INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
08–141/NCP/2008/10–6–715–718
http://www.fspublishers.org

Short Communication

Sodium Adsorption Ratio Pedotransfer Function for Calcareous Soils of Varamin Region

MAJID RASHIDI[1] AND MOHSEN SEILSEPOUR†
Department of Agricultural Machinery, Faculty of Agriculture, Islamic Azad University, Takestan Branch, Iran
†Varamin Soil and Water Research Department, Soil and Water Research Institute, Iran
[1]Corresponding author's e-mails: majidrashidi81@yahoo.com; m.rashidi@aeri.ir

ABSTRACT

For almost five decades many attempts have been made to predict some complex soil properties from some easily available soil properties using empirical models. In soil science, such empirical models are named pedotransfer functions. For instance, soil Sodium Adsorption Ratio (SAR) are often determined using laborious and time consuming laboratory tests, but it may be more suitable and economical to develop a pedotransfer function, which uses a more simple soil salinity index. In this study, a pedotransfer function for predicting soil SAR from soil Electrical Conductivity (EC) was suggested and soil SAR was estimated as a function of soil EC. The statistical results of the study indicated that in order to predict soil SAR based on soil EC the pedotransfer function SAR = 1.91 + 0.68 EC with R^2 = 0.69 can be recommended.

Key Words: Sodium adsorption ratio; Electrical conductivity; Pedotransfer function; Prediction; Soil; Varamin

INTRODUCTION

Saline soils are among the serious concerns to irrigated agriculture in arid and semi-arid regions of the world (Tanwir *et al.*, 2003; Ahmad *et al.*, 2006). In Iran, approximately 44.5 M ha of arable land are affected by dry land salinity (Banaei *et al.*, 2005). In addition, the application to soil of poor quality irrigation water may result in an increase in soil salinity. Salinity becomes a problem when enough salts accumulate in the effective crop root zone to negatively affect plant growth. Excess salts in the effective crop root zone hinder plant roots from withdrawing water from surrounding soil. This lowers the amount of water available to the plant, regardless of the amount of water actually in the effective crop root zone (Sumner, 1993).

Two different criteria are currently recognized in the scientific literature as indices of soil salinity. These are the soil Electrical Conductivity and the soil Sodium Adsorption Ratio (Ahmad *et al.*, 2006). The soil Electrical Conductivity is abbreviated as EC with units of dS m^{-1} or mmhos cm^{-1}. Both are equivalent units of measurement and give the same numerical value (Page *et al.*, 1982). The soil Sodium Adsorption Ratio is abbreviated as SAR and is defined as Equation 1 (Sumner, 1993; Rengasamy & Churchman, 1999; Quirk, 2001; Rashidi & Seilsepour, 2008):

$$SAR = Na^{+} / [(Ca^{2+} + Mg^{2+})/2]^{0.5} \qquad (1)$$

Where:

SAR = Sodium adsorption ratio, $(cmol\ kg^{-1})^{0.5}$.

Na^{+}, Ca^{2+}, Mg^{2+} = Measured exchangeable Na^{+}, Ca^{2+} and Mg^{2+}, respectively, cmol kg^{-1}.

As shown in Equation 1, for determining soil SAR, it is necessary to have exchangeable Na^{+}, Ca^{2+} and Mg^{2+}. However, since these soil parameters are often determined using laborious and time consuming laboratory tests (Rashidi & Seilsepour, 2008); it may be more suitable and economical to develop a method, which determines soil SAR indirectly from a more simple soil salinity index such as soil EC.

For almost 50 years many attempts have been made to predict some complex soil properties from some easily available soil properties using empirical models. In soil science, such empirical models are named pedotransfer functions (MacDonald, 1998; Krogh *et al.*, 2000).

Up to now many of the pedotransfer functions have been developed to predict various soil properties. MacDonald (1998) developed two pedotransfer functions to predict soil Cation Exchange Capacity (CEC) based on soil Organic Carbon (OC) and soil Clay (CL) content (% by weight) as CEC = 2.0 OC + 0.5 CL and CEC = 3.8 OC + 0.5 CL for Quebec and Alberta soil state in Canada, respectively. Seilsepour and Rashidi (2008b) studied Varamin soils in Iran and proposed a pedotransfer function to predict soil Cation Exchange Capacity (CEC) based on soil Organic Carbon (OC) and soil pH as CEC = 26.76 + 8.06 OC – 2.45 pH with R^2 = 0.77. Seilsepour and Rashidi (2008a) also predicted soil Cation Exchange Capacity (CEC) from soil Organic Carbon (OC) using the pedotransfer function CEC = 7.93 + 8.72 OC with R^2 = 0.74

