

Response to Referee Comment #2:

Dear editor, reviewer #2,

We sincerely thank the reviewer for the detailed and constructive comments, which will greatly help us to improve the clarity, robustness, and focus 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.

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 revision, we will clarify the new and exploratory nature of the framework and improve it by re-running the modelling to

- (i) distinguish soil from vegetation parameters,
- (ii) keep soil parameters constant while varying vegetation parameters (e.g., LAI, radiation extinction factor, interception capacity parameter), and
- (iii) incorporate forest-specific calibrations to represent broadleaf, conifer, and agroforestry systems more robustly.

These revisions will make the framework much more transparent and physically consistent, while maintaining comparability across scenarios. We believe that the revised version will substantially strengthen the scientific quality and readability of the manuscript, making it suitable for publication in HESS. Below, we provide detailed, point-by-point responses describing how each comment will be 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 summarizing our approach and main findings so well. 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 designed 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 especially 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 will revise the manuscript accordingly to improve its clarity and scientific rigor. As part of the revision, we will adopt a different approach to the modelling as suggested by the reviewer. We believe that these revisions will substantially enhance the quality of the manuscript, and we hope that the revised version will be considered suitable for publication in HESS.

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 apologise 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), passive interception storage mixing volume (INTp), and the root distribution parameter (β). Soil-related processes are characterized by parameters such as maximum soil moisture content (S_{max} , GW_{max} , L_{max}), saturated hydraulic conductivity (k_1 , k_2 , k_3) and nonlinear scaling parameter (g_1 , g_2 , g_3) for each soil layer. We will ensure that this is 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 any vegetation-type-specific parameterization should also involve other canopy-related parameters (as suggested by the reviewer). Accordingly, in the revised manuscript, we will refine our forest management scenarios framework by incorporating forest-type-specific parameters for broadleaf, conifer, and agroforestry systems. These vegetation parameters (rE , α , INTp) will be derived from new site-specific calibrations for each forest type, while maintaining soil parameters from the broadleaf site to ensure

comparability (see Figure S8 provided in the response to Q2). Specifically, we will use the median parameter values from 100 behavioural simulations at each site, or apply a cross-combination of the retained parameter ensembles, to represent realistic canopy characteristics across forest types. The calibrated vegetation parameters appear physically consistent, showing median patterns of rE (in absolute magnitude: broadleaf > agroforestry > conifer) and α (agroforestry < conifer < broadleaf), as illustrated in Figure S8.

We also note that the conifer site was not included in the first version because some observations—such as extremely dry deeper-layer (30-70 cm) soil moisture due to local vertical texture heterogeneity—were not representative of typical catchment conditions (see update Table 1, provided in response to Q7). However, the derived vegetation-type-specific parameters (rE , α , $INTp$) from the conifer calibration remain valuable and will be incorporated into the scenarios modeling framework of the revision to better represent forest-type differences.

We will further clarify that the root distribution parameter (β) will not be fixed as vegetation-specific in the scenario modelling framework. As shown in Figure S8, the β value at the conifer site indicates a higher near-surface density, 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, we considered β as part of the scenario dimension representing variations in root water uptake efficiency with depth—such as those associated with forest age, 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 highly 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 will incorporate vegetation-type-specific parameters (rE , α , $INTp$) derived from the calibrated real sites, further quantitative comparison is in our view not essential. Instead, we will 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 will use the validated vegetation-type-specific parameter sets (rE , α , $INTp$) 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 will strengthen 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 L_{max} and β . (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 parametric 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 will 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 will also add a new figure (Figure S8) 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 updated / revised Figure S8, Table S2 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 $\beta = 0$ 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, generally reflecting deeper rooting in forest sites and shallower rooting in cropland and grassland. 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 $\delta^2\text{H}$) are well reproduced. To address this, in the revision, we will explicitly include 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 will expand 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.

