# Response to Reviewer #1

We sincerely thank the reviewer for the careful evaluation of our manuscript and for the many constructive comments and suggestions. We appreciate the time and effort devoted to reviewing our work. We have carefully considered all comments and have revised the manuscript accordingly. Reviewer comments are reproduced below in italic, followed by our responses.

# Introduction

## Comment 1

*Line 84: Please clarify the rationale for focusing on SSP1-2.6. If the intention was to minimize the influence of anthropogenic forcing and better isolate the effects of reforestation, this should be explicitly stated and discussed, including the implications for the generalizability of the results. The simulated response still occurs within a climate system already affected by low anthropogenic greenhouse-gas forcing. To what extent could the reported reforestation effects depend on the SSP1-2.6 background climate state? Could anthropogenic forcing amplify, attenuate, or otherwise modify the simulated reforestation response? At least, a discussion of this potential limitation would help assess the broader applicability of the results.*

### Response

We agree that the rationale for selecting SSP1-2.6 and the implications for the generalizability of our results should be stated more explicitly. We selected SSP1-2.6 because it is consistent with the mitigation context in which large-scale reforestation is commonly considered, and because the relatively low level of anthropogenic forcing provides a clearer framework for isolating land-cover-driven hydroclimatic responses relative to a fixed-land-cover baseline. We have revised the Introduction and Methods to clarify this rationale.

We also now explicitly state that the simulations are conducted under an anthropogenically forced climate and that the response to reforestation may depend on the background climate state. Although the baseline and reforestation simulations are subject to the same SSP1-2.6 forcing, higher greenhouse-gas concentrations could interact with the reforested land surface through vegetation physiological and biophysical processes. For example, elevated atmospheric $CO_2$ may increase plant water-use efficiency by reducing stomatal conductance, thereby modifying transpiration, evapotranspiration, and associated land–atmosphere feedbacks. Similarly, changes in snow cover, cloud feedbacks, and large-scale circulation under different forcing scenarios could alter the magnitude and spatial pattern of the simulated reforestation response. This limitation is now discussed explicitly in the Discussion, and the manuscript consistently frames our findings as the hydroclimatic response to reforestation under SSP1-2.6 rather than as scenario-independent estimates. This limitation is now discussed explicitly in the Discussion, and the manuscript consistently frames our findings as the hydroclimatic response to reforestation under SSP1-2.6 rather than as scenario-independent estimates.

"We focus on SSP1-2.6 because this low-emission pathway is consistent with the mitigation context in which large-scale reforestation is most often proposed. Using a low-forcing scenario also helps limit the magnitude of externally forced climate change relative to higher-emission pathways, thereby providing a clearer framework for isolating the hydroclimatic effects of land-cover change. Nevertheless, the simulated response occurs in a climate system that is still affected by anthropogenic greenhouse-gas and aerosol forcing. Although the baseline and reforestation simulations experience the same SSP1-2.6 forcing, the response to reforestation itself may depend on the background climate state and atmospheric composition. Recent work has likewise shown that both the biogeophysical and biogeochemical effects of reforestation exhibit scenario dependence under different future climate pathways (Jayakrishnan et al., 2026). For example, under higher atmospheric $CO_2$ concentrations, increased plant water-use efficiency resulting from reduced stomatal conductance could modify transpiration, evapotranspiration, and associated land–atmosphere feedbacks. Likewise, changes in snow cover and large-scale circulation under different forcing scenarios could alter the magnitude and regional expression of the simulated reforestation response. The results presented here should therefore be interpreted as the hydroclimatic response to reforestation under SSP1-2.6, rather than as a scenario-independent estimate. "

And

"Reforestation responses may interact nonlinearly with the background climate state and atmospheric composition. For example, elevated atmospheric $CO_2$ may increase plant water-use efficiency through reduced stomatal conductance, thereby modifying transpiration, evapotranspiration, and associated land–atmosphere feedbacks. Changes in snow cover, cloud processes, and large-scale circulation under different forcing scenarios could likewise alter the magnitude and regional expression of the simulated reforestation response. Recent studies have similarly shown that both the biogeophysical and biogeochemical effects of reforestation are scenario dependent (Jayakrishnan et al., 2026)."

Changes have been made on Page 3, Lines 96–106; Page 22, Lines 505-514 and 516-522

## Comment 2

*Missing literature in the Introduction:*

- *Fahrenbach et al. (2026)*; *Seydou et al. (2025)*; *Ingrosso and Pausata (2024)*

### Response

We appreciate these suggestions. The recommended references have been reviewed and incorporated into the Introduction where appropriate to better place our work within the context of recent studies on global reforestation, regreening initiatives, and regional hydroclimatic responses.

"At the global scale, reforestation influences atmospheric circulation beyond the reforested areas. Multi-model ensemble experiments indicate that tropical reforestation increases evapotranspiration and local rainfall but can also alter large-scale circulation patterns and moisture transport (Fahrenbach et al., 2025). Similarly, Portmann et al. (2022) demonstrated that afforestation outside the tropics can shift the Intertropical Convergence Zone (ITCZ), modifying rainfall patterns worldwide. Recent work further highlights that the climatic outcome of reforestation depends strongly on where forests are restored, with different reforestation pathways producing substantially different regional and global temperature responses (Fahrenbach et al., 2026). These findings emphasize the importance of considering not only the magnitude but also the spatial distribution of reforestation when evaluating its climatic impacts.

