Geophysical Research Abstracts,
Vol. 10, EGU2008-A-05363, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-05363
EGU General Assembly 2008

Structure and function in soil hydrology

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Structure of soil and soil cover is the major control of soil functioning, being in turn controlled with multiple feedbacks. Existing methods and parameters to characterize soil and soil cover structure are scale-dependent.

The purpose of this talk to suggest that the effect of structure on soil hydrologic function is best quantified if soil structure and soil hydrologic function are defined at the same scale with the caveat that void structure is better suited to be related to soil hydrologic function functions as compared with structure of soil solids.

Parameters controlling soil hydrologic functions are different at different scales. This is reflected in "functional models" in soil hydrology which rely on the scale-specific hydraulic parameters. These scale-specific parameters have shown to be related to the structural parameters.

At the ped scale ($n \cdot 10^{-2}$ m laterally), important soil hydrologic functions are to provide water and nutrients to roots, and the survival media and oxygen to microorganisms. Parameters of this hydrologic function - unsaturated hydraulic conductivity, water retention, and gas diffusion coefficient) - have been satisfactorily related to soil void structure defined, for example, in terms of fractal dimensions or in terms of the Markovian probabilities. An example will be presented that shows that a single structural parameter is sufficient to predict soil unsaturated hydraulic conductivity with the respectable accuracy.

At the horizon scale ($n \cdot 1$ m laterally), important soil hydrologic functions are to provide plants with water and to provide drainage to prevent waterlogging. Existing data will be summarized to show the close relationship between soil hydrologic function parameters - saturated hydraulic conductivity and plant available water or water accessibility - and soil structure defined in terms of ped size, ped orientation, ped shape, etc.

At the field scale (n $\cdot 10^2$ m laterally) important soil hydrologic functions are to provide groundwater recharge, to filter surface water from chemicals and particulates, and to provide base flow to rivers and streams. Example of the HOST system will be presented to show that parameters of these hydrologic functions, are closely related to structural parameters of both soil and the geological substrate, such as the presence of a surface organic horizon, presence and position of the gley layer, presence and position of the slowly permeable layer, soil air capacity, the degree of substrate consolidation, the substrate macroporosity, and the presence of preferential flow pathways in the substrate.

The interscale relationships between parameters of soil structure and soil hydrologic function are difficult to infer if scales of structure and function do not match. Fine-scale heterogeneities important for coarser scales typically are not reflected in structure parameters at finer scales. In turn, parameters of structure at coarser scales do not reflect intricacies of the fine-scale structure. An attempt to estimate the "field" field capacity from fine-scale data, and an attempt to estimate fine-scale hydraulic properties from coarse-scale structure description will illustrate this point.

Defining structural parameters specific for the scale of hydrologic function in question becomes of paramount importance. Physical, geophysical and biophysical methods for partially and variably saturated soils and substrates are needed to address this matter. We will conclude with example of the ground penetration radar and the crop monitoring data fusion at the field scale to delineate locations of the subsurface slowly permeable layer and preferential subsurface pathways in the shallow groundwater layer.

Realization of the "structure-function" relationship in soil hydrology calls for better methods of representing qualitative data on soil structure in quantitative predictive models. As synthetic examples of porous media are gaining popularity in subsurface hydrology, realistic generators have to be able to cross the scale boundary and the resultant structures have to be realistic in terms of the soil or soil cover parameters of the coarser scale.

Overall, given the implications that interactions of structure and function have for soil functioning in natural and made-made ecosystems at different scales, these interactions deserve to become the focus of attention in soil hydrology.