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Modeling water retention characteristics of major shrink-swell soils of Jalgaon district, Maharashtra, India

A.S. GAJARE, D.K. MANDAL[1], NIRMAL KUMAR[1] AND JAGDISH PRASAD[1]

Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola 444104
[1]ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur-440 033, India

Abstract: The soil water retention and release characteristics help in modelling hydrological process, irrigation-rainwater management planning, soil-plant-water relationship, crop modelling *etc*. However, data on soil water retention release characteristics are not easily available because conventional methods of measurement are very difficult, time consuming and expensive. Therefore, it is imperative to adopt indirect estimation technique, so called Pedo Transfer Function (PTF). Most of the PTFs reported are derived from complex mathematical algorithm. It is imperative to develop simplified approach for PTF. With objective of developing simplified regression-based PTF model the present investigation was undertaken for the major shrink-swell soils of Jalgaon district of Maharashtra. Ten soil pedons from representative major physiographic units namely hill ridges, table land, upper piedmont, lower piedmont, piedmont plain, river terrace and dissected flood plains were selected for study. The soil properties were determined according to standard laboratory techniques. The soils belong to the order of Vertisols, Inceptisols and Entisols. The soils are clayey, slightly acidic to mildly alkaline in reaction, low to medium in OC content, calcareous and having moderate shrink-swell potential. The soil water retention at different suctions was determined using Troxller® pressure plate apparatus. Multiple stepwise regression technique was used to work out the coefficients for each model developed for soil water content at different suctions namely -33kPa, -300 kPa, -500 kPa, -1000 kPa, -1500 kPa and soil properties. The developed PTF indicated that water content at different suctions mainly depends on sand, silt and BD (bulk density) for swell-shrink soils. The high R^2 values of all the developed PTF indicate their applicability in evaluating soil water content from soil properties for major cotton growing soils of Jalgaon district.

Key words: *Soil water retention, Pedo Transfer Function*

Introduction

The dynamic crop simulation models often require input parameters and soil physical properties which are difficult to measure directly as it consumes a lot of time and resources. Therefore, efforts have been made to establish relationship between different easily measurable parameters and properties that are not available which are called as pedotransfer function (PTF). Singh *et al*. (2004) reported that soil science discipline needs PTF development of major soil physical properties through database management. Several PTFs have been developed from particle size distribution, bulk density and organic matter content for soils (Abrol *et al*. 1968; Bloemen 1980; Briggs and Shantz 1912; Burrows and Kirkham 1958; Gupta and Larson 1979; Kaur *et al*. 2002; Mckeague *et al*. 1982; Patil *et al*. 2013; Salter *et al*. 1966). Analogue approach like k Nearest neighbor (kNN) (Lall and Sharma 1996; Lakzian *et al*. 2010; Rajagopalan and Lall 1999) and Artificial Neural Network (ANN) (Jain *et al*. 2004; Minasny *et al*. 1999; Minasny and Mc Bratney 2002; Schaap *et al*. 1998) is another alternative preferred by the researchers. All these methods require complex mathematical computation of various constants used in these methods. Therefore, attempt has been made to develop simplified regression-based PTF model. So far, PTF for soil water retention at different suctions for shrink-swell soils of Jalgaon district has not been reported. In the present study an attempt has been made to develop relationship between soil moisture content at various soil moisture suctions and easily measurable soil properties. The developed PTFs will help for crop growth modeling, water management research and determining irrigation scheduling.

