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Studies on physical properties of red and black soil pedons in Kavalur-1 micro-watershed, Karnataka

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Abstract
The physical properties of soil pedons of Kavalur-1 micro-watershed of northern dry zone (Zone -3) of Karnataka were investigated during 2016-17 for evaluation of soil resources for optimizing their use and enhancing the productivity of the watershed. The results indicated that Kavalur-1 micro-watershed has both red and black soils, though the former is dominant. The climate is semi-arid with a mean annual average rainfall of 572 mm. A detailed soil survey was conducted in Kavalur-1 micro-watershed using toposheets with 1:50,000 scale. Eighteen soil pedons were characterized in Kavalur-1 micro-watershed and studied for physical properties. Soil texture varied from sandy clay loam (scl) to clay (c). The average bulk density did not vary much between red and black soil pedons. In general, the bulk density was less in the surface horizon and increased with depth. The average maximum water holding capacity of red soil pedons was considerably lower (38.0%) than that of black soil pedons (45.7%). The maximum water holding capacity increased downward upto certain depth and further decreased in lower horizons, especially BC horizon. Special features like strong effervescence with dil. HCl was observed in pedon 3, 5 and 12. Slickensides and pressure faces were observed in pedon 9.

Keywords: Physical properties, red, black soil pedons, Kavalur-1 micro-watershed

Introduction

Soil is a complex, living, changing and dynamic component of the agro ecosystem. It plays an essential role in the biophysical and biogeochemical functioning of the planet. In addition, it is a natural body consisting of layers that are primarily composed of minerals which differ from their parent materials (Basavaraju *et al*., 2005) [2]. Without the knowledge of soil properties, it is not possible to determine soil quality and soil water plant relationship in a given area as well as how it should be managed and conserved.

The rapidly increasing human populations and their needs/uses of the land for various agricultural activities have brought about extensive land use changes and soil management practices throughout the world. Over the years, soil biodiversity and its physical properties that control water movement and retention in the soils are largely affected due to human, animal activities as well as use of machine for soil tillage purposes.

The physical characterization of soils of any micro-watershed is very important as it influences both physical and chemical properties of soil which in turn greatly influence soil productivity. The ability of a soil to generate some products or perform some functions may decline with certain land uses owing to the changes in their physical makeup. In order to have sustainable land use systems, land use development must not only be economically sustainable but also socially acceptable and environmentally sound. Therefore, strategies to improve agricultural productivity have to seek a sustainable solution that better addresses soil fertility management. Physical properties of soils play the dominant role in soil classification and types. It is also necessary to know about the significant role played by different physical properties in soils for various purposes, right from agriculture to engineering constructions.

Materials and methods

Description of the study area

Kavalur-1 micro-watershed having an area of 463.57 ha is located between 15° 16’ 35” and 15° 17’ 40” N latitude and 75° 57′ 30″ and 75° 54′ 55″ E longitude in Koppal taluk of Koppal district in the Northern dry zone of Karnataka, India.

The average elevation of this area is 551.7 m above mean sea level. The length of growing period (LGP) is <90 to 120 days (Ramamurthy *et al.*, 2009) [10]. The Kavalur-1 micro-watershed has both red and black soils, though the former is dominant. The climate is semi-arid with a mean annual average rainfall of 572 mm. The major agricultural crops grown are jowar, bajra, sunflower, maize, groundnut *etc* and tree species like Bellary jali (*Prosopisjuliflora*), banni (*Acacia ferugenia*) and neem (*Azadiractaindica*) were predominantly found in this area.

A reconnaissance soil survey was conducted in Kavalur-1 micro-watershed of Koppal district using toposheets with 1:50,000 scale as per procedure outlined by AIS & LUS (1971). Based on soil heterogeneity, the polygons were drawn on the cadastral map indicating surface features. Pooling information from polygon maps, the transects were drawn on the satellite imagery from ridge to valley covering larger heterogeneity. Totally 18 pedons were opened and studied for their morphological features. Based on the field observations, horizon-wise soil samples were collected from the profiles in the study area and were analyzed for their physical properties using standard procedures. Particle size distribution of soil samples was determined by International pipette method as described by Piper (2002) [8]. Bulk density was determined by clod method (Black, 1965) [3]. Maximum water holding capacity of the soils was determined by using Keen Raczkowaski brass cup as described by (Sankaram, 1960) [11].

