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Discussions

Interactive comment on "Water movement through plant roots: Exact solutions of the water flow equation in roots with varying hydraulic properties" *by* Félicien Meunier et al.

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General comment for both referees:

For most of criticisms and remarks, both reviewers had similar opinions and we understood their requests for clarification. In particular, we were asked to consider the following points in our revised version of the manuscript:

- To more clearly state the importance of analytical (vs numerical) solutions;
- To give more insights on biology and implications of our development;
- To present experimental data.

We have now revised our manuscript to include these points and we have the feeling that these additions have definitely enriched the manuscript and could meet referees' demands. In particular, we now present the results of an experiment that was designed in the meanwhile to illustrate the benefits of our developments. We built a point-by-point response for both referee comments to explicit the changes. Since some of the comments raised by reviewers are similar, we sometimes refer to the other response.

This work presented analytical solutions of the water flow equation for roots with linear and exponential radial and /or axial hydraulic conductivity with the distance from the root tip. My impression is that there are many hypotheses such as the function of the varying hydraulic properties, and the work is so mathematical, not hydrology.

Indeed we presented novel analytical solutions of the water flow equation for roots with linear or exponential changes radial and axial hydraulic conductivity along the root axis. However, we also demonstrated how to combine these solutions on a given root, which makes our new model particularly robust and flexible. Any nonlinear function can always be approximated with piecewise linear functions. We therefore disagree with the reviewer comment that the shape of varying hydraulic brings new hypotheses. It is actually the opposite: these new analytical solutions release hypotheses made by most of the current root water uptake models (which assume root system hydraulics as uniform). We also illustrated with the introduction and subsection 3.2 that such functions (and thus our shape hypothesis) made sense because they were compatible with observations in several studies (for lupine and maize roots, among others). In the revision (see comments to first reviewer), we also would like to include original measurements of maize root axial conductivity and total conductance that are also compatible with our mathematical development.

About the last statement, we rely on editor's decision who declared when giving a first decision "I am happy to report that the topic is within the scope and the broad interest of our readership". We indeed believe that the pattern of root water uptake will have dramatic effects on soils and water distribution, and thus that our MS will have an impact in hydrological sciences. Similar papers can be found is HESS like (Couvreur et al., 2012, 2014), or (Bechmann et al., 2014).

Regarding the mathematical development, we tried, as much as possible, to report them in the Appendix section. We think that the theoretical developments remaining in the Theory section are necessary for the correct understanding of the paper.

The following is my main concerns: 1. Numerical solutions have been obtained for the same problem with any conductivity functions. The authors only obtained the analytical solutions for linear and exponential radial and/or axial hydraulic conductivity. The authors should try to get the semi-analytical solution for any conductance variation. This is great advancement, not only for just two special functions.

We have the impression that the second reviewer did not fully understand our MS. We have adapted the analytical solutions for any combination of linear/exponential hydraulic property distributions, which makes our solution actually able to mimic any conductance variation. The development is given in subsections 2.4 and 2.5 and illustrations of such combinations are presented in subsection 3.2. As stated just above, the model allows any combination of solutions, which provides users a broad flexibility and is compatible with existing and our new observations.

2.Why the authors choose linear and exponential functions? How to determine the parameters in the functions? Any proposed function should have physical meaning, and it should be derived from experimental data, not just hypotheses, also for the parameters in the functions.

These functions have been chosen for three main reasons. First, they allowed the development of analytical solutions that present major advantages as stressed out in response to reviewer 1. Second, they are compatible with observations of local hydraulic properties of many species, such maize. Last but not least, we chose linear function because any other function can be approximated by combinations of linear functions, which make our model robust and flexible. Adding solutions for exponential

functions reinforces the model flexibility.

3.The authors used the obtained solutions to evaluate the impact of root maturation vs. root growth on water uptake, and obtain a so called optimal root traits that maximize water uptake. However, there were not based on real life and biology, and the physical meaning and implication of the results were not substantially discussed.

We carefully took this concern into account. This is why we would like to include additional data of an experiment during which we measured root axial conductivity as well as total conductance of maize main roots. The results and more details can be found in response to reviewer 1. Biological and applied aspects of our developments will be added in the revised version of our work.

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