Misr J. Ag. Eng. 19 (3) : 611 – 626

EVALUATING THE PREDICTION OF SOIL MOISTURE RETENTION VALUES FROM SOIL ROUTINE ANALYSIS

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ABSTRACT

The aim of this work is to evaluate and test the predicted soil moisture retention data, as well as retention curves from the particle-size distribution, organic matter content and soil bulk density. Linear multiple regression equations were derived from measured soil moisture contents at five suctions using soil samples having a wide range of soil texture, bulk density and organic matter content under the condition of Egypt. Twenty-six soil samples were taken to derive regression models from this predicting. Those models are compared with these available in the literature.

The results showed that water retention values, as well as retention curves predicted with these linear multiple regressions, closely approximated the measurements and output of van Genuchten's model. Significant effects for predicted values had been tested with the measuring data and output of van Genuchten's model. The similarity illustrates that data of the soil routine analysis can provide a better and closed estimation to the measured one.

Key words: Moisture retention - van Genuchten – Multiple regression models, prediction.

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INTRODUCTION

The soil moisture retention curve of a soil plays an important role in soil water management practices. Because of its relationship with soil pore-size distribution, soil moisture retention data are often used to estimate the soil water parameters. Arya and Pairs (1981) and Haverkamp and Porlange (1986) found relationships between the particle size distribution and the retention curves data in nonswelling soils. Rawls et al., (1989) used a database which included 2541 soil horizons covering a wide range of sand (mean 56 percent, range 0.1-99 percent) silt (mean 26 percent, range 0.1- 43 percent), clay (mean 18 percent, range 0.1—24 percent), organic matter (mean 0.66 percent, range 0.1-12.5 percent), and bulk density (mean 1.42 g/cm^3, range 1.0-1.95 g/cm^3) to develop three levels of linear regressions relating soil water content to each of the 12 matric potentials specified by Gupta and Larson (1979b). The first level included only the basic soil physical soil properties, i.e., percent silt, percent clay, organic matter, and soil bulk density. Vereecken et al., (1989)concluded that the moisture retention curves could be estimated at a reasonable level of accuracy from simple soil properties as the particle size distribution, dry bulk density and carbon content.

Tyler and Wheateraft (1989) presented estimation of soil water retention data from particle size distribution using an analysis correlating the fitting parameter "α" in the Arya and Paris (1981) model. Many attempt have been made to statistically correlate θ (h) function to soil texture and other soils data, including bulk density, organic matter content, clay mineralogy and paramerters of soil structure. (Kravchemko and Zhang 1999).

Arya et al. (1999) improved their model to predict soil moisture retention curre from particle size distribution. Gimenez et al., (2001) predicted a pore distribution factor to estimate water retention curve from soil textural and mechanical parameters. While in Egypt, Galal (2000) used " rosetta" as a software package to estimate θ (h) function of some soils. He also optimized the input parameters to predict in sandy soils

The objective of this work is, to evaluate output moisture retention values resulted from multiple regression equations in correlation with water content at different soil matric suctions and soil routine analysis using output of van Genuchten's model, (θ (h) function, 1980).

MATERIALS AND METHODS

Soil samples used in this study were collected from different location, which cover the wide range of soil texture in Egypt. Physical and chemical properties were determined according to the standard methods, which described by Klute (1986) and Page (1982). (Table 1). The volumetric soil moisture values of the twenty-six soil samples ware determined at different soil matric suctions according to Richards's (1954) (Table 2).

The predicted data using fine sand, coarse sand, silt and clay fraction, soil bulk density and organic matter percentage were saturation point, 100, 330 and 15000 mbar. These data had been verificated with both the output of van Genuchten's model and the measured data..

Model Description

For predicting soil water content at some fixed matric potentials from soil texture components, bulk density and organic matter were presented different methods to catch it, based on linear multiple regression with experimental data for 26 groups of soil covered a wide range of particle size distribution. In the first step: we choice an important points on the pF curves at zero, 0.1, 8.3 and 15 bars, to be individually function of soil texture components (X1, X2, X3, and X4) and the another dependent variables (Y1, Y3, Y4, Y10). The program of stepwise variable selection was used to obtain the more efficient independent variable for each dependant variable (Y1, Y3, Y4, Y10).

Table (1): Some physical and chemical characteristics of the studied soil samples.

