Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2019-543-AC1, 2019

Hydrology and Earth System Sciences
Open Access
Discussions

Interactive comment on "Disentangling temporal and population variability in plant root water uptake from stable isotopic analysis: a labeling study" *by* Valentin Couvreur et al.

Valentin Couvreur et al.

y.rothfuss@fz-juelich.de

Received and published: 4 December 2019

Authors responses to Anonymous Referee #1

RC| Couvreur and colleagues present an interesting isotopic labelling experiment and innovative simulations of the processes in the soil-roots interactions. Their study is addressing current research gaps and will thus be of interest to the readership of HESS. The manuscript is well prepared and the figures are mostly informative. I provide two general recommendations and several minor technical comments below. I recommend publication after addressing these comments.

AC| Dear reviewer, we thank you for your general comments as well as technical corrections of our manuscript! You will find our answers listed below:

RC| General aspects:

RC| The "rollercoaster hypothesis" and the "swarm pattern hypothesis" both focus on the variation of δ18O in tiller across plants and/or over time, respectively. However, the studied system is likely to be more complex due to heterogeneity of the water flow/capillary rise. Do you see a chance to improve the modelling results when moving from a uniform flow/capillary rise to some kind of dual-permeability approach accounting for potential subsurface isotopic heterogeneity?

AC| This is an excellent comment. Other sources of variability may indeed have affected the variability of measured δ18Otiller and ψleaf, such as: - The lateral heterogeneity of soil water isotopic composition (as mentioned by the referee). The idea is that water in micropores is less mobile than water in meso- and macropores, so that it is likely that, in the lower half of the profile, the capillary rise of labelled water affected the signature of water in meso- and macropores more than in micropores. If roots have more access to meso- and macropore water, then the water absorbed by roots would be isotopically enriched, as compared to the "bulk soil water" characterized experimentally. The importance of this possible bias depends on soil texture and heterogeneity (e.g. existence of more isolated "pockets" of soil or compact clusters), as well as on the speed of water mixing between mobile and immobile water fractions. Including this process in the modelling would necessitate sufficient observations to estimate the aforementioned properties, and ideally some quantification of the lateral heterogeneity of soil water isotopic composition at the micro-scale. We think it would be an excellent idea for a future study, but including it in the model in this study would involve extrapolating simulations beyond what we can justify with the measured dataset;

- The lateral heterogeneity of bulk soil water potential and soil water content (or the observational errors) may have slightly affected our estimation of soil water potential, and in turn our predictions of root water uptake distribution. The experiment was designed to maximize vertical gradients and minimize lateral bulk soil water potential gradients by wetting soil from the bottom and letting it drain, so we consider that any lateral heterogeneity must be small. However, in the revised version of the MS we will test the impact of deviations of soil water potential, that could be due to observational errors, on our results;

- The lateral heterogeneity of soil hydraulic properties and root distribution may also have participated to the generation of lateral soil water potential heterogeneities, particularly in undisturbed soils. If one had access to data on lateral heterogeneity of soil properties and rooting density, it would be possible to simulate 3-D soil-root water flow with a tool such as R-SWMS (Javaux et al., 2008), using a randomization technique for soil properties distribution as in Kuhlmann et al. (2012), in order to obtain estimations of the relative importance of this type of heterogeneity on δ18Otiller and ψleaf variability. However, in this experiment we consider that the substrate and rooting heterogeneity were minimized by the sieving of the soil, and thus focused on the vertical profiling in measurements and modelling. - Overall, our treatment of the soil media in this experiment (sieving, irrigating from the bottom) makes it different from soils in natural systems, which are most likely more heterogeneous laterally. This method allowed us to study specifically the impact of the vertical component of soil water isotopic signature on tiller water isotopic signature. It also justified the use of a simplistic 1-D model adapted to the vertically resolved measurements. This will be clarified in our revisions, and the perspective of comparing bulk soil water isotopic signature to the signature of "mobile water" in meso- and macropores will be discussed.

RC| I was missing a discussion of the uncertainties regarding for example soil moisture estimates and the impact of such uncertainties for the interpretation regarding potential processes (i.e., hydraulic lift).

AC| We agree that this should be added (see second bullet point in our reply to the previous comment).

RC| I further think that the implications of their interesting findings (i.e., no match between the ensemble of various simulations and the observations; Fig. 5) for both field studies labelled or with natural isotope compositions and the modelling of the soil-root interactions could be made clearer. This way, the manuscript might have a higher impact and could provide recommendations to overcome limitations in observation techniques and modelling approaches.

