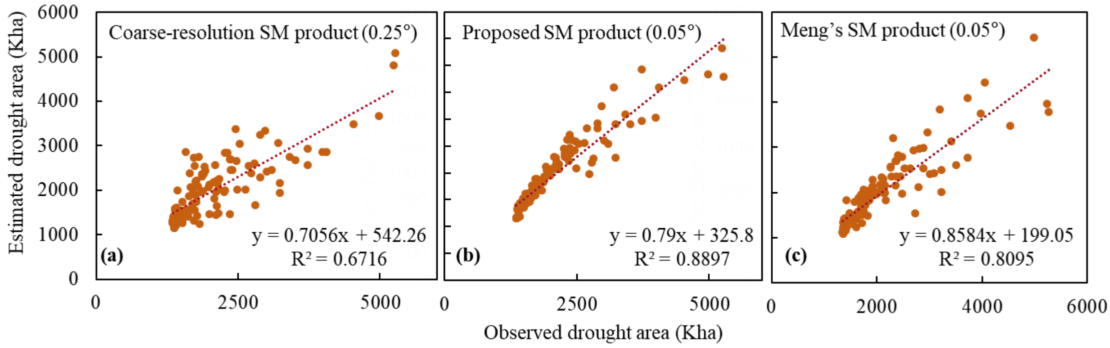

Fig.2 Validation of drought-affected area estimation using multi-source soil moisture products

All the revisions described above have been fully incorporated into the revised manuscript. We believe these changes have significantly clarified the novelty and contribution of our study. We thank the reviewer again for the valuable guidance that has greatly improved the quality of our work.

2. The drought index definition likely has a fundamental conceptual issue. The SSI calculation used the long-term mean and standard deviation and thus didn't account for the seasonal variations in SM. By this construct, the drought assessment results in Section 4.2-4.3 were confounded with the seasonal climate, and normal dry-season conditions seem to have been systematically misclassified as drought.

Reply: We sincerely thank the reviewer for this highly insightful comment, which prompted us to thoroughly re-evaluate our SSI calculation methodology and has significantly strengthened the scientific rigor of our drought analysis.

We would like to clarify the rationale behind our initial approach. Our original design was motivated by the unique characteristics of agricultural drought in China, where cross-seasonal persistent droughts—such as winter-spring continuous drought in North China and autumn-winter drought in Southwest China—have become increasingly frequent and destructive in recent decades. We initially used annual-scale means and standard deviations to retain inter-seasonal comparability, aiming to capture the cumulative effects of soil moisture deficits spanning multiple growing seasons. This choice was also partly inspired by some early regional soil moisture drought studies that adopted simplified annual statistics when long-term monthly data were limited.

However, guided by the reviewer's expert feedback, we fully recognize that this approach is methodologically flawed. Therefore, following the reviewer's suggestion, we have recalculated the SSI using month-by-month means and standard deviations. Specifically, we now compute the long-term mean and standard deviation independently for each calendar month over the 2003–2023 study period. This approach properly removes the inherent seasonal cycle of soil moisture and ensures that the SSI reflects only anomalous deviations from the expected conditions for that specific month. We have fully recalculated the entire SSI dataset and updated all related results and figures. Based on the revised SSI, R^2 between the extracted drought-affected areas and the observed drought areas reached 0.746 (Fig. 1(b)). Compared with our original SSI calculation method, the agreement with observed areas improved significantly, with the correlation coefficient increasing by 18.7%.

All relevant sections of the manuscript have been thoroughly revised. The core findings of our study—including the overall drying trend, spatial heterogeneity, northward migration of drought centers, pyramidal severity distribution, and high drought frequency in ecologically vulnerable areas—remain robust and are now supported by a methodologically sound drought index. We are deeply grateful to the reviewer for pointing out this critical flaw, which has substantially improved the quality and reliability of our work.

3. The Methodology section was extensive and sophisticated, but it read more like a technical documentation of individual steps and included too many details. The effects and added value of each step on the SM product was not clear. There was limited justification for the methodological choices or the improvement over existing methods.

