Modeling Solute Transport Processes in a Plant-Soil System

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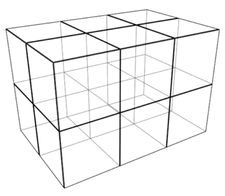
A Water Flow in Soil and Roots

SOIL

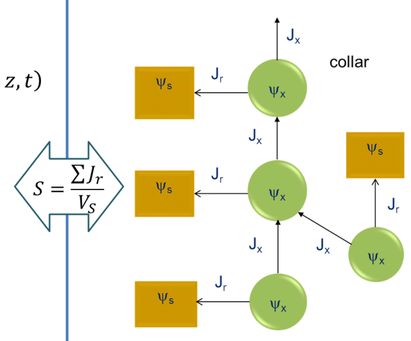
$$\frac{\partial \theta}{\partial t} = \nabla[K\nabla(h-z)] - S(x,y,z,t)$$



NUMERICS: Richards' equation with sink term S given by the soil-root fluxes

Javaux et al. (2008)

ROOT

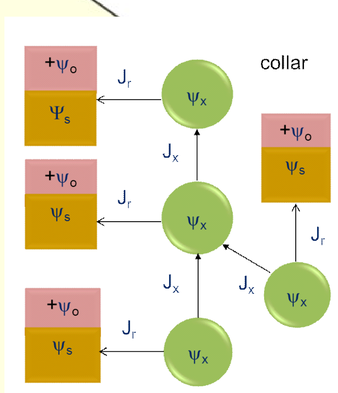


NUMERICS: System of linear equations with boundary conditions given by the soil-root interface water pressure head h_{int} and the plant collar flux time series

B Solute Flow in the Soil

$$J_r^j = K_r^* A_r\left((h_{int} - h_{xylem}) + \sigma(h_{o,int} - h_{o,xylem})\right)$$

Hopmans and Bristow (2002)



- Root water uptake (radial flow into the roots) is driven by <u>total</u> <u>pressure head:</u> $h_{Total} = h_{int} + h_O$
- Change of uptake due to higher salt concentrations around roots and thus a lower pressure head 'felt' by the plant
- Stress onset is earlier, i.o.w. for higher water contents if compared to pure water

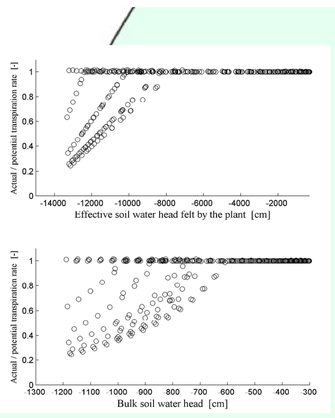


Figure 1: **Difference in root water uptake between averaged and plant felt (at the soil-root interface) pressure head. [Javaux et al., submitted]**

Figure 2: **Three simulations of root water uptake for (A) pure water, (B) salty water, and (C) pure water but hormonal signaling within the roots triggered by local soil water pressure. Root system is colored according to water pressure head (cm), the light blue squares show where water is taken up from the soil.**

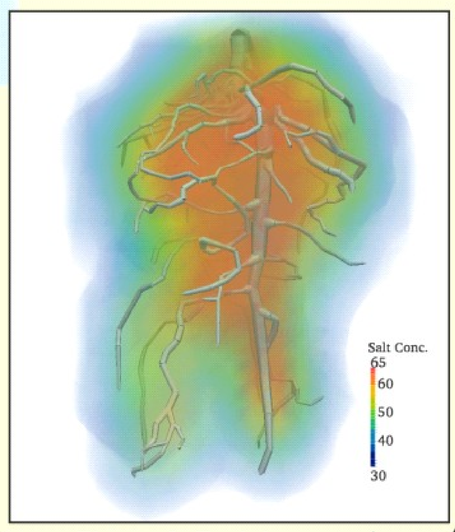


Figure 3: **Enrichment of salt concentration around root structure**

C Solute Flow in Roots

- Hormonal signaling in roots
- Rate of signal production is a function of root pressure head
- Decrease in stomatal conductance as a function of leaf water potential and hormone concentration in the leaf [Tardieu et al. 1998]
- Relative stomatal aperture α is a reduction factor between zero and one that it multiplied to T_{pot}.

$$\alpha = e^{\beta[signal]\, e^{\delta H_{Leaf}}}$$

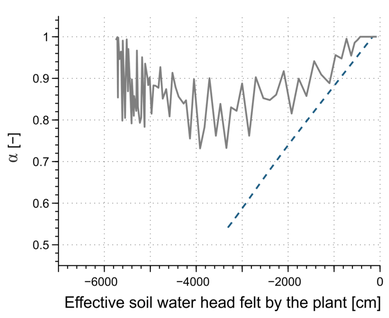


Figure 5: **Hormonal regulation of transpiration reduction ($\alpha = T_{act}/T_{pot}$) can lead to non-linearities. Grey solid line = hormonal signaling, blue dashed line = reference.**

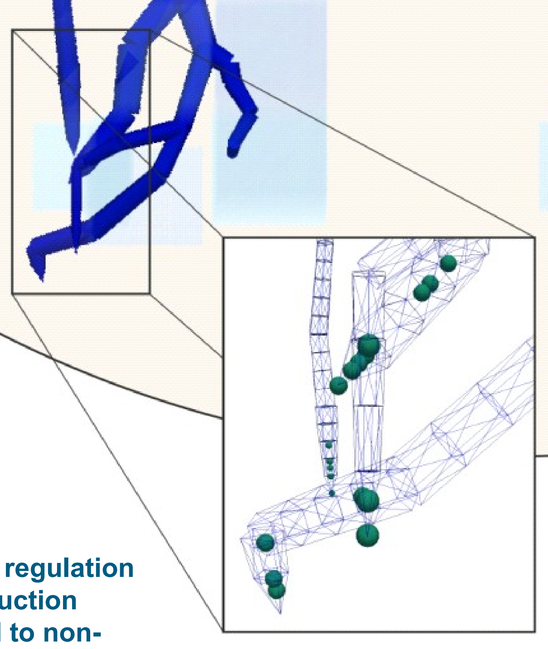


Figure 4: **Closeup of parts of the root system with hormone particles**

Conclusion & Outlook

- **Implementation using the open-source simulator DUMU[x]**
- Combination of solute transport in soil and roots → Salt or solute uptake.
- Adaption of σ to adjust plant resistance in case of prolongued salinity.
- Change of root hydraulic conductivities due to either daptation to soil solutes or hormone concentrations.

References

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Acknowledgments

K.H. is funded by the SFB TR32: Transregional Collaborative Research Center 32 (*www.tr32.de*).