GOÜ. Ziraat Fakültesi Dergisi, 2007, 24 (2), 77-86

Pedotransfer Functions for the Hydraulic Properties of Layered Soils

Tekin Öztekin[1] **Bilal Cemek[1]** **Larry C. Brown[2]**
1- Gaziosmanpaşa Üniversitesi, Ziraat Fakültesi, Tarımsal Yapılar ve Sulama Bölümü, 60240, Tokat
2- The Ohio State University, Department of Food, Agricultural and Biological Engineering, Columbus, OH

Abstract: In this study, the pedotransfer functions for the vertical saturated hydraulic conductivity, water contents at the suctions of 0- (saturation), 60- (drainable porosity), 100-, 330- (field capacity), 1000-, and 15000-cm (permanent wilting point) were developed using easily measurable soil physical and chemical properties obtained from 34 horizons of nine profiles from a lake origin of Northwest Ohio plain. For this analysis, the multiple-linear regression analysis by stepwise method was employed. The accuracy of these functions were evaluated using the measured vertical saturated hydraulic conductivity and water contents at the field capacity and wilting points from the soils of 19 horizons of five profiles of an alluvial Yeşilırmak River valley close to the downtown of Tokat city. The results of evaluation showed that the developed pedotransfer functions for the vertical saturated hydraulic conductivity and field capacity produced under and over predictions, respectively. The developed pedotransfer functions for the wilting point yielded fair results.
Keywords: pedotransfer functions, pF curve, soil water contents, vertical saturated hydraulic conductivity, drainable porozity

Katmanlı Toprakların Hidrolik Özellikleri için Pedotransfer Eşitlikler

Özet: Bu çalışmada, göl orijinli Kuzeybatı Ohio'daki bir ovanın dokuz profiline ait 34 horizonundan alınan toprak örneklerinde ölçülmüş basit toprak fiziksel ve kimyasal özellikleri kullanılarak, düşey doygun hidrolik iletkenlik, 0- (doygun), 60- (drene edilebilir porozite), 100-, 330- (tarla kapasitesi), 1000-, ve 15000-cm (devamlı solma noktası) emme basınçlarındaki su içerikleri için pedotransfer eşitlikleri geliştirilmiştir. Bu işlemde, stepwise yöntemli çoklu doğrusal regresyon analiz yöntemi kullanılmıştır. Geliştirilen eşitliklerin doğrulukları, Tokat merkeze yakın alüvyal Yeşilırmak vadisinde açılan beş profilin 19 horizonuna ait toprak örneklerinde ölçülmüş, düşey doygun hidrolik iletkenlik, 330- ve 15000-cm emme basınçlarına karşılık toprakta tutulan su içerikleri kullanılarak değerlendirilmiştir. Hidrolik iletkenlik ve tarla kapasitesi (330-cm) için geliştirilmiş eşitlikler sırasıyla düşük ve yüksek sonuçlar üretmiştir. Devamlı solma noktası (15000-cm) için geliştirilmiş eşitlikler ise orta derecede iyi sonuçlar üretmiştir.
Anahtar kelimeler: pedotransfer eşitlikleri, pF eğrisi, toprak su içerikleri, düşey doygun hidrolik iletkenlik, drene edilebilir porozite

1. Introduction

The water movement rates into drains and wells, rates of plant uptake, infiltration, and evaporation are couple of the aspects affected by the hydraulic conductivity and water retention properties of soil. These properties are often called the hydraulic properties of the soil. While saturated hydraulic conductivity of a soil is a measure of its ability to transmit water, water retention characteristics are an expression of its ability to store water (Klute and Dirksen, 1986). Hydraulic properties of soil are primarily dependent on clay type, soil compaction, total porosity, distribution of pore sizes, pore geometry, distributions of soil particle sizes (soil texture), and soil structure. Furthermore, organic matter mainly affects the hydraulic properties of soil because of its hydrophilic nature and soil structure improving effect.

While soil hydraulic characteristics are being used widely in modeling studies, measurements of them are time consuming, difficult, and expensive. Then, pedotransfer functions (PTFs) can be employed. The PTFs can be defined as the equations to estimate directly soil hydraulic characteristics from easily obtained or measured soil properties such as bulk density, distributions of particle sizes (sand, silt, and clay contents), organic matter, CEC, etc. Derivations of these equations can be accomplished in a couple of ways such as generating simple and multiple-linear and polynomial regression, curve fitting, residual analysis, stepwise regression, generating regression equations by artificial neural networks (ANN), group method of data handling, etc. In these analyses, relationships between soil hydraulic characteristics (dependent variables) and easily obtained soil properties (independent variables) are searched.

