Modeling Soil Water Dynamics with Time-Variable Soil Hydraulic Properties

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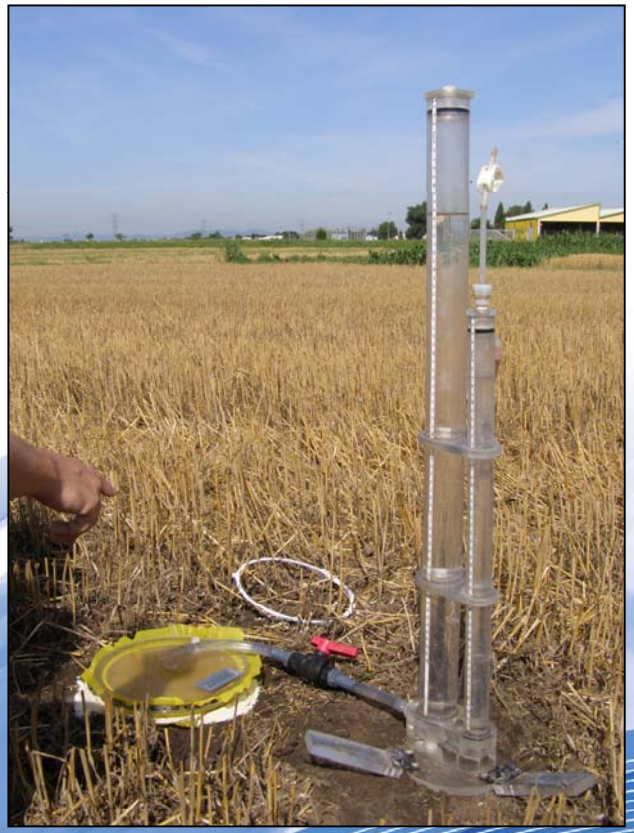
Introduction

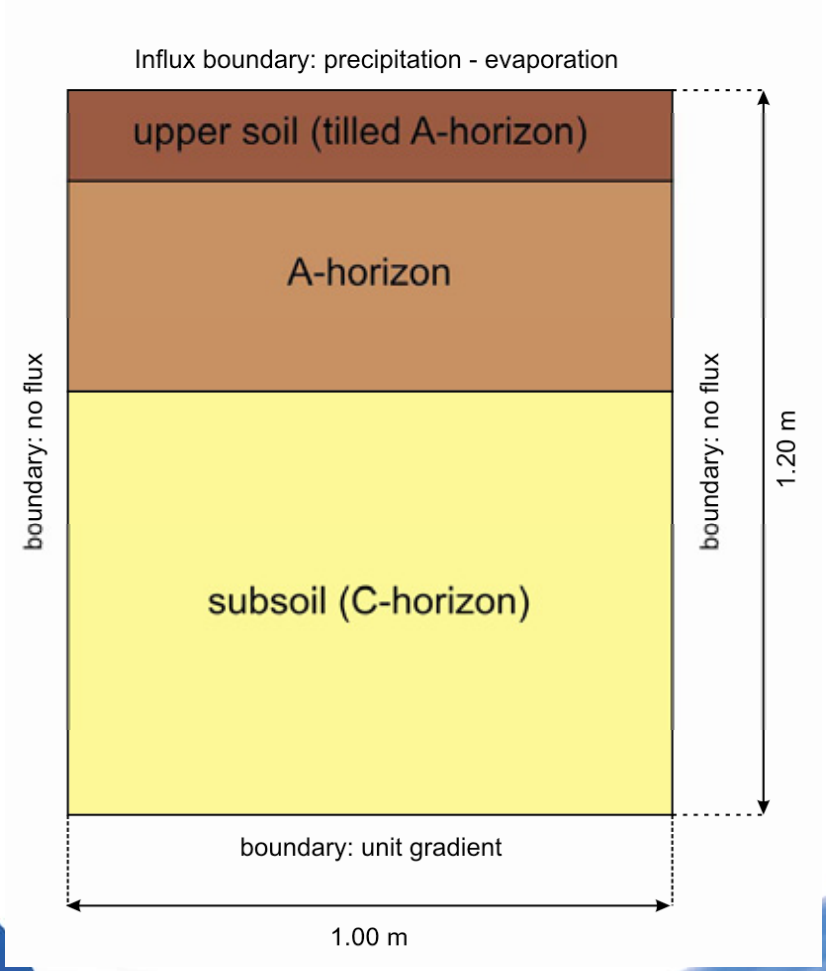
- Modeling of water flow in soils (unsaturated porous media) requires an accurate description of the soil hydraulic properties
- Water retention characteristics (WRC) are assumed to be unchanged over time in most simulation studies (e.g. HYDRUS, Šimunek et al. 2006)
- Empirical evidence that WRC are subject to temporal changes (e.g. Or et al. 2000, Leij et al. 2002): Soil tillage changes the soil pore-size distribution (PSD) → temporal changes in the WRC for top soils

Methods

- Investigation site for the effect of different tillage methods (CT, RT, NT) in Raasdorf, 30 km east of Vienna, Austria
- Infiltration measurements with a minidisc infiltrometer
- Inverse determination of the WRC using HYDRUS
- Calculation of the PSD for each time of meas.