To cite this paper: RASHIDI, M. AND M. SEILSEPOUR, 2008. Sodium adsorption ratio pedotransfer function for calcareous soils of varamin region. *Int. J. Agri. Biol.*, 10: 715–8

for Varamin soils in Iran. The United States Salinity Laboratory (USSL) proposed one of the earlier pedotransfer function to predict soil Exchangeable Sodium Percentage (ESP) from soil Sodium Adsorption Ratio (SAR) as ESP = – 0.0126 + 0.01475 SAR for United States soils (Richards, 1954). Moreover, Rashidi and Seilsepour (2008) developed a pedotransfer function to predict soil Exchangeable Sodium Percentage (ESP) based on soil Sodium Adsorption Ratio (SAR) as ESP = 1.95 + 1.03 SAR with R^2 = 0.92 for Varamin soils in Iran. Previously researches also report a relationship between soil SAR and soil EC (Richards, 1954; Levy & Hillel, 1968; Emerson & Bakker, 1973). Thus, soil EC can be used to approximate or estimate soil SAR. In this direction, Al-Busaidi and Cookson (2003) suggested a pedotransfer function as SAR = 0.464 EC + 7.077 with R^2 = 0.83 for saline soils in Oman.

Since, the above pedotransfer functions have been derived from different saline-zone soils, the general pedotransfer functions between soil properties may be assumed to be similar to those. However, these pedotransfer functions have been shown not to be constant, but to vary substantially with both solution ionic strength and the dominant clay mineral present in the soil (Shainberg *et al.*, 1980; Nadler & Magaritz, 1981; Marsi & Evangelou, 1991; Evangelou & Marsi, 2003; Rashidi & Seilsepour, 2008). Therefore, the pedotransfer functions are not constant and should be determined directly for the soil of interest.

Despite the considerable amount of research done, which shows the relationship between soil SAR and soil EC, very limited work has been conducted to develop a soil SAR pedotransfer function based on soil EC. Therefore, the specific objective of this study was to develop a SAR pedotransfer function based on EC for calcareous soils of Varamin region in Iran and to verify the developed pedotransfer function by comparing its results with those of the laboratory tests.

MATERIALS AND METHODS

Experimental procedure. Fifty-one soil samples were taken at random from different fields of experimental site of Varamin, Iran. The site is located at latitude of 35°-19'N and longitude of 51°-39'E and is 1000 m above mean sea level, in arid climate in the center of Iran. The soil of the experimental site was a fine, mixed, thermic, Typic Haplocambids clay-loam soil.

In order to obtain required parameters for determining a soil SAR pedotransfer function, some soil physical and chemical properties i.e., sand, silt and clay content (% by weight) and pH, EC, Na^+, Ca^{2+}, Mg^{2+} and SAR of the soil samples were measured using laboratory tests as described by the Soil Survey Staff (1996).

Also, in order to verify the soil SAR pedotransfer function by comparing its results with those of the laboratory tests, fifteen soil samples were taken at random from different fields of the experimental site. Again, sand, silt and clay content (% by weight) and pH, EC, Na^+, Ca^{2+}, Mg^{2+} and SAR of the soil samples were determined using laboratory tests as described by the Soil Survey Staff (1996).

Regression model. A typical linear regression model is shown in Equation 2:

$$Y = k_0 + k_1 X \qquad (2)$$

Where:

Y = Dependent variable, for example SAR of soil.

X = Independent variable, for example EC of soil.

k_0, k_1 = Regression coefficients.

In order to develop the soil SAR pedotransfer function based on soil EC, a linear regression model as Equation 2 was suggested.

Statistical analysis. A paired samples t-test and the mean difference confidence interval approach were used to compare the soil SAR values predicted using the soil SAR pedotransfer function with the soil SAR values measured by laboratory tests. The Bland-Altman approach (1999) was also used to plot the agreement between the soil SAR values measured by laboratory tests with the soil SAR values predicted using the soil SAR pedotransfer function. The statistical analyses were performed using Microsoft Excel (Version 2003).

RESULTS AND DISCUSSION

Physical and chemical properties of the fifty-one soil samples used to determine the soil SAR pedotransfer function are shown in Table I. Physical and chemical properties of the fifteen soil samples used to verify the soil SAR pedotransfer function are also shown in Table II.

