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Kalaiselvi Beeman
ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore, India

Rajendra Hegde
ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore, India

Vasundhara R
ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore, India

Anil Kumar KS
ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore, India

Dharumarajan S
ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore, India

Lalitha M
ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore, India

SK Singh
ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur, India

Correspondence
Kalaiselvi Beeman
ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore, India

Characterization and classification of soils of Bilalgodu micro-watershed, Chikmagalur district, Karnataka

Kalaiselvi Beeman, Rajendra Hegde, Vasundhara R, Anil Kumar KS, Dharumarajan S, Lalitha M and SK Singh

Abstract
A detailed soil survey was carried out in Bilalgodu microwatershed of Kalasa block, Mudigere taluk, Chikkamagaluru district of Karnataka at 1:10000 scale. The bilalgodu micro-watershed was selected to study and understand the pedogenic characters of the soil in different physiographic regions for summit, undulating hills, side and foot slopes due to the variability in landform which affects the crop productivity. Five soil series were identified in the study area based on the pedological investigations of typifying pedons and physico-chemical properties. The soils were characterized by deep to very deep, dark reddish brown to dark grayish brown (Munsell colour chart), well drained, slightly acidic to very strongly acidic, medium to high in organic carbon and low to medium in cation exchange capacity showing textural variations ranging from sandy clay loam to clay indicated difference in development apparently due to the varied landform in the region and were formed on ferruginous quartzite schist parent material. The soils were taxonomically classified as *Ustic Kanhaplohumults, Typic Kanhaplustults, Pachic Argiustolls, Ustic Haplohumults, Aquic Dystrustepts* respectively.

Keywords: pedological soil characteristics, physico-chemical properties, taxonomic soil classification

Introduction
Enhancing the sustainable soil productivity is the need of the hour to feed the ever increasing population (Philip *et al.*, 2012) [11]. Indiscriminate use of finite soil resources coupled with lack of management has led to degradation causing concern to planners, researchers and farmers. Scientific approach of soil studies for pedological investigations, physico characterization may aid for development and management of soil resources through mapping at larger scale on 1:10,000 (Kanwar, 1994) [4]. Soil resource studies highlight its potentialities and limitations for its effective management and improve productivity. Precise soil survey at larger scale and in depth laboratory investigations facilitates detailed information on land form, geology, natural vegetation, soil reaction, salt concentration that elaborates limitations and productivity potentials of soils for crop production and also assess suitability of land uses (Manchanda *et al.*, 2002) [6]. The properties of a soil are the basic attributes that directly influence the soil response to any specified use. Rational utilization of land resources can be achieved by optimizing its use, which demands evaluation of land for alternative land use (Udoh, 2015) [20]. Chikmagalur district in Karnataka reported extreme variation in the landform, lack of potential nutrient reserve in the ferruginous parent materials for crop production, and the tropical climate that favored widespread utilization of land for forestry. In the absence of detailed soil survey data and large scale maps the implementation of management strategies and reclamation options were lagging behind. An attempt was therefore taken, for detailed characterization and classification of soil resources in a pilot scale in Bilalgodu watershed, for further upscaling in similar areas.

Materials and Methods
Study area
Geographically, the Bilalgodu watershed lies between 75°17'54" to 75°20'03" E longitude and 13°11'54" to 13°13'49" N latitude with an area of 710 hectare. The general elevation of the area ranges from 700 to 1100 m above mean sea-level (MSL). The drainage is sub-parallel and dendritic in the watershed.

Based on relief features, the area is divided into lowlands, upper, middle and lower part of side slopes of hill. Climate of the watershed is hot humid and sub tropical with mean annual rainfall of 3300 mm, mean annual temperature of 22 °C and PET of 1636 mm. The area qualifies for '*Isohyperthermic*' soil temperature regime. Geology of the study area is dominantly of quartzite schist. The major irrigation command of the area is Tunga River. The major vegetation types are tropical evergreen forests, moist deciduous forests, scrub jungles. The natural vegetation comprises of Jack fruit, Eucalyptus and Forest vegetation etc. Major crops are rice in lowland and arecanut, coffee and coconut in sloping uplands.

