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Preliminary Analysis of Calculation Method of Soil Hydrodynamic Parameters and Influencing Factors

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Abstract

In order to further clarify the calculation method of soil hydrodynamic parameters and the influence degree of soil physical and chemical properties such as soil porosity, soil bulk density, soil texture and soil organic matter on soil hydrodynamic parameters, this paper summarizes the existing calculation methods of soil hydrodynamic parameters, summarizes and analyzes the influencing factors of soil hydrodynamic parameters such as soil porosity, soil bulk density, soil texture and soil organic matter, and clarifies the research progress of soil hydrodynamic parameters at the present stage, so as to provide reference for subsequent scientific research and production.

Keywords

Soil hydrodynamic parameters; Physical and chemical properties of soil; soil texture.

1. Introduction

Soil water movement is an extremely complex process, and its movement parameters are the key parameters to describe the law of soil infiltration, which affects the irrigation time, irrigation amount and the construction of agricultural irrigation system, and also affects the migration of soil nutrients and agricultural pollutants. Therefore, it is of great significance to study the variation of soil hydrodynamic parameters and influencing factors for agricultural production. Soil hydrodynamic parameters are used to solve the equation of unsaturated soil water movement, and further to predict the law of unsaturated soil water movement. The accuracy of soil hydrodynamic parameters and the accuracy of water movement models related to these parameters are closely related. In general, the basic parameters describing soil water movement are unsaturated hydraulic conductivity, specific water capacity, hydrodynamic dispersion coefficient and unsaturated diffusion rate.

2. Calculation Method of Soil Hydrodynamic Parameters

The determination methods of soil hydrodynamic parameters can be generally divided into direct method and indirect method according to the acquisition approach. The direct method is to directly measure the parameters of the experimental sample by experimental equipment or calculate other parameters measured by the formula.The direct method for determining soil hydrodynamic parameters is simple and clear, but its application is limited by the uncertainty of relative time consumption, financial consumption and derivation of water characteristic parameters. There are two indirect methods. One is to determine the soil hydrodynamic parameters by assuming some parameters for trial calculation. The other is to simulate the soil particle composition and capacity reuse software. The indirect method can obtain the water conductivity characteristics within the range of soil moisture content and provide the information of parameter uncertainty, but there are problems of convergence and parameter uniqueness.

2.1. Direct Method

Soil moisture characteristic curve is the relationship curve between soil moisture content and matrix potential, which reflects the characteristics of soil moisture static energy. Direct determination methods are: negative pressure method (tension meter) method, sand funnel method, pressure plate method, stable soil moisture content method. In-situ measurement of soil water characteristic curve in the field mostly uses the tension meter method. Since the range of tension meter is 0-0.08 MPa, it can only be used to determine the water characteristic curve in the low suction range, and the accuracy is poor [1]. Soil matric potential is caused by the surface tension and capillary action of soil particles. At present, there is no theoretical relationship between soil water suction and water content [2]. It is usually described by empirical formula (1), which is an empirical formula used earlier to describe the soil water characteristic curve. Because of less parameters and simple forms, it is widely used in early studies. However, due to the lack of consideration of retention water content, the description of high suction section may be biased. The curve has no inflection point in the near-saturation section, and the saturation point is also inconsistent with the actual situation, so it cannot well describe the measured soil moisture characteristic curve, and it is rarely applied in the practice with high simulation accuracy of soil hydraulic characteristics. Brooks-Corey proposed the formula (2) of soil moisture characteristic curve in 1964 [3]. In the the formula, soil suction is equal to the intake suction when the soil is saturated, so the formula describes the soil moisture characteristic curve of the dehydration process. The intake suction is not strictly measured, but the apparent intake suction obtained by curve fitting. Van Genuchten proposed a formula(3) to describe the soil moisture characteristic curve in 1980 [4]. In the formula, the soil water suction is zero when the soil water content is saturated, so the formula describes the soil moisture characteristic curve of the soil moisture absorption process. This formula can match the shape of most soil water characteristic curves, so it has been widely used.

