O 47. ENVIRONMENTAL MODELLING OF SOIL WATER CHARACTERISTIC CURVE FOR TWO CONTRASTING SOIL TEXTURE

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ABSTRACT: Recently, due to the growing concern about the quality of the environment for unsaturated subsoil, which is negatively affected by agricultural and industrial activities, it becomes necessary to increase knowledge about the mechanism of transmission and distribution of solute and pollutants in the soil environment by modeling their movement in the soil under different conditions. Predicting soil water characteristic curve from van Genuchten model was renowned for reducing the costs and time of measurement methods. The aim of this study was to determine the effect of two levels of compaction on the behavior of soil water characteristic curve of a sandy loam and clay soils, and then compare the measured results with the predicted results obtained from van Genuchten equation with using four different model classes of (m) parameters, then investigating the relationship between them. At the end of the incubation period, soil samples were sampled and thereafter compacted through soil core with known volume at soil bulk density (Pd) of 1.50 and 1.70 g cm^{-3} for a sandy loam soil and 1.20 and 1.35 g cm^{-3} for clay soil. The obtained results indicated that using van Genuchten equation to fitting water characteristic curve with variable (m) parameter had the highest correlation (R^2), and lowest normalized root mean square error (NRMSE), as well as soil compaction significantly affected volumetric water content at the same observed section in both soil textures.

Keywords: Environmental modelling, Soil compaction, Water characteristic curve

1. INTRODUCTION

The soil water characteristic curve (SWCC) is defined as the relationship between water content (gravimetric or volumetric) or degree of saturation under suction (matric or total) (Fredlund, 2012). Because of the effort and time consuming, as well as the high variability of samples to determine the SWCC by conventional methods, a lot of researchers developed various predicting and fitting models depending on other soil properties, which can be easily measured. Soil compaction can be associated with a majority field operation that often performed when the soil is wet. Heavy equipment and tillage implement can cause damage to soil physical properties and structure. Soil structure is important to determine the ability of a soil to hold and conduct water, nutrient, and air necessary for plant root activity (Mada et al., 2013). Compaction causes unfavourable changes in soil bulk density, porosity and penetration resistance (Soane et al., 1981). Aeration decreases as water content increases, with a concomitant reduction in soil resistance (Letey,1985); and this, in turn, has a positive effect on plant development (Quiroga et al., 1999). The aim of this study was to determine the effect of two levels of compaction (low and high) on the behavior of soil water characteristic curve of a clay and sandy loam soils, and then, compare the observed results with the predicted results established with respect to four common van Genuchten (VG) SWCC model classes for investigating the relationship between them and determining the more accuracy model, which give us the best fitting for the soils of study area .

2. MATERIAL AND METHOD

2.1. Site description and soil sampling

The first soil sample, clay textured soil wascollected from the surface (0 - 20 cm) of a field located at Sarıcalar Research and Application Farm of Agriculture Faculty, University of Selçuk. The second soil sample, sandy loam textured soil was collected from the surface (0-20 cm) of a field located at Çumra Plain.

2.2. Soil preparation and incubation experiment

Soil samples from different selected points were sieved in the site by 4 mm sieve, and than transported to the laboratory whereby were passed through a 2 mm sieve after air-drying prior to the experimental establishment in the laboratory. Soil samples were placed in the pots, and than watered to field capacity, and subsequently incubated for 30 days at 23±2°C.

2.3. Soil analysis

Soil texture was measured by Bouyouos hydrometer method according to (Gee and Bauder, 1986). Proctor Test to determine the level of maximum compaction, soil samples were compacted in the cores standard Proctor test according to (Mertoğlu, 1982). Soil water characteristic curve: Three methods were used to determine the relationship between volumetric water content (θ) and suction (ψ), which is; Sandbox for pF of (0, 1, 1.5, 1.8 and 2), Pressure plate apparatus for field capacity FC (pF 2.52) (Klute, 1986), and for pF more than FC to near pF 6 (including permanent wilting point (PWP)) was measured through Dew point water potentiometer (WP4C) device. Soil pH and electric conductivity (EC) (1:2.5) were measured according to (Mclean, 1982; Rhoades, 1982). Calcium carbonate (CaCO3) was determined by measuring the volume of emitted CO2 from carbonates (Nelson, 1982). Soil organic matter (OM) was measured by a wet combustion method proposed by (Smith and Weldon, 1941).