Sample No	Sand % Coarse	Sand % Fine	Sand %	Silt %	Clay %	Bulk density (Bd) g/cm3	Organic matter (O.M.) %
1	85.49	6.21	91.7	4.23	4.07	1.55	0.22
2	79.84	7.16	87	6.61	6.39	1.57	0.27
3	64.48	9.95	74.43	17.24	8.33	1.56	0.48
4	71.71	8.33	80.04	11.02	8.47	1.61	0.48
5	64.39	10.15	74.54	16.19	9.27	1.56	0.36
6	41.44	16.37	57.81	14.64	10.43	1.59	0.43
7	50.59	18.92	69.51	14.37	16.12	1.49	0.49
8	40.66	34.44	75.1	8.06	16.82	1.62	0.41
9	4.53	57.97	62.5	20.27	17.23	1.41	0.62
10	40.08	36.46	76.54	9.21	14.25	1.59	0.59
11	62.1	30.38	92.48	10.31	21.41	1.53	0.39
12	9.21	51.98	61.19	10.1	28.71	1.36	1.19
13	3.24	29.31	32.55	33.25	34.2	1.32	1.62
14	2.44	29.82	32.26	32.45	35.29	1.35	1.13
15	3.45	48.03	51.48	11.55	36.96	1.3	1.11
16	3.24	19.39	22.63	30.85	46.47	1.21	1.25
17	19.6	16.53	36.13	14.56	50.69	1.17	1.04
18	17.04	14.57	31.61	17.66	50.73	1.16	1.11
19	1.23	23.19	24.42	24.72	50.95	1.16	1.2
20	5.12	13.4	18.52	25.16	56.32	1.16	1.4
21	1.63	22.77	24.4	21.82	53.78	1.19	1.22
22	2.7	13.45	16.15	23.85	60	1.11	1.9
23	4.85	10.65	15.5	25.35	59.15	1.12	1.82
24	0.67	9.58	10.25	24.72	65.03	1.1	1.01
25	3.62	11.07	14.69	25.2	60.11	1.18	1.65
26	3.09	10.86	13.95	21.43	64.62	1.03	1.84

Table (2): Soil moisture retention data of the studied soil samples

Sample No	0bar Y1	0.06bar Y2	0.1bar Y3	0.33 bar Y4	1bar Y5	2bar Y6	3bar Y7	10bar Y9	15bar Y10
1	42.59	17.16	14.94	11.64	10.52	8.47	7.35	6.73	6.56
2	42.28	20.64	18.02	15.74	12.34	10.10	9.80	7.33	7.05
3	40.46	36.46	18.56	13.98	12.65	12.04	10.94	9.69	8.33
4	39.25	33.25	20.17	16.45	14.17	13.43	11.4	8.84	8.23
5	39.77	35.77	23.28	18.39	15.94	15.48	14.32	11.58	9.38
6	36.85	35.85	34.92	32.58	26.11	28.84	22.8	15.77	14.2
7	43.77	40.77	37.98	33.06	26.27	25.08	20.86	15.82	14.11
8	37.45	35.45	32.76	32.25	28.11	25.29	20.82	15.99	13.41
9	47.58	41.74	37.86	31.53	24.96	23.03	10.61	11.27	10.74
10	40.89	35.47	34.58	30.50	24.76	21.66	18.36	13.66	9.84
11	42.48	40.48	38.71	37.03	30.49	27.17	22.84	17.70	16.81
12	49.06	42.64	41.72	40.28	32.48	28.32	23.8	14.67	12.95
13	50.75	47.68	45.47	42.85	33.75	29.4	25.58	16.16	14.73
14	46.64	44.64	43.94	41.65	37.97	34.04	31.40	26.43	24.71
15	52.03	46.94	45.36	41.72	33.63	30.68	25.49	16.85	14.73
16	54.85	51.49	49.05	44.78	36.77	35.08	29.09	22.19	19.63
17	56.83	55.27	49.18	46.72	38.86	34.57	31.16	21.34	19.49
18	56.72	55.19	53.67	52.04	43.98	42.05	35.86	27.29	24.67
19	55.56	50.49	46.45	44.42	38.70	36.96	32.18	25.57	23.32
20	55.72	52.97	50.23	46.60	38.74	37.09	35.30	26.01	22.79
21	54.58	49.12	47.47	44.32	40.42	38.62	33.63	25.50	24.36
22	58.74	55.70	52.95	41.57	40.05	36.52	31.81	22.52	20.18
23	58.67	55.76	54.72	47.05	39.14	37.33	33.59	24.74	22.52
24	58.65	54.07	51.51	47.42	42.20	39.39	35.92	27.91	26.05
25	56.13	53.96	49.80	48.29	44.06	40.13	35.74	31.08	28.13
26	61.71	60.79	58.27	47.20	39.26	37.45	23.7	24.82	22.60

RESULTS AND DISCUSSION

Data in Table (3) and Figs. (1 – 2) reveal the predicted soil moisture values at saturation points (θ_s), 0.1 ($\theta_{0.1}$), 0.33 ($\theta_{0.33}$) and 15 bar (θ_{15}) using the multiple regression equations, which contain the soil routine analysis of the soils under investigation.

