Pedology and Environment 2024, 34 (02), 196-202
doi.org/10.47114/j.pedoenv.2024.dec 7

Physical and hydrological characteristics of soils of Tekkali mandal of Srikakulam District, Andhra Pradesh

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Abstract : The assessment of physical and hydrological characteristics of the soils is essential for regulating the sustainability of the agro-ecosystem. Hence, the present study was undertaken to study the physical and hydrological characteristics of major soils in Tekkali mandal of Srikakulam district. Seven representative soil profiles were selected and studied for their physical and hydrological properties. The results showed that the Thirlangi and Ravivalasa profiles had high clay content, while the Parasurampuram profile had low clay content. Bulk density, particle density and porosity of the study area ranged from 1.31 to 1.58, 2.53 to 2.64 and 35.5 to 48.4% respectively. In general, the values of bulk density showed an increasing trend with soil depth, while porosity decreased with soil depth in all the studied profiles. High volume expansion of 5.19 to 7.14% was recorded in Thirlangi and Ravivalsa profiles, while it was found to be low in Telineelapuram, Lingalavalasa and Naupada profiles. In contrast, the Parasarampuram and Narsingapalli profiles showed no volume expansion. The coefficient of linear extensibility is 0.02 to 0.03 in Thirlangi and Ravivalas profiles. Soil water retention at 0.33 and 15 bar potential and available water capacity were higher in Thirlangi and Ravivalasa profiles. Furthermore, all the profiles exhibited an increasing trend in soil water retention with increasing soil depth. The clay content showed a significant positive correlation, while the sand content showed a significant negative correlation with soil water retention. Saturated hydraulic conductivity (SHC) and final infiltration rate (FIR) of Tekkali mandal ranged from 1.52 to 4.72 cm/hr and 14.21 to 26.90 mm/hr. SHC and FIR showed significant negative correlation with clay and positive correlation with sand.

Keywords: *Soil physical properties, Soil water retention, Saturated hydraulic conductivity, Tekkali mandal*

Introduction

Soil, together with the other components of the environment (e.g., rocks, water, and air), is a very important element for maintaining life on Earth, having a defining role in all the physical, chemical, and biological processes. Soil physical and hydrological characteristics are of primary importance in plant growth and successful crop production. Soil texture, bulk density, porosity, soil water retention, and infiltration characteristics are more critical for successful water and nutrient management (Singh *et al*., 2004). Water retention in soil is influenced by various factors, such as: Physical and chemical soil properties, or a series of ecological factors (temperature, distribution of rainfall over the year and their regime, intensity and frequency of winds, ground slope, vegetation type and distribution). Research conducted in the past has highlighted the importance of assessing the physical characteristics of soils to establish their quality, in relation to the soil's

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ability to retain water, its texture, organic matter content, and micro- and mesofauna activity. The physical properties of the soil are directly involved in the absorption and mobility of soil nutrients. Moreover, they are closely related to the hydro-physical parameters of the soil. Some studies on these aspects were carried out earlier in rainfed soils (Srinivasrao *et al*., 2009), Rajasthan soils (Singh et al., 2001), Andhra Pradesh (Gurumurthy et al., 2002; Himabindu et al., 2019), and Maharashtra (Mandal *et al*., 2003). However, a systematic study of soil physical and hydrological properties is lacking. Hence, a comprehensive study was undertaken to examine the soil physical and hydrological characteristics of major soil types of Tekkali mandal of Srikakulam district of Andhra Pradesh

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Materials and Methods

A reconnaissance soil survey was conducted in the area of Tekkali mandal during April to June, 2021, using toposheets of 1:50,000 scale as per the procedure outlined by AIS&LUS (1970). Auger bores, mini pits, and road cuts of 15 profiles located on uplands and plains were studied. Soil correlation exercise resulted in seven representative profiles. These seven soil profiles were exposed, and horizon-wise soil samples were collected for laboratory analysis. The particle size distribution of the soil samples was determined using the International pipette method, as described by Piper (1966), with sodium hexametaphosphate (SHMP) as the dispersing agent. In each horizon, bulk density was determined by the core sampler method. The final infiltration rate was determined near the soil profile using a double-ring infiltrometer, following the variable head method as suggested by Bertrand (1965). The results were expressed in mm h^{-1}. Soil bulk density was determined by using the core sampler method (Black, 1965). Particle density was determined by the specific gravity bottle method, as described by Gurumurthy (2022). Further, soil porosity was calculated using bulk density and particle density using the following equation

$$\text{Porosity (\%)} = [(PD-BD) / PD] \times 100 \quad (1)$$

Where, BD = Bulk density (Mg m^{-3}) and PD = Particle density (Mg m^{-3}). COLE values were calculated as per the formula given by Soil Survey Staff (2014).

$$COLE = [(L_m - L_d)/ L_d] \times 100$$

Where in L_m = Length of bar-shaped soil when moistened to its plastic limit; L_d = Length of bar-shaped soil when air dried.

