

Estimating Soil Hydraulic Parameters of Different Textured Soils in Semiarid Duhok Conditions - Iraqi-Kurdistan Region by using RETC Program

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Abstract:

RETC is a computer program that can be used to estimate soil hydraulic functions by easily determining soil properties. Using van Genuchten model in the RETC program gave high accuracy for estimating the hydraulic functions e.g., $\theta(h)$, $k(\theta)$ and $D(h)$, also the mentioned program is considered a good tool for potential optimization of water management especially though calculating irrigation water after consuming 60% of the available water in root zone restoring technique.

In the current study surface, soil samples (0 – 30 cm) from eight locations with a wide range in texture were collected RETC code is used to refine the water retention curve through minimizing the residual error according to van Genuchten – Mualem approach (1980). the obtained results indicated that the sum square SSQ (residual error) values becomes smaller after refining for eight studied soils which were (Avkendal, Berderash, Chemrash, Kanisark, Keperto, Khanik, Qerwola and Terbsbia), which their SSQ values before RETC refining were (0.0470264, 0.0680298, 0.0240080, 0.0190478, 0.0396200, 0.0166960, 0.094400 and 0.0199100) whereas these values decrease as fallowing (0.000333400, 0.000942618, 0.0000997008, 0.000167315, 0.002448800, 0.000243300, 0.00080000, and 0.000099917) with ha high coefficient of determination (R^2) greater than (0.964) and the maximum refining was (0.000099917) at Chemrash silty clay loam soil with 0.9986 (R^2), whereas the minimum value was(0.002448800) at Keperto loamy soil with 0.9720(R^2) and this means higher precision in fitting using the retention model.

RETC code was used to analyze soil water retention curve and hydraulic conductivity functions which are the key parameters in any quantitative description of water flow into the unsaturated zone of soils, van Genuchten et. al. (1991)

Keywords: water properties of soil, soil, RETC program, water retention curve

Introduction:

Arable soils in Duhok governorate, Iraqi Kurdistan Region, which mainly depends on rainfalls. Has different classes of texture. So, determination of the variations in properties related to soil moisture content of Duhok region soils is an imperative assignment to realize favorable conditions for cultivation.

Duhok region represents a promising and strategic region for urban development. And have major potency for cultivating, a summer sanatorium.

A large portion of this area would depend on rainfalls and suffer from water erosion eventually, for this reason this improvement properties of this area for several uses is a great possibility, and, it could observe different textural classes such as loamy sand, sandy loam, clay loam, clay and silty clay loam (19).

Soil is a non-renewable natural resource that is essential to life. Water movement, water quality, land use, and vegetation productivity all have relationships with soil (4).

The relation between soil moisture content and matric potential considers the most important relationship between soil and water the soil matric potential increase with depleting of water by drainage evaporation or absorption by roots and decreases at the addition of water.

And because the classical methods for obtaining soil water retention curve for soil need more time, large potential, and consider high costs, therefore many researchers try to study the relationships between soil hydraulic properties and many

physical of soil such as texture, structure, and bulk density and sometimes the organic carbon of soil and the results reached to the mathematical and empirical models by using statistical analysis for prediction the water retention.

The process of water movement is very changing dramatically over time and space. Infiltration is defined as the initial process of water motion into the pore space through the soil surface and is of great importance to the assessment of, agricultural management, and irrigation projects

Borek and Bogdal(9) revealed that the predicted values of the water content of the RETC and Rosetta for each soil layer are close to the measured values ($R^2 = 0.825-0.995$)

Knowledge of the soil hydraulic properties is indispensable to solve many soil and water management problems related to agriculture, ecology, and environmental issues. The most important hydraulic properties of soils are the soil water retention curve (SWRC) and soil water permeability (29 and 30).

The role of water retention in soil has been analyzed and reviewed in many scientific studies (25 and 35). By applying soil water models from measured merits, by various models with explained large reliability for the models e.g., Moisture content, unsaturated hydraulic conductivity, and Diffusivity,

The ability of simulation models to accurately predict water flow and solute transport in unsaturated soils usually depends on the accuracy of the parametric models used to describe the water retention

curve θ (h) and unsaturated hydraulic conductivity $K(\theta)$ (23)

The divergences in texture mentioned soil need different levels management of water, to obtain large adequacy of crop productivity and to reach the best benefit for water use.

Van Genuchten *et al.* (32), reported that soil water properties have a great role in any quantitative specifications of water flow through the unsaturated soil layers,

The objective of the current study determination soil water from measured soil merits by applying for a software program

The aims of this study are:

- 1- To evaluate the role of RETC code in refining water retention curve through

- 2- minimizing the residual error according to Van Genuchten – Mualem approach (31).