Table (3): The predicted soil moisture contents using multiple regression equations using the soil data of routine analysis

Sample No	θs	$\theta_{0.1bar}$	$\theta_{0.33bar}$	$\theta_{15\,bar}$
1	42.54	18.67	14.03	5.51
2	41.29	20.79	16.85	7.56
3	40.92	23.64	19.73	9.78
4	39.13	23.36	19.88	9.59
5	40.80	24.07	20.77	10.69
6	38.94	27.65	25.36	11.80
7	43.78	29.54	26.20	11.92
8	38.11	34.28	33.86	14.61
9	46.83	39.02	36.27	12.03
10	39.78	33.10	31.17	11.84
11	42.54	33.72	32.19	15.07
12	49.83	43.78	39.28	11.83
13	49.89	43.94	38.18	16.54
14	47.94	44.55	41.42	20.23
15	51.80	47.39	43.6	15.68
16	53.89	47.54	43.21	21.98
17	56.65	47.34	43.02	20.70
18	56.88	47.24	42.58	20.82
19	56.32	50.06	45.84	22.23
20	56.16	51.33	46.86	24.09
21	55.00	51.79	48.32	23.73
22	58.87	53.40	46.75	22.05
23	58.27	52.40	46.01	22.52
24	57.90	54.82	52.37	29.38
25	55.25	53.55	48.98	25.32
26	62.37	54.55	47.49	22.46

The multiple regression equation which uses to predict the soil moisture content can be expressed as follow:-

