https://doi.org/10.26682/ajuod.2022.25.1.1
Journal of University of Duhok., Vol. 25, No.1 (Agri. and Vet. Sciences), Pp 1-10, 2022

EVALUATION OF DIFFERENT MODELS FOR PREDICTING SOIL WATER RETENTION FROM A SEMIARID REGION OF DUHOK

AKRAM ABBAS KHALAF
Dept. of Soil & Water Sciences, College of Agricultural Engineering Science, University of Duhok, Kurdistan Region-Iraq

(Received: September 14, 2021; Accepted for Publication: February 27, 2022)

ABSTRACT

A study was carried out to examine the capability of bi and uni- models to explore water retention data for two different textured soils from a semiarid region Duhok-Iraqi Kurdistan.

A soil hydraulic model, can be used to derive the parameters of soil hydraulic properties for describing soil water movement. The program "SWRC Fit," which performs nonlinear fitting of soil water retention curves for the two examined soils using six models, was employed for this purpose.

The six models are the Brooks Corey, van Genuchten, Kosugi, Fredlund and Xing model as uni models and Durner and Seki as a bimodal model used for this purpose.

The program can be carried out straightly from a web page at http://purl.org/net/swrc/; The program was used for determining Fifteen parameters of soil hydraulic for two different textured soils. As related to Berderash sandy loam soil the LN uni-model revealed better performance than the FX, BC and VG models and at same time the FX, BC and VG models exhibit similar fitting precision on average. Whereas bi-models is shown that the Durner's bi- model (DB) revealed very well fitting performance than that of the bi-log-normal distribution model (BL) models, regarding to Zawita clay soil it revealed that the uni - models, of BC, VG, FX and LN revealed good fitting performance with similar fitting precision on average. Whereas in bi- models it was noticed that the log-normal distribution model (BL) gave very well-suitable performance than that of the Durner's b- model (DB).

After comparing between the uni-models and bi-models of the six mentioned soil hydraulic models from accuracy and coefficient determination (R^2), for two different textured soils under the study it can be illustrated: firstly, for fine texture soil (clay soil) the most precision fitting performance was found by model (BL), whereas for light texture soil (sandy loam soil) the most very well-fitting performance was noticed by (DB) model, and secondly the bi-models hydraulic were better than uni-models in fitting performance.

KEYWORDS: uni-model, bi-models soil water retention curve, soil texture, saturated moisture content, residual moisture content.

INTRODUCTION

Water is essential for maintenance and production enhancement, while water supply in Iraq's Kurdistan Region is below the minimum level.

The rainfall data of the last decade explained that a huge number of dry spells of long period have been occurred and affected on agricultural production adversely (Muhammed Noori,2016) Furthermore, thunderstorms with highest intensity and for short period are usual and most of the arable lands are not in good conservation management. Through these torrents a considerable amount of the rain goes as precipitation and cause erosion. The variations in soil texture necessitate varied water management strategy in order to gain high water effectiveness and an optimal water balance, as well as potential optimization of soil water management in the soils of our semiarid region. (Khalaf,2010)

In many applications in the fields of irrigation, hydrology, geotechnical engineering and soil science in general Soil water retention characteristic is the key soil property that used for these purposes. (Omit Too.et al 2014) The soil hydraulic properties are key functions to solving the unsaturated Richards equation which is commonly used to simulate soil water movement and concomitant chemical transport in the unsaturated zone (Hopmans and Schoups, 2005).

akram.khalaf@uod.ac

The soil hydraulic properties are often given by analytical relations with unknown parameters that must be found using experimental and optimization techniques to permit comparisons between different soils. (Kosugi et al., 1994).

By comparing predictions to mean water contents recorded over time in numerous places at field scale, the impacts of utilizing uni-models and bi interpretative models of hydraulic characteristics on the ensemble hydrological behavior of the soil were demonstrated by (Vogel, T.,2002). Although the variations in goodness of fit between uni-models and bimodal fitting are not significant.

The relationship between the water content θ and the soil water potential ψ is represented by the water retention curve. This curve, also known as the soil moisture characteristic, is indicative of several types of soil.

The goal of this study is to examine the soil hydraulic parameters of two distinct textured soils using Bi–Uni models, for the potential improvement of soil water management in our semiarid region's soils

MATERIAL AND METHODS

Two different textured soil samples were selected to conduct the current research which were Berderash sandy loam soil used for cultivation of field crops such as wheat and barley and the second one Zawita clay forest soil covered with (*pinus brutia*) which were located in Duhok governorate- Kurdistan region. The map of Fig. (1) shows the coordinates across the study sites across the region that were obtained by GPS Model GARMIN Terex Vista. GARMIN International, Inc and running Map Info. software.

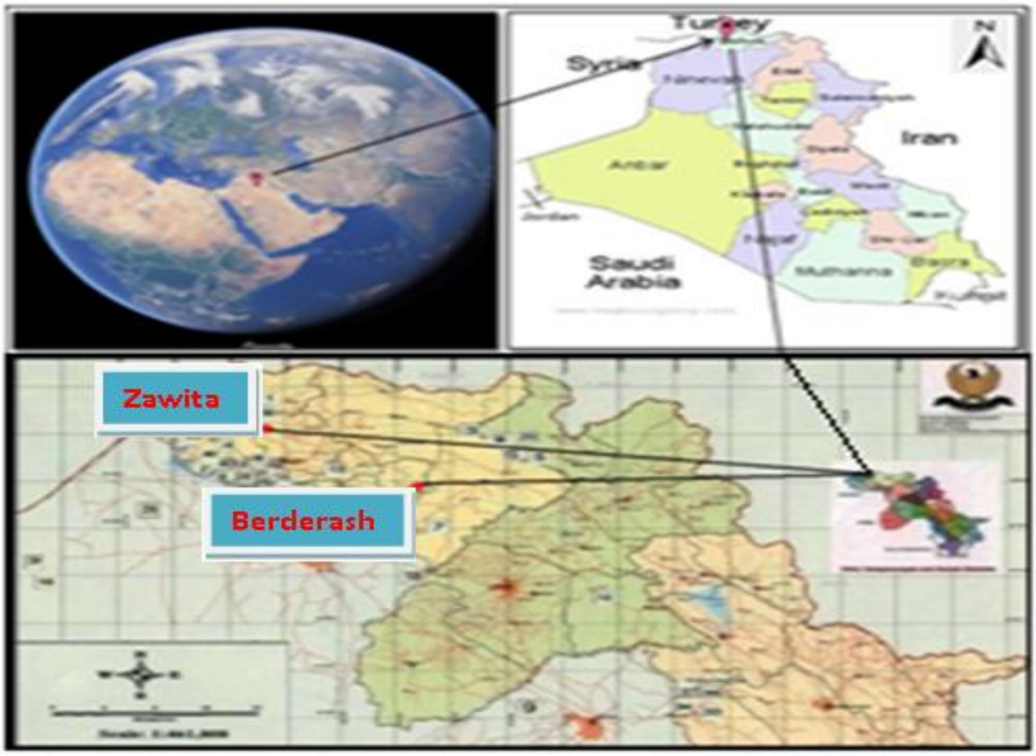


Fig. (1): Location map showing the sites from which the selected soils were sampled

Table (1): Geographical coordinates showing the location of the sampling sites

#	Sample	UTM system		Geographic system		Elevation(m)	Province
	Location	Easting	Northing	Altitude	Longitude		
1	**Berderash**	374389.00	4040674	36.5032	43.5974	372	Duhok
2	**Zawita**	334739.18	4085099	36.9064	43.1450	967	Duhok

Some physical and hydraulic properties of the soils used were illustrated in tables (2) and (3) respectively.

Table (2): Some physical and chemical properties of the studied soils.

Soil	Gran separate kg^{-1} soil			Textural	Bulk Density	PH	EC	O.M
Location	Sand	Silt	Clay	Class	Mg m^{-3}	H_2O 1:2	dSm^{-1}	g kg^{-1} soil
Berderash	**672.3**	**178.2**	**149.5**	**SL**	**1.48**	**7.3**	**0.43**	**14**
Zawita	**351.5**	**139.3**	**509.2**	**C**	**1.35**	**7.7**	**0.23**	**25.8**

Table (3): Some hydraulic properties of the studied soils.

Soil	Field	Wilting	Saturation	Available	Saturated
Location	Capacity	point		water	HC
		Vol.%		$cmcm^{-3}$	$mmhr^{-1}$
Berderash	**18.2**	**10.9**	**43.5**	**0.07**	**37.38**
Zawita	**42.2**	**30.5**	**48.9**	**0.12**	**0.66**

To determine the soil hydraulic parameters the program "SWRC Fit," and because the relation between soil water and matric potential is nonlinear therefore the fitting was developed by applying six models, as clarified in table (4).

Table (4): Soil hydraulic models: (4) uni and (2) bi-models

Soil hydraulic models in SWRC Fit

In SWRC Fit (Web interface and offline version), 6 hydraulic models are used. Out of the 6 models, 4 models (BC, VG, LN, FX) assume unimodal pore structure (unimodal model) and 2 models (DB, BL) assume bimodal pore structure (bimodal model).

Model	Reference	Equation	Parameters
BC	Brooks and Corey (1964)	$S_e = \begin{cases} (\frac{h}{h_b})^{-\lambda} & (h > h_b) \\ 1 & (h \le h_b) \end{cases}$	$\theta_s, \theta_r, h_b, \lambda$
VG	van Genuchten (1980)	$S_e = [\frac{1}{1+(\alpha h)^n}]^m \quad (m = 1 - 1/n)$	$\theta_s, \theta_r, \alpha, n$
LN	Kosugi (1996)	$S_e = Q[\frac{\ln(h/h_m)}{\sigma}]$	$\theta_s, \theta_r, h, \sigma$
FX	Fredlund and Xing (1994)	————	$\theta_s, \theta_r, a, m, n$
DB	Durner (1994)	$S_e = w_1[\frac{1}{1+(\alpha_1 h)^{n_1}}]^{m_1} + (1-w_1)[\frac{1}{1+(\alpha_2 h)^{n_2}}]^{m_2}$ $(m_i = 1 - 1/n_i)$	$\theta_s, \theta_r, w_1, \alpha_1, n_1, \alpha_2, n_2$
BL	Seki (2007)	———— ————	$\theta_s, \theta_r, w_1, h_{m1}, \sigma_1, h_{m2}, \sigma_2$

- h is the suction head
- θ is the volumetric water content
- S_e is the effective water content defined by $S_e = \frac{\theta-\theta_r}{\theta_s-\theta_r}$. Therefore, $\theta = \theta_r+(\theta_s - \theta_r)S_e$
- In LN and BL models, Q(x) is the complementary cumulative normal distribution function, defined by Q(x)=1-Φ(x), in which Φ(x) is a normalized form of the cumulative normal distribution function. Please note that Q(x) is different from error function.
- In FX model, e is Napier's constant. FX model is implemented in SWRC Fit version 3.0 and higher. In the web interface, correction function, C(h)=1. In the offline version, the correction function can be changed. See calculation options.
- Other parameters are soil hydraulic parameters to be estimated.

To obtain the required parameters, enter the soil water retention data. The program can be run directly from a web page at http://purl.org/net/swrc/; an electronic supplement to this paper contains a client version of the software developed in the numeric calculation language GNU Octave.

2. Soil hydraulic models

2.1 BC, VG, LN and FX models

Table (4) reveals' the six soil hydraulic models. Among them, the first four, BC (Brooks and Corey, 1964), VG (van Genuchten, 1980), LN (Kosugi, 1996), FX (Fredlund and Xing,1994), and DB (Durner, 1994), while the last, the BL (Seki, K.,2007).and) the equations are written in *Se*(*h*) functional form. *Se*, the effective saturation, is defined as:

$$S_e = \frac{\theta - \theta_r}{\theta_s - \theta_r}, \qquad \text{Equa.1.1}$$

where θs is the saturated water content and θr is the residual water content. From Eq. (1.2) and the Se(h) functions in Table (4) the soil water retention functions *θ*(*h*) for the models were obtained.

