Significance of tree roots to preferential flow in soil horizons with different degrees of hydromorphy

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- To figure out the influence of roots on the porosity and therefore on infiltrability in hydromorphic soils.

- To assess the significance of the degree of hydromorphy for the relation between roots and hydrologic properties.

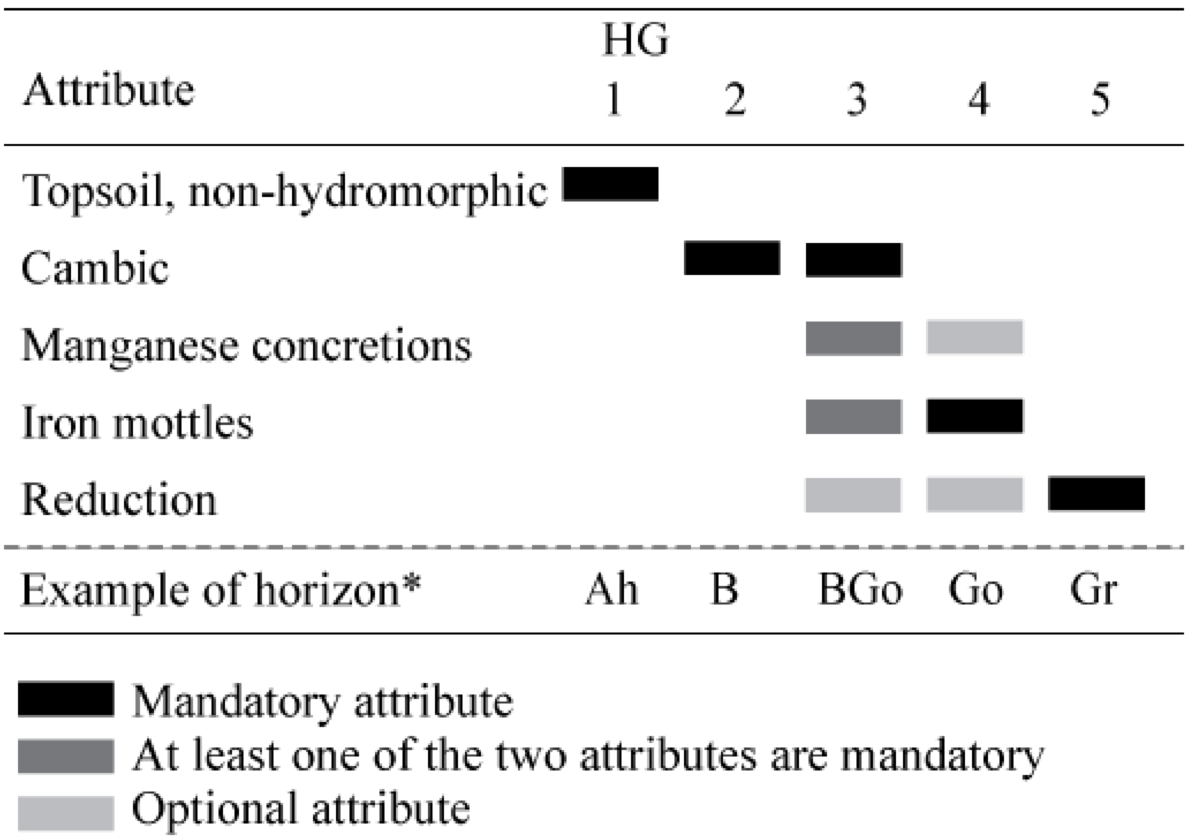
2. Methods

- Study site: “Under Scheidwald”, 30 km south of Bern (Switzerland) at an altitude of 1000 m. The forest stand is classified as a **Bazzanio-Abietetum** (Ellenberg & Klötzli, 1972).
- Soil classification: **stagnic gley** (FAO 2000, Waldböden der Schweiz, Band 3, 2006), bulk density between 0.19 and 1.43 g cm^{-3}.

