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EVALUATING OF USING SOME PEDOTRANSFER FUNCTIONS TO ESTIMATE HYDRAULIC PROPERTIES OF SOME SOILS IN EGYPT.

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ABSTRACT

Pedotransfer functions are commonly used in computer program to estimate the hydraulic parameters of soils . Rosetta and also RETC are computer codes which use some surrogate data to estimate and analyze soil water retention and conductivity data . So, to evaluate the used pedotransfer functions in both programs the estimated values were compared with the observed ones using five soil samples represent four texture classes . The estimated data of both theta (h) or K(theta) were fitted well with the observed ones ,but the degree of accuracy were differ . RETC program is more accurate than the Rosetta one in estimating the hydraulic parameters . Both Rosetta and RETC programs were highly precision in light textured soils because the used pedotransfer functions at them are based on neural network analysis of data base of California and Arizona soils . Generally, RETC code can be used to estimate the hydraulic parameters of some soils of Egypt, especially the light textured ones .
Keywords : Pedotransfer functions – Rosetta program – RETC program

INTRODUCTION

There is an increasing evidence that the quality of the earth's soil and water resources is being adversely affected by the release of a variety of agricultural and industrial pollutants into the environment. In efforts to better monitor and manage the migration of chemicals in the subsurface, scientists and engineers over the past several decades have developed increasingly complex computer models describing how water and chemicals move into and through the unsaturated zone. Computer models have become indispensable tools in research for quantifying and integrating the most pertinent physical, chemical, and biological processes operative in the unsaturated (vadose) zone of soils, *Leij and van Genuchten* [1999]. Planning, action, and extension agencies are also increasingly relying on the use of models for predicting the long-term impacts of alternative soil and water management practices on crop yield and groundwater quality, and for remedial action purposes, *Ahuja et al*.[1999] .

The reliable application of computer models to field-scale flow and transport problems implies a commensurate effort in quantifying a large number of model parameters, especially the unsaturated hydraulic properties. As our ability to numerically simulate complicated flow and transport systems increases, the accuracy of future simulations may well depends on the accuracy with which we can estimate our model parameters. Methods for determining the unsaturated hydraulic conductivity, *K,* in particular, are viewed as inadequate by theoreticians and practitioners alike.

Unfortunately, the hydraulic conductivity is probably the most important parameter affecting water and solute movement in the vadose zone.

Water flow in porous media is typically described with the unsaturated flow or Richards equation:

where *h* is the soil water pressure head, θ is the volumetric water content, *K* is the hydraulic conductivity, t is time, and z is soil depth. A large number of

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left[K(h)\cdot\left(\frac{\partial h}{\partial z}\right)+1\right] \quad \cdots\cdots\cdots\cdots \quad (1)$$

laboratory and field methods have been developed over the years for measuring *K* as a function of *h* or θ. They are based on solving the inverse problem, i.e., an analytical or numerical solution of the hydraulic model describing the flow process is optimized with respect to such flow attributes as water content and pressure head, *Russo et al* [1991]. These methods, nearly without exception, are costly and difficult to implement. Enormous investments of time and money have been made, and continue to be made, by soil scientists, hydrologists, and others, to measure the hydraulic properties of field soils using methods that have only marginally improved over the past several decades. Accurate and effective measurement of the hydraulic properties is confounded by the extreme spatial variability of the hydraulic conductivity in the subsurface. The hydraulic conductivity frequently also shows significant variations in time because of cultivation or other agricultural activities, shrink-swell phenomena of fine-textured soil, the effects of particle dispersion and soil crusting, and changes in the composition of the soil solution.

In sharp contrast to direct methods for measuring the hydraulic properties, relatively little attention is being paid to the development of indirect methods which predict the hydraulic properties from more easily measured data, including water retention data, and pore- or particle-size distributions, *Leij and van Genuchten* [1999].. This is unfortunate since indirect methods generally are more convenient and far less costly to implement. Moreover, indirect methods often give hydraulic conductivity estimates which may well be accurate enough, or are close to being accurate enough, for many applications. However, the formulation and evaluation of indirect methods hinges on experimental data which usually are obtained with direct procedures. Thus, the utility of indirect approaches does not obviate the need for continued research toward improved direct methods.

