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ORIGINAL ARTICLE

Solution to Green–Ampt infiltration model using a two-step curve-fitting approach

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Abstract

Infiltration is an important hydrological process affecting the runoff, groundwater recharge and solute transport process. The Green–Ampt (GA) model, describing one-dimensional infiltration process, yields an implicit equation for estimation of cumulative infiltration with time. In this paper, an explicit approximation to the GA model is derived using two-step curve-fitting technique. The Marquardt's algorithm is employed for least-squares estimation of nonlinear parameters. Performance of the proposed model is compared with the implicit GA model using numerical and published field experimental data. The quantitative statistical indicators namely, percent relative error (RE), maximum absolute percent relative error (MARE), percent bias (PB), and Nash–Sutcliffe modeling efficiency (*E*), are used to assess the performance of the proposed model. The solution of the proposed model matched very well with that of the implicit GA model with MARE $\leq$ 0.146%, PB $\leq$ 0.070%, and *E* value approximately equal to 1 for both the dimensionless numerical and dimensional field experimental infiltration estimates. Simulation results of the proposed model demonstrated the capability of the derived model in estimating infiltration rate and cumulative infiltration accurately and can be applied to solve variety of real-life hydrological problems.

Keywords Green–Ampt · Explicit model · Infiltration · Marquardt's algorithm

Introduction

Infiltration is the key mechanism for entry of water into soil and its subsequent movement in the soil profile. It plays an important role in hydrology as it affects surface runoff, groundwater recharge, irrigation and drainage, and solute transport process. An accurate and reliable infiltration model is determinant to understand and solve both the theoretical and practical hydrological problems. Numerous infiltration models of varying degree of complexity have been developed to describe the infiltration process (Mishra et al. 2003; Kale and Sahoo 2011). These models can be broadly grouped as: (1) empirical (Kostiakov 1932), (2) semiempirical (Horton 1938; Singh and Yu, 1990; Gowdish and Munoz-Carpena 2009), and (3) physically based (Green and Ampt 1911; Richards 1931) models. The empirical models are simple mathematical expression usually derived from laboratory or field experimental data and do not have any physical interpretation. The semiempirical models are based on systems approach and the Darcy's law (Singh and Yu 1990; Parhi et al. 2007). The physically based infiltration models are mathematical formulation derived from either Darcy's law (i.e., Green–Ampt model) or combination of Darcy's and mass conservation laws (i.e., Richards' model) or modified forms of Green–Ampt and/or Richards' models (Philip 1957; Morel-Seytoux and Khanji 1974; Swartzendruber and Clague 1989).

Physically based Richards' model provides the most accurate description of infiltration process. The Richards' equation is generally solved using numerical methods, such as the finite difference method, the finite element method, and the boundary element method (Varado et al. 2006). Numerical solution of the Richards' equation is computationally intensive and requires extensive input data and finer scale spatial and temporal discretization (Rao et al. 2006). The physically based infiltration model of Green–Ampt (GA) (Green and Ampt 1911) is an attractive alternative for simulating one-dimensional infiltration process. The GA model has the

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