Materials and Methods

The study area, Jalgaon district of Maharashtra lies between 20^o and 21^o N latitude and 74^{o}55' and 76^{o}28' E longitude (Official Website 2015). The district has been divided into seven distinct physiographic units, namely, hill ridges, table land, upper piedmont, lower piedmont, piedmont plain, river terrace, dissected flood plains (Fig. 1). Total ten soil pedons of swell-shrink soils representing each of physiographic unit were selected for the study. Soil pedons were collected from soil catena (Fig.1) representative of major soils of Jalgaon district. The catena falls in the tehsil of Chopda where most of the catena is raised. The Particle size distribution (Sand, silt and clay content) was determined by international pipette method (Jackson 1979). The bulk density (dry clod) was determined by clod coating method and organic carbon content was determined by Walkley and Black method (Black 1965). The water retention characteristics were measured by Troxller pressure plate apparatus (Jackson 1973) for moisture content at -33 kPa (field capacity), -300 kPa, -500 kPa, -1000 kPa and -1500 kPa (wilting point). Different combinations of soil properties and moisture contents at these five matric potential were correlated by regression analysis. The PTFs are classified as point estimation, parametric estimation and physico-empirical models (Singh 2004). We developed point PFTs, which usually perform better than the parametric approach (Tomasella *et al*. 2003), The following six models were used for soil water retention studies:

$Y = a + b_1*c + b_2*si$ ……… (1)

$Y = a + b_1*s + b_2*d$ …….. (2)

$Y = a + b_1*c + b_2*si + b_3*d$ …… (3)

$Y = a + b_1*c + b_2*si + b_3*s$ ...….. (4)

$Y = a + b_1*c + b_2*si + b_3*s + b_4*d$ …… (5)

$Y = a + b_1*c + b_2*si + b_3*s + b_4*o + b_5*d$ …… (6)

Where, Y is the volumetric water content at a given matric potential, s is sand (%), si is silt (%), c is clay (%), d is bulk density (Mg m^{-3}), o is organic carbon (%) and a is constant, while b_1, b_2, b_3, b_4 and b_5 are the regression coefficients. Multiple and stepwise regression technique were used to work out the coefficients in the various models and evaluate the relative importance of the soil properties on water retention. The Multiple and stepwise regression techniques was done SPSS (2004) software

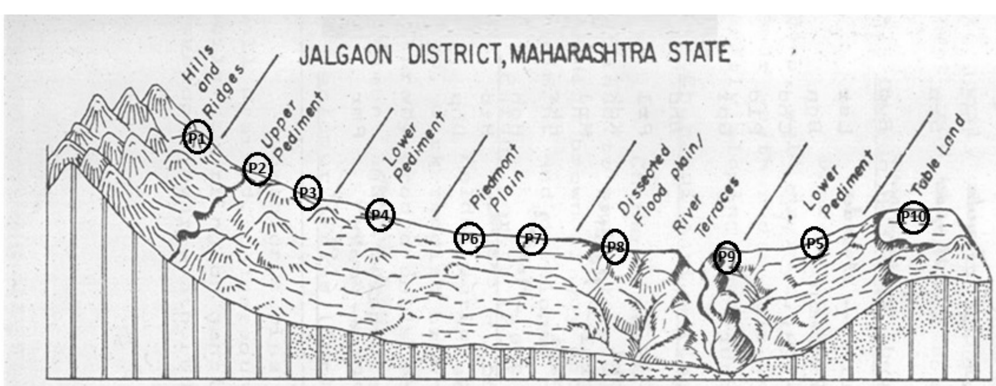


Fig.1. Physiographic units, Jalgaon district, Maharashtra
(P1, P2, P3, P4, P5, P6, P7, P8, P9, P10 – soil pedons (Part of Ph.D work)

Results and Discussion

The soil morphometric data revealed that Typic Haplusterts occupies lower topography as observed in most of the Vertisols of the peninsular plateau. Inceptisol occupies the higher-elevated topography, whereas, pediment and piedmont plains are occupied by medium and deep Vertisols. The soil characteristics namely, sand, silt, clay, bulk density, organic carbon and moisture retention at different matric potentials are presented in Table 1. Entisols (P1) is restricted to 25 cm depth. Sand, silt and clay content varied from 37.4 to 39.2%, 26.0 to 27.3% and 33.5 to 36.6%, respectively. Organic carbon (OC) ranged from 0.44 to 0.53% and bulk density varied from 1.41 to 1.42 Mg/m^3. Moisture content at -33 kPa was 43.0 to 45.4% and at -1500 kPa it was 28.4 to 31.7%. The soils of upper pediment plains (P2, P3) are shallow with depth varying from 55 to 65 cm. The soils are *Typic Haplustepts* and *Vertic Haplustepts*. The sand content of these soils varies from 10.6 to 40.1%, silt 17.2 to 25.5% and clay from 40.9 to 70.0%. OC ranges from 0.26 to 0.55% whereas bulk density varies from 1.29 to 1.42 Mg/m^3. Moisture content at -33 kPa and at -1500 kPa ranged from 47.1 to 52.1% and 27.3 to 37.0%, respectively. The lower pediment soils are classified as *Lithic Haplustepts* (P4) and *Vertic Haplustepts* (P5) having depth varying from 50 to 65 cm. sand, silt and clay content varied from 10.6% to 39.6%, 18.0% to 23.4% and 38.1 to 70.1%, respectively. OC ranged from 0.13 to 0.54%, bulk density varied from 1.25 to 1.43 Mg/m^3 whereas moisture content were ranged from 48.6 to 54.4 and 33.6 to 40.8% at -33 kPa and -1500 kPa, respectively. The soils from piedmont plain (P6, P7) were very deep (120 to 140 cm.), classified as *Typic Haplusterts*. sand, silt and clay content ranged from 15.3 to 27.5%, 19.1 to 26.8% and 47.1 to 64.3%, respectively, OC varied from 0.28 to 0.46%, bulk density varied from 1.26 to 1.35 Mg/m^3 and moisture content at -33 kPa and -1500 kPa were ranged from 48.6 to 54.4 and 33.6 to 40.8%, respectively. The dissected flood plain soils are classified as *Typic Haplustepts* (P8) having depth up to145 cm. Sand, silt and clay varied from 27.9 to 43.0%, 23.7% to 35.5% and 33.3 to 36.9%, respectively. OC was 0.31 to 0.49%, bulk density ranged between 1.37 to 1.44 Mg/m^3. Moisture content at -33 kPa ranged between 44.6 to 46.1% and at -1500 kPa it was 28.8 to 31.4%. The soils of river terraces (P9) was deep and classified as *Typic Haplustepts* where sand, silt and clay content ranged from 29.2 to 49.9%, 23.2 to 32.5% and 26.9 to 38.3%, respectively. OC was 0.15 to 0.54 %, bulk density was 1.37 to 1.47 Mg/m^3 and moisture content at -33 kPa varied between 40.4 to 45.2% and at -1500 kPa it was 24.8 to 30.6%. Table land soils were shallow in depth classified as *Vertic Haplustept* (P10). Sand, silt and clay content varied between 10.9 to 12.4%, 22.2 to 22.5% and 65.4 to 66.6%, respectively. OC ranged between 0.54 to 0.57%, bulk density was 1.33 Mg/m^3 and Moisture content at -33 kPa was 39.9% and at -1500 kPa moisture content varied between 22.3 to 23.3%.