2.4. Soil compaction

Depending on Proctor test results (Figure 1 and 2), two levels of compaction were chosen for each type of soil with low and high, (BD), which is for a clay soil 1.20 and 1.35 g cm^{-3}, and for a sandy loam soil 1.50 and 1.70 g cm^{-3} The soil samples were compacted in the core (volume of 100 cm3) with 5 layers according to the method suggested by (Houskova, 2004).

2.5. Statistical evaluation

Statistical fit-measure indices, the coefficient of determination R2 and the normalized root mean square error (NRMSE), were obtained to assess the goodness of fit between predicted and observed values. The NRMSE can be expressed as absolute by the following:

$$\mathrm{NRMSE} = \frac{100}{\theta_{max} - \theta_{min}} \sqrt{\frac{1}{N}\sum_{j=1}^{N}\left(\theta_{mj} - \theta_{aj}\right)^2}$$

Where:

θ_{mj} and θ_{aj} are, respectively, predicted and observed volumetric water contents,
θ_{max} and θ_{min} are maximum and minimum observed volumetric water contents,
and N is a number of selected points for soil–water retention.

2.6. Modelling of SWCC

A lot of models were investigated for predicting of SWCC by researchers from around the world. The RETC (version 6.02) program was used to determine the parameters of van Genuchten (1980) model,

$$\theta = \theta r + \frac{(\theta s - \theta r)}{[1 + (\alpha h)^n]^m}$$

Where:

θ(ψ) is volumetric water content with respect to suction ψ, θr and θs are residual and saturated volumetric water contents, respectively.and α, n and m are the fitting parameters.

Depending by four model classes of (m parameter) SWCC's were predicted, which is as follows; Mualem,(1976), m=1-1/n; Burdine, (1953), m=1-2/n; Gardner, (1958), m=1 ; and van Genuchten,(1980), m≠1 (variable), In this model, our predicted m was used in the model of VG depending on the highest R2 and lowest NRMSE value.

2. RESULTS

According to the figure 1 and statistical evaluation, the results showed that model of VG with variable m (m≠1) had the best fit with the observed values from pF 0 to 5. Therefore, VG (M) and VG (B) models had the best fit when water suction was more than pF5.

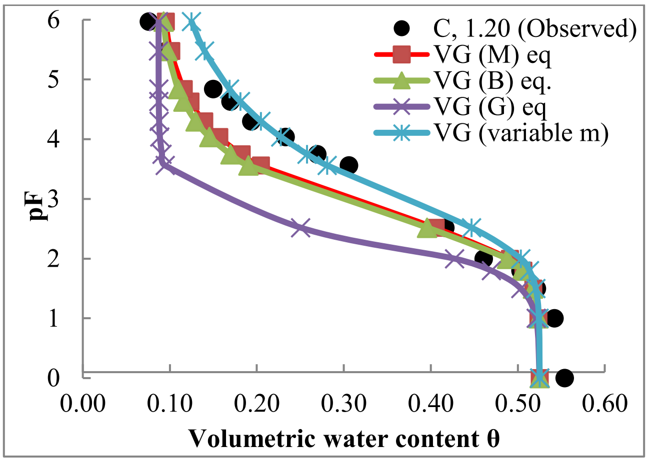

Figure 1. Illustration of the observed and predicted values of SWCC for a clay soil with bulk density of 1.20 g cm^{-3}

From figure 2, and statistical evaluation, the results showed that model of VG with variable m (m≠1) and VG (B) had the best fit with the observed values from pF 0 - 5. Therefore, VG (M) and VG (G) models had the best fit when water suction was more than pF5.

