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Research Progress in Soil Hydrodynamics

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Abstract

The hydrodynamic nature of soil determines its capacity to retain and store wa-ter as well as to supply and release water. The main parameters of soil hydro-dy-namics include soil moisture constant, soil saturated water conductivity and soil moisture characteristic curve. They reflect the soil's capacity to retain and supply moisture as well as its water conductivity. These parameters are in-flu-enced by factors such as soil texture, structure and organic matter content. Conversely, these parameters can also affect the quantity and movement of moisture in the soil.

Keywords

Soil moisture constant; Soil saturated water conductivity; Soil moisture char-acteristic curve

1. Overview of soil moisture constant

The study of soil moisture cannot be separated from the analysis and research of soil moisture constants. It refers to a quantitative indicator that can effectively reflect the soil moisture absorbed and utilized by plants from the perspectives of quantity and degree, and has an indicative role in soil water retention and water movement conditions[1]. Soil moisture constants include field capacity, wilting coefficient, maximum moisture absorption, capillary fracture moisture content and saturated moisture content.

The two most important moisture constants in soil science are field capacity and wilting coefficient. Let's first introduce field capacity. Under capillary force, soil pores will be filled with some water. The soil moisture content when the water suspended in these capillary tubes reaches its maximum value is the field holding capacity. In terms of quantity, the field holding capacity includes three types of water, namely capillary suspended water, hygroscopic water and film water[2].

The wilting coefficient refers to the soil moisture content when plants are in a permanent wilting state. When the soil moisture content reaches the wilting coefficient, it indicates that there is a severe lack of water in the soil at this time. The part of water that crops cannot absorb and utilize is the wilting coefficient, which can also be called "wilting moisture content". The soil water absorption capacity corresponding to the wilting coefficient is approximately 1.5 MPa[3].

Soil hygroscopic water refers to the portion of water content in the air that is adsorbed and retained by soil particles under their adsorption force[4].

Saturated water content is also an important indicator in soil moisture research. It refers to the situation where all the pores in the soil are not filled with gas but are completely filled with water[5].

Capillary breakage water content is also an important parameter in soil moisture research. It refers to the reduction of suspended water in capillary tubes due to evaporation on the soil surface and absorption by plants. When the water content drops to a certain extent, it leads to the breakage of capillary forces. The coarser capillary pores expel water, causing the soil moisture to lose continuity and the continuous water movement to be interrupted. At this point, the soil moisture content is the capillary fracture moisture content, and the soil water suction force at this time is approximately 100 kPa[6].

2. Research Progress on Soil Moisture Energy

The research on water energy cannot do without the SPAC system. The SPAC theory was introduced to China in the early 1980s. It regards soil, plants and the atmosphere as a continuum, and water operates and transmits within this system, interconnecting with each other like a chain link. The energy index of "water potential" is used to represent the water energy state levels of various parts of the medium and between different media, as well as the variation laws of water energy and their interrelated properties.

The fundamental equation for soil moisture movement is based on Darcy's law and combines the concept of soil water potential and the principle of conservation of mass, thereby deriving the basic equation for describing soil moisture movement - the Richards equation[7]. As shown in Equation 1:

$$\frac{\partial\theta(z,t)}{\partial t} = \frac{\partial}{\partial z}\left[K_W(z,t)\frac{\partial\psi(z,t)}{\partial z}\right] + \frac{\partial K_W(z,t)}{\partial z} - S_W(z,t) \quad \text{(Formula 1)}$$

In the formula: the soil matrix potential is represented by ψ (z，t), the volumetric moisture content of soil is represented by θ (z，t), time is represented by t, the negative number of the depth from the ground surface downward is represented by z, Soil water conductivity is denoted by KW(z，t), The water source and sink item is represented by SW(z，t).

3. Overview of soil saturated water conductivity

Soil saturated water conductivity is an important hydraulic parameter and a variable scale closely related to soil moisture. It is not only a very important indicator for evaluating soil water conductivity, but more importantly, it characterizes the distribution of moisture in the soil profile.

At present, there are four most common models of soil unsaturated water conductivity in the academic circle. Including the van Genuchten-Mualem model (Formula 2) [8], the Brooks Corey model (Formula 3) [9], the Campbell Norman model (Formula 4) [10], and the Vauclin-Imbernon-Vachaud model (Formula 5) [11].

$$K(\theta) = K_s(\frac{\theta-\theta_r}{\theta_s-\theta_r})^{1/2}\{1-[1-(\frac{\theta-\theta_r}{\theta_s-\theta_r})^{(\frac{n}{n-1})}]^{(1-\frac{1}{n})}\}^2 \quad \text{(Formula 2)}$$

In the formula, K(θ) represents the unsaturated water conductivity of the soil, in cm/d. θ represents soil moisture content, %. Ks is the saturated water conductivity, cm/d. θr represents the residual soil moisture content, in %. θs represents the saturated water content of the soil, in %. n is a dimensionless parameter of the empirical model.

$$K(\theta) = K_s(\frac{\theta-\theta_r}{\theta_s-\theta_r})^{\frac{2}{\lambda}+2.5} \quad \text{(Formula 3)}$$

In the formula, λ is a dimensionless parameter of the empirical model, and the rest are the same as above.

$$K(\theta) = K_s(\frac{\theta}{\theta_s})^{2b+3} \quad \text{(Formula 4)}$$

In the formula, b is a dimensionless empirical model parameter, and the rest are the same as above.

$$K(\theta) = K_0(\frac{\theta}{\theta_0})^{\beta} \quad \text{(Formula 5)}$$

In the formula, K0 represents the water conductivity of the soil during stable infiltration, which is numerically equal to Ks, cm/d. θ0 represents the moisture content of the soil during stable infiltration, in %, numerically equal to θs. β is a dimensionless empirical model parameter. The rest are the same as above.

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