- Sprinkler **irrigation** ($1m^2$) close to the stem (16 plots)
- **70 mm of water** application within 1 hour.
- Irrigation **three times** within a 23-hour interval.
- Temporal measurements of soil moisture with **TDR probes** during and after the irrigation.
- Sampling of **root probes** with a soil corer, exactly at the same position where TDR-probes were inserted. Analysis with “WinRHIZO”.
- **The basic units for the investigation were morphological horizons**

Grouping of horizons

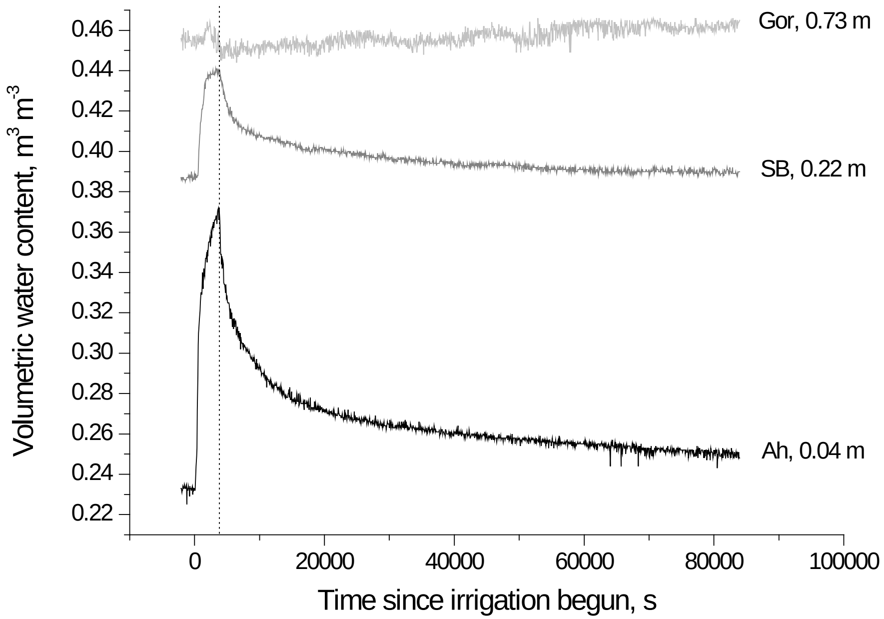
1. Degree of hydromorphy
2. Percentage of organic material in non-hydromorphic horizons

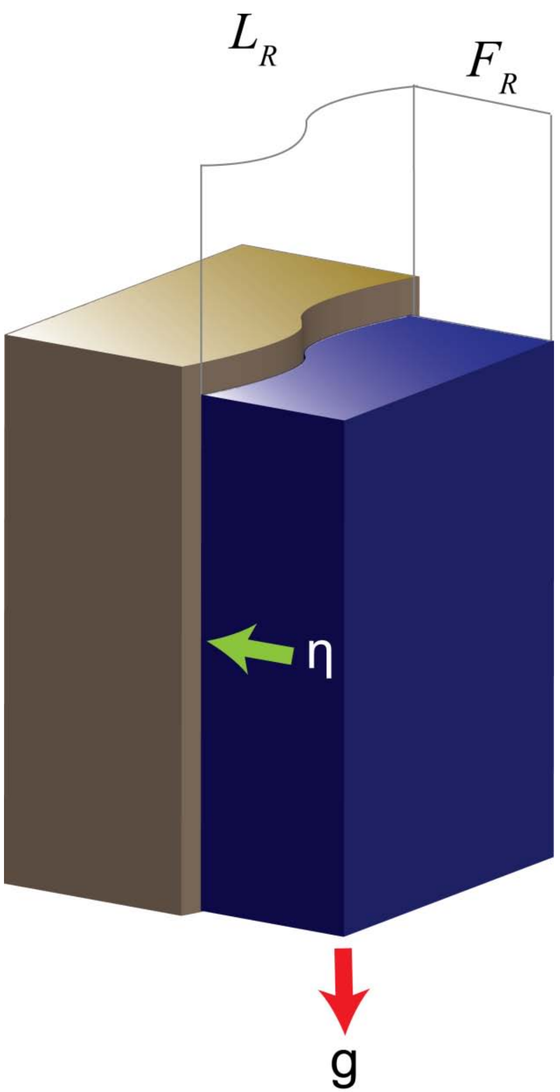


HG: horizon group. *according to Benzler *et al.* (1982)

Rivulet Approach (Germann *et al.*, 2007)

- Tiny water streaks (rivulets) are the basic units of preferential infiltration.
- Rivulets are gravity driven and viscosity controlled.
- A rivulet consists of water film that is defined with its thickness *F* and contact length per area *L*.