$$\theta = \mathrm{a}\, h^{b} \tag{1}$$

The formula, a, b are parameters.

$$\frac{\theta - \theta_r}{\theta_s - \theta_r} = \left(\frac{h_d}{h}\right)^{n} \tag{2}$$

The formula, θ_s is saturated water content; θ_r is retention water content; h_d is intake suction; h is soil suction; n is the shape coefficient.

$$\frac{\theta - \theta_r}{\theta_s - \theta_r} = \left[\frac{1}{1 + (\partial h)^{n}}\right]^{m} \tag{3}$$

The formula, α is a parameter related to suction; n and m are shape coefficients.

The water conductivity of unsaturated soil is the water flux under unit water potential gradient in soil [1].The direct measurement methods include instantaneous profile method, shell

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method, wind evaporation method, drip infiltration method, and single-step outflow test method [5]. Mohanty carried out in-situ measurement of hydraulic conductivity by four methods, namely, double-tube method, Guelph permeameter, indoor constant head permeameter, and flow velocity permeameter, and compared the measured results [6]. It was found that the soil hydraulic conductivity measured by double-tube method was the largest, followed by the saturated soil hydraulic conductivity measured by flow velocity permeameter, and the Guelph permeameter method was the smallest. Among them, the double-tube method had many limitations over 60 cm above the upper soil, which was not applicable in most cases. The hydraulic conductivity of saturated soil measured by indoor constant head method changed greatly at 15-30 cm above the soil, and its value was similar to that of flow velocity permeameter method.

Unsaturated soil water diffusivity is the ratio of unsaturated soil water conductivity to specific water capacity. The commonly used measurement method is the horizontal soil column suction method [1], and the commonly used calculation formula of unsaturated hydraulic conductivity is formula (4)-(7) [2].

$$K(h) = ah^{-m} \tag{4}$$

$$K(h) = \frac{K_S}{ch^m + 1} \tag{5}$$

$$K(\theta) = k_a e^{-\beta(\theta_s - \theta)} \tag{6}$$

$$k = k_s \left\{ 1 - \left[1 - \left(\frac{\theta - \theta_r}{\theta_s - \theta_r} \right)^{1/m} \right]^2 \right\}^2 \left(\frac{\theta - \theta_r}{\theta_s - \theta_r} \right)^{0.5} \tag{7}$$

The formula, KS is saturated hydraulic conductivity; k(θ) is unsaturated hydraulic conductivity; a, b, c, n, m, β and M are empirical coefficients.

2.2. Indirect Method

In the past 20 years, more and more attention has been paid to the indirect method to estimate the soil hydrodynamic parameters. The indirect method mainly estimates the soil hydrodynamic parameters according to the soil water characteristics data, soil texture, bulk density, clay mineral or soil structure, such as Liu et al [8] based on the cumulative infiltration data of one-dimensional water infiltration test, the soil hydraulic characteristics parameters are inversed by Hydrus-1D software. The soil infiltration rate, cumulative infiltration, water content distribution characteristics and wetting front in the process of one-dimensional water infiltration are simulated by Hydrus-1D software and Hydrus-1D software, and compared with the real side value. The results show that the relative average errors between the simulated data and the measured data of soil infiltration rate, cumulative infiltration, water content distribution and wetting front are between 2% and 15%, and the measured data are basically consistent with the simulated data of Hydrus.

3. Factors Influencing Soil Hydrodynamic Parameters

3.1. Soil Porosity

Soil porosity is an important indicator of soil physical properties, and is the percentage of the volume of all soil pores and the total volume of soil [9]. Soil total porosity is the sum of soil water holding porosity and aeration porosity. The relationship between soil water holding porosity and aeration porosity shows a reciprocal change. The distribution, continuity and size of soil pores have a certain impact on the storage and migration of soil water. In general, the larger the total soil porosity is, the smaller the soil bulk density is, indicating that the soil structure is good, and the soil effective water content is also high with strong ability to store and maintain water. At the same time, soil porosity is also affected by soil structure. The better the soil structure is, the better the porosity of the soil is. Moderate pore size is beneficial to soil water holding and ventilation, as well as plant root growth and water absorption [10]. The number and size proportion of soil pores with good structure are moderate. Chen et al studies show that the porosity of high-yield soil is generally greater than 50%, which is beneficial to soil water conservation, water supply and ventilation, and helps to improve crop yield [11].

