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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Monitoring and modelling of soil–plant interactions: the joint use of ERT, sap flow and Eddy Covariance data to characterize the volume of an orange tree root zone" *by* G. Cassiani et al.

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We thank the referee for his/her positive general comments. He/she also provides a number of specific remarks that we feel must be addressed in detail, as shown hereafter (our replies preceded by a » sign):

Even though I think this work can be very interesting and innovative in this field of research, the authors still have to improve

(1) their description of the used methodologies, especially for the modeling part. I did not find any specification on the equations used, especially for the sink term in the Richards equation. Based on the information in the paper, it is very difficult to understand how you can calibrate a volume of root water uptake with a 1-D equation, etc. This really must be explained more systematically. The calibration and validation approach, statistical decision tools, etc. should be discussed.

»We agree with the referee: in the revised version of the paper we will give all the necessary details.

(2) the use of the model outcomes. Next to the active root zone, results on sink term distribution and soil water fluxes based on the coupling of data and model should be given.

»Some more detail on the results of the 1D modelling will be given in the revised paper.

In addition, I do not understand why the authors limit the paper to a two day period, whereas in the M&M part they speak of an experiment on much longer term. . . Next to the daily cycle, the dynamics over the growing season are of main interest in this context!

»The paper presents results derived from both short term (2 days) and long term monitoring. The micrometeorological data set (including the measurements of the energy balance components) and the sap flow data are available since 2009. ERT measurements were carried out only during a 2-day period, but the state of the system at the time of the ERT measurements clearly depends on the past forcings acting on the system. The entire dataset is therefore used when data and simulations are compared. Given the comments from this referee – and not only – we feel that we need to give a more explicit description of how both long and short term data are used. We will definitely do it in the revised paper.

(3) the authors explain in detail their setup to measure ET using an eddy-covariance

tower, but I do not see where they use these data afterwards in the paper. As explained now, I understood that only the sap flow data are used as a forcing for the model.

»This remark is correct. Indeed in the modelling itself we only used sap data, as they are directly and uniquely attributable to the single orange tree we monitored. However we feel that the comparison between sap flow data of transpiration and Eddy Covariance fluxes allows for a better understanding of diurnal plant dynamics with respect to the microclimate of the study area. However, in order to clarify the role we attribute to EC data in this paper, we are considering removing Fig.2 from the revised version of the paper.

DETAILED COMMENTS P 13354 l 8: this is the only place where 4-D inversion appears. If you use this term, please give more information in the M&M part on the type of inversion constraints put on the time dimension, since they can highly influence the result.

»We agree with the comment. We will use “time-lapse” rather than 4D in the Abstract

P 13355 l1 irrigated water that/which is not taken up

»Ok

P 13355 l15-27 This part is a bit unsatisfactory. There are two options, either you do not speak of this at all, since anyhow, you do not aim to test several model types in this paper, if I understand well; either you included some more recent literature and other authors to make this more complete and up to date. See recent papers of Valentin Couvreur, Mathieux Javaux, Tiina Roose, . . . Recent literature shows for example that there is a mathematical link between the two categories you propose and that they are not that different finally.

»We agree that we can reduce/remove this part from the paper.

P13357 l 10-13: As this is the main focus of your paper, I would be more complete on the existing literature applying ERT to characterize root water uptake and root system

characterization. (You could deleted some of the general papers before, to gain space if necessary) More specifically, I would also like to see an indication of lab and field studies, since they have different focus and outcomes. Also studies on woody plants and agricultural crops could be differentiated here, because mainly the influence on the petrophysical relationship seems to be different for these two categories. Therefore I suggest adding the papers of e.g. Beff et al. 2012, Amato 2009, Michot 2003, Garré 2011,2012, Cassiani 2012, . . . If the groups of Binley and/or Kemna already published some of their work on the effect of roots on soil electrical properties, this would also need to be added here (however, of these two I am not sure if there is already some formal paper).

»We agree, and will expand the literature review as suggested.

P 13358 l 15 mean leaf area index => over space AND time?

