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Hydrology and Earth System Sciences Discussions

Interactive comment on "Implementing small scale processes at the soil-plant interface – the role of root architectures for calculating root water uptake profiles" *by* C. L. Schneider et al.

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General reply

We thank Guido d'Urso for his comment, and critical discussion of our manuscript. We address the raised concerns in the following paragraphs, and add below comments on two more specific points.

We agree with Guido d'Urso that environmental models need to be supported by observation. We also agree that the Feddes Model is applicable on the pedon scale, that

is, if the entire root system of a given plant is considered. In fact, we do not disagree with applying a reduction function, such as proposed by Feddes et al. (1976). The pattern proposed there agrees well with observation on entire plants (Sinclair et al. 2005). However, we are concerned about how root water uptake is modeled in a vertically discretized soil model, where the root systems extends over multiple layers. In such a case, an estimate is needed on how much water is taken up by a given fraction of the root system. Often modelers recede to assuming that uptake should be somehow proportional to root abundance. Where this assumption is made, root distribution strongly affects the modeling result (Feddes et al. 2001). On the other hand, observation suggests that root water uptake "moves" relatively fast (within days) along the root system (Lai and Katul 2000; Li et al. 2002), pointing researchers to ask for alternatives. For example, in the original paper (Feddes et al. 1976) the sink term function produces moving uptake fronts, because it is there applied without using a root length density distribution. Instead the sink term distribution hinges mainly on the soil water content in individual layers. Deciding between applying a version with or without using, say, root length density, decides mainly, on what we need to measure, in order to validate the model or provide necessary model input and parameters. In this context (i.e. what we should measure), we think it is worthwhile asking theoretically, which processes are possibly at play. We believe our model represents a useful tool to investigate possible alternative parameterization.

Thus, the main focus of our paper is not to predict water uptake in sorghum at a precise time and place. We agree that we would not succeed validating such a prediction. Instead we emphasize the qualitative result that root water uptake profiles took very different shapes, although root distribution was rather similar. We would also argue that taking into account more variation (like making axial resistance dependent on physiological or environmental conditions) would probably lead to even greater difference in the predicted uptake profiles. Qualitatively our model corresponds well to the experiments conducted at a similar scale by Garrigues et al. (2006)

We agree that the nomenclature in our paper is misleading in that it suggests criticism towards the Feddes et al. (1976) model, when the focus is actually on understanding how strongly root abundance determines root water uptake profiles. We changed the names of the model scenarios. Thus, the third scenario was re-named to RLD ("proportional to root length density").

Reply to Specific comments (comments are italic, response in standard script)

Furthermore, some parts of the proposed approach are dependent on empirical parameters which have a fixed value in the present study, without any consideration of the model sensitivity. This is especially the case of the axial resistance of xylem in Tab.1, .. Axial resistance is an extremely variable parameter related to many physiological factors in a quite complex and not precisely quantifiable way.

We agree that also axial resistance varies. In this paper we derived axial resistances based on the expected number and size of xylem vessels in the respective root order, and applying Poiseuilles Law for axial resistance per unit length:

$$R_l = \frac{8\eta}{\pi n r^4} \; (R.E1)$$

where η is the viscosity of water, n the number of xylem vessels and r the average radius of the vessels. Thus, in our model the root order (and thus age) decides about root axial resistance. We assume that our axial resistances per length are relatively small, i.e. the resistance might increase due to environmental factors (vulnerability curves), but would not decrease unless the size or number of xylem vessels was increased further.

In our scenarios we only consider changes of specific radial resistance. This is because it was shown earlier (Zwieniecki et al. 2003) that the major design parameter governing water uptake along a root is the ratio between axial and radial resistance (R_{ax}/R_{rad}).

$$R_{ax} = R_l \times l \; (R.E2)$$

$$R_{rad} = \zeta_p \times 2\pi l r_0 \; (R.E3)$$

where l is the root segment length, r_0 the root radius, ζ_p and R_l are the material properties of hydraulic resistances for the radial pathway (per root surface area) respectively the axial pathway (per segment length). The material properties are given in Table 1 of the manuscript. The outcome of these calculations are the radial and axial resistance R_{rad} respectively R_{ax} for a given root segment of distinct length and radius.

Zwieniecki et al. (2003) concluded, that for small R_{ax}/R_{rad} (similar to Scenario A) root water uptake would extend over the entire root length, while larger ratios R_{ax}/R_{rad} (similar to Scenario B) lead to uptake only along a portion of the root. Our results concur with this. Thus, by changing R_{rad}, we already manipulated the ratio R_{ax}/R_{rad}. Figure 1 and 2 show the distribution of root lengths for respective ratios (R_{ax}/R_{rad}) in Scenarios A and B.

A sensitivity analysis of changes of R_{ax} would also lead to changes of the same ratio (R_{ax}/R_{rad}). Since we start with axial resistances per length, which are rather low, we expect that any change would lead to an increase of R_l . For example, increasing R_l in Scenario A (with high specific radial resistance) would shift the results to scenario B, i.e. leading to a larger scatter of uptake profiles between the individual realizations. However, water limitation would occur earlier, because total resistance is increased.

Furthermore, some parts of the proposed approach are dependent on empirical parameters which have a fixed value in the present study, without any consideration of the model sensitivity. [...] as well as the simplifications adopted for the matric flux potential in Eq.(15).