Reply: We thank the reviewer for this careful and constructive observation. Following the reviewer's guidance, we have substantially revised the Methodology section to improve its clarity and readability.

Specifically, we have:

Restructured and streamlined the entire Methodology section – The revised version focuses on core principles and rationales. Each major step now includes a clear justification of why it is needed and how it improves upon existing methods.

Reduced excessive technical details – As the reviewer pointed out, the subsection on Reconstruction of missing values in passive microwave remote sensing data has been significantly condensed, and the description of TVDI calculation has been simplified and made more concise.

We believe these revisions make the methodology more accessible and transparent, and clearly demonstrate the novelty and added value of our approach relative to existing methods. We greatly appreciate the reviewer's insightful suggestions, which have significantly improved the quality of our manuscript.

Specific comments

Introduction

L60-L85: The main idea for text here is that microwave remote sensing observations of SM have coarse spatial resolution and thus requires downscaling for finer-scale, more accurate agricultural drought monitoring. Consider shortening the context to make this point sharp and succinct. For example, the detailed introduction of each microwave SM sensor can be simplified, while the '25 to 50 km resolution' can be moved to earlier in the paragraph.

Reply: We thank the reviewer for this helpful suggestion. In the revised manuscript, we have shortened the context to make the key point sharper and more succinct. Specifically, we have simplified the detailed introduction of each microwave SM sensor and moved the statement about "25 to 50 km resolution" earlier in the paragraph. These revisions will be visible in the updated manuscript.

L99-L100: DISPATCH method 'which synergizes physical insights with statistical formulations to enhance interpretability while maintaining operational efficiency': This description was far too generic and repeats the summary of semi-empirical approach in the earlier sentence. What are the actual variables considered in DISPATCH (e.g., soil evaporative efficiency; SEE).

Reply: Thank you for your invaluable guidance. We have revised Lines 99–100 to clarify the specific variables and physical basis of the DISPATCH method, replacing the previous generic description. The DISPATCH method integrates physical insights with statistical downscaling, with soil evaporative efficiency (SEE) as its core physical variable that directly links surface energy balance to soil moisture status. In addition to SEE, the method explicitly incorporates three key remote sensing variables: land surface temperature (LST), enhanced vegetation index (EVI), and surface albedo. These variables collectively characterize the surface energy and water balance: LST reflects the thermal response to soil moisture deficits, EVI quantifies vegetation cover and transpiration activity, and albedo accounts for surface radiative properties. Topographic and land cover data are also used as auxiliary variables to account for spatial heterogeneity.

The revised text now reads: "The DISPATCH method, which uses soil evaporative efficiency as the core physical variable along with land surface temperature, enhanced vegetation index and surface albedo, synergizes physical insights with statistical formulations to enhance interpretability while maintaining operational efficiency."

L108-126: The review of past studies was too generic and lacked specific references, leading to a quite weak logical linkage between existing work and the proposed objectives and methods. Specifically, the authors made a point on the limitations of current applications of downscaled SM in agricultural drought monitoring, but only provided generic description of issues in current SM product characteristics (algorithm, spatio-temporal continuity, accuracy of global products). To really substantiate the point, this paragraph should synthesise past studies using downscaled SM products for agricultural drought monitoring and then discuss any challenges/limitations they had in producing reliable drought assessments. This will provide a logically clearer and more powerful justification for the new SM downscaling approach proposed in this MS.

Reply: Thank you for this constructive guidance. In the revised manuscript, we have strengthened the literature review by synthesizing past studies that used downscaled SM products for agricultural drought monitoring. We now provide specific references and explicitly discuss the challenges and limitations those studies faced in producing reliable drought assessments (e.g., issues related to algorithms, spatio-temporal continuity, and accuracy of global products). This revision establishes a clearer and more powerful logical linkage between existing work and the proposed objectives and methods. These improvements will be visible in the updated manuscript.

Also, more specific explanation is preferable to generic wording, and specific references need to be added to support the argument. For example, for 'regional dependencies' for existing algorithms, the authors can quantify the spatial extent in previous studies and see if the extent is too narrow for spatial generalisability.

