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Characterization of irrigated soils in Upper Wardha command area of Maharashtra

P. R. KADU, S. R. KANASKAR AND S. S. BALPANDE

Section of Soil Science and Agricultural Chemistry, College of Agriculture, Nagpur - 440 001, India

Abstract : Six typical pedons (irrigated) from Upper Wardha command area were characterized for physical and chemical properties. These soils (Typic Haplusterts and Sodic Haplusterts) have high clay content (51.1% to 62.5%), high water holding capacity (53 to 78 %) and saturated hydraulic conductivity of 0.01 to 3.82 cm hr^{-1}. These soils are calcareous, moderately to strongly alkaline in reaction, high in cation exchange capacity, dominated by exchangeable Ca followed by Mg, Na and K. Exchangeable sodium percentage and exchangeable magnesium percentage ranged from 0.5 to 19.2 and 20.4 to 57.5, respectively. The continuation of canal irrigation induced the sodification process in sub-soil and thereby reduced the hydraulic conductivity of these soils.

Additional key words: *Shrink-swell soils, irrigability, saturated hydraulic conductivity, exchangeable sodium percentage*

Introduction

Upper Wardha Project in Maharashtra is one of the biggest irrigation command areas and is dominated by shrink-swell soils (Typic Haplusterts and Sodic Haplusterts) of varying depths. Though irrigation is a major input in intensive agriculture for higher production, it may be harmful, if used indiscriminately for a longer time, particularly in Vertisols. The operation of irrigation project in such heavy black soils warrants systematic evaluation of soil properties. As, the Upper Wardha Project canal irrigation system was commissioned in 1997, the data generated may serve as a benchmark for monitoring and evaluating the temporal changes in soil characteristics periodically under different cropping systems on account of the introduction of perennial irrigation.

Materials and Methods

Six pedons were exposed in Ashti and Arvi tahsils of Upper Wardha command area (21° 10' to 21° 18' N, 78°5' to 78°15' E) and characterized for their morphological properties (Soil Survey Division Staff 1995). The pedons 1 to 5 (P1 to P5) are irrigated and pedon 6 is un-irrigated. The average elevation of the study area varies from 310 to 400 m from mean sea level. Geology of the area mainly consists of Deccan Trap basalt and soils of the area are developed from basaltic alluvium. The climate of the study area is semi-arid, sub-tropical with an annual rainfall of 979 mm. The horizon-wise soil samples were analysed for mechanical composition following international pipette method (Piper 1966). The saturated hydraulic conductivity was determined by the constant head method (Richards 1954) using a permeameter. The fine earth fractions (< 2 mm) were analysed for pH, cation exchange capacity (CEC) and exchangeable cations according to methods outlined by Jackson (1973), free calcium carbonate by rapid titration method and organic carbon by Walkely and Black method (Jackson 1973). The saturation extracts of the soils were analysed for their electrical conductivity, soluble cations and anions and the sodium adsorption ratio (SAR) was calculated according to the method outlined by Richards (1954).

Results and Discussion

The soils were deep with slickensides and crack upto considerable depth. The soil colour varied from dark brown (10YR 3/3 M) to very dark gray (10YR 3/1 M). The surface horizons of all the pedons had sub-angular blocky structure whereas, sub-surface horizons had angular blocky structure. The consistency of these soils was hard (dry) and friable to firm (moist) in surface horizon and hard to very hard (dry) and firm to very firm (moist) in sub-surface horizons. The effervescences observed with dilute HCl were slight to strong in surface horizons and strong to violent in sub-surface horizons. Mottles (5YR 5/6 and 5YR 4/1) were observed in P1 (below 60 cm).

All the soils were clayey with clay content ranging from 45.2 to 62.5 % (Table 1). Pal and Deshpande (1987) also reported high content of clay and smectitic mineralogy in these soils. Bulk density at maximum water holding capacity varied from 1.15 to 1.37 Mg m^{-1}. Low values of bulk density in these soils can be ascribed to high clay content dominated by expanding type of clay mineral. Maximum water holding capacity of the soils varied from 53 to 78 %. Hydraulic conductivity of the soils varied from 0.01 to 3.82 cm hr^{-1} (Table 1), which rapidly decreased with depth in all the pedons.

