Interactive comment on "Isotopic approaches to quantifying root water uptake and redistribution: a review and comparison of methods" by Youri Rothfuss and Mathieu Javaux

Anonymous Referee #2

General comments: The manuscript aims to compare different methods to locate root water uptake depth. I understand that it is a review paper, however, it is rather long, way too complex, and unfortunately hard to follow (it even comes with an appendix). This is mainly due to the many formulas that are presented and which disturb the text flow.

> *The authors present only equations that are needed to understand all three methods (graphical inference, two to n end-member mixing models) plus the physically based approach of Couvreur et al. (2012). The appendix section was also meant in this way: not to disrupt the text flow. You also noted that sections 2.1 and 2.2 sections do not – on purpose – incorporate equations.*

I agree that a method comparison is needed but the manuscript is blown up with a lot of "basic isotope knowledge" which for my feeling is not necessary in such extent. I would suggest to reduce the length of the whole manuscript and focus on what differentiates the three methods to be compared.

> *We will reduce sections 2.1 and 2.2 lengths significantly in a revised version of the manuscript.*

Further, the authors should only present equations which are really needed to understand the method comparison. I believe that this would increase the readability.

> *Please see the answer to you first general comment.*

Concerning the presented figures, I would recommend to keep them simpler as they should generally be self-explaining and not as complex as they are now.

> *Could you give some specifics? How the results were illustrated is directly inspired from the reviewed literature. Even though some figures might not be straightforward to all readers at first, the authors tried as much as possible to make them self-explaining by adding a thorough description in the caption.*

I would consider the manuscript ready for publication after major revision.

Specific comments:

Title: "quantify" instead of "quantifying"

> *Done*

p. 3ff: Introduction needs a better/clearer structure

> *The Introduction section is articulated thusly:*
>
> *1- RWU definition;*
> *2- RWU controlling variables and factors (e.g., concept of compensation and extreme case of Hydraulic redistribution);*
> *3- Difficulty of measuring RWU;*
> *4- Water stable isotopic compositions as a way to measure RWU;*
> *5- Mention of objectives: review and comparison of the isotopic methods.*
>
> *Where/what would you propose we change?*

p. 3 l. 2-6: References are missing

> *Done (Javaux et al., 2013)*

p.3 l. 7: "driven by transpiration taking place. . ."

> *Done*

p. 3 l.11: "spatial distribution. . .is very variable in time and space"; spatial in space ! avoid duplication

> *Done*

p. 3 l. 13-14: Reference missing; permanent wilting point concept; what is a dry soil in this context?

> *Sentence was rewritten:*

"The flux of water depends also on soil water availability, i.e., the ability of the soil to provide water at the plant imposed rate (Couvreur et al., 2014): a highly conductive root segment will not be able to extract water from a dry soil."

p. 5 l. 1: "each other" without hyphen

Done

p. 5 l. 3-6: Repetition from abstract

This sentences state two objectives of the paper addressed in the section "challenges and progresses". This is why the authors mentioned it in both Abstract and Introduction sections. We do not feel this constitute repetition.

p. 5 chp. 2.1: This chapter is too detailed; fundamentals of isotope hydrology do not have to be explained in such detail

These paragraphs will be significantly shortened.

p. 6 l. 20: Reference missing

Done. (Sprenger et al., 2016)

p. 7 l. 8: "grey" instead of "gray"

Thanks (color wasn't actually grey but blue).

p. 7 l. 12-14: Repetition

Sentence was erased.

p. 7 l. 24: Mention this earlier in the manuscript

What exactly should we mention earlier?

If you are referring to "for plants growing in homogeneous external conditions, e.g., in hydroponic solution, root xylem sap water and external water have the same isotopic compositions", the authors think this is the right place to mention this.