Most of the PTFs were developed to predict single values in soil water characteristic curve, for example water contents at the matrix suctions of field capacity (FC) or permanent wilting point (PWP) (Gupta and Larson, 1979; Rawls et al., 1982; Bell and van Keulen, 1995; Salchow et al., 1996; Pachepsky and Rawls, 1999; Cemek et al., 2004). In drainage simulation models such as DRAINMOD (Skaggs, 1978), WEPP-WTM (Oztekin, 2000; Oztekin and Brown, 2001), ADAPT (Chung et al., 1992), and SWATREN (Feddes et al., 1978), beside of saturated hydraulic conductivity (K), not only PWP and FC corresponding water contents, but as many as (point estimation) such as those by Saxton et al. (1986) to represent the whole soil water characteristic curve (pF) or to predict the parameters (parameterization) of an expression to describe the water retention curve such as those of van Genuchten (1980) or Brooks and Corey (1964) may be needed for each soil or layer. From the point estimations, a continuous curve of soil water retention through the individual points can be derived either through interpolation, smoothing, or other data-fitting techniques. In drainage simulation models, vertical saturated hydraulic conductivity and soil water characteristic values are used to determine vertical seepage and the relationships between water table depth and drainage volume-upward flux rates.

Saxton et al. (1986) developed PTFs for estimating saturated-unsaturated hydraulic conductivity and water contents at the suctions of 10-, 20-, 33-, 60-, 100-, 200-, 400-, 700-, 1000-, and 1500-kPa using linear regression. On the other hand, Tomasella et al. (2000) derived a PTF to predict the parameters of soil water retention of the van Genuchten (1980) equation using data from more than 500 Brazillian soil horizons. Furthermore, as stated by Vereecken et al. (1992), for the measured hydraulic properties of 42 Belgian soil types, Vereecken (1988) had derived PTFs for the van Genuchten (1980) model for the soil water retention function and the Gardner (1958) model for the hydraulic conductivity-pressure head function. In addition, Wösten and van Genuchten (1988) derived PTFs for the soil water retention and hydraulic conductivity equations of van Genuchten (1980) using regression analysis to relate estimated model parameters to more easily measured soil properties such as bulk density and percentages of silt, clay, and organic matter.

In this study, our purposes are: i) to derive PTFs of vertical saturated hydraulic conductivity and water contents at the suctions of 0-, 60-, 100-, 330-, 1000-, and 15000-cm of water using easily obtainable soil properties of 34 soil samples from a small Northwest Ohio watershed, and ii) to validate the derived PTFs using the properties of 19 soil samples from a small North Central Turkey watershed.

2. Materials and Methods

The soil data used to derive PTFs was obtained from the study by Oztekin (2000). In the year of 1998, a 12.8 ha small, flat agricultural watershed located in Defiance county, one of the wetland-reservoir-subirrigation system site in Northwest Ohio was sampled. From the Soil Survey of Defiance County (USDA, 1984), the dominant soils at the site are Paulding clay (dark grayish Brown) and Roselms silty clay (changing from dark grayish Brown to gray).These soils are dominant where clayey sediment was deposited in glacial lakes (USDA, 1984). The soils have four and five major layers, respectively. Using an automatic hydraulicly driven soil sampler mounted on a pickup (called Gidding's apparatus), total of 34 horizons from nine profiles were sampled with disturbed and undisturbed soil samples by the cores of 7.6 cm in diameter and 7.6 cm in height. The soil particle sizes were determined by the pipette method (Gee and Bauder, 1986) and dry bulk density was determined by the core method (Blake and Hartge, 1986). The organic matter content was determined after determining total carbon amounts employing the procedures given by Post (1956) and Soil Survey Staff (1972), and later the amounts were multiplied by 1.724 (van Bemmelon factor). To determine CEC values, $BaCl_2$-triethanolamine-extractable acidity of the samples were measured (Peech et al., 1947), and extractable Ca, Mg, K, and Na amounts were determined following the procedures given by Holmgren et al. (1977). The constant head saturated hydraulic conductivity test (Klute and Dirksen, 1986) was applied to the undisturbed soil samples to measure vertical saturated hydraulic conductivities. The same samples were used to determine soil water retention at the suctions of 0-(saturation), 20-, 60-(drainable porosity), 330-(field capacity), 1000-, and 15000-cm of water (permanent wilting point) using the combination of tension table (Clement, 1966) and pressure plate extractors (Klute, 1986).