Figure 3 of this reply shows the plot of $\Phi_{soil}(\psi_{soil})$ calculated from Eq. 14 (numerical solution – solid line) and Eq. 15 (approximate analytical solution with fitting coefficients a = 335.435, b = -161.795, c= 0.0115, d= 138.718 for the sandy soil used within this exercise – dotted line). The fit is rather good. Regardless, we agree that the description of the soil hydraulic properties near the roots might be a problem, since neither hysteresis nor the influence of the roots on the soil hydraulic properties are accounted for. We plan to work further on this in the future.

Further References

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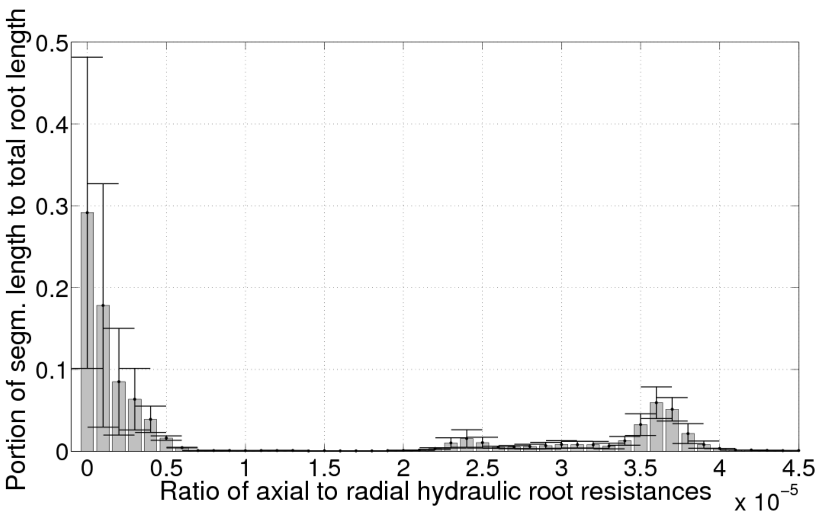

Fig. 1. Length distribution of hydraulic root resistance ratio R_ax / R_rad of 50 root system realizations for Scenario A; Bars denote for the median where the error bars denote for the 90% quantile.

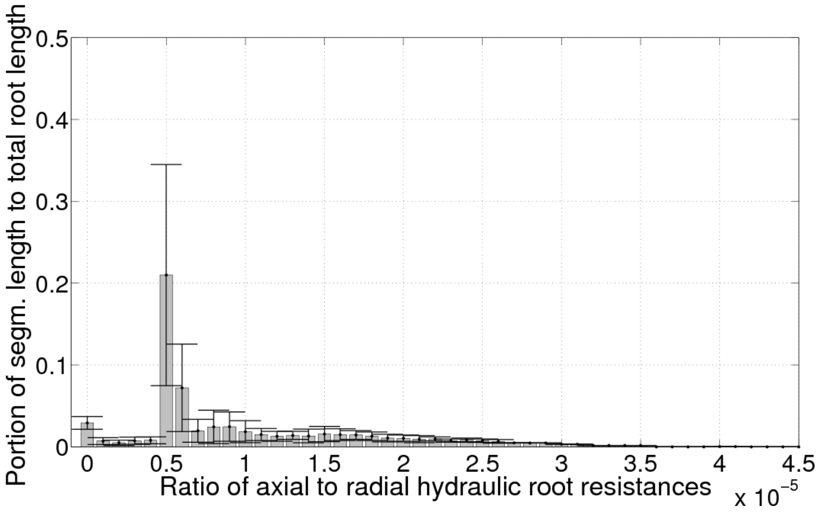

Fig. 2. Length distribution of hydraulic root resistance ratio R_ax / R_rad of 50 root system realizations for Scenario B; Bars denote for the median where the error bars denote for the 90% quantile.

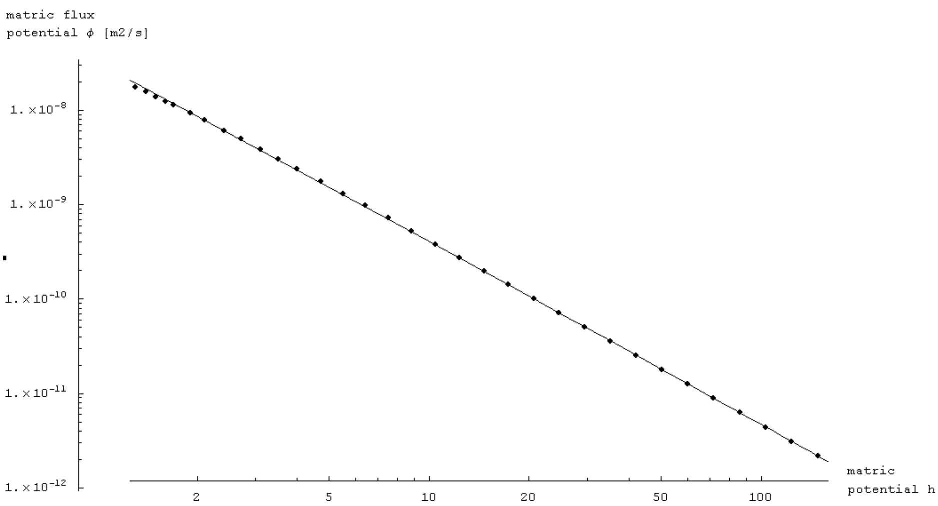

Fig. 3. LogLogPlot of matric flux to matric potential for the Dutch star series sandy soil (numerical solution – solid line, approximate analytical solution – dotted line)