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Use of various equations for modelling pF curve of soils of Jian, Muzaffarpur in Bihar

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Abstract

Soil water retention curves of three soil series, viz., Tauratola loam (Typic Ustochrept), Ghocha silt loam (Typic Ustochrept) and Dhublui silt loam (Fluventic Ustochrept) were modelled by five different approaches. The equation of 3rd degree ($pF = A + b\theta + c\theta^2 + d\theta^3$) with log of suction (pF) as the dependent and the volumetric water content as the independent variable, gave the best fit with an average R^2 value of 99.2 per cent. The power form of this relationship was also effective in describing this relationship (average R^2 was 98.7%) followed by inverse form ($pF = a + b\theta + C\ 1/\theta$) with an average R^2 values of 98.4 per cent for the prediction of pF over entire range of soil water suction.

Additional keywords: Moisture retention, soil moisture characteristic curve.

Introduction

Soil water retention characteristics is one of the most important hydrophysical properties of the soil and is important for optimum crop production and soil water management. Researchers (Ali *et al.* 1966; Singh 1982;Gardner *et al.* 1970) have proposed different types of relationship to describe soil water retention curve, varying from empirical to semi-empirical and analytical in nature. To predict water retention it is essential that models used should describe the retention curve over the entire range. In this study, the performance of five different models have been evaluated for their effectiveness in describing the pF curve of three soil series under Jian Minor of Gandak Command, Muzaffarpur.

Materials and methods

The experiment was carried out both in field and laboratory in the year 1991-92 for the soils of Jian Minor of Gandak Command located in Muzaffarpur district of North Bihar. The study was conducted in pre-established three different soil situation viz., upland, mid-land and lowland of Tauratola, Ghocha and Dhublui series. The Tauratola series is a member of coarse loamy, mixed, hyperthermic family of Typic Ustochrept. The Ghocha series is a member of coarse loamy, mixed, hyperthermic family of Typic Ustochrept and the Dhublui series is a member of coarse loamy, mixed hyperthermic family of Fluventic Ustochrept. The physico-chemical characteristics of surface (0-15 cm) soil are presented in Table 1. The various soil physical and chemical properties such as mechanical analysis by International Pipette method (Piper, 1966), bulk density using undisturbed cores (Biswas *et al.* 1961), organic carbon content (Walkley and Black rapid titration method (Jackson, 1978), calcium carbonate by rapid titration method were determined. Determination of moisture retention at different tensions were made with the help of pressure plate apparatus (Richards, 1954) to develop moisture characteristic curve (Fig. 1).

Five different models have been examined to describe the functional dependence of pF (logarithm of soil water suction expressed in cm) on the per cent volumetric soil water content. They are presented in Table 2. The magnitudes of a, b, c and d, the coefficients occurring in various equations differ from equation to equation (Table 3). These coefficients were estimated by the least square technique.

Table 1. Physical and chemical characteristics of surface (0-15 cm) soil

Parameter	Soil Series		
	Tauratola	Ghocha	Dhublui
pH (1:2)	8.70	8.90	8.40
EC (1:2) (dS m^{-1})	0.40	0.84	0.26
Organic Carbon (%)	0.56	0.39	0.65
Bulk density (g cm^{-3})	1.30	1.45	1.39
$CaCO_3$ (%)	8.80	46.80	35.70
Sand (%)	63.90	49.60	53.20
Silt (%)	23.60	37.70	31.80
Clay (%)	12.50	12.70	15.00
Porosity (%)	50.90	45.30	47.50
Texture	loam	silt loam	silt loam

