Comment # 1

We thank the independent reviewer for the comments. The comments are all valuable and extremely helpful for revising and improving our paper, as well as the important guiding significance to our research. We have studied comments carefully and have made corrections accordingly, which we hope meet with approval. The main corrections in the paper and the response to the reviewer's comment are as follows:

This manuscript investigates how ecosystem primary productivity recovers after experiencing flash droughts using the random forest model and an explainable model. These results reveal the response time of GPP over China and its influencing factors. The topic is of significance to assess flash droughts' ecological impacts, which is probably a concern to the community of hydrologists, ecologists, and policy-makers. However, the study should clarify some comments before it is accepted by *Hydrology and Earth System Sciences*.

***R*: Thank you for your summary. We really appreciate your efforts in reviewing our manuscript. We have revised the manuscript accordingly. Our point-by-point responses are detailed below.**

Major comments:

(1) The abstract pointed the most novel finding is proposing a new method of a machine learning method to study the recovery of GPP to flash droughts. In my opinion, the method is not quite new and has been widely used in analyzing the interactions between soil moisture and vegetation. Whereas the recovery of GPP is less involved in previous studies, this study contributes a lot to provide a perspective on this topic.

***R*: Thank you for your thorough review and valuable feedback. We appreciate your comments regarding the novelty of the machine learning method and its extensive use in analyzing soil moisture and vegetation interactions. While the method itself may not be entirely new, our aim was to apply it in a novel way to study the recovery of GPP (Gross Primary Production) following flash droughts.**

We hope that this specific application can provide new insights and perspectives in this area. As you pointed out, the recovery of GPP has been less explored in previous studies, and we believe our work contributes significantly to this aspect of research.

(2) The metric of GPP recovery from flash droughts used in this study may be influenced by data noises, for example, during a flash drought event that persists for 2 months, negative GPP anomalies only occur for 5 days. Such cases should be excluded in the analysis. The precondition of GPP recovery from flash droughts is that GPP has been negatively influenced by flash droughts. Besides, the terminating point of the recovery process is difficult to detect and should not be recognized at the point where the GPP anomaly is above 0, as there are many noises including whether it has experienced another drought or other extreme, the stable condition may be higher or lower than the normal conditions, etc.

***R*: Thank you for your insightful comments regarding the GPP recovery metrics used in our study. We acknowledge that data noise can influence the analysis, particularly in cases where negative GPP anomalies are sporadic during a flash drought event. We have already implemented a data preprocessing step to reduce the impact of noise. We agree that only those events where GPP has been significantly impacted by the flash drought should be considered in the analysis. We also recognize the challenge in accurately identifying the termination point of the recovery process. As you pointed out, simply using the point where the GPP anomaly becomes positive might not be appropriate due to various noise factors, including subsequent droughts or other extreme events, and the potential deviation of stable conditions from the norm. To address these concerns, we plan to apply stricter criteria for selecting flash drought events and further refine our methodology for determining the recovery endpoint. We will exclude cases where the negative GPP anomalies are minimal.**

(3) Does the declining magnitude of GPP caused by flash droughts influence GPP's recovery time?

***R*: Thank you for your insightful question. Indeed, the declining magnitude of GPP caused by flash droughts may affect the recovery time of GPP. This impact is influenced by various biological factors. However, the current manuscript primarily focuses on abiotic factors, specifically climatic factors and the characteristics of flash droughts. We will include a discussion on how the speed and severity of GPP's response to flash droughts can influence its recovery time.**

(4) What are the hydro-meteorological conditions during the recovery stage of GPP? Is there a connection between hydro-meteorological conditions and GPP recovery?

***R*: Thank you for your insightful question regarding the hydro-meteorological conditions during the recovery stage of GPP and their connection to GPP recovery. In our study, we considered a range of hydro-meteorological conditions during the recovery stage, including radiation, temperature, drought index, wind speed, precipitation rate, and vapor pressure deficit (VPD). Our results indicate a connection between these conditions and GPP recovery. Post-flash drought radiation emerged as the primary environmental factor influencing GPP recovery, followed by the aridity index and post-flash drought temperature. This connection is particularly strong in semi-arid and sub-humid areas. We also observed that temperature has a non-monotonic relationship with recovery time, where excessively cold or overheated temperatures lead to longer recovery periods.**

(5) The study period is a little short and the available datasets have been updated to 2023 even longer.

***R*: Thank you for your valuable feedback. We acknowledge that the study period may be considered short. In response to your comment, we will review and incorporate the most recent datasets updated to 2023, to extend our analysis and**

provide a more comprehensive assessment. We appreciate your suggestion and will address it in our revised manuscript.

Minor comments:

L23: “response function functions”

***R*: Thank you for pointing out the spelling error "response function functions" in our manuscript. We will correct this mistake in the revised version.**

L41: “productivity” should be more clear. Maybe “terrestrial ecosystem productivity” is better.