»The LAI values are spatially averaged and are referred to the ERT measurement period (October 2013). In the specific case of a mature orange orchard, LAI values are fairly constant in time in the region of interest.

P 13358 l22 Ks with falling head permeameter => specify how many replicates, variation of result- ing values, . . .

»We have 32 Ks measurements over the study site; we will add some details in the revised version of the paper.

P 13358 l 26 reflectomeTErs?

»Ok

P 13358 – 13359 Is it possible to make a scheme of the field with the location of all sensors relevant to the data presented in this paper with respect to the tree rows etc?

»We also feel that a scheme is needed. Attached you can find a first tentative scheme of the sensor distribution around the investigated tree. The tree falls within the microm-

eteorological station footprint area. We will add a similar figure to the revised paper.

P 13359 l 5 why did you adopt this setup with horizontal and vertical TDRs? How did you install them exactly, especially the horizontal ones?

»The TDR probes location is considered well suited with the specific characteristics of the micro-irrigation system used in the area and the textural soil main features. Specifics about TRD installation will be provided.

P 13359 l 17 Something that strikes me in the paper is the different time scales of the various data sources: eddy covariance since 2009, sap flow ??, TDR ??, ERT only 2 days in 2013. Can you specify this better in the beginning of the paper and also explain why this is so different. For example, why do you only have two days of ERT data. If you have a specific reason for this, state it more clearly in the objectives of the paper.

»Here again we acknowledge that in the original paper the different use of the data was not explained in sufficient detail. See our reply to major comment number (2) of this same referee. We will make sure that the overall description is improved in the revised paper.

P 13359-13360 Some things need to be specified more clearly to ensure reproducibility of the research:

P 13360 l 2 CSAT3, I suppose. I may be wrong but, to my knowledge, CSAT3 is a sonic and not a gas analyser. I think thus that information about the GA is lacking. Especially, it's important to specify if it's an open path (type LI-COR 7500) or a closed path (type LI-COR 7000 or 6262). Each system requires specific corrections. On the photograph in Figure 1 I can see the IRGA at intermediate height: that's a LI-COR 7500 open path. Higher, I see a sonic sensor but no IRGA. . .

P 13360 l 10 That's a little bit short : you should give more info about flux computation procedure and corrections : how do you cope with high frequency attenuation (in closed path), with rain periods (if open path)? Do you apply the Webb Pearman Leuning

(WPL) correction (if open path)? Do you apply a stationarity screening for data filtering? Eddy covariance computation packages cannot be used as black boxes. They must be parameterised in taking the system specificities into account.

»The open path infrared absorption gas analyser is a LI-7500 from LI-COR. The eddy covariance measurement system and the data processing followed the guidelines of the standard EUROFLUX rules (Aubinet et al., 2000). A data quality check was applied during the post processing together with some routines to remove the common errors: running means for detrending, three angle coordinate rotations and despiking. Stationarity and surface energy balance closure were also checked (Kaiman and Finningan, 1994). These details will be added to the revised paper.

P 13360 l 16 This is a quite good result that probably validates the whole method.

»agreed

P 13360 l 19 Why the choice for the HPV technique, since it seems to be more and more abandoned by the community due to difficulties to find the 0 flow point. Please specify this.

»Heat-pulse techniques can be used to measure sap flow in plant stems with minimal disruption to the sap stream (Swanson and Whitfield, 1981; Cohen et al., 1981; Green and Clothier, 1988). The measurements are reliable, use inexpensive technology, provide a good time resolution of sap flow, and they are well-suited to automatic data collection and storage. Sequential or simultaneous measurements on numerous trees are possible, permitting the estimation of transpiration from whole stands of trees.

