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Evaluation of Soil Structure of Some Arid and Semi-Arid Soils of Rajasthan

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Six representative soil profiles of Rajasthan were examined for their structural properties, viz., hydraulic conductivity, water-holding capacity, % aggregate stability (> 0.25 mm), aggregate index, mean weight diameter and water-stable aggregates (> 0.25 mm). Limited correlations were observed between the structural indices and their related properties. Clay and clay plus silt content correlated significantly with water-holding capacity, hydraulic conductivity and % aggregate stability (> 0.25 mm). These three properties give a satisfactory estimate of soil structure.

Key Words: Physics—Chemical properties, Soil structure, Structure relationships

Introduction

Soil structure is a complex resultant component of a large number of biological, chemical and physical factors and a large number of workers (Dakshinamoorthy & Pradhan 1966, Biswns et al. 1971, Singh et al. 1975, Khanna et al. 1975) have evaluated the soil structure by analysing several physical properties and expressing the soil structure in the form of different single value constants but such an information on the soils of Rajasthan is inadequate. Attempts therefore have been made to (i) analyse some of the soil physical properties, (ii) correlate them with the soil structure indices and (iii) also to find out the best structural index to express the structure of these soils.

Materials and Methods

Thirty-two soil samples from different depths of six main representative soil profiles were

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collected from Panchayat Samiti Farm—Bharatpur (Pale Brown), 3rd milestone between Desuri and Pali (Reddish grey), near Arjia Farm—Bhilwara (Reddish-brown), near 7th milestone on Kota-Bundi Road (brown) and Tabiji farm—Ajmer (Reddish brown), Udaipur University Research Farm, Kushal Bagh, Udaipur (Reddish grey) (table 1). Bulk density was determined from soil clods by using crape rubber solution (Abrol & Palta 1968) particle density by Pycnometer Method (Dakshinamoorthy & Gupta 1968). Hydraulic conductivity by constant head method as described by Richards (1954), mechanical analysis by international Pippete Method, calcium carbonate by HCl titration Method, organic carbon by Walklay and Blake method, CEC by N-Ammonium Acetate method and water holding capacity were determined by Keen Box method as described by Piper (1950). The soil samples were analysed for water-stable aggregates according to Yoder's technique using sieve openings of 5.0, 2.0, 1.0, 0.5, 0.25 and 0.10 mm screen. The water-stable aggregates (>0.25 mm) mean weight diameter, aggregate index and per cent aggregate stablity (>0.25 mm) were determined as described by Dakshinamoorthy and Gupta (1968).

Results and Discussion

The structural properties of these soils show (table 2) that on the basis of particle size distribution these soils can be classified into three main categories viz. (i) clay loam (Udaipur and Kota), (ii) loam (Bharatpur and Pali) and (iii) Sandy loam (Ajmer and Bhilwara). On the basis of mechanical analysis, the clay and clay plus silt were in the order: Kota>Udaipur>Bharatpur>Pali>Bhilwara>Ajmer and this can be taken as an order of the textural fineness of these soils.

Hydraulic conductivity

According to the standard laid down for hydraulic conductivity by Tamhane et al. (1966)

Table 1 *Range of soil characteristics of the profiles*

Soil	Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Texture	*pH*	CEC meq/ 100 g	$CaCO_3$%	O.M.%
Bharatpur	0-149 (7)*	16.7–27.1	15.3–22.8	54.8–65.7	SL-SCL	7.9–8.4	10.6–14.3	1.0–3.0	0.22–0.40
Pali	0-83 (4)	18.2–23.0	13.0–15.5	62.5–67.0	SL-SCL	7.8–8.5	7.0–10.6	1.1–7.5	0.10–0.55
Bhilwara	0-127 (5)	16.2–20.2	8.8–13.7	67.8–71.6	SL-SCL	7.8–8.0	10.2–11.2	1.0–7.2	0.02–0.3
Kota	0.113 (5)	36.5–39.2	22.0–24.5	38.0–41.5	CL-C	7.9–8.1–	25.3–28.3	0.9–7.5	0.15–0.78
Ajmer	0-136 (6)	10.5–14.0	6.2–9.0	79.0–83.3	LS-SL	8.0–8.4	4.8–6.8	1.0–6.8	0.10–0.49
Udaipur	0-130 (5)	26.7–31.2	19.5–22.2	49.3–50.8	CL	8.2–8.5	12.2–14.0	2.1–21.9	0.02–0.40