Eighteen soil pedons were characterized in Kavalur-1 micro-watershed. Among them, eight (pedons 1, 3, 4, 5, 9, 12, 13 and 18) and 10 soil pedons (pedons 2, 6, 7, 8, 10, 11, 14, 15, 16, 17) fell under black and red soils, respectively. Pedons such as 4, 8, 11 were deep (100 - 150 cm); 1, 2, 3, 5, 6, 7, 9, 10, 12, 13, 14, 15, 16, 17 and 18 were very deep (>180 cm) in nature.

Results and discussion
Physical properties
Particle size distribution

Coarse sand: The coarse sand content in surface horizon (Ap) of red soil pedons ranged from 28.3 to 47.4 per cent while it ranged from 24.9 to 38.6 per cent in black soil pedons (Table 1). The highest coarse sand content in the surface horizon was observed in pedon 10 (47.4%) and least in case of the pedon 9 (20.9%). The coarse sand content was generally higher in the Ap horizon, irrespective of soil type and decreased with depth except in BC horizons where usually a higher coarse sand content was observed. Interestingly, no such trend was observed in pedon 3.

Fine sand: The fine sand content ranged from 5.2 to 18.9 per cent across soil types and horizons. However, the average fine sand content of red soil pedons was higher (14.3%) compared to black soil pedons (10.9%). The fine sand content followed an irregular distribution with depth in almost all pedons except pedons 2 and 11, where it decreased with depth (Table 1).

Total sand: The total sand content in soil pedons varied from 31.6 to 66.3 per cent. The highest total sand content (66.3%) was recorded in red soil pedon (pedon 10, Ap) and lowest (31.6%) in black soil pedon (pedon 9, Bss3). The distribution of total sand with depth followed almost the same trend as observed in coarse sand. The total sand content was approximately 10 per cent higher in red soil pedons (51.7%) compared to black soil pedons (41.3%). The more coarser fractions in red soil pedons was related to the silicaceous / granite gneiss parent material. The higher sand content in BC horizons might be attributed to partially weathered silicaceous / granite gneiss parent material.

The sand content (total) was generally higher in the Ap horizon, irrespective of soil type and decreased with depth except in BC horizons where usually a higher coarse content was observed. The enrichment of sand fraction in the surface horizons might be related to the clay eluviation and removal clay by surface runoff (Dasog and Patil, 2011; Gangopadhyay *et al*., 2012 and Pulakeshi *et al*., 2014) [4, 6, 9].

Silt: The silt content in soil pedons ranged from 8.2 to 21.1 per cent without any trend in distribution with depth. The average silt contents of both red (12.4%) and black soil (11.7%) pedons did not vary much. All pedons exhibited an irregular distribution in silt content with depth. Such irregular trend in silt content was reasoned to variation in the weathering of the parent material (Denis *et al.*, 2015) [5]. This could also be due to variable rate of clay movement and extent of coarse sand content in soil profile. A higher coarse sand content might favour more mobility of both silt and clay and their redistribution in the soil profile.

Clay: The clay content of pedons ranged from 17.9 to 56.2 per cent across soil types and depths (Table 1). There was an increase in clay content from A to B horizon but, a decrease was observed in BC horizons. The mean clay content in the black soil pedons was higher (47.1%) compared to the red soil pedons (35.8%). This might be largely due to the schist parent material from which these soils are formed. Increase in clay content with depth was observed in both red and black soil pedons was accredited to clay illuviation during profile development (Dasog and Patil, 2011) [4]. In the red soil pedons, the clay content stabilized in the B, C or transition AC or BC horizons. The clay content was less in BC horizons due to slow rate of weathering evidenced by higher sand content. It was interesting to note that the clay content never crossed more than 60 per cent in any of the black soil horizons indicating that the soils were not so heavy.