The p-value of the independent variable, Coefficient of Determination (R^2) and Coefficient of Variation (C.V.) of the soil SAR pedotransfer function is shown in Table III. Based on the statistical result, the soil SAR pedotransfer function was judged acceptable. The R^2 value and C.V. of the soil SAR pedotransfer function were 0.69 and 23.8%, respectively. The soil SAR pedotransfer function is given in Equation 3:

$$SAR = 1.91 + 0.68\ EC \qquad (3)$$

A paired samples t-test and the mean difference confidence interval approach were used to compare the soil SAR values predicted using the soil SAR pedotransfer function with the soil SAR values measured by laboratory tests. The Bland-Altman approach (1999) was also used to plot the agreement between the soil SAR values measured by laboratory tests with the soil SAR values predicted using the soil SAR pedotransfer function.

The soil SAR values predicted by the soil SAR pedotransfer function were compared with the soil SAR values determined by laboratory tests and are shown in Table IV. A plot of the soil SAR values determined by the soil SAR pedotransfer function and laboratory tests with the line of equality (1.0: 1.0) is shown in Fig. 1. The mean soil

Table I. The mean values, Standard Deviation (S.D.) and Coefficient of Variation (C.V.) of soil physical and chemical properties of the fifty-one soil samples used to develop the soil SAR pedotransfer function

Parameter	Minimum	Maximum	Mean	S.D.	C.V. (%)
Sand (%)	14.0	44.0	33.1	6.31	19.1
Silt (%)	30.0	56.0	45.3	4.13	9.12
Clay (%)	9.00	50.0	22.0	6.65	30.2
pH	7.00	8.10	7.50	0.27	3.60
EC (dS m^{-1})	0.25	14.4	6.91	3.53	51.0
Na^+ (cmol kg^{-1})	3.00	96.0	42.6	24.6	57.6
$Ca^{2+} + Mg^{2+}$ (cmol kg^{-1})	5.60	81.0	42.7	19.2	45.1
SAR (cmol $kg^{-1})^{0.5}$	1.50	11.8	6.64	2.91	43.9

Table II. The mean values, Standard Deviation (S.D.) and Coefficient of Variation (C.V.) of soil physical and chemical properties of the fifteen soil samples used to verify the soil SAR pedotransfer function

Parameter	Minimum	Maximum	Mean	S.D.	C.V. (%)
Sand (%)	10.0	34.0	24.1	5.87	24.4
Silt (%)	40.0	56.0	48.2	4.40	9.13
Clay (%)	18.0	50.0	28.2	7.90	28.0
pH	7.00	8.00	7.31	0.33	4.51
EC (dS m^{-1})	0.40	14.0	7.26	4.67	64.3
Na^+ (cmol kg^{-1})	3.00	96.0	44.2	30.6	69.3
$Ca^{2+} + Mg^{2+}$ (cmol kg^{-1})	5.20	84.0	40.1	26.4	65.8
SAR (cmol $kg^{-1})^{0.5}$	1.90	11.8	6.78	3.30	48.7

Table III. The p-value of independent variable, Coefficient of Determination (R^2) and Coefficient of Variation (C.V.) of the soil SAR pedotransfer function

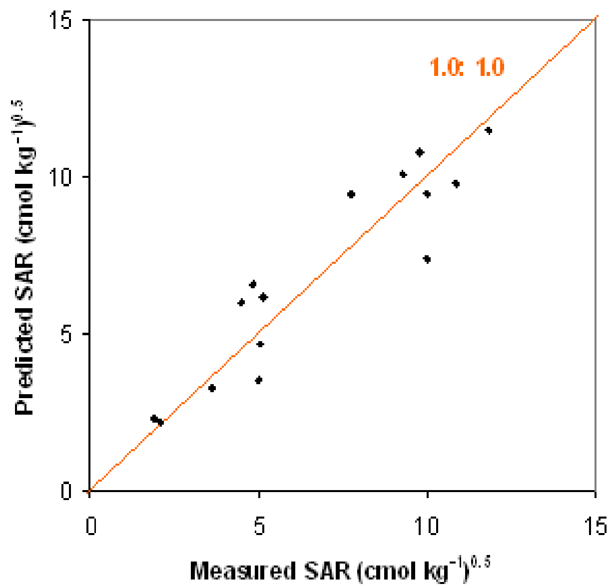
Pedotransfer function	Independent variable	p-value	R^2	C.V. (%)
$SAR = k_0 + k_1 EC$	EC	5.93E-14	0.69	23.8

Table IV. Chemical properties of soil samples used in evaluating the soil SAR pedotransfer function