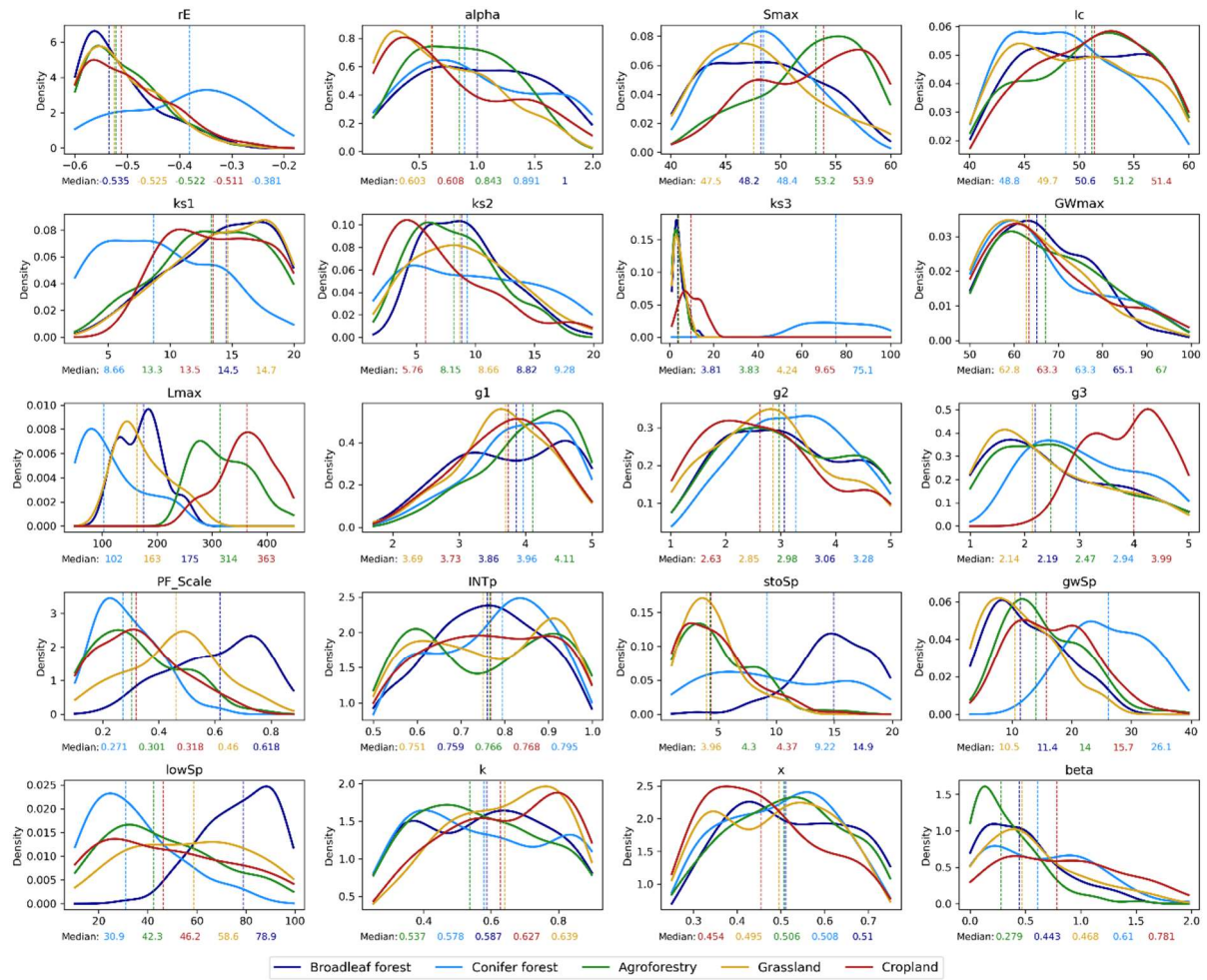


Figure S8. Probability density distributions of the 20 calibrated ecohydrological parameters for five land-use types (broadleaf forest, conifer forest, agroforestry, grassland, and cropland) based on 100 behavioural simulations from the EcoPlot-iso model. Each panel represents one parameter, with kernel 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 S2. 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	[-0.6, -0.1]	-0.598	-0.535	-0.308
		CF		-0.599	-0.381	-0.182
		AF		-0.599	-0.522	-0.257
		GL		-0.600	-0.525	-0.283
		CL		-0.598	-0.511	-0.264
α	Interception storage capacity parameter (mm per unit of LAI)	BF	[0.1, 2.0]	0.123	1.001	1.993
		CF		0.121	0.891	1.951
		AF		0.127	0.843	1.758
		GL		0.107	0.603	1.745
		CL		0.104	0.609	1.936
S_{max}	Maximum soil moisture content in the upper soil compartment (mm)	BF	[40, 60]	40.080	48.202	59.032
		CF		40.541	48.439	57.821
		AF		41.776	53.206	59.903
		GL		40.194	47.507	59.820
		CL		40.531	53.894	59.962
Ic	Soil infiltration capacity (mm/day)	BF	[40, 60]	40.163	50.559	59.845