Bulk density

In red soil pedons, the bulk density ranged from 1.21 (pedon 10 and 17) to 1.34 Mg m^{-3} (pedon 2 and 14) in surface horizons and from 1.23 (pedon 10, Ap) to 1.45 Mg m^{-3} (pedon 15, Bt4) in subsurface horizons. In case of black soil pedons, the bulk density varied from 1.26 (pedon 9 and 18) to 1.31 (pedon 4) in surface horizons. Among subsurface horizons, the lowest bulk density (1.29 Mg m^{-3}) was observed in Bw1 horizon of pedon 12 and highest bulk density (1.49 Mg m^{-3}) was observed in BCk horizon of pedon 13 (Table 1). The average bulk density did not vary much between red and black soil pedons. In general, the bulk density was less in the surface horizon and increased with depth.

The bulk density is a reliable index for determining the presence of compact layers particularly in the subsoil. Irrespective of soil type and horizons, the bulk density of soil pedons varied from 1.21 to 1.49 Mg m^{-3}. The bulk density of surface horizons (Ap) ranged from 1.21 to 1.34 Mg m^{-3} and increased with depth. The lower bulk density in the Ap horizon was attributed to higher organic matter content, better and stable aggregation, and increase in the porosity of soil. The increased bulk density with depth was attributed to increased compaction due to the load of overlying horizons (Nagendra and Patil, 2015) [7] and diminishing amounts of organic matter with depth. Similar results and revelations were reported by Tumbal and Patil (2015) [14] in Balapur micro-watershed in Koppal district of Karnataka. Singh and Rathore (2015) [12] while studying the soils of Aravalli mountain ranges and Malwa plateau, in Pratapgarh district also found similar results of increasing trend of bulk density with depth.

Maximum water holding capacity

The highest (52.3%) maximum water holding capacity was recorded in the subsurface horizon (Bss3) of black soil pedon (pedon 9) and the lowest (26.3%) in the Ap horizon of red soil pedon (pedon 11). The average maximum water holding capacity of red soil pedons (38.0%) was considerably lower than that of black soil pedons (45.7%). The maximum water holding capacity increased downward up to certain depth and further decreased in lower horizons, especially BC (Table 1). The maximum water holding capacity of different pedons ranged from 26.29 to 52.33 per cent. These differences were due to the variation in clay, silt and organic carbon content (Thangasamy *et al.*, 2005) [13]. The average maximum water holding capacity of red soil pedons (38.0%) was considerably lower than that of black soil pedons (45.7%). This might be attributed to high sand and less clay content (Denis *et al.*, 2015) [5]. The maximum water holding capacity, in general, was low in the surface horizon and increased downward up to certain depth and further decreased in lower horizons, especially BC. The enhanced moisture retention capacity with depth was mainly due to increased clay content with depth. The lower clay content in BC horizons was responsible for its reduced moisture retention capacity.