Sample No.	EC (dS m^{-1})	SAR (cmol $kg^{-1})^{0.5}$ Laboratory test	SAR (cmol $kg^{-1})^{0.5}$ Pedotransfer function
1	0.60	1.90	2.30
2	0.40	2.10	2.20
3	6.80	4.90	6.60
4	2.00	3.60	3.30
5	6.00	4.50	6.00
6	4.00	5.00	4.60
7	2.30	5.00	3.50
8	6.20	5.10	6.20
9	11.0	7.70	9.50
10	11.0	10.0	9.40
11	13.0	9.80	10.8
12	12.0	9.30	10.1
13	11.5	10.9	9.80
14	8.00	10.0	7.40
15	14.0	11.8	11.5

SAR difference between two methods was -0.11 (cmol $kg^{-1})^{0.5}$ (95% confidence interval: -0.80 and 0.60 (cmol $kg^{-1})^{0.5}$; P = 0.747). The standard deviation of the soil SAR differences was 1.26 (cmol $kg^{-1})^{0.5}$. The paired samples t-test results showed that the soil SAR values predicted with the soil SAR pedotransfer function were not significantly different than the soil SAR measured with laboratory tests (Table V). The soil SAR differences between these two methods were normally distributed and 95% of the soil SAR differences were expected to lie between $\mu+1.96\sigma$ and $\mu-1.96\sigma$, known as 95% limits of agreement (Bland & Altman, 1999; Rashidi & Gholami, 2008; Rashidi & Seilsepour, 2008; Seilsepour & Rashidi, 2008a,b). The 95% limits of agreement for comparison of soil SAR determined with laboratory test and the soil SAR pedotransfer function were calculated at -2.57 and 2.36 (cmol $kg^{-1})^{0.5}$ (Fig. 2). Thus, soil SAR predicted by the soil SAR pedotransfer function may be 2.57 (cmol $kg^{-1})^{0.5}$ lower or 2.36 (cmol $kg^{-1})^{0.5}$ higher than soil SAR measured by laboratory test. The average percentage differences for soil SAR prediction using the soil SAR pedotransfer function and laboratory test was 16.5%.

Fig. 1. Measured SAR and predicted SAR using the soil SAR pedotransfer function with the line of equality (1.0: 1.0)



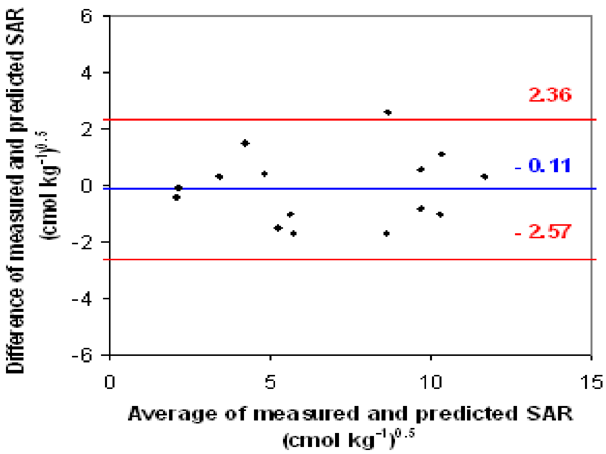
CONCLUSION

A linear regression pedotransfer function based on Electrical Conductivity (EC) was used to predict Sodium Adsorption Ratio (SAR) of calcareous soils of Varamin region in Iran. The soil SAR values predicted using the soil SAR pedotransfer function was compared to the soil SAR values measured by laboratory tests. The paired samples t-test results indicated that the difference between the soil SAR values predicted by the soil SAR pedotransfer function and measured by laboratory tests were not statistically significant (P > 0.05). Therefore, the soil SAR pedotransfer function can provide a short, simple and economical method to estimate soil SAR.

Table V. Paired samples t-test analyses on comparing soil SAR determination methods

Determination methods	Average difference (cmol kg^{-1})$^{0.5}$	Standard deviation of difference (cmol kg^{-1})$^{0.5}$	p-value	95% confidence intervals for the difference in means (cmol kg^{-1})$^{0.5}$
Laboratory test and pedotransfer function	-0.11	1.26	0.747	-0.80, 0.59

Fig. 2. Bland-Altman plot for the comparison of measured SAR and predicted SAR using the soil SAR pedotransfer function; the outer lines indicate the 95% limits of agreement (-2.57, 2.36) and the center line shows the average difference (-0.11)



Acknowledgement. The financial support provided the Agricultural Extension, Education and Research Organization of IRAN under research award number 100-15-76048 is gratefully acknowledged.