A pressure plate apparatus was used to determine water retention at -0.33 bar and -15 bar potentials, and the difference between these two was used to calculate the available water capacity (Richards, 1965). Undisturbed soil samples, collected in cylindrical core samplers from different horizons, were used to determine saturated hydraulic conductivity in the laboratory using the constant head method, as outlined by Jalota *et al*. (1998). A correlation matrix was worked out as per Gomez and Gomez (1984).

Results and Discussion

Soil Physical properties

The data on particle size distribution are presented in Table 1. Gravel content varied from 2.32 to 44.31 per cent, and sand content of various horizons of the profiles varied from 52.40 to 72.00 per cent. In general, the total sand content was found to decrease with depth. In general, all seven profiles showed relatively higher sand content compared to silt and clay, which is attributed to the dominance of physical weathering (Dinesh & Grewal, 2017). The silt content varied from 7.50 to 16.50 per cent. The clay content of the profiles ranged from 15.50 to 33.00 per cent, and it increased with depth of profile. The clay content was relatively higher in Thirlingi and Ravivalasa profiles and lower in the Parasurampuram profile. The texture variation among profiles may be due to variations in parent material, topography, and the differential degree of weathering. Similar observations of variations in soil particle distribution were reported by Himabindu *et al.* (2019) in the soils of Thotapalli reservoir ayacut areas in north coastal Andhra Pradesh, and by Geetha Sireesha and Naidu (2013) in the soils of Banaganapalli mandal in Kurnool district.