		CF		40.260	48.785	59.989
		AF		40.048	51.176	59.999
		GL		40.111	49.657	59.924
		CL		40.100	51.396	59.843
<i>ks1</i>	Saturated hydraulic conductivity of the upper soil compartment (mm/day)	BF	[1, 20]	4.533	14.540	19.951
		CF		2.320	8.660	19.668
		AF		4.388	13.316	19.844
		GL		4.114	14.656	19.930
		CL		6.411	13.468	19.961
<i>ks2</i>	Saturated hydraulic conductivity of the lower soil compartment (mm/day)	BF	[1, 20]	3.993	8.816	19.060
		CF		1.516	9.277	19.693
		AF		2.760	8.147	16.426
		GL		1.905	8.660	19.393
		CL		1.350	5.763	19.858
<i>ks3</i>	Saturated hydraulic conductivity of the deeper soil compartment (mm/day)	BF	[1, 20]	1.040	3.809	13.291
		CF	[50, 100]	51.940	75.149	99.879
		AF	[1, 20]	1.017	3.831	11.877
		GL	[1, 20]	1.045	4.245	10.895
		CL	[1, 20]	1.337	9.655	19.841
<i>GWmax</i>	Maximum soil moisture content in the lower soil compartment (mm)	BF	[50, 100]	50.058	65.115	95.584
		CF		50.180	63.310	98.699
		AF		50.198	67.032	94.860
		GL		50.137	62.785	98.715
		CL		50.222	63.300	99.462
<i>Lmax</i>	Maximum soil moisture content in the deeper soil compartment (mm)	BF	[100, 300]	102.369	175.049	260.336
		CF	[50, 250]	50.198	101.915	249.346
		AF	[250, 450]	250.178	314.194	447.936
		GL	[100, 300]	100.485	163.030	295.118
		CL	[250, 450]	254.509	362.647	446.292
<i>g1</i>	Nonlinear scaling parameter for the upper soil compartment	BF	[1, 5]	2.078	3.862	4.994
		CF		1.973	3.962	4.990
		AF		2.211	4.110	4.993
		GL		1.707	3.692	4.999
		CL		2.024	3.735	4.958
<i>g2</i>	Nonlinear scaling parameter for the lower soil compartment	BF	[1, 5]	1.053	3.064	4.994
		CF		1.283	3.281	4.989
		AF		1.139	2.978	4.988
		GL		1.049	2.854	4.894
		CL		1.022	2.626	4.887
<i>g3</i>	Nonlinear scaling parameter for the deeper soil compartment	BF	[1, 5]	1.006	2.191	4.998
		CF		1.702	2.938	4.967
		AF		1.161	2.469	4.998
		GL		1.000	2.139	4.861
		CL		2.235	3.993	4.979
<i>PFScale</i>	Preferential flow path parameter (dimensionless)	BF	[0.1, 0.9]	0.217	0.618	0.880
		CF		0.108	0.271	0.623
		AF		0.101	0.302	0.755
		GL		0.105	0.460	0.806
		CL		0.110	0.318	0.715
<i>IntSp</i>	Passive interception storage mixing volume (mm)	BF	[0.5, 1]	0.502	0.759	0.999
		CF		0.516	0.795	0.997
		AF		0.506	0.766	0.998
		GL		0.506	0.751	0.993
		CL		0.500	0.769	0.995
<i>StoSo</i>	Passive upper soil storage mixing volume (mm)	BF	[1, 20]	3.173	14.941	19.809
		CF		1.364	9.220	19.236
		AF		1.089	4.296	16.457
		GL		1.048	3.964	12.078
		CL		1.003	4.372	15.261
<i>gwSp</i>	Passive lower soil storage mixing volume (mm)	BF	[3, 40]	3.159	11.427	27.790
		CF		11.950	26.103	39.548
		AF		3.383	13.983	36.908
		GL		3.006	10.503	25.603
		CL		3.751	15.748	35.511
<i>lowSP</i>	Passive deep soil storage mixing volume (mm)	BF	[10, 100]	32.718	78.886	98.972
		CF		10.304	30.913	84.782
		AF		11.818	42.310	97.798
		GL		10.906	58.591	98.924
		CL		10.600	46.176	99.389
<i>k</i>	Seasonality factor in the Craig-Gordon model (dimensionless)	BF	[0.25, 0.9]	0.262	0.587	0.899
		CF		0.262	0.578	0.899

		AF		0.251	0.537	0.898
		GL		0.250	0.639	0.885
		CL		0.265	0.627	0.896
x	Water vapor mixing ratio in the Craig-Gordon model (dimensionless)	BF	[0.25, 0.75]	0.251	0.510	0.749
		CF		0.266	0.508	0.745
		AF		0.251	0.506	0.744
		GL		0.251	0.495	0.748
		CL		0.252	0.454	0.748
		BF		0.009	0.443	1.423
β	Root distribution factor (dimensionless)	CF	[0, 2]	0.001	0.610	1.967
		AF		0.004	0.279	1.514
		GL		0.029	0.468	1.698
		CL		0.007	0.781	1.973

Revised Table 3. Kling–Gupta Efficiency (KGE) values for soil moisture and soil water isotopes ($\delta^2\text{H}$), comparing observed and mean simulated values at each land-use site.

