Simulation of Water Distribution Under Drip Irrigation with Artificial Neural Network

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Abstract

We explore the prediction of subsurface water distribution from trickle emitters using artificial neural networks (ANN’s). The first steps are transparent to the user and include: (i) preparation of input-output databases from a numerical model (HYDRUS-2D) (ii) Training an optimal ANN (iii) Confirming that the ANN gives an accurate answer for a test case.

The boundary condition at the soil surface was for constant discharge (Gardenas et al., 2005). For all simulations, data was saved at 20 evenly-spaced times resulting in a matrix with 1,684,500 vectors. Each vector had eleven elements, \( \theta_r \), \( \theta_z \), \( \alpha \), \( n \), \( K_s \), \( Q \), \( S_r \), \( t \), \( r \), \( z \), \( \theta \). After completing the simulations, data were processed and the spatial and temporal subsurface wetting patterns were described using moment analysis (Lazarovitch et al., 2006). Moment analyses can accurately describe the water content distribution in a statistical manner with just three numbers: the center of the added water (plume), \( z_C \), and the spread of the plume about its center in the \( z \) and \( x \) directions, \( \sigma_z \) and \( \sigma_x \). Then spheroids can be depicted about \( z \) describing the “water plume.” This procedure yielded a data set of 1500 vectors with 11 variables including 8 inputs (\( \theta_r \), \( \theta_z \), \( \alpha \), \( n \), \( K_s \), \( Q \), \( S_r \), \( t \)) and 3 outputs (\( z_C \), \( \sigma_z \), \( \sigma_x \)). We used a multi-layer perceptron architecture for the ANN with back propagation for training the connection weights.

After training was completed, a test was performed using a new simulation with different soil properties, initial conditions and discharge rate. Input values in the new simulation were \( \theta = 0.062 \), \( \theta = 0.426 \), \( \alpha = 0.08 \) cm\(^{-1} \), \( n = 1.96 \), \( K_s = 10.04 \) cm h\(^{-1} \), \( Q = 4000 \) cm\(^3\) h\(^{-1} \), \( S_r = 0.05 \), \( t = 5h \).

Results

ANN predictions are compared to independent model results for the center of the added water, \( z_C \) in Figure 1. The spread of the plume about its center in the \( r \) and \( z \) directions, \( \sigma_r \) and \( \sigma_z \) are presented in Figure 2 and 3 respectively. The high \( r^2 \) as presented in figures 1-3 suggests good agreement between the observed and predicted variables.

A comparison of spheroids resulting moments calculations between HYDRUS-2D and ANN predictions for the test case is shown in Fig. 4. The ANN accurately predicts the center of gravity as well as spheroids that represents 19%, 71% and 100% of the applied water at the end of infiltration.

Conclusions

This work encapsulates numerical modeling of complex systems into an easy to use form. The results are accurate and allow the user to get an answer for any given time, soil hydraulic properties, initial and boundary conditions without having to perform a detailed numerical simulation. The results shown here are for infiltration from a surface point source. However, this procedure was tested successfully for infiltration from surface line sources and subsurface source cavities.

References


Lazarovitch, N., Warrick, A.W., Furman, A. and Šimunek J. Water content distribution in drip irrigation described by moment analyses. (Failure Zone J. In press)


Fig. 1 - ANN prediction as a function of the numerical model results for the center of the added water, \( z_C \).

Fig. 2 - ANN prediction as a function of the numerical model results for the spread of the plume about its center in the \( r \) direction, \( \sigma_r \).

Fig. 3 - ANN prediction as a function of the numerical model results for the spread of the plume about its center in the \( z \) direction, \( \sigma_z \).

Fig. 4 - Comparison of spheroids resulting moments calculations between HYDRUS-2D and ANN with the test case. (The gray curves are lines of equal water content).