Authors' responses to RC1' comments

Hydrology and Earth System Sciences

https://doi.org/10.5194/egusphere-2025-6195-RC1

Title: Weakening Correlation and Delaying Response Time of Ecosystem Water Use Efficiency to Drought

Dear RC1:

Thank you very much for carefully reviewing our manuscript and helping us improve its quality. On behalf of my co-authors, we thank you very much for giving us an opportunity to revise our manuscript. We have made significant revisions to our manuscript to address the comments. Those comments are all valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our researches.

Below, we provide a detailed point-by-point response to the comments. Text by the reviewer is indented and in black font. Our reply is in blue font and not indented. The "References" are in green and italic, and follow immediately after the reply. For ease of referencing our replies, we numbered them. All changes in the revised manuscript have been highlighted with a colored background for your convenience.

We believe that through these revisions, the quality of the manuscript will meet the publication standards of the journal *Hydrology and Earth System Sciences*. If you have further suggestions, we are happy to continue discussing them with you.

> General Comments: This manuscript investigates the long-term changes in water use efficiency (WUE) under water stress, a classic and important topic in ecohydrology. The study contributes to understanding vegetation carbon–water trade-off strategies during drought conditions. However, the manuscript would benefit from substantial improvements in writing clarity and in the mechanistic interpretation of the findings.
>
> 1. The current version lacks sufficient mechanistic explanations and reads more as a statistical description rather than a process-based analysis.

2. Different types of drought (e.g., soil moisture drought vs. atmospheric drought) involve distinct mechanisms that influence vegetation responses. The manuscript should clearly specify the drought type throughout and discuss their differing impacts on WUE.
3. The importance of the timing of WUE changes under drought is not sufficiently justified. The authors should clarify why the temporal evolution of WUE under drought matters from a physiological or ecohydrological perspective.

Thank you for your careful review of our work. We fully acknowledge the limitations you have identified, which indeed highlight areas where the manuscript requires further improvement and refinement. As one of the most widely used drought indices, SPEI not only accounts for the cumulative water balance but also incorporates the effects of temperature (Beguería et al., 2014), and has therefore been extensively applied to monitor and quantify the spatiotemporal characteristics of drought at both regional and global scales (Beguería et al., 2010). Moreover, previous studies have demonstrated that meteorological drought is the initial drought type occurring in the drought propagation cascade, making it the most critical component that exerts the most profound impacts on ecosystems (Yan et al., 2025). This is one of the core rationales for our focus on the SPEI in this study. However, vegetation exhibits distinct response mechanisms to different types of drought; accordingly, we have now explicitly clarified in the revised manuscript that the drought considered in this study refers to meteorological drought. In addition, in this revision we have placed greater emphasis on strengthening the interpretation of the observed phenomena and deepening the discussion of the underlying ecohydrological mechanisms, thereby enhancing the overall scientific rigor of the study.

Reference:

[1] *Beguería, S., Vicente-Serrano, S. M., and Angulo-Martínez, M.: A Multiscalar Global Drought Dataset: The SPEIbase: A New Gridded Product for the Analysis of Drought Variability and Impacts, Bulletin of the American Meteorological Society, 91, 1351-1356, https://doi.org/10.1175/2010BAMS2988.1, 2010.*