COMSOL Model (1)



- Implementation of a model for the water flow dynamics using the Earth Science Module of COMSOL Multiphysics (transient flow)
- Governing equation (Richards 1931):

$$C\frac{\partial h}{\partial t} = \frac{\partial}{\partial z}\left(K\frac{\partial h}{\partial z} - K\right)$$

- 2D model geometry & boundary conditions: see illustration
- Initial condition: hydraulic pressure head $h_0 = -0.5$ m
- Simulation time: 1 year (day steps)

COMSOL Model (2)

- WRC are described by Kosugi's lognormal retention model (Kosugi 1994):

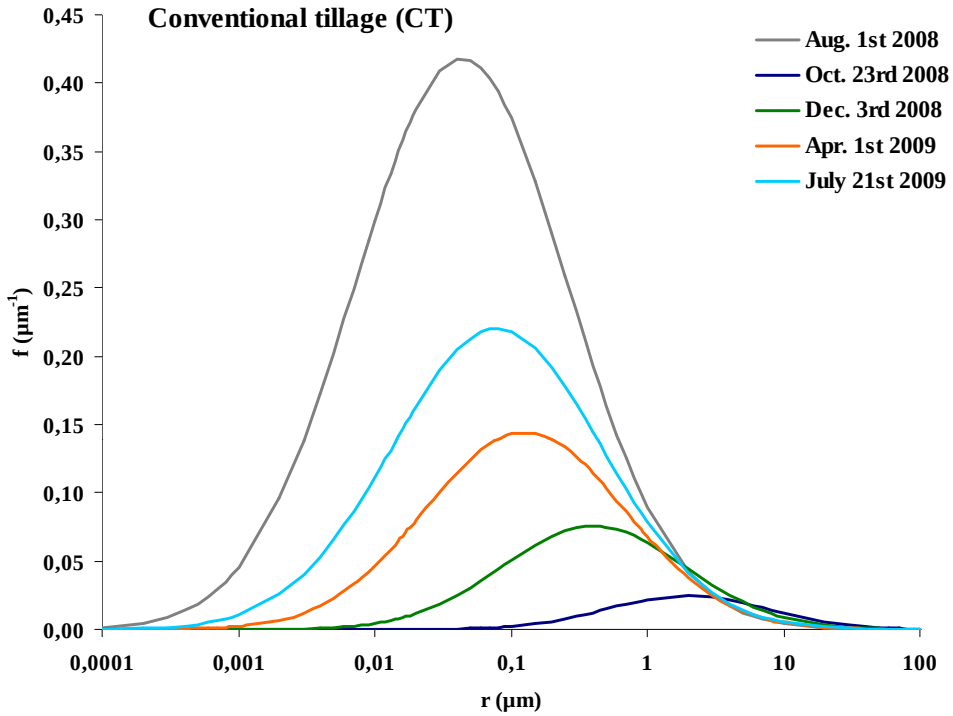
$$\theta(h) = \begin{cases} \left(\frac{1}{2} \operatorname{erfc}\left[\frac{\ln(h/\psi)}{\sqrt{2}\sigma} \right] + \theta_r \right)\left(\theta_s - \theta_r\right) & (h < 0) \\ \theta_s & (h \geq 0) \end{cases}$$

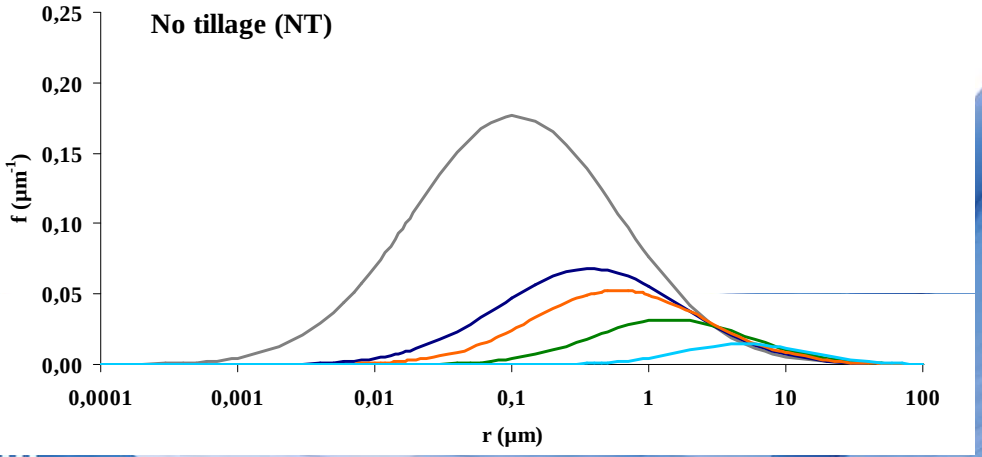
- The relative hydraulic conductivity K_r is defined as follows:

$$K_r(\theta) = \begin{cases} K_s \sqrt{S_e} \cdot \left(\frac{1}{2}\right)^2 \left[\operatorname{erfc}\left(\frac{\ln(h/\psi)}{\sqrt{2}\sigma} + \frac{\sigma}{\sqrt{2}} \right) \right]^2 & (h < 0) \\ K_s & (h \geq 0) \end{cases}$$

