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Physical and chemical characterization of selected soil series of kavalur-2 micro-watershed and their classification

Anjali MC and Manjunatha Hebbara

Abstract
A study was undertaken to assess the physico-chemical properties of selected soil profiles of Kavalur-2 micro-watershed of Koppal district, Karnataka and classified them taxonomically. Five representative pedons covering five different soil series were selected for the study. The soils showed low bulk density (1.20 to 1.39 Mg m^{-3}) and high water holding capacity (31.8 to 49.7 %). The coefficient of linear extensibility (COLE) increased gradually from surface to subsurface horizon with COLE values ranging from 0.24 to 0.36. The soil texture varied from sandy clay to clay. The soils under the study were slightly alkaline to alkaline in reaction (8.21 to 8.97) and non-saline (0.21 to 0.60 dS m^{-1}). The soil organic carbon content was low to medium (1.56 to 5.45 g kg^{-1}) and decreased with depth. The free calcium carbonates in soils ranged from 21.3 to 120.0 g kg^{-1} and in general, increased with depth. Cation exchange capacity, base saturation and exchangeable sodium percentage ranged from 37.4 to 56.9 cmol (p^+) kg^{-1}, 74.6 to 95.9 per cent and 2.00 to 8.68, respectively. The calcium and magnesium were the dominant exchangeable cations followed by sodium and potassium. Soils were classified up to Family level. Taxonomically, the soils of the study area were classified under the orders Inceptisols and Vertisols.

Keywords: kavalur-2 micro-watershed, physical and chemical properties, soil classification, inceptisols and vertisols

Introduction
The capacity of the soil to produce is limited and limits to production are set by intrinsic soil characteristics, agro-ecological setting and soil-crop management aspects. This demands systematic appraisal of our soil resources with respect to their extent, distribution, characteristics, behavior and use potential. This is very important for developing an effective land use system for augmenting agricultural production on sustainable basis (Basavaraju *et al*., 2005) [3]. Soil characterization helps in determining soil's potential and in identifying the constraints in crop production besides giving detailed information about soil properties (Khan and Kamalakar, 2012) [6]. The system of farming in Kavalur-2 micro-watershed (Koppal district) is changing over years in tune with introduction of newer technologies and crops/varieties in the area as like in other parts of the state. Unfortunately, it is the soil which has to bear all these stresses and still we want it to be sustainably productive. It was felt imperative to characterize these soils for their fertility status and productivity functions so as to plan for their efficient use.

Material and Methods
An investigation was carried out on soils of Kavalur-2 micro-watershed, situated at 15^0 18' 13.6" to 15^0 18'30.1" N latitude and 75^0 54'56.7" to75^0 55' 44.9" E longitude, respectively (mean elevation of 539.4 m) in nearly level land of Koppal taluk, Karnataka (India) with an objective to know the physical and chemical properties of the soils. The micro-watershed lies in low rainfall zone (zone 3; northern dry zone) with an average annual rainfall of around 572 mm. Based on soil heterogeneity, Five profiles belonging to different series were studied for their physico-chemical properties by using standard methods like Particle size analysis, MWHC and Free calcium carbonate as given by Piper (2002), Bulk density by Black (1965) [15], COLE as given by Schafer and Singer (1976), Soil pH, EC, Organic Carbon, Exchangeable Cations as given by Jackson (1973) and CEC as given by Anon. (1987) [1]. Based on the soil morphological properties, the soils were classified up to family level by following Keys to Soil Taxonomy, Soil Survey Staff (Anon., 2014) [1]. Five pedon selected are: pedon 1- Murlapura (MLR) series, pedon 2- Alavandi (AWD) series, pedon 3- Budagumpa (BGP) series, pedon 4- Dambarahalli (DRL) series and pedon 5 – Kavalur (KVR) series.