No. of profile samples is given in parenthesis

Table 2 *Structural indices of some soil profiles of Rajasthan*

Depth (cm)	Hydraulic conductivity cm/min	Water holding capacity %	Percent aggregate stability >0.25	Mean weight diameter	Agg. index	Bulk density (g/cc)	Particle density
			Bharatpur				
0–15	0.019	28.0	6.00	0.207	0.037	1.60	2.33
15–37	0.010	28.5	5.28	0.330	0.050	1.57	2.34
37–60	0.015	28.4	6.21	0.220	0.047	1.62	2.19
60–82	0.010	28.9	8.90	0.265	0.054	1.64	2.38
82–105	0.005	29.2	9.04	0.341	0.057	1.67	2.33
105–127	0.004	29.6	10.30	0.288	0.050	1.70	2.42
127–149	0.004	30.0	15.58	0.334	0.077	1.75	2.43
			Pali				
0–15	0.049	22.2	5.77	0.657	0.053	1.68	2.42
15–37	0.045	22.8	8.88	0.646	0.096	1.71	2.46
37–60	0.049	22.9	17.00	0.727	0.097	1.72	2.48
60–83	0.045	22.8	18.38	0.977	0.077	1.86	2.45
			Bhilwara				
0–23	0.045	20.2	13.98	0.304	0.112	1.69	2.44
23–53	0.084	20.2	20.51	0.243	0.127	1.71	2.46
53–83	0.060	20.2	20.64	0.235	0.108	1.77	2.46
83–105	0.060	20.8	22.61	0.247	0.071	1.80	2.41
105–127	0.080	20.6	20.20	1.900	0.100	1.90	2.39
			Kota				
0–23	0.012	34.2	14.25	0.380	0.094	1.58	2.40
23–45	0.012	33.2	14.71	0.464	0.090	1.60	2.46
45–68	0.019	33.0	18.23	0.372	0.105	1.65	2.45
68–90	0.015	33.6	22.02	0.449	0.103	1.65	2.46
90–113	0.010	35.6	24.98	0.422	0.135	1.70	2.43
			Ajmer				
0–23	0.090	17.0	3.84	0.280	0.046	1.75	2.66
23–45	0.089	17.2	4.00	0.292	0.042	1.77	2.68
45–68	0.090	17.1	4.05	0.296	0.046	1.75	2.59
68–90	0.080	17.4	6.80	0.329	0.073	1.75	2.57
90–113	0.100	17.3	5.18	0.284	0.063	1.76	2.59
113–136	0.112	17.4	5.25	0.338	0.067	1.86	2.53
			Udaipur				
0–23	0.011	30.0	11.91	0.407	0.073	1.68	2.23
23–45	0.023	30.2	17.32	0.546	0.091	1.70	2.23
45–75	0.033	30.6	25.47	0.580	0.096	1.70	2.24
75–105	0.024	31.0	15.91	1.050	0.105	1.76	2.43
105–130	0.017	30.6	16.43	0.888	0.106	1.74	2.38

the soils of Bharatpur, Kota and Udaipur show moderate values and those of Pali, Bhilwara, and Ajmer are of moderate to rapid. Thus from the point of view of water transmission property, soils of Bharatpur and Kota are likely to show poor structure by virtue of their low water transmission property and that of Ajmer due to relatively faster water movement property. Hence, in Kota, besides the higher total clay content, its swelling characteristic upsets the water transmission property in the soil profile. It may, therefore, be concluded that the soils of Kota and Bharatpur are problematic in relation to low hydraulic conductivity and that of Ajmer to high hydraulic conductivity.