Yet, multi-model intercomparison projects continue to reveal substantial structural uncertainty, differences arising from model formulations and parameterizations, in how land-use forcing translates into atmospheric and hydrological responses (De Hertog et al., 2022; Amali et al., 2025), while some studies report limited large-scale circulation responses (King et al., 2024). These disparities highlight the need for a deeper comprehension of regional effects as well as model sensitivity.

Regional and high-resolution analyses further emphasize spatial contrasts. Regional studies in humid regions such as the UK show that ET increases associated with reforestation/afforestation frequently outstrip precipitation gains, lowering streamflow (Buechel et al., 2022; 2024b). Conversely, a greater summer precipitation in reforested portions of continental Europe, ascribed to enhanced evapotranspiration and moisture recycling (Meier et al., 2021), implies that local hydrological feedbacks can partially offset water losses in some regions. The hydroclimatic impacts of reforestation are particularly uncertain in semi-arid environments, where vegetation recovery may simultaneously influence local precipitation, soil moisture, water availability, and land-atmosphere feedbacks. A recent review of regreening and afforestation efforts in dryland regions highlighted the complexity of these interactions and emphasized that hydrological responses often depend on local climate conditions, vegetation characteristics, and the scale of restoration activities (Seydou et al., 2025). These uncertainties are particularly relevant for ongoing large-scale restoration initiatives. For example, simulations of the African Great Green Wall suggest that extensive reforestation and regreening may reduce regional aridity while simultaneously increasing the frequency of heat extremes, illustrating the existence of important trade-offs among different climate impacts of restoration efforts (Ingrosso and Pausata, 2024)."

Changes have been made on Pages 2-3, Lines 54-61 and 70-78.

# Methods

## Comment 3

*The construction of the "reversed" scenario requires further clarification and, in my opinion, represents a key methodological issue...*

*Lines 109–115: The construction of the "reversed" scenario requires further clarification. The manuscript states that forest cover is restored on all lands converted to cropland after 1850 based on LUH data. However, cropland expansion has not exclusively occurred at the expense of forests. Could the authors clarify how the pre-agricultural land-cover type was determined? Is the assumption that all cropland expansion since 1850 originated from forested land justified?*

### Response

We agree that the construction of the reversed reforestation scenario required further clarification. We have substantially revised the Methods section to better describe its construction and underlying assumptions.

The reversed scenario is based on the 1850 forest distribution, such that reforestation is spatially constrained to areas where forest cover declined between 1850 and 2015. Consequently, the locations of reforestation broadly follow the historical pattern of forest loss.

To allocate the restored forest area, we adopted a priority-based approach. Cropland is converted to forest first, reflecting the dominant role of agricultural expansion as the primary driver of global deforestation since the nineteenth century. Where the target forest recovery cannot be achieved through cropland conversion alone, additional forest area is allocated by converting grassland. We have also clarified that this approach restores the magnitude and broad spatial pattern of historical forest loss but does not reconstruct the exact historical land-use transition at every grid cell. Accordingly, the reversed scenario should be interpreted as an idealized reforestation experiment rather than a complete reconstruction of historical land-cover change.

"These cropland-driven changes served as the basis for defining the 'reversed' reforestation scenario, in which forest cover is restored on lands that were converted to cropland after 1850. The reversed reforestation scenario was constructed using the 1850 forest distribution as the reference state. Grid cells where forest cover declined between 1850 and 2015 were identified as potential reforestation areas, so the spatial pattern of reforestation broadly follows the historical pattern of forest loss. Within these areas, forest cover was restored toward its 1850 extent using a priority-based allocation. Tree cover was first increased by replacing cropland, reflecting the dominant role of agricultural expansion in historical deforestation. Where the target forest recovery within a grid cell or region could not be achieved through cropland replacement alone, additional tree cover was allocated by replacing grassland. This approach restores forest preferentially in areas that experienced forest loss since 1850, but it does not explicitly reconstruct the exact historical transition pathway responsible for that loss. In both cases, tree cover is prescribed to increase linearly between 2015 and 2070 (Fig. S1)."

Changes have been made on Pages 4-5, Lines 135-144

## Comment 4

*Figure 1: Please improve the readability of the legend (just put one, maybe outside the maps) and the colorbar labels (they are too small). I would write percentage change as some areas show a decrease.*

**Response**

Figure 1 has been revised to improve readability. The legend has been simplified and consolidated, the colorbar labels have been enlarged, and the label has been changed to indicate percentage change, reflecting both increases and decreases in forest cover. Page 5, Figure 1

## Comment 5

*Lines 132–137: More information is needed regarding the perturbations applied to generate the ensemble members. The authors should also justify why five ensemble members are deemed sufficient to isolate the forced hydroclimatic response from background internal variability.*

**Response**

We agree that additional information regarding the ensemble generation and ensemble size should be provided. The Methods section has been expanded to clarify that the simulations use five existing CanESM5 ensemble members generated following the standard initialization procedure described by Swart et al. (2019). Rather than generating new perturbations, we selected five realizations from the existing ensemble to sample internal climate variability while maintaining identical external forcing.