Table 1. Characteristics of the soils

Depth(cm)	Sand (%)	Silt (%)	Clay (%)	O.C. (%)	BD (Mg/m^3)	Moisture content (%)				
						-33 kPa	-300 kPa	-500 kPa	-1000 kPa	-1500 kPa
Hill ridges										
P1: *Lithic Ustorthent*, Umarti										
0-9	39.2	27.3	33.5	0.44	1.42	45.4	37.6	35.5	32.0	28.4
9-25	37.4	26.0	36.6	0.53	1.41	43.0	38.1	35.3	33.1	31.7
Upper pediment										
P2: *Vertic Haplustept*, Dharangaon										
0-12	10.6	23.4	66.0	0.54	1.29	47.1	35.5	32.5	29.7	28.4
12-30	12.0	18.0	70.0	0.50	1.30	48.1	35.5	32.6	30.6	27.3
30-65	11.5	20.5	68.0	0.44	1.29	47.7	34.8	32.3	29.7	28.4
P3: *Typic Haplustept*, Lasur										
0-10	30.7	25.5	43.8	0.55	1.37	52.1	42.7	39.7	37.3	37.0
10-26	39.6	19.5	40.9	0.29	1.42	51.1	39.1	38.3	36.9	35.5
26-55+	40.1	17.2	42.7	0.26	1.42	49.7	44.0	39.8	39.1	36.9
Lower pediment										
P4: *Lithic Haplustept*, Parola										
0-15	39.6	22.3	38.1	0.27	1.43	48.6	39.3	37.2	35.0	33.6
15-50	31.1	18.7	50.2	0.13	1.36	54.4	46.2	44.9	42.2	40.8
P5: *Vertic Haplustept*, Khadki										
0-12	10.6	23.4	66.0	0.54	1.25	50.0	41.9	40.6	37.5	36.9
12-30	12.0	18.0	70.0	0.50	1.26	50.4	43.5	41.0	38.1	37.5
30-65	11.5	20.5	68.0	0.44	1.25	50.0	43.1	40.6	37.5	37.4
Piedmont plain										
P6: *Typic Haplustert*, Hated										
0-17	16.6	25.6	57.8	0.46	1.26	54.2	47.3	44.7	43.5	42.2
17-60	18.2	26.8	55.0	0.44	1.27	54.0	46.9	44.5	41.9	41.3
60-105	16.5	21.1	62.4	0.40	1.26	53.6	46.0	43.5	41.0	40.3
105-120	15.3	20.4	64.3	0.36	1.26	53.6	45.4	44.1	41.6	41.0
P7: *Typic Haplustert*, Hingona										
0-15	22.6	26.8	50.6	0.44	1.31	52.4	42.6	43.2	41.8	39.3
15-40	23.8	19.6	56.6	0.43	1.30	55.3	48.0	45.8	43.2	42.5
40-85	22.3	19.7	58.0	0.40	1.29	55.5	48.4	46.6	45.2	44.2
85-125	22.8	19.1	58.1	0.35	1.29	54.8	48.5	46.4	45.2	44.1
125-140	27.5	25.4	47.1	0.28	1.35	50.6	44.1	42.3	40.1	37.8
Dissected flood plain										
P8: *Typic Haplustept*, Bhava										
0-15	43.0	23.7	33.3	0.49	1.44	44.6	36.0	32.8	32.3	28.8
15-50	29.3	34.7	36.0	0.36	1.38	45.5	36.6	34.5	32.8	31.2
50-95	31.0	32.1	36.9	0.35	1.39	46.1	37.9	35.0	32.8	31.4
95-145+	27.9	35.5	36.6	0.31	1.37	44.8	37.8	35.1	33.3	31.0
River terraces										
P9: *Typic Haplustept*, Pimpri										
0-15	29.2	32.5	38.3	0.16	1.37	44.5	36.6	33.8	31.1	29.2
15-30	35.7	32.4	31.9	0.15	1.41	42.3	35.3	32.0	29.6	28.2
30-67	41.4	25.0	33.6	0.54	1.45	45.2	38.1	36.1	32.8	30.6
67-115	49.9	23.2	26.9	0.52	1.47	40.4	30.3	29.0	26.0	24.8
Table land										
P10: *Vertic Haplustept*, Bodvad										
0-14	10.9	22.5	66.6	0.57	1.33	39.9	30.3	26.6	24.1	22.3
14-30	12.4	22.2	65.4	0.54	1.33	39.9	30.5	26.7	24.2	23.3

The summery (range) of soil properties are presented in Table 2. The sand, silt and clay ranged from 10.6 to 49.9% (mean= 25.69%, Std. Deviation=11.72), 17.2 to 35.5% (mean=24.02 %, Std. Deviation= 5.01) and 26.9 to 70% (mean= 50.29%, Std. Deviation= 13.86) respectively. Dry bulk density ranged from 1.25 to 1.47 Mg/m^3 (mean=1.34%, Std. Deviation =0.07) while the range of organic C was 0.13 to 0.57% (mean= 48.59%, Std. Deviation= 4.75) of soil. The gravimetric moisture content of the soil samples varied from 39.9 to 55.5% (mean= 48.59%, Std. Deviation= 4.75) at -33 kPa, 30.3 to 48.5% (mean= 40.25%, S.D.= 5.43) at -300 kPa, 26.6 to 46.6% (mean= 37.91%, S.D.= 5.79) at -500 kPa, 24.1 to 45.2% (mean= 35.66%, S.D.= 5.97) at -1000 kPa and 22.3 to 44.2% (mean= 34.17%, S.D.= 6.29) at -1500 kPa.

Table 2. Mean and standard deviation (SD) of soil water content at different tensions and other soil properties

	Mean	Std. Deviation	Min	Max
Matric potential		Soil water content (%)		
-33 kPa	48.59	4.75	39.9	55.5
-300 kPa	40.25	5.43	30.3	48.5
-500 kPa	37.91	5.79	26.6	46.6
-1000 kPa	35.66	5.97	24.1	45.2
-1500 kPa	34.17	6.29	22.3	44.2
Soil parameter		Soil properties		
Sand (%)	25.69	11.72	10.6	49.9
Silt (%)	24.02	5.01	17.2	35.5
Clay (%)	50.29	13.86	26.9	70
O.C. (%)	0.41	0.12	0.13	0.57
Bulk density (Mg/m^3)	1.34	0.07	1.25	1.47

The regression equations developed (Table 3) between the moisture content (V/V) at different suction and sand, silt, clay, bulk density and organic carbon in soils are given with their corresponding coefficient of determination (R^2) values. The analysis indicated that the soil moisture content was positively correlated with clay and negatively with sand contents of soils at all the five suctions (Fig. 1, Table 3). Relationship of moisture contents at -33 kPa potential with per cent sand and silt content is quite strong, but with clay, moderate association was noticed. Relationship of moisture content at -33, -300, -500, -1000 and -1500 kPa with bulk density is quite strong while, no variation in trend in moisture content at various potentials could be explained with organic C content in soils. Soils with high organic C are expected to retain more moisture; however, in the present study the organic C was very low and also had short range of variation.

Table 3. Regression equations and R^2 values of different parameters

Soil properties	Matric potential (kPa)	Regression equations	Coefficient of determination R^2
Sand	-33	y = -0.674x + 58.47	R^2 = 0.074
	-300	y = -0.371x + 40.65	R^2 = 0.029
	-500	y = -0.296x + 36.94	R^2 = 0.021
	-1000	y = -0.232x + 33.96	R^2 = 0.014
	-1500	y = -0.312x + 36.37	R^2 = 0.028
Silt	-33	y = -0.446x + 45.71	R^2 = 0.179
	-300	y = -0.287x + 35.57	R^2 = 0.096
	-500	y = -0.260x + 33.88	R^2 = 0.090
	-1000	y = -0.249x + 32.90	R^2 = 0.088
	-1500	y = -0.248x + 32.52	R^2 = 0.097
Clay	-33	y = 1.121x - 4.192	R^2 = 0.147
	-300	y = 0.658x + 23.77	R^2 = 0.066
	-500	y = 0.556x + 29.17	R^2 = 0.054
	-1000	y = 0.481x + 33.12	R^2 = 0.043
	-1500	y = 0.561x + 31.10	R^2 = 0.064
OC	-33	y = -0.004x + 0.642	R^2 = 0.035
	-300	y = -0.005x + 0.625	R^2 = 0.057
	-500	y = -0.005x + 0.600	R^2 = 0.058
	-1000	y = -0.005x + 0.597	R^2 = 0.067
	-1500	y = -0.004x + 0.563	R^2 = 0.055
BD	-33	y = -0.008x + 1.735	R^2 = 0.315
	-300	y = -0.006x + 1.591	R^2 = 0.241
	-500	y = -0.005x + 1.555	R^2 = 0.225
	-1000	y = -0.005x + 1.525	R^2 = 0.199
	-1500	y = -0.005x + 1.526	R^2 = 0.243

Six multiple linear regression equations with different combinations of the soil parameters and moisture content at five matric potentials (-33, -300, -500, -1000 and -1500 kPa) are presented with their coefficient of determination (R^2) and standard error of estimates (SEE) in Table 4 and Fig. 2. At -33 kPa, prediction improves with the inclusion of more parameters. Clay and silt together resulted in R^2= 0.208, which remains same with inclusion of sand and improved to 0.738 with inclusion of sand+BD and 0.772 with clay+silt+BD and clay+silt+sand+BD while, it was further improved to 0.799 with clay+silt+sand+BD+OC together. Pore size distribution contributes maximum in determining the moisture retention at this potential, which mainly depends on soil structure and bulk density; thus, inclusion of bulk density could slightly improve the predictability. However, in our study, moisture retention characteristics were determined using sieved and air-dry soil samples and hence, bulk density effect might be ignored. Clay, silt and sand content of soils can be easily determined in the laboratory, its usability in obtaining moisture content at -33 kPa could be the most simple and quick option in practical application like scheduling irrigation.

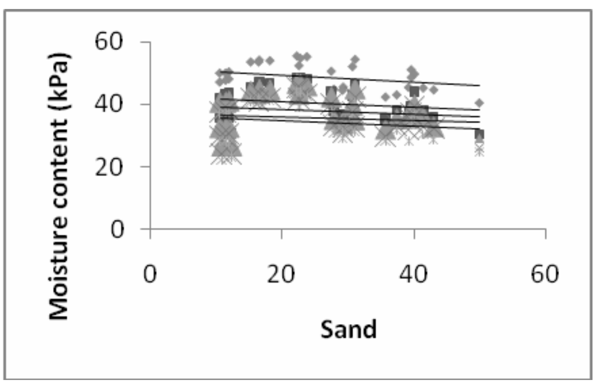
Table 4. Coefficients associated with different soil parameters, coefficient of determination and Standard error values of different tested models with soil water tensions

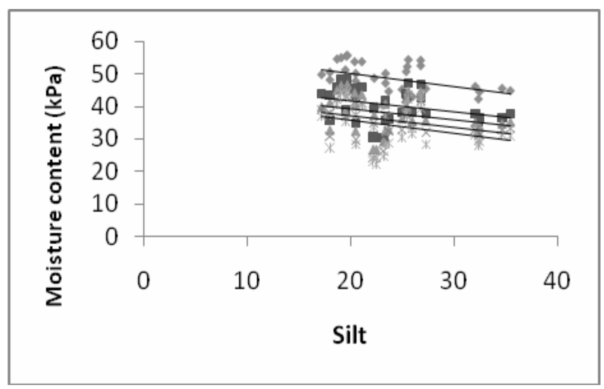
Matric potential		Coefficients associated with					constant	R^2	SEE
(kPa)	Eq	Clay (%)	Silt (%)	Sand (%)	OC (%)	BD (Mg/m^3)			
-33	1	0.072	-0.286	-	-	-	51.856	0.208	4.3658
	2	-	-	0.695	-	–149.736	231.932	0.738	2.5117
	3	-0.673	-0.859			–141.778	293.555	0.772	2.3832
	4	ex*	-0.359	–0.072			59.038	0.208	4.3658
	5	ex	-0.186	0.673		–141.778	226.293	0.772	2.3832
	6	ex	-0.219	0.610	-6.905	-133.852	220.840	0.799	2.2807
-300	1	0.046	-0.263				44.254	0.106	5.304
	2			0.911		-184.025	264.127	0.796	2.531
	3	-0.900	-0.991			-180.146	351.361	0.803	2.536
	4	ex	-0.309	-0.046			48.862	0.106	5.304
	5	Ex	-0.091	0.900		-180.146	261.378	0.803	2.536
	6	Ex	-0.126	0.834	-7.309	-171.756	255.607	0.825	2.429
-500	1	0.037	-0.289				42.975	0.960	5.695
	2			1.009		-201.004	282.071	0.824	2.513
	3	-0.999	-1.085			-197.308	379.34	0.829	2.522
	4	0.037	-0.289	ex			42.975	0.096	5.695
	5	Ex	-0.086	0.999		-197.308	279.451	0.829	2.522
	6	Ex	-0.12	0.935	-7.071	-189.191	273.868	0.848	2.42
-1000	1	0.023	-0.317				42.115	0.090	5.89
	2			1.047		-205.78	285.27	0.805	2.729
	3	-1.036	-1.132			-201.677	385.927	0.810	2.736
	4	Ex	-0.341	-0.023			44.446	0.090	5.89
	5	Ex	-0.096	1.036		-201.667	282.362	0.810	2.736
	6	Ex	-0.134	0.963	-7.997	-192.498	276.048	0.833	2.616
-1500	1	0.051	-0.312				39.095	0.106	6.149
	2			1.082		-217.679	298.882	0.826	2.711
	3	-1.069	-1.173			-213.255	402.647	0.832	2.711
	4	Ex	-0.362	-0.051			44.172	0.106	6.149
	5	Ex	-0.104	1.069		-213.255	295.747	0.832	2.711
	6	Ex	-0.141	0.998	-7.829	-204.269	289.566	0.852	2.596

