Review of Manuscript

'A thermodynamic formulation of root water uptake'

by A. Hildebrandt et al.

Dear Editor, dear Authors,

I have reviewed the aforementioned work. My conclusions and comments are as follows:

1. Scope

The article is within the scope of HESS.

2. Summary

The authors set up a simple model to simulate the energy- and water fluxes related to root water uptake from soil. As the principal goals of the study are to evaluate, in the form of numerical experiments, the effects of soil moisture and root system heterogeneity on the effectiveness of root water uptake and to identify the main bottlenecks of the soil-root water and energy flows, the authors work with several simplifying assumptions to drive and constrain the model: The total root water uptake water flux is kept constant, the initial total soil water content is kept constant, geopotential energy plays no role (soil water storage and root water extraction happen at the same elevation), the xylem potential in the roots dynamically adjusts to the soil hydraulic potential to always yield the fixed total root water uptake (up to a limit of 150 m water column equivalent).

The model architecture consists of a single 'plant' which extends its roots into 4 equal soil boxes. Processes modelled are water fluxes between soil boxes and root water uptake, energy-related states and fluxes involved are soil water binding energy, soil water geopotential energy (this is formulated in the text but not used in the calculations), dissipation from soil water fluxes between boxes, dissipation from root water uptake, energy fluxes from the roots to the soil by drying the soil.

With this model, the authors conduct several numerical experiments in which both the soil water heterogeneity (distribution of the total water content) and root abundance heterogeneity (expressed by the heterogeneity of effective root conductivity) are varied. The results indicate that the overall root water uptake efficiency (work required by the plant to maintain the prescribed total root water uptake) is highest for uniform soil water and root distributions, and its major component being the water flux from the soil into the root.

3. Overall ranking

The work is ranked 'Major revision'.

4. Evaluation

The study is conducted and written in a clear and precise way, all assumptions are clearly stated, the text is well-written and the figures are illustrative. The energy-centered approach to formulate and diagnose dynamics across connected subsystems is interesting and innovative.

However, in the way the study is presented now, the simplifying assumptions are so strong that the study lacks transferability of its insights to real-world soil-plant systems. Although the authors claim that this is not their intention, and they rather seek a proof-of-concept of the energy-based diagnosis system only, the study stays clearly below its potential. Also, without showing that the chosen model parameters are at least in a realistic range and realistic with respect to their relative values, it is not clear whether the overall findings of the paper are transferable to real-world systems.

More specific:

- Are the absolute and relative values of total root water uptake, root system size (and with it the $K_{r,i}$ conductivities) and soil hydraulic properties realistic? Compare to observations.
- Give proof that the negative feedback of soil water availability on the total transpiration rate is not a major constraint and can thus be neglected in the study without compromising the results.
- Why is the process of soil water movement and the associated dissipation in-between the boxes described in the manuscript, but not used in the experiments? It would seem to me that the relative magnitudes of soil water fluxes and root water uptake are a major control on the effectiveness (and strategies) of root water uptake and hence should not be omitted. In this context, the diurnal cycle of transpiration can also play a role (there is time for soil water recharge during the night, where no transpiration occurs). At least show that soil water heterogeneity can indeed persist long enough that it plays a role for root water uptake.

Some minor points

- 13385/24-25: Why can the soil water relation not be formulated in a resistance analogue (e.g. piece-wise linear)? Please clarify.
- 13391/6: Jm^{-3} (the 'J' is missing)
- 13392/20: I suggest 'this additional free energy'
- 13396/9: I suggest 'optimal (from the plant's point of view)'. Also give a link to the later section where you discuss (and resolve) the apparent disagreement of maximum and minimum dissipation states

Yours sincerely,

Uwe Ehret