The soils were moderately to strongly alkaline in pH and non-saline as indicated by the electrical conductivity of saturation extract (0.35 to 1.74 dS m^{-1}). The organic carbon content varied from 0.10 to 1.23 % and decreased with depth. The high CEC [44.1 to 62.2 cmol (p+) kg^{-1}] and high base saturation percentage indicate the potential of these soils in terms of fertility. The exchangeable cations were in order of Ca>Mg>Na>K. The Ca/Mg ratio varied from 0.4 to 3.5 and decreased with depth. The ESP varied from 0.5 to 19.2, whereas exchangeable magnesium percentage (EMP) ranged from 20.4 to 57.5 and increased with depth (Table 2). All these parameters caused the lowering of hydraulic conductivity as the correlation co-efficient showed a significant negative correlation between HC and ESP (r = -0.52 at 1 % level), HC and EMP (r =- 0.37 at 5 % level) and HC and ESP + EMP (r = -0.51 at 1 % level), however, HC and Ca/Mg ratio showed a significant positive correlation (r = 0.42 at 5 % level). The impairment of hydraulic conductivity is due to the dispersion of clay particle by Na and Mg on the exchange complex (Yadav and Girdhar 1981; Rengaswamy *et al.* 1986). In saturation extract, soluble sodium percentage and SAR ranged from 33.7 to 84.0 and 1.1 to 12.0, respectively (Table 2) and generally increased with depth.

The soils of the command area are irrigated with well water as supplementary irrigation since a long time (P1 and P2) and with canal irrigation since 11 years. The quality water rating as per Richards (1954) for well waters used for irrigation are C_3S_1 and C_2S_1 and indicates their medium to high salinity and low sodicity. The rating for canal water is C_2S_1 indicating medium salinity and low sodicity (Table 3). The C_3S_1 water is not suitable for irrigation whereas C_2S_1 water can be used only in soils having better drainage. The continued use of such waters would hasten the sodification process (Nimkar *et al.* 1992; Bharambe *et al.* 1999).

There was increase in clay, ESP and EMP with depth whereas exch. Ca/Mg decreased in P1 and P2. The depth-wise distribution of these properties point out that dispersion and subsequent movement of clays have been possible in alkaline chemical environment caused by the precipitation of $CaCO_3$ (Pal *et al.* 2006) in semi-arid climatic conditions (Balpande *et al.* 1996; Vaidya and Pal, 2002 and Kadu *et al.* 2003). In case of P1, P4 and P5, the above processes seem to be operating. The SAR and ESP raised in surface and sub-surface horizons in root zone due to continuous use of canal irrigation in recent years. P6 did not show any increase in ESP but there was an increase in EMP with depth.

In view of the above, it would be prudent to grow crops under rainfed or irrigated conditions with one or two supplementary irrigations only, otherwise provision for practices facilitating better drainage should be made.