[2] *Beguería, S., Vicente-Serrano, S. M., Reig, F., and Latorre, B.: Standardized precipitation evapotranspiration index (SPEI) revisited: parameter fitting, evapotranspiration models, tools, datasets and drought monitoring, International Journal of Climatology, 34, 3001-3023, https://doi.org/10.1002/joc.3887, 2014.*
[3] *Yan, W., Zhou, J., Lin, H., Luo, J., Duan, X., and Wu, R.: Drivers of the pre-season drought thresholds triggering earlier autumn foliar senescence in the Northern Hemisphere, Nature Communications, 16, 7568, 10.1038/s41467-025-62847-y, 2025.*
In response to your comments, we have made the following revisions：
1. We have expanded the Discussion to elucidate the underlying mechanisms behind our findings. Specifically, Section 5.2 provides a mechanistic interpretation of the variation characteristics of the coupling relationship, while Section 5.3 explains the driving mechanisms of the coupling relationship.
2. We have explicitly clarified throughout the manuscript that this study focuses on meteorological drought, and we have provided the rationale in both the Introduction and Discussion sections. We fully agree with your insightful comment that different types of drought involve distinct mechanisms and exert varying impacts on WUE, which also represents an important direction for future research. Accordingly, we have added a new Section 5.4 to address the limitations of this study and outline potential avenues for future work.
The specific modifications can be found in Introduction (see Lines **59-64** in manuscript (marked version)), and Discussion Section 5.4 (see Lines **572-583** in manuscript (marked version)).
3. As noted above, Section 5.2 focuses on the mechanistic explanation of the variation characteristics of the coupling relationship. In this section, we further clarify why understanding the temporal evolution of WUE under drought conditions is of critical importance. In addition, as an essential research background, this aspect has also been elaborated in the Introduction.
The specific modifications can be found in Introduction (see Lines **99-114** in manuscript (marked version)).

[r1,1] Abstract: The types of data used in this study (e.g., satellite products, flux data, reanalysis, etc.) should be clearly stated in the abstract.

Thank you for your valuable comment. In response to your comment, we explicitly specify in the Abstract the types of data used in this study, including satellite products, flux observations, reanalysis datasets, and model simulations. We hope that this planned revision will meet your expectations.

The specific modifications can be found in Abstract (see Lines **24-28** in manuscript (marked version)).

[r1,2] Abstract: The stated knowledge gap (L19–20) is not entirely accurate, as several previous studies have already examined WUE under drought conditions. The authors should better position their contribution relative to existing literature and clarify the physical interpretation of the proposed drivers of WUE changes.

Thank you for your valuable comment. As you noted, in recent years, increasing attention has been paid to WUE or vegetation responses to drought, including response characteristics and sensitivity (Jiao et al., 2021; Li et al., 2022; Zhang et al., 2022). However, these studies were largely conducted at specific or fixed drought timescales, neglecting the cumulative and lagged effects of drought on vegetation dynamics (Wen et al., 2019), and primarily relied on single indicators such as gross primary productivity (GPP), which represents photosynthetic activity, or vegetation indices that reflect canopy greenness. In contrast, ecosystem WUE provides a more integrative measure of vegetation carbon–water trade-off strategies under water stress. It is widely acknowledged that drought not only impacts vegetation growth synchronously but also exhibits lagged and cumulative effects, where past drought conditions influence current vegetation growth (Huang et al., 2018; Kannenberg et al., 2020). Vicente-Serrano et al. (2013) emphasized that vegetation responses to drought are inherently multi-timescale in nature. Longer timescales imply stronger memory effects, which may buffer the impacts of recent drought events and thereby reduce vegetation drought sensitivity (Seddon et al., 2016). In contrast, shorter timescales indicate more rapid vegetation responses to moisture deficits, reflecting higher drought sensitivity (Jiao et al., 2021).

Despite the growing body of literature on WUE responses to drought, few studies have examined the coupling relationship between WUE and drought, particularly from a multi-timescale perspective. Therefore, incorporating multi-timescale drought effects into analyses of WUE–drought coupling is essential for a more comprehensive and accurate understanding of vegetation carbon–water trade-offs under drought stress.

