Response to Editor:

Dear Prof. Dr. Hildebrandt,

Thank you for your careful assessment and allowing re-submission of the manuscript, as well as for your additional constructive comments and suggestions. We have carefully considered both reviewers' comments together with your remarks and revised the manuscript accordingly.

We appreciate your recognition of the relevance of investigating root water uptake for understanding precipitation partitioning and ecohydrological functioning. At the same time, we fully understand your assessment and the reviewers' concerns that the previous version required clearer framing and stronger methodological justification—particularly regarding (i) the scope and validity of the forest management scenario framework and (ii) the transparency and robustness of calibration and validation.

In response, we have re-run the model experiments and fundamentally changed the scenario design, the manuscript and supplementary material has been thoroughly revised accordingly. The main revisions are summarized below:

1) The primary aim of this study is to develop a parsimonious modelling and generic forest management scenario framework to evaluate how basic characteristics of forest type, forest density, and root distribution—associated with forest age—affect long-term water partitioning and ecohydrological resilience under similar environmental conditions, particularly the context of limited data. To avoid misleading interpretation, we revised the wording throughout the manuscript, replacing "species composition" with "forest type" and explicitly stating that the framework targets generic, dominant vegetation-structural controls rather than species-specific physiological processes.

2) We rebuilt the scenario framework using site-specific calibrations for all forest types, including broadleaf forest, conifer forest, and agroforestry, rather than relying solely on the broadleaf site. The scenario analysis is now repeated consistently across all three forest sites using different baselines.

   In addition, we explicitly disentangle vegetation effects from site-specific soil properties by extending the scenario design to include soil–forest combinations. This allows us to demonstrate how site properties modulate both absolute water partitioning and sensitivity to management, directly addressing concerns regarding site dependency.

3) We now report model performance separately for calibration and validation periods for soil moisture and clarify how the shorter isotope record is incorporated within the multi-objective evaluation framework.

   Furthermore, we added an independent validation of simulated evapotranspiration using MODIS-derived ET and report Kling–Gupta Efficiency (KGE) metrics for each land-use type to support the simulated flux partitioning.

4) Following Reviewer 2's comments (notably Q5, Q7, and Q4-2), we improved the clarity of figures, added uncertainty envelopes to key results, and expanded the analysis of parameter sensitivity and equifinality. This includes explicit propagation of parametric uncertainty into scenario results and clearer discussion of its implications for interpretation.

Detailed, point-by-point responses to all reviewer comments are provided in the accompanying documents. A tracked-changes version of the revised manuscript and an updated Supplement are also included to facilitate the review.

We believe that these revisions substantially enhance the quality, clarity, and robustness of the manuscript, and we hope that the revised version will now be suitable for publication in *Hydrology and Earth System Sciences*.

We thank you and the reviewers once again for your careful consideration, constructive guidance, and continued support during the revision process.

Sincerely,

Cong Jiang

(on behalf of all co-authors)

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Dear Cong Jiang and co-authors,

two reviewers have given through feedback on your manuscript in HESS. Both appreciate that investigations on the role of root water uptake distribution on precipitation partitioning is a valuable contribution to the ecohydrologic literature and I agree. Both have raised serious concerns with the regard to the validity of the sensitivity analysis on species composition (as suggested in the abstract), as well as calibration and validation of the model. I agree that the reviewers raise valid critical points, and I also agree that the manuscript needs much more work to make a valid claim. You have addressed most of the comments in your response. I have given both comments and responses a close look, and have also some additional comments below this email, which I ask you to attend to in addition to the reviewers comments.

I invite you to implement the changes in a new version. Please note that currently it is not foreseeable, whether the manuscript can be published. It will be sent to another round of reviews. To support the review process, please submit a track-changed version of the manuscript together with a step-by-step response.

With kind regards,

Anke Hildebrandt

Comments by the editor:

Q1. The reviewers and myself are confused as to why different models were fitted to data from different sites (KGEs in Table 3) but in the scenario analysis only the calibration for the broadleaf site is retained as a baseline. It seems awkward that not the site calibrations were used instead. You state that different soil factors also influence precipitation partitioning there. If this is the case, site specific differences may also affect the magnitude of the partitioning and how it changes with management types. Thus why not repeat the analysis at all three sites with different baselines to showcase how exactly that site specific properties affect the results?

Reply to Q1: Thank you for this important and constructive comment.

In retrospect, we fully agree that the original presentation of the scenario framework was not sufficiently clear, and that our initial use of a single broadleaf-site calibration as the baseline appeared arbitrary and insufficiently justified.

Our original intention was to develop a parsimonious and generic forest management scenario framework to evaluate how forest type, forest density, and root distribution—associated with forest age—influence long-term water partitioning and ecohydrological resilience under comparable environmental conditions. The broadleaf forest site was initially selected as the baseline because it represents a mature, well-characterized forest system with long and consistent observational records, and because its soil profile is representative of the dominant freely draining sandy soils in the study region. In the original framework, soil parameters were therefore held constant to isolate vegetation-structural controls (e.g. LAI, rooting distribution) on precipitation partitioning.

However, as you correctly point out, site-specific soil properties can indeed influence both the absolute magnitude of water partitioning and its sensitivity to forest management. We acknowledge that this limitation was not sufficiently explained in the original manuscript and that relying on a single baseline calibration may obscure the role of edaphic controls.

In response to your comment and related concerns raised by Reviewer #2 (notably Q1-1), we have substantially revised the scenario framework in three key ways:

1) Incorporation of forest-type–specific calibrations

   Rather than modifying LAI alone, we now incorporate forest-type–specific vegetation parameterizations (radiation extinction factor rE and interception capacity α) derived from site-specific calibrations at the broadleaf, conifer, and agroforestry sites. This ensures that differences among forest types are represented more realistically, beyond canopy density alone.

2) Explicit separation of vegetation and soil controls

   To disentangle vegetation effects from site-specific soil properties, we extended the scenario design to include a 3 × 3 soil–forest scenario matrix (illustrated in Figure 3), in which each forest type is combined with each soil type. The observed site combinations represent realistic baseline conditions, while the cross-combinations represent plausible but hypothetical configurations. This design allows us to explicitly assess how soil properties modulate both the magnitude of water partitioning and its response to management.

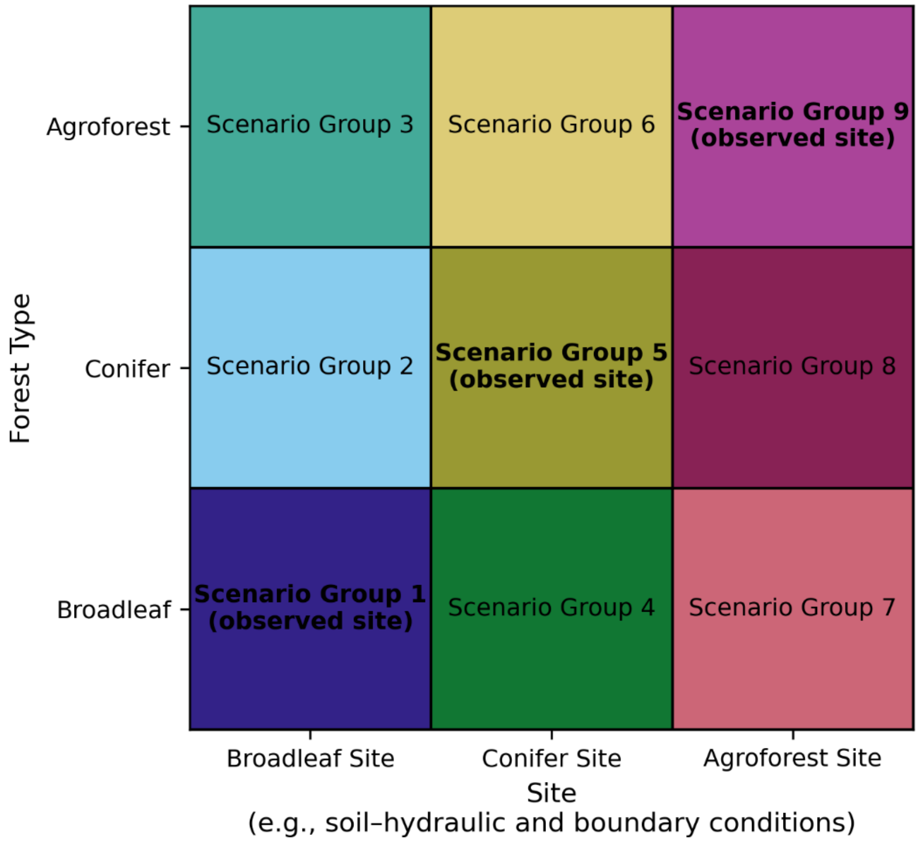


Figure 3. Matrix of nine Scenario Groups formed by combining three site-specific configurations (Broadleaf Site, Conifer Site, and Agroforest Site) with three forest types (Broadleaf, Conifer, and Agroforest). Each colored block represents a Scenario Group consisting of multiple sub-scenarios (e.g., varying forest densities and root water uptake distributions). Diagonal entries (Scenario Groups 1, 5, and 9), marked as "observed configuration", correspond to forest–site combinations observed at the field sites, where vegetation type and site-specific soil–hydraulic and boundary conditions are consistent with real-world conditions.

3) Repetition of scenario analyses using multiple baselines

We now repeat the scenario simulations using each forest site (broadleaf, conifer, agroforestry) as an alternative baseline. These additional analyses demonstrate that while absolute partitioning fluxes differ across soils, the qualitative responses to forest characteristics management remain consistent across sites, thereby supporting the generality of our conclusions. For comparisons between forest types, ensemble means across soil types are now used to derive more robust and transferable inferences.

These revisions are now explicitly described in the Methods and Results sections, with supporting figures and tables provided in the Supplementary Material. We believe that this revised framework directly addresses the editor's and reviewers' concerns and substantially improves the physical consistency, transparency, and interpretability of the scenario analysis.

Q2. I strongly support Reviewer 2's request for more information on the model quality.
Q2-1. Soil moisture was available for 7 years, and isotope data only for 3 years. How was this discrepancy dealt with in the multi-objective calibration?
Reply to Q2-1: Thank you for highlighting this point. Regarding the unequal lengths of soil moisture and soil water isotope observations, this discrepancy was handled through the structure of the multi-objective calibration. Model performance was evaluated separately for soil moisture and soil water isotopes using Kling–Gupta Efficiency (KGE), and the overall objective function was defined as the mean of the individual KGE values, thereby assigning equal weight to each data type rather than weighting by record length. As a result, the shorter isotope record contributes equally to parameter constraint and is not dominated by the longer soil moisture time series. This design ensures that isotope information effectively constrains key partitioning processes despite its more limited temporal coverage.

Q2-2. Please explicitly indicate the calibration and validation periods. From the text it sounds as if the KGE reported from the calibration period? This is not very reliable, given that model quality typically deteriorates between calibration and forward runs. Please add this information.
Reply to Q2-2: Thank you for highlighting this important point. We fully agree that the calibration–validation strategy, particularly given the unequal lengths of soil moisture and isotope observations, required clearer explanation in the original manuscript.

In the original submission, the model was calibrated using the full available observation period, comprising seven years of soil moisture data and three years of soil water isotope data.

This choice was motivated by the limited availability of isotope observations and follows recent studies suggesting that, under such data constraints, calibration to the full dataset can provide more stable and robust parameter estimation than further reducing the calibration window (e.g., Shen et al., 2022).

At the same time, we fully understand that independent validation is often preferred to assess model robustness beyond the calibration period. In response to your comment, we therefore conducted an additional split-sample experiment, which was applied consistently across all land use types (broadleaf forest, conifer forest, agroforestry, cropland, and grassland). For each land-use type, the model was re-run using an independent calibration period based on soil moisture and isotope data, followed by a validation period using soil moisture data only, due to the limited availability of soil water isotope observations.

The validation results (Table S4 and Figs. S5–S7) show that model performance remains robust outside the calibration window, though there is some limited degradation, particularly at the grassland and cropland sites, which is consistent with their shorter and more fragmented validation records. Overall, these results support the reliability of the calibrated model for simulating water partitioning beyond a calibration period.

In addition, to further assess model performance using an independent data source, we evaluated simulated evapotranspiration against MODIS-derived ET for all land-use types. Kling–Gupta Efficiency (KGE) metrics were calculated for daily ET, providing an external validation of simulated fluxes that is independent of the calibration data (see Fig. S8 and Table S4).

In the revised manuscript, we now explicitly specify the results of this calibration and validation experiments and clarify that for the modelling used in the main scenario analysis is performed over the full observation period, to maximize the information content from all available soil moisture and soil water isotope data. This approach was retained because, under data limitations—especially for isotopes—using the full dataset provides more stable parameter estimates and reduces sensitivity to interannual variability (e.g., individual wet or dry years). Therefore, while the split-sample calibration–validation results are presented transparently in the Supplementary Material for the reader's reference, they are not used as the basis for the main scenario simulations.

Furthermore, we added an independent validation of simulated evapotranspiration using MODIS-derived ET and report Kling–Gupta Efficiency (KGE) metrics for each land-use type, strengthening confidence in simulated flux partitioning.

Reference:

Shen, H., Tolson, B. A., & Mai, J. (2022). Time to update the split-sample approach in hydrological model calibration. Water Resources Research, 58, e2021WR031523. *https://doi.org/10.1029/2021WR031523*

Table S4. Kling–Gupta Efficiency (KGE) values for soil moisture and soil water isotopes (δ^2H), comparing observed and mean simulated values at each land use site. Soil moisture KGE values are reported for both the calibration and validation periods, whereas soil water isotope KGE values are shown for the calibration period only due to limited isotope observations. The calibration and validation periods are 2000–2021 and 2022–2024 for broadleaf, conifer forest and agroforestry sites, and 2000–2022 and 2023–2024 for cropland and grassland sites, respectively.