The values of bulk density in different horizons

Table 1: Soil physical properties

Horizon	Depth (m)	% Gravel	Sand (%)	Silt (%)	Clay (%)	Texture	BD (Mg m^{-3})	PD (Mg m^{-3})	Porosity (%)	VE (%)	COLE
P1. **Telineelapuram**											
Ap	0.00-0.22	10.04	62.60	12.50	24.90	scl	1.39	2.62	46.9	2.85	-
Bw1	0.22-0.34	15.61	62.40	12.50	25.10	scl	1.43	2.62	45.4	2.93	0.01
Bw2	0.34-0.55	17.28	59.50	12.50	28.00	scl	1.46	2.60	43.8	3.19	0.01
Bw3	0.55-0.88	19.17	62.30	10.50	27.20	scl	1.53	2.60	41.2	3.13	0.01
C	0.88-1.02+	26.00	61.00	12.50	26.50	scl	1.58	2.61	39.5	3.44	-
P2.Thirlangi											
Ap	0.00-0.16	8.23	59.50	10.00	30.50	scl	1.31	2.54	48.4	6.78	0.02
Bw1	0.16-0.28	13.41	57.00	12.50	30.50	scl	1.40	2.54	44.9	5.81	0.02
Bw2	0.28-0.47	19.50	52.40	15.00	32.60	scl	1.39	2.55	45.5	5.89	0.03
Bw3	0.47-0.72	21.21	54.50	12.50	33.00	scl	1.42	2.53	43.9	6.40	0.02
Ck	0.72-0.97+	44.31	59.00	10.00	31.00	scl	1.44	2.57	44.0	6.78	0.02
P3. **Lingalavalasa**											
Ap	0.00- 0.15	4.51	66.00	15.00	19.00	sl	1.40	2.61	46.4	3.10	-
Bt1	0.15-0.34	4.37	62.00	13.00	25.00	scl	1.44	2.60	44.6	4.56	-
Bt2	0.34-0.50	3.60	53.00	16.50	30.50	scl	1.47	2.61	43.7	3.56	-
Bt3	0.50-0.70	7.82	57.40	13.00	29.60	scl	1.48	2.63	43.7	4.16	-
Bt4	0.70-0.90+	14.13	57.30	12.50	30.20	scl	1.56	2.61	40.2	5.56	-
P4. **Parasurampuram**											
Ap	0.00-0.12	14.01	72.00	12.50	15.50	sl	1.41	2.63	46.4	-	-
A1	0.12-0.24	21.22	68.70	15.00	16.30	sl	1.45	2.64	45.1	-	-
A2	0.24-0.34	18.50	66.70	15.00	18.30	sl	1.45	2.70	46.3	-	-
C	0.34-0.74+	39.52	70.90	12.50	16.60	sl	1.48	2.68	44.8	-	-
P5. Ravivalasa											
Ap	0.00-0.14	6.98	66.00	7.50	26.50	scl	1.33	2.57	48.2	6.67	0.01
Bw1	0.14-0.28	4.37	62.44	10.00	27.56	scl	1.41	2.59	45.6	7.14	0.02
Bw2	0.28-0.52	2.32	63.74	10.00	26.26	scl	1.41	2.53	44.3	6.93	0.02
Bw3	0.52-0.72	9.52	61.00	12.50	26.50	scl	1.45	2.58	43.8	5.19	0.02
Ck	0.72-0.94+	28.12	64.50	10.00	25.50	scl	1.45	2.54	42.9	5.13	0.02
P6. **Narsingapalli**											
Ap	0.00-0.21	12.30	69.50	12.50	18.00	sl	1.41	2.62	46.2	-	-
Bt1	0.21-0.43	10.30	69.50	8.00	22.50	scl	1.44	2.62	45.0	-	-
Bt2	0.43-0.77	15.60	67.00	9.50	23.50	scl	1.47	2.65	44.5	-	-
Bt3	0.77-0.94+	14.72	65.40	12.00	22.60	scl	1.57	2.64	40.5	-	-
P7. **Naupada**											
Ap	0.00-0.23	4.80	64.10	12.50	23.40	scl	1.46	2.62	44.3	5.18	-
Bw1	0.23-0.45	8.12	61.60	15.00	23.40	scl	1.52	2.64	42.4	6.53	0.01
Bw2	0.45-0.60	11.30	61.54	12.50	25.96	scl	1.58	2.62	39.7	6.43	0.02
Bw2	0.60-0.92+	20.86	64.70	10.50	24.80	scl	1.59	2.65	40.0	4.66	-

BD-Bulkdensity; PD- Particle density; VE- Volume expansion; COLE-Coefficient of linear extensibility; sl- sandy loam; scl- sandy clay loam.

Table 2: Soil hydrological properties

Horizon	Depth (m)	Water retention (cm m^{-1})			SHC cm hr^{-1}	FIR mm/hr
P1 - **Telineelapuram**		FC	PWP	AWC		
Ap	0.00-0.22	16.50	5.75	10.75	3.84	21.8
Bw1	0.22-0.34	17.80	5.81	11.99	3.16	-
Bw2	0.34-0.55	18.30	6.02	12.28	2.38	
Bw3	0.55-0.88	18.10	5.90	12.20	1.91	
C	0.88-1.02+	17.80	5.70	12.10	1.91	
P2 - Thirlangi						
Ap	0.00-0.16	22.30	6.60	15.70	2.49	14.21
Bw1	0.16-0.28	23.70	6.50	17.20	1.96	
Bw2	0.28-0.47	23.10	6.70	16.40	1.75	
Bw3	0.47-0.72	24.70	6.90	17.80	1.75	
Ck	0.72-0.97+	24.10	6.50	17.60	1.88	
P3 - **Lingalavalasa**						
Ap	0.00- 0.15	15.80	4.50	11.30	4.35	26.30
Bt1	0.15-0.34	17.60	4.80	12.80	3.60	
Bt2	0.34-0.50	19.20	5.60	13.60	3.16	
Bt3	0.50-0.70	19.40	5.80	13.60	2.70	
Bt4	0.70-0.90+	19.20	6.00	13.20	2.67	
P4 - **Parasurampuram**						
Ap	0.00-0.12	12.70	3.50	9.20	4.72	15.68
A1	0.12-0.24	13.20	3.70	9.50	3.84	
A2	0.24-0.34	14.50	4.30	10.20	3.40	
C	0.34-0.74+	13.10	3.60	9.50	2.91	
P5 - Ravivalasa						
Ap	0.00-0.14	19.80	5.50	14.30	2.74	15.68
Bw1	0.14-0.28	19.70	5.70	14.00	2.05	
Bw2	0.28-0.52	20.10	5.80	14.30	1.75	
Bw3	0.52-0.72	18.80	5.40	13.40	1.52	
Ck	0.72-0.94+	19.20	5.30	13.90	1.55	
P6 - **Narsingapalli**						
Ap	0.00-0.21	15.10	5.30	9.80	4.11	26.90
Bt1	0.21-0.43	15.30	4.50	10.80	3.20	
Bt2	0.43-0.77	16.90	4.50	12.40	2.38	
Bt3	0.77-0.94+	16.50	4.30	12.20	2.09	
P7 - **Naupada**						
Ap	0.00-0.23	16.80	5.60	11.20	3.55	21.07
Bw1	0.23-0.45	17.10	5.80	11.30	2.60	
Bw2	0.45-0.60	17.60	5.80	11.80	2.28	
Bw2	0.60-0.92+	18.10	6.00	12.10	1.91	

