Sept. 6th, 2023

Dear Dr. Coenders-Gerrits,

Thank you for your time and attention during the peer-review of our manuscript, “The seasonal origins and ages of water provisioning streams and trees in a tropical montane cloud forest.” We have replied to reviewer #1’s comments directly on the annotated PDF they submitted. Below are detailed replies to reviewer #2, with reviewer #2’s comments in *italics* and our replies in **bold**. We thank both reviewers for their thoughtful and constructive suggestions.

During the revision process, we made several improvements to the manuscript and we believe that it is ready for publication. In particular, we 1) distinguished between the soil lysimeter waters collected in riparian versus hillslope zones (in figures and text) and 2) added the new water fraction calculations for soil lysimeter waters. We have improved the figures and revised the text.

We hope that the paper will make an important contribution to the field of ecohydrology by improving our understanding of how water moves through landscapes by exploring the application of multiple metrics in hydrology (young and new water fractions) to tree branch xylem waters.

Thank you again for your support.

Sincerely,

Emily I. Burt
Postdoctoral Fellow
Chapman University
Orange, CA

Referee #2

The paper "The seasonal origins and ages of water provisioning streams and trees in a tropical montane cloud forest" by Burt et al. presents an assessment of indices of young and new water fractions of tree, soil and stream water as well as indices of the seasonal origin of these water pools in a tropical forest catchment in the Andes of Peru. Even though I find the paper generally well written, I consider that some parts of the methods and discussion sections could be further developed to support the findings of the study. Given the relevance of the paper for the isotope ecohydrology of the understudied Andean region, I consider it is a manuscript suitable for publication in HESS after some points described below are implemented in the manuscript.

General comments

Soil water isotopic data: In most figures the authors show soil water isotopic data without accounting for differences due to landscape position. However, the signals are different between those positions (valley vs hillslope). I suggest to consistently report the soil water isotopic composition results separately, as they show differences useful for interpretation. Please also note throughout the manuscript that soil water for isotopic analysis was collected at 1 m depth, as the variability in the depth and position across the landscape where soil water was collected can cause important differences in the observed isotopic signals. I also encourage the authors to check out papers in which this has been observed in other tropical montane catchments in the northern Andes (e.g., Mosquera et al., 2016; Mosquera et al; 2020; Lahuatte et al., 2022) to put their work in context and support some of their inferences yielded from the presented data.

Description of study site: The interpretation in the discussion section would benefit if the paper would include a more complete description of the study site (e.g., land use, the areal distribution, depth and properties of soils, and the vegetation characteristics such as root depth and leaf area index). Please expand the section with as much information as available, and use for interpretation.

We thank the reviewer for their comments. We are encouraged that they find the paper to be generally well-written and relevant for the field of isotope ecohydrology. We appreciate the reviewer's comments about the lysimeter locations and the importance of distinguishing between the hillslope and riparian lysimeters. Indeed, many of the comments from the other reviewer were also related to the lysimeter data. We revised all the figures in the paper to clearly illustrate the differences between the hillslope and riparian lysimeter. Additionally, we clarified the text relating to the lysimeters, to indicate whether the lysimeter data is from the hillslope or riparian zone.

Regarding the description of the study site, we agree with the reviewer's suggestion to include information about land use, areal distribution, depth and properties of soil, root depth and leaf area index. We added soil organic layer depth (Girardin et al., 2010; Wu et al., 2019), dominant plant genera (Rapp et al.,

2012), leaf area index (Girardin et al., 2014) and available information on plant root depth (Girardin et al., 2013).

Additionally, we added two of the references suggested by the reviewers from studies in tropical montane watershed in Ecuador to help contextualize the data from our study.

Specific comments:

L40-41: replace "twice monthly" in line 40 by "every two weeks" at the end of the sentence in line 41

We prefer the phrase "twice monthly" preceding "collections of precipitation, lysimeter and tree branch xylem waters," rather than describing sampling frequency at the end of the sentence. We believe the sampling frequency will be overlooked at the end of the sentence with the proposed change.

L44: It is important to highlight throughout the manuscript the depth at which soil water was collected (i.e., 1 m; L156), as the isotopic signal would likely be different if soil water would have been collected at different depths. Perhaps it would be even worth noting that soil water was collected below the root zone.

We agree that noting the soil water collection depth is important. We added clarification about the depth of soil water collection to lines 45 and 114. Though we do not have access to detailed measurements of root depth, Girardin et al. (2013) suggests that most roots are in the organic horizon, which is approximately 20–26 cm deep (Girardin et al., 2010; Wu et al., 2019).