Sites	Soil moisture – Calibration period			Soil moisture – Validation period		Soil water isotope (δ^2H) – Calibration period		
	Upper	Lower	Deep	Lower	Deep	Upper	Lower	Deep
Broadleaf Forest	0.57	0.76	0.85	0.73	0.83	0.63	0.74	0.70
Conifer forest	0.61	0.62	0.61	0.73	0.78	0.77	0.81	0.53
Agroforestry	0.72	0.77	0.74	0.80	0.76	0.82	0.84	0.79
Grassland	0.89	0.75	0.78	0.65	0.53	0.71	0.76	0.62
Cropland	0.53	0.64	0.77	0.54	0.41	0.83	0.85	0.37

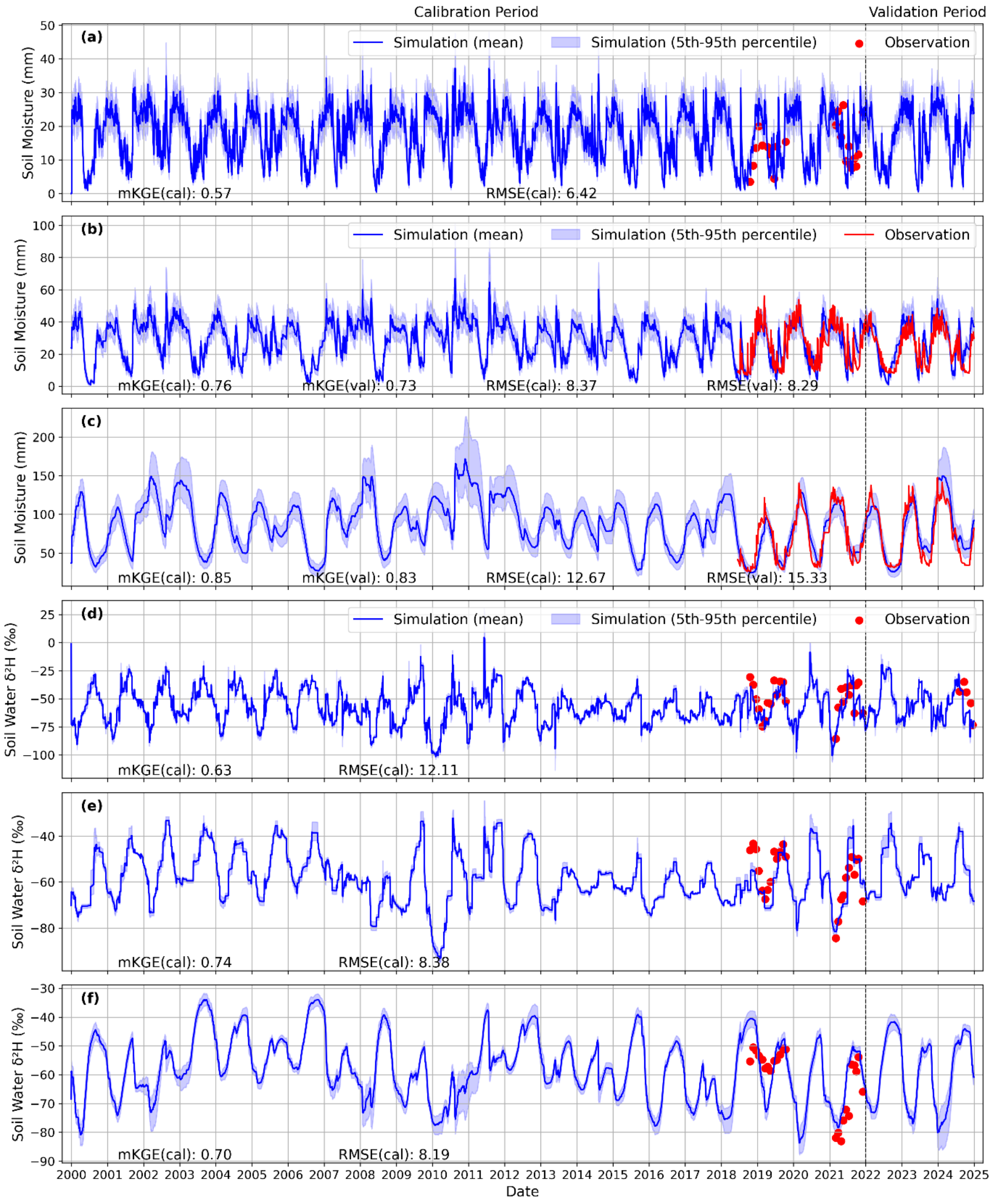


Figure S5. Observed and simulated soil moisture and soil water stable isotope dynamics for the broadleaf forest site. Panels (a–c) show soil moisture time series for the upper (0-10 cm), middle (10-30 cm), and deep (30-100 cm) soil layers, while panels (d–f) show the corresponding soil water δ²H for the same layers. Solid blue lines indicate the ensemble mean of the simulations (n = 100), and the shaded bands represent the 5th–95th percentile range. Red symbols or lines denote observations. The vertical dashed line marks the separation between the calibration period (2000–2021) and the validation period (2022–2024)**.** Model performance is quantified using the modified Kling–Gupta efficiency (mKGE) and root mean square error (RMSE), reported separately for the calibration period in all panels and for the validation period in the middle and deep soil moisture layers, where observations are available.

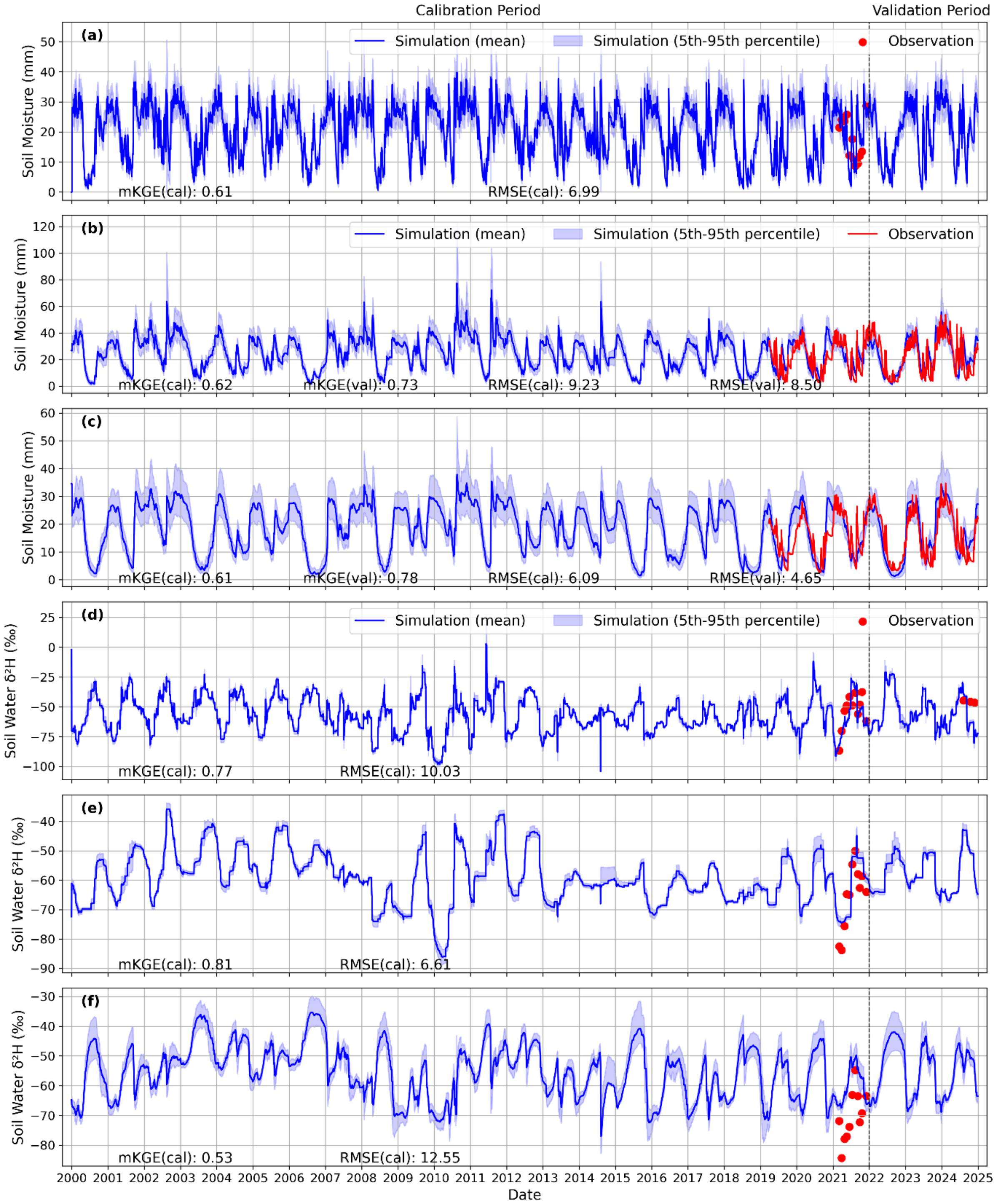


Figure S6. Observed and simulated soil moisture and soil water stable isotope dynamics for the conifer forest site. Panels (a–c) show soil moisture time series for the upper (0-10 cm), middle (10-30 cm), and deep (30-100 cm) soil layers, while panels (d–f) show the corresponding soil water δ²H for the same layers. Solid blue lines indicate the ensemble mean of the simulations (n = 100), and the shaded bands represent the 5th–95th percentile range. Red symbols or lines denote observations. The vertical dashed line marks the separation between the calibration period (2000–2021) and the validation period (2022–2024)**.** Model performance is quantified using the modified Kling–Gupta efficiency (mKGE) and root mean square error (RMSE), reported separately for the calibration period in all panels and for the validation period in the middle and deep soil moisture layers, where observations are available.

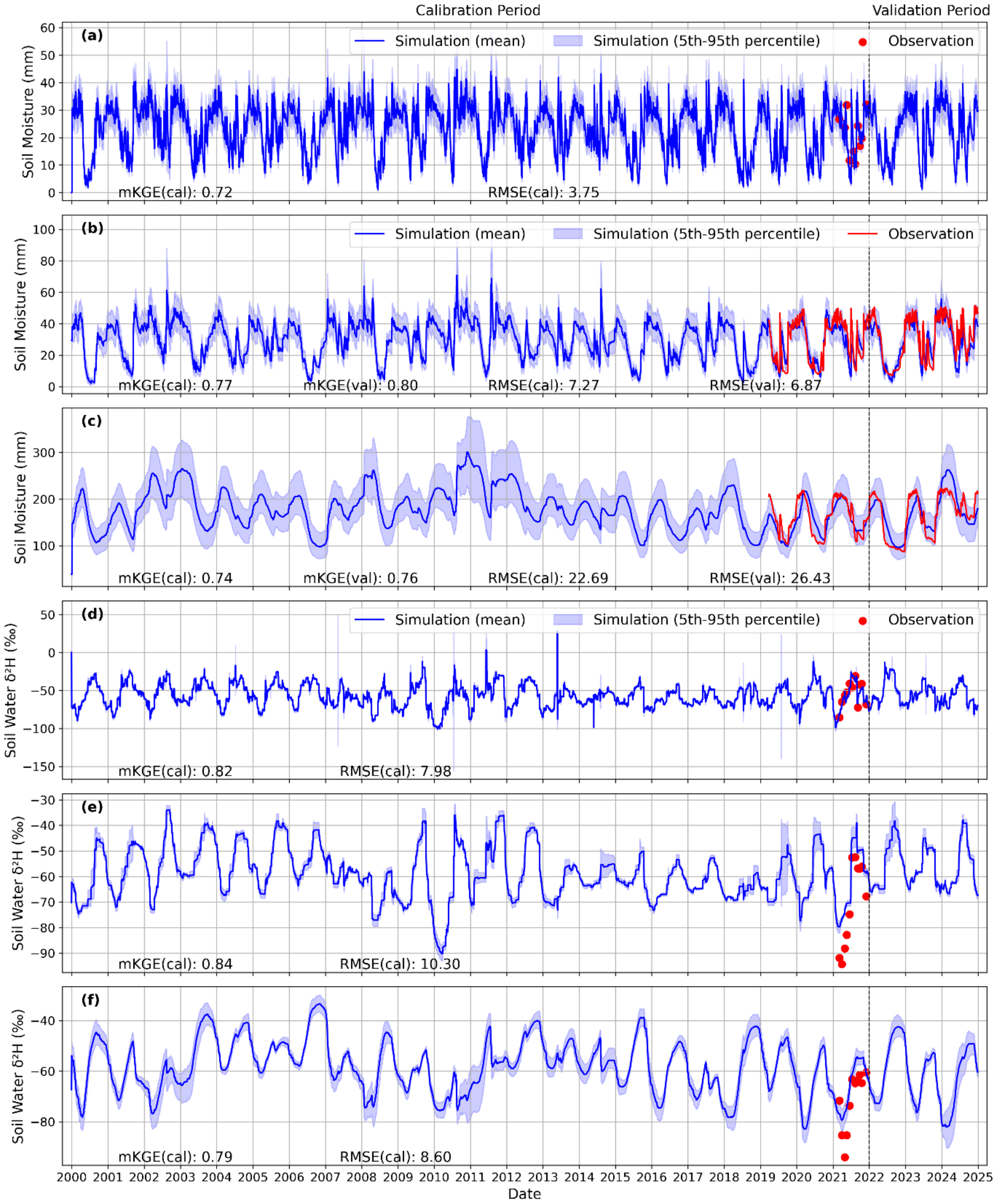


Figure S7. Observed and simulated soil moisture and soil water stable isotope dynamics for the agroforestry site. Panels (a–c) show soil moisture time series for the upper (0-10 cm), middle (10-30 cm), and deep (30-100 cm) soil layers, while panels (d–f) show the corresponding soil water δ²H for the same layers. Solid blue lines indicate the ensemble mean of the simulations (n = 100), and the shaded bands represent the 5th–95th percentile range. Red symbols or lines denote observations. The vertical dashed line marks the separation between the calibration period (2000–2021) and the validation period (2022–2024)**.** Model performance is quantified using the modified Kling–Gupta efficiency (mKGE) and root mean square error (RMSE), reported separately for the calibration period in all panels and for the validation period in the middle and deep soil moisture layers, where observations are available.