Reference:

[1] *Jiao, W., Wang, L., Smith, W. K., Chang, Q., Wang, H., and D'Odorico, P.: Observed increasing water constraint on vegetation growth over the last three decades, Nature Communications, 12, 3777, 10.1038/s41467-021-24016-9, 2021.*

[2] *Li, H., Wei, M., Dong, L., Hu, W., Xiong, J., Sun, Y., Sun, Y., Yao, S., Gong, H., Zhang, Y., Hou, Q., Wang, X., Xie, S., Zhang, L., Akram, M. A., Rao, Z., Degen, A. A., Niklas, K. J., Ran, J., Ye, J.-s., and Deng, J.: Leaf and ecosystem water use efficiencies differ in their global-scale patterns and drivers, Agricultural and Forest Meteorology, 319, 108919, https://doi.org/10.1016/j.agrformet.2022.108919, 2022a.*

[3] *Zhang, Y., Gentine, P., Luo, X., Lian, X., Liu, Y., Zhou, S., Michalak, A. M., Sun, W., Fisher, J. B., Piao, S., and Keenan, T. F.: Increasing sensitivity of dryland vegetation greenness to precipitation due to rising atmospheric CO2, Nature Communications, 13, 4875, 10.1038/s41467-022-32631-3, 2022b..*

[4] *Wen, Y., Liu, X., Xin, Q., Wu, J., Xu, X., Pei, F., Li, X., Du, G., Cai, Y., Lin, K., Yang, J., and Wang, Y.: Cumulative Effects of Climatic Factors on Terrestrial Vegetation Growth, Journal of Geophysical Research: Biogeosciences, 124, 789-806, https://doi.org/10.1029/2018JG004751, 2019.*

[5] *Huang, M., Wang, X., Keenan, T. F., and Piao, S.: Drought timing influences the legacy of tree growth recovery, Global Change Biology, 24, 3546-3559, https://doi.org/10.1111/gcb.14294, 2018.*

[6] *Kannenberg, S. A., Schwalm, C. R., and Anderegg, W. R. L.: Ghosts of the past: how drought legacy effects shape forest functioning and carbon cycling, Ecology Letters, 23, 891-901, https://doi.org/10.1111/ele.13485, 2020.*

[7] *Vicente-Serrano, S. M., Gouveia, C., Camarero, J. J., Beguería, S., Trigo, R., López-Moreno, J. I., Azorín-Molina, C., Pasho, E., Lorenzo-Lacruz, J., Revuelto, J., Morán-*

Tejeda, E., and Sanchez-Lorenzo, A.: Response of vegetation to drought time-scales across global land biomes, Proc Natl Acad Sci U S A, 110, 52-57, 10.1073/pnas.1207068110, 2013.

[8] *Seddon, A. W. R., Macias-Fauria, M., Long, P. R., Benz, D., and Willis, K. J.: Sensitivity of global terrestrial ecosystems to climate variability, Nature, 531, 229-232, 10.1038/nature16986, 2016.*

In response to your comment, we reorganized and refined the presentation of the current research gaps. We hope that this revision will meet your expectations.

The specific modifications can be found in Abstract (see Lines **18-24** in manuscript (marked version)).

[r1,3] Abstract: The abstract contains too many abbreviations, which reduces readability. Consider minimizing abbreviations to improve clarity.

Thank you for your valuable comment. In response to your comment, we will reduce the use of abbreviations in the revised manuscript to improve its readability. We hope that this revision will meet your expectations.

The specific modifications can be found in Abstract (see Lines **16-45** in manuscript (marked version)).

[r1,4] Abstract: The findings derived from the causal analysis should be explicitly summarized.

Thank you for your valuable comment. We acknowledge that the previous version of our manuscript lacked the presentation of results derived from the causal analysis.

In response to your comment, we incorporate these findings into the Abstract in the revised manuscript. We hope that this revision will meet your expectations.

The specific modifications can be found in Abstract (see Lines **38-43** in manuscript (marked version)).

[r1,5] Introduction: Lines 46-71 list a large number of studies without clear synthesis. This paragraph should be restructured to highlight key insights from

previous research. Based on the cited literature, what are the dominant drivers of WUE under drought?

Thank you for your valuable comment. In the original manuscript, Lines 46-71 were organized around three aspects: (i) the impacts of drought events on WUE; (ii) the relationships between drought characteristics and WUE; and (iii) vegetation responses of different WUE metrics to drought across scales (e.g., intrinsic water use efficiency, IWUE; transpiration-based WUE, TWUE; underlying WUE, uWUE; and ecosystem WUE). Your comment has made us realize that this structure lacks logical coherence and a clear, integrative synthesis.

