Identification of the heterogeneity in water transport through the unsaturated zone of lysimeters using 18-Oxygen

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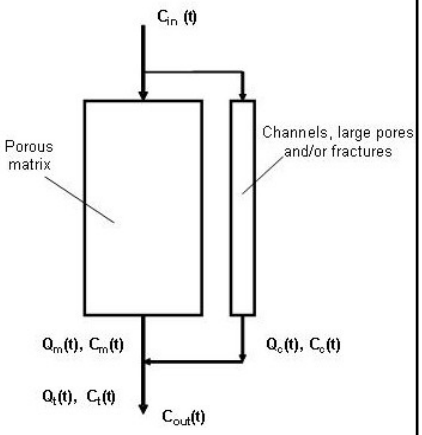
Objective

- modelling transport processes in the unsaturated zone
- application of environmental isotopes → $\delta^{18}O$
- quantification of preferential flow
- description of transport heterogeneity
- influence of vegetation on heterogeneity
- introduction of vulnerability diagrams

Methods

parallel flow system

- matrix flow: $Q_m(t)$, $C_m(t)$
  → Richard´s Equation, CDE
- preferential flow: $Q_c(t)$, $C_c(t)$
  → Piston Flow

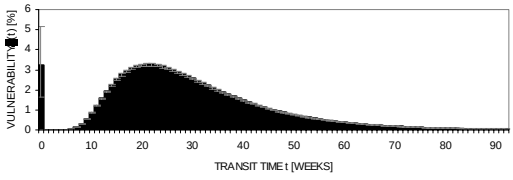


fraction of preferential flow

- $$p(t) = \frac{Q_c(t)}{Q_t(t)} = \frac{C_t(t) - C_m(t)}{C_c(t) - C_m(t)}$$

Vulnerability diagram

$$\omega(\tau_i) = [\,\overline{p} \int_{\tau_i}^{\tau_{i+1}} g_{PFM}(\tau)\,d\tau + (1-\overline{p}) \int_{\tau_i}^{\tau_{i+1}} g_{DM}(\tau)\,d\tau\,] \cdot 100\% \qquad \text{for i =1, N}$$



ω: vulnerability
τ: transit time of tracer particle [T]
$\overline{p}$: mean fraction of direct flow

g(τ): weighting function → transit time distribution function
PFM: Piston Flow Model
DM: Dispersion Model

Lumped parameter approach

$$C_{out}(t) = \int_0^t C_{inp}(\tau) \cdot g(t-\tau)\, d\tau$$

direct flow

→ piston flow model (PFM)

$$g(\tau) = \delta(\tau - t^*)$$

assumed parameter: t*=0

matrix flow

→ dispersion-model (DM)

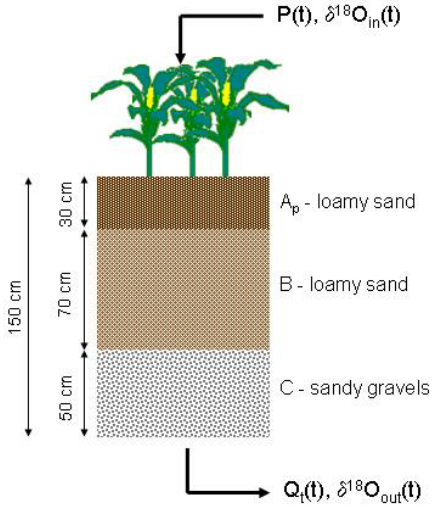
$$g(\tau) = \frac{1}{\sqrt{4\pi (P_D)^* \cdot \frac{\tau^3}{t^*}}} \exp\left[- \frac{\left(1 - \frac{\tau}{t^*}\right)^2}{4(P_D)^* \cdot \frac{\tau}{t^*}} \right]$$

fitting parameter: t*, P_D*=D/(vz)

Material

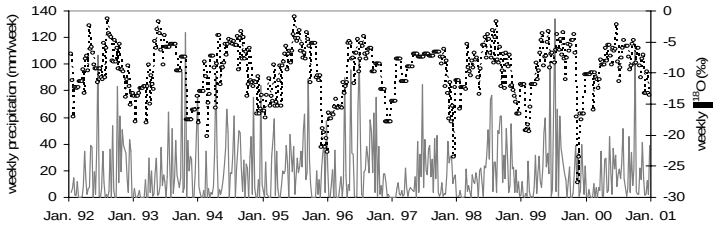
- lysimeter at Wagna research station
- maize monoculture
- 1992-2000
  - precipitation
  - leachate
  - isotopes
  - climate data

    →ETp (Allen et al., 1998)