We added the following sentence to the discussion to clarify on the tree root zone in this study:

"Though we do not have detailed measurements of rooting depth, Girardin et al. (2013) found that most roots were contained in the soil organic layer, which is approximately 20–26 cm deep (Girardin et al., 2010; Wu et al., 2019)."

L49: please add "in this study" after "2 years old", as that time step is specific for the presented monitoring setup and not general for the method applied.

We agree. This is updated.

L55: I think that the importance of the study lies on the fact that it was carried out in a humid environment, as opposed to drier environments where this type of research has been carried out before. Consider specifying this "HUMID tropical montane cloud forest".

Updated.

L122: is the reported elevation the mean catchment elevation? Please specify.

The reported elevation was the elevation of the sampling location. We updated the text to the mean elevation of the watershed.

L145: please discuss whether the spatial variability in the selection of trees at different distance from the streams could have influenced (or not) in the interpretation of the presented tree water isotopic data.

Undoubtedly there is spatial variation in the tree water isotope composition within the watershed. However, we do not believe there is sufficient evidence within the literature to hypothesize on systematic trends in plant water isotope composition with distance from the stream and this is not central to the questions that we are addressing.

L164-167: the reader would really appreciate a plot of the rainfall amount and stream water level data measured at the study site to put the finding in context in relation to the site hydrometeorological conditions. I strongly suggest the authors to include a plot of these data in the manuscript for facilitate interpretation.

We added rainfall amount and stream discharge to Figure 1.

L164 and L166: report the brand, model and accuracy of the tipping bucket used to measure rainfall amount, and the accuracy of the type and accuracy of the logger used to measure water level.

For the rain gauge, we added the following to line 129: (Tipping bucket raingauge model TB3; Hydrological Services PTY LTD; Liverpool, NSW, Australia; accuracy ± 2 %),

And for the water level logger, we added the following to line 171: accuracy ± 0.2 %

L184-187: Since the samples were analyzed in different laboratories, were some replicate samples analyzed using both instruments to correct for potential analytical discrepancies? If yes, please explain; if not, please discuss the implication in the manuscript.

This concern was raised by Reviewer #2, and we replied as follows:

All three labs use internationally accepted standards that are governed by IAEA (V-SMOW). We carried out post-processing of samples using appropriate calibration, drift and memory correction procedures.

While it would have been ideal to process all samples on the same instrumentation, this was not practical especially given the multi-year duration of

this research project (for example, during that time some of the instruments were decommissioned). Many current studies mix precipitation samples processed by CRDS with xylem water samples processed by IRMS. Moreover, there have been dozens of meta-analyses in isotope ecohydrology that have taken no precautions to account for inter-lab variability. Given the congruence of the data, we have no evidence for there to be systematic errors.

Additionally, each lab utilized rigorous quality control measures:

Chapman Picarro – 4 standards and 5 measurements of an independent QC sample

LBL LGR – 6 measurements of an independent QC sample

Caltech LGR – used sample-standard bracketing and re-ran 3 certified standards every 5 samples.

L188-190: was potential contamination in water samples assessed (e.g., using the ChemCorrect software)? If yes, please explain how this was accounted for and report the number of reanalyzed or discarded samples; if not please discuss the potential implication of contamination if the reported isotopic signals, particularly for tree water data.

Tree water samples were analyzed via IRMS, which precludes the organic compound interference that can occur when analyzing branch xylem waters via isotope ratio infrared spectroscopy.

Stream and soil lysimeter waters were filtered to 0.2µm when collected per standard practice in the literature.

L200: I think the correction was only carried out for xylem water samples? Please update if needed.

We updated line 204 to provide clarity that only the xylem water isotope values were corrected for the SOI and young water fraction calculations.

L210-211 values >+1 and <-1 are reported in Fig. 4. Please describe what they mean.

We added the following text to explain the SOI values outside of the +1 to -1 range:

"Given the high variation in precipitation isotopes, individual xylem water samples responding to a given precipitation event may fall outside of the average seasonal precipitation endmembers, resulting in SOI greater than +1.0 or less than -1.0."

L237: I believe it should be Eqts. 4-6 instead of 4-7. Please update if needed.

Updated.

L264: not sure what "cloud waters" means (e.g., fog, drizzle, or the combination of both). Please specify. Also, isn't the isotopic composition of cloud water actually enriched as it plots above the LMWL? Clarify if needed.

"Cloud waters" refers to cloud water vapor, sampled via a line pumped through a cold trap (from Clark et al., 2014 HESS).

We revised the text to state that cloud water is enriched in deuterium relative to the LMWL.

L270: I suppose the corrected data is shown in the paper figures. If so, please specify in the caption and/or legend of the figures. I would also be useful for the reader to see how the correction changed the measured isotopic composition in supplementary material for reference.