AC| We will remove the regression lines in Figure 4 for which the p-value of the linear model was higher than 0.01, hoping that it will clarify the absence of significant linear correlation between given hydraulic (e.g., Transpiration flux T) and isotopic variables (e.g., oxygen stable isotopic composition of tiller water, δtiller). We will provide in a separate discussion section 3.3 "Progresses and Challenges in soil water isotopic labeling for RWU determination" recommendations for overcoming the aforementioned limitations.

RC| I appreciate that the authors will upload the data of the study. Are they further intending to make the model code available?

AC| We are indeed, as it may be useful to the scientific community working on such data. We will upload it as soon as the MS is accepted.

RC| Technical comments:

RC| L 77: monotonic gradient? Consider sinusoidal variability across the depth, which would cause issues of identifiability

AC| You are right! It will read: "…the soil water isotopic composition depth gradient is strong and monotonic (thus avoiding issues of identifiability)"

RC| L 80: Not only GW, also due to increasing dispersion with depth – even if the GW table is several meters deep

AC| We agree, this will be mentioned as well at this point of the introduction

RC| L 100: This paragraph is kept quite general after a very informative introduction. I suggest to be more specific and especially pose hypothesis or specific research questions.

AC| Indeed, the objectives were not clearly stated in our initial submission. We will write: "Building on the work of Meunier et al. (2017a), the objective of the present study is to (i) model in a physically-based manner (i.e., by accounting for soil and plant environmental factors) the temporal dynamics of the isotopic composition of RWU of a population of Festuca arundinacae cv Soni (tall fescue) during a semi-controlled experiment following an isotopic labeling pulse of deep soil water, (ii) investigate the implication of the model-to-data fit quality in terms of meaningfulness of the isotopic information to reconstruct RWU profiles, and finally (iii) confront the simulated root water uptake profiles with estimations obtained on basis of isotopic information alone (i.e., provided by a Bayesian mixing model)."

RC| L 117: Since you provide the variable and unit for soil moisture, you probably should also add that to matric potential.

AC| It will be done, thank you!

RC| L 140: replace "isotopic" with "δ18O"

AC| Consider it done as well.

RC| L 140: How was the sampling done? Soil corer? How much soil was sampled?

AC| Soil was sampled before (DaS 166 - 15:45) and after labeling on DaS 167 - 07:00, DaS 167 - 17:00 and DaS 168 - 05:00 using a 2 cm diameter auger through the transparent polycarbonate side of the rhizotron. This will be reported in the revised version of the manuscript.

RC| L 149: provide info about temperature, applied vacuum and time of extraction

AC| Water from plant (i.e., tillers and leaves) and soil samples were extracted by vac-

uum distillation for 14 to 16 hours depending on the sample mass (e.g., ranging between 18 to 28 g for soil) at temperatures of 60 and 90°C, respectively. The residual water vapor pressure at the end of each successful extraction procedure invariably reached 10–1 mbar. This will be specified as such in the revised version of the manuscript.

RC| L158: Not sure what "(95 m root (g root)$--$1)." Means

AC| We will remove "root" from the mention of the dimension for clarifications, so it will simply read "m g–1".

RC| Figure 1: The circles connecting the bottom of the profile of Figure 1a and the histogram of 1c are more confusing than helping. I suggest to get rid of them. The same would apply for the arrow connecting to 1b.

AC| Done. Fig. 1 will be changed accordingly!

RC| L 172: All variables should be explained here. For example Lpr is explained in L 216

AC| That is right. We will explain the meaning of Lpr higher up.

RC| L 181: The variable "n" should be briefly explained as one of the MVG parameters. Also, consider adding n and Sej to the list of variables.

AC| We agree with the referee and will make the suggested changes in the revised version of the MS.

RC| L 209: Please define conditions for exudation. I believe it is for Sj<0, but not sure.

AC| The referee is correct. This will be clarified in the revised version of the MS.

RC| L 239: I do not see how the soil moisture varied notably at 1.3 m depth. What do you mean here? How comes that you refer to 12:00 and 20:00 on DaS 167, while that is not shown in Figure 2a?

AC| Thank you, this will be corrected as: “Soil moisture remained unchanged in the top 25 cm during the sampling period (θ = 0.08 $\pm$0.00 m3 m–3) as well as at –1.30 m from DaS 166 - 15:45 to DaS 168 - 05:00 (θ = 0.33 $\pm$0.01 m3 m–3).”

RC| L 243: Again, you refer to a time (7:30), which is not shown in the Figure and you should refer to it as soil labelled” and not “soil” to be consistent with Figure 2.