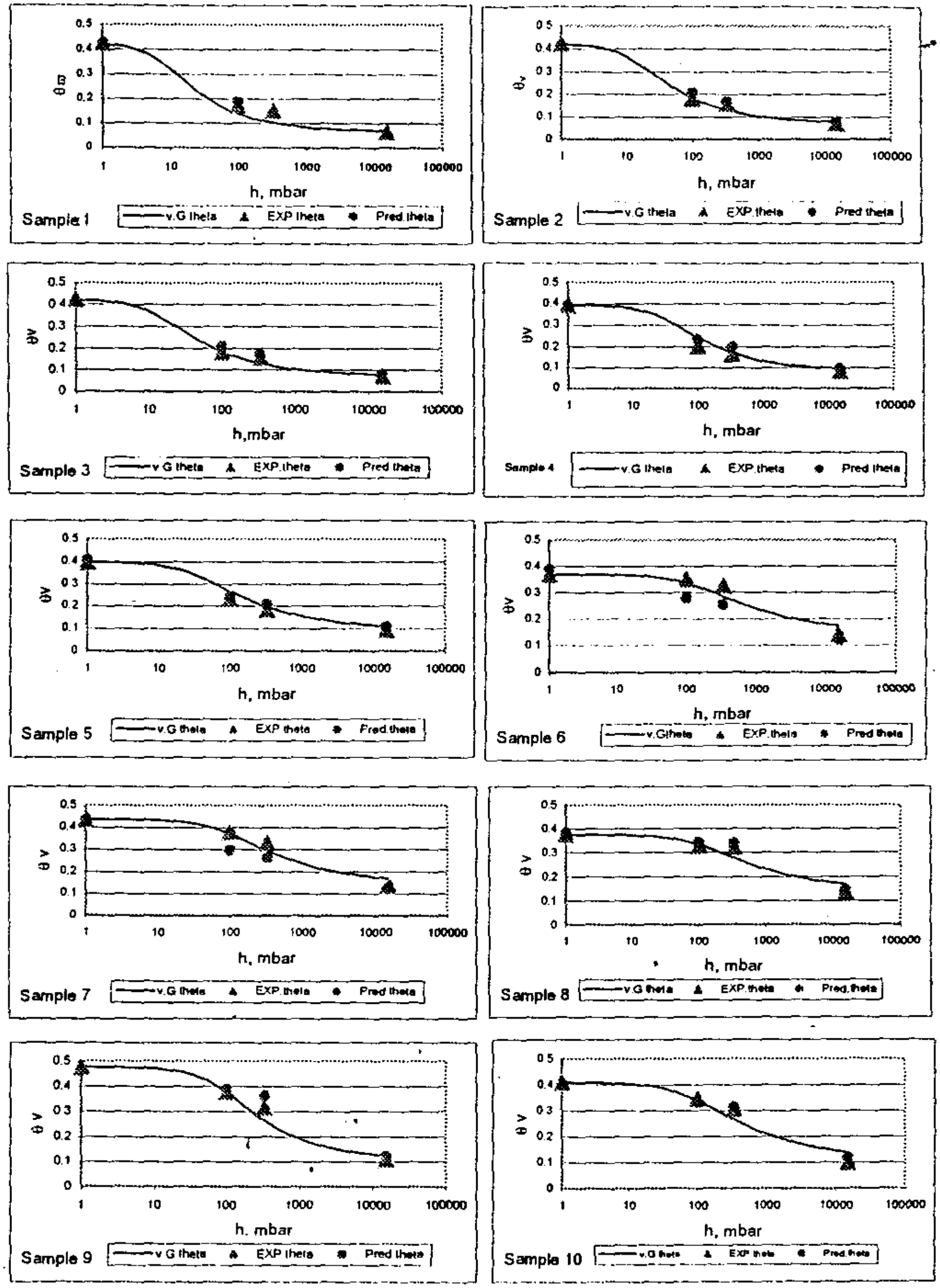
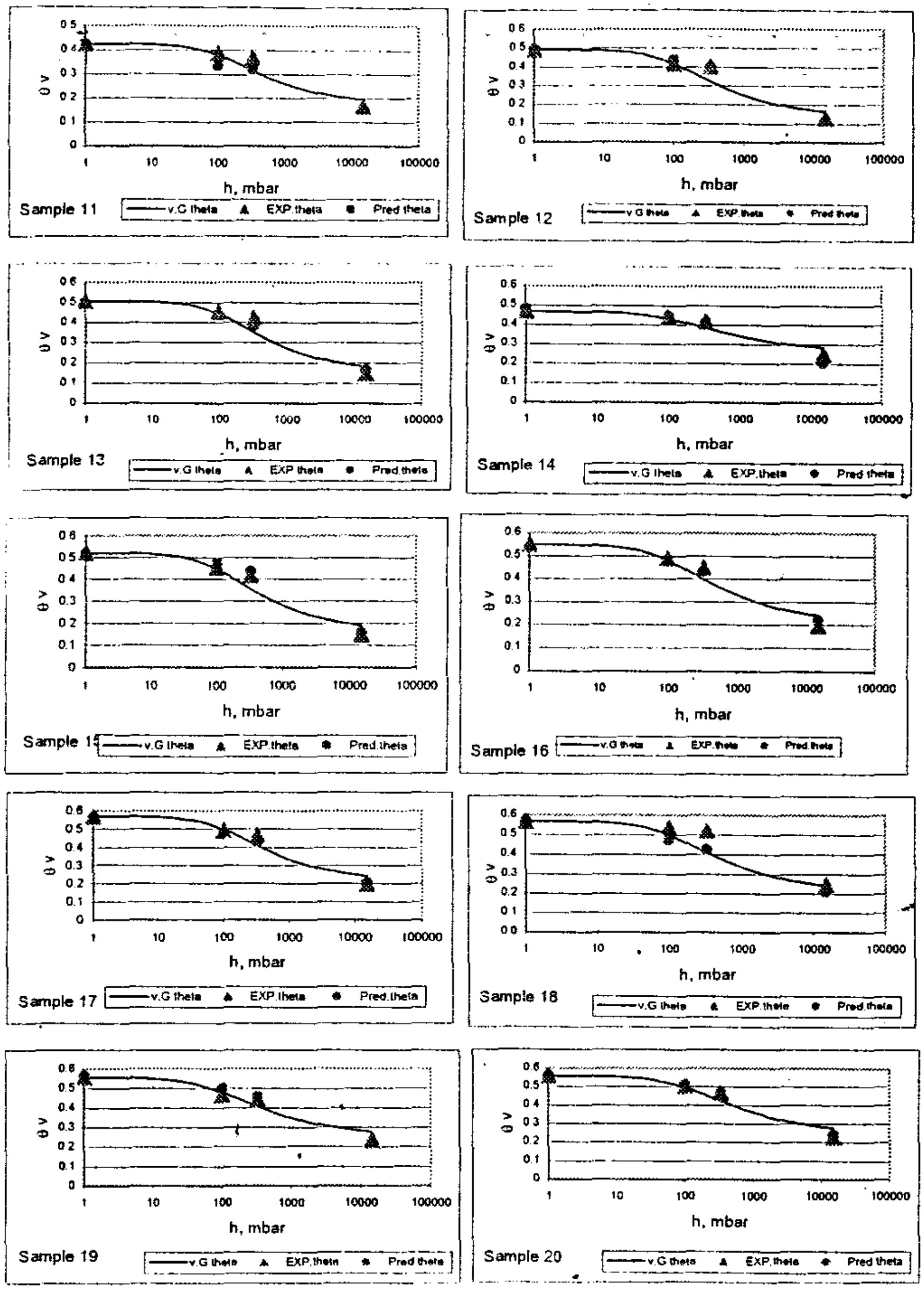