The derived PTFs for the soils from Northwest Ohio are going to be validated using the soil hydraulic properties obtained from Simsek et al. (2007) and Aydın (2006). The soils from these references were obtained from the flood plain of Yeşilırmak River and were developed in an alluvium over lacustrine materials. These soils were taken along a left transect perpendicular to the plain by sampling five profiles with increasing distances from the river bed. The same methods used for the soils of Northwest Ohio for determination of the dry bulk density, saturated hydraulic conductivity, and water contents at 330- and 15000-cm of water were used for the soils of Yeşilırmak River. The hydrometer method (McLean, 1982) for particle size distribution, the method by Nelson and Sommers (1982) for the contents of organic matter, and the method by Richards (1954) for determination of CEC values were used in the studies of Simsek et al. (2007) and Aydın (2006).

To derive PTFs, the multiple-linear regression analysis by stepwise method was employed. In the multiple-linear regression analysis, first, the most essential input variables were selected using backwards stepwise method, and then linear, quadratic, and possible interaction terms of these basic soil properties were investigated using the Statistical Analysis System (SAS, 1999). The general form of the regression equations were:

$$Y = b_0 + b_1X_1 + \ldots + b_7X_7 + b_8X_1^2 + \ldots + b_{14}X_7^2 + b_{15}X_1X_2 + \ldots + b_{35}X_6X_7$$

where Y is the dependent variable representing each soil hydraulic parameter; b_0 is the intercept; $b_1, \ldots, b_{35}$ are regression coefficients; and X_1–X_7 are independent variables referring to basic soil properties.

The agreements between measured and PTFs predicted values were analyzed with the 1:1 line, and the statistics of mean residual error (MRE) and average relative percent error (ARPE). The equations of MRE and ARPE are

$$MRE = \frac{\sum_{i=1}^{n}(y_i - x_i)}{n} \qquad (1)$$

$$ARPE = 100x\frac{\sum_{i=1}^{n}(y_i - x_i)}{\sum_{i=1}^{n}x_i} \qquad (2)$$

where x_i is the measured value, y_i is the predicted value, and n is the total number of observations. The MRE gives information whether the PTF is over or under predicting; and the ARPE expresses this on a percentage basis.

3. Results and Discussions

The mean, standard deviation (Std. Dev.), coefficient of variation (CV), and ranges of bulk density (BD), cation exchange capacity (CEC), pH, vertical saturated hydraulic conductivity (K_v), contents of organic matter (OM), clay (C), sand (S), silt (Si), volumetric water at 0-cm of water (θ_0), 20-cm of water (θ_{20}), 60-cm of water (θ_{60}), 330-cm of water (θ_{330}), 1000-cm of water (θ_{1000}), and 15000-cm of water (θ_{15000}) suctions for the soils of Ohio were listed in Table 1. At 34 horizons, the K_v ranged from 0.01 to 8.88 cm/hr with maximum variability (425.0 %); the sand contents ranged from 26.55 to 1.70 % with the second highest variability (66.09 %); and the OM contents ranged from 0.88 to 5.96 % with the third highest variability (54.82 %). The water contents at different suctions produced small and similar variability.

The properties of soils taken from totally 19 horizons of five profiles of the Yeşilırmak River plain and used to validate the developed PTFs were summarized in Table 2. When we compare the properties of Ohio and Yeşilırmak soils, we can see some differences. Except for the pH, K_v, and sand content, the values of coefficient of variability are higher for the soils of Yeşilırmak than those for the soils of Ohio (Tables 1 and 2). Considering the mean values given in Tables 1 and 2, the higher values of CEC, clay and silt contents, θ_{330}, and θ_{15000}, whereas the lower values of pH, K_v, and sand content were seen in the soils of Ohio.

Table 1. Descriptive statistics for the physical properties of soils from Northwest Ohio, which were used to develop PTFs.

Soil Property		Mean	Min.	Max.	Std. Dev.	CV(%)
Organic matter(%)		1.97	0.88	5.96	1.08	54.82
Bulk Density(g/cm^3)		1.47	1.11	1.67	0.10	6.80
CEC(meq/100g soil)		36.48	27.18	58.12	7.13	19.55
pH		5.85	4.50	7.70	0.95	16.24
Ver. Sat. Hyd. Con.(cm/hr)		0.36	0.01	8.88	1.53	425.00
Clay(%)		43.84	16.56	68.11	11.54	26.32
Sand(%)		9.76	1.70	26.55	6.45	66.09
Silt(%)		46.43	26.02	63.18	8.95	19.28
Volumetric Moisture Content(%)	*0-cm of water suction*	50.99	41.10	61.60	4.48	8.79
	20-cm of water suction	50.35	40.10	61.40	4.53	9.00
	60-cm of water suction	49.91	39.50	61.30	4.55	9.12
	330-cm of water suction	49.03	37.90	61.00	4.71	9.61
	1000-cm of water suction	47.48	37.10	60.40	4.46	9.39
	15000-cm of water suction	33.27	26.20	39.00	3.00	9.02

Table 2. Descriptive statistics for the physical properties of soils from Yeşilırmak River plain, Tokat-Turkey, which were used to validate the developed PTFs.