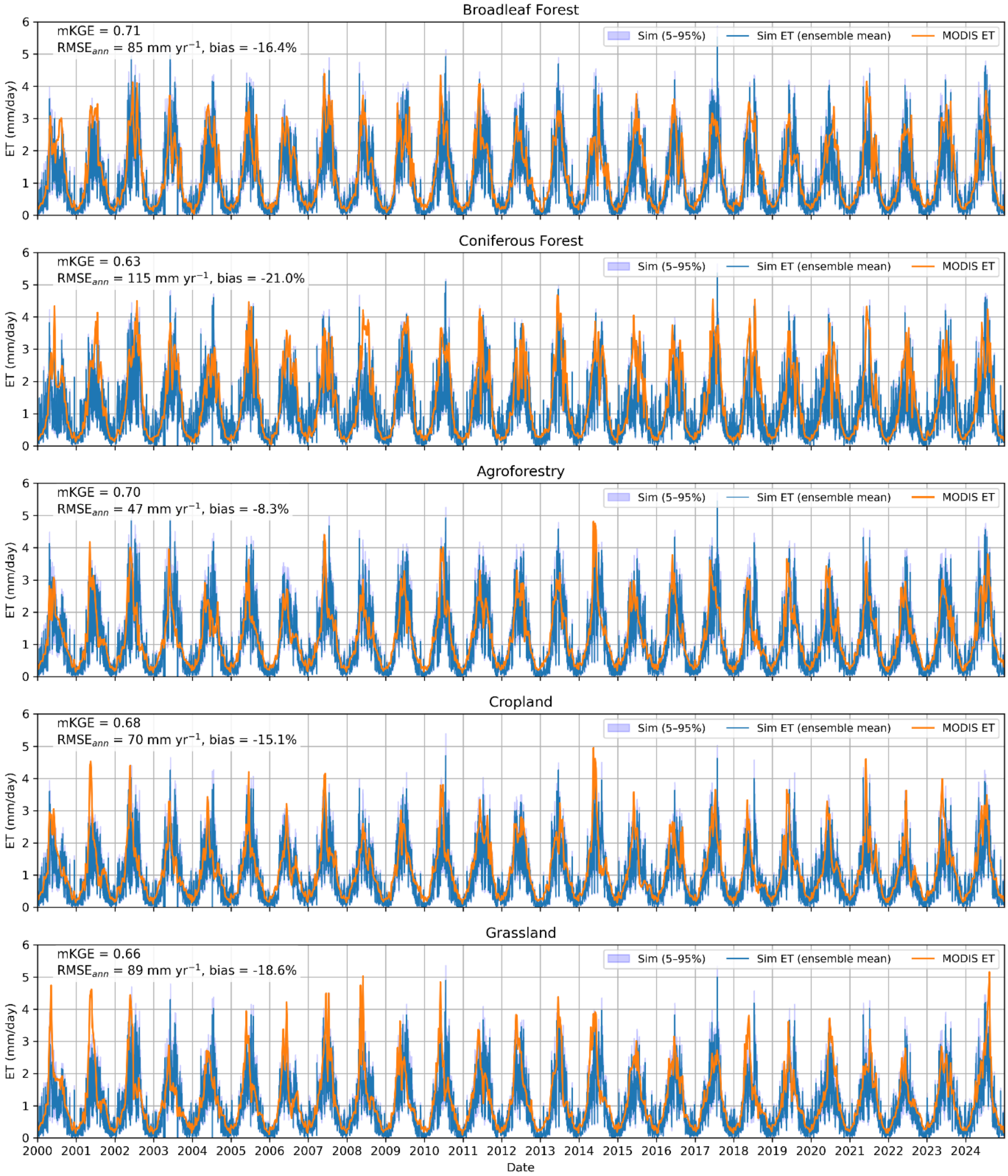


Figure S8. Comparison of simulated and MODIS-derived evapotranspiration (ET) for five land-use types (Broadleaf Forest, Coniferous Forest, Agroforestry, Cropland, and Grassland) over the period 2000–2024. Solid blue lines show the ensemble mean of simulated daily ET across 100 model simulations, while the shaded blue envelope indicates the 5th–95th percentile range. Orange lines denote observed daily ET derived from MODIS. Model performance is quantified using the mean Kling–Gupta Efficiency (Kling et al., 2012) calculated from daily ET across the 100 simulations, , together with the root mean square error of annual ET sums (RMSE; mm yr^{-1}) and the relative bias of annual ET sums (%). Performance metrics shown in each panel represent ensemble averages across all simulations.

Table S5. Performance of simulated evapotranspiration (ET) against MODIS-derived ET for five land-use types (Broadleaf Forest, Coniferous Forest, Agroforestry, Cropland, and Grassland) over the period 2000–2024. Model skill is evaluated using the Kling–Gupta Efficiency (Kling et al., 2012) computed from daily ET time series, together with the root mean square error of annual ET sums (RMSE; mm yr^{-1}) and the relative bias of annual ET sums (%). Annual ET sums were derived from daily ET for each of the 100 EcoPlot-iso ensemble simulations and compared against MODIS observations. Reported values represent ensemble statistics across the 100 simulations for each land-use type.

Sites	Evapotranspiration		
	KGE	RMSE (mm yr^{-1})	Relative bias of annual ET sums (%)
Broadleaf Forest	0.71	85	-16.4
Conifer forest	0.63	115	-21.0
Agroforestry	0.70	47	-8.3
Grassland	0.68	70	-15.1
Cropland	0.66	89	-18.6

Q3. Table 1: Only braodleaf forest is shown, the information on the other forest types is missing.
Reply to Q3: Thank you for pointing this out. We agree that the original version of Table 1 was limited to the broadleaf forest site, reflecting its role as the baseline in the initial scenario framework.

In the revised manuscript, Table 1 has been expanded to include soil properties and soil moisture statistics for all forest types considered in this study (broadleaf forest, conifer forest, and agroforestry). This revision ensures consistency in the use of all three forest sites within the revised scenario framework and provides information on site-specific soil differences relevant to the analysis.

Q4. Line 379-380: How were the forward runs informed by the isotopes?
Reply to Q4: Thank you for this important clarification. In this study, stable water isotopes (δ^2H) are used to constrain model parameters during calibration, rather than as dynamic inputs in the forward scenario simulations. Specifically, EcoPlot-iso is an isotope-enabled model, and the baseline simulations were calibrated using both soil moisture and soil water isotope observations in a multi-objective framework. This isotope-based calibration constrains key process representations related to evaporation, transpiration, and soil water mixing.

The subsequent forest management scenario simulations were then conducted as forward runs using these isotope-constrained parameter sets, without additional isotope forcing. We have revised the manuscript to clarify that the green and blue water partitioning results (summarized in Fig. 8 and detailed in Fig. S10) are indirectly isotope-informed through calibration, rather than directly driven by isotope data during the scenario simulations.

Q5. Figure 12: Is this based on the baseline simulation or on the site specific calibrations? Please specify.
Reply to Q5: Thank you for this question. In the original version of the manuscript, the mean annual water fluxes were based primarily on the baseline simulation and associated scenario runs. In the revised manuscript, Figure 12 has been redefined to improve interpretability and consistency with the revised scenario framework.

Specifically, Figure 12 now shows forest-type–specific mean annual water fluxes, derived as ensemble means across all soil types for each vegetation class (Broadleaf, Coniferous, and Agroforestry). For each forest type, the reported values represent the mean of one row of the 3 × 3 soil–forest scenario matrix (Figure 3), thereby averaging across soil types while keeping vegetation characteristics constant.

This approach was adopted to reduce the influence of site-specific soil properties and to highlight differences attributable primarily to vegetation structure and forest management. The results therefore do not represent a single baseline simulation or a single site-specific calibration, but rather vegetation-specific mean responses derived from the full scenario ensemble.

Reply to Editorial Support:

Notification to the authors: Please ensure that the colour schemes used in your maps and charts allow readers with colour vision deficiencies to correctly interpret your findings. Please check your figures using the Coblis – Color Blindness Simulator (https://www.color-blindness.com/coblis-color-blindness-simulator/) and revise the colour schemes accordingly. --> S4

Editorial Support: Mario Ebel
Reply to Mario Ebel: Thank you for drawing our attention to this issue. We have checked all maps and charts using the Coblis – Color Blindness Simulator and revised the colour schemes to ensure they are interpretable for readers with colour vision deficiencies. Figure S4 has been updated accordingly, and the revised version is included in the Supplementary Material.

Response to Referee Comment #1:

We thank the referee for their careful review and insightful, constructive suggestions. We believe that addressing the comments has strengthened the paper and has improved the clarity of our key findings. From the reviewer's comments, we can see that we did not explain some aspects sufficiently well or explore alternative analyses that would have made the study more robust.

We have carefully considered all comments raised by the referee, together with those from the other reviewer and the editor, and we have revised the manuscript accordingly.

Below, we provide a point-by-point response to each comment, indicating the changes that have been made in the revised manuscript to address the referee's questions and suggestions.

Sincerely,

Dr. Cong Jiang (on behalf of all co-authors)

Major Comments:

Q1. The study differentiates forest types by adjustments to LAI. All other aspects of forest functioning (i.e., rooting depths, sensitivities to low soil moisture anomalies, water needs, etc.) are presumed to be identical. My intuition tells me that these other factors do matter for accurate simulation of the hydrological fluxes this paper seeks to explore. The sensitivity tests demonstrate to me that uncertainty attributable to rooting depths alone greatly overwhelms the differences estimate across forest types. I understand the desire for a simple modeling framework to estimate the benefits of forest management, but this seems maybe too simplistic. Is there a way to better represent the functional differences across the forest types beyond canopy LAI?
Reply to Q1: We thank the reviewer for summarizing our approach so concisely and highlighting the importance of functional differences among forest types beyond canopy LAI. We agree that forests differ in multiple functional traits beyond canopy LAI which affect water partitioning; including those that we also considered in the study (e.g. rooting depth) and others which we did not (stomatal conductance, VPD sensitivity, and tolerance to soil water stress).

In this study, however, our original intention was to adopt a parsimonious and generic modelling framework to assess the dominant factors of forest management in the study area (e.g., forest type, forest density, and forest age) on water partitioning through a controlled modelling experiment. We were this not seeking to reproduce detailed species-specific physiology. Within this context, in the original version of the manuscript, LAI was used as an integrative canopy descriptor, while belowground functional differences were explored explicitly through considering contrasting rooting distributions. This design allowed a transparent assessment of relative sensitivities under comparable conditions in a data-limited setting. Our tracer-aided framework is new, though it is built upon the widely applied EcoPlot-iso model, which was successfully used to investigate long-term ecohydrological partitioning across contrasting land-use systems (Tables 3, S4 and S5).

At the same time, with hindsight, we agree that a more explicit representation of functional differences beyond forest types beyond canopy LAI would have improved the robustness and realism of the scenario analysis, as also suggested by the other reviewer and the editor. Accordingly, we have implemented the following revisions.

First, we have rebuilt the scenario framework using site-specific model baselines for all three forest sites (broadleaf, conifer, and agroforestry) and have repeated the scenario analysis consistently at each site, rather than relying solely on the broadleaf baseline. This revision has ensured that scenario responses have reflected forest-type-specific baseline conditions.

Second, we have introduced forest-type–specific canopy parameterization beyond LAI. In the revised manuscript, we have derived vegetation-type–specific values of the radiation extinction factor (rE), interception storage capacity (α), and passive interception storage mixing volume (INTp) from new site-specific calibrations for each forest type. Each forest type has been represented using the median values from 100 best calibrated simulations, providing realistic and internally consistent canopy characteristics.

Third, to address the reviewer's concern that uncertainty in rooting depth can dominate simulated differences among forest types, we have kept soil parameters fixed across forest types so that differences in simulated water flux partitioning primarily reflect vegetation functional contrasts, while rooting effects are explored explicitly and separately within the sensitivity framework.

Finally, we have strengthened the Discussion to clearly acknowledge that additional traits (e.g., stomatal regulation, VPD sensitivity, drought stress strategies) are not explicitly represented in this framework. We have framed the scenario analysis as exploratory and management-oriented, rather than species-specific, and we have identified the inclusion of additional physiological constraints as an important direction for future model development. We have also adjusted the title to better reflect the exploratory nature of the study.

Regarding rooting depth, we clarify that rooting distribution has not been intended as a proxy for forest type, but rather as a representation of forest age or developmental stage, which strongly influences rooting depth and water uptake strategies. In the revised scenario analysis, we have therefore used scaling of the β parameter to represent contrasting rooting conditions associated with forest development:

(i) 0.5 × β represents a more developed, deeper-rooting forest with a less surface-weighted rooting distribution;

(ii) 1 × β represents the observed rooting distribution at each forest site

(iii) 2 × β represents a younger or less-developed forest with a shallower, surface-weighted rooting system.

This design has allowed us to explicitly test the reviewer's observation that uncertainty in rooting depth can dominate simulated differences, while keeping canopy and soil conditions controlled. For further clarification on the conceptual relationship between rooting depth, forest type, and scenario design—and on why rooting distributions were varied independently of canopy properties—we refer the reviewer to our detailed response to Q16.

Q2. The LAI scaling that is performed is the only major factor that differentiates the forest types. I was unclear on exactly how this scaling was performed and justified. Given that this is the only primary difference considered I would expect to see a strong justification of the approach.
Reply to Q2: We thank the reviewer for raising this important point. To clarify, the differentiation of forest types in our study was not only based on LAI scaling, but on the use of forest-type–specific LAI time series derived from the MODIS product (2000–2024), which capture realistic seasonal and interannual variability. The LAI scaling was then applied to these type-specific trajectories to represent changes in forest density within a given forest type (e.g., thinning or regeneration), rather than to differentiate forest types per se. Thus, forest type is represented by distinct observed LAI trajectories (broadleaf, conifer, agroforest), while the scaling factors capture forest management-induced density changes.

We would also emphasize that the LAI changes should also be interpreted in the context of the different rooting depths. We have clarified this point explicitly in the Section 3.5 of revised manuscript.

"Within this framework, LAI and rooting distribution were treated as independent scenario dimensions. LAI scaling represented management-induced changes in canopy density, while rooting distribution scenarios represented contrasts in belowground water uptake; their combined effects on water fluxes were evaluated without assuming a fixed linkage between canopy structure and rooting depth."

A similar LAI scaling factor approach has been applied in tracer-aided modelling by the author team before; for example**,** Neill et al. (2021) applied scaling factors of 0.04–1.37 with EcH2O-iso to examine the effects of natural forest regeneration on water flux partitioning, water ages, and hydrological connectivity. In the present study, the applied scaling range (0.2–1.8) is deliberately broader, allowing us to explore canopy density scenarios from strongly thinned to very dense stands. The potential maximum LAI of forests is difficult to define, as it depends not only on stand age, tree density, and site conditions, but also on broader environmental gradients such as soil fertility, acidity, and precipitation. Nevertheless, LAI values up to 9.5 $m^2 m^{-2}$ have been reported for mature Central German beech forests (Leuschner et al., 2006). Thus, although our scaling range is intentionally broad, the resulting scaled LAI values remain within the variability observed in European forests and provide a plausible envelope for management-induced changes in canopy density.

We have expanded Section 3.5 to explicitly describe the derivation and justification of LAI scaling range, and to emphasize that the scaled LAI values remain within realistic ranges for each forest type. We have also discussed this point more explicitly in the revised Discussion.

To justify the realism of this range, we have added the following sentence in Section 3.5:

"The applied LAI scaling range (0.2–1.8) follows previous tracer-aided modelling approaches (Neill et al., 2021) and spans realistic management-induced variability in canopy density, while remaining consistent with reported LAI values for mature European forests (Leuschner et al., 2006)."

In addition, we have added the following clarification in Section 5.1 (Discussion) to guide interpretation of the scenario results:

"The applied LAI scaling range represents an intentionally broad, management-relevant envelope for exploring canopy density effects, and scenario results should be interpreted in a relative rather than prescriptive sense."