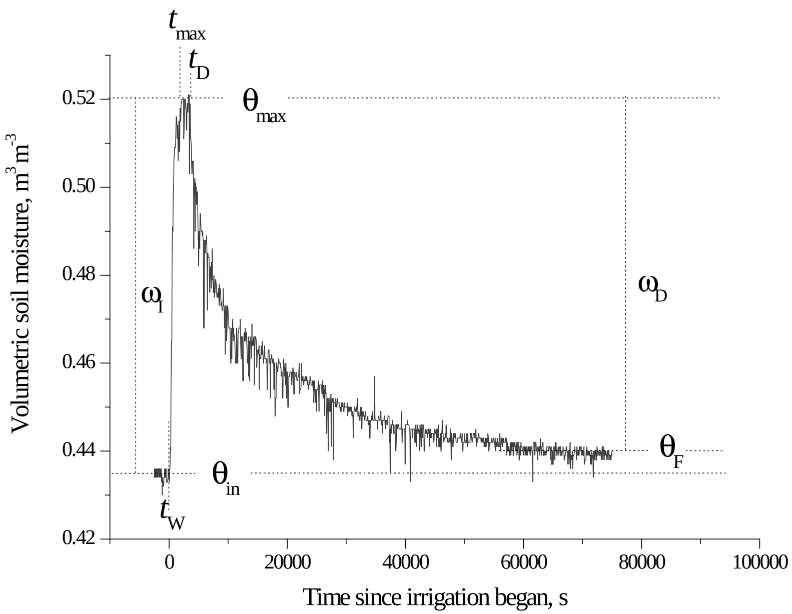




Calculation of contact length and film thickness

1. Determination of the arrival time of the wetting front t_W.
2. Calculation of the velocity of the wetting front v:

$$v = \frac{Z}{t_W} = \frac{g}{3 \cdot \eta} \cdot F^2$$



3. Calculation of the film thickness F

$$F = \sqrt{\frac{3 v \eta}{g}}$$

4. Determination of the water storage capacity w_I
5. Calculation of the contact length L

$$w_I = L \cdot F \Rightarrow L = \frac{w_I}{F}$$

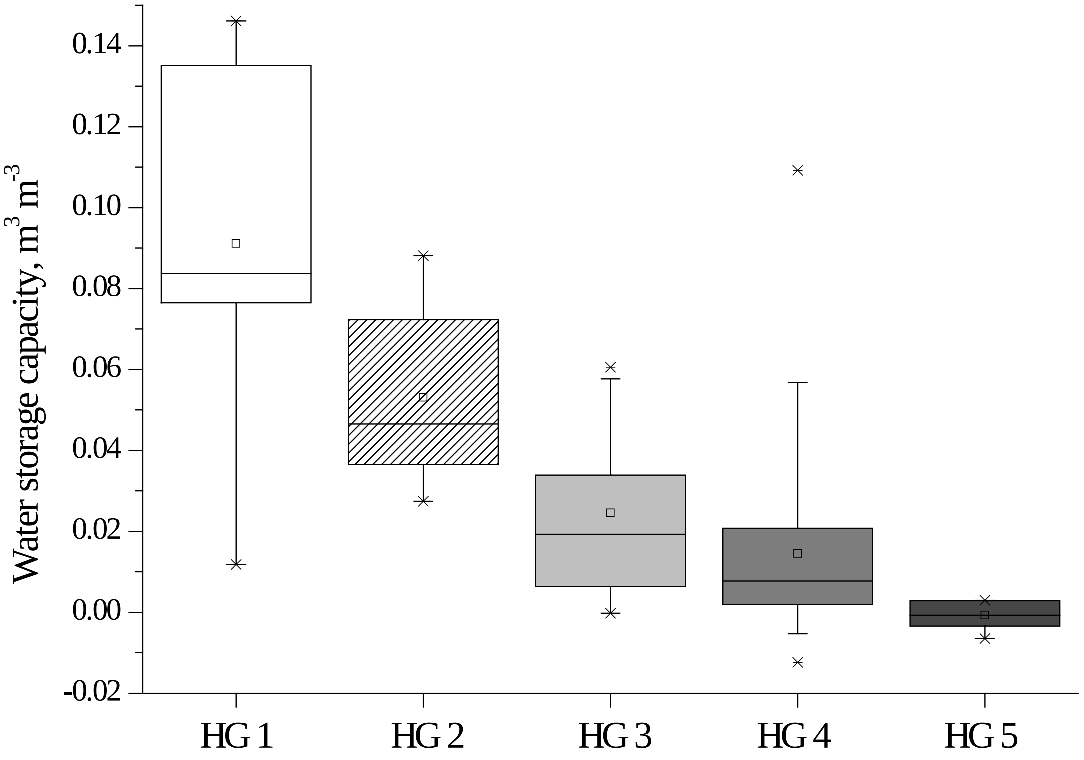
v: velocity of wetting front $m\ s^{-1}$
Z: depth m
t_W: arrival time of wetting front s
g: acceleration due to gravity 9.81 $m\ s^{-2}$
η: viscosity of water 10^{-6} $m^2\ s^{-1}$
F: film thickness m
L: contact length $m\ m^{-2}$
w_I: amplitude of infiltration $m^3\ m^{-3}$