In response to your comment, we have comprehensively rewritten this section in the revised manuscript. In this revision, we reorganized the paragraph to emphasize the spatiotemporal heterogeneity of WUE responses to drought. Meanwhile, the revised text provides a clearer transition to the subsequent paragraph, thereby ensuring a more coherent narrative flow. We hope that this revision meets your expectations.

The specific modifications can be found in Introduction (see Lines **65-72** in manuscript (marked version)).

[r1,6] Data and Methods: The descriptions of datasets and metrics are mixed in the current "Data" section. It would be clearer to move the definition and calculation of WUE to the Methods section and separate data description from methodological explanation.

Thank you for your valuable comment. In response to your comment, we move the definition and calculation of WUE to the Methods in the revised manuscript, thereby improving the overall readability. We hope that this revision will meet your expectations.

The specific modifications can be found in Methods Section 3.1 (see Lines **231-245** in manuscript (marked version)).

[r1,7] Results: The figure presentation should be improved for readability. Some text elements are too large, while others are too small. Additionally, abbreviations in figure captions should be reduced.

Thank you very much for pointing out these shortcomings in our manuscript. As you rightly noted, there are still issues with the figure presentation: for example, the text in subpanels (c-1) to (c-4) of Figure 2 is too small, and the font size of the colorbar labels in Figure 3 is also insufficient. These issues indeed hinder readability.

In response to your comment, we will comprehensively reorganize all figures in the revised manuscript and reduce the use of abbreviations in the figure captions. Our revisions include the following:

1. Reorganizing the layout of Figure 2 and enlarging the font size to improve clarity;
2. Adjusting the font size of the color bar in Figure 3;
3. Redrawing Figure 6 to ensure that all text is clearly legible;
4. Redrawing Figure 7 with optimized font sizes to enhance readability……

It should be noted that some textual elements in the figures are of secondary importance. To better highlight the key information, we have not modified these elements (e.g., the font size of latitude and longitude labels in Figure 2). We hope for your understanding. The specific modifications can be found in Figures (see Lines **337-338, 359-360, 416-417, and 465-467** in manuscript (marked version)).

[r1,8] Results: The labeling in Fig. 2 is unclear and should follow a consistent alphabetical format (e.g., a, b, c). Moreover, the color schemes in Fig. 2a(1-2) and Fig. 2b(1-2) are too similar, making global patterns difficult to distinguish.

Thank you for your valuable comment. We would like to clarify that the left and right columns in Figure 2 represent results from remote sensing observations and model simulations, respectively. To facilitate a direct comparison between the two, the same color scheme was intentionally adopted. As you pointed out, “the color schemes in Fig. 2a (1–2) and Fig. 2b (1–2) are too similar, making global patterns difficult to distinguish,” which, to some extent, also reflects the high consistency between the remote sensing based and model simulated results. Therefore, we have retained the same color scheme for both the remote sensing observations and the model simulations. We hope for your understanding.

In response to your comment, and as noted in our reply to [r1,7], we will comprehensively reorganize all figures in the revised manuscript. This will include, but not be limited to, adopting a consistent panel labeling format (e.g., a, b, c) and improving the overall clarity of visual presentation. We hope that this revision will meet your expectations.

The specific modifications can be found in Figure 2 (see Lines **338-339** in manuscript (marked version)).

> [r1,9] Results: The manuscript lacks a physical explanation for how elevated CO_2 concentrations lead to a decoupling between GPP and ET during drought conditions. A clearer eco-physiological interpretation is necessary.

Thank you very much for pointing out this limitation in our manuscript. As you rightly noted, our discussion of the underlying ecohydrological mechanisms remains insufficient in depth.

In response to your comment, we have strengthened the mechanistic explanation of this phenomenon from two main perspectives: CO_2 enhances the carboxylation efficiency of Rubisco to promote GPP, and induces partial stomatal closure to reduce transpiration water loss. We hope that this revision will meet your expectations.