Reference:

Neill, A. J., Birkel, C., Maneta, M. P., Tetzlaff, D., & Soulsby, C. (2021). Structural changes to forests during regeneration affect water flux partitioning, water ages and hydrological connectivity: Insights from tracer-aided ecohydrological modelling. Hydrology and Earth System Sciences, 25(9), 4861-4886. https://doi.org/10.5194/hess-25-4861-2021

Leuschner, C., Voß, S., Foetzki, A., & Clases, Y. (2006). Variation in leaf area index and stand leaf mass of European beech across gradients of soil acidity and precipitation. Plant Ecology, 186(2), 247-258. https://doi.org/10.1007/s11258-006-9127-2

Specific Comments:

Q3. Line 45: The use of "resilience" here is a little unclear to me. Are you talking about resilience of the vegetation or resilience of human-accessible water?
Reply to Q3: Thank you for point this out. In our study, we use "ecohydrological resilience to drought" in an ecohydrological sense (as defined in Tetzlaff et al., 2024), referring to the ability of the soil–plant–water system to sustain green-water use (evapotranspiration) while maintaining blue-water availability (runoff, recharge) under drought stress. This definition goes beyond vegetation or human-accessible water alone by considering their coupled dynamics. We have clarified this in the Introduction in the revision.

The revised text now read:

"Consequently, forest management decisions, (e.g., afforestation, thinning, forest type selection etc.) can significantly affect water yield, the partitioning into blue (runoff, groundwater recharge) and green (evapotranspiration) water fluxes, and the ecohydrological resilience to drought; defined here as the ability of soil–plant–water system to sustain key hydrological and ecological functions under drought stress (Falkenmark & Rockström, 2006; Neill et al., 2021; Tetzlaff et al., 2024)."

Q4. Line 51 – 52: The central hypothesis of this work seems to be "does land management use and forest management impact water fluxes?" Here you are stating that this is the case. Consider rewording.
Reply to Q4: We thank the reviewer for the detailed observation. We agree the current phrasing may read as a statement of fact, and we have reworded it to highlight research motivation instead of a conclusion.

The revised text now read:

“Because land use practices—particularly forest management—are expected to strongly influence water partitioning, it is important to assess their impacts under changing hydroclimatic conditions in order to evaluate the ecohydrological resilience of soil–plant–water systems, especially in drought-sensitive areas.

Q5. Line 65: To my knowledge, EcH2O-iso does include species defined root water uptake functions. This sentence makes it sound as if that is not the case. Please edit if I am right about this.
Reply to Q5: We thank the reviewer for pointing this out. You are correct that EcH2O-iso includes species-defined root water uptake functions, where total transpiration is first constrained by the surface energy balance and stomatal conductance, and subsequently distributed among soil layers based on soil water availability and root distribution. Our original sentence was imprecise and has been revised to more accurately reflect EcH2O-iso root water uptake modelling approach.

The revised text now reads:

“Many ecohydrological models include some form of root water uptake parameterization (e.g., mHM, EcH2O-iso), in which canopy transpiration is typically constrained by surface energy balance and stomatal conductance and subsequently distributed among soil layers based on soil water availability and root distribution.”

In addition, our model EcoPlot-iso differs in structure: because it does not include an energy-balance module, total transpiration is not calculated a priori. Instead, we use an alternative “bucket-style” parameterisation, where transpiration is sequentially satisfied from upper to deeper soil layers according to the relative soil moisture availability (STO/Smax) of each layer, while evaporation is governed by canopy fraction and topsoil water content (Eqs. S5–S9).

Q6. Lines 62-93: This all feels more like discussion to me. The central aim of the paper is about how forest management impacts water cycling. These paragraphs are a good discussion of model complexity that are relevant but tangential to the central aim. I would recommend that the authors consider reorganizing.
Reply to Q6: We thank the reviewer for this constructive suggestion. The original text in Lines 62–93 was intended to introduce the challenges of modelling ecohydrological processes and forest-management scenarios and to motivate our use of a tracer-aided, intermediate-complexity model. We agree that the present level of technical detail is better placed in the Discussion.

In response, we have substantially condensed Lines 62–93 to a concise five-sentence paragraph so that the Introduction remains tightly focused on the study objective. The more detailed discussion of model complexity has been moved to the Discussion, where alternative modelling approaches, limitations, and remaining research gaps are now addressed more appropriately.

The revised text in Lines 62–93 now reads:

In forest ecosystems, ET is particularly challenging to simulate due to complex interactions among canopy structure, stomatal behavior, and root water uptake (Tague & Band, 2004). Many ecohydrological models include some form of root water uptake parameterization (e.g., mHM, EcH2O-iso), in which canopy transpiration is typically constrained by surface energy balance and stomatal conductance and subsequently distributed among soil layers based on soil water availability and root distribution. While such models provide detailed representations of land–atmosphere and soil–vegetation interactions, their application in forest management studies is often constrained by high data requirements, computational demand, and parameter uncertainty, particularly in data-scarce regions (Fatichi et al., 2012; Ricci et al., 2020; Tague & Band, 2004). In this context, conceptual tracer-aided ecohydrological models can provide a complementary, process-based, and practical framework for systematically exploring long-term forest management impacts on water partitioning and ecohydrological resilience (Landgraf et al., 2023). By integrating climatic forcing, canopy structure (e.g., leaf area index), soil moisture dynamics, and stable water isotopes, such approaches facilitate robust assessment of green- and blue-water fluxes under contrasting forest management scenarios (Neill et al., 2021).

Q7. Line 172: Are these depth variations selected by the user? How do we know that they are appropriate to capture vertical variations in soil isotopic compositions and root water uptake?
Reply to Q7: Thank you for this helpful comment. Yes, the vertical discretization into three soil layers (0–10 cm, 10–30 cm, and 30–100 cm) follows the established configuration of EcoPlot-iso, which has been successfully applied in several recent studies in this region (e.g., Landgraf et al., 2023). Multi-layer soil structures of this type are also common in widely applied hydrological and land surface models. For example, Noah-Multiparameterization Land Surface Model (Noah-MP, Niu et al., 2011) typically employs a four-layer scheme (0–10, 10–40, 40–100, and 100–200 cm), and Community Land Model (CLM) also uses a comparable multilayer configuration, although the exact depth intervals differ.

Moreover, in this study soil water isotopes were sampled at finer vertical resolution (0–5, 5–10, 10–20, 20–30, and 30–50 cm; see Section 3.3, second paragraph). Soil moisture was measured with handheld probes at 0–10 cm and with permanently installed sensors at 15–20 cm and 40–100 cm (Table S2). These depths and observations align with the three model layers (0–10, 10–30, 30–100 cm), providing higher-resolution observations within each layer to support calibration and validation of soil moisture and soil water isotopic dynamics.

Overall, such discretizations have proven effective for representing vertical variations in soil moisture, and isotopic compositions. Although the discretization can be adjusted in principle, we adopted this configuration to ensure comparability with previous applications and consistency with established practice.

We have added the following clarification in the revised manuscript (Section 3.1):

"The vertical discretization follows the established EcoPlot-iso configuration and effectively represents vertical gradients in soil moisture and isotopic composition, broadly consistent with soil moisture and isotope measurements within each layer."

Reference:

Landgraf, J., Tetzlaff, D., Birkel, C., Stevenson, J. L., & Soulsby, C. (2023). Assessing land use effects on ecohydrological partitioning in the critical zone through isotope-aided modelling. Earth Surface Processes and Landforms, 48(15), 3199–3219. https://doi.org/10.1002/esp.5691

Niu, G. Y., Yang, Z. L., Mitchell, K. E., Chen, F., Ek, M. B., Barlage, M., ... & Xia, Y. (2011). The community Noah land surface model with multiparameterization options (Noah-MP): 1. Model description and evaluation with local-scale measurements. Journal of Geophysical Research: Atmospheres, 116(D12). https://doi.org/10.1029/2010JD015139

Q8. Section 3.2: Do the different vegetation classes differ in any ways other that the beta term defining the decay of root water uptake demand?
Reply to Q8: Yes. The different vegetation classes differ in several aspects beyond the β parameter that controls the decay of root water uptake with depth. Each vegetation class (site) was calibrated separately using a Monte Carlo approach. The calibration includes not only the β parameter, but also a broader set of vegetation and soil parameters, such as canopy properties and soil hydraulic characteristics (see Tables S2 and S3).

In the revised manuscript, EcoPlot-iso was applied to five contrasting land-use sites: broadleaf forest, coniferous forest, cropland, agroforestry, and grassland. The broadleaf, coniferous forest and agroforestry sites were used as the baseline scenarios; from its calibration, we retained the 100 best-performing simulations and their corresponding parameter sets for each site.

For the forest management scenarios, we then varied three key dimensions of forest characteristics — generic forest type, forest density, and root distribution — considered separately. This allowed us to test how differences in other vegetation canopy and root distribution and influence water uptake and ecohydrological resilience.

Q9. Line 193: I'm a little unclear from this description if the model simulates multiple vegetation classes within the same simulation. This sounds like only one is possible. How then does this support study of intercropping that you discuss previously?
Reply to Q9: EcoPlot-iso is applied at the plot scale and typically represents a single dominant vegetation type per simulation, rather than explicitly simulating multiple vegetation classes within the same run. For agroforestry or intercropping, this is approximated by applying MODIS-derived LAI and calibrating canopy and soil parameters to represent mixed crop–tree systems, rather than simulating multiple vegetation types simultaneously.

We have clarified this point and the treatment of agroforestry simulations more clearly in the revised manuscript (Methods section 3.3).

"Given the plot-scale nature of EcoPlot-iso, agroforestry systems, characterized by mixed crop–tree vegetation, are represented implicitly using MODIS-derived LAI and calibration against plot-scale soil moisture and isotope observations, rather than explicitly resolving multiple vegetation types."

Q10. Line 218: The model computes E/T from PET? I'm guessing it uses some downregulation of PET to AET based on soil moisture in the root zone? Please specify the approach. Is there any consideration for how different canopy structures impact E/T? This was mentioned previously as an important consideration for understanding how forest management strategies impact water cycling and resilience.
Reply to Q10: We have clarified in the Methods how PET is downregulated to AET and how canopy structure influences the E/T partitioning.

Specifically, a new paragraph and a summary table with variable definitions and governing equations has been added in the Supplementary Material (Table S1; Eqs. S1–S12), describing how interception, evaporation, transpiration, and soil evaporation are constrained by canopy storage and soil-moisture conditions. In brief, PET is partitioned into canopy and soil fractions based on canopy surface cover fraction SCF derived from LAI via Beer's law, and differences in canopy structure among management scenarios (broadleaf, conifer, agroforestry) are represented through their LAI time series (thus SCF), interception capacity, and rooting-depth distributions, which together control the E/T partitioning.

Text now added in the Method Section 3.1:

"In EcoPlot-iso, canopy surface cover fraction (SCF) is derived from LAI using Beer's law with an extinction coefficient rE (Eq. S1). Maximum canopy storage is determined by the SCF and an interception threshold parameter α. Interception is represented by a nonlinear saturation-type function (Eq. S2), whereby precipitation is first stored in the canopy until maximum canopy storage is reached, and any excess is routed as throughfall. Potential evapotranspiration PET is partitioned into canopy and soil fractions according to SCF (Eqs. S3 and S4). The canopy fraction drives evaporation from the interception store and transpiration from the soil layers, while the soil fraction drives evaporation from the upper soil layer (Eqs. S5–S6). Actual fluxes are constrained by water availability: interception evaporation depends on canopy storage, transpiration is sequentially satisfied from the upper to deeper soil layers according to the relative soil-moisture availability (STO/Smax) of each layer (Eqs. S7–S9), and soil evaporation is limited by moisture availability in the upper soil. Surface runoff is represented using a Hortonian threshold approach, where precipitation in excess of infiltration capacity is routed as runoff (Eq. S10). Preferential flow is triggered when throughfall exceeds a threshold, with a calibrated parameter controlling the bypass proportion (Eq. S11). Percolation, compartment flow and groundwater recharge are represented as storage–discharge relationships, where outflows are parameterised as power functions of soil or groundwater storage (Eqs. S12-S14). Groundwater recharge is defined as the downward percolation flux at the lower boundary of the soil domain (30–100 cm layer), corresponding to a total soil depth of 1 m. Full variable definitions and governing equations are provided in Table S1 of the Supplementary Material (Eqs. S1–S14).

Table S1. Ecohydrological processes in EcoPlot-iso: variable definitions and governing equations.

Variable	**Description**	**Equation**
SCF	Surface cover fraction	$SCF = 1 - e^{(rE*LAI)}$ (S1)
Int	Canopy interception	$Int = (\alpha * \mathrm{LAI}) * \left(1 - \frac{1}{1 + \frac{SCF * P}{\alpha * LAI}}\right)$ (S2)
T_p	Canopy fraction of PET	$T_p = PET * SCF$ (S3)
E_p	Soil fraction of PET	$E_p = PET * (1 - SCF)$ (S4)
Ei	Canopy evaporation	$E_i = \begin{cases} Int_S & \text{if } T_p > Int_S \\ T_p & \text{if } T_p \le Int_S \end{cases}$ (S5)
Es	Soil evaporation of upper soil layer	$E_s = E_p * \left(\frac{STO}{S_{\max}}\right)$ (S6)
Tr_Upper	Transpiration from the upper soil layer	$T_{p1} = (T_P - E_i) * \left(\frac{STO}{S_{\max}}\right)$ (S7)
Tr_Lower	Transpiration from the lower soil layer	$T_{p2} = (T_P - E_i - T_{p1}) * \left(\frac{GW}{GW_{\max}}\right)$ (S8)
Tr_Deep	Transpiration from the deep soil layer	$T_{p3} = (T_P - E_i - T_{p1} - T_{p2}) * \left(\frac{SDeep}{SDeep_{\max}}\right)$ (S9)
Qs	Surface runoff	$Q_s = PN - I_c$ (S10)
Pref_Flow	Preferential flow	$\mathrm{Pref\_Flow} = PN * PF_{scale}$ (S11)
Perc	Percolation flux	$Perc = ks1 * \left(\frac{STO}{S_{\max}}\right)^{g1}$ (S12)
Sdeep	Compartment flow	$Sdeep = ks2 * \left(\frac{GW}{GW_{\max}}\right)^{g2}$ (S13)
Recharge	Groundwater recharge	$Recharge = ks3 * \left(\frac{SDeep}{SDeep_{\max}}\right)^{g3}$ (S14)

Q11. Section 3.2 (line 189-199): Is there a reference for this root depth model? The equations look very similar to the water uptake equations of the SWAT model.
Reply to Q11: The exponential root depth function that we implemented in EcoPlot-iso builds on earlier root uptake formulations, where uptake was assumed to decline with depth either linearly (Hoogland et al., 1981; Prasad, 1988) or exponentially (Li et al., 1999; Wu et al. 1999). Our implementation follows this exponential form and is conceptually similar to those used in models such as EcH2O-iso and SWAT. In EcoPlot-iso, the β term serves as a fitted extinction coefficient and is the only parameter estimated in the root uptake function, representing the exponential decline of root uptake efficiency with depth. We have revised Section 3.2 to include the relevant references and clarify this.

"This formulation builds on the common assumption that potential root water uptake decreases exponentially with depth (Li et al., 1999; Wu et al., 1999) and is intentionally simplified for a plot-scale, data-constrained model setup."