- 3- To calculate the optimum amount of water that could be applied at irrigation to avoid over-irrigation from aside and save irrigation water.

Materials and Methods:

Sampling and measurement

In the Duhok region, soil samples with a depth of 0-30 cm were chosen to represent eight textural classifications. Table (1) shows some of the soil hydraulic and physical parameters that were measured.

Table (1) Physical characteristics of the investigated soils.

Location of soil	Gram separate kg^{-1} soil			TEXT. Class	BD Mg m^{-3}	sat. HC mm h^{-1}	Vol. Moisture Content, $\text{cm}^3 \text{cm}^{-3}$			
	Sand	Silt	Clay				W.P	F.C	Sat.	AW cm
Avkendal	214.2	325.0	460.6	C	1.32	2.16	27.6	40.7	50.3	0.13
Berderash	64.4	312.5	623.1	C	1.19	2.49	34.5	44.9	55.3	0.10
Chemrash	569.0	200.0	231.0	SCL	1.48	13.67	15.4	26.3	44.0	0.11
Kanisark	314.4	289.5	398.1	CL	1.38	2.89	24	37.3	47.8	0.13
Keperto	329.4	410	260.6	L	1.40	9.07	16.9	31.9	47.0	0.15
Khanik	81.9	516.4	401.7	SIC	1.27	4.92	24.1	39.7	52.1	0.16
Qerwola	789.4	140	70.6	LS	1.45	79.03	6.3	13.5	45.5	0.07
Terbsbia	175.5	321.6	302.9	SICL	1.34	6.88	19.0	35.8	49.4	0.17

The collected soil samples were used to measure the percentages of water content under range levels tensions from (0.1 to 15 bar and revealed on volume bases, Part of these samples were used for routine physical analysis by using hydrometer for particle size distribution as mentioned in

Gee and Bauder (16), bulk density by core sample by using metal cylinder opened form two end its diameter 4.8cm and height is 6cm as in Blake and Hartage (8). And saturated hydraulic conductivity was measured by using a constant-head method as described in Black *et al.*(6).

RETC (Retention Curve Program)

RETC is a computer program that may be used to analyze the soil water retention and hydraulic conductivity functions of unsaturated soils. These hydraulic properties are key parameters in any quantitative description of water flow into and through the unsaturated zone of soils. The program uses the parametric models of Brooks-Corey and van Genuchten to represent the soil water retention curve, and the theoretical pore-size distribution models of Mualem and Burdine to predict the unsaturated hydraulic conductivity function from observed soil water retention data. The program comes with a manual that gives a detailed discussion of the different analytical expressions used for quantifying the soil water retention and hydraulic conductivity functions.

A brief review is also given of the nonlinear least-squares parameter optimization method used for estimating the unknown coefficients in the hydraulic models. The RETC program may be used to predict the hydraulic conductivity from observed soil water retention data assuming that one observed conductivity value (not necessarily at saturation) is available.

The program also permits one to fit analytical functions simultaneously to observed water retention and hydraulic conductivity data. Several examples are presented to illustrate a variety of program options.

The program comes with a user manual giving detailed information about the computer program along with instructions for data input preparation and

listings of sample input and output files. A listing of the source code is also provided.

The RETC Code for Quantifying the Hydraulic Functions of Unsaturated Soils, the program comes with a user manual giving detailed information about the computer program along with instructions for data input preparation and listings of sample input and output files. A listing of the source code is also provided.

RETC Main Window - Input data Output - Soil Hydraulic Properties RETC is a computer program which may be used to analyze the soil water retention and hydraulic conductivity functions of unsaturated soils. These hydraulic properties are key parameters in any quantitative description of water flow into and through the unsaturated zone of soils. The program uses the parametric models of Retention Curve (RETC) Computer Program | US Brooks and Corey (10), Van Genuchten (27), the lognormal distribution model of Kosugi (22), and the dual-permeability model of Durner (12)

The RETC Code for Quantifying the Hydraulic Functions of Unsaturated Soils, Version 1.0. EPA Report 600/2-91/065, U.S. Salinity Laboratory, USDA, ARS, Riverside, California. Version 1.0. EPA Report 600/2-91/065, U.S. Salinity Laboratory, USDA-ARS, Riverside, California. Intel Pentium or higher processor, 16 Mb RAM, hard disk with at least 20 Mb free disk space, VGA graphics (High Color recommended), MS Windows 95, 98, NT, 2000, XP See all >>RETC download page Retention Curve (RETC) Computer Program | US (EPA<https://www.epa.gov/water-research/retention-curve>)(Dec 14, 2021)

Is a computer program that may be used to analyze the soil water retention and hydraulic conductivity functions of unsaturated soils, especially to predict the hydraulic conductivity from observed soil water retention data assuming that one observed conductivity value (not necessarily at saturation) is available (Van Genuchten et al.(31); Hollenbeck *et al.*(18).

