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Estimating Soil Hydraulic Parameters In El-Tina Plain Using RETC Program

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Abstract

Arable soils in Northern Sinai, will be irrigated from El-Salam canal, which passes through El-Tina plain. The soils of El-Tina plain are characterized by a heterorganic texture. So, quantifying the variations in the hydraulic properties of El-Tina plain soils is urgent task to achieve optimum water management. RETC is a computer program which can be used to estimate soil hydraulic functions from easily determined properties. Using van Genuchten model in RETC program gave high accuracy for estimating the hydraulic functions e.g., $\theta(h)$, $k(\theta)$ and $D(\theta)$, under the various textures of the studied soils. Therefore, RETC program is considered a good tool for potential optimization of soil water management in the soils of El-Tina plain and the adjacent ones.

Introduction

Sinai peninsula represents a promising and strategic region for urban development. The northern territories of Sinai have considerable potential for agriculture, fisheries and summer resorts. Much of the arable soils in this area would eventually be irrigated with Nile water from El-Salam canal which passes below the Suez Canal and though El-Tina plain (LMP, 1986). Therefore, the development of this area for such multipurpose is a high national priority. The soils in the area of El-Tina plain are characterized by five texture classes namely, loamy sand, sandy loam, clay loam, clay and sandy (Rabie *et al.,* 1991). The variations in soil texture require different water managements, to achieve high efficiency of water use and to get optimum water balance.

Hydraulic properties are the key parameters in any quantitative description of water flow into and through the unsaturated soil zones ,van Genuchten *et al.* (1992). Unfortunately, laboratory and field methods, which developed over the years to measure the hydraulic functions are relatively costly, difficult to implement and time-consuming. One alternative for predicting the unsaturated soil hydraulic conductivity is the use of theoretical methods in which the more easily measured soil properties and measured water retention data are used. These methods are, generally, based on statistical pore — size distribution models, Mualem (1986). RETC is a computer program used for analyzing soil water retention and hydraulic conductivity functions of unsaturated soils, van Genuchten *et al* (1992).

A nonlinear least-squares optimization approach is used in this program to estimate the unknown model parameters from observed retention and / or conductivity or diffusivity data. The aim of curve fitting process is to find an equation that maximizes the sum of squares associated with the model, while it minimizes the residual sum of squares, van Genuchten *et al* (1992).

The purpose of this work is to estimate soil hydraulic parameters from easily measured soil properties by using a high precision computer program. The use of this program also optimizes the required parameters for water flow models under unsaturated soil conditions.

Material and Methods

Five soil samples (0-30 cm depth) were selected to represent five texture classes in El-Tina plain, Northern Sinai. Some physical properties of the studied soil samples were determined according to the standard methods described by Klute (1986) and presented in Table (1).

Table (1): Some physical properties of the studied soil samples.

Soil Property	Sample No.				
	1	2	3	4	5
Sand %	84.2	52.0	35.2	17.7	98.5
Silt %	8.4	32.3	36.8	33.8	1.5
Clay %	7.4	15.7	28.0	48.5	0
Texture class	Loamy sand	Sandy loam	Clay loam	Clay	Sandy
Bulk density (g/cc)	1.58	1.56	1.42	1.24	1.67
θ_{33} kPa (cm^3/cm^3)	0.1524	0.1998	0.2275	0.3645	0.1025
θ_{1500} kPa (cm^3/cm^3)	0.0791	0.0951	0.1285	0.1852	0.0258

The soil samples, which collected from different locations of El-Tina plain, were saturated with water before subjecting them to suction on sand box instrument (under low values of pressure heads, e.g., 10, 30, 60 and 100 cm water). While, the saturated soil samples were subjected to high pressure on pressure apparatus 200, 330, 500, 1000, 2000, 5000, 10000 and 15000 cm water). After equilibrium, soil water contents were determined, immediately and presented on volume bases, Fig (1). “Rosetta program”, was used to obtain the closed form expressions of van Genuchten parameters, from the values of particle size distribution, soil bulk density and soil water contents on volume bases at 33 kPa and 1500 kPa, *Schaap*, *et al* (1998). Output data of “Rosetta program”, e.g., θs, θr, α and n were used in RETC program as input data besides the determined values of soil water retention.
Output file of RETC run was converted to “Excel” file and the fitted parameters are presented in Table (2). Measured and fitted relationships among pressure head (cm) and soil water content (cm^3 / cm^3), unsaturated hydraulic conductivity K(θ) (cm / day) and water diffusivity D(θ) (cm^2 / day) are presented in Figs (1, 2 and 3).

Results and Discussion

Table (2) contains the fitted parameter values and the calculated sum of squares (SSQ) of the fitted values versus the measured water contents after and before RETC refining. The SSQ values reflect the relative accuracy of the retention models in describing the measured data. Generally, as the value of SSQ (residual) becomes smaller, this means higher precision in fitting using the retention model, van Genuchten *et al* (1992).

RETC program is refined the values of van Genuchten parameters to get the smallest values of summation squares (SSQ). The largest refining is found for soil sample no. 4 (clay soil) where SSQ changed from 0.01773 to 0.00051. While the smallest one is observed in the case of soil sample no. 5 (Sandy soil) where, SSQ changed from 0.00077 to 0.00047. This finding means that van Genuchten model with Mualem - based restriction is more successful in describing soil water retention in light texture soils than in heavy ones.

Fig. (1) reveals that, the measured and fitted water characteristics curves are close matched and the coefficients of determination (R^2) are higher than 0.99, Table (2).

So, using van Genuchten model (where m = 1-1/n) in RETC program is succeeded in estimating θ(h) function of all soil samples under study.

Fig. (2) shows the relationship between soil hydraulic conductivity (cm/day) and pressure head (cm), in the studied soil samples. From the abovementioned figure, there are good fittings in all investigated soil samples and the coefficients of determination are higher than 0.99. The same findings were obtained in respect to water diffusivity in these soils, Fig. (3). Coefficients of determinations are higher than 0.99 for the relationship between water diffusivity and pressure head. From the above mentioned findings, it can be concluded that, RETC program can successfully estimate the hydraulic functions of the soil by using van Genuchten model, (1980) and easily measured parameters (e.g., particle size distribution, bulk density and water contents at 33 kPa and 1500 kPa of the studied soil samples which represent the soils adjacent to El-Salam Canal.

Table (2): The fitted values of van Genuchten parameters by RETC program of the studied soil samples.

Sample No.	θ_r	θ_s	α	n	SSQ before RETC refining	SSQ after RETC refining	R^2
1	0.0577	0.3445	0.0567	1.4210	0.00141	0.00038	0.9962
2	0.0791	0.3624	0.0734	1.2181	0.00271	0.00042	0.9955
3	0.1080	0.4033	0.0243	1.4410	0.00347	0.00012	0.9989
4	0.1627	0.4997	0.0075	1.4647	0.01773	0.00051	0.9968
5	0.0145	0.3405	0.0404	1.4541	0.00077	0.00047	0.9966

θ_r = Residual water content. (cm^3/cm^3) n = Water release parameter (Dimensionless).
θ_s = Soil water at saturation.(cm^3/cm^3) SSQ = Sum of squares (Residual).
α = Water release parameter (cm^{-1}) R^2 = Coefficient of determination

Also, Figs (1, 2 and 3) reveal that, there are noticeable variations in water behaviour among the studied soil samples which means that the different water managements are required.

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