If you are referring to "In natural soils where the liquid phase is not homogeneous and a vertical gradient of isotopic composition due to evaporation exists…", it is explained earlier in Section 2.2.

p. 9 l. 16: 21 studies: Based on which criteria have these studies been selected? Literature review using ISI web of knowledge? Please mention briefly.

This (non-exhaustive) list of publication was chosen according to, amongst other things, number of citation / retrospective contribution to field (publication year <2015) or novelty (publication year >= 2015). This will be specified.

p. 9 l. 20: "unambiguously identified"! What about issues with regard to water extraction techniques which might be a cause for this?

At this point of the demonstration, there is, for sake of clarity and concision, no question of techniques-related issues but rather the concept behind the graphical method (i.e., $\bar{z}$ is the depth where the soil water isotopic profile (δ_S) equals that of the tiller water (δ_{Ti})). Extraction techniques are evocated later (section 5).

p. 10 l. 7: grey ! correct throughout the manuscript

Done

p. 11 l. 26: Table 1 should rather go into the Introduction section, also it is too detailed

The authors agree that Table 1 is too detailed and will be substantially simplified (e.g., less columns). However the authors feel it should remain in Section 3 as it illustrates the studies described in this very section.

p. 12 l. 22: Replace www. by an abbreviation for example EPA, 2015; same for p. 13 l.

The authors' intention was to provide the readers with direct access links to the zip files for each model (as this is generally done in the literature with, e.g., R packages).

p. 13 l. 20ff: Why did the authors not intercompare the methods based on a dual isotope approach?

We opted for a single isotope (^{18}O) approach because we wanted to compare the different methods at natural isotopic abundance. As explained in the text a dual isotope approach only adds value if there is a disconnection between the oxygen and hydrogen stable isotopic composition profiles, which can be ideally realized following ^{18}O and ^{2}H labelling pulses in different portions of the soil profile.

How reliable/meaningful is a single isotope approach?

The point of the model inter-comparison is to determine if using the different approaches is meaningful in the context of a single isotopic approach. Note that the vast majority of published studies use(d) a single isotopic approach. Reliability depends on whether or not uncertainty is properly accounted for, which we address as well.

p. 14 l. 26: Is it necessary to mention the function?

Mention to the function was erased.

p. 18: Think about renaming the subsection e.g. method uncertainties and. . .

Subsection will be split and renamed. Done

p. 18 l. 1-20: This does not belong into the discussion section

Certainly. Please note that this section is not about discussing results but reviewing materials and isotopic techniques with focus on new developed techniques.

p. 18 l. 21: Reference missing

Reference will be added ("e.g., Koeniger et al., 2011; West et al., 2006")

p. 18 l. 21-24: Is this water plant available? Does it make sense to extract at such conditions if plant available soil water pools are of interest? Please discuss briefly.

Although this adsorbed water might not be directly available to plants it is in equilibrium with the bulk water and needs to be accounted for as a potential source in the root zone for modeling purposes.

p. 18 l. 24ff: Methods are also not intercomparable and each method comes with a huge uncertainty (e.g. Sprenger et al., 2015; Orlowski et al., 2016). How reliable is such data in the end when utilized for RWU calculations? How would RWU depth vary if e.g. extraction method uncertainty is accounted for?

Uncertainty associated with extraction techniques are explicitly accounted for in each method and addressed in details in the manuscript:

- *through the uncertainty associated with measurement of δ_{Ti} (width of the vertical band) [graphical method];*
- *through $\sigma_{\delta Ti}$, $\sigma_{\delta s}$ etc [two end-members method];*
- *through the parametrization of the approach of Phillips and Gregg (2001) (tolerance parameter) and Parnell et al. (2013) (sources ($\delta_{S,J}$) and product (δ_{Ti}) uncertainties) [multi-sources mixing models]*
- *through the sensitivity analysis [the model of Couvreur et al. (2010) was run a 1000 times, see Appendix B]*

p. 19 l. 3ff: Again, does this represent plant available water?

See answer to previous comment.

p. 19 l. 15: Gaj et al. (2015) is not a method comparison paper.