Rosetta is a computer program, who implements pedotransfer functions that use the widely available basic soil data, e.g. texture class, particle-size distribution, bulk density, etc., as input. Rosetta follows a hierarchical approach to estimate van Genuchten and water retention parameters using limited or more extended sets of input data. The hierarchical approach is reflected in five models, the simplest one consist of a lookup table for average hydraulic parameters for each soil texture class, while the other four models are based on neural network analysis, *Schaap et al.,* [1998]. Generally, the use of more input data often leads to better prediction of water retention and conductivity data*, Schaap et al.* [1998] *Galal*

[2000] found in some soil samples from Egypt having different texture classes, that the soil particle size distribution had a major effect on the predictive parameters from Rosetta. He also noticed that the adding of bulk density value to particle size distribution in the used model of Rosetta was quit enough to increase the accuracy of the prediction of van Genuchten and water retention parameters.

RETC is a computer code for analyzing the soil water retention and hydraulic conductivity functions of unsaturated soils. The soil water retention curve θ (h), according to van Genuchten model contains five potentially unknown parameters: θr, θs, α, n, and m. The predictive equation for hydraulic conductivity introduces *l* and K_s as two additional unknowns. Hence, the hydraulic functions contain a maximum of seven independent parameters. The model parameters are represented here schematically by the parameter vector b = (θr, θs, α, n, m, *l,* $K_{s)}$. The RETC code may be used to fit any one, several or all of these parameters simultaneously to observed data.

Generally, the objectives of this investigation are to evaluate some pedotransfer functions and computer programs used in estimating some hydraulic properties of the soil .

Materials and Methods

Five soil samples (0-30 cm depth) were selected to represent four texture classes in some locations in South of Delta (soil samples number 1 and 3) and El-Salhya (soil samples number 2,4 and 5). 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 %	28.5	53.0	30.5	66.5	75.2
Silt %	27.4	18.3	34.6	23.5	10.5
Clay %	44.1	28.7	34.9	10.0	14.3
Texture class	Clay	Sandy clay loam	Clay loam	Sandy loam	Sandy loam
Bulk density (g/cc)	1.17	1.34	1.31	1.55	1.56
θ_{33} kPa (cm^3/cm^3)	0.4544	0.3107	0.3485	0.3645	0.3005
θ_{1500} kPa (cm^3/cm^3)	0.2498	0.1595	0.1473	0.1852	0.0984

The studied soil samples were saturated with water before subjecting them to suction on sand box instrument (under low values of pressure heads, e.g., 10, 60 and 100 cm water). In addition, the saturated soil samples were also subjected to high pressure on pressure apparatus (330, 660, 1000, 2000, 5000, 10000 and 15000 cm water). After equilibrium, soil water contents were determined, immediately and presented on volume bases. Soil hydraulic conductivity under unsaturated conditions was determined according to Klute and Dirksen [1986] “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 content on volume bases at 33 kPa, *Schaap*, *et al.* [1998]. The obtained parameters were used to estimate theta(h) and K(theta) curves . Output data of "Rosetta program", e.g., θs, θr, α and n were used in RETC program as input data beside the determined values of soil water retention.

Output file of RETC run was converted to "Excel" file and the fitted parameters were used to obtain soil water characteristic curve and K(θ) curve .Measured and fitted relationships among pressure head (cm) and soil water content (cm^3/cm^3) θ(h) and unsaturated hydraulic conductivity K(θ) (cm / day) are presented in Figs (1 and 2).

Statistical analysis and fitting procedure were carried out using " Microsoft Excel " program .

