Shahid Chamran University of Ahvaz
Irrigation Sciences and Engineering Vol. 41, No. 3, Fall 2018, p. 133-144

EXTENDED ABSTRACT

Estimation of Unsaturated Soil Hydraulic Conductivity Using Inverse Approach Under Soil Salinity Condition

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Received:10 November 2016 Accepted: 22 February 2017

Keywords: Inverse Estimation, Soil Hydraulic Properties, Soil Salinity, Unsaturated Soil.

Introduction

Moisture flow through unsaturated zone is vital in agricultural engineering, soil science, groundwater hydrology, and environmental engineering. Moisture flow through unsaturated zone is complex due to the dependencies of flow and storage properties on the pressure head and is commonly analyzed by solving Richards' equation. Solution of Richards' equation requires the knowledge of soil hydraulic conductivity and water content versus pressure head functions referred to herein as the soil hydraulic properties. Since these functions are highly nonlinear, direct laboratory and field measurements are tedious, time consuming, and involve considerable uncertainty (Hari Prasad et al., 2010). An alternative to the direct determination is to employ the parameter estimation methods using inverse procedure for the determination of hydraulic properties. Indirect methods are divided into several categories, including methods based on pedotransfer functions, semi-physical, and inverse methods (Abbasi, 2007). Determination of hydraulic properties by inversion of in situ measured moisture contents, pressure heads and cumulative infiltration have become an alternative to direct measurements due to decrease in the computational costs and development of efficient optimization algorithms. Inverse solutions based on the Richards' equation are now increasingly used for estimating the unsaturated soil hydraulic properties. The HYDRUS-1D model is one of the advanced models have been widely used to simulate one-dimensional water movement in soil. Examples of numerical studies in which infiltration data were used to inversely estimate the near-saturated soil hydraulic properties using HYDRUS model are by Simunek and van Genuchten (1996) and Rashid et al (2015). Water quality can impact on soil hydraulic conductivity changes. The effect of salinity on the hydraulic conductivity of soil has been studied by many researchers, including Moutier et al. (1998) et al. and Levy (2005). The researchers reported that increasing the salinity has increased the hydraulic conductivity of the soil. The purpose of this research was to evaluate saline water effect on unsaturated hydraulic properties and estimate these properties inversely using infiltration data.

Methodology

The field experiments were carried out in 2012 at the research farm of Department of Irrigation and Reclamation Engineering, University of Tehran, Karaj, Iran. Soil sampling at three depths for each treatment was carried out to determine soil texture based on the USDA soil classification.

A double ring infiltrometer was used to conduct the field infiltration to obtain estimates of the soil hydraulic properties. Soil samples were collected additionally at depths of 0–60 cm at various measurement locations using a soil ring (height = 5 cm, diameter = 5 cm). In all samples were collected to determine for each location the initial water content, θ_i, the bulk density, ρ_b, the, the total porosity, ε, and the residual water content, θ_r (the latter simply approximated initially by the wilting point). Due to the nature of the research, this experiment was conducted in the form of a completely randomized block design. The area of each plot was approximately 16 square meters (4 × 4). Three levels of water salinity (EC) 1.1, 2.2 and 8.5 ds/m were used. Soil hydraulic parameters were determined by direct method for three treatments and three different depths. Soil hydraulic parameters were estimated by inverse solution using HYDRUS-1D model. In addition, the most sensitive van-Genuchten parameters to soil water infiltration data were inversely estimated due to limitation in estimating several parameters simultaneously. Results were evaluated using statistical parameters, including the coefficient of determination (R^2) and the root mean square error (*RMSE*).

Results and Discussion

According to the simulation targets in the study area, the sensitivity analysis of the the cumulative infiltration was calculated in soil. The highest sensitivity coefficient belonged to n, θ_s and K_s, respectively. These three parameters are considered as the most sensitive input parameters in the sensitivity analysis of water and soil models (Hopmans and Simunek, 1999 & Mau et al., 2013). According to the results of cumulative infiltration of water in soil, there was no significant difference between all three treatments. Cumulative infiltration values have decreased with increasing salinity in the studied treatments.

The final cumulative infiltration after 240 minutes in the first, second and third treatments was 22.87, 16.83 and 16.53 cm, respectively. Also, the results of the ANOVA and variance analysis test in Minitab statistical software showed that there was no significant difference between the final cumulative infiltration values of three treatments after four hours with three replications and 95% confidence.

The values of infiltration coefficients of the Phillip equation, soil saturated hydraulic conductivity estimated by reverse method and statistical indices (R^2 and RMSE) are determined for evaluating the measured and estimated infiltration values for treatments. The results showed that, S and Ks decreased with increasing soil salinity. While the coefficient A did not show a clear trend with increasing salinity. There is a significant difference between the estimated hydraulic conduction values by inverse method and the coefficient A in all three treatments. Comparison of measured and simulated values of unsaturated hydraulic conductivity was performed using the t-paired comparison test in Minitab software. The results shown, the estimated curve of the model simulation results is well correlated with the measured values. Therefore, the model has a high potential for inverse modeling of soil hydraulic parameters using infiltration data. Unsaturated hydraulic conductivity values, in contrast to expectations, decreased by increasing of the salinity.

Conclusions

According to the results, salinity had no significant effect on soil water infiltration and soil hydraulic conductivity variations. Values of R^2 coefficient were found 0.75, 0.85 and 0.82, for EC of 1.1, 2.2 and 8.5 ds/m, respectively, indicating a good correlation between simulated and measured values of cumulative infiltration data by using inverse solution. Measured and simulated values of unsaturated soil hydraulic conductivity were also very good fitted. As a result, the unsaturated soil hydraulic conductivity could be inversely estimated using the measured infiltration data through the double ring method.

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