Modeling The Moisture Distribution To Measured And Simulated Pattern By Using Hydrus -2d

M.U. Kale[1], P.A.Gawande[2] and R. S. Thute [3]

[1]Assistant Professor, Department of Irrigation and Drainage Engineering,Dr.PDKV, Akola, Maharashtra.
[1]Assistant Professor, Department of Soil and Water Conservation Engineering, Dr.PDKV, Akola, Maharashtra.
[2] Post Graduate Student, Department of Irrigation and Drainage Engineering, Dr. PDKVAkola, Maharashtra, India.

ABSTRACT

In the present study, HYDRUS-2D was used to study the moisture movement through soil under drip irrigation system. Richard's equation was solved using HYDRUS and vGM parameters obtained by using ROSETTA were used as input forHYDRUS.The HYDRUS model was calibrated and validated for different discharge rate and volume application combination. The modeling results showed that the HYDRUS-2D simulated the soil moisture satisfactorily in terms of statistical parameters R^2 and RMSE.

The well known computer software package is numerical model HYDRUS-2D (Simunek *et al*. 2006), widely used for simulating soil water movement in two dimensional, variably-saturated porous media. The software consists of the HYDRUS computer program, and the HYDRUS-2D interactive graphics-based user interface. The HYDRUS program numerically solves the Richard's equation for variably saturated water flow. The flow equation includes sink term to account for water uptake by plant roots. HYDRUS can be used to analyze water movement in unsaturated, partially saturated or fully saturated porous media.

Keywords: HYDRUS, Soil moisture, Modeling

INTRODUCTION

Soil moisture is the key variable for understanding hydrological processes within the soil. Agricultural and irrigation management practices, especially in arid and semi-arid regions, largely depend on timely and accurate characterization of temporal and spatial soil moisture dynamics in the root zone because of the impact of soil moisture on the production and health status of crops and salinization.

HYDRUS-2D is a computer software package widely used for simulating soil water movement in two dimensional, variably-saturated porous media. HYDRUS-2D model can use for evaluation of various irrigation schemes, evaluation of the effects of plant water uptake on groundwater recharge, assessing the transport of particle like substances in the subsurface, and using the models in conjunction with various geophysical method. The emitters sometimes interact, for instance, for irrigation of row crops, emitters have to be closely spaced along the laterals to maintain the necessary strip of wetted soil along the row. During irrigation the water content in the soil changes spatially and temporally. Water distribution in the soil is strongly dependent on the design parameters of the irrigation system (drip lateral spacing, system pressure, flow rate, trickle emitter type), climatic conditions, root distribution, soil type, rates of water application and vegetation. Factors affecting the spread of water from drip sources include various soil physical properties such as texture and structure (e.g., Warrick, 1974; Bresler, 1975; Cote *et al.* 2003; Thorburn *et al.* 2003). It has also been suggested that certain management techniques such as pulsed applications, high application rates, and preirrigation of soil beds may increase horizontal spreading of water (e.g. Li *et al.* 2004). For example, some irrigation guidelines indicate that the emitter rate will significantly affect the horizontal/vertical ratio of the wetted soil, with a higher emitter rate increasing the ratio.

MATERIAL AND METHODS

The experiment was conducted during 21st March 2018 to 11th April 2018 at Research Farm of Department of Irrigation and Drainage Engineering, Dr. PDKV, Akola. Average annual precipitation of Akola is 760 mm. The minimum temperature over the period of study varied from 17.2° to 26°C whereas maximum temperature varied from 36.4° to 45°C and Evaporation varied from 8.2 to 13.9 mmday^{-1} respectively.

Numerical approximation of Richard's equation

The basic equation for flow of water through an unsaturated porous medium was originally developed by Richards van Genuchten (1980) and was expressed as

$$\frac{\partial \theta}{\partial t} = \nabla.(K\nabla\emptyset) \qquad ....1$$

where,

θ = the soil water content on volume basis; t = time; K = capillary conductivity; ϕ =potential function.