While the BC and VG models were derived empirically, the LN model was derived theoretically. The derivation of the LN model by Kosugi (1996) is outlined as follows. The pore radius distribution function g(r), defined as is expressed in the LN model as

g(r) = dθ/dr Equa. 1.2

$$g(r) = \frac{\theta_s - \theta_r}{\sqrt{2\pi}\sigma r} \exp\left[-\frac{[\ln(r/r_m)]^2}{2\sigma^2}\right], \quad \text{Equa. 1.3}$$

where *r* obeys the log-normal distribution, i.e., ln(r) obeys the normal distribution of N [ln (r_m), σ2]. Here the pore radius r is inversely proportional to the soil capillary pressure head h by the capillary function:

$h = A/r$, $A = 2\gamma \cos \beta/\rho_w g$ Equa. 1.4

where γ is the surface tension between the water and air, β is the contact angle, ρ*w* is the density of water, and g is the acceleration of gravity. A constant value of A=0.149 cm^2) is often used (Brutsaert, 1966**)**

DB, and BL, models

Durner's model requires the assumption that the soil characteristic curve of soils with a heterogeneous void structure can be represented as a superposition of the curves of a homogeneous void structure.

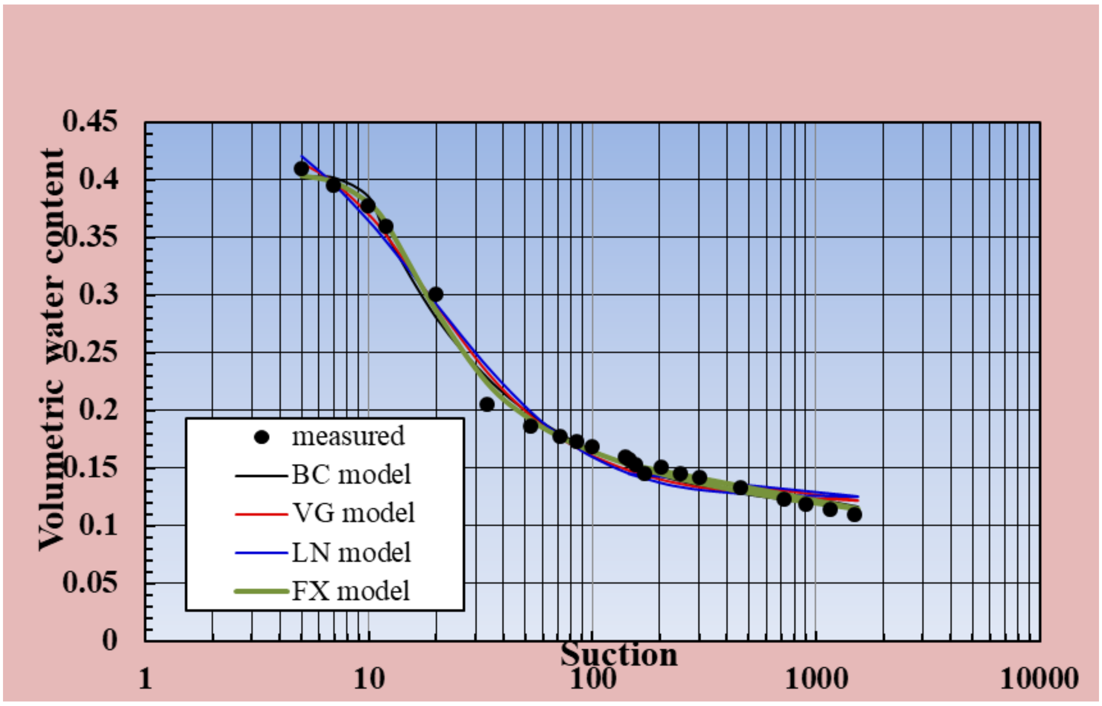
RESULTS &DISCUSSION

The results of SWRC-fit show the parameters values and R^2 and AIC of four uni-model and two bimodal of six soil hydraulic models for studied soils which were Berderash sandy loam and Zawita clay soil

The results of Berderash sandy loam soil the nonlinear fitting program with it water retention curve cleared in Tables (5), (6) and Figures (2). (3), it noticed that from the uni-models explore well performance. was LN model and revealed better achievement than FX, BC and VG models and the FX, BC and VG models show similar precision on average.

Table. (5): Model parameters values, determination coefficient (R^2) and (AIC) of uni-model soil hydraulic models of Berderash sandy loam.