Reply: Thank you for the valuable comment. Following your suggestion, we have replaced the generic wording in the Introduction with more specific explanations. For example, regarding the "regional dependencies" of existing downscaling algorithms, we have provided illustrative examples and added corresponding references. These changes can now be seen in the updated revised manuscript.

Materials

L127: Section heading = should only be “Materials” as Section 3 is the Methods.

Reply: Thank you for the comment. We have revised the section heading to "Materials" as suggested.

L162-166 Benchmarking datasets of downscaled SM products. More specific information about the 2 benchmarking products are needed, as current wordings like “integrating multiple datasets”, “reconstruction-based” are too generic. Consider using a Table to clearly summarise and compare the key information 2 benchmark products and the proposed new product, such as spatio-temporal resolution and coverage, input data and downscaling methods, which enables straightforward comparison. Additionally, it could be worthwhile to describe the 2 products earlier in the Introduction and critically explain why they have limitations for agricultural drought monitoring.

Reply: Thank you for this constructive suggestion. In the revised manuscript, we have added a new table that clearly summarizes and compares the key information of the two benchmark products and our proposed product, including spatio-temporal resolution, coverage, input data, and downscaling methods. This allows for a straightforward comparison. In addition, we have moved the description of these two products earlier to the Introduction and critically explained their limitations for agricultural drought monitoring (e.g., coarse resolution, limited temporal coverage, and lack of seamless continuity). These revisions have been incorporated into the updated manuscript.

Methods

L192-204: The writing style of this method summary paragraph was very similar to a technical note rather than a scientific paper, such as the note-taking type words like “Stage 1: Gap-filling of passive microwave SM products – A spatiotemporally adaptive gap-filling algorithm …”. Since Figure 2 was provided, there is no need to repeat the name of each step. For the example sentence above, it could be re-written as “Firstly, we developed a spatiotemporally adaptive gap-filling algorithm to …”

Reply: Thank you for your detailed guidance. Following your suggestion, we have rephrased the method summary paragraph (Lines 192–204) to adopt a more natural academic writing style. The revised text has been incorporated into the updated manuscript.

Section 3.1.1 Reconstruction of missing values in passive microwave remote sensing data: While I appreciate that the methodology for spatio-temporal gap-filling was sophisticated, this section is too long. The summary L209-L215 for the 3 major steps was redundant. Moreover, It will be much more informative to provide a new figure that shows the sequential changes in the spatio-temporal completeness of SM data by the 3 steps (temporal Savitzky-Golay filtering, GWR spatial gap-filling, harmonisation). This can help demonstrate and quantify the effect of each step on the SM data completeness, and thus provide much better justification for the selected spatio-temporal gap-filling methods.

Reply: Thank you for your insightful comment. We have streamlined Section 3.1.1 by removing the redundant 3-step summary (Lines 209–215) and trimming unnecessary technical details. Regarding the suggested new figure, our existing technical roadmap (Figure 2) already clearly illustrates the sequential workflow of the gap-filling process. Given the journal's limit on the total number of figures, we have instead added quantitative results in the text to demonstrate the effect of each step. We have also explicitly referenced the corresponding panels in Figure 2 to guide readers through the process.

Section 3.1.2 Downscaling of passive microwave remote sensing data: Given the sub-headings in this section (e.g., "(1) Calculation of the TVDI") have already broken down the key steps, the summary L303-317 can be removed or integrated into the method description to shorten the text.

Reply: Thank you. Done as suggested.

L319-L326 calculation of temperature-vegetation dryness index (TVDI): It's unclear how the dry/wet edge and the coefficients for TVDI are defined. Are they estimated on a per-pixel basis? What is the temporal period used to define the LST-NDVI feature space?