Estimation of parameters of van Genuchten

The measurement of $\Theta(h)$ from soil cores (obtained through pressure plate apparatus) can be fitted to the desired soil water retention model. Once the retention function is estimated, the hydraulic conductivity relation, k (h), can be evaluated if the saturated hydraulic conductivity, K_s, is known. The soil water content as a function of the pressure head is given by Eqs. 3.2 and 3.3 as follows

$$\theta = \theta_r + \frac{(\theta_s-\theta_r)}{[1+(\alpha h)^n]^m} ....2$$

whereas before it is understood that h is positive and m = 1-1/n

Θ = the water retention curve, $cm^3\ cm^{-3}$

Θ_r = residual water content, $cm^3\ cm^{-3}$

Θ_s = saturated water content, $cm^3\ cm^{-3}$

α = related to the inverse of the air entry suction, cm^{-1}

n = a measure of a pore size distribution (dimensionless)

The observed data and simulated data of soil moisture was compared**.**The performance of the model was evaluated by using dimensionless statistical performance criteria, viz., coefficient of determination (R^2) and Root Mean Square Error (RMSE). Simulated data was compared with the observed one. The value of R^2 generally ranges from zero to one. Value of more R^2 than 0.7 is usually acceptable. The performance can be visually interpreted by plotting the simulated and observed data simultaneously on a single plot. R^2 and RMSE is determined by using following formulae.

Coefficient of determination

$$R^2 = \frac{[\sum(x-\bar{x})(y-\bar{y})]^2}{\sum(x-\bar{x})(y-\bar{y})^2}$$

where,

x - Observed values
$\bar{x}$ - Mean of observed values.
y - Simulated values
$\bar{y}$ - Mean of simulated values

Root mean square error

$$\text{RMSE} = \sqrt{\sum_{i=1}^{N}\frac{(\text{Oi} - \text{Pi})}{N}}$$

where,

O_i - Observed value
P_i - Predicted value
N - Number of observations

With the objectives as modeling the moisture distribution using HYDRUS -2D and to compare the measured and simulated moisture distribution pattern.

RESULTS AND DISCUSSIONS

The field experiment was conducted using drip irrigation layout and gypsum block sensors for different discharge rate and volumes combination. In addition, calibration, validation and testing of HYDRUS-2D model was also discussed and simulated results obtained from model were compared with observed data.

Modeling of moisture distribution using HYDRUS-2D

HYDRUS 2D model set up

HYDRUS-2D is a widely used physically based model for soil moisture simulation. In the present study HYDRUS was used for the determination of K-ϴ relationship. HYDRUS requires the value of saturated moisture content (Θ_s), residual moisture content (Θ_r), saturated hydraulic conductivity (K_s) and vanGenuchten's water retention curve parameters *i.e.* α and n. Saturated moisture content was considered equals to total porosity of soil. The saturated moisture content varies from soil to soil and with soil depth. From Table 1 it is understood that the value of Θ_s is 0.40 $cm^3\ cm^{-3}$ for 0-18 depth and 0.38 $cm^3\ cm^{-3}$ for 18-42 cm soil depth.

Determination of soil residual water content, Θ_r is difficult to determine in the laboratory. K-ϴ relationship is influenced by the choice of Θ_s and Θ_r. In the present investigation Θ_r was estimated using ROSETTA software. It was found that the value of Θ_r ranges from 0.1050 to 0.1051 $cm^3\ cm^{-3}$ at different depths for soil under study. α, n and m are independent parameters of vGM. α and n were estimated by ROSETTA software (Art.3.3.1.1.3) and are presented in the Table 1. These parameters were used to obtain K-ϴ relationship.