FC- Field capacity; PWP- Permanent wilting point; AWC- Available water capacity; SHC- Saturated hydraulic conductivity, FIR-Final infiltration rate

ranged from 1.33 to 1.62 Mg m^{-3}, increasing with soil depth. There was a positive correlation between bulk density and sand content (r =0.49*). The particle density of soils of the study area ranged from 2.56 to 2.72 Mg m^{-3}. The pore space in different horizons ranged from 37.45 to 48.88 per cent and showed a decreasing trend with depth. There was a significant negative correlation between pore space and bulk density (r = -0.96**).

The percentage volume expansion in the soils of the study area varied from 3.10 to 9.14 per cent. Thirlangi and Ravivalasa profiles showed more volume expansion, whereas Lingalavalasa, Parasurampuram, and Narsingapalli profiles did not exhibit expansion. The significant quantities of montmorillonitic clay content in these soils caused volume expansion. The significant positive correlation between volume expansion and clay content (r = 0.53**) supports this finding. Similar observations were reported earlier by Gurumurthy (2019) in the soils of the Agricultural College Farm of Naira. The coefficient of linear extensibility (COLE) was observed in profiles 1, 2, 5 and 7 and ranged from 0.01 to 0.03 per cent.

Hydrological Characters

The water retention at 0.33 and 15 bar, corresponding to field capacity and permanent wilting point, respectively, and the available water capacity in the soil are presented in Table 2 and Figure 1. The water retention at field capacity and permanent wilting point ranged from 12.7 to 24.7 cm m^{-1} and 3.50 to 6.90 cm m^{-1}, respectively. Available water capacity ranged from 9.50 to 17.80 cm/m. High water retention and available water capacity were associated with Thirlangi and Ravivalasa profiles. The higher water retention values in the soils of the study area were attributed to higher clay contents, as a significant positive correlation was found between clay content and available water capacity (r = 0.77**). Similar observations were made earlier by Srinivasarao et al (2009) and Prasad et al (1998).

Saturated hydraulic conductivity (SHC) and final infiltration rate (FIR) of Tekkali mandal ranged from 1.52 to 4.72 cm h^{-1} and 14.21 to 26.90 mm h^{-1}, respectively. Higher SHC and FIR were recorded in the Parsurampuram and Narsingapalli profiles. Clay content

Table.3: Correlation matrix of Soil physical and hydrological properties

	Sand	Clay	BD	Porosity	AWC	SHC	FIR	VE
Sand	1	-0.69**	+0.49*	-0.52**	-0.85**	+0.70**	+0.66**	-0.25
Clay		1	-0.39*	+0.41*	+0.77**	-0.68**	-0.81**	+0.53*
BD			1	-0.96*	+0.23	-0.40*	-0.24	-0.15
Porosity				1	-0.31*	-0.27	+0.25	+0.18
AWC					1	-0.33*	-0.30	+0.33*
SHC						1	+0.63**	-0.24
FIR							1	-0.21
VE								1

BD- Bulk density; PD- Particle density; AWC- Available water capacity; SHC- Saturated hydraulic conductivity, FIR-Final infiltration rate, VE- Volume expansion.
**Significant at 5% level of significance*
*** Significant at 1% level of significance.*

