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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 Vanessa Dunbabin for the insightful comments to our paper, and we believe that the suggested changes really helped to improve the manuscript. We implemented most of the suggested changes (see details below, comments are in italics, reply in standard script).

Reply to Specific comments

Consider rewording the abstract. The first time I read the abstract it was hard to work out what was going on with the scenarios, model approaches, and individuals. Reword to make the treatment design clearer.

We reworded the abstract as follows.
"In this paper, we present a stand-alone root water uptake model, called aRoot, which calculates the sink term for any bulk soil water flow model. The model accounts explicitly for water flow from the soil towards single roots and within the root network up to the root collar. By doing so, it allows for taking into account differences in root system morphology. The boundary conditions for the model are the water demand at the root collar and the bulk soil matric potential. In the current version, we present an implementation of aRoot coupled with a 3-D Richards model (GeoSys). The coupled model is applied to investigate the role of root architecture on the spatial distribution of root water uptake. For this, we modeled root water uptake for an ensemble (50 realizations) of root systems generated for the same species (one month old Sorghum). The investigation was divided into two Scenarios for aRoot, one with comparatively high (A) and one with low (B) root radial resistance. We compared the results of both aRoot scenarios with root water uptake calculated using a classical representation of root water uptake distribution (Feddes model with root length density). The vertical rooting density profiles of the 50 generated root systems were similar. In contrast the vertical water uptake profiles differed considerably between the 50 individuals, and more so for Scenario B than A. Also, limitation of water uptake occurred at different bulk soil moisture for different modeled individuals. Finally, the aRoot model simulations show a redistribution of water uptake from more densely to less densely rooted layers with time. This behavior is in agreement with observation, but was not reproduced by the classical model."

2.1 Bulk water flow in the unsaturated zone: Page 4238 'the porosity of all soil grid cells is decreased by the corresponding fraction of volumetric root content.' Could you please tell us a bit more about this? Have other models included this? Has the valid-

ity/effect/importance of this been demonstrated? I understand why you have included this here, but it is a complex phenomena that has a direct impact on your modelling results. The intention is that as root volume increases in a soil volume, there is less pore space for water to occupy. Hence as RLD increases available water decreases. Hence, water uptake will reduce as RLD increases just because porosity has decreased.

This is a good point. However, we think that this correction has little influence on our results. First, the reduction of porosity by the fraction of root length per soil volume is relatively low in all 50 realizations (below 4-5 %). This might be due to the quite young root system (30 days) with only a few roots clustering in a certain area. Hence we regard the effects within this exercise as not dominating the overall uptake behaviour since the water availability is lowered in regions of high RLD by less than 5 %. Second, within this exercise, we did not consider further growth of the root system, such that there is no feedback of increasing RLD over time.

We changed the text as follows:
"This is motivated by the fact that as root volume increases in a soil volume, there is less pore space for water to occupy. The resulting reduction of porosity was in all realizations relatively low (up to 5 % in some soil voxels)"

However, in reality roots have a complex effect on soil water content and the movement of water through a soil volume. As roots grow they move the soil around them affecting the pore space distribution. Old root channels and roots that have 'shrunk' with age can provide preferential flow paths, further impacting on the water holding and water movement characteristics of the soil.

This is true, but it was not considered in this model version. However, we plan ton include some of these effects in future model versions. This part was included in the discussion section with the outlook to future investigations by using root systems with clustering roots (very high RLD) and including a temporal change of RLD by adding root growth during simulation time. We added the following text to the last paragraph

of conclusions section:
"Also, roots have a complex effect on soil hydraulic properties and the flow of water through the soil, especially if the interaction between root growth and the surrounding soil is considered. In case of roots clustering in a certain soil volume this might significantly affect the pore space distribution, further impacting the water holding capacity, pore distribution and soil water movement."

2.2.2 The microscopic radial water flow within the soil: Could you explain a little bit more about r_{disc}? How big is r_{disc}? Is there the potential of cylinders to overlap in high root density zones? How is this accounted for?

The routine for calculating the soil disc radius is statically linked to the root length and is calculated by $\sqrt{\frac{SoilVolume}{\pi * RootLengthSoilVolume}}$. A more elaborated routine would be to link r_{disc} for each root segment to the soil water potential gradient along the radial distance of neighboring roots. In this case , r_{disc} would have to be set dynamically at each time step to the distance between the roots where dh/dr is zero. However, this would make the use of the analytical solution very complicated since the current input parameter r_{disc} would turn into a flux dependent variable for which the system has to be solved for.

We added the following sentence:
"The soil disc radius r_{disc} is linked to the root length in a given soil volume and is set equal for all root segments n within the same voxel."

2.5 Model input and scenarios: Consider rewording this section (particularly lines 16 to 23, page 4245). It was hard to follow what the various models and scenarios were. Consider a simple diagrammatic representation of the 3 modelling options.