Soil survey was carried out using base map on 1:10,000 scale. A detailed traverse of the watershed was made to identify the uplands, midlands and lowlands. Pedon sites were located in transects along the slope from the upper to lower slopes and 21 profiles were studied for morphological characteristics as per Soil Survey Manual (Soil Survey Staff, 1999) [18]. The details of the pedons are given in Table.1. Horizon-wise soil samples were collected, air dried and passed through 2 mm sieve and analyzed for particle-size distribution following International Pipette method (Richards, 1954) [13], pH and electrical conductivity (EC) in 1:2.5 soil:water suspension (Piper, 1966) [12]. Organic carbon was estimated by Walkley and Black (1934) [23] method. The cation exchange capacity (CEC) and exchangeable cations were determined as described by Jackson (1973) [3]. The soils were classified as per Soil Taxonomy (Soil Survey Staff, 2003) [19].

Table 1: Landscape characteristics of pedons

Pedons	Villages	Location	Elevation	Physiography	Slope	Drainage
B1	Muthkoli	13°12'4.8" N, 75°18' 57.7" E	986	Upper part of side slope	5-10%	Well
B2	Kalbadi	13°12'39.93" N, 75°19' 23.34" E	848	Summit	10-15%	Somewhat excessive
B3	S. K. Vegal	13°13'417.37" N, 75°19' 34.17" E	766	Mid part of the side slope	5-10%	Well
B4	S. K. Vegal	13°12'49.53" N, 75°19'2.66" E	846	Mid part of the side slope	5-10%	Well
B5	Konegud	13°13'16.72" N, 75°18' 19.85" E	778	Valley	1-3%	Moderately well

Result and Discussion

Soil morphology

Pedon B1 occurring on uplands were deep, well to somewhat excessively drained with rapid permeability, clay texture, dark reddish brown (5YR 3/3) to red (2.5YR 4/6) color. These soils occur on rolling slope with 3-10 per cent slopes at an elevation of 780 m above MSL. Pedon B2 occurring on midland of side slope are deep, well drained with rapid permeability, sandy loam surface texture and sandy clay sub-surface texture, yellowish red (5YR 4/4) to red (2.5YR4/6) color. Pedon B3 were very deep, well drained with rapid permeability, clay loam surface texture and clay textured sub surface, dark reddish brown (5YR3/4) to dark reddish brown (2.5YR 3/4) in colour. The pedon B4 were very deep, well drained with moderate permeability, sandy clay loam surface texture followed by clay loam sub-surface texture, strong brown (7.5YR 4/6) and dark red (2.5YR 3/6) in colour. The pedon B5 occurring on lowlands are very deep, moderately well to well drained with moderate permeability, clay loam texture, grayish brown (10YR 5/2) to dark grayish brown (10YR 4/2) in colour. The soil colour appears to be the function of chemical and mineralogical composition as well as textural make up of soils and conditioned by topographic position and moisture regime (Walia and Rao, 1997) [21, 22]. Textural class of the soils varied from sandy loam to clay. This textural variation might be due to differences in topography, *in-situ* weathering and translocation of clay by eluviation and age of soils (Geetha Sireesha and Naidu, 2013) [2]. The structure of the soils was subangular blocky. The blocky structure *i.e.,* angular and sub-angular blocky were attributed to the presence of higher quantities of clay fraction (Sharma *et al.,* 2004) [17]. The consistence of the soils varied from soft to slightly hard (dry), friable (moist) and slightly sticky and slightly plastic to very sticky and very plastic (wet). Presence of sticky and plastic to very sticky and very plastic, firm to very firm and slightly hard to very hard consistence in wet, most and dry conditions, respectively may be due to high clay content of soil (Sarkar *et al.,* 2001) [14] and also due to dominance of smectite clay mineral (Leelavathi *et al*., 2010) [5]. Pedons 1, 2, 3, 4 exhibited argillic (Bt) sub-surface diagnostic horizon and pedon 5 had shown presence of cambic endopedon (Bw).