(Ag Data Commons
<https://data.nal.usda.gov> › dataset › etc.
Jan 12, 2022) Steps of obtaining RETC output

Van Genuchten parameters were found by applying the “Rosetta program”, which was used to obtain the closed expressions of van Genuchten parameters from the values of particle size distribution, soil bulk density, and soil water content on a volume basis at 33 kpa and 1500 kpa, Schaap, *et al*(27).

Output data of mentioned program, were used in RETC program as input data besides the determined values of soil water retention “Rosetta program”.

Output file of RETC, and the parameters' values are cleared in Table (2). And Figs (1, 2, and 3).

Results and Discussion:

Table (2) represents the values of van Genuchten parameters θ_r , θ_s , α , n and m as related to θ_r ranged between minimum of 0.057 for Qerwola (LS) and maximum of 0.1for Avkandal © ; θ_s from 0.34 for Qerwola (LS) to 0.43 for Berderash (C), the explanation of this behaviour is that high content of clay fraction, high percent of capillary pore spaces and increase soil water retention capacity (Arya et al 1999); α

parameter ranged from minimum value of 0.0005 for Qerwola (LS) to maximum value of 0.124 for Berderash(C)soil ,whereas the value of constant n fall between 1.08 for Avkandal (C) to 2.28 for Qerwola (LS) and the parameter m value was 0.1170 as a minimum value for Berderash (C) to 0.5614 for Qerwola(LS) and these results in agreement with findings of (van Genuchten, 1980; Vogel et al,2001; Schaap and van Genuchten,2006),they indicated to reducing value of n constant by increasing clay content of soil that also the parameter (m) was appeared same trend as n parameter , because of the parameter m related directly with parameter n (m), and these findings in agreement with AL-Wazan(2), and AL-Wazan(3) and Hassan(17).

Also, the same Table revealed the sum squares values versus the measured values before and after refining. Generally, the SSQ (residual error) values become smaller after refining which means higher precision in fitting using the retention model.

The values of van Genuchten parameters were refined by applying RETC program in order to reduce the values of summation squares (SSQ).and finally to achieve optimum water quantities of VG parameters the results of Table (2) indicated that the big change were found in Terbsbia (silty clay loam soil) where SSQ reduced from (0.0199100 to 0.000099970). And Chemrash (sandy clay loam soil) where SSQ decreased from (0.0240080 to 0.000097008) While the small reduction is noticed in Qerwola (Loamy Sand soil) where, SSQ decreased from (0.094400 to 0.00580). Water retention characteristics are fundamental input parameters in any modeling study on water flow (35).

Table (2) van Genuchten parameters values of the investigated soils.

Location of soil	Textura l Class	van Genuchten Parameters					SSQ before RETC refining	SSQ after RETC refining	R2 Det. Coe.
Avkenda l	C	0.10 0	0.4 1	0.089 0	1.0 8	0.124 3	0.0470264	0.0003334	0.9964
Berderas h	C	0.06 5	0.4 3	0.124 0	1.0 9	0.117 0	0.0680298	0.0009426	0.9746
Chemras h	SCL	0.08 9	0.3 8	0.010 0	1.2 3	0.186 9	0.0240080	0.0000970	0.9983
Kanisark	CL	0.09 5	0.4 2	0.001 9	1.1 1	0.236 6	0.0019478	0.0001673	0.9883
Keperto	L	0.07 8	0.3 7	0.036 0	1.5 6	0.358 9	0.0396200	0.0024488	0.9720
Khanik	SIC	0.06 8	0.3 8	0.008 0	1.4 9	0.316 6	0.0166900	0.0002433	0.9944
Qerwola	LS	0.05 7	0.3 4	0.000 5	2.2 8	0.561 4	0.0944000	0.0058000	0.9645
Terbsbia	SICL	0.07 0	0.3 6	0.075 0	1.0 9	0.082 5	0.0199100	0.0000999	0.9983

The obtained data after refining are could be used to calculate the amount of needed irrigation water for each soil and also to get refining water retention curves of the studied soil, the results of the current study is in agreement with the finding of Galal(14) and Gee and Bauder(16).