Result and Discussion

Physical properties

A certain trend in particle size distribution was discernible. The coarse sand content in surface horizon (Ap) of soil pedons ranged from 30.7 to 34.2 per cent (Table 1). Among soil pedons, the highest coarse sand content in the surface horizon was observed in pedon 2 (34.2 %) and the least in case of the pedon 5 (30.7 %). 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. The fine sand content ranged from 8.5 to 12.7 per cent across horizons. The highest fine sand was observed in soils of pedon 5 (12.7 %) and the lowest in pedon 2 (8.5 %). The fine sand content followed an irregular distribution with depth in almost all pedons.

The total sand content in soil pedons varied from 39.0 to 47.8 per cent. The highest total sand content (47.8 %) was recorded in soil pedon 1, BC horizon (Table 1) and lowest (39.0 %) in soil pedon 2, Bw_2 horizon. Total sand content was generally higher in the Ap horizon and decreased with depth except in BC horizons where usually a higher coarse sand content was observed. It indicated the variation in weathering as well as erosion of finer particles due to runoff. The fine sand content followed an irregular distribution with depth in almost all pedons. The literature suggested that the irregular distribution of sand and silt could be due to sedimentations (Bhaskar *et al*., 2004) [4].

The distribution of silt was in the range of 5.2 to 13.1 per cent (Tables 1). The highest silt content (13.1 %) was recorded in soil pedon 2, CB horizon and lowest (5.2 %) in soil pedon pedon 1, Bw_3 horizon and pedon 4, Bw_1 horizon. The distribution of silt content did not follow definite trend in the soils of pedons under study. It might be due to variation in weathering of parent material or *in situ* formation (Kumar and Naidu, 2012) [13].

Clay content in the horizons ranged from 44.4 to 58.6 per cent (Tables 1). The highest clay content (58.6 %) was observed in soils pedon 3 (Bw_3 horizon) and lowest (44.4 %) in soil pedon 1 (BC horizon). The clay content increased with the depth in all the pedons except in BC horizons where usually lower clay content was observed. This might be due to in-situ weathering and translocation of clays to deeper layers along with percolating water. These results are in conformity with earlier observations made by Reddy *et al.* (2005).

The maximum water holding capacity of soil pedons ranged from 43.3 (pedon 4) to 45.6 (pedon 1) in the surface and 49.7 (pedon 15, BC horizon) to 48.2 per cent (pedon 6, Bt_2 horizon) in sub-surface horizons in case of red soil (Table 1).

In general, the bulk density and maximum water holding capacity (MWHC) were less in the surface horizon and increased with depth. The bulk density and MWHC of the lower solum were more than the upper solum. It could be due to the increase in clay content and decrease in organic carbon content with depth. Pulakeshi *et al*. (2014) attributed this trend to clogging of pores by dispersed clays in sub-soil layers and reduction of organic carbon with depth. This might also be due to compaction of finer particles in deeper layers caused by the over-head weight of the surface layers (Thangasamy *et al*., 2005) [18]. The lower bulk density in surface layers was attributed to cultivation practices, high organic matter and biotic activities (Rao *et al.*, 2008) [13].

The coefficient of linear extensibility (COLE) is a measure of swell-shrink property of soils. The COLE values increased gradually from surface to sub-surface horizon with values ranging from 0.14 to 0.37 (Table 1). The highest COLE value was noticed in the pedon 8 (0.37) and lowest value in pedon 21 (0.18). The higher COLE value was accompanied by higher amount of clay. High clay content and abundance of smectite is known to increase COLE value (Pal *et al*., 2001; and Moustakas, 2012) [10, 12].

Chemical properties

The soil pH in the surface layer ranged from slightly alkaline to alkaline (8.21 to 8.97). The pH increased with increasing soil depth in almost all pedons. The highest soil pH (8.97) was recorded in soil pedon 4, BC horizon (Table 2) and lowest (8.21) in soil pedon 3, Ap horizon. The increase in pH with depth may be attributed to accumulation of exchangeable bases (Singh *et al*., 2013). The electrical conductivity ranged from 0.21 to 0.60 dS m^{-1} and in most of the pedons, soluble salt distribution showed irregular trend with depth. This might be due to varied topographical position and thereby drainage conditions. These results are in conformity with the findings of Sivasankaran *et al.* (1993) and Dabi (2011) [5].