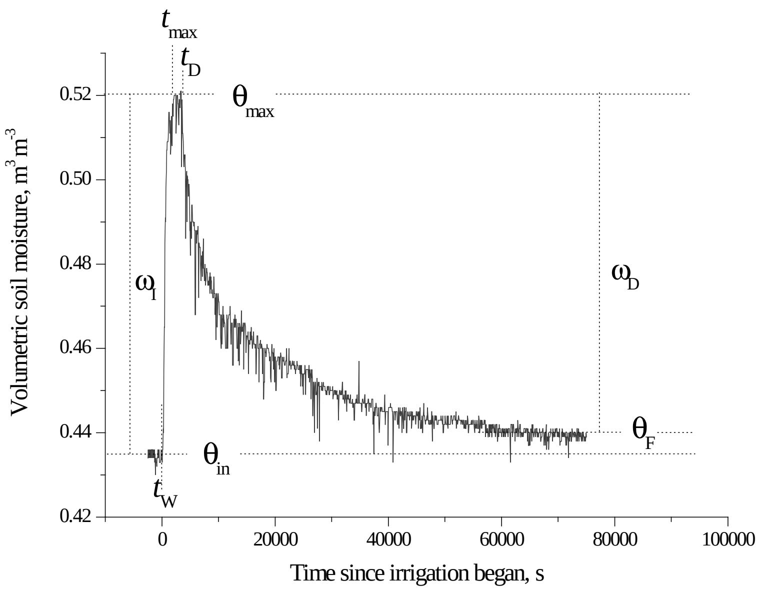
Initial water content θ_{in}

HG	*n*	First irrigation *m³ m⁻³*		Second irrigation *m³ m⁻³*		Third irrigation *m³ m⁻³*	
1	*13*	0.368	*0.137*	0.411	*0.118*	0.415	*0.109*
2	*10*	0.359	*0.094*	0.405	*0.066*	0.410	*0.059*
3	*20*	0.389	*0.094*	0.414	*0.091*	0.421	*0.085*
4	*31*	0.439	*0.066*	0.455	*0.059*	0.454	*0.057*
5	*6*	0.440	*0.037*	0.468	*0.031*	0.471	*0.031*

Averaged initial water content of the horizon groups (*italics: standard deviation*):HG 1: non-hydromorphic topsoils; HG 2: non-hydromorphic subsoils; HG 3: few hydromorphic subsoils; HG 4: hydromorphic subsoils; HG 5: waterlogged subsoils; *n*: sample size