Water-holding capacity

The value for water-holding capacity (WHC) is maximum for Kota soil by virtue of its high clay contents and its swelling characteristics; and for Ajmer the value is extremely low. Both these extreme conditions are unfavourable for optimum moisture retention in the soil for a satisfactory crop growth. Lack of aeration on one hand, and low moisture retention on the other hand, are undesirable for maintaining a proper air-water relationship for the growing plants.

Water-stable aggregates

In case of water-stable aggregates (>0.25 mm) the soils of Udaipur, Pali and Bhilwara show a high value due to the presence of more coarse size particles particularly at the lower horizon.

Aggregate index

A high value of aggregate index and aggregate stability (>0.25 mm) for Bhilwara soil appears to be due to that only one crop is grown in a year and, therefore, it is less cultivated. Indications are there in literature that a virgin soil is more aggregated than the cultivated soil (Yao et al. 1967, Shankar Narayan et al. 1967).

On the basis of the mean value of all these structural indices, these soils can be arranged on the following order:

Hydraulic conductivity	=A>Bhi>P>U>K>Bha
Water-holding capacity	= K>U>Bha>P>Bhi>A
Water-stable aggregate >0.25 mm	=P>U>Bhi>K>A>Bha
Per cent aggregation stability>0.25 mm	= Bhi>K>U>P>Bha>A
Aggregate index	= K=Bhi>U>P>A>Bha

A, Ajmer; *Bha*, Bharatpur; *Bhi*, Bhilwara; *K*, Kota; *P*, Pali; *U*, Udaipur

It may be concluded that there is no clear-cut line of demarcation on quantitative basis for a particular physical property of these soils which could be applied. But a combination of WHC and HC clearly shows that retention and movement of water are governed by these properties. On the basis of these properties soils of Kota and Ajmer are of relatively poor structure. However, the other four types of soil viz. Pali, Bhilwara, Bharatpur and Udaipur may be classified as of moderate structure. Amongst these, soils of Pali and Bhilwara, are relatively better than those of Udaipur and Bharatpur in relation to soil structure.

Structural relationships

Clay, silt and organic matter contents form important contributing factors in influencing the soil structure except in laterite soils. Correlations of these properties with other structural properties of soils are presented in table 3. On the basis of the individual profile, hydraulic conductivity was positively correlated (r=0.998) with clay

plus silt content of pali soil and with the organic matter (r=0.815) content of Bharatpur soil. On combining all profiles together, the hydraulic conductivity was negatively correlated both with clay (r=—0.719) and clay plus silt content (r=—0.839) at 1% level with a degree of validity from 51.68 to 70.37%. This indicates that the clay plus silt content is one of the important soil property influencing hydraulic conductivity.

The WHC was also highly correlated (r=0.9214 to 0.9785) with the clay content

Table 3 *Coefficient of correlation between some structural indices and soil properties of some representative profiles of Rajasthan*

