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Advances in soil water permeability model

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Abstract. Water resources is the most common but it's also a vital element of life, agricultural production is an important industry of water consumption, how to improve the water resources efficient utilization of water resources in agricultural production and the role of global many experts and scholars on the water infiltration numerical simulation research, and put forward the different water permeability model, for efficient utilization of water resources in the process of agricultural production has played a significant role in this paper, through the comparison and analysis of all kinds of water permeability model, analyzed the advantages and disadvantages of the permeability model proposed by Green - Ampt, Philip and Horton et al. It's intended to provide references and basis for the selection of the permeability model for different purposes in the subsequent scientific research.

1. Introduction

Soil, especially surface soil plays an extremely important role in the hydrological cycle, rainfall (or irrigation) infiltration of surface runoff, surface evaporation and transpiration of moisture in the soil, such as dynamic savings and deep seepage in soil for medium occur repeatedly and in nature, the transformation of the water cycle and the conversion is a continuous process evolving infiltration refers to the process of water into the soil, is an important link in the process of water circulation in nature. At the same time, soil water infiltration is closely related to the stability of slope. Soil water infiltration is an important parameter for analyzing soil erosion process and also an important guiding method for agricultural irrigation.

2. Soil water permeability model

Soil water permeability model has been studied for nearly a century, and the models of water infiltration are relatively mature. The permeability models proposed by foreign scholars include: Green-Ampt model (1911), Richard equation (1931), Kostiakov model (1932), Horton model (1938), Philip model (1957,1969), Holtan model (1961), Overton model (1964), Huggins-Monke model (1966).Smith model (1972) and Collis-George model (1977), linear and nonlinear Smith-Parlange model (1978), Smith-yu



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model (1990), Mishra model (1998), Hydrus-1/2D model, etc., are developed later in this field in China, and many domestic scholars have put forward infiltration formulas. Richards equation is equivalent to the new soil water movement model (Zhang Yaofeng, Geng Zhilin, 2006) and so on.

These models can be divided into three categories: models based on physical meaning (Green-Ampt model, Philip formula (1957), Smith model, and smith-parlange infiltration formula, etc.), semi-empirical formula (Horton model, Holtan model, Overton model, singh-yu model, etc.), and empirical model (Kostiakov model, huings-monke model, modified Kostiakov model, and collis-george model). Among the above models, Kostiakov model is the simplest permeability model. Although its parameters have no clear physical significance, it is widely used due to its simple form, convenient calculation and lack of too many conditions. The Richard equation is the basic expression of water infiltration in unsaturated soil. Philip formula is, on the basis of Richard equation obtained in form than Kostiakov model has a constant term, but by Philip model considering the lag effect of the soil and soil spatial variability [1], so the formula is applicable to the one-dimensional vertical infiltration of homogeneous soil [2], the heterogeneity of soil water infiltration also need further research and improvement, There is a great difference between the results of rainfall infiltration and water infiltration under natural conditions [3]. The smith-parlange model is an improved common form of Philip's formula, especially for infiltration under rainfall conditions. The model can well simulate the actual rainfall process and soil infiltration law of slope cultivated land [4], but due to its numerous parameters, its application is more complicated than other models. Holtan model is an empirical model of infiltration. Although the model is an empirical formula, it has high accuracy in describing the characteristics of long-term infiltration and has strong practicability. Green-Ampt permeability model is a model with physical significance, which connects infiltration rate with measured soil characteristics (such as porosity, hydraulic conductivity and water content). However, it is difficult to determine the average suction of the wetting front as a model parameter. Singh-yu model is a general model, which can be converted into Green-Ampt model, Holtan model, Honton model, Kostiakov model, modified Kostiakov model, Overton model and Philip model under specific conditions [5]. However, when simulating most soil moisture infiltration, the accuracy of simulation firing is far higher than other models[1]. Singh-Yu model, Holtan model, Huggins-Monke model, Smith-Parlange model, and Horton model have the advantage of being able to apply the parameters obtained in previous experiments in different soil types[5]. Hydrus-1/2D, a commercial software developed by the international groundwater simulation center in 1999, is one of the most widely used codes for the simulation of unsaturated flow and solute transport. It is a one-dimensional (two-dimensional) evil finite element computer model for simulating water, heat and solute in two-dimensional unsaturated soil with soil physical parameters.

2.1. Green- Ampt infiltration model

Green- Ampt infiltration model[6] was proposed in 1911 by Green and Ampt, the model mainly research is the initial dry soil in a thin layer of water infiltration problem, its basic assumption is that the infiltration when there is a clear horizontal wetting front[7], the wet area and wet area separated, also can saying is the distribution of moisture content into ladder-like, wet area for the saturated moisture content, wetting front is the initial moisture content before, this model, called the piston (pump) model. This model has been paid attention to for a long time because of its physical model foundation. Although this formula is derived from homogeneous soil, it has been applied to non-homogeneous soil or non-uniform distribution of initial moisture content after the 1970s, and good results have been obtained. The difficulty in application of Green-Ampt model is how to correctly determine the parameters K_s and s_t . In the case of infiltration, the assumption of uniform distribution of water content between the surface and the humid front generally does not cause a large error, but the surface water content is a certain value with relatively thin and small water content. Therefore, some parameter substitution is needed in the infiltration formula. It is more difficult to define the average or effective matric suction of moist front. Bouwer (1969) suggested that matric suction should be 1/2 of the intake value. In fact, it is sometimes difficult to determine the intake value of soil. Mein and Larson (1973) proposed to use the weighted average value of soil water suction as the matrix suction, which was generally considered to

be more reasonable. Green-Ampt model is a model of water infiltration in dry soil. Mein and Larson (1973) proposed a method to apply it to rainfall infiltration. This model is suitable for non-homogeneous soil and non-uniform initial moisture content [8]. The disadvantage is that it is difficult to determine the soil matrix suction at the humid front, and it cannot describe the actual distribution of water. It is not meaningful for the model to solve the moisture content. The main task is to find the relationship between the infiltration amount, infiltration rate and the position and time of the wet front.