AC| Indeed! This will be also corrected as “δsoil reached a value of 36.9 ‰ at –1.50 m on DaS 167 - 17:00.”

RC| L 244: “lead us to assume” or “leads to the assumption” AC| Thank you. We will take you first proposition.

RC| L 262: It is unclear which of the correlations are describe a significant relationship. I suggest to only draw the regression lines for significant relationships in Figure 4.

AC| Thank you for this suggestion: we will remove the regression lines for which the p-value of the linear model was higher than 0.01 and indicate this also in the caption of Figure 4:

RC| L 281: replace “et” with “and”

AC| Thank you, this will be done.

RC| L 298: Unclear what is meant with “over all dataset”. I believe you mean the 60 different root system classes. Please be more specific.

AC| That is right. We will clarify the sentence as follows: “However the predicted versus observed average δtiller and its standard deviation including all plant classes and observation times were not significantly different (. . .)”.

RC| L 315: It seems to me that in-situ measurements would overcome these limitations. One could sample in parallel several plants and thus, observe the temporal dynamics at individual plant level.

AC| We could not agree more! We will mention these new methodological developments in a dedicated new subsection 3.3 “Progresses and Challenges in soil water isotopic labeling for RWU determination”

RC| L 319: What is the expected accuracy of your volumetric soil moisture measurements. Given that you derived this from gravimetric water content and a bulk density, which was assumed to be constant in the repacked soil. However, relatively small differences in bulk density of just a few g cm$-$3will affect the estimates of the volumetric water content. It would be good to account for such uncertainties in this discussion.

AC| The hypothesis of a constant value for b across the reconstructed soil profile could be validated from the quality of the linear fit (coefficient of determination R2 = 1.0) between the θ values measured by the sensors at the six available depths and (–0.05, –0.10, –0.30, –0.60, – 1.05 and –1.30 m) and those computed from θgrav. We will add this information to the text. Yet, the impact of observational errors will be investigated as a sensitivity analysis in the revised MS.

RC| L 325: What do you mean with “significantly higher”? Did you apply a statistical test? I believe that you mean that the difference is higher than the measurement uncertainty.

AC| Yes, the p-value is 1.4e-04, which we will add to the revised version of the MS.

RC| Figure 6b: The title says “standard error”, but the caption says “standard deviation”. Which one is it? Please correct.

AC| It is standard deviation, thank you for spotting this typo. We will update Figure 6b accordingly.

RC| L 360: the upper half of the soil profile

AC| Done, thank you!

RC| L 367: “water addition is localized and not broadcasted in the soil” is unclear. What do you mean with “broadcasted”?

AC| We propose not to use the term “broadcasted” anymore and to write instead: “This case study highlights (i) the potential limitations of water isotopic labeling techniques for studying RWU: the soil water isotopic artificial gradients induced from water addition result in an improvement in RWU profiles determination to the condition that they are properly characterized spatially and temporally.”

RC| L 370: “simple”? In addition to the usual struggle of assessing meaningful MVG parameters to describe the soil water transport, also like for example Lpr and Kaxial are needed, which are not easily derived, but its estimation adds to the uncertainty of the uptake depths.

AC| We meant “simple soil-root model”, relative to (i) complex soil-root models, which include more parameters (e.g. profile of root hydraulic properties changing with root segment age, etc.), and (ii) absent soil-root models, in the typical Bayesian approach. We will clarify that more measurements are needed than with no soil-root model. Extra measurements could be limited if appropriate assumptions on the model parameters can be done (e.g. using soil pedotransfer functions, root hydraulic properties reported in the literature, etc.).

Javaux, M., Schroder, T., Vanderborght, J., and Vereecken, H.: Use of a three-dimensional detailed modeling approach for predicting root water uptake, Vadose Zone J., 7, 1079-1088, doi:10.2136/Vzj2007.0115, 2008. Kuhlmann, A., Neuweiler, I., van der Zee, S. E. A. T. M., and Helmig, R.: Influence of soil structure and root water uptake strategy on unsaturated flow in heterogeneous media, Water Resour. Res., 48, doi:10.1029/2011wr010651, 2012. Meunier, F., Rothfuss, Y., Bariac, T., Biron, P., Durand, J.-L., Richard, P., Couvreur, V., J, V., and Javaux, M.: Measuring and modeling Hydraulic Lift of Lolium multiflorum using stable water isotopes, Vadose Zone J., doi:10.2136/vzj2016.12.0134, 2017a.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-543, 2019.