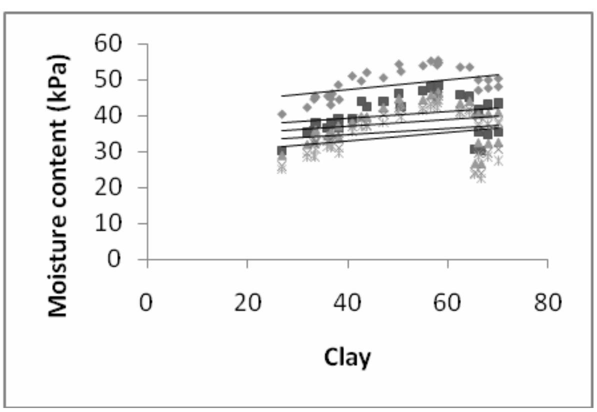
*ex: excluded from the equation

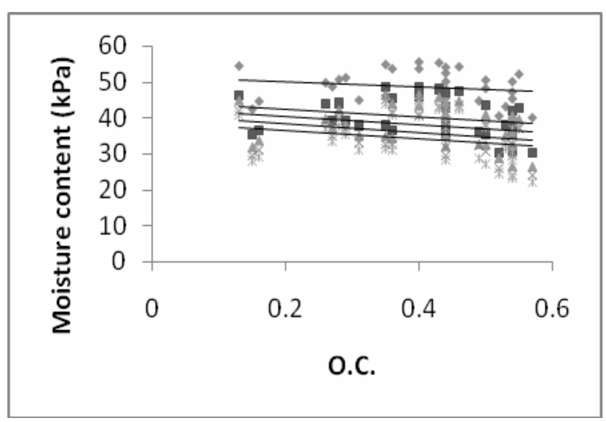
In case of predication of moisture at -300 kPa, R^2 improved with addition of more parameters. Equations 3 and 5 performed equally well with same R^2 (0.803) and comparable SEE (2.536 for equations 3 and 5, respectively). However, the predictive potential is better for eq. 6 (R^2 = 0.825 and SEE = 2.429) considering the comparable validation indices. This function has taken more parameters as compared to eq. 3 and 5. At -500 kPa potential, soil moisture content could be predicted most satisfactorily by using eq. 1 (R^2= 0.96, SEE= 5.695); inclusion of BD or sand and BD or BD, sand and OC could not improve the prediction with eq. 3 (R^2= 0.829, SEE= 2.522), eq. 2 (R^2= 0.824, SEE= 2.513) or 6 (R^2= 0.848, SEE= 2.42).