The specific modifications can be found in Discussion (see Lines **529-543** in manuscript (marked version)).

Reference:

Beguería, S., Vicente-Serrano, S. M., and Angulo-Martínez, M.: A Multiscalar Global Drought Dataset: The SPEIbase: A New Gridded Product for the Analysis of Drought Variability and Impacts, Bulletin of the American Meteorological Society, 91, 1351-1356, https://doi.org/10.1175/2010BAMS2988.1, 2010.

Beguería, S., Vicente-Serrano, S. M., Reig, F., and Latorre, B.: Standardized precipitation evapotranspiration index (SPEI) revisited: parameter fitting, evapotranspiration models, tools, datasets and drought monitoring, International Journal of Climatology, 34, 3001-3023, https://doi.org/10.1002/joc.3887, 2014.

Huang, M., Wang, X., Keenan, T. F., and Piao, S.: Drought timing influences the legacy of tree growth recovery, Global Change Biology, 24, 3546-3559, https://doi.org/10.1111/gcb.14294, 2018.

Jiao, W., Wang, L., Smith, W. K., Chang, Q., Wang, H., and D'Odorico, P.: Observed increasing water constraint on vegetation growth over the last three decades, Nature Communications, 12, 3777, 10.1038/s41467-021-24016-9, 2021.

Kannenberg, S. A., Schwalm, C. R., and Anderegg, W. R. L.: Ghosts of the past: how drought legacy effects shape forest functioning and carbon cycling, Ecology Letters, 23, 891-901, https://doi.org/10.1111/ele.13485, 2020.

Li, W., Migliavacca, M., Forkel, M., Denissen, J. M. C., Reichstein, M., Yang, H., Duveiller, G., Weber, U., and Orth, R.: Widespread increasing vegetation sensitivity to soil moisture, Nature Communications, 13, 3959, 10.1038/s41467-022-31667-9, 2022.

Seddon, A. W. R., Macias-Fauria, M., Long, P. R., Benz, D., and Willis, K. J.: Sensitivity of global terrestrial ecosystems to climate variability, Nature, 531, 229-232, 10.1038/nature16986, 2016.

Vicente-Serrano, S. M., Gouveia, C., Camarero, J. J., Beguería, S., Trigo, R., López-Moreno, J. I., Azorín-Molina, C., Pasho, E., Lorenzo-Lacruz, J., Revuelto, J., Morán-Tejeda, E., and Sanchez-Lorenzo, A.: Response of vegetation to drought time-scales across global land biomes, Proc Natl Acad Sci U S A, 110, 52-57, 10.1073/pnas.1207068110, 2013.

Wen, Y., Liu, X., Xin, Q., Wu, J., Xu, X., Pei, F., Li, X., Du, G., Cai, Y., Lin, K., Yang, J., and Wang, Y.: Cumulative Effects of Climatic Factors on Terrestrial Vegetation Growth, Journal of Geophysical Research: Biogeosciences, 124, 789-806, https://doi.org/10.1029/2018JG004751, 2019.

Yan, W., Zhou, J., Lin, H., Luo, J., Duan, X., and Wu, R.: Drivers of the pre-season drought thresholds triggering earlier autumn foliar senescence in the Northern Hemisphere, Nature Communications, 16, 7568, 10.1038/s41467-025-62847-y, 2025.

Zhang, Y., Gentine, P., Luo, X., Lian, X., Liu, Y., Zhou, S., Michalak, A. M., Sun, W., Fisher, J. B., Piao, S., and Keenan, T. F.: Increasing sensitivity of dryland vegetation greenness to precipitation due to rising atmospheric CO2, Nature Communications, 13, 4875, 10.1038/s41467-022-32631-3, 2022.

Authors’ responses to RC2’ comments

Hydrology and Earth System Sciences

https://doi.org/10.5194/egusphere-2025-6195-RC2

Title: Weakening Correlation and Delaying Response Time of Ecosystem Water Use Efficiency to Drought

Dear RC2:

Thank you very much for carefully reviewing our manuscript and helping us improve its quality. On behalf of my co-authors, we thank you very much for giving us an opportunity to revise our manuscript. We have made significant revisions to our manuscript to address the comments. Those comments are all valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our researches.