REFERENCES

Ahmad, S., A. Ghafoor, M. Qadir and M.A. Aziz, 2006. Amelioration of a calcareous saline-sodic soil by gypsum application and different crop rotations. *Int. J. Agri. Biol.*, 8: 142–6

Al-Busaidi, A.S. and P. Cookson, 2003. Salinity-pH relationships in calcareous soils. *Agricultural and Marine Sci.*, 8: 41–6

Banaei, M.H., A. Moameni, M. Bybordi and M.J. Malakouti, 2005. *The Soil of Iran: New Achievements in Perception, Management and Use*. SANA Publishing, Tehran, Iran

Bland, J.M. and D.G. Altman, 1999. Measuring agreement in method comparison studies. *Stat. Methods Med. Res.*, 8: 135–60

Emerson, W.W. and A.C. Bakker, 1973. The comparative effects of exchangeable calcium, magnesium and sodium on some physical properties of red-brown earth sub-soils. II. The spontaneous dispersion of aggregates in water. *Australian J. Soil Res.*, 11: 151–7

Evangelou, V.P. and M. Marsi, 2003. Influence of ionic strength on sodium-calcium exchange of two temperate climate soils. *Plant Soil*, 250: 307–13

Krogh, L., H. Breuning and M.H. Greve, 2000. Cation exchange capacity pedotransfer function for Danish soils. *Soil Plant Sci*., 50: 1–12

Levy, R. and D. Hillel, 1968. Thermodynamic equilibrium constants of sodium-calcium exchange in some Israel soils. *Soil Sci.*, 106: 393–8

MacDonald, K.B., 1998. *Development of Pedotransfer Functions of Southern Ontario Soils*, pp: 1–23. Report from greenhouse and processing crops research center. Harrow, Ontario, No.: 01686-8-0436

Marsi, M. and V.P. Evangelou, 1991. Chemical and physical behavior of two Kentucky soils: I. Sodium-calcium exchange. *J. Environmental Science and Health, Part A: Toxic-Hazard. Subs. Environ. Engg*., 267: 1147–76

Nadler, A. and M. Magaritz, 1981. Expected deviations from the ESP-SAR empirical relationships in calcium and sodium-carbonate-containing arid soils: field evidence. *Soil Sci*., 131: 220–5

Page, A.L., R.H. Miller and D.R. Keeney, 1982. *Methods of Soil Analysis, Chemical and Microbiological Properties*. Madison, Wisconsin, USA.

Quirk, J.P., 2001. The significance of the threshold and turbidity concentrations in relation to sodicity and microstructure. *Australian J. Soil Res.*, 39: 1185–217

Rashidi, M. and M. Gholami, 2008. Determination of kiwifruit volume using ellipsoid approximation and image-processing methods. *Int. J. Agri. Biol.*, 10: 375–80

Rashidi, M. and M. Seilsepour, 2008. Modeling of soil exchangeable sodium percentage based on soil sodium adsorption ratio. *J. Agri. Biol. Sci*., 3: 22–6

Rengasamy, P. and G.J. Churchman, 1999. Cation exchange capacity, exchangeable cations and sodicity. *In*: Peverill, K.I., L.A. Sparrow and D.J. Reuter (eds.), *Soil Analysis: an Interpretation Manual.* CSIRO Publishing, Collingwood

Richards, L.A., 1954. *Diagnosis and Improvement of Saline and Alkali Soils*. United States Department of Agriculture, Washington, DC

Seilsepour, M. and M. Rashidi, 2008a. Modeling of soil cation exchange capacity based on soil colloidal matrix. *American-Eurasian J. Agric. Environ*. Sci., 3: 365–9

Seilsepour, M. and M. Rashidi, 2008b. Prediction of soil cation exchange capacity based on some soil physical and chemical properties. *World Appl. Sci. J.*, 3: 200–5

Shainberg, I., J.D. Oster and J.D. Wood, 1980. Sodium-calcium exchange in montmorillonite and illite suspensions. *Soil Sci. Soc. America J*., 44: 960–4

Soil Survey Staff, 1996. *Soil Survey Laboratory Methods Manual*. Soil Survey Investigations Rep. 42. Version 3.0. U.S. Govt. Print, Washington, DC

Sumner, M.E., 1993. Sodic soils: new perspectives. *Australian J. Soil Res.*, 31: 683–750

Tanwir, F., A. Saboor and N. Nawaz, 2003. Soil salinity and the livelihood strategies of small farmers: a case study in Faisalabad district, Punjab, Pakistan. *Int. J. Agri. Biol.,* 5: 440–1

(Received 19 May 2008; Accepted 9 September 2008)