The values of correlation coefficient , mean error of prediction (MEP) and standard deviation of prediction (SDP) were calculated to measure the precision of the predictions , Table (2)

The mean error of prediction (MEP) and the standard deviation of prediction (SDP) were computed as follow :-

$$MEP = 1/n \, \Sigma \, (\theta_m - \theta_p) ,$$

$$SDP = [\, 1/n \, \Sigma \, (\theta_m - \theta_p - MEP)^2 \,]^{0.5}$$

Where θ_m is the measured soil water content, θ_p is the predicted soil water content and n is the number of tested points.

To evaluate the precision of the predictions, both standard deviation of prediction (SDP) and geometric standard deviation of the error ratio (GSDER) were calculated as described by *Tietje* [1999] .Because hydraulic conductivity values are generally exhibits a lognormal distribution, .so it is necessary to use the geometric mean error ratio (GMER) rather than an arithmetic error . GMER and GSDER values were calculated as follow :-

$$\varepsilon_i (K) = (K_p / K_m)$$

$$GMER = \exp [\, 1/n \, \Sigma \, Ln \, \varepsilon_i (K) \,]$$

$$GSDER = \exp [\, 1/n \, \{ \, \Sigma \, (Ln \, \varepsilon_i (K) – Ln \, GMEP)^2 \,]^{½}$$

Where :

n….. is number of observations

ε_i (K) is error ratio

K_m …. is the measured value of unsaturated hydraulic conductivity

K_p…… is the estimated value of unsaturated hydraulic conductivity at the same pressure head

The obtained values are presented in Table (2).

RESULTS AND DISCUSSION

The selected soil samples represent four texture classes with wide range of clay content, from 14.3 up to 44.1 %, while sand contents are ranged between 28.5 to 75.2% .While bulk densities of the selected soil samples are flocculated from 1.17 up to 1.56 g/cc, Table(1)

Table (2) contains the values of SDP and GSDER for both using of Rosetta and RETC program versus the measured water contents and hydraulic conductivity . The SDP values reflect the relative accuracy of the retention model in describing the measured data. Generally, as the value of SDP becomes smaller, this means higher precision in fitting using the retention model, van Genuchten *et al.* (1992). While the values of GSER reflect the relative accuracy of the conductivity model.

Table (2): The values of standard deviation of prediction (SDP)and geometric standard deviation of the error ratio (GSDER) of the estimated theta (h) and K(theta) functions using both Rosetta and RETC programs in the studied soil samples

Soil Sample No.	Rosetta		RETC	
	SDP	GSDER	SDP	GSDER
1	1.089	3.012	0.897	0.612
2	1.061	2.811	0.852	0.781
3	1.084	2.932	0.619	0.513
4	1.031	2.502	0.606	0.599
5	1.025	2.362	0.805	0.752

It is clearly noticed that the lowest values of both SDP and GSER are found in the case of soil samples number 4 and 5 which represent the coarsest texture in the studied soil samples and also means best fitting to the observed data . This may be due to the nature of used database which collected from the soils of California and Arizona, after develop it by Carsel [1992]

Data presented in the same Table and illustrated in Figs.(1&2) reveal also that RETC program is more efficient in estimating both theta (h) or K(theta) functions This finding may be due to that , RETC uses more input parameters than needed in Rosetta, especially the water content at some critical levels of pressure head . Also RETC program based on the prediction of poe size distribution from texture class and some mechanical composition of the soil gives the high accuracy in estimating the hydraulic properties ,Gimenez [2001].

Generally , the pedotransfer functions which are used in RETC program are more suitable under the conditions of soil samples under study, especially the coarse texture ones.

Fig1

Fig2

REFERENCES

Ahuja, L.R; W. J. Rawls and D. R. Nielsen (1999). Determining soil hydraulic properties and their variability from simpler measurements. Agric. and Drainage, 41 :1207-1233

Carsel, R. F. (1992). Development of an agricultural soils database for estimating soil water characteristics. p. 369-378. *In* M. Th. van Genuchten, F. J. Leij, and L. J. Lund (Ed.) *Proc. Int. Workshop on Indirect Methods for Estimating the Hydraulic Properties of Unsaturated Soils.* University of California, Riverside, CA.