Table 1: Physical properties of red soil pedons in Kavalur-1 micro-watershd

Horizon	Depth (cm)	Gravel (%)	Particle size distribution					Bulk density (Mg m^{-3})	MWHC (%)
			Coarse sand	Fine sand	Total sand	Silt	Clay		
			← (%) →						
Red soil pedons									
Pedon 2									
Ap	0-19	11.5	39.2	18.0	57.2	12.4	30.4	1.34	34.0
Bt	19-49	23.8	37.0	16.4	53.4	14.8	31.7	1.36	37.0
CB	49-88	28.8	43.4	11.1	54.5	16.9	28.6	1.43	31.2
Cr	88-140	Weathered parent rock (Schist)							
Pedon 6									
Ap	0-27	9.8	28.3	13.6	41.9	10.7	44.7	1.29	38.1
Bw	27-82	9.4	26.8	15.3	42.2	12.1	45.7	1.34	35.1
Bt_1	82-112	8.7	25.1	15.3	40.4	12.2	47.5	1.38	33.2
Bt_2	112-180+	8.1	23.1	16.8	39.9	11.6	48.5	1.41	38.6
Pedon 7									
Ap	0-21	13.5	40.0	12.8	52.8	9.7	37.4	1.28	40.3
Bt_1	21-70	9.8	37.6	10.8	48.5	12.9	38.7	1.31	43.3
Bt_2	70-115	9.4	35.5	10.1	45.6	11.6	42.8	1.36	46.4
Bt_3	115-141	28.8	33.3	9.6	42.9	10.6	46.5	1.39	49.6
BC	141-180	16.4	41.6	11.2	52.8	10.2	37.1	1.41	38.9
Pedon 8									
Ap	0-18	19.5	42.0	12.3	54.3	11.3	34.5	1.30	42.1
Bt	18-52	22.5	38.2	13.8	52.0	11.7	36.3	1.34	44.8
BC	52-89	28.1	42.6	13.8	56.4	13.3	30.3	1.42	35.1
C	89-152	Weathered granite-gneiss							
Pedon 10									
Ap	0-18	16.4	47.4	18.9	66.3	15.8	17.9	1.21	30.4
Bt_1	18-44	13.1	36.4	15.9	52.3	8.2	39.5	1.23	42.1
Bt_2	44-95	26.8	36.2	11.7	48.0	10.8	41.2	1.31	48.2
BC	95-180	29.7	43.1	11.8	54.9	14.9	30.3	1.37	35.0
Pedon 11									
Ap	0-20	18.4	41.3	16.9	58.2	18.8	23.0	1.23	26.3
Bt	20-91	26.4	39.5	13.8	53.4	10.3	36.4	1.29	38.0
Cr	91-110	Weathered granite-gneiss							
Pedon 14									
Ap	0-19	20.45	46.9	15.8	62.8	10.7	26.5	1.34	31.9
Bt_1	19-83	24.89	42.3	12.8	55.1	16.3	28.6	1.40	32.0
Bt_2	83-103	27.46	39.0	12.8	51.8	9.7	38.5	1.43	45.4
Cr	103-175	Weathered granite-gneiss							
Pedon 15									
Ap	0-24	12.5	43.4	13.8	57.1	14.3	28.6	1.31	31.4
Bt_1	24-74	14.6	39.2	15.5	54.6	12.4	33.0	1.36	39.5
Bt_2	74-129	15.7	37.4	16.0	53.4	10.2	36.5	1.39	35.3
Bt_3	129-173	19.4	34.5	17.0	51.5	10.3	38.2	1.42	32.6
Bk	173-180+	20.8	32.6	16.3	48.9	11.1	40.0	1.45	47.9
Pedon 16									
Ap	0-26	9.4	39.1	12.7	51.8	10.2	38.1	1.25	42.8
Bt_1	26-81	8.7	33.3	14.1	47.4	11.1	41.4	1.28	45.1
Bt_2	81-139	4.8	31.0	13.7	44.8	12.2	43.1	1.33	47.6

Bt_3	139-180	22.8	29.5	13.7	43.2	11.7	45.1	1.35	44.8
Pedon 17									
Ap	0-25	17.4	39.3	15.3	54.6	14.3	31.1	1.21	34.3
Bt_1	25-47	27.8	36.4	14.9	51.3	10.3	38.5	1.25	41.8
BC	47-82	33.4	39.9	16.8	56.7	14.3	29.0	1.31	30.7
CB	82-151	37.1	43.7	16.2	59.9	21.1	19.0	1.37	27.0
C	151-186+	Weathered granite-gneiss							
Red soil (mean)			37.4	14.3	51.7	12.4	35.8	1.34	38.04