Below, we provide a detailed point-by-point response to the comments. Text by the reviewer is indented and in black font. Our reply is in blue font and not indented. The "References" are in green and italic, and follow immediately after the reply. For ease of referencing our replies, we numbered them. All changes in the revised manuscript have been highlighted with a colored background for your convenience.

We believe that through these revisions, the quality of the manuscript will meet the publication standards of the journal *Hydrology and Earth System Sciences*. If you have further suggestions, we are happy to continue discussing them with you.

> This study systematically reveals the spatiotemporal evolution and driving mechanisms of the coupling relationship between global water use efficiency (WUE) and drought through the integration of multi-scale and multi-source datasets combined with model ensembles. The study represents a significant innovation in ecohydrology and possesses considerable scientific value for understanding carbon-water cycles under a changing climate. Although the methodology is rigorous and the results are scientifically meaningful, there is still room for improvement in terms of presentation and technical details. Therefore, I

recommend the acceptance of this manuscript after the following revisions are addressed.

Thank you for your careful review of our work. We have carefully read your comments, and below is our point-by-point response. If you have any questions, we hope to further discuss them with you.

[r2,1] Section 3.1: Why is R_{max} defined as the maximum value of the correlation coefficient rather than the maximum absolute value of the correlation coefficient? The authors should provide a reasonable explanation for this choice. In addition, a more comprehensive explanation of both R_{max} and T_{opt} should be provided in this section.

Thank you for your valuable comment. Lower WUE indicates a reduced capacity of vegetation to utilize water, whereas lower SPEI values correspond to more severe drought conditions (i.e., larger negative SPEI values indicate stronger drought intensity). In general, more severe drought is associated with lower WUE, while under mild or non-drought conditions, WUE tends to be higher. Therefore, WUE and drought conditions exhibit an overall positive relationship. Accordingly, R_{max} was defined as the maximum value of the correlation coefficient rather than the maximum absolute value of the correlation coefficient. This phenomenon and its underlying rationale have also been supported by previous studies (Vicente-Serrano et al., 2013).

Reference:

[1] *Vicente-Serrano, S. M., Gouveia, C., Camarero, J. J., Beguería, S., Trigo, R., López-Moreno, J. I., Azorín-Molina, C., Pasho, E., Lorenzo-Lacruz, J., Revuelto, J., Morán-Tejeda, E., and Sanchez-Lorenzo, A.: Response of vegetation to drought time-scales across global land biomes, Proceedings of the National Academy of Sciences, 110, 52-57, doi:10.1073/pnas.1207068110, 2013b.*

It is widely acknowledged that drought not only impacts vegetation growth synchronously but also exhibits lagged and cumulative effects, where past drought conditions influence current vegetation growth (Huang et al., 2018; Kannenberg et al., 2020). Different values of T_{opt} represent the characteristic timescales over which WUE responds to drought, whereas R_{max} reflects the maximum sensitivity of WUE to drought.

Reference:

[2] *Huang, M., Wang, X., Keenan, T. F., and Piao, S.: Drought timing influences the legacy of tree growth recovery, Global Change Biology, 24, 3546-3559, https://doi.org/10.1111/gcb.14294, 2018.*

[3] *Kannenberg, S. A., Schwalm, C. R., and Anderegg, W. R. L.: Ghosts of the past: how drought legacy effects shape forest functioning and carbon cycling, Ecology Letters, 23, 891-901, https://doi.org/10.1111/ele.13485, 2020.*

In response to your comment, we incorporate the above clarification into the revised manuscript. We hope that this revision will meet your expectations.

The specific modifications can be found in Methods Section 3.2 (see Lines **247-259** in manuscript (marked version)).