Galal, M. E. (2000). Optimizing the input of “Rosetta” program to predict the hydraulic parameters of some soils in Egypt. J Agric. Sci. Mansoura Univ.,25 (8) :5515-5526

Gimenez, D. ; W.J. Rawls; Y. Pachepsky and J.P.C. Watt (2001) . Prediction of a pore distribution factor from soil textural and mechanical parameters. Soil Sci., 166 (2) :79-88.

Klute, A. (1986). Water retention: laboratory methods. p. 635-662. *In* A. Klute (Ed.) *Methods of Soil Analysis.* Part 1. 2nd ed. Agronomy Monogr. 9. ASA and SSSA, Madison, WI.

Klute, A. and C. Dirksen. (1986). Hydraulic conductivity and diffusivity: Laboratory methods. p. 687-734. *In* A. Klute (Ed.) *Methods of Soil Analysis.* Part 1. 2nd ed. Agronomy Monogr. 9. ASA and SSSA, Madison, WI.

Leij, F. J. and M. Th. Van Genuchten (1999). Characterization and measurement of the hydraulic properties of unsaturated porous media *In:* M.Th.van Genuchten, F.J. Leij and L. Wu (Eds.) ,Proc. Int. Workshop on the characterization and measurement of the hydraulic properties of unsaturated porous media .pp 1-12.University of California , Riverside , CA.

Rawls, W. J. ; T.J. Gish and D.L. Brankensiek (1991). Estimating soil water retention from soil physical properties and characteristics. *In* Stewart, B.A .*Advances in soil science* ,Springer-Verlag, New York, USA

Russo, D.; E. Bresler; U. Shani and J. C. Parker (1991). Analyses of infiltration events in relation to determining soil hydraulic properties by inverse methodology. *Water Resour Res.,* 27:1361-1373.

Schaap, M.G.; A. J. Koolen and F.J. Leij (1998). Using neural network to predict soil water retention and soil hydraulic conductivity . Soil and tillage Res., 47 (1-2) : 37-42 .

Tietje,O (1999). Pedotransfer functions with interdependency of hydraulic parameters . *In:* M.Th.van Genuchten, F.J. Leij and L. Wu (Eds.) ,Proc. Int. Workshop on the characterization and measurement of the hydraulic properties of unsaturated porous media .pp 1225-1237.University of California , Riverside , CA.

van Genuchten, M.Th. and F.J.Leij (1992) .On estimating the hydraulic properties of unsaturated soils . p 1-14 *In* M. Th. van Genuchten, F. J. Leij, and L. J. Lund (Ed.) *Proc. Int. Workshop on Indirect Methods for Estimating the Hydraulic Properties of Unsaturated Soils.* University of California, Riverside, CA.

تقييم استخدام بعض الدول التحويليه للتنبؤ بالخواص الهيدروليكيه فى بعض الأراضى بمصر.

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تستخدم الدوال التحويليه عادة فى برامج الحاسب الآلى لتقدير المعايير الهيدروليكيه للأراضى و برنامج روزيتا و RETC يستخدما بعض البيانات المتاحه من تحليلات الأراضى لتقدير و تحليل بيانات الخواص المائيه للتربه و تم استخدام هذه الدوال تم مقارنة النتائج المتحصل عليها من هذاالبرنامجان و النتائج المعمليه لخمس اراضى مصريه تختلف فيما بينها فى رتبة القوام و بعض الخواص الفيزيقيه الأخرى . وبالتحليل الأحصائى للنتائج المتحصل عليه وجد أن برنامج RETC أكثر قدرهو ملائمه على تمثيل بيانات كل من منحنى الخواص المائيه و دالة التوصيل الهيدروليكى كما ان بيانات التربه ذات القوام الخشن كانت أكثر تمثيلا من غيرها من ذوات القوام المتوسط و الثقيل.