Soil Property		Mean	Min.	Max.	Std. Dev.	CV(%)
Organic matter(%)		1.91	0.14	5.28	1.76	92.15
Bulk Density(g/cm^3)		1.29	1.05	1.50	0.12	9.30
CEC(meq/100g soil)		28.22	10.86	45.28	10.46	37.07
pH		8.02	7.38	8.40	0.21	2.62
Ver. Sat. Hyd. Con.(cm/hr)		1.73	0.01	9.46	2.77	160.12
Clay(%)		39.13	14.80	55.40	11.80	30.16
Sand(%)		26.36	17.55	50.65	8.67	32.89
Silt(%)		34.53	24.55	52.00	8.10	23.46
Volumetric Moisture Content(%)	*330-cm of water suction*	33.60	17.61	39.75	6.11	18.18
	15000-cm of water suction	20.13	6.78	27.23	5.08	25.24

To determine the relationship between K_v and soil properties such as the contents of OM, C, Si, S; BD; CEC; and pH, the K_v was used as dependent variable, whereas the soil properties listed were used as independent variables. Similar to this relationship, for the relationships between the water holding capacities of soils at different suctions ($\theta_{0,\ 20,\ 60,\ 330,\ 1000,\ 15000}$) and the soil properties listed, the θs were used as dependent variables, whereas the soil properties were used as independent variables.

In a simple regression analysis, the correlation coefficients (*r*) between soil properties were determined and given in Table 3. The significance levels of the relationships were also indicated in the table. The most significant or strong relationships (0.001 probability level) were found between OM with those of BD, C, S, and Si; CEC with those of pH and S; C with those of S and Si; S with those of θ_{60} and θ_{15000}; θ_0 with those of θ_{20}, θ_{60}, θ_{330}, and θ_{1000}; θ_{20} with those of θ_{60}, θ_{330}, and θ_{1000}; θ_{60} with those of θ_{330} and θ_{1000}; and θ_{330} with θ_{1000}. From these results, except θ_{15000}, there are strong relationships among θs. Among the soil properties, the sand content is the most effective property affecting θs. A similar result between S content and θ_{330} was found by Cemek et al. (2004). The authors found a significant negative relationship between θ_{330} and S fraction. In our research, after the S content, the C content was the most second effective property on θs. The relationships between S contents and θs are better than the relationships between C contents and θs for all six θs. The correlation at the 0.05 level between K and those of OM, CEC, C, S, θ_{20}, θ_{60}, θ_{330}, and θ_{1000} were found important.

Table 3. The correlation coefficients (*r*) between the soil properties

Property	BD	CEC	pH	K^+	C	S	Si	θ_0	θ_{20}	θ_{60}	θ_{330}	θ_{1000}	θ_{15000}
OM	-0,743***	-0.206	-0.232	0.381*	-0.795***	0.592***	0.596***	-0.242	-0.277*	-0.297*	-0.274*	-0.184	-0.396*
BD		0,160	0,404*	-0.119	0,480**	-0,263	-0,427*	-0,327	-0,285*	-0,260	-0,244	-0,354*	0,244
CEC			0.536***	-0.392*	0.352*	-0.532***	-0.073	0.247	0.294*	0.315*	0.330*	0.329*	0.276*
pH				-0.178	0.266	-0.201	-0.203	-0.108	-0.093	-0.081	-0.072	-0.122	0.091
K^+					-0.336*	0.505*	0.069	-0.293	-0.370*	-0.423*	-0.392*	-0.317*	-0.258
C						-0.637***	-0.830***	0.474*	0492*	0.504*	0.492*	.0409*	0.417*
S							0.100	-0.484*	-0.542**	-0.567***	-0.531**	-0.494*	-0.652***
Si								-0.264	-0.246	-0.242	-0.252	-0.171	-0.072
θ_0									0.993***	0.982***	0.961***	0.938***	0.303*
θ_{20}										0.997***	0.979***	0.945***	0.341*
θ_{60}											0.985***	0.944***	0.355*
θ_{330}												0.947***	0.331*
θ_{1000}													0.294*