Reply: Thank you for the valuable comment. We followed the original TVDI method proposed by Sandholt et al. (2002) and adopted the standardized implementation scheme used by Meng et al. (2021) for soil moisture downscaling over China. The dry/wet edges and their coefficients are not estimated on a per-pixel basis. Instead, they are derived by fitting the upper and lower envelopes of the monthly LST-NDVI feature space for the entire study area. Per-pixel estimation would introduce excessive noise and lack sufficient valid samples for reliable regression. We have clarified this point in the revised manuscript (Section 3.1.2) and added a reference to Meng et al. (2021) for further details. Thank you again for your helpful comment.

L356-L359 Section 3.2, SSI drought index definition: The mean and standard deviation (SD) in the equation 13 are calculated from all months in the 2003-2023 study period. This failed to account for seasonality in SM dynamics and the variations in SSI will mix both the interannual and seasonal variability. For eastern and southern parts of China influenced by monsoons, warmer wet seasons will have higher rainfall and SM on average than cooler dry seasons, so SSI will have artefacts of low values for 'drought conditions' in cooler dry seasons. In other words, SSI captured climate aridity rather than a true drought event that shows an abnormal water deficit relative to long-term conditions. As a solution, the authors can compute the mean and SD for each calendar month and re-calculate the SSI with respect to the month-specific mean and SD. This will account for the seasonality for SM and highlight the interannual variability due to climatic fluctuations, which would better capture the occurrence of drought events and trigger more scientifically meaningful interpretations.

Reply: Thank you for your detailed and rigorous guidance. We have completely recalculated the SSI using month-by-month climatological standardization as suggested. Specifically, we now compute the long-term mean and standard deviation independently for each calendar month over the 2003–2023 study period. This approach properly removes the inherent seasonal cycle of soil moisture and ensures that SSI only reflects anomalous deviations from the expected conditions for that specific month, rather than mixing seasonal and interannual variability.

The entire SSI dataset has been recalculated, and all related results and figures have been updated. The revised SSI shows an 18.7% improvement in correlation with observed drought areas, confirming its superior ability to identify true drought events rather than normal seasonal aridity. All relevant sections of the manuscript have been thoroughly revised.

Results

L396-L400 and Fig 4: SM before and after downscaling showed similar fluctuations in the west-east latitudinal gradient, so it did not provide useful evidence to support the advantage of downscaled SM. The authors may improve Figure 4 if they zoom into multiple small regions (e.g., 1 x 1 degree) with strong spatial heterogeneity (e.g., cropping regions, boundaries between distinct land cover types) and produce inset maps that compare the SM spatial patterns before and after downscaling. This will better support the argument that the downscaling method "significantly enhancing the representation of localized hydrological heterogeneity".

Reply: Thank you for this constructive guidance. Following your advice, we have improved Fig. 4 in the revised manuscript in two aspects. First, we selected three small regions with strong spatial heterogeneity (including an agro-pastoral ecotone, a cropland-forest transition zone, and a mountainous irrigated area) and produced inset maps to directly compare the spatial patterns of SM before and after downscaling, highlighting the advantage of our product in capturing localized hydrological heterogeneity. Second, we reversed the color palette so that higher soil moisture appears in blue (wetter) and lower values in red (drier), following conventional hydrological visualization. The revised figure will be presented in the updated manuscript. Thank you again for your valuable guidance.