We also clarify that the choice of five ensemble members represents a balance between reducing the influence of internal variability and the substantial computational expense associated with conducting multi-century Earth System Model simulations for three land-use scenarios. This choice is further supported by previous studies showing that five realizations are sufficient to robustly isolate the forced climate response, particularly for global mean surface air temperature (e.g., Milinski et al., 2020). The manuscript now explicitly references the original CanESM5 model description for details of the ensemble generation procedure.

Milinski, S., Maher, N., & Olonscheck, D. (2020). *How large does a large ensemble need to be?* **Earth System Dynamics, 11**(4), 885–901. https://doi.org/10.5194/esd-11-885-2020

"For each land-use scenario (baseline, sustainable, and reversed), simulations were performed for five ensemble members (n = 5) selected from the existing CanESM5 ensemble. The ensemble members were generated using the standard CanESM5 initialization procedure described by Swart et al. (2019), in which small perturbations to the model initial conditions produce independent realizations that sample internal climate variability while maintaining identical external forcing. In the present study, five ensemble members were selected as a compromise between sampling internal variability and the substantial computational cost of conducting multi-century (2015–2200) Earth System Model simulations for each land-use scenario. This choice is supported by previous work demonstrating that five realizations are generally sufficient to robustly isolate the forced climate response, particularly for global mean surface air temperature (Milinski et al., 2020)."

Changes have been made on Pages 5-6, Lines 165-170

# Results – Temperature response

## Comment 6

*Line 157: The statement "widespread cooling" appears somewhat overstated. While a relatively widespread cooling signal is evident over South America, the cooling response in Central Africa and Southeast Asia appears more spatially localized and heterogeneous. Moreover, a slight warming signal is observed across parts of the Sahara/North Africa region for the sustainable scenario.*

### Response

We agree that the original wording overstated the spatial extent of the cooling response. The term **"widespread"** has been replaced with **"predominant"** to better reflect the spatial patterns shown in the simulations while emphasizing the common response across the reforested regions.

The text has also been revised to more accurately describe the regional heterogeneity of the temperature response.

Changes have been made on Page 6, Line 193

## Comment 7

*Figure 2: The use of a continuous color scale may also make it difficult to assess the spatial extent of the signal. Consider using discretized color bar intervals and/or providing additional quantitative information to better support the characterization of the cooling as widespread.*

**Response**

To improve the quantitative interpretation of the regional responses, we have added regional bar plots summarizing the temperature changes across the seven major reforested regions. These complement the spatial maps and provide a clearer comparison of the magnitude of the simulated temperature responses.

Changes have been made on Page 8, Figure 2

## Comment 8

*I think that adding bar plots with temperature and cloud-cover changes with associated uncertainties (or alternatively boxplots) across the seven reforested areas could be useful, as some changes are very local.*

**Response**

We agree that a quantitative regional summary improves the presentation of the results. Accordingly, we have added bar plots showing the regional temperature and cloud-cover responses across the seven reforested regions. These figures complement the spatial maps and facilitate comparison of the magnitude of the responses between the two reforestation scenarios.

Changes have been made on Page 8, Figure 2

## Comment 9

*Lines 160–161: The results are consistent with evaporative/cloud-driven cooling in low latitudes and albedo-driven warming at high latitudes, but these mechanisms are still not quantified at this stage. Consider replacing "highlight" with a more cautious term such as "suggest".*

**Response**

We agree that the previous wording was too strong. The word **"highlight"** has been replaced with **"suggest"** to better reflect the level of evidence provided by the present analyses.

Changes have been made on Page 6, Line 196

## Comment 10

*Lines 165–169: The authors should better explain why local responses appear stronger in the sustainable scenario, explicitly relating these differences to the different density of reforestation in the two experiments. In addition, the discussion of the underlying energy-balance mechanisms remains largely qualitative. A more quantitative description of the main energy-budget contributions would be helpful, particularly since these fluxes are already presented in Fig. S3. I suggest adding a few sentences summarizing their relative roles in the cooling or warming effects.*

**Response**

We agree that this aspect of the analysis required further explanation. The Results section has been expanded to explicitly relate the stronger local climate responses in the sustainable scenario to its greater density of reforestation, which produces stronger local biophysical forcing.

We have also added a more quantitative discussion of the surface energy budget using Fig. S3, summarizing the relative contributions of net shortwave radiation, latent heat flux, sensible heat flux, net longwave radiation, and albedo. The revised text explains that the simulated temperature response results from the competing effects of enhanced solar energy absorption associated with reduced albedo and enhanced evaporative cooling associated with increased latent heat flux, with both effects being more pronounced in the sustainable scenario.

"The local temperature responses are generally stronger in the sustainable scenario because this experiment contains a greater density of reforestation, resulting in stronger land–atmosphere interactions. South America, Central Africa, and both Southeast Asia exhibit cooling of -0.5 to -1.0 °C, coinciding with statistically significant increases in total cloud fraction over the same regions. As shown in Fig. S2, reforestation modifies several components of the surface energy budget. Net shortwave radiation exhibits the largest positive anomalies, locally approaching 2 W $m^{-2}$, reflecting increased absorption associated with reduced surface albedo. At the same time, latent heat flux increases by approximately 0.5–1 W $m^{-2}$ over many reforested regions, indicating enhanced evapotranspiration that acts to cool the surface. Changes in sensible heat and net longwave radiation are generally smaller, while the reduction in albedo is consistent across both experiments."

