Quantification of Available Water content Comparing Standard Methods and the Pedostructure Concept on Four Different Soils

The purpose of this study is to evaluate the use of the pedostructure soil concept to determine the available water within soil. Specifically, the hydro-structural behavior of the soil in the pedostructure is compared to standard methods of determining field capacity and permanent wilting point. The standard methods evaluated are: the FAO texture estimate, Saxon and Rawls' pedotransfer functions, and the pressure plate method. Additionally, there are two pedostructure methods that are assessed: the water retention curve (WRC) and the soil shrinkage curve (ShC) methods (figure 1).

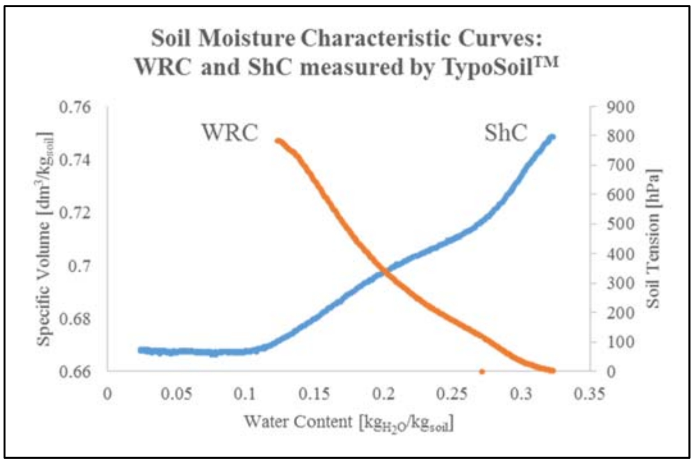

Figure 1: ShC and WRC example from TypoSoil data

Following the work of Braudeau and Mohtar (2004, 2009), Braudeau et al. (2014b) developed thermodynamically-based equations for water retention curve (WRC) and soil shrinkage curve (ShC) so as to characterize the aggregates structure of the soil medium (defined as the pedostructure) and how it interacts with water. The ShC shows the change in the volume of the soil column as water is removed; whereas, the WRC indicates the change in water potential, or retention, within the soil as water leaves the system (figure 1). In these equations of the WRC and ShC, the state variables namely: water content, volume, and retention and the characteristic parameters were referenced to the fix dry mass of the soil pedostructure, represented by the dry mass of a soil core. The parameters of these thermodynamic equations are characteristic of the two characteristic curves and in many cases represents transition points in the curves. Therefore, it is very important to have accurate continuous data measurements to capture these important transition points. Fortunately, Bellier and Braudeau (2013) developed an apparatus (TypoSoil^{TM}) that can simultaneously and continuously measure the mass, diameter, height, and pressure within the soil sample to create these two curves. Saturated soil samples with diameters and heights of 5 cm are used. Within the device, there are separate mechanisms that allow for measurement of the four quantities needed for modeling the two curves. The inner-workings and operation of the TypoSoil^{TM} can be found in Assi et al. (2014). The curves are then modeled using the thermodynamically derived equations to find the hydro-structural parameters that represent specific measurable physical properties of the soil. Consequently, the major advantage to this process is that the curves can be modeled by using physical characteristic parameters. Thus, when a given parameter changes, it is easy to identify what was altered within the soil medium.

Three specific objectives to be achieved through this study are: (1) to develop a quantitative methodology to estimate available water using the pedostructure concept, (2) to demonstrate the applicability of the pedostructure methods on different soil types and (3) to compare the standard methods with the pedostructural methods. The strengths and weaknesses of each will be discussed.

In this study, three different types of soils were used, as following: (1) Loamy Fine Sand: Undisturbed cores: Millican, Texas, USA; (2) Silty Loam: Reconstituted cores: Versailles soil, France; and (3) Silty clay loam: Reconstituted cores, Rodah Soils, Qatar. First, the Millican soil was used in the comparison. In this comparison, the three standards methods and the pedostructure WRC method used the water contents values at specific water potentials, empirically suggested values, of 330 hPa and 15,000 hPa for estimating the field capacity and permanent wilting point, respectively. The results showed that these four methods were in relative agreement. However, the ShC method used transition characteristic points in the shrinkage curve to estimate the field capacity and permanent wilting point. Compared to the other four methods, the result showed that the ShC method overestimated the field capacity value, while its estimation of permanent wilting point was in relative agreement with the other four methods.