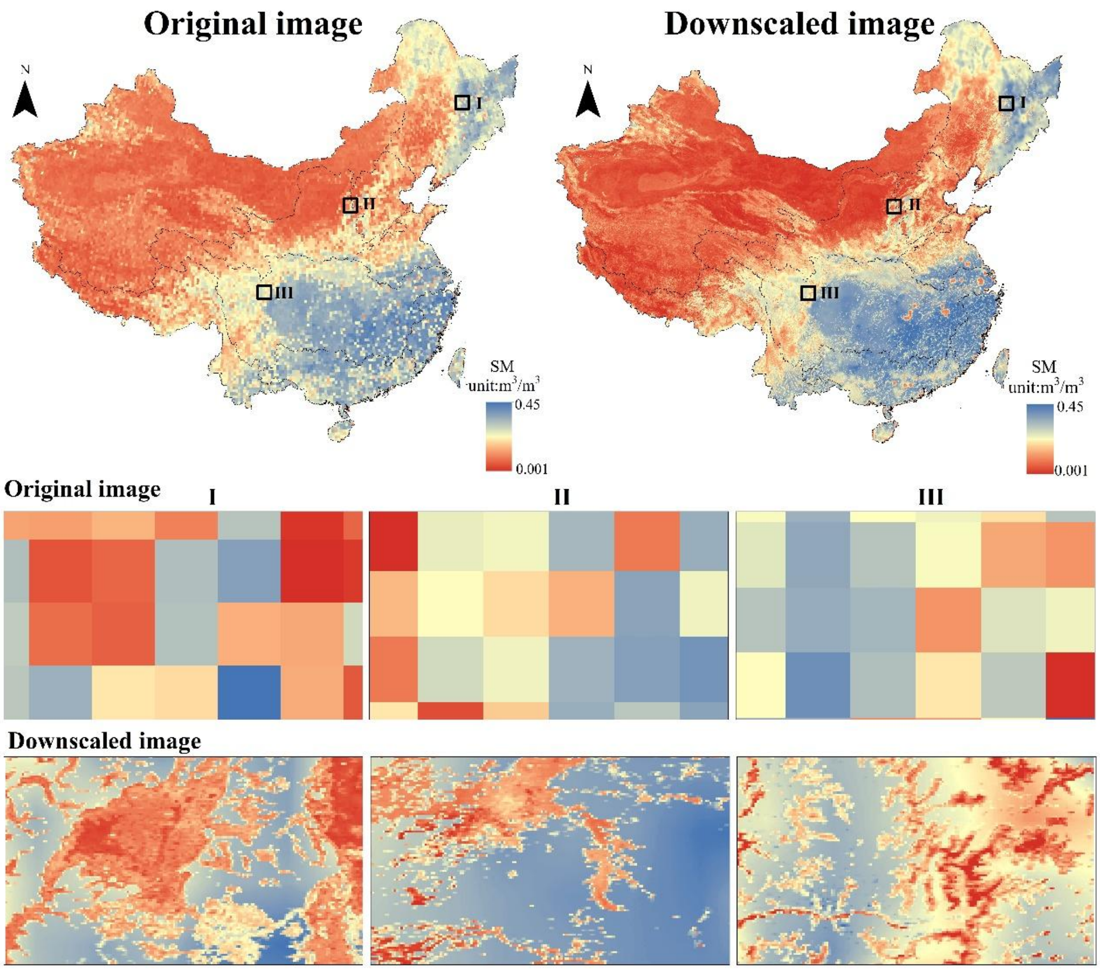

Fig.4 in the revised manuscript — Comparison of original images and downscaled SM images

L404-405: What is the definition of “precision”? Please specify.

Reply: Thanks a lot for pointing this out. We are sorry for our unclear expression. What we intended to convey is that, for the zoomed-in area shown in Fig. 4, we have a set of in-situ soil moisture measurements collected by our team. We compared the pre-downscaling (coarse) SM data and our downscaled (0.05°) data against these ground measurements. The downscaled product achieved a higher accuracy, with an error metric (root mean square error) of 0.038 m^3/m^3 relative to the in-situ observations.

Therefore, the term "precision" here actually refers to RMSE of the downscaled product validated against local measurements.

As suggested in your previous comment, we have replaced the original inset region in Fig. 4 with three new regions. For these new regions, we compared the pre-downscaling SM data and our downscaled data against these ground measurements. The downscaled product achieved a higher accuracy, with RMSE values of 0.029, 0.037, and 0.039 m^3/m^3 relative to the in-situ observations. We have revised the sentence in the manuscript to clearly state this comparison and the resulting accuracy value.

Again, we appreciate the reviewer's careful reading and valuable suggestion.

L432-433: How can the improvement over PI benchmark from Zhang et al. (2023) lead to the conclusion "This underscores the critical role of localized algorithm calibration in mitigating biases from generic global models"? More specific description of SM downscaling benchmark datasets will be useful to make this point clearer.

