A survey about characteristics of soil water retention curve

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Abstract. The characteristic of soil water retention curve is a hot issue in soil water search. There is multifarious variation of soil water matrix potential if soil water content change. The relation curve is of great importance. In this paper, based on fractal theory, we analyze and discuss several aspects including mathematics models, application and measurement methods.

1. Introduction

Soil, is the loose material on earth surface, consists of porous medium which is made up of various granular minerals, organic substances and other solid matter. There are two crucial factors of soil structure. One is the size and the other is compound mode of materials. The classic method of studying the texture and structure of soil is relatively immature. Nevertheless, the various studies since 1980s have shown that the solid matter in the soil, the surface of the soil particles and the pores all have the self-similarity. As early as 1986, Tucotle has studied the calculation approach of soil fractal dimension. Therefore, fractal has become an important method to study the structure and nature of soil. The soil hydraulic characteristic parameters and soil physical property have a close relationship [1]. Consequently, we can use it to represent the structure and other properties of soil. There is no doubt that characteristic of soil water retention curve is uppermost focus which is about quantitative simulation of soil water flow and solute migration [2]. The curve refers to the relationship between the matrix potential of soil water and soil water content. It also demonstrates the interaction between soil water moisture and amount of soil water. It is also a vital parameter to study the nature of soil water dynamics, which is of great significance in production practice.

2. The application of characteristics of soil water retention curve

How to give the quantitative analysis on soil water movement? Soil water characteristic curve is a good way. It is also helpful to research the soil hydrodynamics. At the same time, it reflects the relation between amount and energy of soil water.

2.1. Reflects the water holding and water release characteristics of different soils

Environmental problem has attracted more attention at present. There are members of researchers eager to find a way to greening the barren land. In the process, the study of the soil becomes extremely important.

The curve can illustrate two problems. On the one hand, the water suction is very different when different textures of soil moisture content. On the other hand, when the soil of different texture reaches

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the wilting coefficient and the field holding water, the actual water content is very different but soil water suction is similar. So we can draw two conclusions: (1) the greater the soil water suction does, the less effective has to plants. (2)The higher the soil moisture content has, the smaller the soil water suction does and the higher the potential energy of the soil water will be. It is of great significance to understand the nature of soil to change desert as green space.

2.2. It is a tool to study soil water movement, regulate the use of soil water and improve soil

It is an important parameter to solve the water movement with diffusion theory. The inflection point of the curve can reflect the soil water state under the corresponding water content.

When the soil water suction approaches 0, the soil is close to saturated and the water state is dominated by the capillary gravity water. When the soil water suction is slightly increased and the moisture content decreases sharply, the water suction value expressed by the negative pressure head is about the same as the lifting height of the supporting capillary water. However, when the soil water suction increases and the moisture content decreases, the water content is close to the water content in the field if we focus on capillary hanging water. Soil water supply determined by the difference between saturated water content and field water content. According to the analysis above, characteristics of soil water retention curve is crucial in soil water and soil properties exploration [3]. Furthermore, it is associated with soil particle research. [4-6]

3. Method for determining characteristics of soil water retention curve

3.1. The tension meter method

The tension meter mainly made by the clay head, connected pipe and pressure gauge. The clay head is a key component of the tension meter. And it is a practical method of studying soil moisture movement from energy point of view. The tension meter is the best equipment to reflect the soil condition. Vacuum pressure gauge and the mercury pressure gauge with curved pipe are the use of more tension meter.

The tension meter will first full of airless water (the clay head is saturated) when we using it. Then we should set the meter in the soil and ensure that the clay head is in close contact with the soil. From the thermodynamic point of view, the tension meter and soil can be viewed as a whole. The water in tension meter through the clay head of the membrane connect with the soil water in this system. In the process of balance, the water flows from the clay head to the soil or from the soil to clay head.

When this system get to balance, the chemical potential of soil waterand the chemical potential of tension meter wateris same.

$$\mu_{wo} = \mu_{wt} \tag{1}$$

Do not consider the impact of temperature:

$$\mu_{w0} = \mu_w^0 + \psi_p + \psi_m + \psi_r \tag{2}$$

$$\mu_{wt} = \mu_w^0 + \psi_{st} + \frac{1}{\rho_w}(P_t - P_0) \tag{3}$$

In the formula (1),(2),(3),

μ_{w0} is chemical potential of free water under standard conditions. ψ_p is soil water pressure potential. ψ_m is soil water-based mode potential. ψ_r is soil water potential of the solute. ψ_{st} is tension meter solute potential. ρ_w is water density. P_t is tension water under water pressure.

When P_0 is one atmosphere, $P_t - P_0 = \tau$. τ is the value showed by pressure gauge called soil water tension. It is the opposite of soil base mode potential and the soil water tension is positive. When the system becomes balance, soil water pressure potential equal to zero. The solved in soil water and tension meter water through the exchange of water to achieve equilibrium.

$$\mu_{w0} = \mu_{wt} \tag{4}$$

And then get:

$$\psi_m = \frac{1}{\rho_w}(P_t - P_0) \tag{5}$$

From

$$\rho_w = 1g / cm^3 \tag{6}$$

Equation(5) becomes:

$$\psi_m = (P_t - P_0) \tag{7}$$

Therefore, tension meter measured is the soil base mode potential when the system comes to balance. Tension meter water pressure are all under one atmosphere when determining soil base potential. So there must be air though the clay head and the mercury or water in pressure gauge to the pressure gauge, then continues to spread to the tension meter.