Also, Table (2) indicated that the coefficients of determination (R^2) are higher than 0.99, for soils of Avkenda clay, Chemrash sandy clay loam, Khanik silty clay, and Terbsbia silty clay loam soils and statistical index of coefficient (R^2) for mentioned soils were (0.9964, 0.9986,

0.9944, 0.9983) respectively, It means these results are very satisfactory and show that the estimation procedure works well (8). It clears from Fig. (1) that the higher ratios of water content were at lower points of pressure head (cm), at the same time the locations soils of fine texture appeared large retention of water content than the medium and coarse texture because of increase of clay ratio led to increasing the ability of soil to keep the water and these results in the agreement of findings of Arya *et. al* (5) Borek and Bogdal(11) and Klute(20)

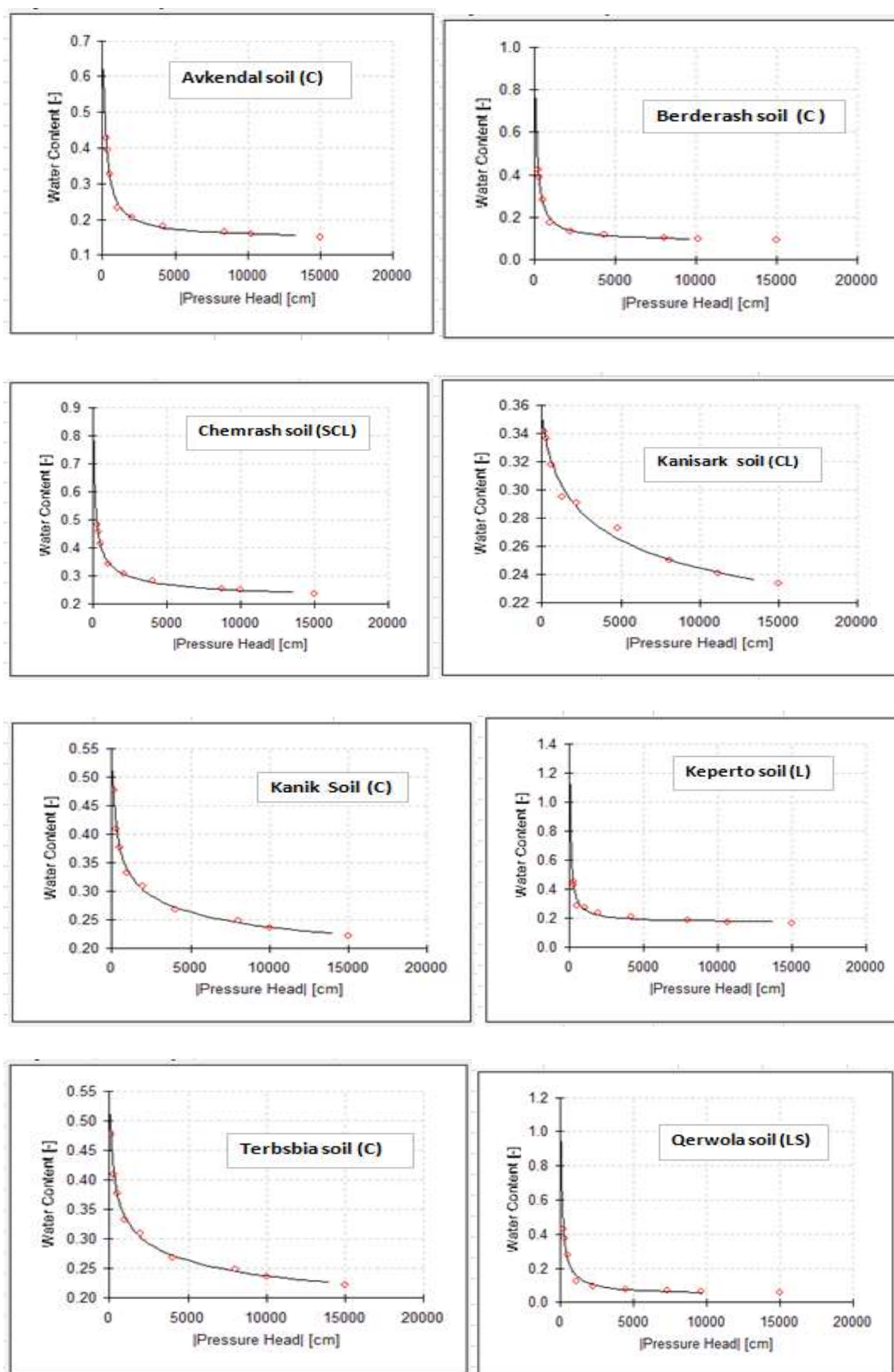


Fig. (1) Relationships between water content (%) and pressure head (cm water) of the investigated soils

The results of Fig.(2) illustrated that the relationships between pressure head (cm) and conductivity indicated that the higher values were at water levels close to saturation condition and these values decreased with increasing at initial water levels for all locations soils and these results

came in agreement with results of AL-Wazan(2), Kool, *et al*,(21) and Schaap and Leij(26) which they were mentioned that the values of conductivity in higher-level close saturation conditions and these values in lower at initial water conditions.