Soil properties	Properties and structural indices					
	Organic carbon	Hydraulic conductivity	Water-holding capacity	Percent agg. stability >0.25	Mean weight diameter	Aggregate index
			All profiles combined			
Clay	0.2584	—0.7189**	0.9102**	0.5388**	0.0301	0.3584*
Clay+Silt	0.2521	—0.8389**	0.9515**	0.5374**	0.0502	0.2408
Org. carbon	—	—0.2698	0.2468	—0.9600**	—0.4684**	—0.3895*
			Bharatpur			
Clay	0.4010	0.0430	0.2600	0.3010	0.9816**	0.5010*
Clay+Silt	0.2004	—0.5001	0.6085	0.8430*	0.2992	0.5610
Org. carbon	—	0.8151*	—0.8911**	—0.7701*	0.5010	—0.6860
			Pali			
Clay	—0.4810	0.1111	0.9418	0.8755	0.2010	0.8770
Clay+Silt	—0.6812	0.9982**	0.7501	0.9565*	0.5001	0.5610
Org. Carbon	—	0.6970	0.6420	—0.8489	—0.9393	0.3001
			Bhilwara			
Clay	0.8580	—0.7361	—0.5660	—0.4000	—0.8058	0.7448
Clay+Silt	0.0750	0.2001	—0.3412	—0.9503*	—0.2210*	0.0310
Org. Carbon	—	—0.6100	0.7298	—0.8465	—0.4274	0.9716**
			Kota			
Clay	—0.6794	—0.7010	0.9785**	0.5001	—0.1002	0.8099
Clay+Silt	—0.0670	0.1001	0.0040	—0.0902	—0.4005	0.2812
Org. Carbon	—	—0.0492	—0.4215	—0.9715**	—0.0009	0.8130
			Ajmer			
Clay	—0.8981*	0.3640	0.9214**	0.8410*	0.8119*	0.9236**
Clay+Silt	—0.5192	0.2010	0.5010	0.1210	0.5828	0.3010
Org. Carbon	—	—0.7105	—0.8118*	—0.5939	0.6829	—0.8032
			Udaipur			
Clay	—0.4010	0.6060	0.2610	0.8312	0.0250	0.8297
Clay+silt	—0.5350	0.8234	0.5002	0.8851*	0.2500	0.9239*
Org. Carbon	—	—0.3000	—0.7390	—0.4111	—0.8367	—0.7982

*Significant at 5% level
**Significant at 1% level

of Kota and Ajmer soil. It was also negatively correlated with the organic matter content of Bharatpur and Ajmer soil. On combining all profiles, the WHC was positively correlated with the clay content (r=0.9102) and more so with clay plus silt content (r=0.9515). This indicates that WHC of these soils can be predicted on the basis of clay plus silt content upto 90.5% degree of accuracy.

In case of % aggregate stability (>0.25 mm) it was positively correlated with clay plus silt content of Bharatpur, Pali, Bhilwara and Udaipur soils and only with clay content of Ajmer soil. However, it was also negatively correlated with organic carbon content of Kota and Bharatpur soils. The mean weight diameter of the soils was positively correlated with the clay content of Bharatpur and Ajmer and with clay plus silt content of Udaipur soil. It was also correlated with organic matter content of Bhilwara soil.

Amongst the main structural indices viz. per cent aggregate stability (>0.25mm), mean weight diameter and aggregate index, the per cent aggregate stability (>0.25mm) showed a much higher correlation with the clay and clay plus silt content than the other properties, and a negative correlation with the organic carbon (0.96). Inspite of the fact that correlations were at 1% level of significance, with the clay and clay plus silt contents, these are of limited practical utility as the degree of predictibility is only 29.0%. A positive correlation was also observed between clay and clay plus silt with aggregation properties earlier by Qumar et al. (1967) and others.

A wide range of correlations between the structural indices and the main soil properties capable of influencing the soil structure of each profile and also combining all together, suggest that soil analysis helps in evaluating soil structure but has some degree of limitation in actually assessing a single structural index. Possible reasons for the limited applicability of single structural index for the entire profile are (i) heterogeneous distribution of clay and silt content, (ii) their swelling characteristic during wetting and drying cycles, (iii) abrupt and nonuniform reduction in organic matter content, (iv) presence of large size lime concretions at the lower horizon and (v) wide variations between the quantity of the clay and its clay mineralogical composition.

Amongst the structural indices hydraulic conductivity, WHC and % aggregate stability (>0.25 mm) combined together appear to give a reasonable satisfactory picture of the relative structural properties of these representative soils of Rajasthan. On the basis of this structural properties and physical condition these soils can be arranged in the following descending order: Bhilwara> Pali>Bharatpur>Udaipur>Kota>Ajmer.

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