Response to Reviewer #1

1. Singh et al. classified the tropical terrestrial ecosystems under current climate and future climate by calculating the hydroclimate-derived root zone storage capacity. Then they assessed the potential rainforests tipping risk with the global warming. They found that the forest-savanna transition risk would largely increase if the climate warming is beyond 1.5-2 degrees. The topic is meaningful and interesting since the land cover change used in current ESMs of CMIP6 is lacked of the consideration of the effects of hydroclimate.
   Response: We are pleased to hear that the reviewers found the research topic to be of considerable interest.

2. However, readers could be hard to follow and even confused in the main text, because some introduction of method and discussions are not easy to understand.
   Response: In the revised manuscript, we will enhance the clarity and articulation of our methods and discussion sections. We plan to refine the *'Root zone storage capacity-based framework for projecting forest transitions*' and '*Projecting forest transitions under future climate change*' subsection, a fundamental part of our methodological framework, by dividing it into several subsections for better understanding. Additionally, in the discussion section, we will clarify '*Comparing prescribed future land-use with projected transitions*' and '*Limitations and sensitivity analyses*' to address any complexities around projected and prescribed land-uses and current limitations of the ESMs in projecting tipping risk that may have made them difficult to follow.

3. More importantly, the main findings are not clearly shown in the main text. For example, in the Abstract, the "1.5-6 times" growth is the key finding for this study (also corresponding to the title), but how these values are derived is not shown.
   Response: To better convey the escalating risk of rainforest tipping under different shared socioeconomic pathways (SSPs), we articulate that "For Amazon, this risk can grow by about 1.5-6 times compared to its immediate lower warming scenario,.....". This explanation corresponds with Fig. 2, which shows the escalating risk of tipping in the Amazon rainforest (measured by area). Relative to SSP1, the risk of tipping increases sixfold under SSP2, twentyfold under SSP3, and thirty-threefold under SSP5. However, compared to their immediate lower warming scenario, the risk multiplies six times when transitioning from SSP1 to SSP2, 3.5 times from SSP2 to SSP3, and 1.5 times from SSP3 to SSP5.
   These detailed comparisons will be incorporated into the results section of the revised manuscript for enhanced clarity.

4. In this study, >20% of model convergence are regarded as 'moderate model agreement' or 'moderate-high model agreement'. Given that the findings with >20% of model convergence are important in this research, I doubt whether the 20% is too low to hardly help obtain the robust results.
   Response: In our study, a model convergence > 20%—or agreement among more than 20% of Earth System Models (ESMs)—indicates that if the same pixel across multiple models is classified similarly, it is then designated as undergoing a certain transition. For example, for a pixel to be considered part of the forest-savanna transition in the context of more than 20% model convergence, it requires the consensus of more than 7 out of 33 models confirming this transition.
   While a threshold of >20% may seem low based on the total number of ESMs analyzed, it's important to recognize the varying and often limited capabilities of these models, particularly in simulating biophysical interaction and emerging properties due to our limited understanding of the Earth system (Arora et al. 2023; Reyer et al. 2015). **Opting for a majority-based**

consensus in ESMs could overlook critical tipping risks identified by a subset of models, which may be as likely to reveal the actual state of such risks as their counterparts.

Therefore, recognizing these challenges in accurately modeling land surface interactions and transitions within ESM, our study showcases model agreement levels of both >20% and >50% (Fig. 2). Contrary to previous studies that either relied on a single model or used an ensemble of hydroclimate estimates from (6 to 7) ESMs for projecting tipping risks (Supplementary Table 3), which could introduce a selective bias, our approach seeks to address this concern. By integrating a broad spectrum of transitions projected by different ESMs, our model enhances transparency and offers a more comprehensive understanding of rainforest tipping risk. Through this, we aim to illuminate both the discrepancies and alignments among the projected transitions, offering a foundation for future research into the causes behind these potential variances.

We will emphasize these points in the revised manuscript.

Arora, Vivek K., et al. "Towards an ensemble-based evaluation of land surface models in light of uncertain forcings and observations." Biogeosciences 20.7 (2023): 1313-1355.

Reyer, Christopher PO, et al. "Forest resilience and tipping points at different spatio-temporal scales: approaches and challenges." Journal of Ecology 103.1 (2015): 5-15.