Changes have been made on Page 6, Lines 201-211

## Comment 11

*Line 169: Fig. S3 is mentioned before Fig. S2.*

**Response**

Thank you for noting this inconsistency. The order of the supplementary figures has been revised so that the figures are cited sequentially throughout the manuscript.

## Comment 12

*Figure S3: I do not get the point of not using the same scale for latent heat fluxes.*

**Response**

The figure has been revised to use a consistent color scale for the latent heat flux panels, facilitating a more direct comparison between the two reforestation scenarios.

Supplementary document page 2, Figure S2

## Comment 13

*Lines 205–209: In contrast to the temperature response discussed above, the reversed scenario appears to produce stronger but more spatially localized hydrological anomalies. This difference between the thermal and hydrological responses is interesting and deserves further discussion. The authors should explain why the reversed reforestation pattern leads to a more localized hydrological response despite producing a more spatially extensive temperature signal.*

**Response**

We agree that the contrasting thermal and hydrological responses warranted further discussion. The manuscript has been revised to clarify that temperature responds primarily to local changes in the surface energy balance, whereas hydrological variables are additionally influenced by nonlinear atmospheric processes, including moisture recycling, convection, and regional moisture convergence.

Although the sustainable scenario produces stronger local biophysical forcing because of its denser reforestation, the broader spatial distribution of reforestation in the reversed scenario perturbs land–atmosphere moisture exchanges over a larger geographical area. These perturbations translate into stronger hydrological anomalies only where land–atmosphere coupling is sufficiently strong, resulting in larger but more spatially heterogeneous regional responses. The Results and Discussion have been revised accordingly.

"These changes are consistent with statistically significant anomalies in evapotranspiration in many tropical land areas. Outside the tropics, anomalies remain generally weak, including over reforested areas, highlighting the considerable geographic dependency of hydrological changes. In both land-cover scenarios, evapotranspiration increases over areas of forest expansion, but the magnitude and spatial distribution differ. The sustainable scenario shows broadly distributed yet moderate ET gains of about +0.1 to +0.3 mm day$^{-1}$ across tropical reforested regions, whereas the reversed scenario produces stronger but more spatially localized increases, reaching +0.4 to +0.6 mm day$^{-1}$, particularly over South America and the Congo Basin. Although the sustainable scenario generates stronger local temperature responses because of its denser reforestation and associated surface energy-balance changes, the reversed scenario produces larger hydrological anomalies despite its lower local reforestation density. This contrast reflects the different processes governing thermal and hydrological responses. Surface temperature responds primarily to local modifications of the surface energy balance, whereas hydrological variables additionally depend on nonlinear land-atmosphere interactions, including moisture recycling, convection, and regional moisture convergence. Because reforestation in the reversed scenario is distributed across a broader geographical area, it perturbs land-atmosphere moisture exchanges over a larger portion of the tropics. However, these perturbations translate into substantial hydrological changes only in regions with strong land-atmosphere coupling, resulting in larger but spatially localized ET and precipitation responses, especially over the Amazon and Congo basins."

Changes have been made on Page 10, Lines 251-264

# Results - Hydrological Response and Atmospheric Circulation

## Comment 14

*Figure 3: The current continuous color scale tends to mask weaker anomalies. A non-linear color normalization (or discretized contour intervals) could help highlight small but potentially meaningful changes.*

### Response

We appreciate this suggestion. Figure 3 has been revised using discretized contour intervals to improve the visibility of weaker anomalies while maintaining consistency across the two reforestation scenarios. Page 13

## Comment 15

*Lines 230–238: Looking at both the annual maps and the zonal means, I do not see clear evidence of a common pattern of modest soil-moisture reduction across subtropical regions... Furthermore, the attribution of the soil-moisture reductions to increased evaporative demand under warmer conditions is plausible, but it is not fully supported by the analyses presented...*

### Response

We agree that the previous wording overstated the existence of a common subtropical drying pattern. The Results section has been revised to describe the soil-moisture response as regionally heterogeneous, emphasizing the pronounced drying over South America, Central Africa, and South Asia under the reversed scenario, while explicitly discussing the localized increases over North America.

We also replaced the attribution to increased evaporative demand under warmer conditions with a more cautious interpretation, noting that the simulated soil-moisture changes result from the combined effects of precipitation, evapotranspiration, runoff, and, at higher latitudes, snow accumulation and melt. The corresponding discussion has been revised accordingly.

"Both scenarios exhibit regionally heterogeneous soil-moisture responses (Fig. 3). These soil-moisture changes are consistent with the combined effects of changes in precipitation, evapotranspiration, runoff, and seasonal snow processes associated with reforestation. Drying is most evident in parts of tropical and subtropical South America, West Africa, and South Asia, whereas localized increases occur in portions of North America and high-latitude Eurasia. These patterns become more pronounced in the reversed scenario, where drying locally reaches −20 to −40 mm, particularly during DJF and MAM (Fig. S5). Under the sustainable scenario, soil-moisture anomalies remain relatively small across most regions (generally within ±10 mm), with localized increases in tropical South America and Central Africa during DJF and MAM, consistent with enhanced precipitation. In contrast, the reversed scenario produces substantially larger spatial variability, including pronounced drying in South America, West Africa, and South Asia, while parts of North America exhibit seasonal soil-moisture increases of approximately +20 to +30 mm. This wetting likely reflects the combined influence of increased cold-season snow accumulation and subsequent snowmelt, together with relatively small increases in evapotranspiration compared with the tropics, resulting in greater water availability during part of the year (Fig. S5, S6)."

