Environment and Ecology 36 (4A) : 1270—1280, October—December 2018
Website: environmentandecology.com ISSN 0970-0420

Characterization and Classification of Soil Resources of Dongaragaon Micro-Watershed

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Received 26 June 2018 ; Accepted 1 August 2018 ; Published on 25 August 2018

Abstract A study was undertaken to characterize and classify the soil resources of Dongaragaon micro-watershed in Kalaburagi district of Karnataka. Eight soil series were tentatively identified and mapped into ten mapping units using GIS technique. These mapping units were studied for their morphological, physical and chemical properties. Ten representative pedons covering all the soil types were selected and classified. The soils were shallow (25–50 cm) to very deep (> 150 cm) in depth and varied from dark grayish brown to very dark grayish brown in black soil series and dark reddish brown to dark brown color in red soil. Soils under the study were predominantly sub-angular blocky in structure, neutral (6. 5) to slightly alkaline (8.3) in reaction (pH) with non-saline soils and organic carbon content was low (2.1 g kg^{-1}) to medium (6.4 g kg^{-1}). Irrespective of soil type, dominance of exchangeable cations was in the order of $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$. Soils studied were classified up to family level according to revisions in soil taxonomy using morphological, physical and chemical properties. Major proportion of the soils in the micro-watershed belonged to the order Inceptisols, Alfisols and Vertisols.

Keywords Soil classification, Physiography, Land forms.

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Introduction

Land is a scarce resource and basic unit for any material production. It can support the needs of the growing population, provided they use land in a national and judicious manner. Constraints of land resources across the state are cause for concern for their effective management at the grassroots level. The area available for agriculture is about 51% of the total area and more than 50% of the people are still relying on agriculture for their livelihood (GOI 2016). The limited land area is under severe pressure due to increased population density and competing demands of various land uses leading to their severe degradation. This trend over period of time had diverted significant area of farm lands and water resources for non-agricultural purposes. Also lack of interest in farmers towards farming in many parts of the state over efficient management of available land resources has converted large tracts of cultivable lands into fallow and this scenario is growing at an alarming rate. There-

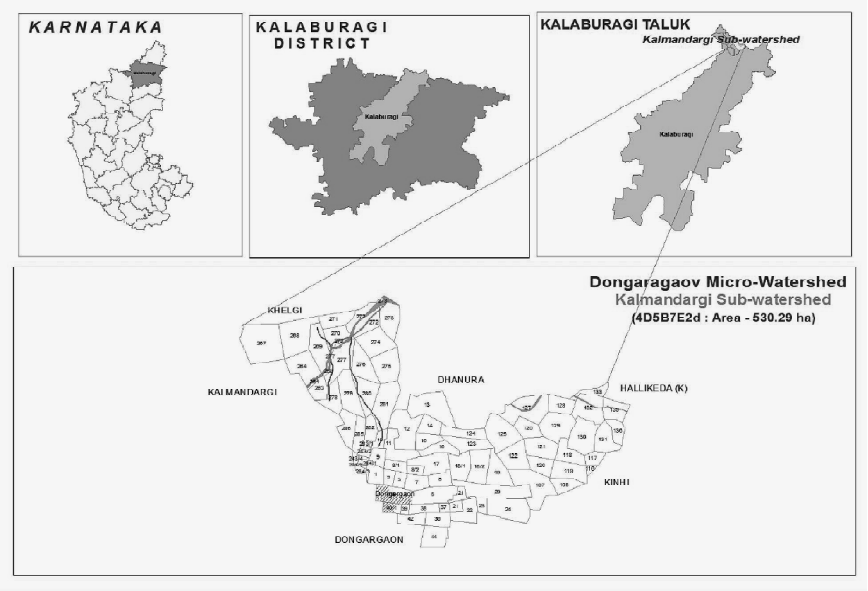

Fig. 1. Location map of Dongaragaon micro-watershed.

fore, systematic study of the soils covering morphology and taxonomy will provide valuable information on nature and type of soils. Hence, current study was carried out to characterise and classify soils resources of the Dongaragaon micro-watershed based on physiography, landforms, physical and chemical properties of the soils.

Materials and Methods

Dongaragaon micro-watershed is located in Kalaburagi taluk of Kalaburagi district, Karnataka and having total area of 530.3 hectares which lies between 17°67´43.91´´ longitudes and 77°21´ 53.85´´ North latitudes of 454 m above mean sea level (MSL) (Fig. 1). The average rainfall of this region is 774.4 mm with a large spatial and temporal variability. The maximum temperature during summer is 40.9°C and the minimum of 29.7°C in winter. Study area is characterized by basalt, granites and gneiss complex.

The detailed soil survey was carried out using IRS P6 data. Ten pedons were exposed and studied for their geomorphological features such as slope, surface stoniness, erosion, drainage and gravels of landscape and morphological features like soil depth, texture, color, structure, consistency and coarse fragments of the pedons. The physico-chemical properties of soils collected from different horizons were estimated by following the standard procedures (Soil Survey Staff 1999).

