HOW SPATIAL VARIABILITY OF SOIL PHYSICAL PROPERTIES AFFECTS MEASUREMENTS AND ESTIMATED HYDRAULIC PROPERTIES: LESSONS LEARNED FROM VIRTUAL SOILS

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SUMMARY

Soils are inherently heterogeneous. Variability of soil physical properties originates from multiple sources, such as inhomogeneity of the parent material, pedogenesis, action of soil organisms and plant roots, or tillage. The resulting heterogeneity affects the transport of water, gas and solutes in soil. To assess the impact of individual or combined structural components on the water dynamics within a soil, we created complex 2D virtual realities, representing cultivated soils with spatial heterogeneity on multiple scales (Fig. 1).

We performed then numerical simulations of water flow under different boundary conditions, to obtain datasets of internal water contents and matric heads, as are recorded in typical field campaigns. This enabled us to assess the impact of the soil structures on the variability of measured data and the prediction of the water balance.

Based on a multitude of “measurements” at different vertical soil profiles, we estimated effective soil hydraulic properties by 1D inverse simulation, which were then used to predict the water balance. We examined (i) the impact of the within-field structures on the lateral variability of state variables, (ii) the feasibility of effective 1D description of 2D systems, (iii) the variability of effective parameters estimated from laterally different measurement positions, and (iv) the impact of this variability on the assessment of the water balance.

The results showed that measurements, particularly those of water contents, depended strongly on the measuring position and hence led to different estimates of the soil hydraulic properties. Thus, using data from only one observation profile, the correct calculation of the water balance was rather a lucky coincidence than the rule. However, the average of the predicted water balances obtained from the 1D simulations and soil hydraulic properties estimated from averaged measurements agreed very well with those attained from the 2D systems.
Fig. 1: Spatial distribution of material properties (top) and sub-scale heterogeneity (bottom) of three virtual soils: soil A – reference soil with macroscopic homogeneous topsoil (upper 150 cm) with stochastic heterogeneity, realized by a random field of a Miller-Miller scaling factor, and with a subsoil (150 cm to 500 cm) composed of sand with embedded loam lenses and no small-scale heterogeneity. Soil B – a seedbed and a plough horizon are added as 1D features, soil C - Full complexity: plough pan is interrupted and certain positions and wheel tracks are added. The inlays depict a magnification of a 100x100 cm² section (after Schlüter et al. 2012, modified).

References: