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REVIEW PROCESS OF WATER MOVEMENT IN SOIL IN THE SPRINKLER IRRIGATION SYSTEM USING A SIMULATION MODEL HYDRUS-1D

Amirpouya SARRAF[1], Saeed SAFARI DOLATABADI[2], Morteza SALEHPOOR[3]

[1]Faculty member of agricultural Dept, Islamic Azad University, Roudehen Branch, Roudehen-Iran, E-mail: *Sarraf@riau.ac.ir*
[2]Faculty member of agricultural Dept, Islamic Azad University, Roudehen Branch, Roudehen-Iran
[3]Faculty member of agricultural Dept, Islamic Azad University, Roudehen Branch, Roudehen-Iran

Corresponding author e-mail: amirpooya@hotmail.com

Abstract

In the present study, how water moves in soils in the sprinkler irrigation system has been considered. According to preliminary soil and water information, soil physical and experimental parameters, cumulative amounts of input flow in upstream, Cumulative amounts absorbed by the roots and values of the cumulative output flow in downstream, have been estimated. Suction changes, moisture, hydraulic conductivity and flow depth at different times during the simulation have been determined by HYDRUS-1D Software. At the end, the soil moisture characteristics curve and Suction relationship with hydraulic conductivity was also determined.

Key words: *Simulation, Sprinkler System irrigation, Water movement, HYDRUS-1D.*

INTRODUCTION

HYDRUS-1D is one of the advanced models associated with one-dimensional movement of water, solutes and heat in the soil [3].

The mentioned model has been developed by (Simunek, et, .al) in American Soil Salinity Laboratory [9].

This model involves the numerical solution of Richards's equation for water movement in soil and release and transfer equations for heat and solute movement in soil.

Relevant equations in this model have been solved using finite difference.

This model can simulate root growth in terms of saturated and unsaturated conditions and has the ability to estimate soil hydraulic characteristics and solute transport with inverse method [1, 11].

Many of Subsurface water pollution problems are happened due to the simultaneous of water flow, solute, heat transfer and Bio chemical processes.

Models based on these processes can also be valuable tools for studying the movement of a wide range of organic and inorganic substances and pollutants from hydrologic and geochemical conditions [1, 7].

In water; soil and vegetation system, rainfall, irrigation and capillary rise are the unsaturated zone inputs.

Deep percolation and drainage are the outputs of unsaturated zone.

Evapotranspiration from soil and plants is also the output.

HYDRUS software has the ability to simulate water movement, salts, heat, carbon dioxide and water uptake by roots in both saturated and unsaturated zone.

Governing equations

One-dimensional motion of water in soil using numerical solution of Richards's equation in the model can be expressed as follows [8]:

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x}\left[K(\theta)(\frac{\partial h}{\partial x} + \cos\alpha)\right] - S \qquad (1)$$

θ :Volumetric moisture
$K(\theta)$:Unsaturated hydraulic conductivity
h :Matrix suction
α :Angle between flow direction and the vertical axis

S :Water uptake by roots
x :Distance
t Time

HYDRUS-1D Model to simulate water movement in soil, Solves the Richards equation using linear finite elements model [1, 2].

In this model, to describe features such as hydraulic soil moisture curve and unsaturated hydraulic conductivity, numbers of relationships are defined.

Mualem-Van Genuchten (1980) is the most common relationship shown in follows (10):

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

$$n>1 \qquad (2)$$

$$K(h)=K_s Se^1\left[1-(1-Se^{\frac{1}{m}})^m\right]^2 \qquad (3)$$

Where:

θr : Residual moisture
θs : Saturated moisture
α ‹m ‹ n & l : Experimental parameters
Ks : Saturated hydraulic conductivity
Se: Relative saturation

Water uptake by roots (S term in equation 1) on water uptake by plants per unit soil volume per unit time is determined.