Changes have been made on Page 12, Lines 284-295

## Comment 16

*Lines 232–234: Indication of the reference figure is missing. I think authors are referring to Figure S6, but it should be Figure S4. Please, be consistent with the order of the mention in the main text.*

**Response**

The figure references throughout the manuscript have been carefully reviewed and corrected where necessary. The appropriate supplementary figure is now cited, and the order of figure citations has been made consistent throughout the manuscript.

## Comment 17

*Lines 242–243: The figure reference appears incorrect. Figure S4 shows seasonal runoff changes, whereas the text is discussing precipitation changes. Please check and correct the figure citation.*

**Response**

We appreciate the reviewer identifying this error. The incorrect figure reference has been corrected, and the manuscript now cites the appropriate supplementary precipitation figure.
Supplementary document page 4, Figure S4

## Comment 18

*Lines 240–243: This paragraph would benefit from substantial clarification... Please consider rewriting this paragraph in a clearer and more coherent way, explicitly distinguishing local and remote responses and explaining the physical interpretation of the reported anomalies.*

**Response**

We agree that the original paragraph lacked clarity. It has been rewritten to distinguish local tropical responses from broader atmospheric adjustments. The revised text clarifies that the enhanced precipitation between approximately 10°S and 10°N partly reflects local responses over tropical reforested regions, while its more zonally coherent structure may also indicate the influence of larger-scale atmospheric adjustments.

We further distinguish these local responses from the more evident remote effects in the reversed scenario, where the hemispheric precipitation dipole is consistent with an ITCZ-related response. These revisions improve both the logical flow and the physical interpretation of the results.

"In nearly all regions, ET increases following forest expansion. Precipitation also rises modestly in most regions (≤ +0.2 mm $day^{-1}$ per $Mkm^2$ of reforested area), except Central Africa, where both scenarios show persistent declines of up to −0.1 mm $day^{-1}$ per $Mkm^2$ of reforested area. Changes in precipitation in South Asia remain close to neutral. Despite these broadly similar responses, the resulting terrestrial water budget (P-ET-R) differs substantially among regions and between the two reforestation scenarios. Positive P-ET-R anomalies dominate in North America and Central America under both scenarios and in East Asia under the sustainable scenario, indicating increased net water availability. In contrast, South America and Central Africa consistently exhibit negative P-ET-R anomalies, reflecting enhanced evapotranspiration and runoff losses that exceed precipitation gains. Under the reversed scenario, Europe and South Asia also show modest negative P-ET-R responses, highlighting the greater regional heterogeneity associated with this reforestation pathway."

Changes have been made on Page 13, Lines 330-335

## Comment 19

*Line 244: "There is little evidence of ITCZ displacement..." Please verify the figure reference... Could the authors provide the climatological ITCZ position...*

**Response**

The figure reference has been corrected to the appropriate supplementary precipitation figure. Because the present study does not explicitly diagnose the climatological ITCZ position, we have revised the text to state that the simulated precipitation anomalies are consistent with regional circulation adjustments and, in the reversed scenario, with a possible ITCZ-related response, while avoiding a definitive conclusion regarding ITCZ displacement.

"Central America exhibits particularly strong precipitation gains, coupled with the largest positive P-ET-R response under the reversed scenario. South America shows the strongest contrast between scenarios: while the sustainable scenario produces near-neutral water-budget anomalies, the reversed scenario results in substantial negative P-ET-R despite increased precipitation, indicating that enhanced evapotranspiration and runoff more than offset the additional rainfall and reduce overall water availability. Soil-moisture responses are generally consistent with these regional water-budget changes. Regions with the largest negative P-ET-R anomalies, particularly Central Africa and South America, also experience the greatest soil-moisture deficits, whereas North America and Central America exhibit positive water-budget anomalies accompanied by increased soil moisture. East Asia shows a weaker correspondence between the annual water budget and soil-moisture response, suggesting that seasonal storage dynamics and land–atmosphere interactions also influence the simulated soil-moisture changes"

Changes have been made on Page 13, Lines 335-340

## Comment 20

*Line 246: "and reduced rainfall across 0–10°N"... Could the authors clarify which regions contribute to this signal and provide additional evidence supporting this interpretation?*

### Response

We agree that the previous wording overstated the zonal character of the precipitation response. The text has been revised to describe the anomalies in terms of the regions where they are observed, particularly parts of West Africa and northern South America, as shown in the seasonal precipitation maps, rather than implying a uniform reduction across the entire 0–10°N latitude band. We also adopted more cautious wording regarding the possible role of large-scale circulation changes, noting that the present analyses do not explicitly diagnose an ITCZ displacement.