The organic carbon content of surface horizon, in general, varied from low to medium (1.56 to 5.45 g kg^{-1}). The highest organic carbon (1.56 g kg^{-1}) was recorded in soil pedon 4, BC horizon (Table 2) and lowest (1.56 g kg^{-1}) in soil pedon 1, BC horizon. In all the pedons, the organic carbon content was higher in the surface and decreased with depth. It is naturally expected as plant residues and farmyard manure were applied to surface horizons (Thangaswamy *et al*., 2005; Kumar and Prasad 2010). The low carbon content in the soils may be attributed to the prevalence of tropical condition, where the degradation of organic matter occurs at a faster rate coupled with low vegetation cover (Nayak *et al.,* 2002) [11].

The free $CaCO_3$ is the dispersed precipitate of calcium carbonate in the solum. The free calcium carbonate in soil ranged from 21.3 to 120.0 g kg^{-1} (Table 2). Accumulation of $CaCO_3$ due to a negative precipitation-evapotranspiration (P−ET) balance and some geological properties (parent material). The presence of calcium carbonate nodules is common due to seasonal climates yielding mean annaual precipitation (MAP) between 760 mm and 1000 mm. The calcitic rhizoliths are common in arid regions where evapo-transpiration is greater than effective precipitation (Srivastava *et al.*, 2002) [12].

Exchangeable bases, across pedons were in the order of $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ on the exchange complex. Among the exchangeable bases, calcium dominated over magnesium followed by sodium and potassium. Similar cationic predominance was reported by Khan and Kamalakar (2012) [6] and Balpande *et al.* (2007) [2]. The low Mg^{2+} content than Ca^{2+} in all soil pedons is attributed to higher mobility of Mg^{2+} over Ca^{2+} in soils. The low value of exchangeable monovalents compared to divalents was attributed to preferential leaching of monovalents than divalents. These findings of dominance of divalent cations than the monovalent cations are in accordance with the findings of Thangaswamy *et al.* (2005).

The cation exchange capacity (CEC) ranged from 37.4 to 52.8 cmol (p^+) kg^{-1} in surface horizon (Table 3). The highest cation exchange capacity (56.9 cmol (p^+) kg^{-1}) was recorded in soil pedon 3, Bw_2 horizon and lowest (37.4 cmol (p^+) kg^{-1}) in soil pedon 4, Ap horizon. In most of the soil pedons, CEC increased with depth (except in BC horizons) which could be attributed to increase in clay content at lower depths. The results are endorsed by the findings of Kumar *et al.* (2005) [14] [14], Rao *et al*. (2008) [13] and Leelavathi *et al.* (2009) [9]. The magnitudes of CEC were indicative of presence of mixed type of clay minerals in the pedons. Variation in clay type and content, organic matter and presence of free iron oxides were responsible for variation in CEC in different pedons at varying physiographic positions.

The base saturation and ESP ranged from 74.6 to 95.9 per cent and 2.00 to 8.68 per cent (Table 2), respectively. The base saturation and ESP distribution showed irregular trend with depth. The higher base saturation in soils was due to the prevailing semi-arid climate facilitating less leaching and more accumulation of bases. Sekhar *et al*. (2014) and Das and Shinde (2014) also observed direct relation between base saturation and accumulation of bases due to less leaching.

The soil classification (up to family level) was done as per revisions of USDA Soil Taxonomy (Anon, 2014) [1] (Table 4). Pedon 2 was grouped under the order- Vertisol, suborder-usterts, great group-Haplusterts, subgroup- Vertic Haplusterts and family- clayey smectite superactive isohyperthermic. Soil pedons 1, 3 and 5 were grouped under the order- Inceptisol, suborder-ustepts, great group- Haplustepts, subgroup- Vertic Haplustepts and family-clayey mixed superactive isohyperthermic and pedon 4 was grouped under the order-Inceptisol, suborder- ustepts, great group- Haplustepts, subgroup- Typic Haplustepts and family- clayey mixed active isohyperthermic. This type covered 73 ha (10.85 per cent) area of micro-watershed.

The pedons 1, 3, 4 and 5 were grouped under order Inceptisol owing to the presence of cambic horizon. Because of the prevailing ustic moisture regime, they were identified as Ustepts under suborder. At the great group level, pedon 4 was classified as Haplustepts. This pedon which exhibited no inter-gradation with other taxa or an extra-gradation from the central concept was keyed out as Typic Haplustepts. The remaining pedons under Inceptisol (pedons 1, 3 and 5) were classified as Vertic Haplustepts as they possessed cracks within 125 cm of the mineral soil surface. They covers 410 ha (65.19 per cent) area of micro-watershed.

Pedon 2 was classified under Vertisol at the order level which had a weighted average of > 30 per cent clay in all the horizons down to a depth of 100 cm and possessed cracks that open and close periodically. These pedon had a layer of slickensides (> 25 cm thickness) and wedge shaped peds within 100 cm from the soil surface. At the great group level, the pedon was keyed out as Haplusterts. Because of absence of inter-gradation with other taxa or an extra-gradation from the central concept, the pedon 5 is keyed out as Typic Haplusterts. This covers 58 ha (8.66 per cent) area of micro-watershed. Soils of Kavalur-2 micro-watershed varied with respect to morphological, physical and chemical properties and were classified based on these at the order level as Inceptisols and Vertisols. Similar occurrence of soils was reported by Rudramurthy and Dasog (2001) [15] in North Karnataka.

Table 1. Physical characteristics of the red soil pedons in Kavalur-2 micro-watershed

Horizon	Depth (cm)	Gravel (%)	Particle size distribution (%): Coarse sand	Fine sand	Total sand	Silt	Clay	Bulk density (Mg m^{-3})	MWHC (%)	COLE
Pedon 1										
Ap	0-20	14.2	32.5	10.8	43.3	11.5	45.2	1.27	44.1	0.30
Bw_1	20-63	13.1	30.3	11.5	41.8	8.3	49.9	1.29	46.4	0.33
Bw_2	63-97	14.5	32.6	9.9	42.5	9.4	48.1	1.35	45.9	0.34
Bw_3	97-133	15.4	31.8	10.4	42.2	5.2	52.6	1.39	47.9	0.34
BC	133-180+	16.1	36.7	11.1	47.8	7.8	44.4	1.42	31.8	0.30
Pedon 2										
Ap	0-30	15.4	34.2	9.9	44.1	9.4	46.5	1.24	44.9	0.32
Bw_1	30-66	17.2	32.7	9.8	42.5	6.8	50.7	1.27	45.9	0.33
Bss	66-94	18.7	30.6	9.9	40.5	6.8	52.8	1.32	46.5	0.35
Bw_2	94-150	17.9	30.5	8.5	39.0	10.6	50.3	1.37	48.8	0.37
BC	150-180+	18.7	30.9	10.2	41.2	13.1	45.8	1.38	33.0	0.26
Pedon 3										
Ap	0-15	16.3	30.9	10.3	41.2	9.3	49.5	1.20	45.6	0.28
Bw_1	15-48	15.8	30.1	10.3	40.4	9.3	50.3	1.27	47.5	0.30
Bw_2	48-87	17.6	28.5	10.6	39.1	7.5	53.4	1.33	47.8	0.32
Bw_3	87-106	19.8	24.8	9.8	34.6	6.8	58.6	1.38	49.7	0.31
BC	106-180+	20.4	31.2	9.3	40.5	10.4	49.1	1.42	33.2	0.25
Pedon 4										
Ap	0-9	16.8	33.1	11.3	44.4	5.8	49.8	1.19	43.3	0.24
Bw_1	9-33	18.8	31.8	10.3	42.1	5.2	52.7	1.24	45.4	0.29
Bw_2	33-64	19.2	28.2	11.4	39.6	3.8	56.7	1.30	44.3	0.34
BC	64-98	17.8	33.2	10.8	44.0	5.7	50.3	1.36	30.2	0.36
Ck	98-140+	Weathered granite gneiss								
Pedon 5										
Ap	0-26	15.2	30.7	12.7	43.4	8.8	47.8	1.29	44.9	0.24
Bw	26-64	16.5	29.1	12.0	41.1	7.9	51.0	1.35	48.2	0.27
BC	64-112	17.8	28.0	11.3	39.3	7.0	53.7	1.39	30.7	0.26
Cr	112-156+	Weathered granite gneiss								

Table 2. Chemical properties of red soil pedons in Kavalur-2 micro-watershed

Horizon	Depth (cm)	pH $_{2.5}$	$EC_{2.5}$ ($dS\ m^{-1}$)	Organic carbon ($g\ kg^{-1}$)	Free $CaCO_3$ ($g\ kg^{-1}$)
Pedon 1					
Ap	0-20	8.49	0.45	4.29	21.3
Bw_1	20-63	8.57	0.48	3.51	36.3
Bw_2	63-97	8.62	0.50	3.12	41.3
Bw_3	97-133	8.69	0.52	2.73	82.5
BC	133-180+	8.64	0.60	1.56	97.5
Pedon 2					
Ap	0-30	8.51	0.24	5.45	28.8
Bw_1	30-66	8.84	0.27	4.29	35.0
Bss	66-94	8.53	0.32	3.51	48.8
Bw_2	94-150	8.63	0.30	3.90	62.5
BC	150-180+	8.81	0.34	2.73	80.0
Pedon 3					
Ap	0-15	8.21	0.21	4.29	26.3
Bw_1	15-48	8.24	0.24	3.90	22.5
Bw_2	48-87	8.26	0.23	3.51	66.3
Bw_3	87-106	8.31	0.26	3.12	120.0
BC	106-180+	8.26	0.23	2.73	78.8
Pedon 4					
Ap	0-9	8.65	0.24	5.26	23.8
Bw_1	9-33	8.43	0.28	4.48	30.0
Bw_2	33-64	8.76	0.30	3.86	57.5
BC	64-98	8.97	0.31	3.31	66.3
Ck	98-140+	Weathered granite gneiss			
Pedon 5					
Ap	0-26	8.36	0.31	4.09	66.3
Bw	26-64	8.49	0.34	3.70	78.8
BC	64-112	8.62	0.36	3.31	87.5
Cr	112-156+	Weathered granite gneiss			