Table 1. Hydraulic properties and vGM parameters for soil at the experimental plot using ROSETTA

Soil depth, cm	Saturated moisture content, $cm^3\ cm^{-3}$	Residual moisture content $cm^3\ cm^{-3}$	Saturated hydraulic conductivity, $cm\ h^{-1}$	vGM parameters	
				α, cm^{-1}	n
0-18	0.40	0.1050	1.07	0.0187	1.2872
18-42	0.38	0.1051	1.06	0.0189	1.2809

Comparison between observed and simulated moisture distribution pattern

Comparison between observed and simulated soil moisture data for test combination is depicted in Fig.1 and 2 for 0-10 and 10-30 cm depth respectively.

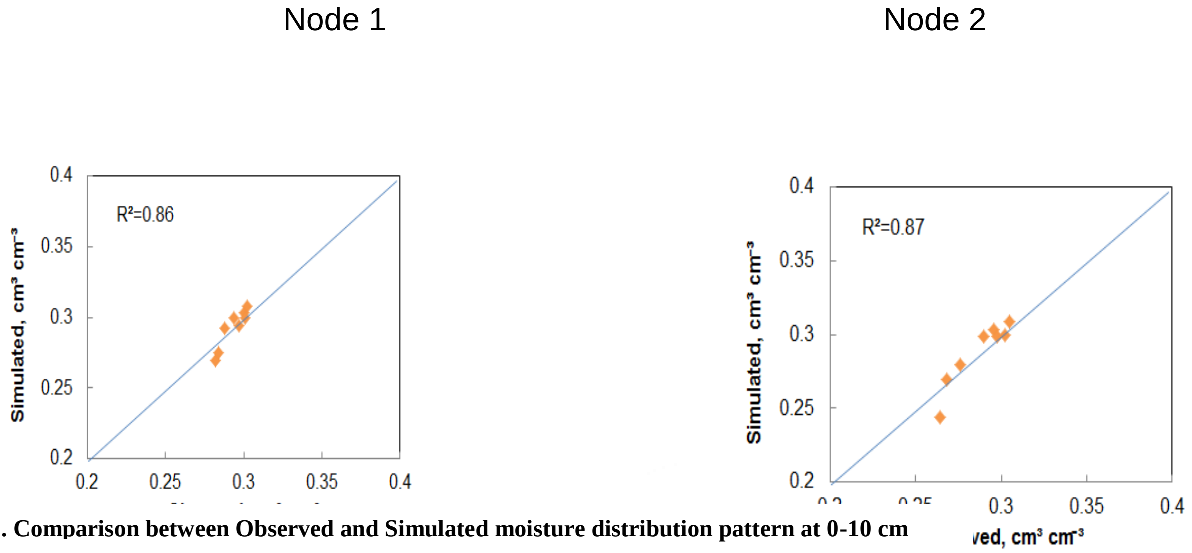
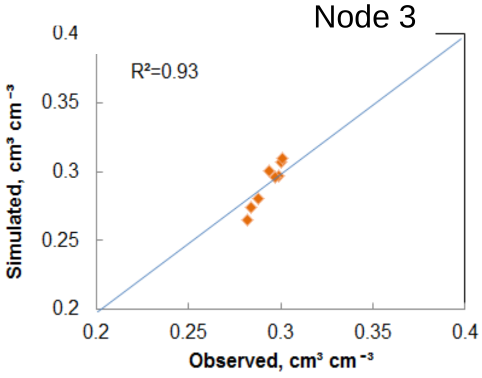


Fig. 1. Comparison between Observed and Simulated moisture distribution pattern at 0-10 cm



The scattered plots between the simulated and observed soil moisture data matches for 0-10 and 10-30 cm depth clears that the model does not over or underestimate the soil moisture consistently. The simulated soil moisture lies along the 1:1 line. The value of R^2 for 0-10 cm depth ranges from 0.82 to 0.95, while for 10-30 cm it ranges from 0.81 to 0.98, which shows that there is good match between the stimulated and observed soil moisture. It indicates that the model could be implemented for simulation of water front advance for any combination of emitted discharge and volume application through drip irrigation for the study area.