P13361 -13362 For the ERT M&M part add answer to following questions in the text: - what was the material and size of the buried, mini- and stick-electrodes? - how was the borehole made and good electrode contact ensured? How did you minimize hydraulic disturbance due to the vertical holes or if you didn't can you comment on the extent of disturbance of the flow field? - Did you arbitrarily choice the electrode

configuration (based on some general characteristics) or you conducted some virtual or real field tests prior to the experiment. If yes, please give some info on that. - If I understand well, you have no measurements between sticks, only along the sticks? - An image of sensitivity distribution of the configuration for a homogeneous medium would be interesting to evaluatethe set-up. - Which ERT device did you use for the measurements. - What kind of error model did you use and how did you obtain it? Or did you just put a constant error and if yes, is it the average value of all timeframes and all electrodes? The data quality seems good, especially under complex field conditions, so that's positive. – Specify which constraint was used for the timelapse inversion (time dimension).

»Many of the details requested here are already in the paper. But just to clarify: the electrodes are made of stainless steel, plates 3cm high and wound around the PVC pipe. The boreholes were made by percussion with the help of a pre-drilling with a smaller diameter in order to avoiding the disturbance of the electrical flow. A similar setup was used by Boaga et al., (2013). The electrical contact is excellent for all 48 buried electrodes, as checked before each measurement. The 4 boreholes are water tight and in tight contact with the soil, so they cannot act as pathways for preferential water infiltration. In addition, we focused our attention to an area slightly smaller that the square defined by the boreholes, in order to avoid the inevitable disturbance caused by borehole installation (indeed, slightly compacting the surrounding soil). There are also 24 surface electrodes, and this covers partly the region between the boreholes. Note however that by its own nature ERT is NOT a LOCAL measurement. We used an IRIS Syscal Pro resistivimeter for all measurements. Sensitivity distribution is well known from the literature (e.g. Binley and Kemna 2005) and there is no need to repeat these concepts specifically in this paper. The error model is described in Binley and Kemna 2005 for the error level chosen here (10%, as specified already). All other details of the inversion have been published in a number of papers using the same inversion codes (all in http://www.es.lancs.ac.uk/people/amb/Freeware/freeware.htm). The time lapse inversion is a ratio inversion, already described in the paper and relevant

literature is referred to (e.g. Cassiani et al., 2006).

Figures 5 and 6: I have the impression the color scales are not optimally chosen to see the variability in the 3-D images. I think images in log scale or EC instead of resistivity would show more. Figure 6 is really not readable. Scales are too small.

»We disagree concerning the colors. We will increase the font size to make figures more readable.

P13363 l5 You refer to fig 6 here, but it is not clear at this point how you obtained the 'EC derived total ET'. Please explain.

»It is of course derived from the EC measurements. We do not quite understand what the referee is asking for at this point.

P 13363 l 20-25 I particularly like the fact that you checked the effect of pore water salinity, an parameter that is often neglected, as you state yourself. However, could you specify with which frequency, which method of pore water extraction, where in the field, etc.?

»We used laboratory suction cups for water extraction from the soil samples.

P 13364 l 5: Can you detail the experimental protocol? Did you wash the samples several times with the solution to obtain homogeneous pore water concentration? What was the sample size? Figure 7: why don't you show all data?? I they fall on top of each other, the image should remain readable and the value of the graph would be much higher. . . Could you also show the fit you decided to use to convert rho in WC in the same graph?

»We will add some of these details in the paper. The procedure for testing the soil samples is similar to the one in Cassiani et al. (2009).

p 13365 l17 This would be a really interesting case-study indeed. Looking forward to that piece of work.

ïĄŁ P 13365 l 21 I see the importance and interest of coupling model and data, but I do not know why you have to throw away all the 3-D information to be able to do it. . . In that case, you could simply have put a vertical profile of TDRs and use that data as a source for the model. This would have been cheaper and faster. . .

»The wealth of information in the time-lapse 3D has not been fully exploited using the 1D simulation, but the information is anyway much more abundant than the one that can be derived from a few scattered TDR probes!

P13366 l 1 I think you should clearly split, both in M&M and in Results, experimental considerations and modeling considerations, in order not to loose the reader.

»This comment is not clear to us. We will anyway try to improve the paper readability in the direction of splitting model and measurement descriptions.