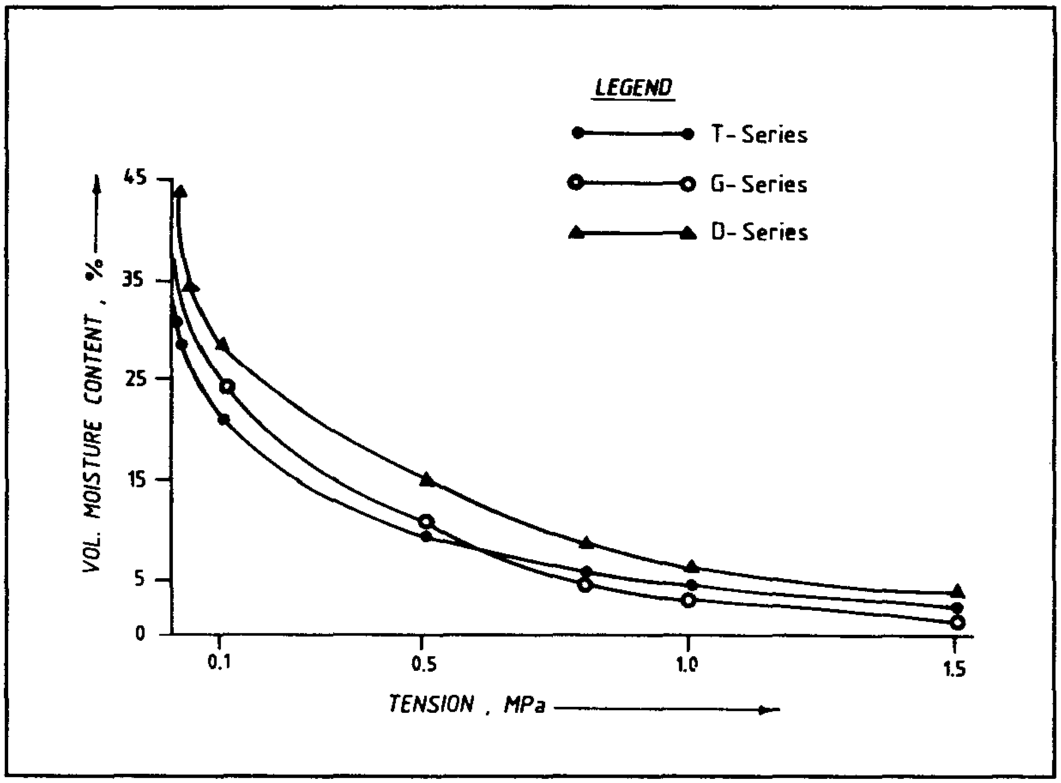

Fig. 1 Moisture retention curves of surface soil for Tauratola, Ghocha and Dhublui series

Table 2. Relationships used for modelling pF curve

Model	Functional Relationship
I	$pF = a + b\theta$; Ali *et al.* (1966)
II	$pF = a + b \log \theta$; Gardner *et al.* (1970)
III	$pF = a + b\theta + c\theta^2$;
IV	$pF = a + b\theta + c\theta^2 + d\theta^3$; Singh (1982)
V	$pF = a + b\theta + c (1/\theta)$; Singh (1989)

Where,

PF = log Ψ ; where Ψ is the soil water suction (cm), and

θ = soil water content

Results and discussion

The performance of various models in describing the soil water characteristic curve over the entire range is expressed in forms of R^2 values and the coefficients obtained by least square technique are given in Table 3. The results obtained show that R^2 values ranged from 88.9 to 99.5 per cent. It indicates that model IV, III and V have performed well giving the average percentage values of R^2 as 99.1, 98.7 and 98.3, respectively. The best fit is obtained by Model IV in all three soils.

The observed and calculated values obtained by above 5 models were compared by working out the slope and intercept values for all three soils series (Table 4). The polynomial form of 3rd degree (Model IV) has slope nearly unity (0.9399, 0.9145 and 1.0257) in Tauratola, Ghocha and Dhublui series, respectively. These soil series have extremely high correlation coefficient (0.9929, 0.9866, 0.9948) between the observed and predicted values indicating thereby a good fit for these soil series, respectively (Table 4). The results obtained for all the other models also followed trend indicated in Table 3. On an average Model I has performed better than Model II. The dependence of pF on soil water content as described by Model II was proposed by Gardner *et al.* (1970). They had obtained 'b' value as 4.3 for fine sandy loam, while Singh (1989) reported the value for sandy loam as 3.9. In case of loamy soil Singh (1989) reported the value of 'b' as 3.00. But the value of 'b' obtained in this study for loam is -2.0 (Table 3). Table 3 further indicates that the values of 'b' in Model II for silt loam in Ghocha series and Dhublui series varies from 1.60 to 2.09. The coefficients a, b of this relationship were related to silt and clay content of the soil.