Reply: Thank you for the valuable comment. In the original manuscript, we compared our product (0.05°) with the global 1 km product of Zhang et al. (2023) (PI). Despite our product having a coarser spatial resolution, it achieved comparable or even higher accuracy in several regions of China. We attribute this to the fact that PI was trained on globally distributed samples and thus may not capture region-specific hydroclimatic characteristics (e.g., monsoon influence, soil texture variability). In contrast, our downscaling model was calibrated using local in-situ data and environmental predictors tailored to China's diverse landscapes. Therefore, the improved performance of our product over a globally trained product supports the conclusion that localized algorithm calibration plays a critical role in mitigating biases inherent in generic global models.

To make this point clearer, we have added a more specific description of the PI benchmark dataset in the revised manuscript, including its training data sources and potential limitations for China-specific applications. These revisions will be visible in the updated manuscript. Thank you again for your valuable suggestion.

Fig 6: The figure was hard to understand. In the inner circle, the statistics for the downscaling product (D) repeat for 3 times, due to the comparison against the 3 benchmarks. The figure can be easily simplified into a table to report evaluation metric values, or a multi-part, side-by-side barplot of R and RMSE for 4 products separated by the 7 land cover types.

Reply: Thank you for your guidance. Following your suggestion, we have replaced the original Fig. 6 with two tables.

Fig 7: SSI vs crop drought-affected areas. There are multiple issues in this figure. The letters for each sub-part were problematic, e.g., Yunan has a sub-part letter (abc), where it should be (c); Shandong should be part (h) not (egh).The y-axis scales for SSI were concerning. SSI was fitted by normal distribution and converted into z-scores. For standard normal random variables, 99.9% of data will be between -3 and 3, so why the area-averaged SSI values reached outside of -5 and 5 in many cases? The authors should revisit their calculations. Moreover, there were many instances where the SSI's performance was not convincing. For example, in Henan, 2012-2014 had high drought-affected areas, but SSI was the highest among the record. Can the authors critically discuss these instances in better details? Finally, consider adding an annotation of the temporal correlation or R-squared for each sub-region to aid with the readers' interpretation.

Reply: Thank you for your constructive comments. We fully acknowledge that the issues in the original Figure 7 (e.g., SSI values falling outside the [-3,3] range, inconsistencies with drought-affected areas) were mainly caused by our previous inaccurate SSI calculation (lack of monthly standardization) and the use of a fixed threshold.

Inspired by your guidance, we have recalculated the SSI using month-by-month climatological standardization and developed a dynamic threshold method based on kernel density estimation to extract drought-affected areas. We then compared the extracted drought areas with observed drought areas and evaluated the applicability of the SSI index across different regions using the relative error (RE). The results show that the mean RE between the extracted and actual drought-affected areas is 94.53% (i.e., an average accuracy of approximately 94.5%). We have thoroughly revised the relevant sections and figures in the manuscript, corrected the axis scales, sub-figure labels, and added annotations of correlation coefficients or R^2 for each sub-region. These revisions will be visible in the updated manuscript. Thank you again for your detailed and rigorous guidance.

L472-L473: Please define the location for the "tri-junction hotspots" for readers who are not familiar with China's landscapes.

Reply: Done as suggested. Thank you.

L501-502 Intra-annual variations of SSI: All the results and interpretation in this part were very likely to suffer from the artefacts of SSI construction and thus require a new iteration. For example, the authors found two drought peaks in spring (March–May) and late autumn to early winter (October–December). These "drought peaks" were not really drought events, but the inherent characteristics of monsoonal climates where the cooler seasons (October to May in China) have lower rainfall and thus lower SM. Similarly, the “winter–spring drought and summer–autumn wetness” (L512-513) is already known due to the seasonal monsoon cycle, so there is limited extra information provided by the SSI.

Reply: Thank you for this insightful comment. Following your suggestion, we have recalculated the SSI using month-by-month climatological standardization and further optimized the dynamic threshold method. The revised SSI no longer shows obvious seasonal artifacts in its intra-annual variation.