*** : Correlation is significant at the 0.001 level (2-tailed)
** : Correlation is significant at the 0.01 level (2-tailed)
* : Correlation is significant at the 0.05 level (2-tailed)
+ : $K = \log(K_v*1000)$

The pedotransfer functions for water holding capacities at different suctions (*p*) developed by using some soil physical and chemical properties as independent variables were given in Table 4. The units in these equations are: % for the contents of OM, C, S, and Si; g/cm^3 for BD; meq/100 g soil for CEC; %/100 for θ; and cm/h for K. The θ_p equation in table is for all kinds of soil suction values (*p*), therefore the equation includes the soil suction value (*p*). Beside of the soil properties of OM, BD, C, S, Si involved in PTFs of θ_0, θ_{20}, θ_{60}, θ_{330}, θ_{1000}, and θ_{15000}, the θ_p equation also includes the soil properties of CEC and pH. Grouping or separating the soils by textural classes to increase the efficiency of functions was not considered in this study. In the Table, the determined pedotransfer functions were given with the coefficients of determination (r^2) for observed vs. predicted values by PTFs, and standard errors (*SE*) for the estimates from each part of pedotransfer functions. The significance levels of these values were also indicated in the table. This approximate value for the standard error (SE) tells us that the accuracy with determined probability level to expect from our prediction. The coefficients of determination for all determined pedotransfer equations of θ are statistically significant at $P < 0.001$. The values of r^2 were in the range of 0.51 and 0.86. The highest value obtained by the θ_p function is due to increased number of data value (204 in place of 34) used to develop this function. The smallest value was obtained for the pedotransfer function of θ_{15000}. The obtained PTF for K_v is also produced the high r^2 value (0.85). The BD, OM, C, S, CEC, and pH were the soil properties involved in the PTF of K_v.

The developed PTFs were tested by predicting the soil hydraulic properties (θ_{330}, θ_{15000}, and K) of Yeşilırmak river plan. To measure the efficiency of PTFs, the measured and predicted values of soil hydraulic properties were depicted on the 1:1 line in Figure 1. As it can be seen from the figure, both θ_{330} (field capacity) and θ_{15000} (permanent wilting point) were predicted two times. The firsts of them were done by the individual PTFs of θ_{330} and θ_{15000} (Table 4), and the seconds of them were done by the PTFs of θ_p (Table 4). The general view of graphs in Fig. 1 indicates that PTFs developed by Ohio soils are not good predictors for the soil properties (θ_{330}, θ_{15000}, and K) of Yeşilırmak river plan. Except one measurement, both PTFs for the field capacity yielded over predictions. Furthermore, again except couple of values, the values by PTF θ_{330} are higher than those by PTF θ_p. Therefore, overall over prediction by θ_{330} is larger than that of θ_p. The statistics of MRE and ARPE are 7.2 cm^3/cm^3 and 21.42% for the PTF of θ_{330}, 6.6 cm^3/cm^3 and 19.77% for the PTF of θ_p, respectively. The statistics for the PTF of θ_p are also better than those for the θ_{330}. The predictions for permanent wilting point (middle graph) are better than those for field capacity (upper graph). Except couple of values, the permanent wilting points by PTF θ_{15000} are not bad. This PTF sometimes produced under sometimes over predictions. However, the predictions are not far distances from the 1:1 line. The PTF of θ_p produced over predictions for all measurements of permanent wilting point and its predictions all times are larger than those by PTF θ_{15000}. The statistics of MRE and ARPE for the permanent wilting points are 2.7 cm^3/cm^3 and 13.62% for the PTF of θ_{15000}, 7.5 cm^3/cm^3 and 37.39% for the PTF of θ_p, respectively. The statistics for the PTF of θ_{15000} are almost three times better than those for the θ_p. The predictions by the PTF for saturated hydraulic conductivity (K) are not good, too. The PTF produced under predictions for all measurements. The distances of points from the 1:1 line are far. The statistics of MRE and ARPE for the K are -1.553 (0.036 cm/hr) and -57.71%, respectively. The under predictions of K are clear from these negative statistic values.

There can be many reasons getting so poor predictions by the developed PTFs especially for field capacity and saturated hydraulic conductivity. One of them is that the 34 values or measurements are not adequate number for development of PTFs. The soil properties of these 34 measurements are not in enough diverse to cover a broad range of soil particle size distribution. It is thought that the variability differences in soil properties of two plains as stated before are major reason to get poor predictions from PTFs. When we consider specific reasons; one of them can be that the soils from Ohio are silt dominant while the soils from Yeşilırmak are sand dominant. The other one can be that the soil formations are also different at both locations, one of them lake, the other one river (alluvial) origins.

