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Model and experimental investigations of water retention of repellent and subcritical repellent soils

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Soil organic matter can modify the surface properties of the soil mineral phase by changing the surface tension of the mineral surfaces. This modifies the soil's solid-water contact angle, which in turn would be expected to affect its water retention curve (SWRC). Here we model the impact of differences in the soil pore-water contact angle on capillarity in non-cylindrical pores by accounting for their complex pore-geometry.

Theoretical modeling, assuming a constant surface tension of soil particle surfaces, supported by experimental observations using materials with different water repellency levels ('model soil' soils containing grains that exhibit 'permanent' hydrophobicity and field soil samples), demonstrate that (i) water retention depends strongly on the solid-water wetting angle for the wetting curve, but has little impact on the drying curve and (ii) that water retention is a feature not of only wettable soils, but also soils that are in a water repellent state. This behavior cannot be explained on the basis of the commonly used, but vastly simplifying, capillary bundle model for soil pores. The new model presented here takes account of the wavy nature of soil pores and explains the experimental observations made on model and field soils. Although the model is based on a simplified ('permanent') hydrophobicity of soil particle surfaces, its principles and implications are relevant also to more complex scenarios in which particle surface hydrophobicity may change during wetting and drying phases. The currently used methods for measuring the Young's wetting angle on soil samples are insufficient in representing the variable wetting angle in the soil pore space and hence its impact on the SWRC.

The theoretical predictions and experimental results obtained here indicate that small changes in wetting angle can cause switches between wettable and water repellent soil behaviour of the soil pore space. This may explain the common observation that relatively small changes in soil water content can cause substantial changes in soil wettability irrespective of changes in surface tension (i.e. hydrophobicity) of individual soil particle surfaces. The model derived here would also help to explain the substantial reductions in water repellency observed following soil compaction, which results in changes in pore geometry and hence wetting angle. The above findings are not only relevant for soils, but also for predicting wettability and water retention of other, potentially water repellent, porous media such as reservoir rocks containing hydrocarbons, or the wide variety of man-made materials used in engineering, construction or medicine.