Model	Equation	Parameters	R^2	AIC
Brooks and Corey	$S_e = \begin{cases} \left(\frac{h}{h_b}\right)^{-\lambda} & (h > h_b) \\ 1 & (h \le h_b) \end{cases}$	$\theta_s = 0.40186$ $\theta_r = 0.10792$ $h_b = 9.1576$ $\lambda = 0.68102$	0.99237	-202.50
van Genuchten	$S_e = \left[\frac{1}{1+(\alpha h)^n}\right]^m \quad (m = 1 - 1/n)$	$\theta_s = 0.43870$ $\theta_r = 0.11931$ $\alpha = 0.080394$ $n = 1.9588$	0.99056	-197.82
Kosugi	$S_e = Q\left[\frac{\ln(h/h_m)}{\sigma}\right]$	$\theta_s = 0.49295$ $\theta_r = 0.12504$ $h_m = 16.902$ $\sigma = 1.4026$	0.98466	-187.14
Fredlund and Xing	$S_e = \left[\frac{1}{\ln[e + (h/a)^n]}\right]^m$	$\theta_s = 0.40601$ $\theta_r = 0.0056259$ $a = 12.186$ $m = 0.44893$ $n = 3.7268$	0.99594	-214.40



.

Fig. (2): BC, VG, LN and FX curves of Berderash sandy loam soil.

Where as in bi-models is shown that the Durner's bimodal model (DB) gave very well-fitting performance than that of the bi-models log-normal distribution model (BL) model (Xu, Y. 2004)**.**

Table. (6): Model parameters values, determination coefficient (R^2) and (AIC) of bi-models soil hydraulic models of Berderash sandy loam Soil.

Model	Equation	Parameters	R^2	AIC
Durner	$S_e = w_1\left[\frac{1}{1+(\alpha_1 h)^{n_1}}\right]^{m_1} + (1-w_1)\left[\frac{1}{1+(\alpha_2 h)^{n_2}}\right]^{m_2}$	$\theta_s = 0.56607$ $\theta_r = 0.055206$ $w_1 = 0.76961$ $\alpha_1 = 1.3025$ $n_1 = 1.2586$ $\alpha_2 = 0.047457$ $n_2 = 8.3108$	0.99934	-250.45
Seki	$S_e = w_1 Q\left[\frac{\ln(h/h_{m1})}{\sigma_1}\right] + (1-w_1)Q\left[\frac{\ln(h/h_{m2})}{\sigma_2}\right]$	$\theta_s = 0.86016$ $\theta_r = 0.13324$ $w_1 = 0.54227$ $h_{m1} = 1.9779$ $\sigma_1 = 0.20254$ $h_{m2} = 17.685$ $\sigma_2 = 1.1482$	0.98181	-177.38