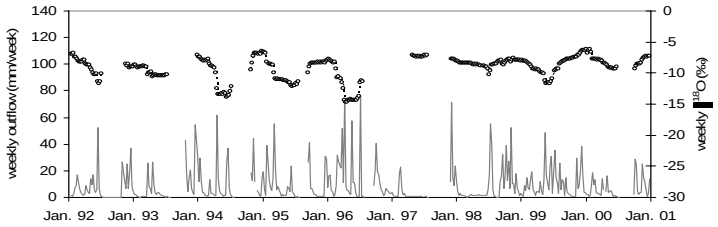


Experimental data

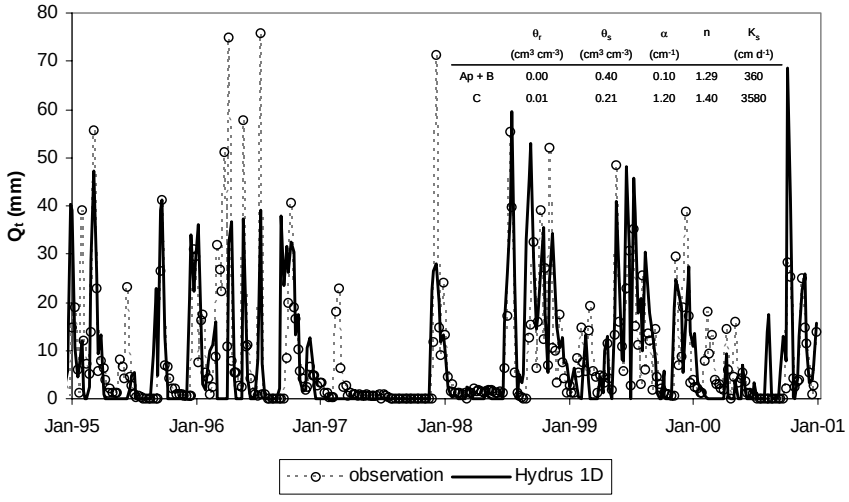
Input



Output

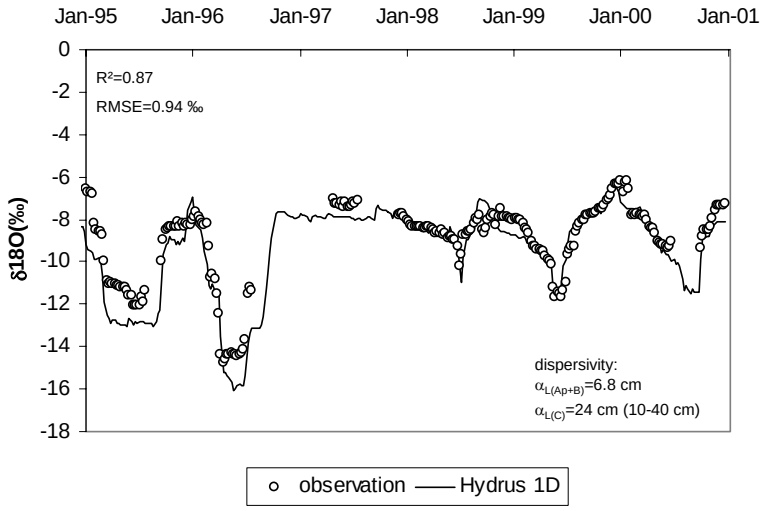


Water transport

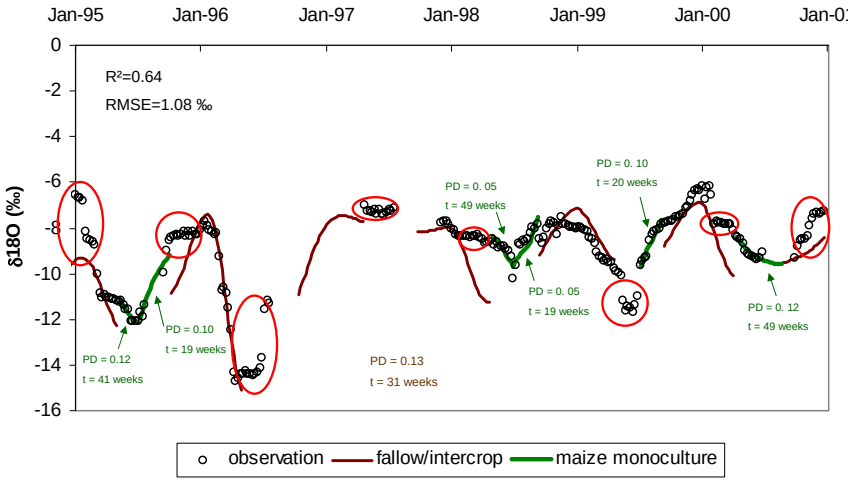


	θ_r ($cm^3\ cm^{-3}$)	θ_s ($cm^3\ cm^{-3}$)	α (cm^{-1})	n	K_s ($cm\ d^{-1}$)
Ap + B	0.00	0.40	0.10	1.29	360
C	0.01	0.21	1.20	1.40	3580