Table 4. The determined pedotransfer functions of saturated vertical hydraulic conductivity (K_v) and water contents (θ) (volumetric moisture content) at different suctions

Θ_0 = 1.14-0.0251*OM-0.40946*BD+0.0000464*(CxSi)-0.00103*(SixBD)
SE = (0.14)*** (0.010)* (0.08)***(0.0001)* (0.0005)*
r^2 = 0.69***
n = 34

Θ_{20} = 1.115-0.022*OM-0.4*BD+0.00000164*C-0.000007*S
SE = (0.12)*** (0.010)** (0.07)***(0.0001)** (0.0001)**
r^2 = 0.72***
n = 34

Θ_{60} = 1.06-0.023*OM-0.4*BD+0.000000788*(C^2xSi)
SE = (0.13)*** (0.010)* (0.07)***(0.0001)**
r^2 = 0.70***
n = 34

Θ_{330} = 0.99-0.33*BD+0.0000242*C-0.0001*S-0.0006*(OMxC)
SE = (0.10)*** (0.060)*** (0.0001)***(0.0001)** (0.0003)*
r^2 = 0.68***
n = 34

Θ_{1000} = 0.877-0.296*BD+0.0000227*C^2-0.000097*S^2
SE = (0.08)*** (0.050)*** (0.0001)***(0.0001)***
r^2 = 0.63***
n = 34

Θ_{15000} = 6.6-0.062*C-0.066*S-0.062*Si
SE = (2.80)* (0.03)* (0.03)*(0.03)*
r^2 = 0.51***
n = 34

θ_p = 0.877-0.000011*p-0.023*OM-0.32*BD+0.0019*CEC-0.00000026*$(CECxpH)^2$+0.0000239*C^2+0.0000147*Si^2
SE = (0.08)***(0.0001)***(0.004)***(0.04)***(0.0007)*(0.0001)*(0.0001)*
r^2 = 0.86***
n = 204

Log(1000*K_v) = -5.54+3.114*BD+0.387*OM-0.00039*C^2-6.3*10^{-6} *$(CEC*pH)^2$+0.013*CEC+0.048*C+0.026*S
SE = (0.6861)*** (0.2478)*** (0.0494)*** (0.0001)*** (0.00001)*** (0.0045)*** (0.0145)***(0.0066)***
r^2 = 0.85***
n = 34