In this model, S, based on the relationship between Feddes et, al (1978) is defined as follows:

$$S(h)=\alpha(h)S_P$$

Where:

$\alpha(h)$: Function of water stress
S_P : Potential of water absorption

Solution Method:

HYDRUS-1D model for simulate water movement in soil, Solves Richards equation using linear finite elements pattern. Since the one-dimensional, linear model of finite elements and finite differences are similar, the equation (1) with a non-explicit finite difference model has been following discrete:

$$\frac{\theta_i^{j+1,k+1}-\theta_i^j}{\Delta t}=\frac{1}{\Delta x}\left(K_{i+1/2}^{j+1,k}\frac{h_{i+1}^{j+1,k+1}}{\Delta x_i}-K_{i-1/2}^{j+1,k}\frac{h_i^{j+1,k}-h_{i-1}^{j+1,k+1}}{\Delta x_{i-1}}\right)+\frac{K_{i+1/2}^{j+1,k}-K_{i-1/2}^{j+1,k}}{\Delta x}-S_i^j$$

(5)

Where:

$$\Delta t=t^{j+1}-t^j \qquad (6)$$

$$\Delta x=\frac{x_{i+1}-x_{i-1}}{2}\ ,\ \Delta x_i=x_{i+1}-x_i\ ,\ \Delta x_{i-1}=x_i-x_{i-1} \qquad (7)$$

$$K_{i+1/2}^{j+1,k}=\frac{K_{i+1}^{j+1,k}+K_i^{j+1,k}}{2}\ ,\ K_{i-1/2}^{j+1,k}=\frac{K_i^{j+1,k}+K_{i-1}^{j+1,k}}{2} \qquad (8)$$

Where:

$i-1$ ‹ i ‹ $i+1$, are referred to The location of network points, k and $k+1$, to iteration, j and $j+1$, as different steps.

The mass conservation by (Celia et al., 1990), to become part of the first relation to matrix suction is used:

$$\frac{\theta_i^{j+1,k+1}-\theta_i^j}{\Delta t}=C_i^{j+1,k}\frac{h_i^{j+1,k+1}-h_i^{j+1,k}}{\Delta t}+\frac{\theta_i^{j+1,k}-\theta_i^j}{\Delta t} \qquad (9)$$

Where:

C_i, refers to Soil water capacity.

(Celia et al., 1990) method has shown that the mass balance has been successful in minimizing the error.

With replacing equation (1) in equation (2) after placing the order simple, the following equation is obtained:

$$\left[P_W\right]^{j+1,k}(h)^{j+1,k+1}=(F_W) \qquad (10)$$

So in terms of solving the above equation over the field, a diagonal system of equations can be obtained that is solved standard method such as Gauss elimination.

Procedure generally consists of three parts, pre-processing software, and the process is calculated. Data entry is done in a pre-processing step. Richards's equation is solved using the finite element method in Section II and finally, the model output data is obtained after processing.

This data includes simulation time, number of replicates at each time step, the cumulative number of iterations, the flow changes in the upstream boundary, the total cumulative inflow in the upstream, the cumulative water uptake by roots, the total cumulative output flow in the downstream, Matrix suction in the upstream, downstream, and by the roots [4].

Consequently, the purpose of this study is to use HYDRUS-1D model to simulate water movement in soil, soil hydraulic parameters to evaluate changes in depth during the irrigation period.

MATERIAL AND METHOD

Soils studied, homogeneous, single-layer texture is loam. Soil depth is 100 cm and the initial moisture content is measured 14% by volume. Sprinkling intensity is about 0.016 centimetres per minute and irrigation time is 13.5 hours.

A property of this model is mass balance estimation in time steps.

In this research, calculating the total balance in the soil profile is considered. Start time calculation usually starts from zero, but not always.

In this study, the number zero (start of irrigation) has been considered. Also, the irrigation time is 13.5 hours and the optional unit is minutes. As a result, 8 minutes, as calculations are terminated.

For more accurate simulations, we considered 9 outputs until the model once every 90 minutes; determine the amount of suction, flow and moisture content. The number of iterations is considered 20 that represent the maximum iteration for each time step (Δt).

Model with a variable Δt is starting simulation. Thus, given an initial value Δt for the model calculations can start. If the model, evaluate appropriate conditions, multiply this value in more than a multiplication factor and increase it and in poor condition, this value multiplied by a coefficient less than this value and its value decreases.

Thus, if the amount of calculated time steps (Δt) is small, the model can consider the value of a coefficient equal 1.3 and increases (Δt) and if the value of (Δt) is large, is capable by taking of values equal to 0.7, reduce the time step (Δt). Consequently, the loam soil texture and the possibility of predicting soil parameters using the neural network in considered model, parameters of residual moisture, moisture saturation, and saturated hydraulic conductivity and values of empirical equation are determined.