The moisture content at -1000 kPa potential, could be predicted using 2, 3, 5 and 6. However eq. 3 and 5 showed same effect (R^2= 0.81, SEE = 2.736). Prediction improved with eq. 6 (R^2= 0.833, SEE= 2.616), which can be considered as best equation for moisture content at -1000 kPa. As indicated by R^2 values, moisture content at -1500 kPa could be predicted well by equations 2, 3, 5 and 6. Linearity was the best with equation 6 (R^2= 0.852, SEE= 2.596) with inclusion of all parameters. At lower potential, *i.e.* towards the dry end of the moisture curve, moisture is retained mainly through the adsorptive forces, and thus related to the specific surface area and more of texture controlled. So moisture at this point could be best predicted by clay+silt content of soils. In either of the case, eq. 6, which included all the five parameters (% clay, silt and sand, per cent organic C and bulk density), could be chosen as the best PTF.









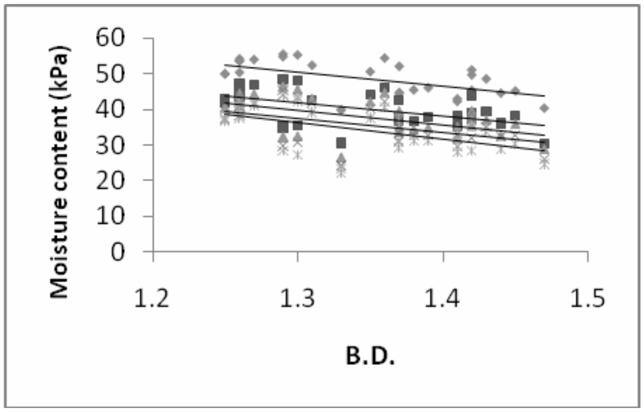


Fig 2. Relations between moisture content at –33, –300, –500, 1000 and –1 500 kPa and % clay, % sand, bulk density (Mg/ m) and % organic C

Development of PTFs at given matric potentials

Multiple and stepwise analysis were carried out to develop the regression equations for computation of moisture retention at different soil moisture tensions. It is very important to develop pedotransfer functions using easily measurable soil properties (Das and Singh 1989; Singh *et al*. 1992). The results revealed that the R^2 value at -33 kPa was 0.799 whereas, 0.825, 0.848, 0.833, 0.852 at -300 kPa, -500 kPa, -1000 kPa and -1500 kPa moisture tensions respectively. The high R^2 values (highly significant) for all developed PTFs showed their applicability in evaluating soil water content using minimum soil properties like dry bulk density (BD), sand, clay, and OC for shrink-swell soils of Jalgaon district.

The difference in the prediction potential of the PTFs at given matric potential might be due to role of structure in influencing the moisture retention at different matric potential. Considering all the evaluation indices, the present PTFs are most distantly related to De Jong *et al*. (1983). Relatively high sand (10.6 to 49.9%) and silt (17.2 to 35.5%) content in the evaluation data set resulted in better agreement with Bhavanarayana *et al*. (1986).

Table 5. Computation of pedo-transfer function (moisture retention characteristics) from easily measurable soil properties in Jalgaon district

Moisture tension at	Model equation	R^2 values
-33kPa	= 220.840 + 0.610*sand - 0.219*silt - 6.905*OC - 133.852*BD	R^2 = 0.799
-300 kPa	= 255.607 + 0.834*sand - 0.126*silt - 7.309*OC - 171.756*BD	R^2 = 0.825
-500 kPa	=273.868 + 0.935*sand - 0.120*silt - 7.071*OC - 189.191*BD	R^2 = 0.848
-1000 kPa	= 276.048 + 0.963*sand - 0.134*silt - 7.997*OC - 192.498*BD	R^2 =0.833
-1500 kPa	= 289.566 + 0.998*sand - 0.141*silt - 7.829*OC - 204.269*BD	R^2 = 0.852

Conclusion

The developed PTFs involving minimum number of easily measurable soil properties like sand, silt, clay, organic carbon and bulk density with high predictability indicates robustness of the method used to predict water content at different suctions of swell-shrink soils of Jalgaon district. However, more number of data point can be incorporated for fine tuning the present developed equations and improving the predictability and application efficiency.

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