Reference:

Hoogland, J. C., Feddes, R. A., & Belmans, C. (1981, March). Root water uptake model depending on soil water pressure head and maximum extraction rate. In III International Symposium on Water supply and Irrigation in the open and under Protected Cultivation 119 (pp. 123-136). https://doi.org/10.17660/ActaHortic.1981.119.11

Prasad, R. (1988). A linear root water uptake model. Journal of Hydrology, 99(3-4), 297-306. https://doi.org/10.1016/0022-1694(88)90055-8.

K. Y. Li, J. B. Boisvert, and R. De Jong. 1999. An exponential root-water-uptake model. Canadian Journal of Soil Science. 79(2): 333-343. https://doi.org/10.4141/S98-032

Wu, J., Zhang, R. & Gui, S. Modeling soil water movement with water uptake by roots. Plant and Soil 215, 7–17 (1999). https://doi.org/10.1023/A:1004702807951

Q12. Line 220: Linear interpolation?
Reply to Q12: Yes, we have incorporated this in the revised manuscript.

The revised text now read in Section 3.3:

"The Leaf Area Index (LAI) time series was extracted from the MODIS 8-day LAI product at the location of each study site and linearly interpolated to daily timesteps."

Q13. Line 226-229: Do you know the make and model of the moisture probes? Different probes represent different soil volumes.
Reply to Q13: Yes, we know the make and model of the soil moisture devices and has added the info into the revised text. Surface soil moisture (0–10 cm) was measured using a Theta ML3 handheld probe. For subsurface soil moisture, permanently installed probes were used: SMT-100 sensors (Umwelt-Geräte-Technik GmbH) for forest and grassland sites, and CS650 probes (Campbell Scientific) for agroforestry and crop sites. We have added this information in the Methods section 3.3 and also update Table S2 (Soil Moisture Measurement Devices and Aggregation Methods) in the Supplementary Material.

The revised text now read:

"Surface soil moisture (0–10 cm) was measured using a handheld soil moisture device (Theta handheld probe ML3 Sensor) on a monthly basis during two field observation periods (2018–2019 and 2021). For subsurface soil moisture, permanently installed soil moisture probes: SMT-100 at forest and grassland sites, and CS650 at agroforestry and cropland sites. Measurements were recorded at 15-minute intervals with two replicates per depth. To facilitate data processing and consistency, all soil moisture datasets were aggregated into daily mean values, resulting in one volumetric water content value per site and soil depth. Details of the measurement devices, depth intervals, and aggregation methods is summarized in Table S2."

Q14. Line 239: The abstract reads “simulation of transpiration across forests with different rooting distribution, stand ages, and species compositions.” I’m just finished reading through the model description and I’m unclear if the model can simulate different species co-occuring within plots. It sounds like the answer is no. If that’s the case, then the line in the abstract may be a little misleading. It can handle species-level rooting distributions, but only if the forest is a monoculture. I understand this is the common condition in many European forests, but in many other parts of the world this is not the case.
Reply to Q14: We agree that the wording in the abstract may be misleading; apologies for this lack of clarity. EcoPlot-iso could, in principle, be applied to simulate mixed-species stands, since it operates at the plot scale, where a wide range of ecohydrological parameters (e.g., canopy, rooting, and soil properties; see Table S1) can be calibrated at the plot-scale using a Monte Carlo approach, rather than being rigidly tied to a single forest type. However, the scenarios in this study did not simulate multiple species co-occurring within the same stand. Instead, we represented generic monoculture scenarios, where forest type (broadleaf, conifer, agroforestry), forest density, and rooting distributions were varied. We also agree with the reviewer’s point that this assumption reflects conditions in many European forests, but may be less representative of regions with high species diversity.

To address this concern, we have revised the manuscript as follows:

- clarified in the abstract that transpiration is simulated across generic forest scenarios with contrasting forest types, stand density, and rooting distributions, rather than across mixed-species stands;
- emphasized in the Methods that the current simulations are based on monoculture scenarios; and
- explicitly noted this limitation in the Discussion**,** while also highlighting that EcoPlot-iso could be extended to simulate mixed-species stands in future applications.

Specifically, we have added the following text to Section 5.1 of the Discussion:

“While this study focused on idealized, homogeneous vegetation scenarios (broadleaf, conifer, and agroforestry) for clarity and comparability, EcoPlot-iso can be extended to simulate mixed-species stands, as its ecohydrological parameters are calibrated at the plot scale using a Monte Carlo approach, making it suitable for regions where diverse forest compositions are the norm.”

Q15. Line 266: What do you mean “adjusted for three forest types”? If you’re testing different forest types influence hydrological fluxes, then this adjustment is going to completely drive the answer. Much more information is needed here.
Reply to Q15: Thank you for pointing this out; our wording was misleading. What we meant is that the model was driven by observed LAI time series specific to each forest type (broadleaf, coniferous, and agroforestry). As described earlier in the methods, these were derived from the 8-day MODIS LAI product (2000–2024) and then bias-corrected using site measurements (minimum and maximum LAI values) to improve accuracy and reduce noise. This ensured that the LAI inputs reflect realistic seasonal and interannual variability for each land-use type, rather than being artificially tuned. We have revised the text to make this clearer.

The revised text now read:

“For vegetation forcing, we used forest-type–specific observed LAI time series (broadleaf, coniferous, and agroforestry), derived from the MODIS LAI products, described in Section 3.3 (Table 2; Figure S3d).”

Q16. Lines 273 – 278, Scenarios b and c: I don’t really understand how you can separate species composition from rooting depths? A number of studies are presenting strong evidence that rooting depths are related to species identity. Another concern is: why do we think rooting distributions are

independent of forest type? It seems you are varying root distributions independently of LAI which doesn't seem correct.
Reply to Q16: We agree with the reviewer that rooting depths are strongly related to species identity and forest type. In this study, however, our aim was to explore the influence of water partitioning in relation to general vegetation structure, canopy, and root characteristics by examining the sensitivity of model results to three key dimensions of forest management—generic forest type, forest density, and root distribution—considered separately. This framework was designed to capture the dominant effects of vegetation structure—such as interception and transpiration through canopy and root networks—on water partitioning, rather than to reproduce detailed species-specific physiology.

To achieve this, forest type was generically represented by type-specific LAI time series, forest density by scaling factors applied to LAI, and forest age by varying rooting depth (β parameter), with younger stands represented by shallower rooting and older stands by deeper rooting. We have clarified this modelling assumption in the revised manuscript to emphasize that we are not suggesting rooting depth is independent of species in reality, but rather that this separation was introduced as a scenario design choice for sensitivity testing. Part of the motivation for the study was to illustrate to land managers in our study area how generic choices of land use (e.g. conifers vs broadleaves) could affect water use in terms of canopy structure

Accordingly, we added the following clarification in Section 3.5.

"Within this framework, LAI and rooting distribution were treated as independent scenario dimensions. LAI scaling represented management-induced changes in canopy density, whereas rooting distribution scenarios reflected contrasts in belowground water uptake. Their combined effects on water fluxes were evaluated without assuming a fixed linkage between canopy structure and rooting depth. This separation acknowledges that canopy density can change rapidly through management (e.g., thinning or harvesting), while rooting characteristics typically reflect longer-term stand development, thereby allowing realistic representation of above- and belowground controls on water partitioning."

Q17. Fig. 3: Can you report a metric that is scale dependent? Something like RMSE would help to give a better sense of the model fit. The fit looks good, I just want to pair my subjective interpretation with an objective value.
Reply to Q17: Thank you for this helpful suggestion. According to your suggestion, we have added a scale-dependent metric in the revised manuscript. Specifically, in addition to the Kling–Gupta Efficiency (KGE), we have reported the root mean square error (RMSE) for each simulation in Figure 4 (Fig. 3 in the previous version) to provide a unit-based measure of model fit in the revised manuscript.

Q18. Fig. 3: The font size is really small on the y-axis. Can you increase the size?
Reply to Q18: Thank you for pointing this out. We have increased the y-axis font size in Figure 3 to improve readability in the revised manuscript.

Q19. Fig 4: Same issue with font sizes. They are unreadable unless I zoom in to 200% and I'm even very old yet.
Reply to Q19: Thank you for the comment. We have also increased the font sizes in Figure 4 (now Fig. 5 in the revised manuscript) to ensure readability in the revised manuscript.

Q20. Lines 347 – 350: I still don't really understand this LAI scaling. This seems the be the only factor that differentiates the different forest types that are simulated. This is really just an exercise in how sensitive is transpiration to this LAI adjustment. Why were root parameters kept constant across different forest types?
Reply to Q20: We have clarified that the LAI scaling was implemented to represent differences in forest density rather than forest type per se. As we explained in the reply to Q1 and Q16, our aim in this study was to explore the impact of water partitioning to three key dimensions of forest management characteristics—generic forest type, forest density, and root distribution separately. LAI scaling was

used to represent forest density varying, species type was represented by type-specific LAI timeseries, and rooting depth (β parameter) was varied independently to reflect forest age. We have revised the manuscript to make this modelling assumption clearer.

Q21. Fig 8: This is a good sensitivity test, but its telling me that uncertainty in the rooting depth and LAI scaling factors are driving the results completely.
Reply to Q21: The aim of this study was to examine how uncertainty in both vegetation structure (represented by the LAI scaling factor) and rooting characteristics (represented by β values) influences ecohydrological fluxes across different forest types (captured by the distinct LAI time series for agroforest, broadleaf, and conifer). Figure 8 shows that while rooting depth and LAI scaling factors strongly affect ET, transpiration, and recharge partitioning, these sensitivities vary systematically with forest type. In particular, higher LAI scaling factors generally increase ET and reduce recharge, although the magnitude of this trade-off differs among forest types. Similarly, rooting depth (β) modulates the balance between transpiration and recharge, with deeper rooting systems sustaining higher transpiration. Our intention was not only to highlight the role of rooting depth and LAI scaling factors, but also to demonstrate how forest type and canopy density interact with these parameters to shape long-term water partitioning trends. We have clarified this objective (and finding) in the revised manuscript text around Fig. 8 to avoid any impression that the results are driven by a single factor.

Q22. Line 483: There is much more than canopy structure that differentiates different forests from one another. For example, rooting depths likely vary. Beyond that there are different conductance rates, sensitivities to VPD, different tolerances for soil water stress, etc. This study really only considers how these forests might vary in one specific way and presumes forests are monolithic along every other axis. I think this might be too limiting for this study to really tell us about the water fluxes with much confidence.
Reply to Q22: We agree that forests differ in many additional aspects beyond canopy structure, and would note that we are also evaluating rooting distributions as well. In this study, however, our main intention was to use a parsimonious and generic framework for assessment, rather than to reproduce detailed species-specific physiology. The framework systematically explores variation in three main factors that strongly influence water fluxes at our study sites: canopy density (via LAI scaling factors), rooting distribution (via β), and forest type (broadleaf, conifer, agroforest, each with distinct LAI time series). These dimensions were selected as they represent key controls on ecohydrological partitioning and allow us to investigate long-term trade-offs between transpiration, evapotranspiration, and recharge. We acknowledge the limitations of this simplified representation and have clarified this in the Discussion, emphasizing that our results should be interpreted as scenario-based insights into generic forest management strategies, rather than detailed predictions for specific species or physiological traits.

Q23. Line 498: I strongly disagree with this logic. These models need more information not because these other models are overly complicated, but rather because the real life system you are trying to model is actually that complicated. This model presented here is probably too simplistic to really capture what is happening. Models should be as simple as possible and no simpler. I speculate that this model has gone too far towards simplicity for the specific question being asked to the point where it doesn't fully inform us.
Reply to Q23: With respect, there may be a misunderstanding here. We are not arguing for simple models per se, nor do we suggest that more complex ecohydrological models are “overly complicated.” We fully agree with the reviewer that real-world forest ecohydrological systems are inherently complex, and that models should be as simple as possible, but no simpler.

Our point is that the data required to parameterize, drive, and evaluate highly complex models are rarely available outside well-instrumented research sites. As a result, the application of such models in regional forest and land management contexts is often constrained by data availability rather than by model structure itself.

Accordingly, the aim of this study was not to reproduce all species-specific physiological processes, but to develop a parsimonious, tracer-aided modelling framework that can robustly quantify relative trade-offs in long-term water partitioning under alternative forest management scenarios in a data-limited, lowland European setting.

To ensure that model parsimony has not come at the expense of realism or robustness, we have taken several steps to constrain uncertainty and evaluate model performance:

(i) We set up and calibrated EcoPlot-iso consistently across multiple land-use and vegetation types (broadleaf forest, conifer forest, agroforestry, cropland, and grassland) to test model transferability and robustness across contrasting vegetation systems. In the revised manuscript, we additionally include site-based simulations for a conifer forest plot.

(ii) We dual-calibrated the model against both soil moisture and soil-water isotopes using a Monte Carlo, multi-criteria procedure (1,000,000 parameter sets, with the best 100 retained for scenario analyses). This approach constrains equifinality and improves the robustness and transferability of the retained parameter sets across sites.

(iii) We further evaluated model realism by independently validating simulated evapotranspiration against MODIS-derived ET and reporting Kling–Gupta Efficiency (KGE) metrics for each land-use type, strengthening confidence in overall model performance.

(iv) Rooting distribution was explicitly represented using a depth-dependent uptake function (β), while canopy density (LAI scaling) and forest type (broadleaf, conifer, agroforestry) were varied independently. This design allows aboveground and belowground controls on water partitioning to be explored without imposing a fixed or deterministic linkage between canopy structure and rooting depth. These modelling choices are described in Sections 3.2–3.5 and supported by the performance metrics and uncertainty envelopes presented in Figures 3–10.

We have revised the sentence around line 498 to clarify that our intention was not to imply that complex process-based models (e.g., RHESSys, EcH2O) are unnecessarily complicated. Rather, we emphasize that their broader application in management-oriented studies is often limited by high data and computational requirements. We have also strengthened the Discussion to frame our results explicitly as generic, management-relevant insights, rather than species-level predictions, and to acknowledge that additional processes (e.g., stomatal conductance, VPD sensitivity, sap-flux or xylem-isotope constraints, and lateral flows) remain important directions for future model development.

Response to Referee Comment #2:

Dear editor, reviewer #2,

We sincerely thank the reviewer for the detailed and constructive comments, which have greatly helped us to improve the focus, clarity, and robustness of our manuscript. We particularly appreciate the reviewer’s recognition of the relevance of isotope-enabled ecohydrological models and the importance of understanding forest management effects on hydrological partitioning.

In light of the review comments we recognize that several aspects of the work—particularly the rationale and implementation of our simplified forest-management scenario framework—were not explained sufficiently in the original submission. In the revised manuscript, we have clarified the novel and exploratory nature of the framework and have improved it by re-running and extending the modelling to:

(i) distinguish soil parameters from vegetation parameters, and keep soil parameters constant while varying vegetation parameters (e.g., LAI, radiation extinction factor, interception capacity parameter);

(ii) revise the scenario framework using site-specific calibrations for all forest types (broadleaf forest, conifer forest, and agroforestry), rather than relying solely on the broadleaf forest site, and repeat the scenario analysis consistently across all three forest sites using different baselines;

(iii) report model performance separately for calibration and validation periods for soil moisture and soil water isotope;

(iv) add an independent validation of simulated evapotranspiration using MODIS-derived ET and report Kling–Gupta Efficiency (KGE) metrics for each land-use type, supporting simulated flux partitioning.