Soil physical characteristics

The particle size analysis (Table 2) revealed that the clay content varied from 17 to 60 per cent in Bilalgodu soils. Pedon 1, 3, 4 and 5 shown increase in clay content with depth which might be due to downward translocation of finer particles from the surface layers (Murthy, 1988) [8]. The decrease in clay content with depth in pedon 2 might be due to variability of weathering in different horizons. Silt content in general exhibited an irregular trend with depth (Table 2), which might be due to variation in weathering of parent material or *insitu* formation (Satish Kumar and Naidu, 2012) [15]. In pedon 2 and 3, the coarse fragments are significantly higher than other pedons. Due to the high gravel content in control section, they were classified into skeletal nature of soils.

Soil chemical properties

Cation exchange capacity of typifying pedons ranged from 1.73 to 21.83 cmol (p^+) kg^{-1}. The CEC of the soils are increased with increase in clay content of the pedons. Irrespective of the pedons, the CEC decreased with depth due to variation in clay and organic matter content (Mishra and Ghosh, 1995) [7]. The exchangeable bases showed distinct pattern regarding their sequential dominance (Table 2). In all the pedons, the order followed was Ca>Mg>K>Na. The Ca^{2+} in soils ranged from 0.28 to 13.14 cmol (p^+) kg^{-1}, with a mean value of 2.33 cmol (p^+) kg^{-1}, Mg^{2+} ranged from 0.09 to 1.58 cmol (p^+) kg^{-1} with a mean value of 0.65 cmol (p^+) kg^{-1}, Na^+ ranged from 0.004 to 0.09 cmol (p^+) kg^{-1}, with a mean value of 0.03 cmol (p^+) kg^{-1} and K^+ ranged from 0.018 to 0.422 cmol (p^+) kg^{-1} with a mean value of 0.078 cmol(p^+) kg^{-1}.

Exchangeable cations were found in traces, it may be due to heavy rainfall although calcium is slightly higher. The variation observed in base saturation percentage (BSP) indicates the degree of leaching which was used as diagnostic character for classifying the soil orders (Patil and Dasog, 1997) [10]. Comparatively high base saturation is observed in pedon 1 and 3 which is directly related to clay and organic carbon content.

Physico-chemical characteristics

The pH of the soils ranged from 4.3 to 6.4, electrical conductivity ranged between 0.01 to 0.15 dSm^{-1} with an average value of 0.031 dSm^{-1}, OC varied from 0.16 to 3.8 g kg^{-1} with a mean value of 1.22 g kg^{-1}. The soils are slightly acidic to very strongly acidic in nature with pH varying from 4.5 to 6.5. In pedon 1, soils are slightly to moderately acidic pH (5.5 to 6.5), in pedon 2, moderate to strongly acidic (5.3-5.8), in pedon 3 slightly acidic to moderately acidic pH (5.5-6.5), in pedon 4 strongly acidic pH (5.0-5.5) and in pedon 5 very strong to moderately acidic pH (4.5-6.0). This wide variation was attributed to the nature of the parent material, leaching, presence of calcium carbonate and exchangeable sodium (Shalima Devi and Anil Kumar, 2010) [16]. All the pedons showed low electrical conductivity values ranging from 0.01 to 0.0.15 dSm^{-1}, indicating non saline nature. The low electrical conductivity may be due to high rainfall and free drainage (Table 2). Organic carbon content of these soils was found to be low to high and varied from 0.16 to 3.8 per cent (Table 2). The organic carbon conternt of the surface is significantly higher in all the pedons compared to sub surface layers. This is attributed to the addition of plant residues and farm yard manure to surface horizons (Ashok Kumar and Jagdish Prasad, 2010) [1]. The low carbon content in the soils might be attributed to the prevalence of tropical condition, where the degradation of organic matter occurs at a faster rate coupled with low vegetation cover, thereby leaving less organic carbon in the soils (Nayak *et al.*, 2002) [9]. The CEC in all the pedons estimated by ammonium acetate extract varied from 1.73 to 21.83 cmol (p^+) kg^{-1}soil which corresponds to clay content, organic carbon content and also type of clay mineral present in these soils. Exchangeable bases in all pedons are in the order of $Ca^{2+} > Mg^{2+} > K^+ > Na^+$ on the exchange complex. The base saturation (BSP) varied from 9 to 90 per cent. The higher value of per cent base saturation was observed due to higher amount of Ca^{2+} ions occupying the exchange sites on the colloidal sites. The ratio between CEC and clay ranged from 0.08 to 0.63 and the CEC : clay ratio was used to identify the clay mineralogy (Ashok Kumar and Jagdish Prasad, 2010) [1].

Soil taxonomy

Based on morphological, physical and physicochemical properties, the typifying pedons were classified according to Soil Taxonomy (Soil Survey Staff, 2003) [19] into the orders Mollisol, Inceptisols and Ultisols. Due to the presence of high organic carbon and base saturation > 60 per cent by sum of cations in control section, Pedons 1 was grouped under humults. Because of the CEC clay ratio is less than 0.16 in subsurface and based on presence of ustic moisture regime the pedon 1 was further classified into *Ustic Kanhaplohumults* in sub-group level. Pedon 2 was classified as ustults at sub-order level due to presence of ustic soil moisture regime and the base saturation less than 35 per cent. It was classified under *Typic Kanhaplustults* at great group level due to presence of kandic horizon. Pedon 3 was placed under Ustolls at sub-order level because of high organic carbon content and base saturation. Further, it was classified as *Pachic Argiustolls* at sub-group level as it showed mollic epipedon more than 40 cm thickness and argillic endopedon. Pedon 4 was placed under humults at sub-order level due to <35 per cent base saturation in control section and organic carbon content is 0.9 per cent or more than that in upper 15 cm of the argillic or kandic horizon and further classified into *Ustic Haplohumults*. Pedon 5 exhibited cambic (Bw) sub-surface diagnostic horizon, were classified under Inceptisols and Ustepts at sub-order level due to ustic soil moisture regime. The base saturation < 60% by neutral normal ammonium acetate within first 75 cm of the pedon classified into Dystrustepts at great group level and due to the presence water saturated layer in one or more layer, classified into *Aquic Dystrustepts* at sub group level.

Table 2: Important Properties of Bilalgodu Microwatershed Soils, Kalasa, Chikmagalur, Karnataka