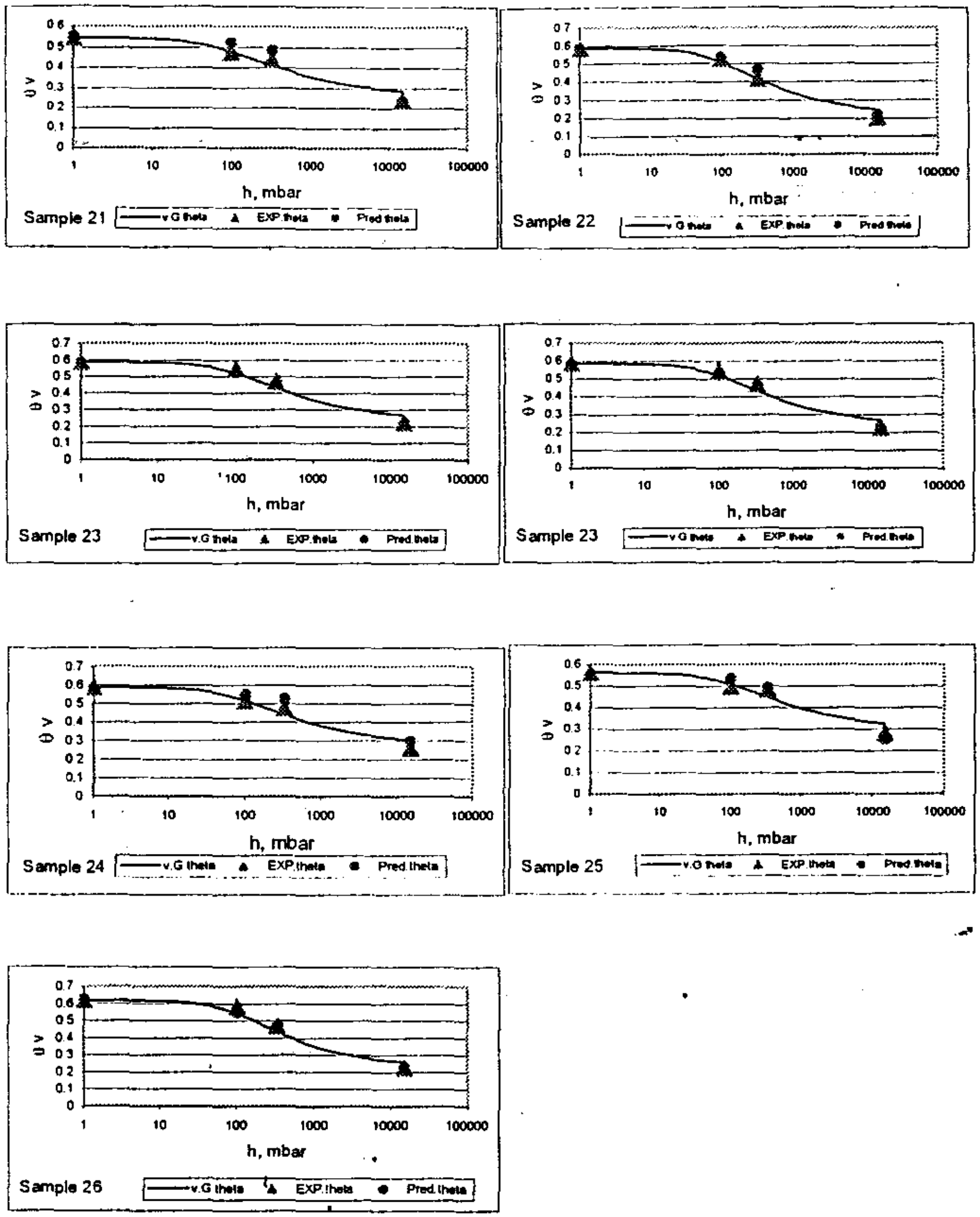


