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Interactive comment on "Time-lapse monitoring of root water uptake using electrical resistivity tomography and Mise-à-la-Masse: a vineyard infiltration experiment" *by* Benjamin Mary et al.

Anonymous Referee #3

Received and published: 14 June 2019

We thank the Reviewer for his/her comments. In the ensuing text, we try and address all raised issues. The reviewer's comments are reported in black, our replies in *italic blue*. Please also find attached a version of the manuscript with all changes highlighted in red.

B. Mary et al.

Review comments on Mary et al., 2019 SOIL This paper by Mary et al., proposed a novel and integrated geophysical monitoring framework to investigate the complex soil root system, especially focusing on assessing the root water uptake and delineating the active root density. Such multidisciplinary and innovative research should be encouraged and supported as the authors are developing tools to provide quantifiable and potentially spatiotemporal intensive data for SPAC modeling. However, there are few major flaws in this paper that prevent it from publishing in its current form. I suggest the authors redesign the experiment, revise and expand the current manuscript according to the reviewers' comments, and resubmit it. Some general comments:

1. I assume this paper is meant to be an extension of Mary et al (2018) and to focus on infiltration experiment. However, the datasets presented in this study and the affiliated discussions are not sufficient for a regular full paper, particularly, the lack of linking to any ground-truth data (such as soil samples, soil water chemistry, TDR measurements, rhizotron measurements, and so on). The authors also did not the full advantage of their >24 hours time-lapse measurements, only limited snapshots are presented without quantitative analysis. As a result, it is not convincing that this work has advanced the work from Mary et al., (2018), yet exhibits problematic overlaps.

Indeed, this can be viewed as a companion paper of the previous paper by Mary et al. (2018) – the same was suggested by Rev.1; note that the results contained in both papers are different, complementary to each other, and too extensive to be summarised in a single paper, referring also to different experiments. Given this, we reformulated the objectives of this paper to better convey its originality and importance as compared to the paper by Mary et al. (2018):

The objectives are:
- *define a non-invasive investigation protocol capable of "imaging" the root activity as well as the distribution of active roots, at least in terms of their continuum description mentioned above;*
- *integrate the geophysical results with mass fluxes measurements in/out of the soil-plant continuum system using a simple 1D simulation reproducing the infiltration experiment.*
- *give recommendations for future experiments that deal which focus on the validation aspect.*

Furthermore, in the revised version of the manuscript we took care of showing the full advantage of the time-lapse measurements by:

- *showing the time-lapse variation of absolute ER inverted values for all time steps*
- *inverting and showing the time-lapse ratios after time lapse inversion of ERT data*
- *showing the time-lapse variation of MALM for all time steps*

Also, in the revised version and in order to comply with the new objectives, we present the results of a 1D simulation of the infiltration experiment. The time-lapse results are now discussed in the light of the hydrological model. This allowed to clearly identify the dynamics such as daily evaporation and/or RWU.

Finally, in the revised version of the manuscript (also considering the comments by Reviewer 1) we also improved the inversion algorithm in the F2 formulation.

2. In both current study and Mary et al., (2018), the biggest technical issue is that the electrode spacing is too small (0.1 m) and this might have violated the point-source assumption. The authors didn't explain what the electrodes they were using, or how deep the electrodes were buried in the ground. But from Figure 1 in this paper, it seems like authors used standard stainless steel electrodes with at least 10 cm into the ground (equal or even greater than the electrode spacing) This is extremely important as the current course in such setup (electrodes too close to the target and experiment dimension is on the same order as of the target) is very likely not 'point-source' anymore, and the noise could overwhelm the actual data due to target property changes. Such electrode mislocation errors can be very complicated but can be simulated in synthetic experiments. Furthermore, due to the principle of reciprocity, such data error cannot be caught and eliminated by reciprocal measurements. There are few studies on this problem and I strongly suggest the authors read related literature. I personally had failed experiments before due to this very reason.

The reviewer is right at raising the question but is wrong in his/her conclusions that we used standard electrodes buried as deep as 10 cm. We are perfectly aware of the issues related to the assumption of point sources inherent in most inversion algorithm, and we have 20 year experience in small scale ERT applications where these issues are constantly taken into account – the literature is well known. In this particular case the risk is invariably that of having an apparent conductive layer at the surface. And the impact in time-lapse measurements tends to be factored out, of course.

Nevertheless, not that the surface electrodes are 1.4 mm in diameter, but are stuck in the ground by no more than 3 cm – note that the soil surface is very irregular between the rows of the vineyard due to field work of the land surface.

3. The results and discussion are too brief and qualitative to provide an in-depth discussion on how the ERT and MALM reveal the actual root functions. For the readership of this journal, the actual root-soil mechanisms that were revealed and supported by geophysical methods are very appealing. The authors did a time-lapse (>24 hours) experiment, why the time-lapse ERT resistivity changes or MALM results are not shown? Only the initial condition and 2-hr snapshot are shown? More time-step data would provide significantly more information into the root system function.

Thanks for the suggestion. In the revised version of the manuscript, the time-lapse ERT resistivity changes, derived from a time-lapse ratio inversion and MALM results for all time steps and for both plants are presented (plant B shown only in appendix for brevity). Also, a dedicated section was added to discuss integration of ERT with the hydrological model and ET data.

4. More detailed soil information and geophysical survey design information should be provided.

Soil information (type, roots density and granulometry) is now reported in the new figure 2a and a detailed scheme of the survey design is now added in appendix A1.

5. An illustration showing the borehole locations is very necessary. Also, please label the borehole number in the geophysical results plots as well.

See previous comment. All the electrodes numbering is now labelled in the figures.

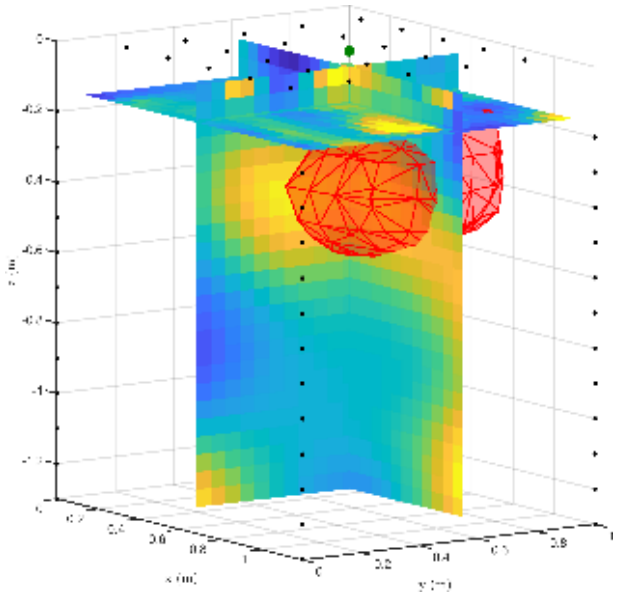
6. Figure 5 shows the normalized voltage ratios for plant B, but this figure was not discussed or mentioned in the manuscript.

Figure 5 has been removed from the new version of the manuscript because the raw MALM data does not provide a straightforward information. We added in the appendix the time-lapse variation of the absolute normalised voltage measured.

7. Figure 7 and the corresponding text section 3.4 are difficult to follow. First, where is the boundary of this estimated active root zone? What are the exact times from T1 – T5? Are these boxes representing all the ER values outside and inside the zone? Or just selected values?

- *Our assumption is that the region identified by MALM F1 (albeit very rough) for the background time corresponds to the RWU region. The inner area (IN) is then defined as the area within the closed isosurface at the background time T0.*
- *The times for T1 to T5 are given in the table 1 (note that there is no exact time since the measurement last approximately 30min. Legend has been rephrased to stressed out this (We invite the reader to report to this table otherwise the figure would be overloaded).*
- *Boxes represent selected values inside and outside the hypothetic rooted zone. Left size figure boxes refer to the OUT zone while right size to the IN. Figure and figure legend were improved to better convey this.*

For the reviewer information we show hereafter a plot the boundary of the active zone below to illustrate our comment.



8. Line 150. It is not very clear what is the electrode spacing for the surface electrodes, 0.1 m? what is the exact measurement configuration? The current description is too brief to get the idea of how the measurements were done (for example, any surface to borehole electrode pairs for current injection?) I've tried to read the Mary et al. 2018 paper, despite the similarity between these two studies, the ERT/MALM acquisition was not fully explained in that paper either.

In the revised version of the manuscript we detailed the set-up geometry adding a figure in appendix A1.

We also added a more in-depth description of the protocol (see L. 165).
"

The total dataset includes three types of measurements: 430 surface-to-surface, 2654 surface-to-borehole and 4026 in-hole measurements.
"

9. Figure 3 needs to be improved with better visualization showing the 3D feature. The facets are not distinct in this current plotting style and the authors may organize the subplots into two rows for easier comparison.

The new figure shows now the 3D pattern via a combination of vertical and horizontal slices through the 3D interpolated ER, slice positions were chosen to correspond to the control point of the hydrological simulation.

Detailed comments:

Line 35. Is the word 'expended' supposed to be 'expanded'? *Corrected*
Line 36. SPAC is repeated. *Deleted*
Line 37. I suggest more references here besides the work by Dirmeyer et al.,

Added a reference to Newman et al., (2006).
"Newman, B. D., Wilcox, B. P., Archer, S. R., Breshears, D. D., Dahm, C. N., Duffy, C. J., McDowell, N. G., Phillips, F. M., Scanlon, B. R. and Vivoni, E. R.: Ecohydrology of water-limited environments: A scientific vision: OPINION, Water Resour. Res., 42(6), doi:10.1029/2005WR004141, 2006."

Line 39. More references should be included.

We added a sentence and a reference to Richter and Mobley, (2009).
"Richter, D. deB. and Mobley, M. L.: Monitoring Earth's Critical Zone, Science, 326(5956), 1067–1068, doi:10.1126/science.1179117, 2009."

Line 55. Can the authors reiterate the main motivation of the work?

Sentence rephrased:
"

However, calibration requires that suitable data such as roots and soil water content evolution are available in a form comparable with the model to be calibrated.

"

Line 85-94. This part introduces the potential of SP and IP in monitoring water update and root systems. However, this part seems to be a bit out of place as the prior and following paragraphs discuss the actual methods have been used in this study. Suggest moving this part to either prior to ERT or after MALM.

Thanks. Done

Line 209. 'less intense', what does this mean?

"Intense" replaced by "resistive"

Line 213 – 214. 'The input of low resistivity water (15 Ohm.m, measured in laboratory) caused a homogeneous drop of the resistivity values that make the two images around plant A and plant B very similar to each other'. How much is the resistivity decrease? Could you give a specific number? Maybe the authors can plot the delta resistivity (difference) for both plant A and B and show more time-step results.

Thanks for the suggestions.
In the revised version of the manuscript we added the time-lapse inversion to evaluate the resistivity decrease or increase in term of % of change on the ratios between two consecutive times for both plants.
Absolute change of ER is about 50 Ohm.m and up to 100 Ohm.m (added in the revised manuscript L. 278)

Figure 6. Please label 'stem/soil injection' directly on the plot to aid the reading.

Done

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