*** : $P < 0.001$, ** : $P < 0.01$, and * : $P < 0.05$

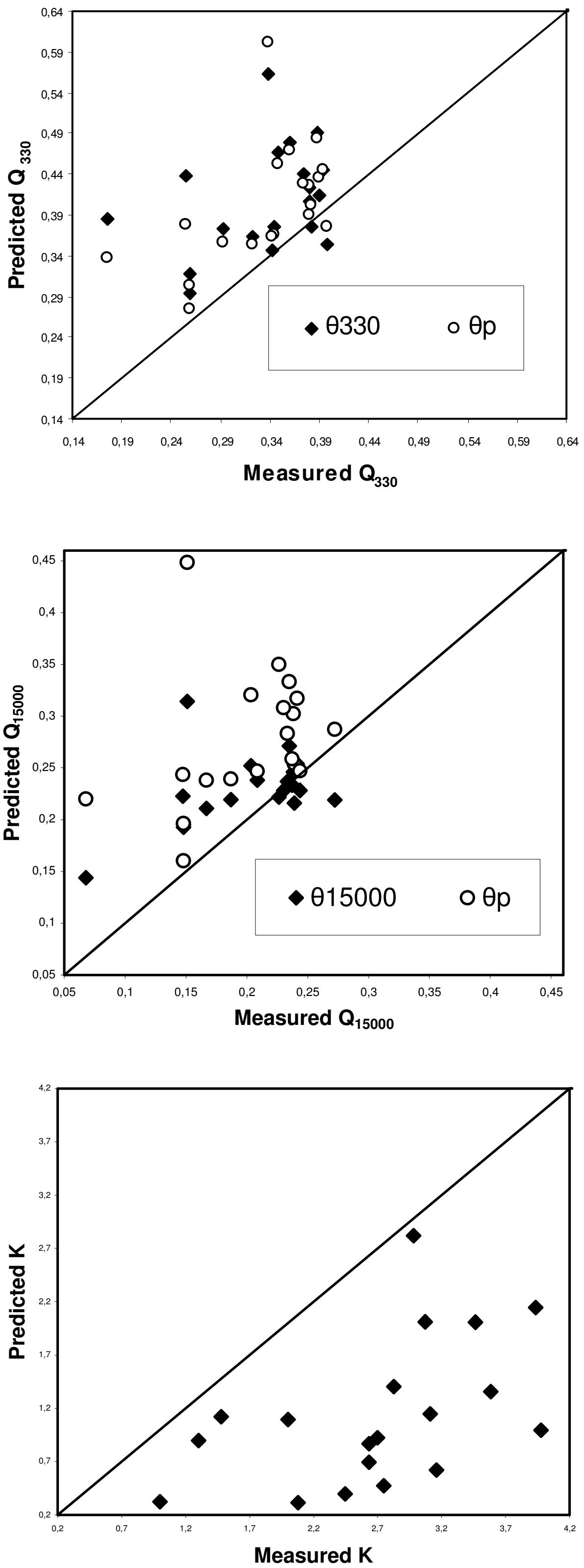

Figure 1. The measured versus PTFs predicted volumetric water contents at the suctions of 330- (upper graph) and 15 000-cm of water (middle graph), and the saturated hydraulic conductivity (log (1000K_v)) (lower graph) with the 1:1 lines.

4. Conclusions

After employment of easily measurable soil properties of 34 soil samples from each horizons of nine profiles dug at a lake origin Northwest Ohio plain, pedotransfer functions for vertical saturated hydraulic conductivity and water contents at different suctions were developed by multiple –linear regression analysis with stepwise method. The sand content was found as the highest effecting soil property on water contents. The highest coefficients of determinations (r^2) were found for the general pedotransfer equation of water content (0.86) and saturated hydraulic conductivity (0.85).

The developed pedotransfer equations were used to predict hydraulic conductivity and water contents at field capacity and permanent wilting points for the 19 soil samples of each horizon of five profiles dug perpendicular to the Yeşilırmak river plain with varying distances. Overall, the developed pedotransfer equations for permanent wilting point yielded acceptable results, while the developed pedotransfer equations for the field capacity and saturated hydraulic conductivity produced weak performances. The origin differences of soil formations at two plains, number of samples used to develop pedotransfer equations, and high variability of soil properties of Yeşilırmak soils are being thought as the main reasons to get poor performances.

References

Aydın, M.E. 2006. Soil formation and taxonomy in Yeşilırmak River terraces. Master Thesis. Graduate School of Natural and Applied Sciences of Gaziosmanpaşa University, Turkey, p.49.

Bell, M.A. and H. van Keulen. 1995. Soil pedotransfer functions for four Mexican soils. Soil Science Society of American Journal 59:865-871.

Blake, G.R. and K.H. Hartge. 1986. Bulk density. In: A. Klute (Editor), Methods of Soil Analysis, Part 1, 2nd ed. Agron. Monogr. 9, ASA, Madison, WI, pp.363-375.

Brooks, R.H. and A.T. Corey. 1964. Hydraulic properties of porous media. Hydrology Paper no. 3. Colorado State University, Fort Collins.

Cemek, B., R. Meral, M. Apan and H. Merdun. 2004. Pedotransfer functions for the estimation of the field capacity and permanent wilting point. Pakistan Journal of Biological Sciences 7(4):535-541.

Chung, S.O., A. Ward and C.W. Schalk. 1992. Evaluation of the hydrologic component of the ADAPT water table management model. Transactions of the ASAE 35(2):571-579.

Clement, C.R. 1966. A simple and reliable tension table. J.Soil Science 17:133-135.

Feddes, R.A., P.J. Kowalik and H. Zaradyn. 1978. Simulation of field water use and crop yield. Simulation Monographs. Wageningen, the Netherlands: PUDOC.

Gardner, W.R. 1958. Some steady state solutions of the unsaturated moisture flow equation with application to evaporation from a water table. Soil Science 85:228-232.

Gee, G.W. and J.W. Bauder. 1986. Particle size analysis. In: A. Klute (Editor), Methods of Soil Analysis, Part 1, 2nd ed. Agron. Monogr. 9, ASA, Madison, WI, pp.383-409.

Gupta, S.C. and W.E. Larson. 1979. Estimating soil water retention characteristics from particle size distribution, organic matter content, and bulk density. Water Resources Research 15:1633-1635.

Holmgren, G.S., R.L. Juve, and R.C. Geschwender. 1977. A mechanically controlled variable-rate leaching device. Soil Science Society of American Journal. 41(6):1207-1208.