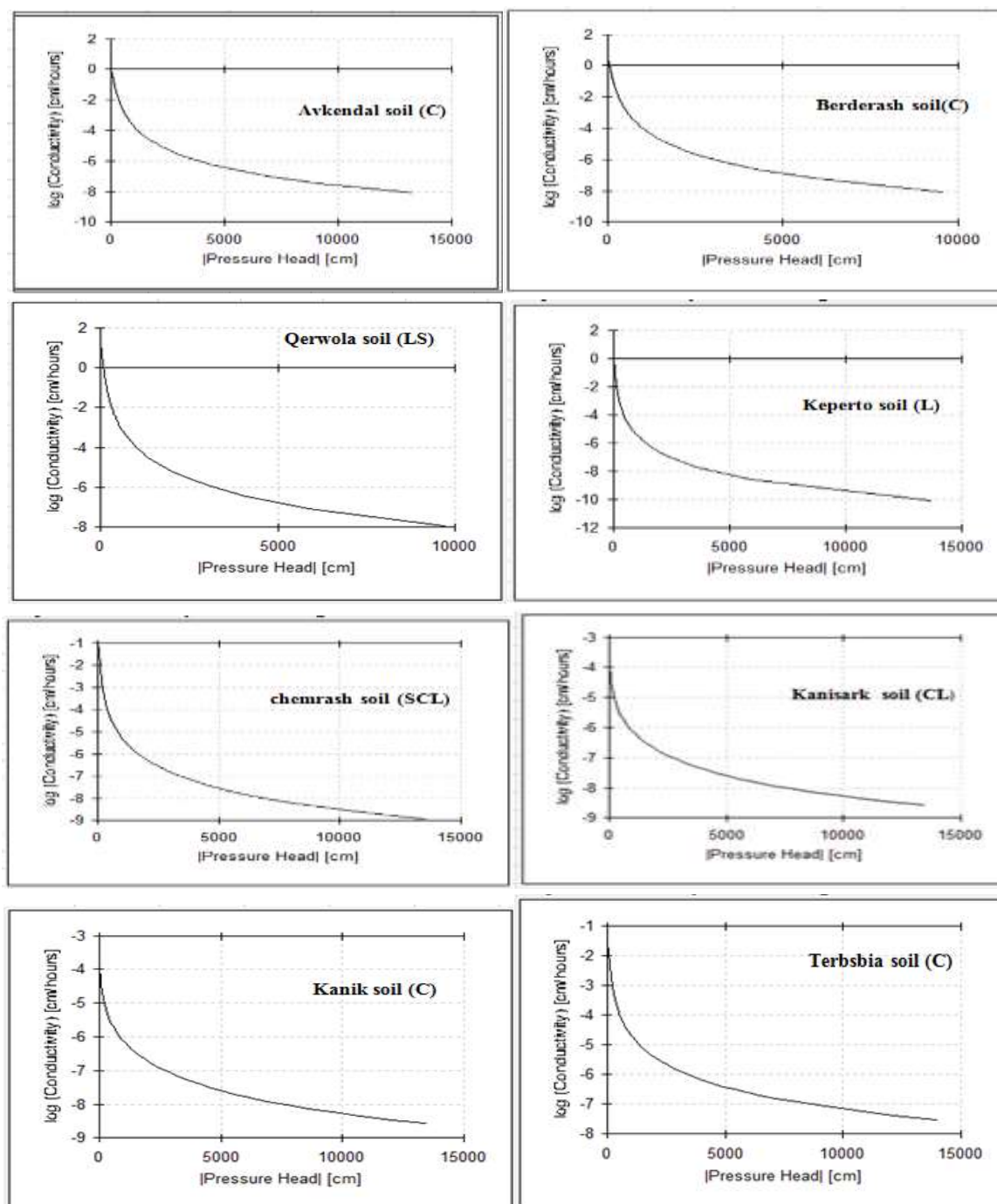