2.2. Philip infiltration formula

Philip infiltration formula[9]: Philip Richard equation for the system research, proposed the Philip equation obtained analytical solution on the basis of the simplified formula of Philip, Philip about the solutions of the basic equations of one-dimensional vertical water movement, take the form of infinite series, usually in the first two is the commonly used formula, Philip one-dimensional vertical infiltration Philip think at any time in the process of infiltration of the infiltration rate and infiltration of a function of time can be expressed as:

$$I = St^{0.5} + At. \quad (1)$$

Philip permeability model can approximate to take the first two [10], and take the first item is the only ignore gravity Philip one-dimensional horizontal infiltration absorption formula:

$$I = St^{0.5}. \quad (2)$$

And corresponding infiltration rate were respectively: $i = 0.5St^{-0.5} + A$ and $i = 0.5St^{-0.5}$.

Philip infiltration formula can generally be verified with field infiltration experiment data, so also has important application value, however, Philip series solution of vertical infiltration and its coefficient of $\eta_1(\theta)$ and $\eta_2(\theta)$ are semi-infinite homogeneous soil. Therefore, this infiltration formula is only applicable to the one-dimensional vertical infiltration of homogeneous soil. Philip formula is characterized by simple formula, easy to determine parameters and clear physical significance, especially in the one-dimensional case.

2.3. The other formula

Horton formula: Horton is the study of one of the pioneers of the field soil water infiltration, he set up a both can describe different soil infiltration characteristics and contains the infiltration process of the physical concept model of Horton infiltration equation[11] : $i = i_c + \alpha(w-i)^n$, represents the infiltration rate and the relationship between the surface soil pond age, this formula applies only to $I < w$. Horton said, in the initial stages of infiltration, the infiltration rate decreases with the passage of time is mainly affected by soil surface layer of silver, the pure experience formula, although the lack of a physical basis, but as a result of its application is convenient, in a lot of experimental research is still used today the above formula of infiltration is reflected to a certain extent of the law of soil water infiltration, so has the use value of objective.

Smith infiltration formula: in 1972, according to the basic equation of soil moisture movement, Smith carried out a large number of numerical simulation calculations of rainfall infiltration for various types of soil with different textures.

Smith Parlange infiltration formula: Smith and Parlange from the fundamental equations of soil water movement in 1978, export any rainfall intensity formula of the infiltration of their proposed method can be used to calculate water time, and only with two parameters can be calculated after the infiltration rate of water infiltration, these two parameters can be measured by determining the soil properties, also can be determined by infiltration testing. Smith and Parlange put forward two hypotheses: (1) the soil infiltration formula under the conditions of unsaturated hydraulic conductivity change very slowly near saturation scope, (2) the unsaturated hydraulic conductivity of the soil near saturation within the scope of change sharply Finalized, regardless of the above cases, as long as know the parameters of the soil S

which depends on the initial moisture content and value of K_r can be of any given rainfall infiltration calculation process.

Jiang Dingsheng formula: Jiang Dingsheng on the basis of the analysis on Horton and Kostiaikov infiltration formula, the combination of the loess plateau of field test data, put forward the description of the loess plateau soil under the condition of water infiltration formula: $f = f_c + (f_1 - f_c) t^{-\alpha}$, the type with clear physical meaning. As for the study on the influencing factors of soil water infiltration, the prospect and direction of the study on soil water infiltration should be transformed into the study on the problem of heterogeneous infiltration with spatial variability, which has important theoretical significance and application value for the explanation of soil water infiltration mechanism and soil erosion prediction.

D. Schwartzendruder[12] made use of two hypotheses :(1) there was a linear relationship between soil unsaturated water conductivity and soil moisture content; For one-dimensional vertical moisture equation, Parlange[13] presented an approximate solution for Richards equation. This method was simplified, and the formula for determining the wet surface was obtained. J·Ben-Asher et al put forward the linear and nonlinear models for point source infiltration.

2.4. Improvement on formula

Wen-yan wang[14] according to the variation characteristics of soil moisture profile of water infiltration, the water permeability model is derived by using the model to estimate the distribution of the soil moisture profile, according to the distribution of soil wetting front above the initial moisture content and its average value, and then determined by soil water characteristic curve of soil matrix suction Shao Mingan use a way simple with Philip infiltration formula provides a transient flow method is used to determine soil water characteristic curve and alternative usually balance method, it is a completely new and concise and the determination of soil hydraulic conductivity method, according to the forecast of unsaturated soil water movement back the ball to the soil water movement parameter[15]. Zhang based on graphic feature, the solving methods of key parameters in Ampt permeability model, think Green - Ampt permeability model is widely used, is to simulate slope runoff process commonly used in infiltration method [16] Chen li using the wave theory and the improved Green - Ampt model established slope runoff due to infiltration dynamics model, analyzes the rainfall intensity violations resistance coefficient of slope, soil initial moisture content and slope length. Influence law of slope and other factors on slope constant flow process [17].

3. Conclusion

The study of water permeability model has been continuously deepened, and more profound research has certain guidance and guiding effect on production practice, which can provide a certain degree of guarantee for the correct development and operation of practical activities.

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