These revisions make the framework more transparent and physically consistent, while maintaining comparability across scenarios. We believe that the revised version substantially strengthens the scientific quality and readability of the manuscript, making it suitable for publication in *Hydrology and Earth System Sciences*. Below, we provide detailed, point-by-point responses describing how each comment is addressed in the revised text.

Sincerely,

Dr. Cong Jiang (on behalf of all co-authors)

Dear editors, dear authors,
After careful consideration of the submission I recommend that the manuscript in its present form is not sufficient for publication in HESS.
The described study extended an existing water balance model with a root water uptake (RWU) parametrization from 3 distinct soil layers that is partitioned according to an exponential root distribution function. The authors calibrated four model parametrizations to data of four sites (broadleaf forest, agroforestry, grassland, cropland). At each site seven years of soil moisture and three years of soil water d2H isotopes were available from multiple depths. With the parametrization obtained for broadleaf forest, the authors performed a sensitivity analysis of the model predictions (i.e. of hydrologic partitioning and soil moisture status) to variations in model parameters, namely the seasonal timing and magnitude of LAI (Figure S2d). Furthermore, additional sensitivity analyses further explored the impact of stronger variations in LAI (factors ranging from 0.2 to 1.8) as well as variations in efficiency of root water uptake (parameter beta). As main findings, the authors quantified differences in the water partitioning of yearly available precipitation: highest evapotranspiration (ET) and lowest groundwater recharge (RE) were observed in the model forced with highest LAI and longest growing season (Figure S2d, attributed to coniferous forest). Inversely, lowest ET and highest RE were observed in the model forced with lowest, shortest LAI (Figure S2d, attributed to agroforestry). They quantified the differences between these two model runs on the order of 12% (ET) and 11% (RE) of the yearly precipitation.
Reply: We thank the reviewer for concisely summarizing our approach and main findings. The primary goal of this study was to develop a new, parsimonious and generic forest management scenario framework to evaluate how forest type, forest density, and root distribution —associated with forest age—influence long-term water partitioning and ecohydrological resilience under comparable environmental conditions. This new framework was intended to capture the dominant effects of vegetation structure on water partitioning, rather than to reproduce detailed species-specific physiology

General comments:
The development of isotope-enabled ecohydrological water balance models with realistic RWU parametrizations is a welcome addition in the field of critical zone hydrology. Such developments are needed to advance our understanding of hydrological partitioning in the critical zone (Guswa 2020). Different model complexities and multiple calibration targets are means to better validate models and reduce model equifinality, thereby leading to mechanistic models that show lower parametric uncertainty (Kuppel 2018, Birkel 2023).
Reply: Yes, we agree, these are exactly our intention (and some of our team have been coauthors of these previous studies).

Having high confidence in the parametrization of model processes is especialy crucial when predicting model-derived outputs (such as the hydrologic partitioning) to which the model was not directly calibrated, and which is thus entirely depending on the structural correctness of the model. Understanding hydrological partitioning in the critical zone of forest systems as a function of forest stand properties (land management scenarios) or climate parameters (dry years vs. wet years) is a relevant research problem of importance to forest managers and in scope for HESS.
However, the manuscript in its present form is not sufficient for publication in HESS:
Reply: We thank the reviewer for recognizing the relevance and importance of developing these isotope-enabled ecohydrological models with realistic root water uptake parameterizations to advance understanding of hydrological partitioning in the critical zone. We are grateful for the reviewer’s valuable and constructive feedback and for acknowledging the significance of this research within the scope of HESS.

We have carefully considered all comments and have revised the manuscript accordingly to improve its clarity and scientific rigor. As part of the revision, we have adopted a revised modelling approach, as suggested by the reviewer and the editor. We believe that these revisions substantially enhance the quality of the manuscript, and we hope that the revised version is now suitable for publication in *Hydrology and Earth System Sciences*.

Q1-1. The approach of extrapolating the model (that was fitted to soil moisture and soil water isotopes at the broadleaf site) to other vegetation types (conifer and agroforestry sites) by simply modifying LAI, while keeping all other model parameters, is not sufficiently substantiated. Even for a "simplified modelling tool" validating the resulting predictions against data from sites containing these vegetation types is required for robust interpretation. Species or plant functional types affect (among others) stomatal control, root distribution, or soil water availability parameters in models (e.g. Cowan 1978, Kuppel 2014, Li 2022, Peters 2025), i.e. processes that are also implicitly present in the RWU parametrization of the EcoPlot-iso model (eq. 1-3). The parametrization of these processes should thus likely change when extrapolating the model to other vegetation types.

Reply to Q1-1: We thank the reviewer for summarizing our approach and for the insightful comment on the extrapolation of model parameters between vegetation types (broadleaf, conifer and agroforestry).

Of course, we fully agree that vegetation types differ in functional traits beyond canopy LAI—such as stomatal control, root distribution and soil water availability parameters—that can influence model parameterization. We apologies that we did not make that clearer in the original version. To clarify: vegetation-related processes—spanning canopy interception, evaporation, and root water uptake—are represented in the EcoPlot-iso model by parameters including the leaf area index (LAI), radiation extinction factor (rE), canopy interception storage capacity (α), and the root distribution parameter (β). Soil-related processes are characterized by parameters such as maximum soil moisture content (Smax, GWmax, Lmax), saturated hydraulic conductivity (k1, k2, k3) and nonlinear scaling parameter (g1, g2, g3) for each soil layer. We have ensured that this parameter distinction is now more clearly explained in the revised manuscript.

Importantly, the primary goal of this study was to develop a new, parsimonious and generic forest management scenario framework to evaluate how forest type, forest density, and root distribution —associated with forest age—influence long-term water partitioning and ecohydrological resilience under comparable environmental conditions. This framework was designed to capture the dominant effects of vegetation structure—such as interception and transpiration through canopy and root networks—on water partitioning, rather than to reproduce detailed species-specific physiology. To isolate the effects of vegetation characteristics, in the original version, we kept soil parameters constant while vegetation-related parameters, particularly LAI, were varied initially, as LAI strongly controls canopy interception and evapotranspiration partitioning.

However, we acknowledge that vegetation-type-specific parameters should also include other canopy-related parameters, in addition to LAI, as suggested by the reviewer. Accordingly, in the revised manuscript, we have refined our forest management scenarios framework by incorporating forest-type-specific parameters for broadleaf, conifer, and agroforestry systems. These vegetation parameters (rE, α) are derived from site-specific calibrations for each forest type, while maintaining soil parameters from the corresponding forest sites (broadleaf, agroforestry, conifer) to ensure comparability (see Figure S4 provided in the response to Q2). Specifically, we use the median parameter values from 100 best-performing simulations at each site to represent realistic canopy characteristics across forest types. The calibrated vegetation parameters appear physically consistent, showing median patterns of rE (in absolute magnitude: broadleaf > conifer > agroforestry) and α (agroforestry < broadleaf < conifer), as illustrated in Figure S4.

We also note that the conifer site was not included in the first version because some observations—such as an extremely dry deeper-layer (30-70 cm) with low soil moisture caused by poorly retentive sands—were not representative of wider catchment conditions (see update Table 1, provided in response to Q7). Nevertheless, the vegetation-type-specific parameters (rE, α) derived from the conifer calibration remain valuable and are now incorporated into the scenarios modeling framework of the revision to better represent forest-type differences.

Finally, we clarify that the root distribution parameter (β) is not treated as vegetation-specific parameter in the scenario modelling framework. As shown in Figure S4**,** the β value at the conifer site indicates a higher near-surface density and water uptake efficiency, likely reflecting the extremely dry conditions in the deeper soil layer (30–70 cm) rather than inherently shallower rooting compared to grassland or cropland. We'd argue that it is therefore reasonable to consider the parameter β as jointly influenced by vegetation type, soil properties, and soil water availability. Accordingly, β is treated as part of the scenario dimension representing variations in root depth and water uptake efficiency with depth associated with forest age and stand development, which is an important aspect of forest management—rather than as a strictly vegetation-specific parameter.

Q1-2. Potentially, the extrapolated model predictions could be compared with observations e.g. with those available from the agroforest site, to better substantiate the chosen approach.
Reply to Q1-2: Furthermore, we appreciate the reviewer's suggestion to compare the extrapolated model results with observations from the agroforestry site. We agree that such a comparison could ideally provide a useful plausibility check. However, we would argue that because soil hydraulic and boundary conditions differ between sites, a direct quantitative validation would not reflect the controlled conditions intended in our generic scenario framework. In addition, since the refined framework has incorporated vegetation-type–specific parameters (rE, α) derived from the calibrated real sites, further quantitative comparison is in our view not essential. Instead, we include a qualitative comparison of seasonal dynamics and magnitudes where feasible, while clearly stating the associated limitations in the Discussion.

In summary, the refined framework uses the validated vegetation-type-specific parameter sets (rE, α) from the three real site simulations (broadleaf, conifer, agroforestry) to represent more realistic functional differences among the three forest types.

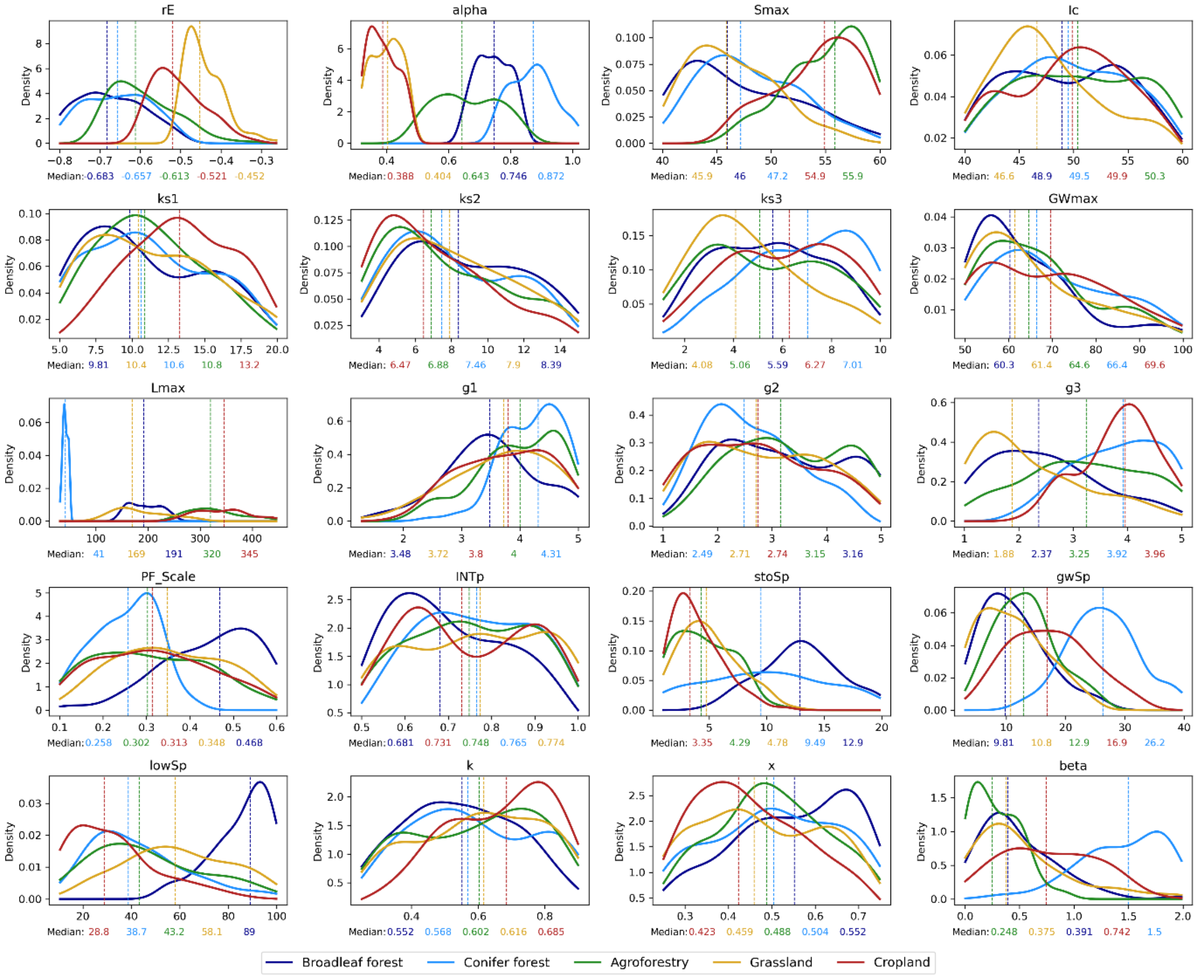
We are confident that this refinement strengthens the physical consistency and interpretability of the scenario analysis while preserving the study's objective of providing a parsimonious and transferable modelling tool for assessing forest management impacts on ecohydrological resilience.

Q2. The calibration to data of the broadleaf site, (as well as the other three listed in Table 3), were not shown to have constrained the parameters relative to their initial ranges (Table S2), except for Lmax and beta. (And same for the other sites.) This should be not discussed. What does this mean? Does it mean that the initial ranges are already providing "good simulations" for all of these calibration sites? In order to use the calibrated model for the sensitivity analysis of hydrologic partitioning, I would expect the authors to provide more evidence of a successful calibration. Be it through comparison with further data or at least through an analysis of the 100 best parameters sets and equifinalities among the parameter values. These equifinalities might not impact the calibration target, but they might impact the partitioning fluxes (Birkel 2023). The parameteric uncertainty was propagated onto the model predictions in Figures 5 and 6. It turned out to be on the order of the difference between the forest types and its impact on the main findings should be discussed. Parametric uncertainty is lacking from Figures 12 and 11 as well as those figures exploring the impact of beta and LAI scaling.
Reply to Q2: We thank the reviewer for this valuable comment and for highlighting the importance of demonstrating parameter constraint, equifinality, and the role of parametric uncertainty in interpreting our results.

We acknowledge that in the original version, Table S2 mistakenly presented the initial parameter ranges instead of the calibrated ranges. In the revised manuscript, Table S2 (now Table S3 in the Supplementary Material) has be corrected to show both the initial and calibrated parameter ranges of the 100 best-performing simulations for each site. To provide clearer evidence of parameter constraint and equifinality, we have also added a new figure (Figure S4) showing the probability density distributions of the calibrated parameters derived from the 100 best-performing simulations for all five sites (broadleaf, conifer, agroforestry, grassland, and cropland). The added / revised Figure S4, Table S3 and Table 3 have been included in this reply document below for the reviewer's reference.