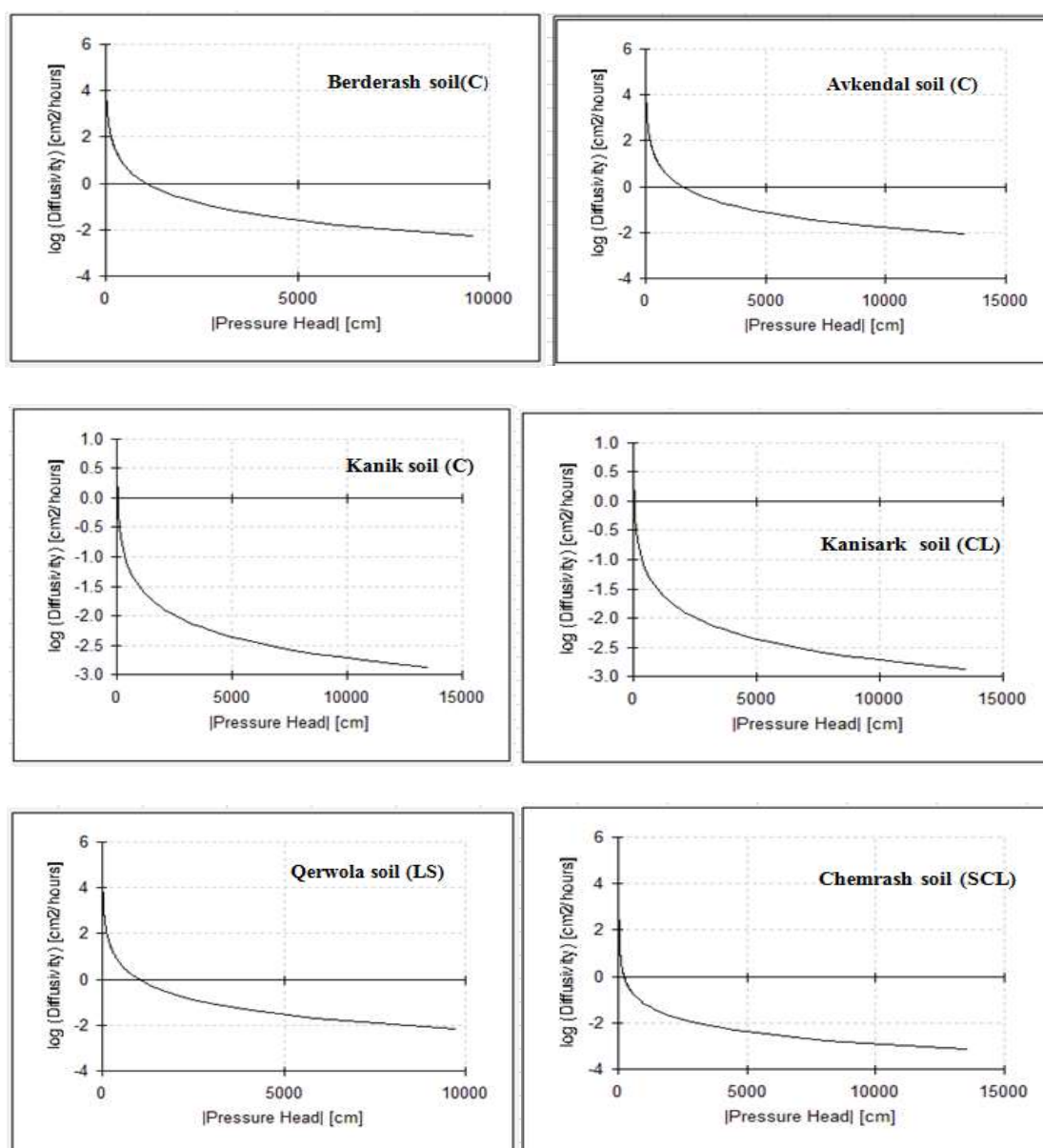