The authors do not agree: Gaj et al. (2015) attempted to compare (i) on-line isotopic measurements, i.e., obtained non-destructively by sampling the soil atmosphere and analyzing with a WS-CRDS with (ii) off-line isotopic measurements, i.e., following destructive sampling and cryogenic vacuum extraction.

Pratt et al. (2015) is wrong!

It is now Pratt et al. (2016). Thanks. Done

Orlowski et al. (2016) and please cite Sprenger et al. (2015) as review paper about extraction method comparisons.

Sprenger in now cited. What about Orlowski et al. (2016)? It is already cited.

p. 19 l. 27: “generalization of coupled approaches” ! What does that mean?

The sentence was reformulated as such:

In order to fully benefit from the potential of water stable isotopologue analysis as tools for partitioning transpiration flux, the authors call for the development of a novel approach making use of physically based models for RWU and isotopic fractionation to analyze experimental data.

Table 1: Too much information

Done (number of columns will be reduced)

Table 3: Not sure if all these numbers are necessary to understand the method comparison/virtual experiments

We propose to simplify Table 3 by removing the columns where absolute differences between the outcome of both methods are reported (numbers are actually already mentioned in the text). Furthermore, results will be rounded to the next whole number for readability.

Couvreur, V., Vanderborght, J., Draye, X., and Javaux, M.: Dynamic aspects of soil water availability for isohydric plants: Focus on root hydraulic resistances, Water Resour. Res., 50, doi: 10.1002/2014WR015608, 2014.

Couvreur, V., Vanderborght, J., and Javaux, M.: A simple three-dimensional macroscopic root water uptake model based on the hydraulic architecture approach, Hydrol. Earth Syst. Sc., 16, 2957-2971, doi: 10.5194/hess-16-2957-2012, 2012.

Gaj, M., Beyer, M., Koeniger, P., Wanke, H., Hamutoko, J., and Himmelsbach, T.: In-situ unsaturated zone stable water isotope (^{2}H and ^{18}O) measurements in semi-arid environments using tunable off-axis integrated cavity output spectroscopy, hydrol. Earth Syst. Sci., 20, 715-731, doi: 10.5194/hess-20-715-2016, 2015.

Javaux, M., Couvreur, V., Vander Borght, J., and Vereecken, H.: Root Water Uptake: From Three-Dimensional Biophysical Processes to Macroscopic Modeling Approaches, Vadose Zone J., 12, doi: DOI 10.2136/vzj2013.02.0042, 2013.

Orlowski, N., Breuer, L., and McDonnell, J. J.: Critical issues with cryogenic extraction of soil water for stable isotope analysis, Ecohydrology, 9, 3-10, doi: 10.1002/eco.1722, 2016.

Parnell, A. C., Phillips, D. L., Bearhop, S., Semmens, B. X., Ward, E. J., Moore, J. W., Jackson, A. L., Grey, J., Kelly, D. J., and Inger, R.: Bayesian stable isotope mixing models, Environmetrics, 24, 387–399, doi: 10.1002/env.2221, 2013.

Phillips, D. L. and Gregg, J. W.: Uncertainty in source partitioning using stable isotopes, Oecologia, 127, 171-179, doi: 10.1007/s004420000578, 2001.

Pratt, D. L., Lu, M., Barbour, S. L., and Hendry, M. J.: An evaluation of materials and methods for vapour measurement of the isotopic composition of pore water in deep, unsaturated zones, Isotopes Environ. Health Stud., doi: 10.1080/10256016.2016.1151423, 2016. doi: 10.1080/10256016.2016.1151423, 2016.

Sprenger, M., Leistert, H., Gimbel, K., and Weiler, M.: Illuminating hydrological processes at the soil-vegetation-atmosphere interface with water stable isotopes, Review of Geophysics, 54, 674-704, doi: 10.1002/2015RG000515, 2016.