Table 1. Physical properties of soils

Depth (cm)	Horizon	Size class and particle diameter (mm)			Bulk Density (W max) ($Mg\ m^{-3}$)	Maximum Water Holding Capacity (%)	Saturated Hydraulic Conductivity ($cm\ hr^{-1}$)
		Sand (2.0 - 0.05)	Silt (0.05 - 0.002)	**Clay** (< 0.002)			
		(% of less than 2 mm)					
		P1 : Talegaon – I (Typic Haplusterts)					
0-13	Ap	7.8	40.6	51.6	1.35	70	1.69
13-35	A	8.9	37.7	53.4	1.33	75	0.28
35-60	Bw	8.4	33.1	58.5	1.27	75	0.23
60-100	Bss1	11.5	28.4	60.1	1.21	77	0.01
100-150	Bss2	13.6	24.6	61.8	1.20	78	0.01
		P2 : Parsoda (Sodic Haplusterts)					
0-11	Ap	13.4	28.5	58.1	1.25	65	0.78
11-33	Bw	12.8	27.7	59.5	1.23	66	0.72
33-86	Bss1	11.8	27.4	60.8	1.19	70	0.17
86-120	Bss2	10.6	27.0	62.4	1.15	71	0.10
		P3 : Antora (Typic Haplusterts)					
0-20	Ap	16.4	25.8	57.8	1.29	69	2.81
20-36	Bw1	18.9	23.0	58.1	1.25	70	2.56
36-64	Bw2	16.7	22.5	60.8	1.24	75	2.43
64-106	Bss1	15.4	24.3	60.3	1.19	75	2.92
106-145	Bss2	15.2	22.3	62.5	1.18	78	2.72
145-160	BC	17.4	28.5	54.1	1.33	64	1.99
		P4 : Manikpur (Typic Haplusterts)					
0-10	Ap	11.6	32.5	55.9	1.27	65	0.81
10-20	A	10.8	30.7	58.5	1.21	66	0.35
20-55	Bw	9.4	30.4	60.2	1.19	72	0.31
55-84	Bss	11.3	29.3	59.4	1.19	70	0.25
84-120	BC	21.1	24.3	54.6	1.34	54	1.89
		P5 : Delwadi (Typic Haplusterts)					
0-15	Ap	7.8	35.3	56.9	1.31	64	2.30
15-37	A	12.8	29.4	57.8	1.27	67	2.18
37-62	Bw	15.3	24.1	60.6	1.24	73	2.58
62-118	Bss	13.2	26.0	60 8	1.19	72	1.35
118-150	BC	14.6	31.8	53 6	1.27	64	1.58
		P6 : Talegaon – II (Typic Haplusterts)					
0-20	Ap	12.8	37.6	49.6	1.30	65	3.82
20-32	A	10.7	36.7	52 6	1.28	70	3.74
32-70	Bw	9.6	35.2	55.2	1.25	73	3.20
70-100	Bss	13.4	30.2	56.4	1.21	76	3.01
100-120	BC	22.6	32.2	45.2	1.37	53	3.81