> [r2,2] Section 3.3: The authors employed XGBoost and Shapley values for attribution analysis; however, essential technical details are lacking, such as key hyperparameters (e.g., max depth, learning rate). These should be provided to improve the clarity and reproducibility of the manuscript.

We sincerely apologize for this oversight. The key hyperparameters of the XGBoost models were optimized using a Bayesian optimization algorithm. Specifically, for the R_{max} model, the learning rate was 0.06, the number of trees (n_estimators) was 1431, and the maximum depth was 4. For the T_{opt} model, the learning rate was 0.07, the number of trees (n_estimators) was 1287, and the maximum depth was 4.

In response to your comment, we include these parameter settings in the revised manuscript. We hope that this revision will meet your expectations.

The specific modifications can be found in Methods Section 3.4 (see Lines **284-286** in manuscript (marked version)).

> [r2,3] Section 3.3: The authors state that "only the seven models that were consistent with the remote sensing results" were used. Please clarify the criteria

used to select these seven models. If the selection follows approaches used in previous studies, appropriate references should be provided.

Thank you for your valuable comment. When separating the contributions of different TRENDY model scenarios, only those models whose trends are consistent with remote sensing observations were retained for subsequent analysis (Zeng et al., 2022). The performance of the model simulations was quantitatively evaluated using a Taylor diagram, as shown in Figure S6 of the Supplementary Material.

Reference:

[1] *Zeng, X., Hu, Z., Chen, A., Yuan, W., Hou, G., Han, D., Liang, M., Di, K., Cao, R., and Luo, D.: The global decline in the sensitivity of vegetation productivity to precipitation from 2001 to 2018, Global Change Biology, 28, 6823-6833, https://doi.org/10.1111/gcb.16403, 2022.*

In response to your comment, we include additional relevant references in the revised manuscript to better support the model selection criteria for the TRENDY simulations. We hope that this revision will meet your expectations.

The specific modifications can be found in Methods Section 3.4 (see Line **271** in manuscript (marked version)).

[r2,4] From the figures, it appears that the analysis was conducted in regions with permanent vegetation. The authors should clarify how grid cells classified as permanent vegetation areas were selected.

Thank you for your valuable comment. Studies on the response of WUE to drought are only meaningful in regions with persistent vegetation; therefore, our analysis was conducted within permanent vegetation areas. These areas were defined by excluding non-vegetated and sparsely vegetated land cover types, such as bare land and impervious surfaces, from the land use classification.

In response to your comment, we provide a more detailed description of the method used to identify permanent vegetation areas in the revised manuscript. We hope that this revision will meet your expectations.

The specific modifications can be found in Data sources and processing Section 2.6 (see Lines **214-216** in manuscript (marked version)).

[r2,5] In the Results section, many geographically specific terms referring to relatively small regions are used, such as the Chersky Range, Chad Basin, Katanga Plateau, and Karaganda Basin. I believe that such detailed geographical descriptions may hinder readability. I suggest replacing them with broader regional descriptions, such as “central Africa”.

Thank you for your valuable comment. We agree with your point that the use of numerous specific geographic terms for relatively small regions may hinder readability. In response to your comment, we replace these terms with broader regional classifications in the revised manuscript. We hope that this revision will meet your expectations.

The specific modifications can be found in the whole manuscript.

[r2,6] In the Results section, the authors repeatedly state expressions similar to “the results remain consistent under the 16-year and 20-year moving window analyses.” I understand that the authors conducted extensive work to ensure the robustness of the results; however, this repeated wording appears redundant. It is unnecessary to reiterate this statement multiple times, and I suggest placing it once in the Methods or Discussion section instead.

Thank you for your valuable comment. We agree that there are still issues with our English expression, including occasional inappropriate phrasing and redundancy.

In response to your comment, we remove statements such as “the results remain consistent under the 16-year and 20-year moving window analyses” from the Results and retain them only in the Discussion. In addition, we will invite a native English-speaking co-author to carefully review and polish the manuscript to improve its overall clarity and readability. We hope that this revision will meet your expectations.

The specific modifications can be found in the Discussion (see Lines **479-480** in manuscript (marked version)).