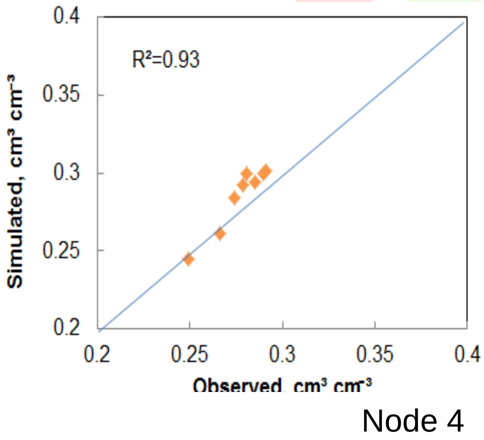


Fig. 2. Comparison between observed and simulated moisture at 10-30 cm

As maximum wetting diameter for 4 and 8 lph emitter is observed as 48 and 52 cm respectively, the spacing between two emitters should not be kept more than 48 and 52 cm in case of 4 lph and 8 lph emitter respectively for the soil at experimental plot. As soil mois ented for simulation of water front advai n through drip irrigation for the study area. The model generated moisture variation in the soil is depicted in Fig. 3 and 4 for 0-10 and 10-30 cm depth below the soil surface respectively.

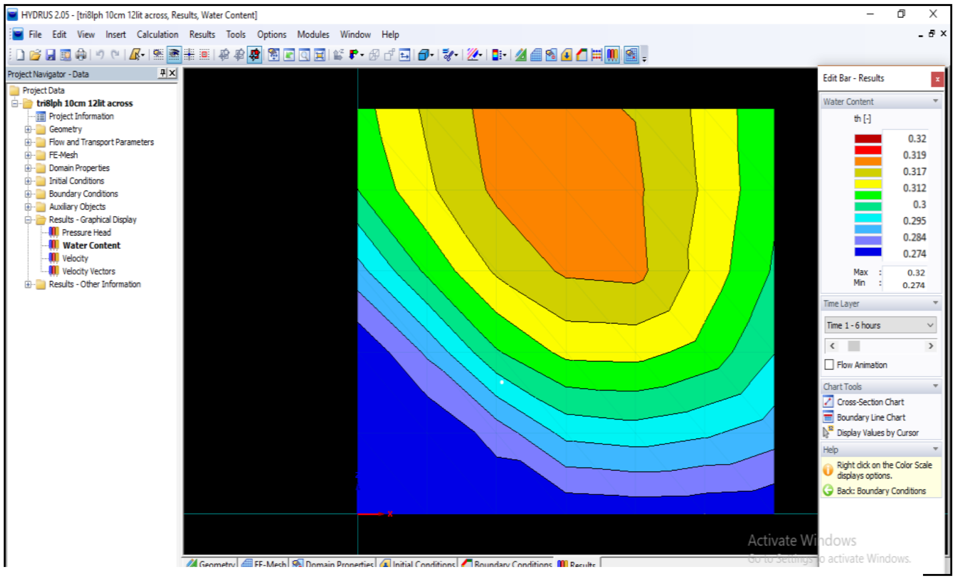


Fig 3 Model generated soil moisture variation view for 0-10 cm

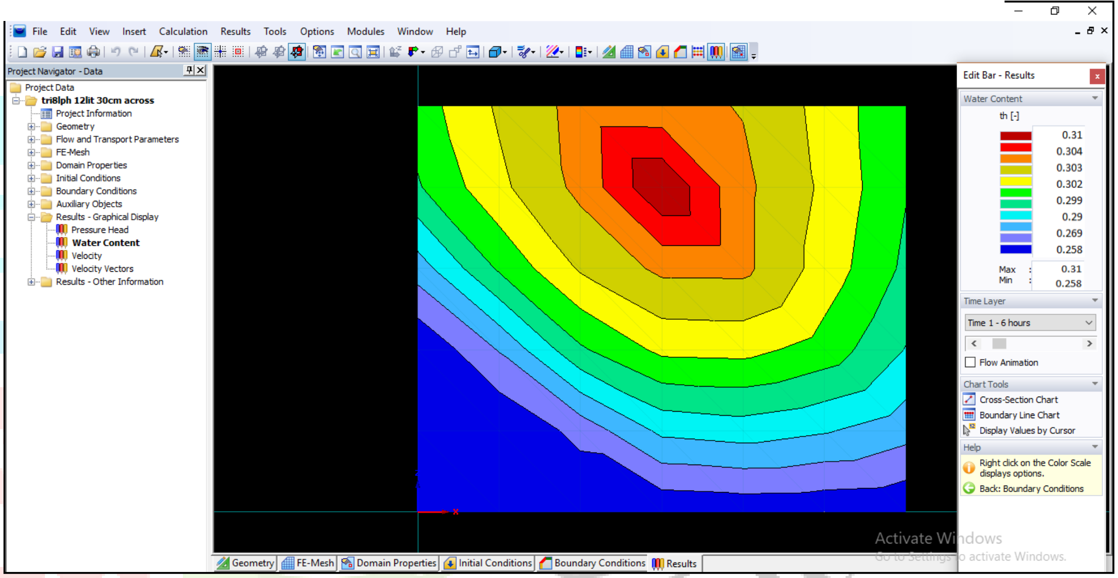


Fig 4. Model generated soil moisture variation view for 10-30 cm

The calibrated model for the soil under study was validated for 8lph discharge rate with 12lit volume. The temporal variations of observed and simulated soil moisture for the soil under study at 0-10 cm and 10-30 cm depth.

CONCLUSIONS:

As maximum wetting diameter for 4 and 8 lph emitter is observed as 48 and 52 cm respectively, the spacing between two emitters should not be kept more than 48 and 52 cm in case of 4 lph and 8 lph emitter respectively for the soil at study area. As soil moisture is simulated well by Hydrus-2D model, it could be implemented for simulation of water front advance for any combination of emitter discharge and volume application through drip irrigation for the study area