3.2. The sand funnel method

The device uses a organic glass sand funnel with a perforated plate(or clay plate) at the bottom. The funnel diameter is 7 centimeters and the dimension is 100 milliliters. Then the soil sample is putted on the plate. The water chamber under the board and the transparent class pipe connected to form a water column. Characteristic of soil water retention curve is determined by the suction on the soil sample placed on the plate [7].

The principle of the sand funnel method is briefly introduced in the thesis of professor Li Yongtao. That is to say the soil in the funnel establishes a hydraulic connection with the suspended water column through the perforated plate. This will deliver hydrostatic pressure. When in balance, the total soil water potential is equal to the total water potential of free water below the perforated plate. Namely:

$$\psi = \psi_m \tag{8}$$

The same as analyzing the pressure gauge principle we can get:

$$\psi_m = \psi_{pw} = -\Delta H \tag{9}$$

where H is the level difference between the funnel and the graduated glass tube on the right. In the experiment, sealed with plastic film above the funnel and punch holes in the plastic film. This way not only can prevent the evaporation of soil samples, but also to maintain soil samples and atmosphere contact.

3.3. Pressure membrane method

This membrane pressure gauge is made by the pressure plate, compressor, pressure gauge and some accessories. Its working principle is to put the wet soil sample in the instrument. Under a known pressure which can pressed the water in the soil under low pressure out of the soil. According to several samples analyzed under different pressures, it can determine the soil moisture and water potential of the standard curve. The advantage of this method is its simplicity of operation and can determine a variety of soil samples at the same time.

Some investigator[8]think that the method of measuring is time-consuming, cumbersome and it is hardly to solve the problem of changing weight.

4. The characteristics of soil water retention curve model

There are many ways to determining the curve. But no matter what method to experience, the last is only a set of data. So only we use empirical models with mathematical formula to describe the curve and use the soil suction formula or soil shrinkage formula to determine the curve. In many empirical models, Van Genuchten model, Brooks-Corey model and Dual-porosity model are common used.

4.1.van Genuchten model(VG)

$$\theta(h)=\theta_r+\frac{\theta_s-\theta_r}{(1+|\alpha h|^n)^m}, h<0 \tag{10}$$

$$\theta(h)=\theta_s, h\geq 0 \tag{11}$$

In the formula(10), (11):

θ, Volume moisture content, cm^3/cm^3

θ_s, Saturated volume water content, cm^3/cm^3

θ_r, Residual volume water content, cm^3/cm^3

h, Negative pressure, m

α, Intake value of the reciprocal.

m and n are shape factor. m and n not related to each other or $m=1-1/n$ or $m=1-2/n$.

4.2. Brooks-Corey model(BC)

$$S_e=\frac{\theta-\theta_r}{\theta_s-\theta_r} \tag{12}$$

$S_e=(\alpha h)^{-n}, \alpha h>1$. $S_e=1, \alpha h\leq 1$.

S_e is the saturation.

4.3. Dual-porosity model(DP)

$$S_e=\omega_1[1+(\alpha_1 h)^{n_1}]^{-m_1}+\omega_2[1+(\alpha_2 h)^{n_2}]^{-m_2} \tag{13}$$

ω_i is the different regions of the weight factor.

5. Factors influencing soil water characteristics curve

The main factors that affect the determining curve are texture, construction and bulk weight. The greatest impact is soil texture. The effect of texture is due to the thinner soil particles, surface area increases and the number of small pores increases. The structure and bulk density mainly when moisture is near saturation, impact on soil pore conditions and then affect the curve.

6. Conclusion

(1) The most influence factor of the characteristics on soil water retention curve is the particle size. The effect of particle size is reflected by the soil pore conditions. According to the specific experimental results, the soil which soil particle size larger, the soil water lost rate is faster. However, if the curve is fine and structured soil is relatively gentle, this soil have good water capacity.

(2) Comparing a variety of the curve fitting model, the research should be based on specific soil example. Then choose the most suitable model and try to minimize the errors.

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References

[1] Huang Guanhua and Zhan Wenhua 2002 Modeling soil water retention curve with fractal theory J.*Advances in Water Science* **13** 55-60

[2] Su Litan, Zhang Zhanyu and Gu Limeila 2004 Fractal model for predicting the curve of unsaturated soil water retention along the mainstream of the Tarim River J.*Arid Land Geography* **27** 530-534

[3] Huang Xiaobo and Gao Bingke 2016 Review of soil moisture characteristic curve J.*Agricultural technology services* **33**

[4] Li Peng and Xu Kang 2013 Application of fractal theory in soil research J.*Journal of JiangXi Agricultural University* **25** 78-84

[5] Arasan S'Akbulut and S'Hasiloglu A S 2011 The relationship between the fractal dimension and shape properties of particles J.*Journal of Civil Engineering* **15** 1219-1225

[6] Li Hantao, Yu Jian, Fang Fengman and Wang Fei 2015 Effect of reclamation on soil particle composition, fractal dimension and aggregate J.*Environment Science and Technology* **38** 11-16

[7] Li Yongtao, Wang Wenke,Liang Xifeng, Wang Xiaodan and Wang Li 2006 Sand funnel method determining soil water characteristic curve J.*Groundwater* **28** 1004-1184

[8] Li Chunyan, Li Hongyan and Shi Lixia 2011 Application of pressure membrane method in the determination of soil water characteristic curve J.*Yellow River* **33** 1000-1379