- Implementation of *user-defined* WRC-functions with:

MATLAB® R2007b
The Language of Technical Computing

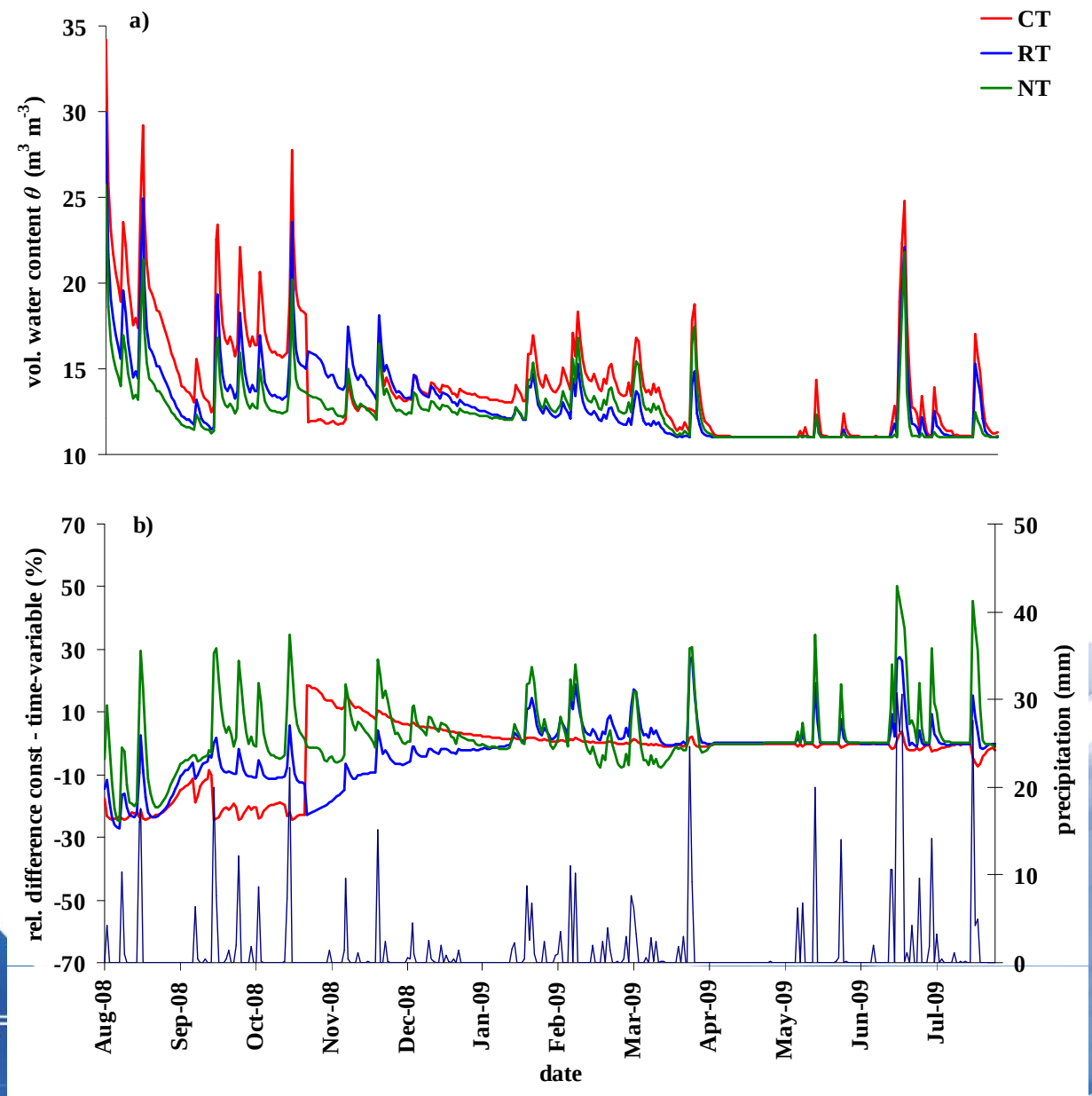




Results

Calculation of the PSD according to Leij et al. (2002):

$$f(r) = \frac{(\theta_s - \theta_r)}{\sqrt{2\pi}\sigma r} \exp - \left(\frac{\ln(r/r_m)}{\sqrt{2}\sigma} \right)^2$$



Results

- distinct differences between the simulations for all methods of tillage
- most effect at high volumetric water contents
- The results of CT simulations show the effect of ploughing in mid-October

Conclusion and perspective

- Implementation of a model approach that enables the flexible definition of time-variable soil retention characteristics.
- The Kosugi retention model allows the definition of the soil retention properties strongly connected to the PSD of the soil.
- Future challenges: Adaptation of a deterministic PSD-evolution model, as proposed by Or et al. (2000).

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Thank you for the audience!