Fig (1) : The predicted soil moisture contents (pred. θ), the measured ones (Exp. θ) and output of van Genuchten's model (v.G. θ) at saturation point, 100, 330, 15000 mbar using soil for routine analysis of the studied soil samples


Sample 11
Sample 12
Sample 13
Sample 14
Sample 15
Sample 16
Sample 17
Sample 18
Sample 19
Sample 20
θ v
h, mbar
1
10
100
1000
10000
100000
v.G theta
EXP.theta
Pred.theta

cont. Fig.(1)


Sample 21
Sample 22
Sample 23
Sample 23
Sample 24
Sample 25
Sample 26
θ v
h, mbar
1
10
100
1000
10000
100000
v.G theta
EXP.theta
Pred.theta

cont. Fig.(1)

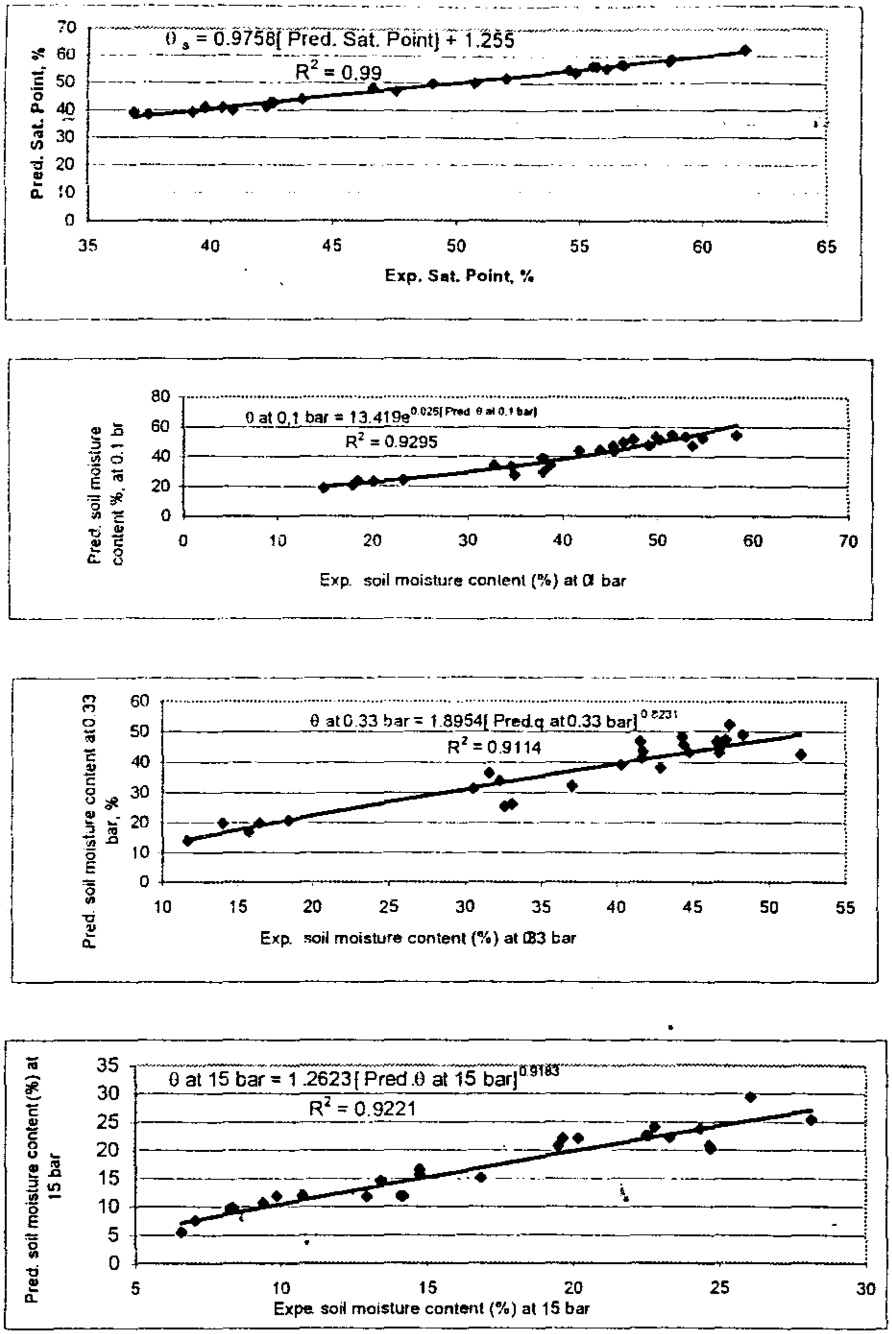


Fig. 2. The relationships between differemnt experimental soil moisture content and predicted one from soil routine analysis

$Y= a_0 + a_1 X_1+ a_2 X_2 + a_3 X_3 + a_4 X_4 + a_5 X_5 + a_6 X_6$

Where:

X_1 is fine sand %, X_2 is the coarse sand %, X_3 is silt content %, and X4 is the clay content %, X_5 is the soil bulk density and X_6 is the organic matter content % and

a_0 , a_1 , a_2 , a_3 , a_4 , a_5 and a_6 are the regression coefficients of X_1, X_2 X_3 , X_4 , X_5 and X_6 respectively.