These values are shown in table (1). Boundary condition at the upstream is the constant flow and in Downstream has been considered as a free drainage. The input flow rate is -0.013 centimetres per minute that considered as upstream boundary conditions for the model.

RESULTS AND DISCUSSIONS

Soil values were estimated by the model is shown in the table 1. After simulation, the output of the program, the simulation time (0 to 810 min) is displayed. The number of iterations is specified in the time step that is usually between 4 to 6 reps.

θ_r $(\frac{cm^3}{cm^3})$	θ_s $(\frac{cm^3}{cm^3})$	K_s $(\frac{cm}{d})$	α $(\frac{1}{cm})$	n	l
0.0609	**0.3991**	**12.04**	**0.0111**	**1.4737**	**0.5**

Results related to The numbers of repeated and cumulative values over time are shown in figures 1 and 2. Total number of iterations of the simulation is repeated in 1723. The model result, changes in the upstream boundary, the cumulative amount of input in the upstream boundary, the cumulative flow that has adsorbed its roots that in this research its value is Zero. Cumulative sum of the output of the downstream boundary of its value is -0.42×10^{-4} (cm) that is almost equal to zero. Because the upstream boundary is in direct contact with the water and is almost saturated, after 810 minutes the amount of suction is insignificant and approaching zero. Matrix suction on the downstream boundary is equal to -1921 (cm) and is constant throughout the simulation period following figures 3 to 6. Suction changes, moisture, hydraulic conductivity and flow depth at different times during the simulation are shown in figures 7 to 10. In given figures, considering irrigation time that is equal to 810 minutes and 9 selected simulations period, Results are shown once every 90 minutes. Soil moisture retention curve and hydraulic conductivity associated with soil suction are shown in figures 11 and 12.