Fig. (2) Relationships between pressures head (cm) and log hydraulic conductivity in (cm hr⁻¹) of the investigated soils.

Fig.(3) express the relationships between pressure head in (cm) and water diffusivity in (cm² hour) that the higher values of diffusivity at water levels near θ_s (saturation condition) and these values decreases with decrease of water content until reaching the lower values were at water levels of initial water content and these finding came in the line with finding of Wishler *et al*(34); Aoda *et al*,(4);Aoda *et.al*.(5); AL-Douri (1) and AL-Wazan(3).

Fig.(3) express the relationships between pressure head in (cm) and water diffusivity in (cm² hour) that the higher values of diffusivity at water levels near θ_s (saturation condition) and these values decreases with decrease of water content until reaching the lower values were at water levels of initial water content and these finding came in the line with finding of Wishler *et al*(34); Aoda *et al*,(4);Aoda *et.al*.(5); AL-Douri (1) and AL-Wazan(3).



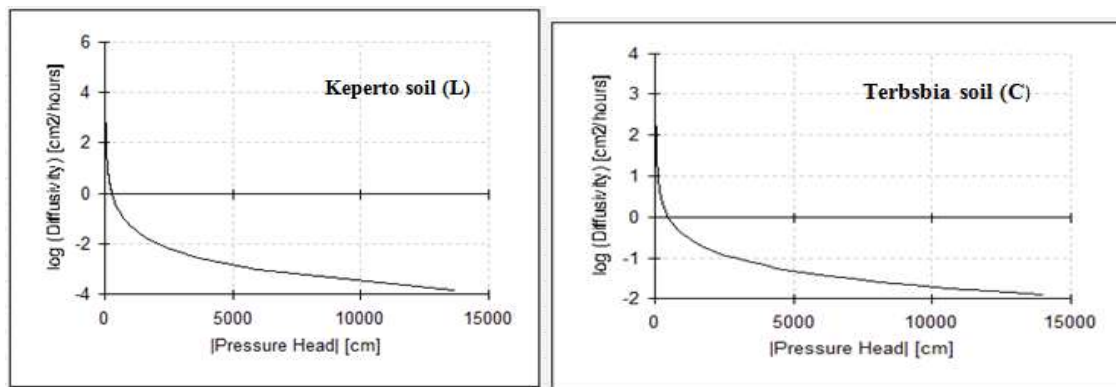


Fig. (3) Relationships between pressure head in (cm) and log of Diffusivity In (cm²) of the investigated soils.

Conclusions:

According the current study It may be concluded that the RETC program can successfully determine the optimum water equations of the soil using the van Genuchten model (1980) for soils representative of the Duhok region.

Recommendations:

- 1- Conduct more investigations on various textures of region using RETC program.
- 2- Determination of soil hydraulic properties at least of main plains of Duhok region are very important for any project of soil conservation, water management, and irrigation

References:

- 1 – **AL-Douri, N.T.**2002.Assessment functions of water transmission for soil treated with fuel oil .Ph.D. Dissertation. College of Agriculture. University of Baghdad. Iraq.
- 2 - **AL-Wazan, F. A.S.**2000). Effect of total carbonate on some physical properties of soil. M.Sc. thesis. College of Agriculture and Forestry. University of Mousel. Iraq.

3 - **AL-Wazan, F.A.S.**2014.Inverse modeling to predict some hydraulic properties by using mathematical and artificial neural network methods for some soils in Nineveh province/ Iraq. Ph. D Dissertation. College of Agriculture and Forestry. University of Mousel. Iraq.

4 - **Aoda, M.I.; D.R. Nedawi and Abul-Rassul, I. A.**1988.A theoretically-derived infiltration equation. J. Agric. Eng. Res., 41: 173- 180.

5 - **Aoda, M.I.; D.R. Nedawi and Abdel-Rassul, I. A.**1993.Salt effects on the water transport function in an unsaturated soil. Iraqi. J. Agric. Sci., 24(1):.20 -29.

6 - **Arya, L.M.; F.J. Leij; M.Th. Van Genuchten and Shouse, P. J.**1999.Scaling parameter to predict the soil water characteristic from particle-size distribution data. Soil Sci.Soc.Am.J.63:510-519. <https://doi.org/10.2136/sssaj1999.0361599500630030013x>.

7 - **Black, C.A.**1965. Method of soil analysis. part1 .Agronomy 9:253-261.

8 - **Blake, G.R. and K.H. Hartge.**1986. Bulk Density in Method of Soil Analysis. part1:(In.

Physical and Mineralogical Methods. 2nd Ed. Edited by A. Klute. USA. pp. 363-375.).

8 - **Borek, L. and A. Bogdal** 1918. Soil Water Retention of the Odra River Alluvial Soils (Poland): Estimating Parameters by RETC Model and Laboratory Measurements. Department of Land Reclamation and Environmental Development, University of Agriculture in Krakow, Al. Mickiewicza 24–28, 20–059 Krakow. Poland. (Email: rbogdal@cyf-kr.edu.pl.)

10 - **Brooks, R. H. and A. T. Corey**.1964. Hydraulic Properties of Porous Media. Hydrology Paper No. 3, Civil Engineering Department. Colorado State University. Fort Collins. CO. USA.

11 - **Bouma S, J.**1989. Using soil survey data for quantitative land evaluation. Part of the Advances in Soil Science. book series. Soil. Volume9. Pp.177-213.

12 - **Durner, W.**1994. Hydraulic conductivity estimation for soils with heterogeneous pore structure. Water Resour. Res., 30(2):211-23 DOI: [10.1029/93WR02676](https://doi.org/10.1029/93WR02676)

13 – **EPA.** <https://www.epa.gov/water-research/retention-curve> (Dec 14, 2021)

14 - **Galal, M. E.**2004. Estimating Soil Hydraulic Parameters (In. El-Tina Plain Using RETC Program. International Conf. on Water Resources & Arid Environment. Soils Dept. Fac. of Agric. Ain Shams Univ. Egypt.

15 - **Galal, M. E.**2006. Saving Irrigation Water in Sandy Soils the 2nd International Conf. on Water Resources & Arid Environment Soil Sci. Dept., Fac. of Agric. Ain Sham Univ., and Cairo. Egypt

16 - **Gee, G.W. and J.W. Bauder** .1986. Particle Size Analysis. (In. Methods of

Soil Analysis .Part 1: Physical and Mineralogical Methods .2nd. Edited by A. Klute. USA. pp. 383-409.).