Table 2: Physical properties of black soil pedons in Kavalur-1 micro-watershed

Horizon	Depth (cm)	Gravel (%)	Particle size distribution (%) Coarse sand	Fine sand	Total sand	Silt	Clay	Bulk density (Mg m^{-3})	MWHC (%)
Black soil pedons									
Pedon 1									
Ap	0-28	2.8	28.0	14.7	42.7	8.7	48.6	1.28	47.9
Bw_1	28-53	3.5	24.0	15.1	39.1	8.2	52.7	1.30	49.8
Bw_2	53-94	7.4	22.4	11.5	33.9	11.2	54.9	1.32	50.5
Bw_3	94-162	3.7	25.0	10.1	35.1	9.2	55.7	1.35	48.9
BC	162-180+	4.9	31.0	13.7	44.7	10.2	45.1	1.40	38.9
Pedon 3									
Ap	0-25	10.5	30.4	10.5	40.9	13.7	45.4	1.28	39.6
Bw_1	25-53	9.8	31.5	12.0	43.5	10.4	46.0	1.30	46.2
Bw_2	53-74	7.4	32.5	10.2	42.7	10.2	47.1	1.38	43.2
Bw_3	74-97	36.1	34.5	9.6	44.1	15.3	40.7	1.42	45.3
BCk	97-135	20.9	42.5	11.0	53.4	10.9	35.7	1.44	36.9
C	135-180		Weathered parent rock (Schist)						
Pedon 4									
Ap	0-23	10.8	32.4	10.3	42.7	10.8	46.5	1.31	40.3
Bw_1	23-45	13.8	30.6	12.4	42.9	9.0	48.1	1.36	44.9
Crk	45-120	Weathered parent rock (Schist) with $CaCO_3$ concretions							
Pedon 5									
Ap	0-22	14.8	30.7	10.1	40.8	13.8	45.4	1.30	49.8
Bw_1	22-58	9.4	27.1	9.8	36.9	13.2	49.8	1.38	46.9
Bwk	58-120	8.2	29.9	11.1	40.9	11.1	48.0	1.43	41.6
Ck	120-180		Weathered parent rock (Schist) with $CaCO_3$ concretions						
Pedon 9									
Ap	0-20	12.5	24.9	12.8	37.7	13.2	49.1	1.26	44.3
Bss_1	20-82	10.8	23.0	13.4	36.4	12.2	51.5	1.31	41.3
Bss_2	82-148	8.5	21.8	13.7	35.5	12.5	52.0	1.32	48.3
Bss_3	148-189	6.2	20.9	10.7	31.6	12.2	56.2	1.40	52.3
Pedon 12									
Ap	0-29	11.8	38.6	10.2	48.7	10.2	41.1	1.27	47.8
Bw_1	29-76	10.4	31.2	5.2	36.4	14.4	49.2	1.29	50.3
Bw_2	76-99	25.4	27.6	10.4	38.0	13.0	49.0	1.34	46.9
BCk_1	99-130	31.4	36.9	9.7	46.6	15.0	38.5	1.39	42.7
BCk_2	130-170	35.1	40.5	11.4	51.9	12.5	35.6	1.46	39.7
Pedon 13									
Ap	0-29	11.5	34.7	11.4	46.1	14.5	39.4	1.29	46.6
Bw_1	29-55	8.4	32.7	12.0	44.6	9.4	46.0	1.32	49.3
Bw_2	55-90	13.1	28.5	10.6	39.1	13.4	47.5	1.44	42.7
BCk	90-118	16.5	42.4	10.7	53.1	11.3	35.6	1.49	44.8
Crk	118-180+	Weathered parent rock (Schist) with $CaCO_3$ concretions							
Pedon 18									
Ap	0-22	11.9	31.7	11.7	43.4	11.2	45.4	1.26	48.5
Bw_1	22-54	10.7	30.5	8.8	39.2	12.4	48.4	1.30	40.6
Bw_2	54-80	9.5	29.4	8.8	38.1	10.3	51.5	1.35	48.3
Bw_3	80-99	8.7	27.2	7.7	34.9	11.8	53.3	1.38	50.2
Bw_4	99-163	5.2	26.0	10.3	36.3	9.6	54.2	1.40	51.9
C	163-200	Weathered parent rock (Schist)							
Black soil (Mean)			30.3	10.9	41.3	11.7	47.1	1.35	45.65
Total									
Max		37.1	47.4	18.9	66.3	21.1	56.2	1.49	52.3
Min		2.8	20.9	5.2	31.6	8.2	17.9	1.21	26.3

