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A thermodynamic interpretation of soil water retention and dynamics

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The state of soil water is a permanent interplay of gravitational and capillary forces acting on the water fraction. The classical concept of "field capacity" is one expression of this notion but remains weakly defined. Similarly, deviations of laboratory and in situ derived soil water retention curves point to limitations of the universality of the concept, reducing the interplay to a unique function. Although the matric potential is defined thermodynamically, a thermodynamic interpretation of soil properties and soil water dynamics is often missing.

We can translate the classic soil water retention concept to free energy consisting of potential energy and capillary binding energy. Alternatively to a tension-defined "field capacity", this relationship has a minimum acting as an attractor of local thermodynamic equilibrium.
Calculating potential energy requires the definition of a reference elevation. While this appears arbitrary at first sight, it becomes an interesting feature when analysed more closely: With regard to the full retention relation, the higher the elevation above a reference ground water, the lower the relative saturation at local thermodynamic equilibrium. Complementary, in-situ retention relations exhibit a local minimum, which can be used to infer the mean elevation above groundwater. The first aspect supports the general finding of more dry soils in the upper part of a catena. As such it allows to explain functional differences of the same soil based on its position. Moreover, the approach unifies laboratory and field derived retention curves in a physically consistent framework of mass and energy.

We will present the theory alongside with exemplary data from laboratory and field measurements. Moreover, we will discuss the capabilities of this approach to serve as a reference to explain more trivial parts of local heterogeneity and to infer on processes at different time scales driven by the deviation from the equilibrium state or driven by stress on the soil system under changing conditions.