Sl. No.	Depth (cm)	Horizon	Per cent Clay	Silt content (%)	Coarse Fragments (Vol.%)	Texture	Organic Carbon%	pH	EC	Exchangeable bases					CEC	CEC/clay	BS%
										Ca	Mg	K	Na	Sum			
		Pedon 1-B1: Fine, Kaolinitic, isohyperthermic family of Ustic Kanhaplohumults															
1	0-18	Ap	34.42	35.20	15	cl	3.83	5.98	0.104	13.138	1.575	0.422	0.035	15.17	21.83	0.63	69
2	18-40	Bt1	56.48	20.34	-	c	3.16	6.34	0.045	8.573	0.995	0.197	0.017	9.78	14.48	0.26	68
3	40-75	Bt2	60.83	19.13	-	c	1.18	6.17	0.024	2.478	0.983	0.111	0.006	3.58	8.77	0.14	41
4	75-110	Bt3	53.22	26.24	-	c	0.67	6.17	0.018	1.594	1.213	0.100	0.024	2.93	7.34	0.14	40
5	110+	Cr	WPM														
		Pedon 2-B2: Loamy skeletal, Kaolinitic, isohyperthermic family of Typic Kanhaplustults															
1	0-16	Ap	19.17	11.35	20	sl	1.12	5.33	0.031	0.813	0.247	0.145	0.018	1.22	5.20	0.27	24
2	16-36	Bt1	26.46	17.05	20	scl	0.68	5.34	0.015	0.431	0.128	0.049	0.010	0.62	5.30	0.20	12
3	36-64	Bt2	17.21	14.47	65-70	sl	0.56	5.41	0.011	0.293	0.090	0.033	0.009	0.43	2.96	0.17	14
4	64-100	BC	11.84	16.89	50	sl	0.16	5.71	0.01	0.283	0.098	0.022	0.004	0.41	1.73	0.15	23
5		Weathered schist material															
		Pedon 3-B3: Loamy – skeletal, Kaolinitic, isohyperthermic family of Pachic Argiustolls															
1	0-16	Ap	32.49	12.07	12	scl	2.84	6.01	0.038	4.383	1.365	0.111	0.010	5.87	9.28	0.29	63
2	16-37	Bt1	39.96	15.42	30	cl	2.05	5.89	0.02	2.197	1.198	0.059	0.012	3.47	7.24	0.18	48
3	37-64	Bt2	44.89	11.68	55	c	1.26	5.73	0.018	2.062	1.056	0.064	0.015	3.20	3.67	0.08	87
4	64-101	Bt3	22.84	8.94	65	scl	0.39	5.52	0.019	1.531	0.711	0.050	0.026	2.78	3.37	0.15	43
5	101-140	Bt4	25.81	4.36	60	scl	0.47	5.62	0.017	1.644	0.651	0.047	0.085	2.43	3.06	0.12	79
6	140-172	Bt5								1.259	0.531	0.030	0.060	1.88	2.35	0.12	80
		Pedon 4-B4: Fine-loamy, mixed, isohyperthermic family of Ustic Haplohumults															
1	0-24	Ap	29.97	15.35	-	scl	1.97	5.43	0.047	2.838	0.721	0.116	0.024	3.70	9.28	0.31	40
2	24-55	Bt1	32.12	15.20	-	scl	1.04	5.2	0.012	0.453	0.222	0.043	0.036	0.75	8.16	0.25	9
3	55-80	Bt2	32.12	17.83	-	scl	0.76	5.3	0.02	0.854	0.189	0.036	0.022	1.10	7.34	0.23	15
4	80-109	Bt3	27.41	16.63	-	scl	0.72	5.25	0.011	0.998	0.235	0.037	0.042	1.31	6.02	0.22	22
5	109-141	Bt4	22.30	14.23	-	scl	0.52	5.57	0.013	0.879	0.174	0.018	0.047	1.12	3.57	0.16	31
6	141-170	Bt5	18.68	17.46	-	sl	0.24	5.43	0.013	0.828	0.191	0.019	0.012	1.05	2.75	0.15	38

		Pedon 5-B5: Fine-loamy, Kaolinitic, isohyperthermic family of Aquic Dystrustepts														
1	0-19	Ap	30.4	30.20	-	scl	2.13	4.39	0.151	1.503	0.349	0.056	0.068	1.98	9.59	0.32	21
2	19-44	Bw1	33.6	30.03	-	scl	1.32	5.75	0.038	2.945	0.951	0.028	0.076	4.00	6.83	0.20	59
3	44-75	Bw2	30.4	24.33	-	c	0.76	5.89	0.02	1.970	0.700	0.028	0.026	2.72	5.81	0.19	47
4	75-110	Bw3	35.0	27.2	-	sc	0.8	5.5	0.02	2.157	0.908	0.056	0.080	3.20	5.30	0.15	60
5	110-150	Bw4	35.5	26.31	-	sc	0.56	5.79	0.017	2.298	0.799	0.061	0.046	3.20	3.6	0.10	90

Conclusion

Based on base saturation, organic carbon content and clay content of the soil, the bilalgodu micro watershed soils are classified into *Ustic Kanhaplohumults*, *Typic Kanhaplustults, Pachic Argiustolls*, *Ustic Haplohumults, Aquic Dystrustepts* respectively. The pH dependent CEC/ clay ratio was used as an indicator to assess the degree of weathering sequence in the order of P2=P4> P1> P3> P5. The study shows the influence of topography in controlling the pedogenic processes and its physico-chemical characteristics of Bilalgodu soils that will certainly help in taking effective measures for sustainable management of the soil for suitable land use.

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