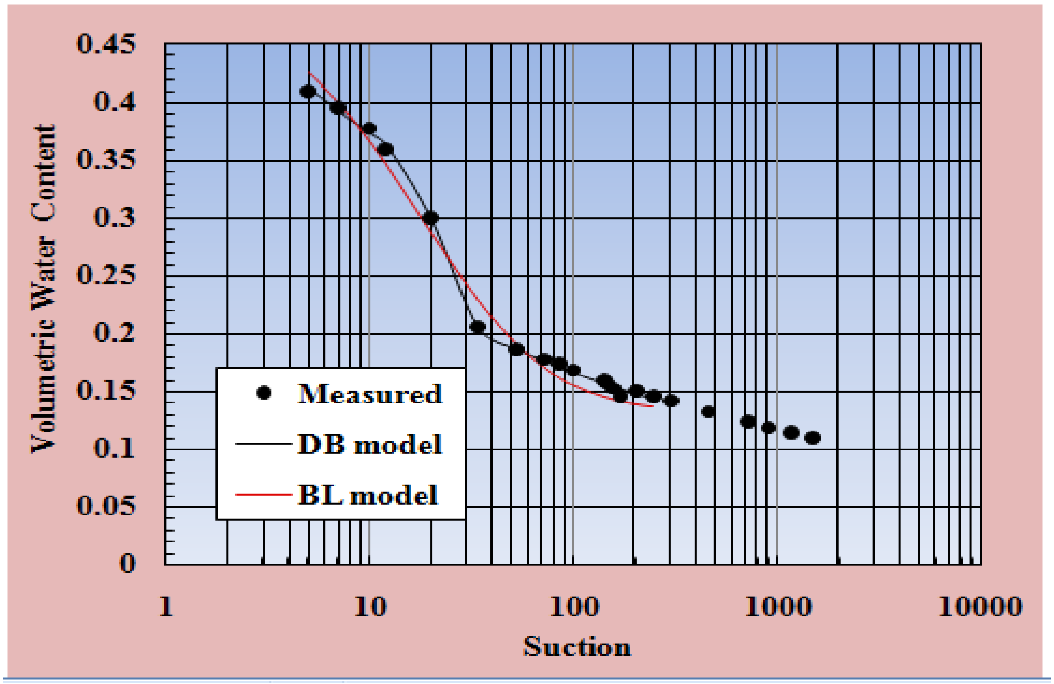


Fig. (3): DB and BL curves of Berderash sandy loam soil.

In comparison accuracy of the fitting between uni and bi models for Berderash sandy loam soil. The Durner's bimodal model (DB) explore very well performance, most precision and had maximum R^2 over all the uni-models and bimodal of six soil hydraulic models.

Uni-models of (Zawita Clay soil)

In concerned to the Zawita clay soil it was illustrated from the results in table (7), and Figure. (4) that In uni-models models, the BC, VG, FX and LN models gave good fitting performance with similar fitting precision on average.

Table. (7): Model parameters values, determination coefficient (R^2) and (AIC) for uni-models soil hydraulic models of Zawita clay soil.

Model	Equation	Parameters	R^2	AIC
Brooks and Corey	$Se = \begin{cases} \left(\frac{h}{hb}\right)^{-\lambda} & (h > hb) \\ 1 & (h \leq hb) \end{cases}$	$\theta_s = 0.48150$ $\theta_r = 0.24558$ $h_b = 91.109$ $\lambda = 0.18983$	0.99786	-324.05
van Genuchten	$Se = \left[\frac{1}{1+(\alpha h)^n}\right]^m \quad (m = 1 - 1/n)$	$\theta_s = 0.49830$ $\theta_r = 0.28673$ $\alpha = 0.0093127$ $n = 1.2936$	0.99599	-307.15
Kosugi	$Se = Q\left[\frac{\ln(h/hm)}{\sigma}\right]$	$\theta_s = 0.51380$ $\theta_r = 0.32396$ $h_m = 496.76$ $\sigma = 2.3115$	0.99341	-293.74
Fredlund and Xing	$Se = \left[\frac{1}{\ln\left[e + (h/a)^n\right]}\right]^m$	$\theta_s = 0.51940$ $\theta_r = 0.30137$ $a = 250.95$ $m = 1.6322$ $n = 0.68652$	0.99373	-293.07

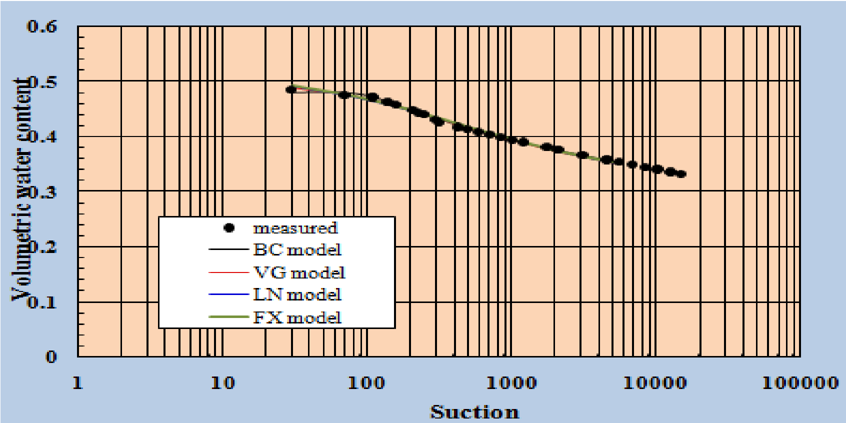


Fig. (4): BC, VG, LN and FX curves of Zawita clay soil.