Klute, A. 1986. Water retention: Laboratory methods. In: A. Klute (Editor), Methods of Soil Analysis, Part 1, 2nd ed. Agron. Monogr. 9, ASA, Madison, WI, pp.635-660.

Klute, A. and C. Dirksen. 1986. Hydraulic conductivity and diffusivity: Laboratory methods. In: A. Klute (Editor), Methods of Soil Analysis, Part 1, 2nd ed. Agron. Monogr. 9, ASA, Madison, WI, pp.687-732.

McLean, E.O. 1982. Soil pH and lime requirement. In: Methods of Soil Analysis Eds. Page et al.) Part 2, 2nd Edn. Agron. Monogr. 9, ASA and SSSA, Madison, WI, pp. 199-224.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, organic carbon, and organic matter. In: Methods of Soil Analysis, Part 2. Microbiological and Biochemical Properties. SSSA Book Series: 5 (formerly Agronomy Monograph 9) (Ed. A. Klute). Madison, Wisconsin, USA, pp. 539-579.

Oztekin, T. 2000. Modification and Evaluation of WEPP Water Table Management Model. Ph.D Thesis, Ohio State University, Columbus, Ohio. 290 p.

Oztekin, T. and L. C. Brown. 2001. Modification of the WEPP Hillslope Model for Subsurface Drained Cropland. 314-317. In Proc. of the International Symposium on Soil Erosion Research for the 21'th Century. ed. J.C. Ascough II and D.C. Flanagan. ASAE.713 p.

Pachepsky, Y.A. and W.J. Rawls. 1999. Accuracy and reliability of pedotransfer functions as affected by grouping soils. Soil Science Society of American Journal 63:1748-1757.

Peech, M.L., A. Dean, and J.F. Reed. 1947. Methods of soil analysis for soil-fertility investigations. USDA Circular No. 757. U.S. Government Printing Office, Washington, D.C.

Post, G.J. 1956. A study of three methods for determination of organic carbon in Ohio soils of several great groups and the profile distribution of carbon-nitrogen ratios. M.S. Thesis, The Ohio State University.

Rawls, W.J., D.L. Brakensiek and K.E. Saxton. 1982. Estimation of soil water properties. Transactions of the ASAE 25(5):1316-1320, 1328.

Richards, L.A. 1954. Diagnosis and Improvement of Saline and Alkaline Soils, USDA Handbook, No:60.

Salchow, E., R. Lal, N.R. Fausey and A. Ward. 1996. Pedotransfer functions for variable alluvial soils in southern Ohio. Geoderma 73:165-181.

SAS Institute Inc., 1999. SAS/STAT user's guide. Ver. 8.0. SAS Institute Inc., Cary, NC.

Saxton, K.E., W.J. Rawls, J.S. Romberger and R.I. Papendick. 1986. Estimating generalized soil-water characteristics from texture. Soil Science Society of American Journal 50:1031-1036.

Simsek, H., T. Öztekin and A. Durak. 2007. Variability in some irrigation related soil properties of the alluvial soils formed by the Yesilirmak River. Asian Journal of Chemistry 19(7):1-8.

Skaggs, R.W. 1978. A water management model for shallow water table soils. Report No. 134. Raleigh, NC. Water Resources Research Institute, Univ. of North Carolina. 175 p.

Soil Survey Staff. 1972. Soil Survey Laboratory Methods and Procedures for Collecting Soil Samples. Soil Survey Investigations Report No. 1. USDA Soil Conservation Service. U.S. Govt. Printing Office, Washington D.C.

Tomasella, J., M. G. Hodnett and L. Rossato. 2000. Pedotransfer functions for the estimation of soil water retention in Brazilian soils. Soil Science Society of American Journal 64:327-338.

USDA. 1984. Soil Survey of Defiance County, Ohio. United States Department of Agriculture-Soil Conservation Service. 246 p.

Wösten, J.H.M. and M. Th. van. Genuchten. 1988. Using texture and other soil properties to predict the unsaturated soil hydraulic functions. Soil Science Society of American Journal 52:1762-1770.

van Genuchten, M. Th. 1980. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Science Society of American Journal 44:892-898.

Vereecken, H. 1988. Pedotransfer functions for the generation of hydraulic properties of Belgian soils. Ph.D diss. Katholieke Universiteit, Leuven, Belgium.

Vereecken, H., J. Diels, J. van Orshoven, J. Feyen, and J. Bouma. 1992. Functional evaluation of pedotransfer functions for the estimation of soil hydraulic properties. Soil Science Society of American Journal 56:1371-1378.