Table 2. Chemical properties of soils

Depth (cm)	pH (1:2.5 H_2O)	ECe (dS m^{-1})	Free $CaCO_3$ (%)	Organic Carbon (%)	Extractable bases Ca	Mg	Na	K	CEC	Base Saturation (%)	ESP	EMP	Exchangeable Ca/Mg	Sodium Adsorption Ratio	Soluble Na (%)
					----------cmol (p^+) kg^{-1}----------										
P1 : Talegaon – I (Typic Haplusterts)															
0-13	8.1	1.16	11.6	0.45	23.0	18.1	0.6	0.8	44.1	97	1.5	41.1	1.3	2.2	47.5
13-35	8.3	0.78	11.8	0.19	24.0	16.2	1.3	0.8	44.6	95	3.0	36.4	1.5	3.3	60.9
35-60	8.5	1.21	10.2	0.13	21.2	19.4	2.4	0.9	46.4	95	5.2	41.8	1.1	5.2	68.9
60-100	8.7	1.51	9.1	0.10	14.9	24.1	5.2	0.8	48.3	93	10.7	49.8	0.6	12.0	84.0
100-150	8.9	1.74	6.8	0.10	11.8	28.8	6.4	0.7	50.1	95	12.7	57.5	0.4	11.1	82.8
P2 : Parsoda (Sodic Haplusterts)															
0-11	8.0	0.53	7.1	0.38	31.7	15.2	0.6	1.1	51.2	95	1.1	29.7	2.1	1.5	42.0
11-33	8.0	0.82	7.6	0.17	30.2	17.5	0.8	1.1	52.4	95	1.5	33.4	1.7	2.6	55.5
33-86	8.5	1.11	10.3	0.11	26.1	21.5	2.7	1.0	53.4	96	5.1	40.3	1.2	6.3	75.9
86-120	8.8	1.24	10.9	0.10	22.5	21.3	10.9	0.9	56.5	98	19.2	37.6	1.1	6.5	76.5
P3 : Antora (Typic Haplusterts)															
0-20	7.6	0.75	3.7	1.23	39.8	11.4	0.3	0.9	55.8	94	0.6	20.4	3.5	1.3	35.9
20-36	7.6	0.64	4.0	1.10	39.3	13.2	3.0	0.8	57.8	97	5.2	22.7	3.0	1.2	35.8
36-64	7.6	0.63	3.8	0.84	37.5	16.2	2.6	0.8	59.0	97	4.3	27.5	2.3	1.1	33.7
64-106	7.9	0.63	4.7	0.35	37.1	19.5	0.5	0.7	58.5	99	0.9	33.3	1.9	2.3	50.8
106-145	8.0	0.61	5.2	0.14	28.2	25.3	1.3	0.8	59.6	93	2.2	42.4	1.1	2.7	57.8
145-160	8.1	0.58	9.0	0.10	23.1	22.6	1.0	0.7	51.4	92	1.9	44.0	1.0	2.1	52.6
P4 : Manikpur (Typic Haplusterts)															
0-10	7.8	0.66	2.4	1.12	32.0	21.6	0.4	1.0	57.2	96	0.6	37.7	1.5	2.2	55.1
10-20	7.9	0.68	2.6	0.85	34.5	22.3	0.9	0.9	60.5	97	1.5	36.8	1.5	2.6	55.8
20-55	7.9	0.57	2.9	0.54	30.8	24.0	3.3	0.9	61.8	95	5.3	38.8	1.3	3.9	67.9
55-84	7.9	0.78	8.8	0.23	28.8	25.1	3.4	0.8	62.2	93	5.5	40.3	1.1	5.1	71.5
84-120	7.7	0.58	9.0	0.12	23.5	22.1	0.3	0.7	48.6	96	0.5	45.4	1.1	1.4	42.8
P5 : Delwadi (Typic Haplusterts)															
0-15	7.7	0.46	6.5	0.86	34.4	19.7	2.9	0.9	60.2	96	4.8	32.7	1.7	1.3	39.0
15-37	8.0	0.35	6.6	0.66	37.3	18.2	2.8	1.0	61.4	96	4.6	29.6	2.1	1.1	37.6
37-62	7.9	0.39	7.4	0.18	33.2	22.1	2.6	1.0	61.8	95	4.3	35.7	1.5	1.2	38.5
62-118	7.9	0.44	11.4	0.13	30.3	24.6	3.2	0.9	62.1	95	5.1	39.5	1.2	3.9	65.3
118-150	7.9	0.56	11.3	0.10	25.2	20.7	3.9	0.8	54.2	93	7.2	38.2	1.2	3.9	65.5
P6 : Talegaon – II (Typic Haplusterts)															
0-20	7.8	0.83	10.0	0.79	29.9	13.6	0.5	0.9	46.6	96	1.0	29.2	2.2	1.4	40.1
20-32	7.8	0.84	10.6	0.28	28.5	17.9	0.5	1.0	48.5	99	1.1	37.0	1.6	1.4	39.5
32-70	7.9	0.88	9.4	0.24	27.7	20.3	0.7	0.9	51.6	96	1.3	39.4	1.4	1.6	45.0
70-100	7.9	0.78	11.2	0.23	26.0	22.1	0.6	0.8	51.2	97	1.2	43.2	1.2	2.0	52.7
100-120	7.9	0.64	5.9	0.10	21.4	18.1	0.6	0.8	44.7	91	1.2	40.6	1.2	1.7	49.0

Table 3. Chemical composition of well and canal waters

Location	Source	pH	EC (dS m^{-1})	Cations				Anions				SAR	RSC me L^{-1}	Water Quality class
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	Cl^{-}	SO_4^{--}			
				<<---------- me L^{-1} ---------->>										
Talegaon (P1)	Well	7.5	0.7	2.4	2.5	0.24	0.1	-	3.1	2.1	0.04	0.15	-	C_2S_1
Parsoda (P2)	Well	8.2	0.9	2.1	2.9	5.51	0.1	3.6	2.9	3.8	0.27	3.48	1.5	C_3S_1
Antora (P3)	Well	8.0	0.5	2.3	2.4	0.34	0.1	-	2.7	2.3	0.14	0.22	-	C_2S_1
Manikpur (P4)	Canal	7.9	0.6	2.8	3.2	0.4	0.1	-	3.2	2.9	0.4	0.23	-	C_2S_1
Delwadi (P5)	Canal	7.9	0.5	2.6	2.6	0.21	0.1	-	3.1	2.1	0.31	0.13	-	C_2S_1

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