Added/Adapted text:
"The model exercise was divided into three characteristic cases: (1) the classical RLD

approach widely applied in current SVAT models, but neglecting the root systems network character as well as the microscopic radial water flow within the soil. That approach was compared for the same root systems to simulations performed with the aRoot model under two scenarios: (2) Scenario A where younger roots (higher order) have higher radial resistances and (3) Scenario B where younger roots have lower radial resistances (see Table 1 for those values). The reason for dividing the aRoot model in two Scenarios (A and B) is the ongoing debate on the range of the radial resistance values (references from Steudle and Peterson (1998); Zwieniecki et al. (2003)).“

Page 4247, lines 12-15, I can see some compensation going on for Scenario B, but it is not obvious to me from Fig 4 that there is compensation happening in Scenario A.

There is a compensation happening also for Scenario A (red squares). We agree that this effect is less than it is for Scenario B (this can be seen also more detailed in the new version of Figures 4(b) and 4(c). The reason for less compensation for Scenario A than for B is that there is an earlier onset of water stress leading to a reduced overall uptake already at day 5-6 in average (see Figure 6(a) compared to 6(b)). We changed the text as follows:
"... water uptake from areas of higher RLD is decreased and this decline is compensated by increased uptake from lower RLD regions where Scenario B shows a stronger compensation than Scenario A does.“

Page 4247, line 18, can you provide some explanation to the reader for what water uptake would be lowest for Scenario B? Why does lower radial resistance (easier for water to travel) lead to less water uptake?

We believe this is a misunderstanding. The sentence was misleading. We intended to state that for areas of lower RLD, Scenario B provides the lowest estimates for water uptake compared to Scenario A and to the Feddes model. The text was changed as follows:

"However, in the part of lower RLD (up to 0.1) the sink terms for the Feddes model remained mostly at the 1:1 line with no compensational effects.“

Page 4248, line 17, and Page 4250, lines 18-22. In both the Results and Discussion you state that the Feddes model does not compensate by increasing water uptake from less densely rooted layers. Please provide a little more discussion to explain this to people who have not used the Feddes model. In your implementation of the Feddes model, water uptake is driven only by the fixed flux Tpot (or the potential at the root collar), and the RLD in a soil volume. Since there is no root growth during in simulation, there is no possible mechanism by which roots could compensate. This is the expected outcome for that model, and would have been known before the simulations were run.

The Feddes model itself does not include any compensation due to water stress except that of altering the RLD. We have a modified the mentioned lines in the corresponding sections to consider your remarks. Added/Adapted text:
"... with no compensational effects. This missing effects are a straight result of the Feddes model assumptions.“ "The Feddes approach does not show this moving uptake behavior (as the model does not consider such effects) and additionally lacks the scattering in water uptake rates versus RLD caused by root system architecture.“

4 Discussion: The outstanding result of this paper was the finding that RLD profiles were similar amongst the 50 realisations, while the water uptake behaviour was different. It would be good to do some rewording of the discussion to make the importance of this finding a bit clearer (more explicit). Tell us a bit about why this result is important and what the implications are for modelling water uptake? Is there a need for water models to consider a spatially explicit root system rather than simulate the development of RLD with depth, and under what conditions? Will this result still hold for root systems that grow and develop over time? What would the impact be on growing root systems?

We have added some paragraphs to the discussion:
"Of course, this model results need to be explicitly tested and validated by experimental investigations. However, Javaux et al. (2008) already pointed out, the parameterization based on RLD seems to have little biophysical basis. Our results support this interpretation."

"Nevertheless, root growth can be implemented into aRoot later where we mainly expect changes in estimating the point of water limitation (appearing later) due to root systems adaptation to water stress."

"For the field scale, an effective simulation of water uptake by the spatial explicit aRoot model would be computationally very expensive. Nevertheless, application of models such as aRoot can help to identify, what sensitive processes and parameters shape the root water uptake behaviour, beside classical root length density distribution. The model can be applied also for communities of plant individuals, and can be used to find effective parameters at the plant community scale, by horizontally averaging. Thus, complex models like aRoot can contribute to defining alternative field scale approximations."

Reply to Technical corrections

We corrected all discovered spelling mistakes.

Figures:
Figure 2, Page 4260, Would be good to show 2 root systems in this figure. Would give us a good feel for how different two individuals are.

The figure shows now 2 root systems.

Figure 4, Page 4261, It is a bit hard to interpret results from these graphs. It is hard to distinguish between scenarios, particularly if the paper is printed out in black and white.

Consider changing the scales on Fig4b and Fig 4c from 0-0.3, to 0-0.15. I know that they will not be consistent with fig 4a, but they will be much easier to interpret which I think is more important for trying to tell your story.

Done. The x-axis for Figures 4(b) and 4(c) was scaled to 0-0.2.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 6, 4233, 2009.