Bimodal Models: (Zawita lay soil)

whereas in bi-models it was noticed from table (8) and fig. (5) that the log-normal distribution model (BL) gave very well-fitting performance than that of the Durner's bimodal model (DB).

Table (8): Model parameters values, determination coefficient (R^2) and (AIC) of bi-models soil hydraulic models of Zawita loamy soil.

Model	Equation	Parameters	R^2	AIC
Durner	$S_e = w_1\left[\frac{1}{1+(\alpha_1 h)^{n_1}}\right]^{m_1} + (1-w_1)\left[\frac{1}{1+(\alpha_2 h)^{n_2}}\right]^{m_2}$	$\theta_s = 0.48718$ $\theta_r = 0.32899$ $w_1 = 0.012518$ $\alpha_1 = 0.0079810$ $n_1 = 2.2284$ $\alpha_2 = 0.0051573$ $n_2 = 1.5422$	0.99082	-278.76
Seki	$S_e = w_1 Q\left[\frac{\ln(h/h_{m1})}{\sigma_1}\right] + (1-w_1)Q\left[\frac{\ln(h/h_{m2})}{\sigma_2}\right]$	$\theta_s = 0.49681$ $\theta_r = 0.29359$ $w_1 = 0.15980$ $h_{m1} = 235.16$ $\sigma_1 = 0.42119$ $h_{m2} = 2021.8$ $\sigma_2 = 2.7534$	0.99969	-370.52

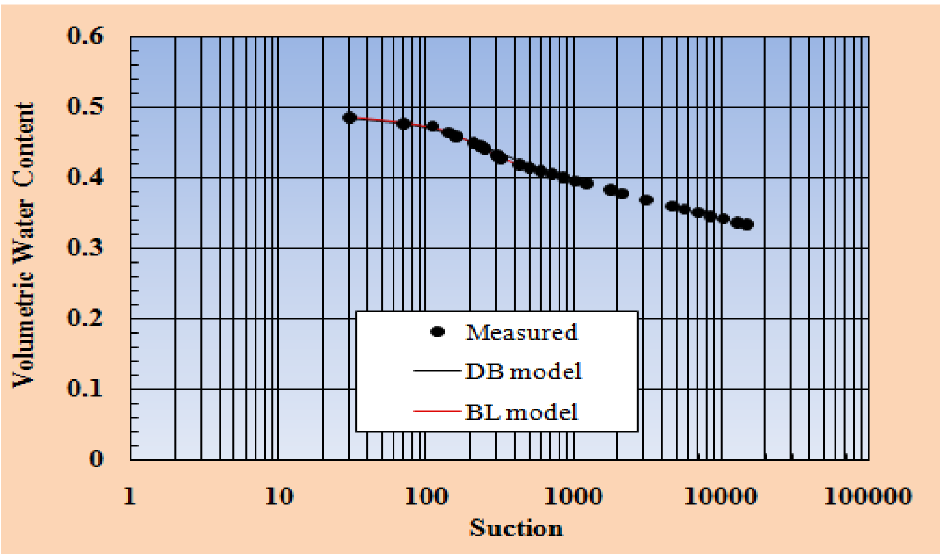


Fig. (5): Fitting of DB and BL for Zawita Clay soil.

A comparison of the precision of the fitting for the uni-models and bimodal models for Zawita clay was strived. The bimodal log-normal distribution model (BL) gave very well-fitting performance, most precision and higher R^2 over all the uni-models and bi-models of six soil hydraulic models.

DISCUSSION

The performance of uni -model in clay soil Zawita clay soil was better than same modal models in loamy soil (Berderash sandy loam soil)and also the performance of Bimodal models for Clay soil better than Bimodal models or in other words we can say the performance of uni-bimodal of soil hydraulic models were better in Clay soil than loamy soil and the performance of Bimodal better than uni-models for two different texture soils with main difference between performance of two Bi-models where the DB was the better from R^2 and AIC for loamy soil whereas the BL was the better for clay soil with notice that the performance of BL model was the better at comparing the results of current study to finding of other researchers we could indicate that the finding obtained in this study in agreement with results of .(Seki, K.2007; Nemes, A., et al,2001; Poulsen, T. G.et al,2002; Schaap, M. G., et al,2001; Xu, Y. 2004; AL*Wazan ,2014).