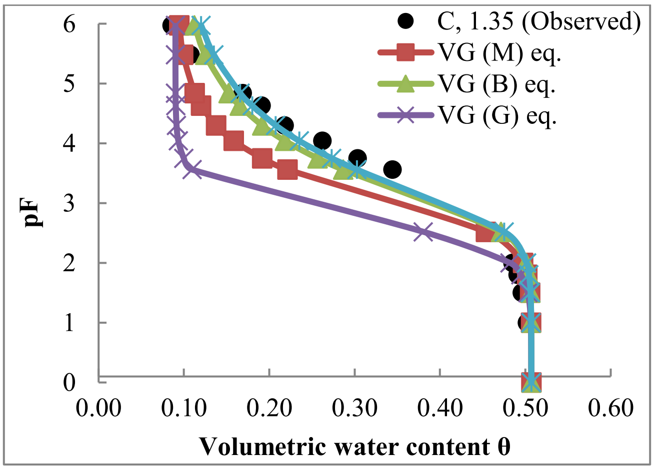

Figure 2. Illustration of the observed and predicted values of SWCC for a clay soil with bulk density of 1.35 g cm^{-3}

Figure 3 showed that the predicting of SWCC with VG (variable m) and VG (M) model classes had the best fit with observed values from pF 0 to 5. Therefore VG (B) and VG (G) models had the best fit when water suction was more than pF5.

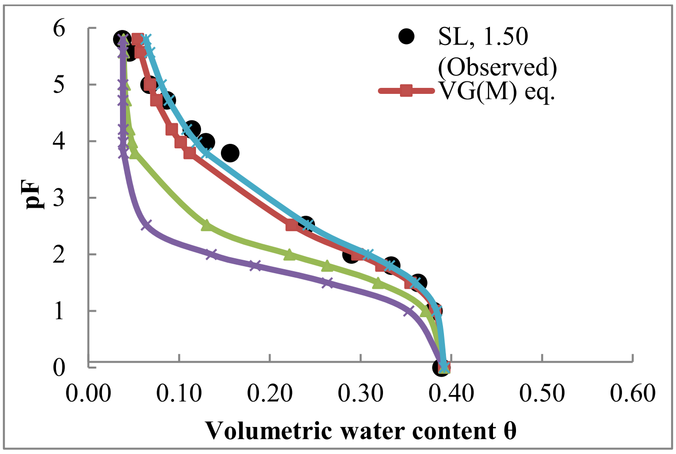

Figure 3. Illustration of the observed and predicted values of SWCC for a sandy loam soil with bulk density of 1.50 g cm^{-3}

Figure 4. Show the same trend of all previous graphics, with a clear preference to fitting for VG (variable) model comparing with other model class from pF 0 - 5. However, VG (M) model had the best fit when water suction was more than pF5.

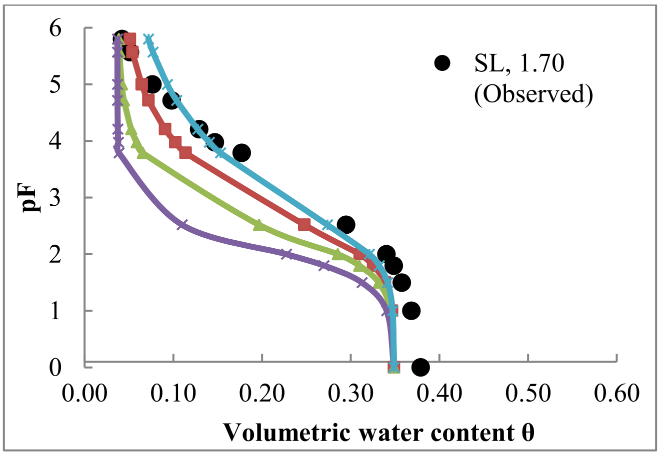

Figure 4. Illustration of the observed and predicted values of SWCC for a sandy loam soil with bulk density of 1.70 g cm^{-3}

3. CONCLUSIONS AND DISCUSSION

The following conclusions can be drawn from this study:

1- In both soils (clay and sandy loam), compaction increased the volumetric water content at FC, PWP as well as AWC and reduced the water content at saturation.

2- The predicting of SWCC in normal clay and sandy loam soils (minimum bulk density) were given as more accuracy to fitting with various model classes than compacted soil (maximum bulk density)

3- The predicting of SWCC by the model of van Genuchten with our variable m that was determined by testing different values of m (m≠1), gave us the best graphical fitting, high correlation and less NRMSE with the observed value.

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