"Outside the tropical reforested regions, precipitation responses remain generally weak, with high-latitude areas showing only small and mostly insignificant anomalies (Fig. 3). These results indicate that direct remote effects of reforestation are limited in the sustainable scenario. Nevertheless, the zonal-mean precipitation exhibits a narrow enhancement between approximately 10°S and 10°N (Fig. S4). Although part of this increase reflects local precipitation changes over tropical reforested regions, its zonal coherence suggests that it may also be influenced by broader atmospheric adjustments associated with land-atmosphere interactions. The reversed scenario exhibits a weak zonal asymmetry, with enhanced precipitation over portions of the Southern Hemisphere tropics and localized reductions in parts of the Northern Hemisphere tropics, particularly over West Africa and northern South America (Fig. S4). While these patterns are consistent with a hemispheric redistribution of tropical rainfall, the present analyses do not explicitly diagnose the magnitude or position of an ITCZ shift. This pattern is consistent with an ITCZ-related adjustment superimposed on the local hydrological response. High-latitude regions also exhibit small positive runoff anomalies (+0.1 to +0.2 mm $day^{-1}$), likely associated with changes in snow accumulation and melt that modify the seasonal water balance (Fig. S5)."

Changes have been made on Page 12, Lines 297-309

## Comment 21

*Figure S5: This is a nice figure. Please avoid overlapping of the legend with the bars. You can add a single larger legend in the empty part of the plot.*

**Response**

Figure S5 has been revised to improve readability. The legend has been repositioned and consolidated into a single larger legend located in the available empty space, eliminating overlap with the plotted data. Supplementary document page 6, Figure S5

## Comment 22

*Line 255 and Figure 4: Since the authors explicitly introduce the terrestrial water-budget equation, it would be useful to show the resulting water-budget terms directly in Figure 4... The discussion should also focus more on the resulting water-budget changes rather than primarily on the individual contributions.*

**Response**

We agree that presenting the integrated terrestrial water-budget response provides a clearer assessment of changes in water availability than considering the individual hydrological components separately. Accordingly, Figure 4 has been revised to include the resulting terrestrial water-budget term (P-ET-R) for each region.

The corresponding Results and Discussion sections have also been reorganized to focus on the integrated terrestrial water-budget response and its relationship to the simulated soil-moisture changes, while still using the individual precipitation, evapotranspiration, and runoff components to explain the underlying hydrological mechanisms where appropriate. We believe these revisions provide a more complete and physically consistent interpretation of the hydrological impacts of the two reforestation pathways.

"The fluxes are evaluated for 2100 (2090-2110) relative to the fixed land cover baseline (Figs.4, S5, S6). In nearly all regions, ET increases following forest expansion. Precipitation also rises modestly in most regions ($\leq +0.2$ mm day$^{-1}$ per Mkm$^2$ of reforested area), except Central Africa, where both scenarios show persistent declines of up to $-0.1$ mm day$^{-1}$ per Mkm$^2$ of reforested area. Changes in precipitation in South Asia remain close to neutral. Despite these broadly similar responses, the resulting terrestrial water budget (P-ET-R) differs substantially among regions and between the two reforestation scenarios. Positive P-ET-R anomalies dominate in North America and Central America under both scenarios and in East Asia under the sustainable scenario, indicating increased net water availability. In contrast, South America and Central Africa consistently exhibit negative P-ET-R anomalies, reflecting enhanced evapotranspiration and runoff losses that exceed precipitation gains. Under the reversed scenario, Europe and South Asia also show modest negative P-ET-R responses, highlighting the greater regional heterogeneity associated with this reforestation pathway.
Central America exhibits particularly strong precipitation gains, coupled with the largest positive P-ET-R response under the reversed scenario. South America shows the strongest contrast between scenarios: while the sustainable scenario produces near-neutral water-budget anomalies, the reversed scenario results in substantial negative P-ET-R despite increased precipitation, indicating that enhanced evapotranspiration and runoff more than offset the additional rainfall and reduce overall water availability. Soil-moisture responses are generally consistent with these regional water-budget changes. Regions with the largest negative P-ET-R anomalies, particularly Central Africa and

South America, also experience the greatest soil-moisture deficits, whereas North America and Central America exhibit positive water-budget anomalies accompanied by increased soil moisture. East Asia shows a weaker correspondence between the annual water budget and soil-moisture response, suggesting that seasonal storage dynamics and land–atmosphere interactions also influence the simulated soil-moisture changes."

Changes have been made on Page 13, Lines 322-340

## Comment 23

*Lines 265–267: Looking at Figure 4, negative P−ET anomalies also appear in South Asia and Europe under the reversed scenario. Please clarify this statement.*

### Response

We agree that the previous wording overlooked the modest negative P-ET anomalies in Europe and South Asia under the reversed scenario. The text has been revised to explicitly acknowledge these smaller negative responses while clarifying that the largest and most persistent negative anomalies occur in South America and Central Africa.