P 13366-13367 Here I was lost and I am still not sure whether I understood correctly. For example, how can you find a volume of active roots if you use a 1-D model? If it were real 1-D, the transpiration rate (T_act) measured in units of L/T could be directly used and only the depth of the root system would matter. Is this what you did? The authors considered that the average horizontal area per tree (dËĘ2, where "d" is the average distance between trees) is larger than the horizontal area the root systems have access to (rËĘ2 < dËĘ2). Thus the tree water uptake is concentrated in a relatively small volume and the horizontal soil moisture is quite heterogeneous. If at this point the authors still use 1-D simulations, they probably considered no horizontal capillary flow between the regions outside and inside of rËĘ2. This has a direct implication on flow boundary condition which has to be taken in a "horizontally smaller" 1-D domain. The volumetric transpiration rate per tree being T_act*dËĘ2 (in units of LËĘ3/T), the uptake rate per tree in a 1-D domain of horizontal area rËĘ2 has to be T_act*dËĘ2/rËĘ2. In other words, considering that the root system doesn't have access to the water lo cated outside of its area, the smaller the area, the more concentrated the 1D uptake rate, with a ratio dËĘ2/rËĘ2. I think this is not quite intuitive

and not well explained in the manuscript. The hypothesis of no horizontal capillary flow between the outside and inside of the root zone can also be questioned and needs to be clearly specified.

»The referee captured the essence of our approach, so to some extent we must have been able to explain it. However we agree that some more effort shall be put in clarifying this matter. The plot given above in this reply is a step forward and we plan to use a similar figure in the revised manuscript. Note however that we do not fully neglect horizontal capillary flow ! Indeed this flow explains the TDR data (Figure 9)! However there is no doubt that at the TDR location moisture content is MUCH higher than closer to the tree, therefore horizontal flow is not such an efficient mechanism in the water migration at this site.

P 13366 l 5 which are the relevant parameters? Further in the text I find the retention curve parameters, but nothing on how you parameterized the sink term. . . In addition, you give no information on how these parameters were obtained. You state on the one hand that main variations are vertically, but on the other hand several characteristics of the field site make that you can expect 2-D surface heterogeneity: drippers, tree plantation (row-interrow), . . . Did you choose your ERT measurement area so small as to eliminate these horizontal heterogeneities?

»The relevant parameters are, of course, the one described in the Van Genuchten model. The sink term is NOT a parameter, rather a boundary condition, that is described as a prescribed flow term. As for the predominant 1D pattern observed at the site: this is clearly supported by the ERT data both in the long and short term (figs 5 and 6). We chose the ERT setup to image the soil around the tree, and TDR proves that important variations occur beyond the extent of the ERT control volume.

In p13367 l 10 you use the TDRs to validate some results, but on the other hand here you speak of heterogeneity yourself. Why aren't the TDRs installed in the same measurement area as the ERT with respect to the tree (even another tree would have

been possible).

»The TDR had been installed previous to the design of the ERT experiment. We do not use the TDR to validate the ERT results, but we highlight how the evidence of the two setups concur to provide a consistent picture of the system's behaviour as shown by the integration of data and modelling.

P 13368 l 1 you speak of lateral forces.

»We speak of capillary forces. The referee's comment is unclear to us.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 13353, 2014.

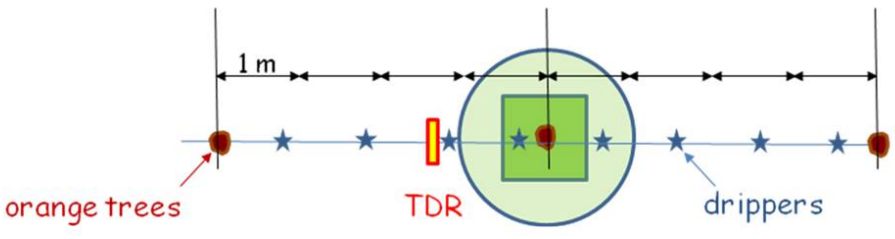

Fig. 1.