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Estimation and inter-comparison of infiltration models

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Abstract

Infiltration models are very helpful in designing and evaluating surface irrigation systems. The main objective of the present work is estimation and inter-comparison of infiltration models which are used to evaluate the infiltration rates of National Institute of Technology (NIT)-campus in district of Kurukshetra, Haryana (India) and for this study, field infiltration tests were carried out at ten different locations comprising of 109 observations by use of double ring infiltrometer. The potential of three infiltration models (Kostiakov, Modified Kostiakov and US- Soil Conservation Service (SCS)) were evaluated by least–square fitting to observed infiltration data. Three statistical comparison criteria including maximum absolute error (MAE), Bias and root mean square error (RMSE) were used to determine the best performing infiltration models. In addition, a novel infiltration model was developed from field tests data using nonlinear regression modeling which suggests improved performance out of other three models. In case of nonexistence of observed infiltration data, this novel model can be used to artificially generate infiltration data for NIT campus.

Keywords: Infiltration; Inter-comparison; Double ring infiltrometer; Novel model

1. Introduction

Infiltration is the term applied for the process of water entry into soil (Hillel and Baker, 1988). It is one of the important components of the hydrological cycle. Water content, field density, suction head, temperature, humidity, rainfall intensity and type of impurity play an important role in influencing the infiltration rate. Many researchers have compared the accuracy of the models by comparing the computed and observed infiltration rates (Hopmans, 1995; Mishra et al., 2003; Chahinian et al., 2005; Turner, 2006; Haghighi et al., 2010). Under specific conditions, a particular model shows better predictions than others. Machiwal et al. (2006) observed infiltration was well described by the Philip's model in wasteland in Kharagpur, India. Návar and Synnott (2000) evaluated the infiltration rates of soils under four land uses in north-eastern Mexico. Among the infiltration models of Horton, Philip, a modified Kostiakov and Green-Ampt, the modified Kostiakov model gave the best fit. Mohammed (2006) evaluated the Kostiakov, Horton, and Philip's infiltration models under different tillage and rotations in a clay-loam in north-west Iran and reported that the Horton's model gave the best prediction of infiltration rate in that area. Under specific conditions, a particular model

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shows better predictions than others. But till date, it is not specific mentioned which model gives better prediction (Turner, 2006). Thus, the main aim of present study is to determine the best model for the soil of NIT-campus in district of Kurukshetra, Haryana (India).

1.1. Infiltration models and parameters

Infiltration models can generally be classified into three groups (Mishra et al., 2003) as below:

1. Physical models: These are deduced from the law of mass conservation and the Darcy's law (e.g. Green and Ampt, 1911; Richards, 1931; Philips, 1957).
2. Semi-empirical models: These consist of simple hypotheses about the infiltration rate and cumulative infiltration relation (e.g. Holtan, 1961; Singh and Yu, 1990).
3. Empirical models: These are based on field data and laboratory experiments (e.g. Kostiakov, 1932; Horton, 1941).

1.1.1. Kostiakov model

$$f(t) = at^{-\mathrm{b}} \quad (1)$$

where f(t) is the infiltration rate (LT^{-1}) as a function of time, a and b are the equation's parameters and t is time (T).

1.1.2. Kostiakov modified model

The modified model of Kostiakov for long time is defined as:

$$f(t) = at^{-\mathrm{b}} + i_c \quad (2)$$

where f(t) is the infiltration rate (LT^{-1}) as a function of time, a and b are the equation's parameters and i_c is the steady infiltration rate (LT^{-1}), t is time (T).

1.1.3. SCS model

Soil Conservation Service (SCS) (Jury et al., 1991), is expressed as follows:

$$I = at^b + 0.6985 \quad (3)$$

where a and b are the equation constants. I is the cumulative infiltration rate (L).

1.1.4. Novel model

A typical non linear regression model has been adopted which is developed from Kostiakov modified model as shown below:

$$f(t) = at^{-\mathrm{b}} + c\, i_c \quad (4)$$

where f(t) Soil infiltration rate (LT^{-1}) at time t (T), i_c steady infiltration rate (LT^{-1}). a, b and c are the equation constants.

1.2. Estimation and inter-comparison of model parameters

For estimation and inter-comparison of models, it is necessary to define the criteria by which inter-comparison is evaluated. To judge the estimated accuracy, the fallowing statistical parameters are used for quantifying the errors.

1.2.1. Maximum absolute error (MAE)

The maximum absolute error is used to measure of success of numeric estimation. The maximum absolute error (MAE) is computed as

$$MAE = \max(|x - y| \quad (5)$$

where

x = observed data values.