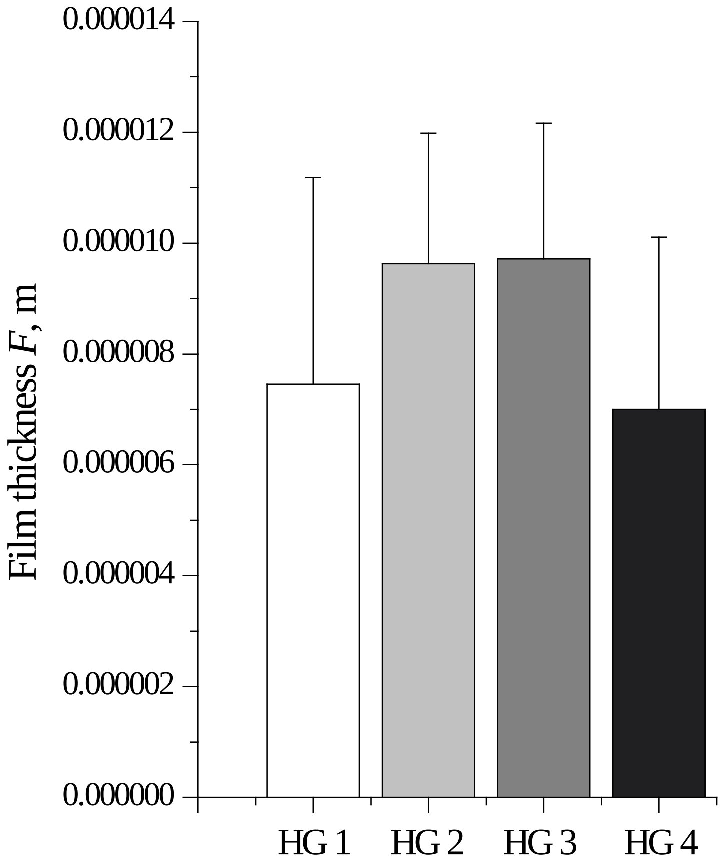
Water storage capacity

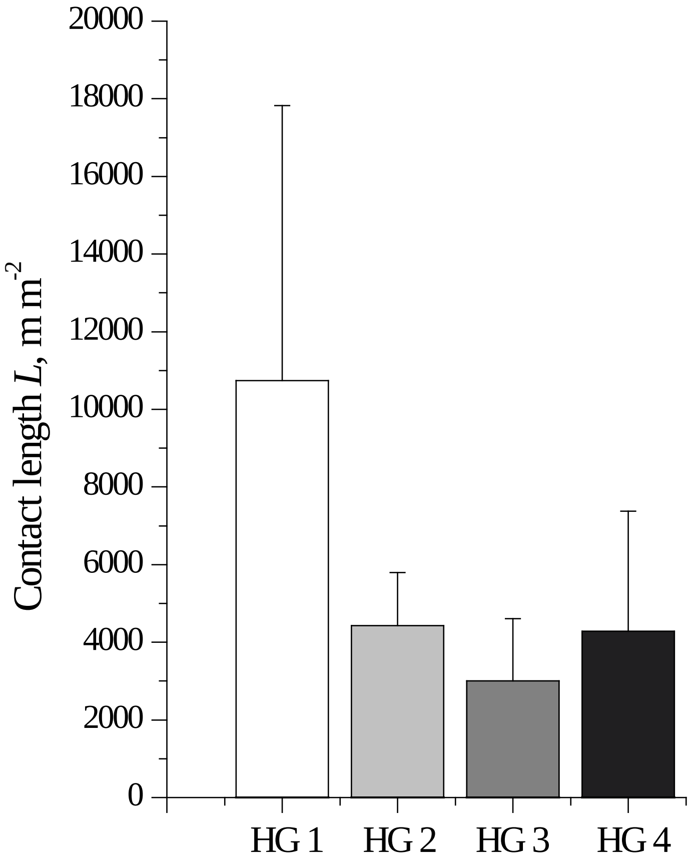


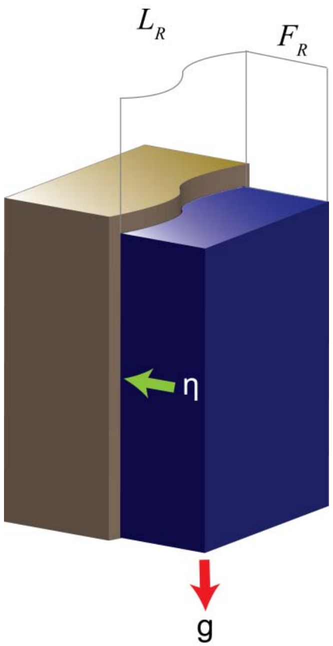


HG 1: non-hydromorphic topsoils; HG 2: non-hydromorphic subsoils; HG 3: few hydromorphic subsoils; HG 4: hydromorphic subsoils; HG 5: waterlogged subsoils