We have already incorporated the conifer-site calibration in the revised analysis and refined the range of the root distribution parameter (β) to 0–2, instead of fixing β = 0 for the broadleaf site as in the previous version, which was based on site knowledge of the mature broadleaf forest with well-developed roots. The β distributions of the forest sites show clear convergence toward small values (except for the conifer site, as explained in response to Q1), with median values below 1 for all vegetation types. These calibrated distributions confirm that a β range of 0–2 is physically realistic and efficient for representing root distribution across the forest management scenarios (see also Q4).

We agree with the reviewer that equifinalities among parameter sets may influence the partitioning of ecohydrological fluxes, even if the calibration targets (soil moisture and δ²H) are well reproduced. To address this, in the revision, we have explicitly included uncertainty envelopes (5th–95th percentile ranges) derived from the 100 behavioral simulations in Figures 11 and 12, making the propagation of parametric uncertainty in model predictions transparent. Furthermore, we have expanded the Discussion section to explicitly address how parameter uncertainty and equifinality may influence the interpretation of the model results and water partitioning outcomes across vegetation types.



Added Figure S4. Probability density distributions of the 20 calibrated ecohydrological parameters for five land-use types (broadleaf forest, conifer forest, agroforestry, grassland, and cropland) based on 100 behavioural simulations from the EcoPlot-iso model. Each panel represents one parameter, with kernel density estimates (KDEs) shown in different colours corresponding to each land-use type. Vertical dashed lines indicate the median values of the posterior parameter distributions. Below each subplot, the median values are listed in ascending order (left to right) with text colours matching the respective land-use type. The density plots highlight parameter sensitivities and the distinct parameterization patterns across contrasting vegetation covers.

Revised Table S3. EcoPlot-iso parameters, initial and calibrated parameters ranges for calibration. BF: Broadleaf Forest, CF: Conifer Forest, AF: Agroforest, GL: Grassland, CL: Cropland.

Parameter	**Description**	**Sites**	**Initial range**	**Calibrated range**		
				Min	**Median**	**Max**
rE	Radiation extinction factor (dimensionless)	BF	[-0.8, -0.5]	-0.8	-0.68	-0.51
		CF	[-0.8, -0.5]	-0.8	-0.66	-0.51
		AF	[-0.7, -0.3]	-0.7	-0.61	-0.33
		GL	[-0.5, -0.2]	-0.5	-0.45	-0.26
		CL	[-0.6, -0.3]	-0.6	-0.52	-0.31
α	Interception storage capacity parameter (mm per unit of LAI)	BF	[0.64, 0.84]	0.65	0.75	0.84
		CF	[1.00, 1.36]	0.75	0.87	1.02
		AF	[0.48, 0.84]	0.49	0.64	0.84
		GL	[0.32, 0.48]	0.32	0.4	0.48
		CL	[0.32, 0.48]	0.32	0.39	0.48
Smax	Maximum soil moisture content in the upper soil compartment (mm)	BF	[40, 60]	40.1	45.96	59.43
		CF		40.32	47.18	58.83
		AF		46.72	55.88	60
		GL		40.45	45.87	57.56
		CL		46.28	54.92	59.92
Ic	Soil infiltration capacity (mm/day)	BF	[40, 60]	40.04	48.89	59.87
		CF		40.12	49.52	59.83
		AF		40.22	50.34	59.91
		GL		40.05	46.62	59.75
		CL		40.08	49.85	59.63
ks1	Saturated hydraulic conductivity of the upper soil compartment (mm/day)	BF	[5, 20]	5.07	9.81	19.14
		CF		5.03	10.6	19.3
		AF		5.05	10.83	19.63
		GL		5.46	10.43	19.93
		CL		5.67	13.25	19.91
ks2	Saturated hydraulic conductivity of the lower soil compartment (mm/day)	BF	[3, 15]	3.05	8.39	14.99
		CF		3.27	7.46	14.97
		AF		3.2	6.88	14.98
		GL		3.12	7.9	14.98
		CL		3.06	6.47	14.49
ks3	Saturated hydraulic conductivity of the deeper soil compartment (mm/day)	BF	[1, 10]	1.58	5.59	9.7
		CF		2.35	7.01	9.97
		AF		1.14	5.06	9.92
		GL		1.13	4.08	9.76
		CL		1.18	6.27	9.78
GWmax	Maximum soil moisture content in the lower soil compartment (mm)	BF	[50, 100]	50.19	60.28	99.67
		CF		50.72	66.36	99.34
		AF		50.04	64.64	98.38
		GL		50.12	61.42	99.61
		CL		50.05	69.57	99.62
Lmax	Maximum soil moisture content in the deeper soil compartment (mm)	BF	[150, 250]	150.73	191.47	249.61
		CF	[30, 50]	31.15	41.01	49.99
		AF	[250, 450]	250.98	319.64	443.03
		GL	[100, 300]	105.12	169.03	298.63
		CL	[250, 450]	251.1	345.34	445.85
g1	Nonlinear scaling parameter for the upper soil compartment	BF	[1, 5]	1.55	3.48	4.97
		CF		2.46	4.31	4.95
		AF		2.28	4	5
		GL		1.29	3.72	4.98
		CL		2	3.8	4.98
g2	Nonlinear scaling parameter for the lower soil compartment	BF	[1, 5]	1.21	3.16	4.98
		CF		1.15	2.49	4.47
		AF		1.19	3.15	4.97

		GL		1.06	2.71	4.89
		CL		1.01	2.74	4.87
g3	Nonlinear scaling parameter for the deeper soil compartment	BF	[1, 5]	1.03	2.37	4.97
		CF		2	3.92	4.99
		AF		1.12	3.25	5
		GL		1.02	1.88	4.96
		CL		2.21	3.96	4.98
PFScale	Preferential flow path parameter (dimensionless)	BF	[0.1, 0.6]	0.12	0.47	0.6
		CF		0.1	0.26	0.41
		AF		0.1	0.3	0.59
		GL		0.12	0.35	0.59
		CL		0.1	0.31	0.59
IntSp	Passive interception storage mixing volume (mm)	BF	[0.5, 1]	0.5	0.68	0.99
		CF		0.5	0.77	1
		AF		0.5	0.75	0.99
		GL		0.5	0.77	1
		CL		0.5	0.73	0.99
StoSo	Passive upper soil storage mixing volume (mm)	BF	[1, 20]	5.15	12.9	19.83
		CF		1.15	9.49	18.99
		AF		1.04	4.29	11.44
		GL		1.05	4.78	12.23
		CL		1.03	3.35	11.48
gwSp	Passive lower soil storage mixing volume (mm)	BF	[3, 40]	3.09	9.81	26.73
		CF		12.65	26.25	39.55
		AF		4.02	12.9	26.21
		GL		3.09	10.75	24.18
		CL		4.56	16.86	31.98
lowSP	Passive deep soil storage mixing volume (mm)	BF	[10, 100]	52.22	88.97	99.85
		CF		11.2	38.66	97.39
		AF		11.08	43.24	98.56
		GL		16.28	58.06	99.49
		CL		10.55	28.81	85.79
k	Seasonality factor in the Craig-Gordon model (dimensionless)	BF	[0.25, 0.9]	0.25	0.55	0.9
		CF		0.27	0.57	0.9
		AF		0.25	0.6	0.9
		GL		0.26	0.62	0.9
		CL		0.25	0.69	0.9
x	Water vapor mixing ratio in the Craig-Gordon model (dimensionless)	BF	[0.25, 0.75]	0.27	0.55	0.74
		CF		0.25	0.5	0.74
		AF		0.25	0.49	0.75
		GL		0.25	0.46	0.75
		CL		0.25	0.42	0.74
β	Root distribution factor (dimensionless)	BF	[0, 2]	0.01	0.39	1.95
		CF		0.24	1.5	1.99
		AF		0	0.25	0.94
		GL		0	0.38	1.97
		CL		0	0.74	1.78

Revised Table 3. Model performance metrics for soil moisture and soil water isotopes (δ^2H) at each land use site over the full evaluation period (2000–2024), evaluated using the Kling–Gupta Efficiency (KGE) and the root mean square error (RMSE, mm for soil moisture and ‰ for δ^2H). Metrics are computed by comparing observed and simulated time series at each soil depth.

Sites	Soil moisture						Soil water isotope (δ^2H)					
	Upper		Lower		Deep		Upper		Lower		Deep	
	KGE	RMSE	KGE	RMSE	KGE	RMSE	KGE	RMSE	KGE	RMSE	KGE	RMSE
Broadleaf Forest	0.56	5.83	0.75	7.51	0.84	13.32	0.58	13.23	0.74	8.35	0.68	8.43
Conifer forest	0.61	5.77	0.68	8.68	0.70	5.56	0.67	11.69	0.80	6.94	0.50	13.09
Agroforestry	0.72	5.22	0.79	6.63	0.77	23.43	0.82	8.09	0.85	10.45	0.79	8.98
Grassland	0.89	1.67	0.71	6.18	0.72	16.01	0.71	9.07	0.77	7.69	0.61	8.36
Cropland	0.53	5.84	0.62	8.88	0.71	22.36	0.83	8.36	0.85	9.19	0.36	13.71

Q3. Eventually the manuscript shows many further (sometimes even redundant, e.g. Fig 7/8) model outputs. I struggled as a reader to understand the decision to show that many. Here less might be more. These figures illustrate the results of varying the two other "management dimensions", for which I believe a "model sensitivity analysis" would be a clearer terminology.
Reply to Q3: We thank the reviewer for this valuable observation. We agree that some figures (e.g., Figs. 7, 8, and 10 in previous version) might be redundant and that a clearer presentation would strengthen the paper. In the revised manuscript, as suggested, we have streamlined the results by removing Figs. 4b–4c and Figure 10 (previous version), as Fig. 4d already represents the sum of 4b and 4c (as also noted in Q7). After restructuring the figures, the previous Fig. 4 is now presented as Fig. 5 in the revised manuscript. In addition, some less central visualizations (e.g., previous Fig. 7) have been moved to the Supporting Information, where it is now shown as Fig. S10.

We acknowledge that our multi-dimensional forest management framework—varying forest type, canopy density, and root distribution—may resemble a model sensitivity analysis in structure. However, importantly, our intention was to use these controlled variations as a generic scenario modelling experiment to isolate the dominant vegetation controls on water partitioning, rather than to quantify formal model parameter sensitivity (further explained in Q4). This approach aligns with the study's main goal of developing a parsimonious and generic forest management framework to assess how forest type, canopy structure, and rooting depth influence long-term ecohydrological dynamics under comparable environmental conditions. However, it is clear that we did not present this sufficiently well. We have clarified this conceptual distinction and terminology in the revised manuscript.

Q4-1. The parameters chosen for this sensitivity analysis of the model (i.e. LAI and beta) have rather straightforward effects on partitioning: increasing LAI and decreasing beta both increase ET relative to RE. The directions (although not the magnitudes) of these effects can be straightforwardly derived from the model formulation: Essentially, water partitioning in the model is driven by the efficiency of different fluxes to access the freshly fallen (and intercepted) or soil-stored precipitation water. Figure 4 illustrates the eventual fate of that water: a) evaporation from canopy, soil evaporation and transpiration (ET), b) groundwater recharge (RE), c) surface runoff (Qs), or d) change in soil storage. We can reduce the options, given that Qs is negligibly small in this broadleaf forest site (Figure 4). Further, ignoring storage change by assuming zero change on yearly time scales leaves us with two remaining options: a) ET or b) RE. Thus any model change that improves efficiency of interception (e.g. larger LAI, Eq. 4 in Stevenson 2023), evaporation, or transpiration (e.g. smaller beta, Eq. 1-3 present manuscript, or larger LAI Eq. 4 in Stevenson 2023) favours ET instead of RE. Only water that is neither intercepted, evaporated nor transpired can eventually become groundwater recharge. Similar argumentation can be made for the fraction Transpiration/ET. This argumentation summarises most of the directions of the trends shown in Figures 7,8,9,10. It is true that the performed sensitivity analysis, however, was able to quantify **magnitudes** of these effects with the chosen model parameterization. However, also note that these magnitudes strongly depend on the chosen range of parameter variation. They appeared to be chosen without clear justification as 0.2 to 1.8 for LAI scaling and 0 to 2 for beta.

Reply to Q4-1: We thank the reviewer for summary of the main modelling findings and the relationships between LAI, β, and water partitioning. And yes, we agree that increasing LAI and decreasing β enhance evapotranspiration relative to recharge, and that the magnitudes of these effects depend on the chosen parameter ranges.

As already detailed in our reply to Q2 of Reviewer #1, the LAI scaling factors (0.2–1.8) were selected to represent canopy density variations from strongly thinned to dense stands within realistic limits of observed European forests. A similar scaling approach has been applied in previous tracer-aided modelling (e.g., (Neill et al., 2021). Reported maximum LAI values of up to 9.5 $m^2 m^{-2}$ for mature beech forests in Central Germany (Leuschner et al., 2006) support that our selected range captures realistic canopy densities for managed Central European forests. For the root distribution parameter (β), the range of 0–2 was derived from site-specific calibrations across the five vegetation types (broadleaf, conifer, agroforestry, grassland, and cropland). The posterior β distributions converge toward smaller values (median < 1) for forest sites, indicating deeper rooting compared with shallower-rooted agricultural systems. This confirms that a β range of 0–2 is physically realistic and suitable for representing root distribution across management scenarios.

We have expanded Section 3.3 in the revised manuscript to clarify the derivation and justification of both the LAI and β parameter ranges.

Please also note that the variations in vegetation parameters—including forest-type-specific LAI, LAI scaling factors, and the root distribution parameter (β)—were selected in combination to represent the full spectrum of realistic land-use changes and forest management scenarios (e.g., differences in forest type, forest density, and rooting depth) for this geographical region, rather than purely theoretical model sensitivity tests of LAI or β. In particular, β captures variations in rooting depth from young to mature stands, reflecting forest age effects that are central to forest management. This aligns with the study's main objective of developing a parsimonious and generic forest management framework to evaluate how vegetation structure and rooting characteristics influence long-term water partitioning and ecohydrological resilience under comparable environmental conditions. While the qualitative effects of LAI and β can be analytically inferred from the model formulation, our scenario-based framework quantifies their magnitudes under physically constrained parameter ranges to assess vegetation structural effects on long-term water partitioning and ecohydrological resilience. However, in retrospect, we can see that we need to stress more that the modelling approach is more specific for regions similar soil/climatic conditions.

Q4-2. Alternatively, I suggest a stronger focus on dynamics introduced by wet/dry years, or when analysing monthly fluxes instead of longterm yearly averages would better justify the sensitivity analysis through carefully chosen synthetic applications of the dynamic model.
Reply to Q4-2: We appreciate the reviewer's valuable suggestion to strengthen the analysis of temporal dynamics. While the original results primarily focus on long-term mean annual water partitioning to isolate structural vegetation effects, the model is fully dynamic and resolves processes at a daily time step. In the revised manuscript, we have therefore added a new and concise analysis in the Results section illustrating how evapotranspiration and recharge under different forest management scenarios respond to interannual (wet vs. dry years) and seasonal variability. This is presented in added Figure 10 and the corresponding Results section, which quantify monthly differences in water balance components between wet and dry years for contrasting forest types, canopy densities, and rooting scenarios. Correspondingly, the Discussion (Section 5.2) has been expanded to interpret these dynamic responses and highlight how vegetation structure modulates hydroclimatic sensitivity across contrasting years.