"Both scenarios exhibit soil-moisture reductions across several tropical and subtropical regions, with anomalies typically ranging from −5 to −10 mm per $Mkm^2$ of reforested area. The largest deficits occur under the reversed reforestation scenario, reaching approximately −15 mm per $Mkm^2$ in South America and Central Africa (Fig. 4). In contrast, Central America exhibits modest soil-moisture gains, while North America shows slight increases under the reversed scenario (+2 to +3 mm per $Mkm^2$ of reforested area), consistent with the positive regional water-budget anomalies discussed above. Seasonal responses are generally more heterogeneous under the reversed scenario (Fig. S5). South America exhibits enhanced precipitation and evapotranspiration during SON but more negative P−E anomalies during DJF and MAM, while East Asia shows pronounced increases in both precipitation and evapotranspiration during MAM under the sustainable scenario. Europe remains comparatively neutral throughout the year, whereas Central Africa exhibits persistently negative P−E anomalies during most seasons. These seasonal hydrological changes are reflected in the spatial distribution of soil-moisture anomalies (Fig. S6), with the reversed scenario producing more coherent and extensive drying over tropical South America and Central Africa than the sustainable scenario. These values represent changes integrated over the CLASS soil column, which spans approximately 4 m. Although the simulated soil-moisture anomalies represent only a small fraction of the total soil-water storage, they are sufficiently large to influence surface fluxes and land–atmosphere coupling and are therefore climatologically meaningful."

Changes have been made on Pages 14-15, Lines 348-363

# Results - Long-Term Climate Response

## Comment 24

*Figure S7: I wonder why the authors diagnose the AMOC using the overturning streamfunction, while the Hadley circulation is not presented using the corresponding atmospheric mass* *streamfunction... Furthermore, I strongly suggest moving Figure S7 to the main manuscript and increasing the size of the ticks and tick labels.*

**Response**

We agree that the atmospheric mass streamfunction provides a more appropriate and widely used diagnostic for assessing changes in the Hadley circulation. Accordingly, we have replaced the previous Hadley circulation diagnostic with the atmospheric mass streamfunction, allowing a more robust assessment of changes in the intensity, width, and latitudinal position of the Hadley cell following the approach of Lionello et al. (2024).

Because the interpretation of the long-term hydroclimatic response relies on changes in the Hadley circulation together with the AMOC and the ITCZ, the figure has been moved from the Supplementary Material to the main manuscript. The figure has also been reformatted with larger tick marks and axis labels to improve readability, and the associated Results and Discussion sections have been revised accordingly. Page 21, Figure 6

## Comment 25

*Lines 319–320: The manuscript states that the Hadley cell undergoes both a southward displacement and a broadening of approximately 5–10°. While a southward shift may be consistent with the proposed ITCZ adjustment, the physical basis for the broadening is not discussed. Please explain in more detail how the broadening was diagnosed and provide a physical interpretation of this response.*

**Response**

We agree that the previous manuscript did not sufficiently explain either how the broadening of the Hadley circulation was diagnosed or its physical interpretation. The Results and Discussion have therefore been revised accordingly.

The revised manuscript now clarifies that changes in the Hadley circulation are diagnosed using the zonal-mean atmospheric mass streamfunction. The reported broadening refers to the increased latitudinal extent of the overturning circulation relative to the baseline simulation, as identified from the streamfunction fields.

We also expanded the discussion of physical interpretation. While the circulation response is relatively weak and localized around 2100, by 2190 the atmospheric mass streamfunction exhibits a broader and more coherent meridional anomaly that develops concurrently with a pronounced weakening of the AMOC. Together with the accompanying evolution of the zonal-mean hydroclimatic responses, this suggests that the late-century circulation changes increasingly reflect large-scale atmosphere-ocean adjustment rather than local land-surface forcing alone. We have revised the manuscript to clarify this interpretation while avoiding attributing the broadening to a specific dynamical mechanism that was not explicitly investigated in this study.

"After 2100, the hydrological components continue to evolve, driven primarily by changes in the Hadley circulation and the AMOC. As shown in Figure 6, a weakened AMOC reduces northward ocean heat transport, leading to cooling of the Northern Hemisphere and a compensatory southward shift of the ITCZ. This thermodynamic adjustment, consistent with energy balance considerations and supported by prior modelling studies (Frierson et al., 2013; Green & Marshall, 2017). By 2190, the atmospheric mass streamfunction exhibits a stronger and more spatially extensive meridional anomaly than at 2100, indicating a southward displacement together with a broader latitudinal extent of the Hadley circulation. The broadening was diagnosed from the zonal-mean atmospheric mass streamfunction by comparing the latitudinal extent of the overturning circulation with the baseline simulation. Unlike the relatively localized circulation response at 2100, the late-century response coincides with a pronounced weakening of the AMOC, suggesting that the long-term atmospheric circulation changes increasingly reflect large-scale atmosphere–ocean adjustment rather than local land-surface forcing alone."

Changes have been made on Page 18, Lines 405-412

## Comment 26

*Long-term effects: If I correctly interpret the results, the warming response simulated over parts of the middle and high latitudes around 2100 is followed by a reversal of the signal after 2100. This appears to be one of the most interesting findings of the study, yet it is not sufficiently highlighted or discussed in the manuscript. Please clarify this transition and its underlying mechanisms. In addition, I strongly suggest including a spatial map of the long-term temperature response, analogous to Figure 2.*

**Response**

We agree that the transition from high-latitude warming around 2100 to a substantially weaker, and in some regions reversed, temperature response during the 22nd century represents one of the key findings of this study. The manuscript has been revised to emphasize this result more clearly.