Contact length and film thickness

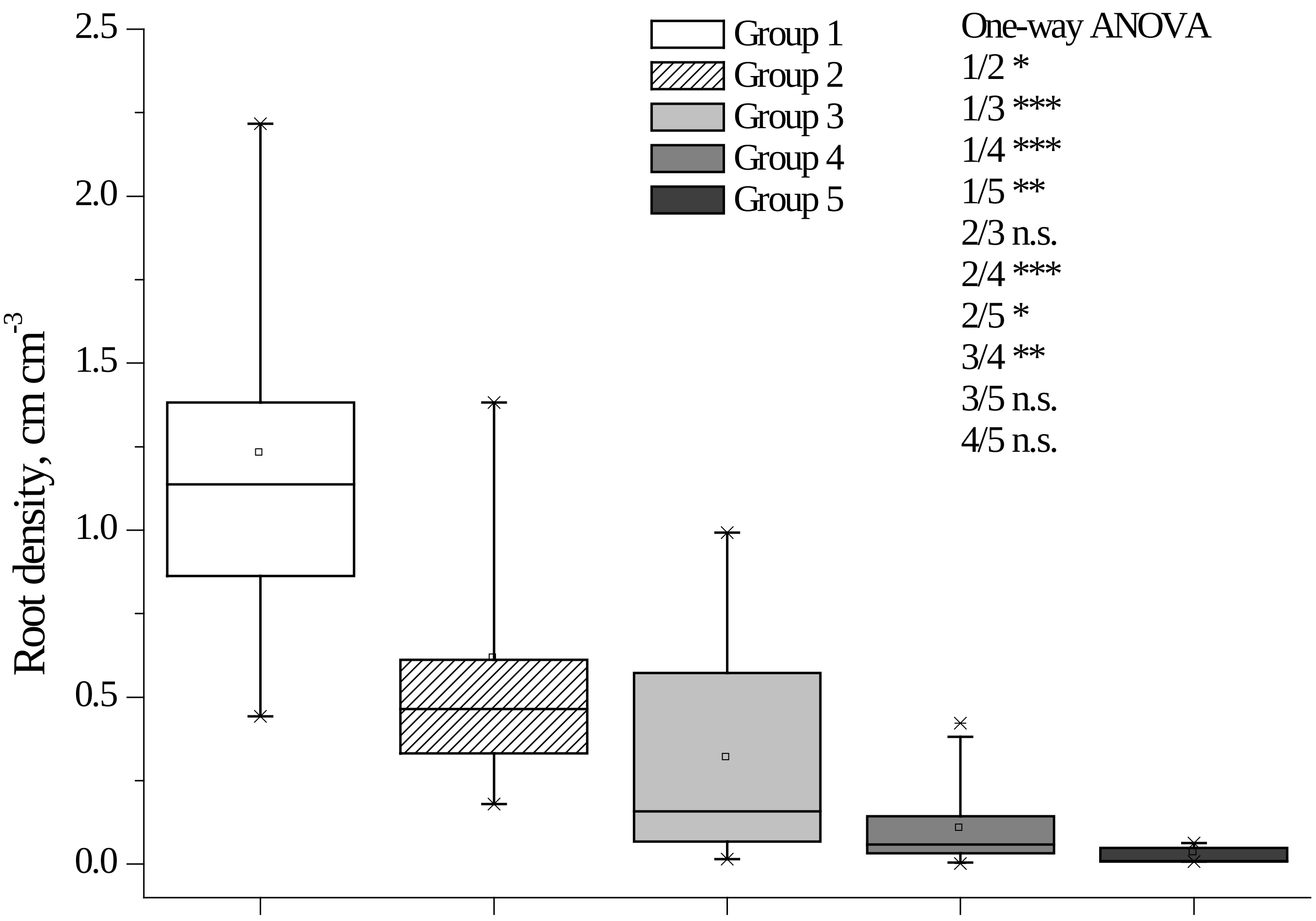






HG 1: non-hydromorphic topsoils; HG 2: non-hydromorphic subsoils; HG 3: few hydromorphic subsoils; HG 4: hydromorphic subsoils