Table 3. Exchangeable cations in red soil pedons of Kavalur-2 micro-watershed

Horizon	Depth (cm)	Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC	BS (%)	ESP
		[cmol (p^+) kg^{-1}]						
Pedon 1								
Ap	0-20	27.9	8.8	1.00	2.90	43.6	93.1	6.65
Bw_1	20-63	29.3	8.2	1.09	3.13	44.3	94.1	7.07
Bw_2	63-97	30.2	7.4	1.12	3.20	45.3	92.4	7.06
Bw_3	97-133	31.6	8.3	1.15	3.39	47.5	93.5	7.14
BC	133-180+	28.5	8.3	1.06	2.64	44.1	91.8	5.98
Pedon 2								
Ap	0-30	23.6	8.3	0.97	3.33	39.7	91.0	8.39
Bw_1	30-66	26.9	9.2	0.86	3.79	43.7	93.0	8.68
Bss	66-94	29.7	10.3	0.55	3.36	47.3	92.8	7.11
Bw_2	94-150	26.3	9.7	0.85	3.58	43.8	92.2	8.17
BC	150-180+	24.6	9.0	0.84	3.41	41.4	91.1	8.24
Pedon 3								
Ap	0-15	31.7	12.5	0.42	2.21	52.8	88.6	4.19
Bw_1	15-48	33.8	13.1	0.53	2.26	55.4	89.5	4.07
Bw_2	48-87	33.9	12.7	0.63	2.61	56.9	87.6	4.58
Bw_3	87-106	29.9	12.8	0.62	2.58	52.6	87.1	4.91
BC	106-180+	32.7	12.8	0.65	3.01	55.3	88.9	5.45
Pedon 4								
Ap	0-9	24.2	7.9	0.86	1.13	37.4	91.1	3.03
Bw_1	9-33	24.8	9.3	0.74	0.96	40.6	88.1	2.37
Bw_2	33-64	25.6	10.1	0.64	2.93	42.4	92.5	6.92
BC	64-98	26.7	10.7	0.59	3.01	42.7	95.9	7.06
Ck	98-140+	Weathered granite gneiss						
Pedon 5								
Ap	0-26	25.7	8.6	0.63	0.96	48.1	74.6	2.00
Bw	26-64	28.7	7.7	0.54	1.94	46.9	82.7	4.14
BC	64-112	29.9	7.5	0.46	2.33	44.2	90.6	5.26
Cr	112-156+	Weathered granite gneiss						

Table 4: Classification of soils of Kavalur-2 micro-watershed

Pedon	Soil properties leading to soil classification	Soil classification
2	Clayey : Have 35 percent or more (by weight) clay Smectite : Dominance of smectite mineral Superactive: Clay: CEC ratio: > 0.6 Isohyperthermic : Difference between mean summer and winter temperature was less than 6 ^{0}C Typic : No inter-gradation with other taxa or an extra-gradation from the central concept Haplusterts: Layer of slickensides (> 25 cm thickness), wedge shaped peds within 100 cm from the soil surface and ustic moisture regime	Clayey, smectite, superactive, isohyperthermic, Typic Haplusterts
1, 3 and 5	Clayey : Have 35 percent or more (by weight) clay Smectite : Dominance of smectite mineral Superactive: Clay: CEC ratio: > 0.6 Isohyperthermic : Difference between mean summer and winter temperature was less than 6 ^{0}C Vertic : Cracks within 125 cm of the mineral soil surface Haplustepts: Presence of cambic horizon and prevalence of ustic moisture regime	Clayey, smectite, superactive, isohyperthermic, Vertic Haplustepts
4	Clayey : Have 35 percent or more (by weight) clay Smectite: Dominance of smectite mineral Superactive: Clay: CEC ratio: > 0.6 Isohyperthermic: Difference between mean summer and winter temperature was less than 6 ^{0}C Typic : No inter-gradation with other taxa or an extra-gradation from the central concept Haplustepts: Presence of cambic horizon and prevalence of ustic moisture regime	Clayey, smectite, superactive, isohyperthermic, Typic Haplustepts