Minor suggestions:
Q5. The structure of the manuscript should be thoroughly revised and streamlined to help the reader understand the study approach. It introduces concepts that are unnecessary to understand the results and discussion (e.g. mulching) or that are disregarded by the chosen methodology (e.g. effective calibration

and equifinality, or dynamic, species-specific root distributions). Moreover, model calibrations to grassland, cropland (and agroforestry?), are not used except for Table 3 (and Table S2).
Reply to Q5: We thank the reviewer for this constructive comment. In the revised manuscript, we will streamline the Study Area and Methods sections to enhance clarity and focus on the elements directly relevant to the modeling framework and scenario analysis. Specifically, we will remove or condense non-essential information or concepts—for example, the brief mention of mulching in Section 2.1 (Study Area)—as this process is not relevant to our modeling framework and will be deleted.

We have also clarified the calibration procedure (see also response to Q9) by more clearly describing the two-step calibration process and explaining how the retained parameter sets were used for final simulations. To address the reviewer's concern about equifinality, we have included parameter probability density plots (PDFs) for all calibrated parameters at each real site to visualize the range and convergence.

Regarding the model calibrations for grassland, cropland, and agroforestry, this point is also addressed in response to Q6. As explained, the main aim of this study was not to build independently calibrated models for each site, but to develop a generic forest-management scenario framework. Site-specific calibrations (Table 3 and Table S3 in revised version) were used to test model transferability and robustness, while the scenario experiments focused on varying vegetation-related parameters—mainly Leaf Area Index (LAI) and the root-distribution factor (β)—under consistent soil and climatic conditions. Importantly, as also noted in our reply to Q1, the revised version has explicitly described how vegetation parameters (such as rE, α) were transferred from the calibrated site models (broadleaf, conifer, and agroforestry) into the generic framework to ensure physical consistency as well as transparency and reproducibility.

Q6. It is unclear whether the model fitted to agroforestry has been used anywhere else than in Table 3. Please clarify. Also note that Table S2 indicates the BF model to have a calibrated Lmax parameter that differs from the AF model. This finding additionally corroborates the invalidity of the extrapolation approach mentioned earlier in this review.
Reply to Q6: We thank the reviewer for this comment. In the previous version, the model fitted to the agroforestry (AF) site was indeed only shown in Table 3. As explained above, in the revised manuscript, we have re-used the vegetation parameters (rE, α) derived from all calibrated forest sites (broadleaf, conifer, and agroforestry) within the generic framework.

As mentioned in our reply to Q2, we acknowledge that Table S2 in the previous submission mistakenly presented the calibrated ranges as initial parameter ranges. We have provided the corrected version of Table S2 (now Table S3 in the Supplementary Material) in this reply report for clarity and reference, and also in the revised supplementary material. The slight differences in the calibrated Lmax values between the broadleaf forest (BF) and agroforestry (AF) sites are realistic given site-specific soil conditions and do not indicate an error. Instead, they reinforce the rationale for keeping soil parameters unchanged and focusing on vegetation changes within this generic scenario framework.

Q7. I suggest to improve the focus on the minimum of results needed to support the findings, instead of representing the model output in various forms. Some Figures and Tables are unclear (e.g Table 1) or redundant (e.g. Fig 7/8 or Fig. 4d = sum of 4b/c) and should be reconsidered. Also consistent color schemes (e.g. throughout Figures 3,5,6,11) would help the reader.
Reply to Q7: We thank the reviewer for this valuable comment and fully agree that the presentation of results can be streamlined much more to improve focus and readability. To address these points, we have revised and simplified the figures and tables accordingly, as detailed below.

(a) Table 1 summarizes soil properties and soil moisture statistics at the broadleaf forest site. It has been extended to include data for all monitored forest sites (e.g., broadleaf, conifer forest, and agroforestry).

(b) Figures 7 and 8 (previous version) describe ecohydrological responses across forest types and management scenarios in annual mean form. Figure 7 presents the full-matrix (heatmap) visualization, whereas Figure 8 shows the same relationships as sensitivity curves. To simplify the main text, we have retained Figure 8 in the main manuscript and move the Figure 7 to the Supplementary Material, where it is now presented as Figure S10.

(c) Following the reviewer's suggestion, since panel Figure 4d represents the sum of 4b and 4c, we have removed panels 4b and 4c and retained 4d as the main summary figure, where it is now presented as Figure 5.

(d) We have unified the color palette across the revised manuscript to ensure consistent representation of forest types and water flux components. Specifically, Figs. 6 and 11 use the same color scheme, while Figs. 5, 9, and 10 share a unified scheme. In line with the editor's guidance (Mario Ebel), all revised figures have also been checked for accessibility to readers with color-vision deficiencies using the Coblis – Color Blindness Simulator.

Revised Table 1. Summary of observed soil types and soil moisture data at the three forest sites.

Site	Soil Type	Texture	Layer	Soil Moisture (mm)				Period
				Max	Min	Mean	SD	
Broadleaf forest	Brown Earth	Loamy sand/sand	0 to 10 cm	26.3	3.5	13.7	6.3	2018.6-2024.12
			10 to 30 cm	56.2	6.9	24.7	11.7	
			30 to 100 cm	147.5	25.8	71.7	33.5	
Conifer forest	Gley (Sand)	Sand, compacted	0 to 10 cm	28.7	8.6	17.3	7.1	2019.3-2024.12
			10 to 30 cm	53.8	2.6	21.8	12.3	
			30 to 100 cm	34.7	2.7	15.9	8.0	
Agroforestry	Podsolic Brown Earth	Loamy sand/sand	0 to 10 cm	32.1	10.4	21.3	7.8	
			10 to 30 cm	53.4	7.2	29.8	13.5	
			30 to 100 cm	223.6	86.8	163.4	42.0	

Q8. If available, the use of d18O in combination with d2H might help to distinguish evaporation from mixing effects (e.g. Penna 2018) and thus improve model calibration.
Reply to Q8: We thank the reviewer for this valuable suggestion. We agree that combining δ^{18}O and δ^{2}H can better distinguish evaporation from mixing effects (Penna et al., 2018) and thus has the potential to improve model calibration. In this study, however, we used δ^{2}H only, following recent isotope-aided ecohydrological modelling applications in this region (e.g. Landgraf et al., 2023), where δ^{2}H provided sufficient sensitivity to evaporative fractionation and avoided potential carbonate-related biases that can affect δ^{18}O in soil waters (Meißner et al., 2014). Nonetheless, we acknowledge the value of dual-isotope calibration and plan to explore this approach in future EcoPlot-iso developments. We have also clarified this rationale and limitation in the Discussion section of the revised manuscript.

We have added the following sentence to Section 5.3 of the Discussion:

"While this study used δ^{2}H to constrain evaporative fractionation given, the combined use of δ^{18}O and δ^{2}H (or d-excess) may help improve the separation of evaporation effects and mixing processes (e.g. Penna et al., 2018) though this was beyond the scope of this paper."

Q9. The provided description of methodology is not sufficient for reproduction, e.g. how are rL1, rL2, rl3 linked to Eq.4, how was the model re-run with the "retained parameter space", is recharge defined at the lower boundary of the simulation domain (how was the size of the domain defined and does it affect timing of the fluxes e.g. in Figure 4)?
Reply to Q9: We thank the reviewer for this valuable comment and apologize for not being sufficiently clearer. Below, we provide point-by-point clarifications how we have addressed all mentioned issues and how we have revised the Methods section accordingly to improve reproducibility.

(1) Definition of rL1–rL3 and linkage to Eq. (4):

As described in Section 3.2, r(z) represents the depth-dependent root water withdrawal efficiency at depth z (Eq. 4). The model domain is divided into three soil layers (0–10 cm, 10–30 cm, and 30–100 cm; Fig. 2a). For each layer, we use the midpoint depth (5, 20, and 65 cm) to calculate the corresponding root water uptake efficiencies, such as rL1 = r(5 cm), rL2 = r(20 cm), and rL3 = r(65 cm). These layer-specific efficiency factors are then used as coefficients in Eqs. (1)–(3) to represent the vertical distribution of root water uptake capacity across the three layers.

We have explicitly stated this midpoint-depth linkage in Section 3.2 of the revised manuscript as follows:

"The soil profile is discretized into three layers (0–10 cm, 10–30 cm, and 30–100 cm; Fig. 2a), and rL1, rL2, and rL3 are calculated by evaluating r(z) at the midpoint depth of each layer (z = 5, 20, and 65 cm, respectively). These layer-specific efficiency values are then used as weighting coefficients in Eqs. (1)–(3) to calculate transpiration from each of the three soil compartments."

(2) Re-running the model with the retained parameter space:

As described in Section 3.4, 100,000 parameter sets were initially generated using Latin Hypercube Sampling within a Monte Carlo framework to explore the full parameter space. Each simulation covered 25 years and produced 27 output variables. To reduce data volume, only the modified Kling–Gupta Efficiency (mKGE) values and the associated parameter sets were stored at this stage. Based on these results, we retained parameter sets that fell within the intersection of the top 60th percentile of multi-criteria mKGE values, jointly considering soil moisture and soil-water isotope metrics across all three soil depths.

The model was then re-run using these retained parameter sets to generate complete simulations and refine parameter estimates. From this refined ensemble, the 100 best-performing runs (based on the highest averaged mKGE values across the three soil layers of soil moisture na d soil wate risotope) were selected for final analysis.

In the revised manuscript, we have clarified and refined his two-step calibration procedure and explicitly describe how the 60th-percentile intersection was used to select and re-run parameter sets in Section 3.4 of the revised manuscript, as provided below for reference.

3.4 Model Calibration and Validation

The EcoPlot-iso model was calibrated using the Monte Carlo approach combined with a multi-criteria evaluation based on soil moisture and soil water isotope observations at each land use site. For each calibration, 100,000 parameter sets were generated using the Latin Hypercube Sampling (LHS) within a Monte Carlo framework (McKay et al., 1979) to broadly sample the parameter space and capture a wide range of plausible model behaviors.

The initial parameter ranges were defined based on a literature values and site-specific knowledge. Specifically, initial ranges for the radiation extinction factor (rE) were guided by vegetation-specific light attenuation coefficients from canopy gap-fraction theory (Larcher, 1975; Gigante et al., 2009), using typical reference values of 0.35 for grasslands, 0.45 for croplands, and 0.65 for forests. Initial ranges for the interception storage capacity parameter (α) were guided by scaling values reported in global syntheses of canopy interception storage (Zhong et al., 2022) and interception sensitivity studies (Barnard et al., 2014), accounting for differences in model time step and formulation. The resulting interception evaporation is consistent with observational studies indicating that canopy interception losses typically represent approximately 10–30% of annual precipitation in forested systems (Staelens et al., 2008; Llorens & Domingo, 2007).

Model performance was evaluated using the modified Kling-Gupta Efficiency (mKGE) (Kling et al., 2012), calculated separately for soil moisture (mKGEsm) and soil water isotopes (mKGEiso) at each of the three soil depth layers. Calibration followed a two-step refinement process. In the first step, based on the initial parameter ranges, parameter sets were retained only if they fell within the intersection of the top 60th percentile of all six individual mKGE metrics (i.e. soil moisture and soil water isotopes at each of the three soil depths). This intersection-based filtering ensured that retained simulations performed consistently well across all evaluated variables and depths. By retaining only the performance metrics and corresponding parameter sets, this step efficiently screened the parameter space while substantially reducing data storage requirements during the initial exploration.

In the second step, the model was re-run using the retained parameter space obtained from Step 1. For these re-run simulations, an average mKGE value across depths and variables was then used as the objective performance metric (Eq. 5), and the 100 best-performing simulations were selected for final analysis. The model parameters, their initial ranges, and the refined ranges for each of land use are summarized in Table S3 in the Supplement. To assess parameter constraints and equifinality, the probability density distributions and median values of the calibrated parameters were derived from the 100 best-performing simulations for each site (see Figure S4). These were then used to evaluate the convergence of the parameters relative to their initial ranges.

$$mKGE = \frac{\sum_{i}^{3} mKGE_{sm} + \sum_{i}^{3} mKGE_{iso}}{6} \tag{5}$$

Model parameters were calibrated using the full available observation, comprising seven years of soil moisture data and three years of soil water isotope data, in order to maximise information content under limited isotope availability (Shen et al., 2022). To additionally assess model robustness beyond a shortter calibration window, a split-sample calibration–validation experiment was conducted consistently across all land-use types. In this experiment, the model was calibrated using an earlier subset of the soil moisture and isotope observations, followed by validation against an independent soil moisture period, as isotope observations were not available for validation. Results from this split-sample evaluation, which showed good paramater transferability across most sites, are reported in Table S4 and Figures S5–S7 of the Supplement. Given this transferability, the full-period calibration was retained for the main scenario simulations, as it provides more stable parameter estimates

(3) Definition of groundwater recharge and model domain:

As illustrated in Figure 2, groundwater recharge in EcoPlot-iso is defined at the lower boundary of the 1 m soil domain as the downward percolation flux from the deepest soil layer (30–100 cm) to the groundwater. (a) This 1 m depth is consistent with previous EcoPlot-iso applications (Birkel et al., 2024; Landgraf et al., 2023; Stevenson et al., 2023), where most soil–plant–atmosphere interactions occur within the upper meter of soil. (b) It also corresponds to the range of in situ soil moisture and isotope sensors at our study sites. (c) In addition, field observations show that groundwater tables are relatively shallow (0–4 m) in this lowland catchment.

Although testing deeper domains was beyond the scope of this study, we acknowledge that extending the lower boundary beyond 1 m would increase soil water storage and delay drainage, potentially affecting recharge timing at sub-daily or daily timescales. However, when fluxes are aggregated at the monthly scale (as in Figure 5), these timing differences become negligible and the overall water balance remains largely unaffected. Therefore, the 1 m domain provides a physically justified and widely used approximation for representing recharge and evapotranspiration processes in lowland catchments.

We have made this rationale explicit in Section 3.1 of the revised manuscript, clarifying both the definition of groundwater recharge and the implications of the chosen soil domain depth for recharge timing, consistent with our response to Reviewer #1 (Q7).

“The vertical discretization follows the established EcoPlot-iso configuration and effectively represents vertical gradients in soil moisture and isotopic composition, broadly consistent with soil moisture and isotope measurements within each layer.”

“Groundwater recharge is defined as the downward percolation flux at the lower boundary of the soil domain (30–100 cm layer), corresponding to a total soil depth of 1 m.”

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