From the measured data of (θ, h) function, van Genuchten's parameters had been calculated for the twenty six soil samples according to van Genuchten (1980). Fig. (1) presents the predicted data which obtained from the surrogate data and both the measured one and outputs of van Genuchten's model. These figures illustrate also, high correspondence between the three methods under study (measured, predicted data (from soil routine analysis) and outputs data of van Genuchten's model.

The output of the multiple regression equations (predicted data) had been correlated with the experimental data as shown in fig. (2). These correlations were represented in the following equations:-

$\theta_s = 0.9758$ (Pred. Sat. point) + 1.255 $\qquad R^2 = 0.9900$

$\theta_{0.1\ bar} = 13.419$ EXP 0.026 (Pred. $\theta_{0.1\ bar}$), $\qquad R^2 = 0.9295$

$\theta_{0.33\ bar} = 1.8954\ (\text{Pred. } \theta_{0.33\ bar})^{0.8231}$, $\qquad R^2 = 0.9114$

$\theta_{15bar} = 1.2623\ (\text{Pred. } \theta_{15bar})^{0.9183}$, $\qquad R^2 = 0.9221$

Data in Table (4) show the regression coefficients of the multiple regression equations and coefficient determination, which were in range from 0.8883 to 0.9922.

Table (4): The regression coefficients of the multiple regression equations saturation points (θs, X1) 0.10. (X2) 33(X3) and 15 bars(X4)

Soil water Parameter	a_0	a_1	a_2	a_3	a_4	a_5	a_6	Reg. Coeff. R^2
θ_s (X1)	111.0694	0.0338	0.0286	-0.0521	-0.0399	-46.0987	1.1284	0.9923
$\theta_{0.1\ bar}$(X2)	4.9544	-0.0698	0.1608	0.0190	0.5466	10.4467	0.8564	0.9113
$\theta_{0.33\ bar}$(X3)	-2.1396	-0.0923	0.1860	0.0465	0.7086	26.1414	-3.1588	0.8883
$\theta_{15\ bar}$(X4)0	-30.8027	-0.0215	-0.0034	0.2056	0.5331	23.4077	-5.2189	0.9075

Significant relationships had been detected using in each pairs of the three tested methods have been tested. These tests were performed between output data of van Genuchten's model and the predicted data from soil routine analysis, as well as, between the predicted data from soil routine analysis and the measured data as shown in Table (5). Results showed that there are no significant differences at (P0.05) between the three methods, except between the measured data and the predicted data from the soil routine analysis of the fifth and eight-soil sample. It is a good approach using the data of soil routine analysis and van Genuchten's model for predicting the soil moisture retention curve.

Table (5) reveals a significant difference between the predicted data and the measured ones in the soil samples number 5 and 8, which indicate that the prediction equations don't represent the water release behaviour in these soil samples. While van Genuchen model is more suitable in both soil samples. This finding may be due to the up-normal pore size distribution in these soil samples which appear also on the highest values of bulk density, especially in No. 8, Table (1). So, the suggested equations can be used to predict soil moisture retention data of normal soil using the data of soil routine analysis.

Table (5): Calculated and tabulated T–values* of the Relationship among the predicted data from soil routine analysis and both of output data of van Genuchten's model and the measured data.

Sample No.	Pred. Data &v.G data			Pred. &measured data		
	Cal. t	Tab. T (0.05)	Sig. test	Cal. t	Tab. T (0.05)	Sig. test
1	1.3409	3.18	N.S	0.9642	3.18	N.S
2	1.2116	3.18	N.S	1.0932	3.18	N.S
3	1.7024	3.18	N.S	0.0661	3.18	N.S
4	0.5441	3.18	N.S	2.3542	3.18	N.S
5	0.2799	3.18	N.S	3.9383	3.18	S
6	1.6897	3.18	N.S	1.6499	3.18	N.S
7	2.4763	3.18	N.S	2.2152	3.18	N.S
8	0.8385	3.18	N.S	5.8108	3.18	S
9	1.0214	3.18	N.S	1.4175	3.18	N.S
10	0.1411	3.18	N.S	0.7900	3.18	N.S
11	1.4610	3.18	N.S	2.3342	3.18	N.S
12	0.5439	3.18	N.S	0.2330	3.18	N.S
13	0.0205	3.18	N.S	1.0539	3.18	N.S
14	0.2108	3.18	N.S	0.5399	3.18	N.S
15	0.7959	3.18	N.S	2.2237	3.18	N.S
16	0.0125	3.18	N.S	0.4522	3.18	N,S
17	0.8458	3.18	N,S	0.3738	3.18	N.S
18	0.9179	3.18	N.S	2.4019	3.18	N.S
19	0.3313	3.18	N.S	1.2113	3.18	N.S
20	0.4827	3.18	N.S	3.0254	3.18	N.S
21	0.6537	3.18	N.S	1.6202	3.18	N.S
22	0.8008	3.18	N.S	.1.6522	3.18	N.S
23	0.2525	3.18	N.S	1.8525	3.18	N.S
24	1.1407	3.18	N.S	2.2293	3.18	N.S
25	0.0983	3.18	N.S	0.1315	3.18	N.S
26	0.2536	3.18	N.S	0.7197	3.18	N.S

* According to Bisher and El-Robi (1979).

