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Relationships between soil constituents, soil life, and the soil physical properties as assessed with shrinkage modelling: goals, insights and issues.

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The soil pore network and its stability result from complex interactions between constituents, life, boundary conditions and soil history; it largely controls soil properties such as transfer, retention, geochemistry, fertility and biodiversity. Therefore, soil physical characterizations should be accurate and inexpensive, as well as accounting for and predicting the impact of soil dynamics – such as water transfers, microbial activity [1], which is far from being the case. Soil physical properties, moreover, present large and often unexplained spatial variability, which results in poor quality maps, while soil constituents exhibit smaller variability and good spatial correlation, thus generally easier and less expensive to map. Soil scientists are, therefore, looking for well determined relationships between physical properties and soil constituents, called pedotransfer functions (PTFs).

Most of the developments in soil physics were based on the assumptions of rigidity, homogeneity and uniformity of the pore network. The soil porosity was, however, long ago recognized as formed of two pore systems, namely plasma and structural pores [2]. The plasma is formed of "materials other than skeleton", that is the colloids and binding elements. This distinction was physically validated [3] and is based on the pore behaviour, although most pore radii are smaller than 10 microns in (air dried) plasma and larger than 10 microns in structural pores. Plasma pores are highly reactive. They shrink and swell like a clay paste with water, thus remaining saturated along most of the water content range, which largely departs from the rigid assumption and the capillary theory. Conversely, the structural pores allow air entry with decreasing water content. The soil is organized in peds of plasma separated by structural pores. Thus, water is going out of the plasma into the structural pores upon shrinking of the plasma [4].

Assuming a unique and uniform pore network leads to analyse antagonists properties in a single determination and is, we believe, at the origin of major today's limitations in soil physics. The physical distinction between these two pore systems can be performed based on the soil shrinkage analysis [4-10]. The determination is inexpensive and allows determining simultaneously the shrinkage and water retention properties of the soil [6]. The measured parameters are pore volumes, water retention properties and hydro-structural stability [10, 11], they show small coefficients of variation [5].

Shrinkage properties can be scaled with respect to field variability of soil constituents [11, 12], thus revealing hidden impacts such as compaction. The separated effects of soil organic carbon (SOC) and clay contents on the physical properties can be quantified for e.g. modelling the feedback effect of SOC mineralization on microbial activity [7, 13]. The relative impact of root, mycorhizae and earthworms on soil structure and soil plasma can be quantified as well.

Shrinkage analysis represents, therefore, an opportunity to overcome strong limitations of soil physics, particularly for soil protection and the modelling water and gas transfers in the SPAC. It is, however, based on assumptions needing further discussion. Establishing deterministic relations between constituents, plasma properties and structural properties will allow bridging the gap between the knowledge in soil constituents, hydrodynamics and mechanic.

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