[r2,7] The Discussion section should further elaborate on the physiological mechanisms. The Results indicate that atmospheric CO_2 is the most important driver of the weakening coupling between WUE and SPEI, yet the manuscript provides insufficient mechanistic discussion regarding this key conclusion. The authors are encouraged to consult relevant literature and expand the discussion to better elucidate the underlying ecohydrological mechanisms.

Thank you very much for pointing out this limitation in our manuscript. As you rightly noted, our discussion of the underlying ecohydrological mechanisms remains insufficient in depth.

In response to your comment, we have further reviewed and synthesized the relevant literature to strengthen the discussion of the mechanisms by which CO_2 drives the weakening of the coupling between SPEI and WUE in the revised manuscript. This mainly involves two aspects: CO_2 enhances the carboxylation efficiency of Rubisco, thereby promoting GPP, and induces partial stomatal closure, which reduces transpiration water loss. We hope that this revision meets your expectations.

The specific modifications can be found in the Discussion (see Lines **529-543** in manuscript (marked version)).

[r2,8] Please carefully check the grammar, tense, and other issues throughout the full text.

1. Line 49: Forests.
2. Line 67: Grammatical error; revise to applied machine learning methods and found.
3. Line 80: increased - Check the tense.
4. Ling 168: Equations.
5. Line 196: were.
6. Line 208: varying the width of the moving window: Here directly state the width of other moving window used.

7. Line 224: The standard expressions for “training/test sets” in scientific papers are training and test subsets, not “testing”.

8. Line 248, Line 249: Was.

9. Line 266-Line 272: According to aridity index, the globe is classified into arid, semi-arid, sub-humid, and humid. These are dryness or aridity gradients, instead of drought gradients.

10. Line 332: Provide an explanation of the sub figures in the figure caption.

11. In the discussion section: academic papers require a clear statement of the study limitations to guide future research, but this subsection is missing in the manuscript. It is recommended to add a subsection entitled “Study Limitations” to objectively analyze the shortcomings of the present work and propose directions for future research.

Thank you very much for your careful review. We acknowledge that there are still shortcomings in the grammar and overall English expression of the manuscript.

In response to your comment, we will thoroughly check the entire manuscript for issues related to grammar, tense, and clarity. In addition, we invite a native English-speaking co-author to further polish the language to improve readability. Meanwhile, we include a dedicated “Limitations and Future Perspectives” section to provide a balanced assessment of the current study and to offer guidance for future research. We hope that this revision will meet your expectations.

The specific modifications can be found in the whole manuscript and Discussion Section 5.4 (see Lines **571-583** in manuscript (marked version)).

Reference:

Huang, M., Wang, X., Keenan, T. F., and Piao, S.: Drought timing influences the legacy of tree growth recovery, Global Change Biology, 24, 3546-3559, https://doi.org/10.1111/gcb.14294, 2018.

Kannenberg, S. A., Schwalm, C. R., and Anderegg, W. R. L.: Ghosts of the past: how drought legacy effects shape forest functioning and carbon cycling, Ecology Letters, 23, 891-901, https://doi.org/10.1111/ele.13485, 2020.

Vicente-Serrano, S. M., Gouveia, C., Camarero, J. J., Beguería, S., Trigo, R., López-Moreno, J. I., Azorín-Molina, C., Pasho, E., Lorenzo-Lacruz, J., Revuelto, J., Morán-Tejeda, E., and Sanchez-Lorenzo, A.: Response of vegetation to drought time-scales across global land biomes, Proceedings of the National Academy of Sciences, 110, 52-57, doi:10.1073/pnas.1207068110, 2013.

Zeng, X., Hu, Z., Chen, A., Yuan, W., Hou, G., Han, D., Liang, M., Di, K., Cao, R., and Luo, D.: The global decline in the sensitivity of vegetation productivity to precipitation from 2001 to 2018, Global Change Biology, 28, 6823-6833, https://doi.org/10.1111/gcb.16403, 2022.