Table 3. Least square coefficients in the various models of three different soil series for 0-15 cm soil depth

Model	Coefficients				
	a	b	c	d	R^2 (%)
		Tauratola series			
I	4.39	-6.9×10^{-2}	—	—	97.86
II	5.42	-2.00	—	—	88.90
III	4.22	-3.6×10^{-2}	-1.0×10^{-3}	—	98.40
IV	4.56	-1.36×10^{-1}	6.0×10^{-3}	-1.3×10^{-4}	99.22
V	4.47	-7.2×10^{-2}	-3.44×10^{-1}	—	97.88
		Ghocha series			
I	4.27	-5.3×10^{-2}	—	—	97.33
II	5.01	-1.60	—	—	89.90
III	4.19	-3.8×10^{-2}	-1.0×10^{-4}	—	98.20
IV	4.35	-8.9×10^{-2}	2.84×10^{-3}	-5.0×10^{-5}	98.69
V	4.27	-5.5×10^{-2}	-2.6×10^{-2}	—	97.93
		Dhublui series			
I	4.43	-5.3×10^{-2}	—	—	98.46
II	5.81	-2.09	—	—	91.50
III	4.32	-3.9×10^{-2}	-1.0×10^{-4}	—	99.50
IV	4.26	-2.6×10^{-2}	-9.1×10^{-4}	-7.0×10^{-6}	99.50
V	4.58	-5.7×10^{-2}	-8.76×10^{-1}	—	99.29

The Model III was effective in describing the relationship between pF and θ. Interestingly, the values of 'b' obtained in Model III in loam (Tauratola series), silt loam (Ghocha and Dhublui series) were negative, -0.036, -0.038 and -0.039, respectively (Table 3).

The polynomial form of 3rd degree (Singh, 1982) represented by Model IV was the most effective in describing the relationship between pF and θ (Table 3 and Table 4). It seems that models using higher degree of polynomial can describe the relationship with greater accuracy than other models using equations of lower degree polynomials.

Table 4. Comparison of observed and predicted values obtained by various models of three different soil series for 0-15 cm soil depth

	Model				
	I	II	III	IV	V
		Tauratola series (loam)			
Intercept	0.0863	0.3171	-0.0246	0.2299	0.0608
Slope	0.9750	0.9046	1.0033	0.9399	0.9810
R^2-value	0.9783	0.9045	0.9845	0.9920	0.9788
		Ghocha series (silt loam)			
Intercept	0.0990	0.4029	0.8993	0.3285	0.0362
Slope	0.9724	0.8789	0.7730	0.9145	0.9870
R^2-value	0.9793	0.8786	0.9810	0.9866	0.9794
		Dhublui series (silt loam)			
Intercept	0.0603	0.3265	0.7465	-0.1038	0.0151
Slope	0.9845	0.9018	1.8135	1.0257	0.9948
R^2-value	0.9914	0.9016	0.9935	0.9948	0.9929

The inverse polynomial form (Model V) was also found to be satisfactory in describing the pF curve. This relationship has not been tried out so far except by Singh (1989) who found this model (Model V) to be better than Model I and Model II. Based on mean R^2 value of 0.9837 the Model V can be rated as only inferior to Model III. Thus, there is need to examine the dependence and sensitivity of the coefficients involved in this expression on other properties of the soil to make it meaningful.

On the basis of five models tested for modelling the pF of the three soils, it can be concluded that the polynomial form of higher degree can be used satisfactorily to describe the pF and θ relationship.

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