5. It is interesting to compare the prescribed future land-use in IAMs with the projected transitions in this study. But it is not clear for readers which results are more robust. Readers cannot figure it out from the discussions of the authors. For example, on the one hand, the author said the extent of forest-savanna transitions is often underestimated in prescribed land-use compared to those projected in their study. In this case, it seems that results from this study are regarded as more robust. However, on the other hand, the authors said forests that revert to a 'less water-stressed state' is overestimated in their analysis. It seems that results from the prescribed future land-use in IAMs are more robust.

   Response: The following statement will be added to the revised manuscript: "Our analysis reveals that the extent of forest-savanna transitions is often underestimated in prescribed land-use compared for South America to those projected in this study (i.e., prescribed land use predicts forests in the region that risk tipping; Fig. 5a). Furthermore, forests that revert to a 'less water-stressed state' are again underestimated for both South America and Africa (i.e., prescribed land-use predicts non-forested areas in the region that can sustain forests; Fig. 5c)."

   We will further add caution on how to interpret the results from this comparison, highlighting how prescribed land use might have introduced unrealistic hydroclimatic trends and how that could influence our comparison.

Specific comments:

6. Line 28: which scenario for this growth by about 1.5-6 times.

   Response: This comment is addressed in our response to Review #1 comment 3.

7. Lines 98-100: please explain why the hydroclimate and ecosystem can be regarded as in equilibrium. The hydroclimate and ecosystem are projected by ESM in SSP scenario simulations, which are apparently not in equilibrium because of the continued warming.

   Response: The aim of this research stems from a key limitation in Earth System Models (ESMs): while hydroclimate is dynamically projected, land use is statically prescribed. To assess whether current forest ecosystems will maintain their status or transition to savannas (i.e., shift between equilibrium states) by the century's end (2086-2100), we rely on the assumption that the projected hydroclimate will dictate the suitable/sustainable ecosystem type, suggesting a balance between hydroclimate conditions and ecosystem states. This approach is necessitated by the complex and often lengthy processes required for ecosystems to reach equilibrium following disturbances (for instance, the Amazon may take 50-200 years to tip; Armstrong McKay et al. 2022). **Factors such as the severity of perturbations, mechanisms of forest decline/mortality, and adaptation play crucial roles, making the dynamic simulation of such transitions in ESMs challenging.**

By assuming equilibrium between ecosystems and their hydroclimates, we admittedly overlook the precise temporal dynamics of rainforest tipping. However, this trade-off allows us to identify areas at risk of tipping, providing valuable insights for developing mitigation strategies to prevent such transitions. This methodological choice enhances our understanding of potential tipping risks and could help inform proactive conservation and climate action plans.

Armstrong McKay, David I., et al. "Exceeding 1.5 C global warming could trigger multiple climate tipping points." Science 377.6611 (2022): eabn7950.

8. Lines 130-131: The spatial resolutions of most of ESMs output are close to 0.25 degree? I suppose that the spatial resolutions of most of ESMs are much lower than 0.25 degree.

   Response: The resolution of Earth System Models (ESMs) typically ranges from 1° to 1.5°, with EC-Earth3 offering the highest resolution at 0.7° and CanESM5 having the lowest at 2.8°. In the manuscript, we do state that 'Though obtained estimates from different ESMs are at different spatial resolutions, we bilinearly interpolated them to 0.25º for this analysis' [Page 4, Line 130-131].

   In the revised manuscript, we will provide detailed resolutions for all ESMs within the Supplementary Information.

9. Line 162: "to reduce loss of root zone moisture storage"?

   Response: Thank you for pointing this out. This will be corrected in the revised manuscript.

10. Line 183: "the actual state of the ecosystems" includes many aspects of ecosystems. "this model can capture the dynamics of actual soil moisture availability for the ecosystems" would be better.

    Response: Indeed, thank you for pointing this out. This will be corrected in the revised manuscript.

11. Line 380-381: please add the references of related figure(s).

    Response: Thank you for noticing this. The figure reference will be added in the revised manuscript.

12. Lines 590-592: But as shown in Figure 3, even in SSP1-2.6, there are still many regions belonging to "Transition to a more water-stressed state".

    Response: Indeed, but depending on how the model was parameterized, SSP1-2.6 still leads to approximately 1.3-2.4ºC warming. This warming is expected to not only decrease precipitation and increase precipitation seasonality but also elevate evaporation rates beyond current climate conditions. The combination of higher evaporation and reduced precipitation favors forest ecosystems that enhance their root zone storage capacity in order to ensure sufficient moisture is retained for dry spells.