The data in Figure 2 are the uncorrected tree branch xylem water isotope ratios. The rest of the tree branch xylem water isotope displayed in Figure 3 onwards are corrected for evaporation. We added supplementary figure S2, which shows how the data is influenced by the evaporation correction.

L306: there is no fig S2 in the manuscript of supplementary material. Please revise and correct as needed.

We revised the supplement: there are now Figures S1–S5, all properly referenced in the text.

L317: specify the geomorphic position where samples were collected.

Throughout the manuscript, we now carefully distinguish between riparian and hillslope lysimeters.

L387-388: I am not convinced that sampling frequency could cause the observed attenuation in soil water isotopic data. I think this relates to the soil water being sampled at 1 m depth only. I think that the papers suggested in the general comment on this subject above could help to better interpret and support the presented findings.

We added a reference to Lahuatte et al. (2022) in this sentence of the manuscript to highlight the similar attention of soil water isotope signals at 1 m depth. However, as also pointed out by Lahuatte et al., there can be a rather diverse range of hydrologic behaviors that occur because of changes in soil and bedrock. For this reason, we have concerns about drawing closer comparisons between the observations from the study site in this paper and the observations from the

study sites in the four papers recommended by the reviewer. Our study site is heavily forested and underlain by a weathered shale bedrock with poorly classified soils. The study sites in the papers recommended by the reviewer have volcanic bedrock, some contain wetlands/paramo, and some are not forested — complicating comparison to data from our study site.

L396-397: I am not entirely convinced of this potential explanation of the differences in the isotopic composition of soil water. I think this could be related to differences in the water storage capacity of soils at different geomorphic positions across the landscape as previously observed in other montane Andean catchments (e.g., Lazo et al., 2019). This is why reporting the properties, areal extent and depth of soils across the catchment is important for interpretation.

We added a citation to Lazo et al. (2019) in this section of the paper.

L425: what about ecophysiological processes (e.g., the possibility of foliar water uptake due to the influence of fog/cloud water at the study area)? Please expand the discussion considering this point.

The primary effect of clouds and leaf wetting is the suppression of transpiration, which would slow plant water turnover time and thus the uptake of water with a distinct isotopic signal (Gotsch et al., 2014). Foliar water uptake may refill leaves and very small branches at times when there is a significant plant water deficit, but is unlikely to consistently affect water isotope ratios (Goldsmith et al. 2019). While there is evidence that common tree species at this site have the capacity for foliar water uptake (Goldsmith et al., 2017), there is no strong evidence that would suggest sufficient and regular foliar water uptake; precipitation exceeds AET, which means leaf water deficits are minimal.

L512: replace "high" by "strong"

Done.

L519: this is likely because the lysimeters were placed below the root zone. This is why I strongly suggest that the sampling depth for soil water must be reported consistently throughout the manuscript.

We have revised the text to now report the sampling depth consistently throughout the manuscript.

Fig 2: Classify soil water isotopic composition into different locations across the landscape. E.g., the text in the caption of Fig 4 clearly indicates this, and I think it would be valuable to specify this in all figures where this is not clear.

We thank the reviewer for this suggestion. Figures and text distinguish between hillslope and riparian lysimeters.

Fig 3. Same as in Fig. 3

In Figure 3, we now distinguish the data from the hillslope and riparian lysimeters.

SUGGESTED REFERENCES TO CONSIDER

Lahuatte, B., Mosquera, G.M., Páez-Bimos, S., Calispa, M., Vanacker, V., Zapata-Ríos, X., Muñoz, T., Crespo, P., 2022. Delineation of water flow paths in a tropical Andean headwater catchment with deep soils and permeable bedrock. Hydrol. Process. 36, e14725. https://doi.org/10.1002/HYP.14725.

Lazo, P.X., Mosquera, G.M., McDonnell, J.J., Crespo, P., 2019. The role of vegetation, soils, and precipitation on water storage and hydrological services in Andean Páramo catchments. J. Hydrol. 572, 805–819. https://doi.org/10.1016/J.JHYDROL.2019.03.050.

Mosquera, G., Crespo, P., Breuer, L., Feyen, J., Windhorst, D., 2020a. Water transport and tracer mixing in volcanic ash soils at a tropical hillslope: a wet layered sloping sponge. Hydrol. Process. 34, 2032–2047. https://doi.org/10.1002/hyp.13733.

Mosquera, G.M., Célleri, R., Lazo, P.X., Vaché, K.B., Perakis, S.S., Crespo, P., 2016b. Combined use of isotopic and hydrometric data to conceptualize ecohydrological processes in a high-elevation tropical ecosystem. Hydrol. Process. https://doi.org/10.1002/hyp.10927.