3.2. Soil Bulk Density

Soil bulk density can comprehensively reflect the soil porosity and compactness of soil particles, and directly affect the size of soil water storage [5].Therefore, soil bulk density is one of the important factors that determine soil water conductivity, and plays an important role in soil water holding characteristics. Li Zhuo showed that soil saturated water content, wilting coefficient, capillary broken water content, soil available water content and soil water characteristic curve could establish a functional relationship with soil bulk density, which laid the foundation for the study of soil salt transfer and water and fertilizer movement transfer [12]. The smaller the soil bulk density is, the looser the soil is. The larger the non-capillary porosity, capillary porosity and total porosity are, the larger the soil water holding capacity and saturated water content are, and the higher the retention water and soil water storage are, which can supply the water needed for crop growth and development. On the contrary, the larger the soil bulk density is, the tighter the soil is. The smaller the non-capillary porosity, capillary porosity and total porosity are, the smaller the soil water holding capacity and saturated water content are, and the less the retained water and soil water storage are, resulting in the shrinking of the ‘ soil reservoir ’ storage capacity, the weakening of the water supply capacity for crops, and the limitation of crop growth and yield. Soil saturated mass water content decreases with the increase of soil bulk density, which is inversely proportional to soil bulk density. The relationship between soil water characteristic curve model parameter a and soil bulk density can be described by power function. The parameter input of soil moisture characteristic curve model decreases with the increase of bulk density, and the two are linearly correlated. The larger the soil bulk density is, the smaller the soil saturated hydraulic conductivity is, and the power function correlation between the two variables is high.

3.3. Soil Texture

Soil texture refers to the variation range of soil particle size, specifically refers to a soil particle size distribution or the relative proportion of various size particles. The effect of soil texture on soil hydrodynamic parameters is mainly manifested in the similar bulk density, soil texture from coarse to fine, clay content in soil, the number of fine pores gradually increased, the specific surface area of soil particles increased, and the water adsorption capacity increased, which eventually led to the increase of soil water holding capacity. Soil water holding capacity determines the buffer capacity of drought and waterlogging resistance. The greater the soil water holding capacity is, the stronger the buffering capacity of soil drought resistance and waterlogging resistance and the ability of soil moisture to supply crop growth are, and the higher the effective utilization rate of soil moisture is [9]. The proportion of soil particles at all levels is moderate, and the degree of soil tightness is good, which will be beneficial to the growth of plant roots. Soil has good structure and permeability, which can better preserve water and fertilizer. At the same time, soil texture affects the growth and development of crops by acting on soil nutrient supply and soil environmental conditions, and has a great impact on biology and soil physicochemical properties [13].

3.4. Soil Organic Matter

Soil organic matter is one of the main indicators of soil fertility. The content of organic matter has a certain impact on soil moisture, physical and chemical properties and biological characteristics, and provides various nutrients for crop growth [14]. Soil organic matter can improve soil structure, increase soil total porosity and capillary porosity, improve soil water holding capacity, improve soil colloid status, enhance soil water adsorption, reduce soil moisture diffusion rate, and enhance soil water use efficiency. Therefore, soil organic matter can well regulate the movement of soil moisture and affect soil moisture dynamics parameters. When the soil organic matter reaches a high content, the effect is more obvious [15].

4. Conclusions

Soil hydrodynamic parameters are closely related to soil physical and chemical properties. Changes in soil physical and chemical properties such as soil porosity, soil bulk density, soil texture, and soil organic matter will have different degrees of influence on soil hydrodynamic parameters, thereby affecting soil moisture retention and supply capacity. In the calculation process of soil hydrodynamic parameters, it is necessary to comprehensively consider the dynamic changes of soil physical and chemical indexes and select suitable methods to obtain more accurate results.

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