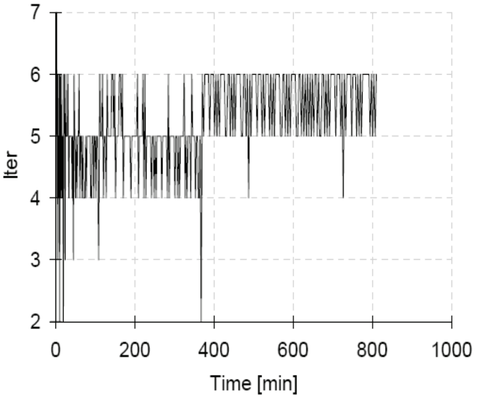

Fig. 1. The number of iterations in each time

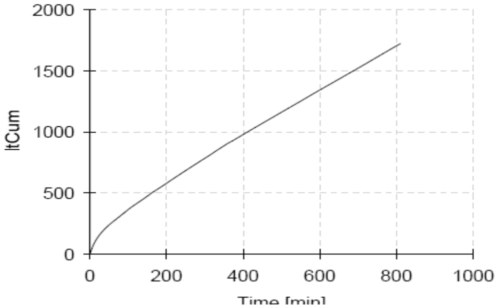

Fig. 2. Cumulative amount of iterations in the simulation

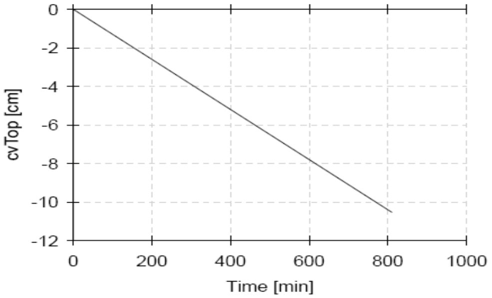

Fig. 3. Cumulative amount of incoming water from upstream

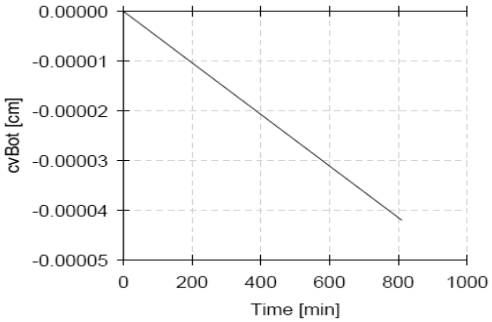

Fig. 4. Cumulative output of the downstream water

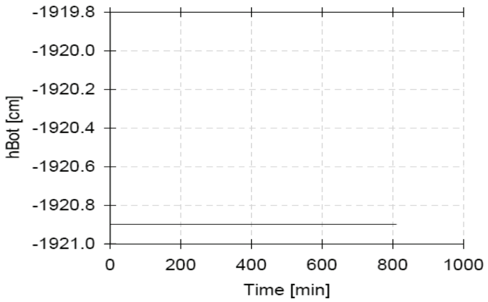

Fig. 5. The amount of suction on the downstream boundary

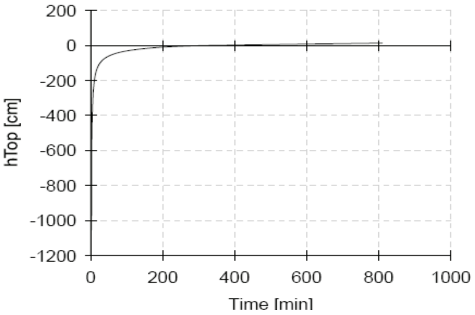

Fig. 6. The amount of suction on the upstream boundary

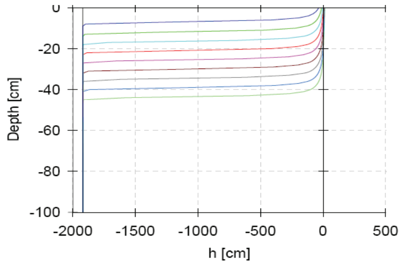

Fig. 7. Suction changes with soil depth at different times

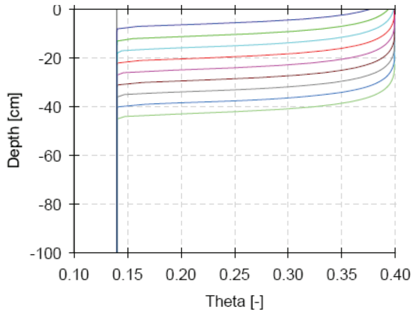

Fig. 8. Soil moisture changes with depth at different times

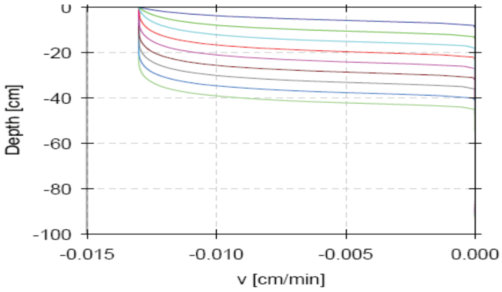

Fig. 9. Soil hydraulic conductivity changes with depth at different times

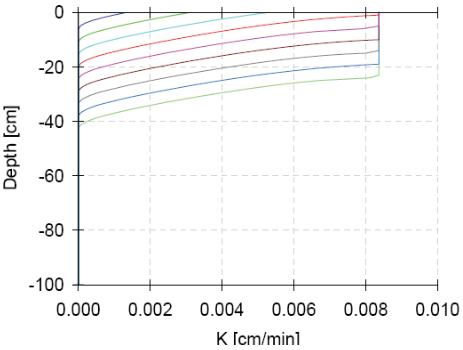

Fig. 10. Flow changes with soil depth at different times

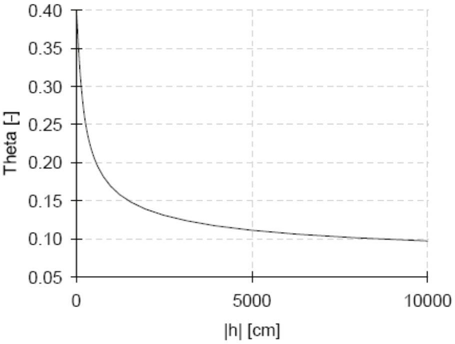

Fig. 11. The relationship between suction and moisture content, moisture retention curve

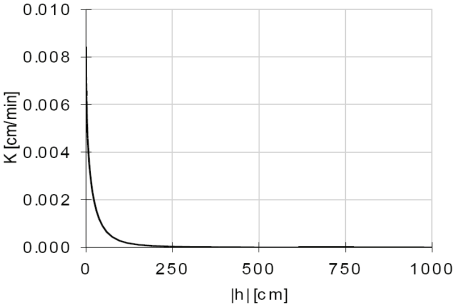

Fig. 12. The relationship between suction and hydraulic conductivity

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