Root densities *RL*

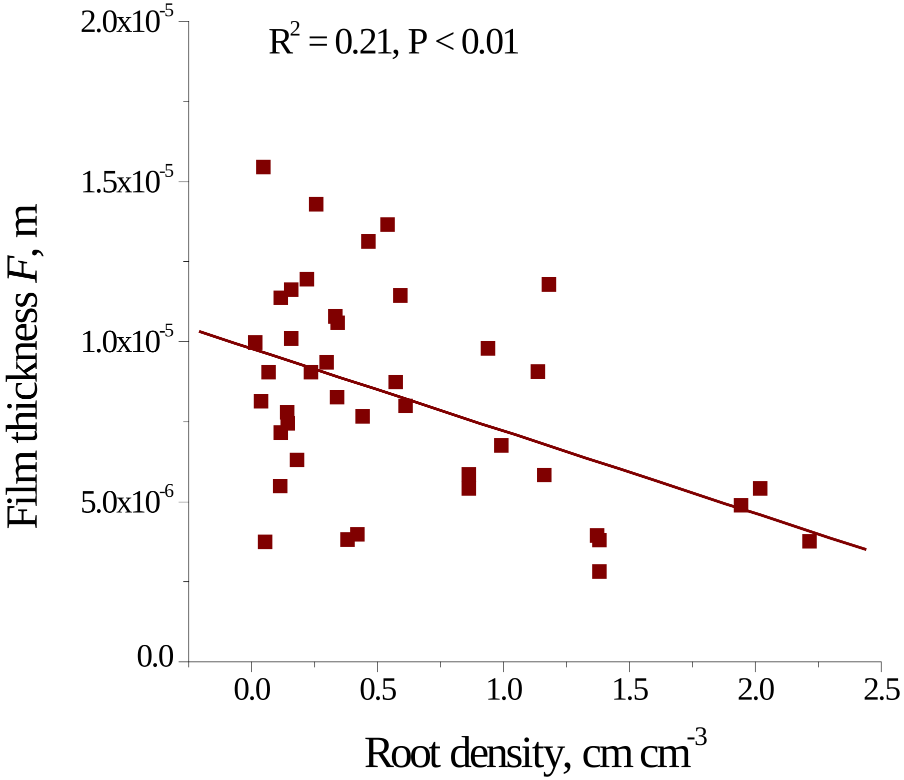


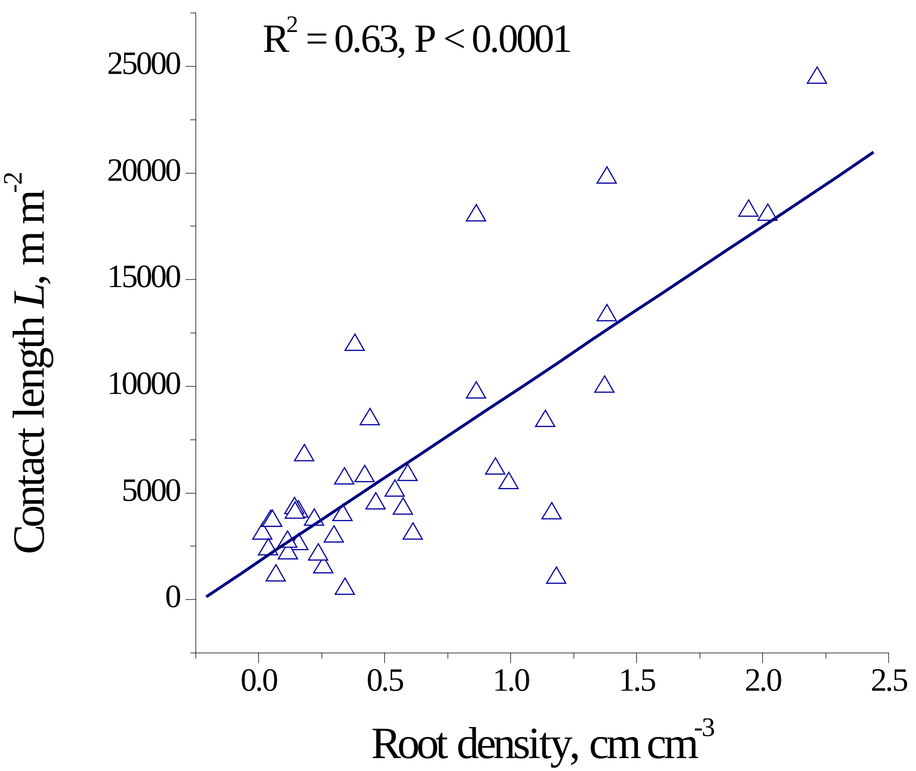
*P < 0.05; **P < 0.01; ***P < 0.001; n.s.: not significant

Group 1: Non hydromorphic topsoil horizons (Ah)
Group 2: Non hydromorphic subsoil horizons (e.g. B)
Group 3: Few hydromorphic subsoil horizons (e.g. Bcn)
Group 4: Hydromorphic subsoil layers (e.g.Go)
Group 5: Waterlogged subsoil layers (e.g. Gr)

Root densities *vs.* film thickness and contact length

- Application of a multiple linear regression analyses to identify soil properties which determine contact length *L*.
- Input data: root length density, bulk density, initial water content, pH, texture (percentage of sand, silt and clay)
- Best predictor for *L*: root length density (R^2 = 0.63), only the consideration of the silt content improved the model slightly (R^2 = 0.66)