REFERCENCES:

Bar Yosef B. and Sheikholami M.K. (1976). Distribution of water and ions in soils irrigated and fertilized from a trickle source. Soil Sci. Soc. Amr. J. 40 : 575-582.

Bresler E. (1975). Twodimensional transport of solutes during nonsteady infiltration from a trickle source. Soil Sci. Soc. Amr. Proc. 39 : 604-612.

Galvez F.J. and Simmonds L.P. (2006). Monitoring and modelling the three – dimensional flow of water under drip irrigation. J. Agril. Water Mgmt. 83 : 197-208.

Jabri A. l., Salem A., Horton R. and Jaynes D.B. (2002). A point source method for rapid simultaneous estimation of soil hydraulic and chemical transport properties. J. Soil Sci. Soc. Am. 66 : 12-18.

Mohammad N., El-Nesr., AlazbaA. A.and Simunek J. (2013). HYDRUS simulations of the effects of dual-drip subsurface irrigation and a physical barrier on water movement and solute transport in soils. Irrig. Sci. 32:111–125.

Provenzano G. (2007). Using HYDRUS-2D simulation model to evaluate wettedsoil volume in subsurface drip irrigation systems.J.Irrig.Drain.Eng. 133 : 342-349.

Simunek J.,Senja M., van Genuchten M.T. (2006). The HYDRUS-2D software package for simulating two and three-dimensional movement of water,heat and multiple solutes in variably saturated media.Technical Manual, Version 1.0,PC progress,Prague,Czech Republic : 1-241.

Skaggs T.H.,Trout T.J. and Rothfuss Y. (2010). Drip irrigation water distribution patterns:Effects of emitter rate,pulsing, and antecedent water. Soil Sci. Soc. Amr. J. 74(6) : 1886-1896.