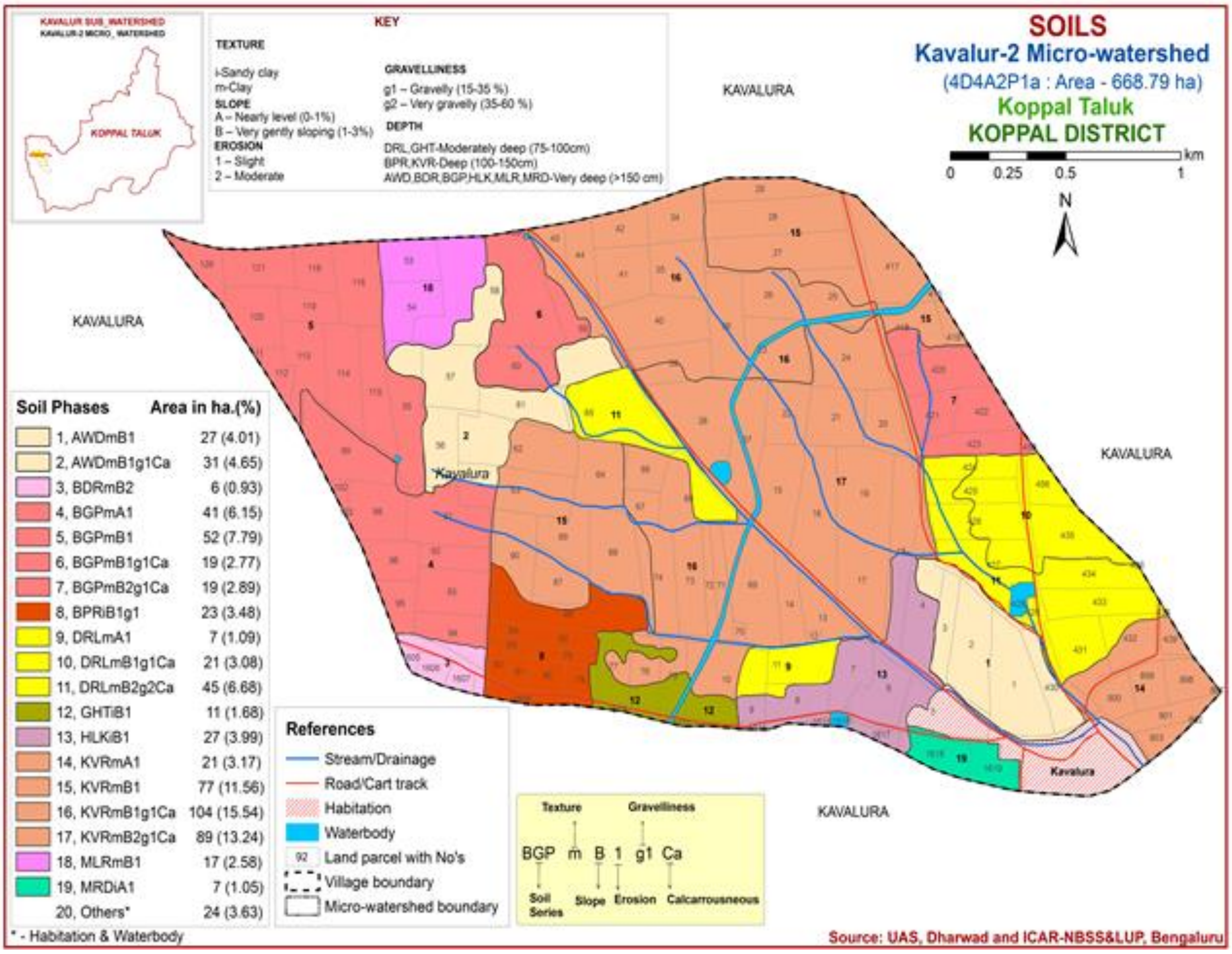

Fig 1: Soil mapping units of Kavalur-2 micro-watershed

Conclusion

The soils of Kavalur-2 micro-watershed were sandy clay to clay in texture with noticeably low bulk density and high water holding capacity. The coefficient of linear extensibility (COLE) values indicated swell-shrink properties of soils and gradually increased from surface to subsurface horizon owing to clay intensification. The soils were slightly alkaline to alkaline in reaction and were non-saline. The organic carbon content was low to medium. The soils had considerably higher amounts of free calcium carbonate and cation exchange capacity, both increased with depth. The base saturation and exchangeable sodium percentage showed irregular trend with depth. The calcium and magnesium were the dominant exchangeable cations followed by sodium and potassium. The soil classified (up to family level) as per revisions of US Soil Taxonomy revealed that pedons under study belonged to Inceptisol and Vertisol.

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