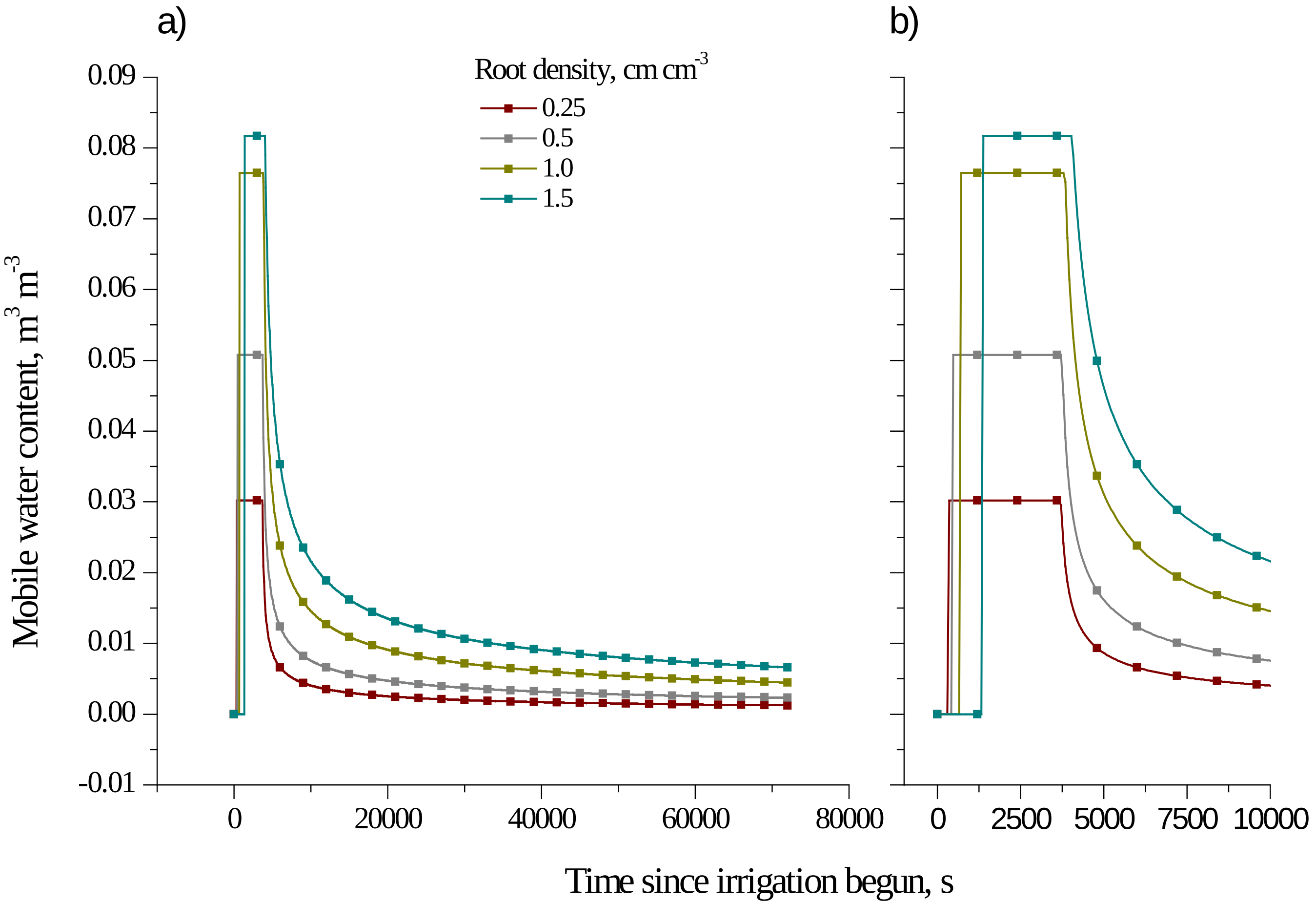
RL vs. *F* and *L* of four horizon groups

Horizon group	*RL* vs. *L*	*RL* vs. *F*
1	0.53**	0.48**
2	0.21 n.s.	0.00 n.s.
3	0.26 n.s.	0.29 n.s.
4	0.62**	0.29 n.s.

HG 1: non-hydromorphic topsoils; HG 2: non-hydromorphic subsoils; HG 3: few hydromorphic subsoils; HG 4: hydromorphic subsoils; *RL*: root density; *L*: contact length; *F*: film thickness

- Roots influence porosity which is effectively involved in water flow in topsoils and hydromorphic subsoils.
- Infiltratbility in cambic horizons seems not to be influenced by the root density. Swelling of clay?

Modelled water content waves for topsoil horizons



- Assumptions: *F* and *L* follow from the correlation lines between root density, *F* and *L* respectively.
- Soil depth is 0.15 m, intensity of irrigation is 70 mm/h, duration 1 h.

- Increasing root density (up to 1.5 cm cm^{-3}) results in increasing water storage capacity.
- Root densities exceeding 1.5 cm cm^{-3} may decrease water storage capacity, but this process is not relevant since root densities were mostly below 1.5 cm cm^{-3}.

5. Conclusions

- Root density influenced the pore system accessible to mobile water in topsoils and hydromorphic subsoils when initial water content was high.
- An increase in the root density by 50 % in hydromorphic horizons would increase the water storage capacity from ≈0.02 to 0.04 $m^3\ m^{-3}$. A 30-cm hydromorphic horizon would be able to store additionally 6 mm water.
- To improve water retention, we propose the cultivation of deep-rooting tree species capable of penetrating into hydromorphic horizons

Acknowledgments

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