17 - **Hassan, Q.M.**199. Simulation of Water Movement from Soil to Plant. University of Baghdad. Ministry of Higher Education and Scientific Research. Iraq.

18 - **Hollenbeck, K. J.; J. Šimůnek and Van Genuchten, M. Th.**2000: RETMCL: Incorporating maximum-likelihood estimation principles in the RETC soil hydraulic parameter estimation code. Computers & Geosciences 26(3):319-327. [https://doi.org/10.1016/S0098-3004\(99\)00138-7](https://doi.org/10.1016/S0098-3004(99)00138-7).

19 - **Khalaf, A.A.**2010 Approaches to evaluate the performance of indigenous materials on seepage reduction. Ph. D. dissertation. College of Agriculture. University of Salahuddin, Erbil. Iraq.

20 - **Klute, A.** Ed.1986. Methods of Soil Analysis, Part 1, Physical and Mineralogical Properties. American Society of Agronomy. Agronomy Monographs 9(1). Madison. Wisconsin. USA.

21 - **Kool, J.B.; J.C. Parker and M.Th. Van Genuchten, M. Th.**1987. Parameter estimation for unsaturated flow and transport models-A review. J. Hydrol.. (Amsterdam) 91: 255-293.

22 - **Kosugi, K.**1996. Lognormal distribution model for unsaturated soil hydraulic properties. Water Resour. Res. 32: 2697-2703. Doi: 10.1029/96WR01776

23 - **Londra, P. and G. Kargas.**2018). Evaluation of hydrodynamic characteristics of porous media from one-step outflow experiments using RETC code Crossmark. Journal of Hydro informatics (2018) 20 (3):

699–

707. <https://doi.org/10.2166/hydro.2018.148>.

24 - **Mualem, Y.**1986.Hydraulic conductivity of unsaturated soils: Prediction and formulas. (In. A. Klute (ed.) Methods of Soil Analysis. Part1.Physical and Mineralogical Properties. American Society Agronomy. Monograph. 9, 2nd ed. Madison, Wisc. USA.).

25 - **Nguyen, P. M.; A. Haghverdi; J. De Pue.; Y-D. Botula; K. V. Le; W. Waegeman and Cornelis, W. M.**2017. Comparison of statistical regression and data-mining techniques in estimating soil water retention of tropical delta soils. Biosystems Engineering 153: 12-27.

26 - **Schaap, M.G. and F.J. Leij.**2000.Improved predication of unsaturated hydraulic conductivity with the Mualem-van Genuchten model. Soil. Sci. Soc. Am. J. 64:843-851.

27 - **Schaap, M.G. and M. Th. Van Genuchten.**2006. A Modified Mualem-Van Genuchten formulation for Improved Description of the Hydraulic Conductivity near Saturation. Vadose Zone Journal, 5:27-34.

28 - **Schoonover, J. E.and J. F. Crim.**2015.An introduction to soil concepts and the role of soils in watershed management. Journal of Contemporary Water Research & Education 154(1): 21-47. <https://doi.org/10.1111/j.1936-704X.2015.03186.x>.

29 - **Shwethaa, P. and K. Varijab.**2015.Soil water retention curve from saturated hydraulic conductivity for sandy loam and loamy sand textured soils. Aquatic Procedia 4: 1142-1149.

30 - **Qanza, H.; A. Maslouhi and Abboudi, S.**2015.Experience of inverse modelling for

estimating hydraulic parameters of unsaturated soils. Russian Meteorology and Hydrology 41(11-12): 779-788.
DOI:[10.3103/S1068373916110066](https://doi.org/10.3103/S1068373916110066)

31 - **Van Genuchten, M. Th.**1980.A closed-form equation for predicting hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am. J. 44: 892-989.

32 - **Van Genuchten, M. Th; F.J. Leij and Yates, S. R.**1992. The RETC code for quantifying the hydraulic functions of unsaturated soils. (In. Project Summary, EPA'S Robert S. Kerr Environmental Research Lab., Ada. OK. USA.).

33 - **Vogel, T.; M. Th. Van Genuchten and Cislserova, M.**2001.Effect of the shape of the soil hydraulic functions near saturation on variably- saturated flow predictions. Advances in Water Resources 24:133-144.

34 - **Whisler, F.D.; A. Klute and Peters, D. B.**1968. Soil water diffusivity from horizontal infiltration. Soil Sci. Soc. Am.Proc.,32:6-11.

35 - **Wassar, F.; C. Gandolfi; M. Rienzner; E. A. Chiaradia and Bernardoni, E.**2016. Predicted and measured soil retention curve parameters in Lombardy region north of Italy. International Soil and Water Conservation Research 4(3):207-214.