For example, in the fine sandy loam Ap horizon analyzed in this study, the field capacity estimates by standard and WRC methods ranged from 0.073 to 0.150 m^3_{H2O}/m^3_{soil} while the ShC method estimate was 0.342 m^3_{H2O}/m^3_{soil} (figure 2). It was noticed that the Millican soil has almost

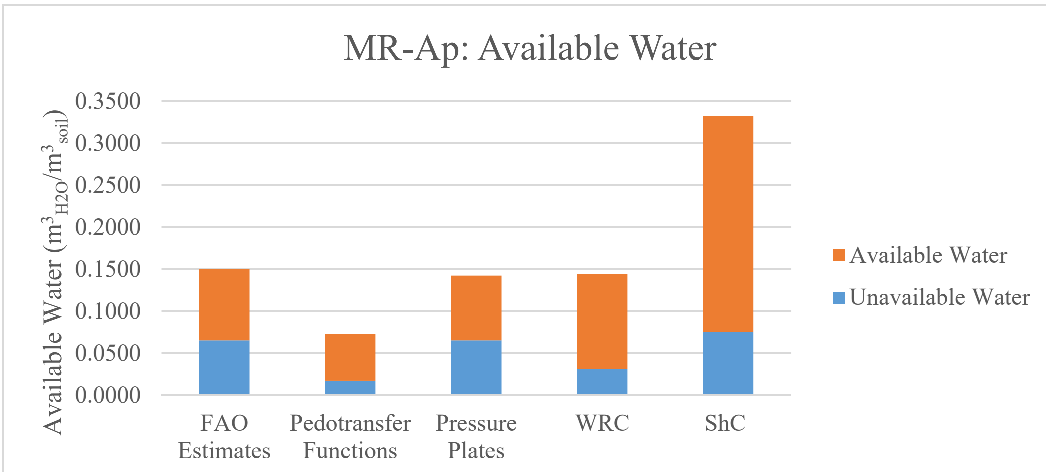

Figure 2: Available water comparison for MR-Ap soil

no shrinkage and hence it was very difficult, if not impossible, to identify the transition points in the shrinkage curve, and consequently, it was difficult to identify the field capacity and permanent wilting point. Therefore, the other two soils, namely, Versailles and Rodah soils were analyzed. The shrinkage curves of these two soils were sigmoidal. It was found that the standard methods, though still lower, were in much closer agreement with the ShC method. This could be due to the easier extraction of the transition characteristic point on the ShC taken to be the field capacity. Overall, it is evident that the process of extracting parameters from the ShC that correlate to the field capacity point of a soil always results in a larger amount of available water. One potential reasons for such a higher value could be in the selection of the transition point that represents the field capacity. In this study, this transition characteristic point was chosen as the intersection point of the tangents of two shrinkage phases: interpedal and structural. Therefore, it is suggested to have further research to identify the most suitable characteristic point on the shrinkage curve to represent the field capacity value. Such work will provide a quantifiable and measurable value for the field capacity which play imperative role in irrigation engineering.

One thing that became clear in this study is that there are both advantages and disadvantages for each method discussed within this paper. In the case of the standard methods, it was evident that the historical reliability of laboratory measurements have helped to make these methods publically acceptable in the scientific community. However, it was observed that the statistical or empirically-based values and assumptions made about a constant bulk density weaken the validity of this methods. On the other hand, the pedostructural methods offer a new way of thinking about soil-water interaction and quantification based on the physical behavior of the soil. Nonetheless, the sample size and lack of field-testing cause the results from the pedostructural methods to be questioned for consistency and reliability. Overall, it can be concluded that the pedostructure concept has opened up new avenues for research and investigation in soil-water that could have an enormous impact on agricultural water management.

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