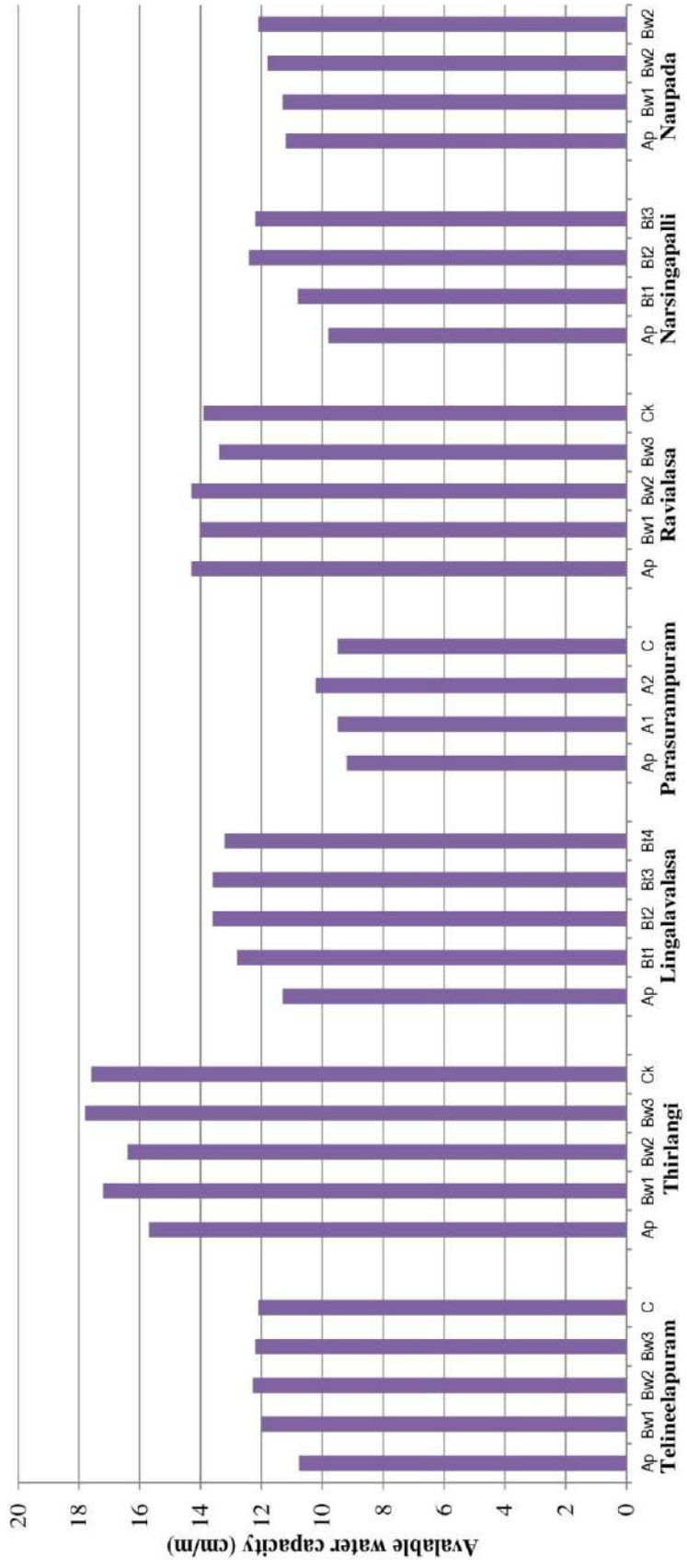

Fig. 1: Avaialble water capacity of soils of Tekkali mandal of Srikakulam District, Andhra Pradesh

showed a significant negative correlation with SHC (r = -0.68**) and FIR (r = -0.81**). Similar observations were reported earlier by Himabindu *et al.* (2019).

Conclusion:

These results demonstrate that significant variations exist in soil physical and water retention characteristics not only among soil profiles but also within individual soil profile horizons. Thirlangi and Ravivals' profiles were relatively finer with significant Vertic characters, while other soils are coarser, having distinct soil physical and hydrological properties. Therefore, it is advocated to adopt suitable soil management practices for sustainable crop production and improving soil health.

Acknowledgements:

The authors are thankful to Acharya NG Ranga Agricultural University for providing financial support and infrastructural facilities for the study.

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Received: October 2024 Accepted: December 2024