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Hydrology and Earth System Sciences Discussions

Interactive comment on "A multi-scale soil water structure model based on the pedostructure concept" *by* E. Braudeau et al.

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Thanks a lot for your remarks and comments. We take this opportunity to clarify this research and its contribution to Pedology (soil organizations mapping) and soil water physics (soil structure and soil water interactions); specifically, why the currently used equations that describe the soil structure and its functionality with water (shrinkage curve, water potential curve, hydraulic conductivity curve) are still empirical. All of the current models of shrinkage curve and soil water potential curve, even those said physically based, do not at all describe the thermodynamic interaction between the water and solid surfaces of the hierarchical soil structure: they are not physically but mathematically based on a assumed arrangement of particles and where the interaction with water is only function of the pore radius.

Thus, there is actually a big problem to resolve in soil science: all models of soil water dynamics used stand alone or integrated in other soil-plant-atmosphere models (cropping systems modeling), are empirical in the sense that i) they don't use the variables that describe the hierarchical soil organization (like the water contents in, and out of, the primary peds) and that ii) equations describing the hydraulic functionality of this organization , like the soil water potential curve, and their parameters have no physical meaning: they characterize the shape of the curve, not the mechanism of soil structure and water interaction that generates the curve. This statement makes the pedostructure concept as transformational science and a new paradigm of soil characterization and modeling in which the soil structure is taken into account.

We demonstrated in a recent paper (Braudeau, E., Mohtar, R.H., Modeling the soil system: Bridging the gap between pedology and soil–water physics, Glob. Planet. Change (2009), doi:10.1016/j.gloplacha.2008.12.002), which is referenced in the current article, how the notion of REV must be completed by that of SREV (structure representative elementary volume) to be able to introduce terms of the soil structure in the usual equations describing soil water hydral states and dynamics. The resulting new paradigm of soil characterization and modeling that takes into account the soil structure was explicated and discussed in the mentioned GPC paper, which, we think, is not known by the reviewer while it could be a good answer to many of his comments. In fact, the current paper is only the application of the theory: a presentation of Kamel, a soil water and structure dynamics model which was built in this new paradigm, based on the pedostructure concept.

Concerning the shrinkage curve and the well known soil water potential curve, we gave a thermodynamic definition of these curves, both "soil moisture characteristics" of the soil fabric. The shrinkage curve deals with specific volumes of hydrostructural units. It serves to define the correct variables describing the soil structure functionality. The fundamental hypothesis made in our work is the recognition of the existence of primary peds such that those described in micromorphology by Brewer (1964). We proved the validity of this assumption in previous work by: Braudeau and Bruand, 1993; and Colleuille and Braudeau, 1996. In contrary to the explanations in the comment, XP model is quite empirical, just modeling the shape of the curve while the SP model is physically based on the soil hydro-functional structure meaning that variables and parameters of the shrinkage curve equation are defined and refer to the structure of the soil medium, made of primary peds assembly. We would like to add that WM, is i) well defined on the ShC when a structural shrinkage phase is present and ii) that it was shown to be equal, in value, to the water content of primary peds at their maximum swelling! If one does not recognize the existence of primary peds, WM, as some other pedostructure characteristics, cannot be defined nor formulated.

In fact, the measurement of WM is one thing and its physical definition is yet another thing. We need, overall the latter for using WM in our equations as a soil characteristic. Obviously, a maximum swelling of primary peds does exist and we have to use it as a functional parameter. This parameter enters in the equation of the water potential in primary peds and in the interped space.

Assuming the presence of primary peds composing the soil medium, the definition of the four water pools goes by itself. Their equations of equilibrium at each water content were formulated in Braudeau et al. 2004 as described by the comment. However, in contrary to the comment, the conditions of the measurement of the shrinkage curve, as well as for the potential curve, are such that evaporation of water is regular with time and slow enough to consider these curves as a suit of equilibrium states.

There is still a lot of works to be conducted as far as shrinkage curve. The shrinkage curves of certain soils are not sigmoidal, especially those of loamic and silty soils. Pedostructure parameters of such curves cannot be determined as for the sigmoidal curves and relationships with the soil water potential curve have to be sought. Further research also must be done about the dynamic of the primary peds swelling since this was studied only on kaolinitic soils and in a certain condition (water potential of the interped water aqual to zero). All these future works can be made by every one.

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Interactive Comment

As far as the last comment about the hydraulic conductivity curve is a little bit surprising "... adds number of empirical expressions for hydraulic conductivity (starting from those of 50 years old)". We just adapted this old equation, which is not longer used today and totally forgotten, because i) it was obtained by measurement in the field (Davidson et al 1969) and ii) corresponded well to our new paradigm. We have shown, in the article, how this equation is in agreement with the ones currently used today as function of water potential instead of the interpedal water content, in an range of water content. Additionally overall, simulations made using published soil characteristics and compared to field measured data showed that the hypothesis of an exponential expression of macro water content for the hydraulic conductivity curve is valid (no need of r2 to say that because water profiles measured and observed are the same at each day, from 1 to 60 days). Few interesting explanations about the exponential shape of the equation and about the meanings of its parameters were given, based on the result of the simulations. This section opens a way for a better understanding of the soil hydraulic conductivity.

In conclusion, we realized what exactly are the stakes and the challenge (in engineering) of modeling the coupled dynamics of soil water and soil structure within a pedon, coupled to the external climate and representative of a soil map unit. It is one way for physically coupling all biological and geochemical processes in soil with the soil types and pedoclimate. If this has not been done yet in soil science, it is only because of the exclusive use of the REV paradigm which is that of the continuous porous media mechanics. The new SREV paradigm opens the way for the physical coupling of soil structure with water and air, then with all processes in soil. All this explains how we were able to say that, referring to this new paradigm, the model Kamel can be taken as a reference etalon for the calibration of the other existing soil water models that do not actually take into account the soil structure.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 6, 1111, 2009.

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Discussion Paper