From the above mentioned results, it can be concluded that, the multiple regression model is a suitable procedure by which soil moisture retention data can be predicted from easily determined soil properties e.g. particle size distribution, organic matter and soil bulk density.

REFERENCES

Arya, L.M. and F. J. Paris 1981. A physioempirical model to predict the soil moisture characteristics from particle size distribution and bulk density data. Soil Sci-Soc. Am. J., 45: 1023-1030.

Arya, L.M; F.J. Feij; M. th. van Genuchten and P.J. Shouse. 1999. Sealing parameter to predict the soil water characteristics from particle size distribution data. Soil Sci-Soc. Am. J., 63: 510-519.

Bisher, M. A. and M. El-Robi, (1979). Introduction to statistical analysis and designs of experiments. Crop Dept. of Agric., Alex. Univ. Egypt.

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

Gimenez, D, W.J. Rawps, 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.

Gupta, S.C., and W.E. Larson. 1979. Estimation soil water retention characteristics from particle size distribution, organic matter percent, and bulk density. Water Resource Res. 15: 1633-1635.

Haverkamp. R. and J. Y. Parlonge 1986. Predicting the water retention cure from particle size distribution: Sandy Soils without organic matter. Soil Sci. 142: 325-339.

Klute, A. (ed.) 1986 "Methods of Soil analysis" part 12 2nd . ed., Agronomy Monogr. θ ASA and SSS A., Madison, WI. Page. D, (ed) (1982) Madison, WI. Part 1 D, (ed) (1982) Madison, WI.

Kravchenko, A. and R Zhang 1999.Estimating the soil water retention from particle size distribution: A fractal approach. Soil Sci., 163 (3): 171-179.

Page, D. (ed), 1982. "Methods of Soil analysis" part 12 2nd . ed., Agronomy Monogr. θ ASA and SSS A., Madison, WI. Page. D, (ed) (1982) Madison, WI. Part 2 D, (ed) (1982) Madison, WI.

Rawls, W.J., L.R. Ahyja and D.L. Brakensick 1989. Estimating soil hydraulic properties from soils data In proc pp. 329-340.

Richards, L. A. (ed.) (1954). Diagnosis and improvement of Saline and Alkali soils, U. S. Dept. Agric. Hand book 60, U.S. Grovt. Print. Office, Washington, D. C., PP. 239-279.

Tyler, S.W. and S.W. Wheatcraft (1989), Fractal aspect of soil porosity. In proceeding of the internal workshop on indirect ,methods for estimating the hydraulic proper es of un. Saturated soils. Edited by M. Th. van Genuehtem, F. G. Lcij. And L. J Lund. October 11-13, pp. 53-63 reverside, California U. S. A.

van Genuchten, M. Th. 1980. A closed-from equation for predicting hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am. J. 44: 892-897.

Vereecken., J. Maes, J. Feyen and P. Darius (1989). Estimating the soil moisture characters from texture, bulk density and carbon. Soil Sci, Vol. 148, No. 6: 289-403.

تقييم التنبؤ بقيم منحني الشد الرطوبي من بيانات التحليلات الروتينية للتربة

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** القسم الزراعي لبحوث الأراضي والمياه ، مركز البحوث النووية ، هيئة الطاقة الذرية ، القاهرة

تهدف الدراسة إلي تقييم واختبار التنبؤ ببعض القيم الخاصة بمنحني الشد الرطوبي للتربة باستعمال بعض النتائج الخاصة بالتحليلات الروتينية للأراضي مثل التوزيع الحجمي للحبيبات و النسبة المئوية للمادة العضوية والكثافة الظاهرية. تم أستعمال معادلات الإنحدار الخطي المتعدد للتنبؤ بخمسة قيم علي منحنيات للشد للرطوبي لعدد 26 عينة تربة تغطي مدي واسع من قوام الأراضي في مصر. تم مقارنة النتائج المتحصل عليها مع أخرى مقدرة عملياً وأخرى مستنتجة من نموذج "فان جنختين".

أثبت التحليل الإحصائي عدم وجود فروق معنوية بين الثلاث طرق وهذا يعني أن التنبؤ بقيم منحني الخواص المائية باستعمال هذه المعادلات ممكناً.