Isotope transport

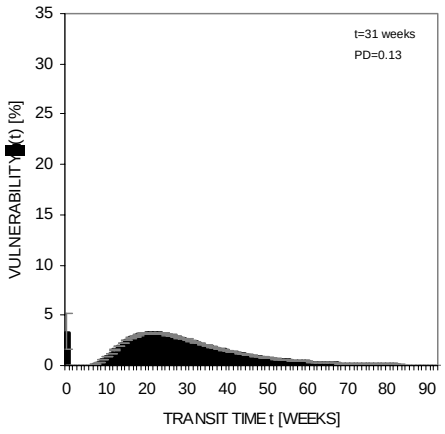


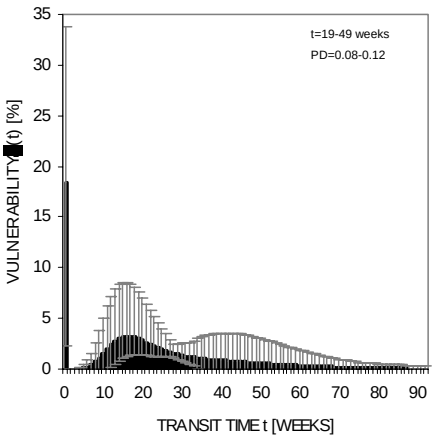
Lumped parameter approach



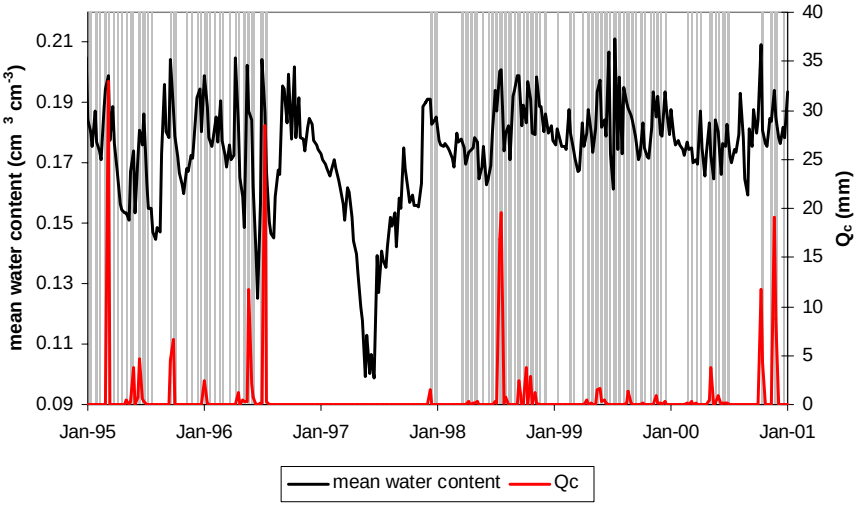
Vulnerability diagrams

- fallow/intercrop
- maize monoculture

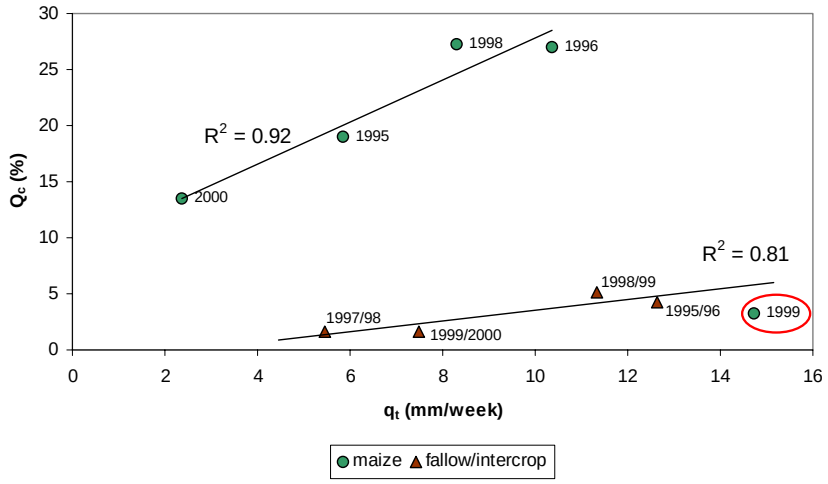




Water content



Preferential flow



Summary

- The presented conceptual model combining hydrological with isotope data enables the **separation and quantification of preferential and matrix flow**.
- The amount of preferential flow varies between **maize vegetation and fallow/intercrop** periods.
- Preferential flow is accompanied by an **increase of mean water content**.
- The fraction of preferential flow is related to the **water discharge**.
- Determination of flow parameters from the lumped parameter approach together with the fractions of preferential and matrix flow give information about **water flux heterogeneity**.
- **Vulnerability diagrams** are constructed based on transit time distributions and are a helpful tool for developing groundwater protection strategies more efficiently.

Thank you for your attention