We expanded the results and discussion section to explain that the initial warming is primarily driven by local snow-albedo feedbacks associated with reforestation, whereas the subsequent evolution reflects the increasing influence of large-scale atmosphere-ocean adjustments, particularly the weakening of the AMOC, which reduces northward ocean heat transport and contributes to Northern Hemisphere cooling. To further illustrate this transition, we have added a new spatial map of the long-term temperature response to the manuscript.

The spatial map of the long-term temperature response also added to the Figure 2.

"Zonal means reveal reduced warming at high latitudes, with temperature increases tapering down to below +0.1 °C at 70-80°N by 2200. An important feature of the long-term response is the evolution of the high-latitude temperature signal after 2100. Although both reforestation scenarios initially produce warming across northern mid- and high-latitudes through reduced snow albedo, this warming weakens substantially during the 22nd century and, in some regions, is partially reversed (Fig. 5). This indicates that the initial response is not stationary but evolves substantially over time, suggesting that long-term climate adjustments modify the direct biogeophysical effects of reforestation. This transition coincides with the gradual emergence of large-scale atmosphere-ocean adjustments, particularly a weakening of the AMOC, which reduces northward ocean heat transport and cools the Northern Hemisphere. Consequently, the long-term temperature response reflects the combined influence of relatively rapid local biophysical effects associated with reforestation and slower ocean-mediated climate adjustments that become increasingly important after tree cover has stabilized. Precipitation consistently decreases north of the equator (0-10°N, -2 to -4%) while increasing across the Southern Hemisphere tropics and subtropics (0-30°S, +1 to +3%), indicating a southward displacement of the ITCZ (Fig. 6)."

"In particular, warming in Northern Hemisphere extratropical regions reflects the combined influence of land-atmosphere feedbacks and large scale energy redistribution, whereas temperature anomalies over the Southern Hemisphere extratropics remain comparatively weak, consistent with the smaller land fraction and more efficient ocean heat uptake.
The temporal evolution of the temperature response suggests that different mechanisms dominate at different timescales. Around 2100, high-latitude warming is primarily associated with reduced surface albedo following reforestation over snow-covered regions, increasing net shortwave radiation. During the 22nd century, however, this initial warming weakens and, in some regions, reverses. Concurrent changes in the atmospheric mass streamfunction and the substantial weakening of the AMOC indicate that large-scale atmosphere-ocean adjustments increasingly influence the climate response. These circulation changes reduce northward ocean heat transport, offsetting part of the earlier albedo-driven warming and contributing to the long-term cooling tendency over northern high latitudes."

Changes have been made on Page 15, Lines 366-377; Page 20, Lines 438-445; page 27, Lines 446-451

### Comment 27

*Figure 5: For consistency with the previous figures, consider showing long-term changes relative to the 2100 state in addition to the current representation. This would facilitate the comparison between near-term and long-term responses.*

#### Response

We appreciate this suggestion. Figure 5 has been revised to include the long-term changes relative to the 2100 state in addition to the original presentation. This additional representation facilitates a more direct comparison between the near-term and long-term responses and highlights the temporal evolution of the simulated climate effects. Page 20, Figure 5

## Discussion

### Comment 28

*The Discussion is generally well structured and representative of the main findings, policy implications, and limitations of the study. However, the elements of novelty are not sufficiently* *emphasized. I encourage the authors to more clearly articulate the key scientific advances provided by this work relative to the existing literature.*

**Response**

We agree that the principal scientific advances of the study should be stated more explicitly. Although the novel aspects of the work were discussed throughout the manuscript, they were not previously synthesized in a dedicated section.

To address this, we have added a concluding paragraph at the end of the Discussion that summarizes the main contributions of this study relative to previous work. In particular, we emphasize (i) the comparison of two contrasting global reforestation pathways with similar total reforested area but different spatial configurations, (ii) the comprehensive assessment of hydroclimatic responses beyond temperature alone, (iii) the extension of the simulations to 2200, which reveals delayed atmosphere–ocean feedbacks and the reversal of some regional climate responses, and (iv) the importance of reforestation spatial configuration in shaping long-term regional hydroclimatic outcomes.

"Beyond documenting the hydroclimatic effects of reforestation, this study provides several advances over previous work. First, by comparing two global reforestation pathways with similar total forest expansion but contrasting spatial distributions, we demonstrate that the location of reforestation exerts a strong control on hydroclimatic responses, independent of the total reforested area. Second, our analysis extends beyond temperature to provide a comprehensive assessment of the hydrological cycle, including precipitation, evapotranspiration, runoff, soil moisture, cloud cover, and P-ET. Third, the simulations extend to 2200, allowing us to distinguish relatively rapid local biophysical responses from slower atmosphere-ocean adjustments that emerge after forest restoration has stabilized. These results demonstrate that the long-term hydroclimatic consequences of reforestation cannot be inferred solely from 21st-century simulations and highlight the importance of considering both the spatial configuration of reforestation and delayed climate feedbacks when evaluating nature-based climate mitigation strategies."

Changes have been made on Page 22, Lines 492-502

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We sincerely thank the reviewer for the thoughtful and constructive comments, which have substantially improved the clarity and robustness of the manuscript. We believe that the revisions have strengthened both the presentation and interpretation of our results, and we hope that the revised manuscript satisfactorily addresses all of the reviewer's concerns.