***R*: Thank you for your suggestion to use "terrestrial ecosystem productivity" instead of "productivity" for greater clarity. We agree with your recommendation and will make this change in the revised version of our manuscript.**

L48-54: The phase reviews the previous research about how vegetation recovers from droughts. It seems that they are inconsistent with the recovery of GPP in terms of GPP’s response across different PFTs. Is there any explanation for it?

***R*: Thank you for your insightful question. Firstly, vegetation recovery can be assessed using various indicators such as greenness, photosynthesis, and productivity. Lines 48-54 of our manuscript provide a summary of vegetation recovery under different indicators. Our study specifically focuses on the recovery of vegetation productivity, as measured by GPP. Then, we recognize that the recovery of GPP in different plant functional types (PFTs) may appear inconsistent compared to the broader understanding of vegetation recovery from droughts. This discrepancy could be attributed to various factors, including differences in species-specific physiological responses, variations in soil and climatic conditions, or differing methodologies used in previous studies. We will investigate this further in our revised manuscript to provide a clearer explanation for these inconsistencies and enhance the discussion around the differential recovery of GPP across PFTs. Your feedback is invaluable, and we appreciate your attention to this detail.**

L54:55 & L303:304: Vegetation over humid regions needs more time to recover to its normal condition. As there is more water available over humid regions, why vegetation is more difficult to recover?

***R*: Thank you for highlighting this point. To clarify, the statement from the article, "When comparing hydro-meteorological conditions, semi-arid and semi-humid regions have a longer recovery time compared to humid and arid regions," indicates that semi-arid and semi-humid regions generally experience a longer period to recover. This does not necessarily mean that vegetation in humid regions faces more difficulty in recovery; rather, it suggests that the recovery dynamics in semi-arid and semi-humid regions are more prolonged. The longer recovery time in semi-arid and semi-humid regions may be related to the specific challenges these regions face, such as soil conditions, water availability, and climatic variability (Huxman et al., 2004; Zhang et al., 2021). We will make sure to clarify this distinction in the revised manuscript to better explain why semi-arid and semi-humid regions may experience longer recovery times compared to other regions. Thank you for bringing this to our attention.**

L57: What is the "background value"?

***R*: It means pre-drought vegetation conditions. Background conditions and drought-damage magnitudes played an important role in regulating drought recovery. Specifically, lower background values and greater damage led to longer recovery times (He et al., 2018).**

1 is difficult for readers to understand the metric used in this study. It is better to clarify flash drought and recovery time in Fig.1 more clearly. Perhaps authors can select a case from the observed events.

***R*: Thank you for your feedback. We understand that clarifying the metrics used in our study is crucial for reader comprehension. We will revise Figure 1 to provide a clearer depiction of flash droughts and recovery times. Additionally, we will include a specific case study from the observed events to illustrate these concepts**

more effectively. This should help to better convey how flash droughts and recovery times are measured and analyzed in our study. We appreciate your suggestion and will address it in the revised manuscript.

L185: In Fig2.b, should the red line be removed?

***R*: Thank you for your suggestion regarding Figure 2.b. We appreciate your keen observation and agree with your recommendation to remove the red line from the figure. Upon reviewing the figure, we concur that the red line does not add value to the clarity or interpretation of the data presented. We will proceed with removing the red line in the revised version of the manuscript to enhance the overall quality and accuracy of the figure. Your feedback is invaluable in ensuring the precision of our presentation, and we are grateful for your input.**

L199: There is no GPP recovery over northwestern China. Is there no response of GPP to flash droughts? As usual, vegetation is more sensitive to water availability in arid or semi-arid regions than in humid regions. Besides, is the response rate the reverse value of response time? If so, they are presenting the same results.

***R*: The lack of GPP recovery over northwestern China in our study is primarily due to the absence or poor quality of GPP data in that region. This limitation prevents us from assessing the response of GPP to flash droughts effectively in that specific area. Regarding your question about response rate and response time, the response rate is indeed the ratio of response magnitude to response time, rather than a simple reciprocal relationship. Given that the magnitude of GPP's loss can vary spatially, the response rate and response time are not straightforward inverses of each other. While they are related, they represent different aspects of how systems respond to drought. We appreciate your attention to this detail and will make sure to incorporate a more detailed explanation in the revised version.**

References:

He, B., Liu, J., Guo, L., Wu, X., Xie, X., Zhang, Y., ... & Chen, Z. (2018). Recovery of ecosystem carbon and energy fluxes from the 2003 drought in Europe and the 2012 drought in the United States. *Geophysical Research Letters*, *45*(10), 4879-4888.

Huxman, T. E., Smith, M. D., Fay, P. A., Knapp, A. K., Shaw, M. R., Loik, M. E., ... & Williams, D. G. (2004). Convergence across biomes to a common rain-use efficiency. *Nature*, 429(6992), 651-654.

Zhang, S., Yang, Y., Wu, X., Li, X., & Shi, F. (2021). Postdrought recovery time across global terrestrial ecosystems. *Journal of Geophysical Research: Biogeosciences*, 126(6), e2020JG005699.