Sites	Soil moisture			Soil water isotope $\delta^2\text{H}$		
	Upper soil compartment	Lower soil compartment	Deep soil compartment	Upper soil compartment	Lower soil compartment	Deep soil compartment
Broadleaf Forest	0.60	0.69	0.78	0.58	0.74	0.62
Conifer forest	0.59	0.60	0.67	0.68	0.81	0.52
Agroforestry	0.72	0.76	0.78	0.81	0.84	0.78
Grassland	0.86	0.69	0.71	0.72	0.77	0.59
Cropland	0.46	0.61	0.73	0.82	0.84	0.31

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) might be redundant and that a clearer presentation would strengthen the paper. In the revised manuscript, as suggested, we will streamline the results by removing Figs. 4b–4c, as Fig. 4d already represents the sum of 4b and 4c (as also noted in Q7) and by moving some of the less central visualizations (e.g., current Figs. 7 and 10) to the Supporting Information.

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 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 seems we did not present this sufficiently well. We will clarify 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 (Q_s), or d) change in soil storage. We can reduce the options, given that Q_s 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 β , 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 β .

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 $9.5 \text{ m}^2 \text{ m}^{-2}$ 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 will expand 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 investigation of temporal dynamics. While the current results primarily focus on long-term mean annual partitioning to isolate structural vegetation effects, the model is fully dynamic and resolves processes at a daily time step. In the revised manuscript, we will add 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. Correspondingly, the Discussion (Section 5.2) will be 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 will also clarify 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 will include 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 S2) 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 will explicitly describe how vegetation parameters (such as rE , α , and $INTp$) 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 L_{max} 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 mentioned above, in the

revised manuscript, we will use the vegetation parameters (rE , α , $INTp$) derived from all calibrated forest sites (broadleaf, conifer, and agroforestry) in the generic framework.

As mentioned in reply to Q2, we acknowledge that Table S2 in the previous submission mistakenly presented the calibrated ranges as initial parameter ranges. We provide the corrected version of Table S2 in this reply report for clarity and reference. The slight differences in the calibrated L_{max} 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 will revise and simplify the figures and tables accordingly, as detailed below.

(a) Table 1 summarizes soil properties and soil moisture statistics at the broadleaf forest site. To reduce redundancy, it will be moved to the Supplementary Material and extended to include data for all monitored forest sites (e.g., broadleaf, conifer forest, and agroforestry).

(b) Figures 7 and 8 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 will retain Figure 8 in the main manuscript and move the Figure 7 to the Supplementary Material.

(c) Since panel Figure 4d represents the sum of 4b and 4c, we will delete panels 4b and 4c and keep 4d as the main summary figure.

(d) We will unify the color palette across all figures (e.g., Figs. 3, 5, 6, 11) to ensure consistent representation of forest types and water flux components. In line with the editor's guidance (Mario Ebel), all revised figures will also be 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	26.28	3.50	13.67	6.30	2018.6-2024.12
			10 to 30 cm	56.19	6.86	24.68	11.70	
			30 to 100 cm	147.51	25.83	71.71	33.50	
Conifer forest	Gley (Sand)	Sand, compacted	0 to 10 cm	28.65	8.62	17.32	7.07	2019.3-2024.12
			10 to 30 cm	53.75	2.59	21.78	12.29	
			30 to 100 cm	34.70	2.68	15.85	7.96	
Agroforestry	Podsollic Brown Earth	Loamy sand/sand	0 to 10 cm	32.06	10.40	21.25	7.77	2019.3-2024.12
			10 to 30 cm	53.35	7.15	29.75	13.49	
			30 to 100 cm	223.62	86.83	163.41	41.98	

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 $\delta^{18}\text{O}$ and $\delta^2\text{H}$ 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 $\delta^2\text{H}$ only, following recent isotope-aided ecohydrological modelling applications in this region (e.g. Landgraf et al., 2023), where $\delta^2\text{H}$ provided sufficient sensitivity to evaporative fractionation and avoided potential carbonate-related biases that can affect $\delta^{18}\text{O}$ 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 will also clarify this rationale and limitation in the Discussion section of the revised manuscript.

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 apologise for not being clearer. Below, we provide point-by-point clarifications how we will address all mentioned issues and how we will revise 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 as $rL1 = r(5 \text{ cm})$, $rL2 = r(20 \text{ cm})$, and $rL3 = r(65 \text{ cm})$. 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 will explicitly state this (mid-point-depth) linkage in Section 3.2 of the revised manuscript.

(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, so only the modified Kling–Gupta Efficiency (mKGE) values and the associated parameter sets were stored to reduce data volume. Based on these results, we retained parameter sets that fell within the 60th-percentile intersection of the multi-criteria mKGE (averaged across soil moisture and soil-water isotope metrics at all three 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 (with the highest averaged mKGE values across the three soil layers) were selected for final analysis. In the revised manuscript, we will clarify this 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.

(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 4), 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 will make this rationale explicit in Section 3.1 of the revised manuscript, clarifying the choice of the 1 m domain and its implications for recharge timing.

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