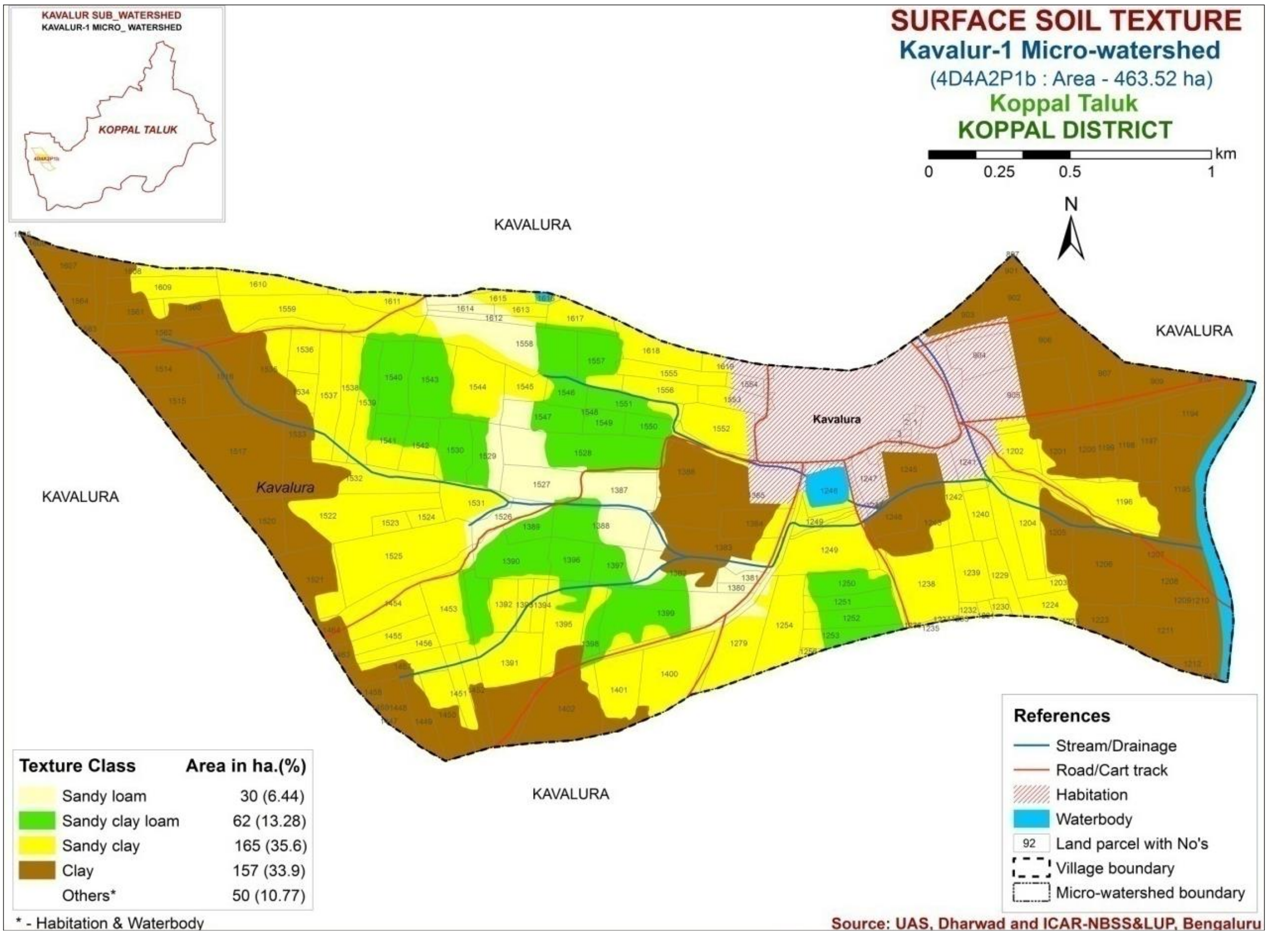

Fig 1: Surface soil texture of Kavalur-1 micro watershed

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