CONCLUSIONS

Based on the performance of the study models between uni-bimodal of six hydraulic models for two different textured soil under the study it can be concluded that. firstly, for fine texture soil (clay soil) the most precision fitting performance was found by bimodal log-normal distribution model (BL), whereas for light texture soil (sandy loam soil) the most very well-fitting performance was noticed by Durner’s bi-model (DB), and secondly the bi-models’ hydraulic models were better than uni- models in fitting performance.

REFERENCES

AL-Wazan, Faris Akram Salih,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. Thesis. University of Mosul. Iraq

Akaike, H. (1974). A new look at the statistical model identification. IEEE Transactions on Automatic Control, AC-19, 716–723.

Brutsaert, W. (1966) Probability laws for pore-size distribution, Soil Sci., 101, 85–92, 412

Brooks, R.H., and A.T. Corey (1964): Hydraulic properties of porous media. Hydrol. Paper 3. Colorado State Univ., Fort Collins, CO, USA.

Durner, W. (1994): Hydraulic conductivity estimation for soils with heterogeneous pore structure. *Water Resour. Res.,* 30(2

Fredlund, D.G. and Xing, A. (1994): Equations for the soil-water characteristic curve. *Can. Geotech. J.*, 31: 521-532. doi:10.1139/t94-061

Hopmans, J.W., and G.H. Schoups. 2005. Soil water flow at different spatial scales. p. 999–1010. *In* M. Anderson (ed.) Encyclopedia of hydrological sciences. John Wiley & Sons, New York.

John R. Nimmo .(1994) Modeling of soil water retention from saturation to oven dryness Cinzia Rossi Instituteo f Hydraulics, Water Researches, Vol. 30, NO. 3, Pages: 701-708M, University of Genoa, Italy.

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

Kosugi, K.(1994) Three-parameter lognormal distribution model for soil water retention, Water Resour. Res. 30(4), 891–901, 420.

Khalaf, Akram. Abbas. (2010) Approaches to evaluate the performance of indigenous materials on seepage reduction A dissertation submitted to the college of Agriculture, University of Salahuddin, Erbil, Iraq.

Muhammed Noori, Muradjan Mudhaffer. (2016) Growth and Yield of Maize as Influenced by Genotype and Irrigation Water Quality Using Aqua Crop Model. M Sc thesis college of Agriculture, University of Duhok.

Nemes, A., Shaap, M. G., Leij, F. J., and W¨osten, J. H. M.: Description of the unsaturated soil hydraulic database UNSODA version 2.0, J. Hydrol. (Amsterdam), 251, 151–162, 2001. 411,418, 419

akram.khalaf@uod.ac

Poulsen, T. G., Moldrup, P., Iversen, B. V., and Jacobsen, O. H.: Three-region Campbell model15 for unsaturated hydraulic conductivity in undisturbed soils, Soil Sci. Soc. Am. J., 66, 744–752,2002. 409

Schaap, M. G., Leij, F. J. and van Genuchten, M. Th. 2001. Rosetta: A computer program for estimating soil hydraulic parameters with hierarchical pedotransfer functions. J. Hydrol. 251: 163–176

Seki, K. (2007) SWRC fit –a nonlinear fitting program with a water retention curve for soils having unimodal and bimodal pore structure. Hydrol. Earth Syst. Sci. Discuss., 4: 407-437. doi:10.5194/hessd-4-407-2007.

Too, V.K., Omuto, C.T., Biamah, E.K. and Obiero, J.P. (2014) Review of Soil Water Retention Characteristic (SWRC) Models between Saturation and Oven Dryness. Open Journal of Modern Hydrology, **4**, 173-18.
http://dx.doi.org/10.4236/ojmh.2014.44017

van Genuchten, M. (1980): A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am J. 44:892-898.

Vogel, T., van Genuchten, M. T., and Cislerova, M.: Effect of the shape of the soil hydraulicfunctions near saturation on variably-saturated flow predictions, Adv. Water Res., 24(2), 133–144, 2000. 420

Xu, Y. 2004. Calculation of unsaturated hydraulic conductivity using a fractal model for the pore-size distribution. Compute. Geotech. 31: 549–557.