Therefore, we have removed the misleading descriptions regarding "bimodal drought peaks" and "winter-spring drought and summer-autumn wetness" from the manuscript. Instead, we have re-analyzed and reported the drought frequency across different river basins to more scientifically characterize the spatiotemporal patterns of drought.

These revisions have been fully incorporated into the updated manuscript. Thank you again for your detailed and rigorous guidance, which has significantly improved the scientific quality of our work.

It is expected that the identified spatio-temporal drought patterns will be quite different if the SSI is re-defined by standardising against the month-specific mean and SD instead of the whole-period statistics. When SSI is re-defined, the analyses in Fig 7 to 10 will need to be repeated to assess the consistencies and discrepancies in the findings.

Reply: Thank you for your guidance. Following your suggestion, we have recalculated the SSI using month-by-month climatological standardization and optimized the dynamic threshold extraction method. Based on this, we have completely re-analyzed the spatiotemporal patterns of agricultural drought in China, including Figures 7–10 and all related results. All figures and conclusions have been updated and are presented in the revised manuscript. Thank you again for your detailed and rigorous guidance.

L539: Please navigate the readers regarding the locations for "China’s key agro-pastoral transition zones and ecologically vulnerable regions". Also, this could be a practically important result for the downscaled SM product, so more in-depth discussions referring to previous drought studies for such ecological vulnerable regions will be useful.

Reply: Thank you for this valuable suggestion. Since it was difficult for us to obtain the precise vector data of China’s key agro-pastoral transition zones and ecologically vulnerable regions, we have instead provided a clear geographical description of these areas in the revised manuscript. We have also added an in-depth discussion on the drought characteristics of these ecologically vulnerable regions. These revisions have been incorporated into the updated manuscript. Thank you again for your detailed guidance.

Discussion and conclusion

The combined "5. Discussion and conclusion" section basically functioned as a conventional Conclusion section that reiterated the main findings. The last paragraph briefly discussed methodological limitations, but was too generic. Moreover, it lacked critical comparison with previous studies and deeper interpretation of the results in the broader scientific context. It is unclear how the downscaled SM product and subsequent analyses in this research provided new scientific insights to the agricultural drought monitoring in China, compared to previous studies in this field. I will really encourage a separate Discussion and Conclusion section respectively, where the Discussion is expanded to critically compare their findings with relevant literature on SM downscaling applications in drought monitoring, examine possible biophysical explanations for observed drought patterns, and clarify the broader implications and limitations of the results. This will substantially improve the scientific quality and clarity of the MS so that it better matches the standards and requirements by HESS.

Reply: Thank you for your guidance. Following your suggestion, we have separated the Discussion and Conclusion sections in the revised manuscript. In the newly written Discussion section, we systematically compare the accuracy gains in drought area extraction achieved by our downscaled product relative to coarse-resolution data and existing benchmark products, and we evaluate the improvement in drought identification accuracy brought by the dynamic threshold method compared to the fixed threshold. We also compare our findings with relevant studies, explore possible biophysical explanations for the observed drought patterns, and clarify the broader implications and limitations of our results. These revisions have substantially improved the scientific quality and clarity of the manuscript, making it better aligned with the standards and requirements of HESS. The revised content is presented in the updated manuscript. Thank you again for your detailed and rigorous guidance.

L572: The first sentence starting with 'Although' is incomplete, and should be integrated with the next sentence.

Reply: Thank you for your guidance. Done as suggested.

Additional remark:

Lines 758-759 in the revised manuscript: “The authors are grateful to the editor, five reviewers, and one reader for their constructive comments and suggestions on this paper.” has been added to Acknowledgments.

Special thanks are extended to you for your valuable comments.

We are doing our best to improve the manuscript and are making substantial changes to address the concerns raised.

We greatly appreciate your help and hope that the revisions will meet with approval once we submit the updated manuscript.

Once again, we would like to extend our sincere gratitude and appreciation for your valuable comments and suggestions.