Results and Discussion

Soil morphology

All the black soil pedons exhibited hue of 10 yr throughout the profile and the dominant color was dark grayish brown to very dark grayish brown (Table 1) due to the clay-humus complex in the presence of lime. In red soil pedons, hue was yellowish (5 yr) (Ram et al. 2014). The dark matrix color was due to presence of high organic matter content in the surface horizons. Structure in all soil series (Dongaragaon, Kamalapur, Bhimnalli, Margutti and Gutti series) was predominantly moderate medium sub-angular to moderate fine sub-angular blocky (sbk) in the surface horizons except Margutti, Bachanal and Kurkota series, whereas angular blocky (abk) structure in the sub-soil horizon. Consistency varied from

Table 1. Morphological properties of Dongaragaon micro-watershed. sh–slightly hard, h–hard, l–loose, vh–very hard, fr–friable, fi–firm, ss–slightly sticky, sp–slightly plastic, vs–very sticky, vp–very plastic, ms–moderately sticky, mp–moderately plastic, m–medium, f–fine, sbk–subangular blocky, abk–angular blocky.

Pedon no.	Horizon	Depth (cm)	Color		Structure
			Dry	Wet	
			Dongaragaon series ((DGNiB2g0)		
P1	Ap	0–30	10 yr 3/2	10 yr 3/2	2m sbk
	Bw	30–58	10 yr 3/2	10 yr 3/2	2m sbk
	Bss1	58–82	10 yr 3/2	10 yr 3/2	2m sbk
	Bss2	82–109	10 yr 3/2	10 yr 3/2	3m abk
	Bss3	109–148	10 yr 3/2	10 yr 3/1	3m abk
	Bss4	148–185	10 yr 3/2	10 yr 3/1	2m abk
			Kamalapur series (KMPiC2g0)		
P2	Ap	0–22	10 yr 3/1	10 yr 3/2	2f sbk
	Bw1	22–32	10 yr 3/1	10 yr 3/2	2f sbk
	Bw2	32–61	10 yr 3/1	10 yr 3/2	2m abk
	Cr	61–96	10 yr 2/1	10 yr 2/1	2m abk
			Bhimnalli series (BMNiB2g0)		
P3	Ap	0–10	10 yr 3/4	10 yr 3/3	2f sbk
	Bw	10–30	10 yr 3/2	10 yr 3/2	2f sbk
	Cr	30–35	10 yr 3/2	10 yr 4/2	2f sbk
			Margutti series (MRGiD3g1S1)		
P4	Ap	0–10	10 yr 3/3	10 yr 3/4	2f sbk
	Bw	10–22	10 yr 3/3	10 yr 3/4	2f sbk
			Margutti series (MRGiC3g1)		
P5	Ap	0–6	10 yr 3/3	10 yr 3/2	1f sbk
	Bw	06–26	10 yr 3/2	10 yr 3/2	3f sbk
			Gutti series (GUTmB2g0)		
P6	Ap	0–13	10 yr 3/3	10 yr 3/2	2m sbk
	Bw	13–39	10 yr 3/2	10 yr 3/1	3m sbk
	Bw1	39–68	10 yr 3/2	10 yr 3/1	2m abk
			Bachanal series (BHNhB2g0)		
P7	Ap	0–17	5 yr 4/4	5 yr 3/4	2m sbk
	Bt1	17–46	5 yr 3/4	5 yr 3/3	3f abk
			Bachanal series (BHNhC3g1S1)		
P8	Ap	0–10	5 yr 3/2	5 yr 3/2	1f sbk
	Bt1	10–32	5 yr 3/2	5 yr 3/3	1f sbk
	Cr	32–41	5 yr 4/3	5 yr 4/3	2f sbk
			Kurkota series (KKThE3g1S1)		
P9	Ap	0–19	2.5 yr 4/4	2.5 yr 3/4	1m sbk
	Bt	19–48	2.5 yr 3/4	2.5 yr 3/3	1m sbk
	Bt1	48–89	2.5 yr 3/4	2.5 yr 3/3	2m sbk
			Ratnagutti series (RTGhC2g0)		
P10	Ap	0–26	5 yr 3/3	5 yr 3/2	2m sbk
	Bt	26–79	5 yr 3/2	5 yr 3/3	2m sbk

Table 1. Continued.

Pedon no.	Horizon	Consistency Dry	Moist	Wet	Slope (%)	Erosion	Drainage	Physio-graphy
				Dongaragaon series (DGNiB2g0)				
P1	Ap	H	fr	vsvp	1–3	Moderate	Well	Upper prediplain
	Bw	H	fr	vsvp				
	Bssl	H	fr	vsvp				
	Bss2	H	fr	vsvp				
	Bss3	H	fi	vsvp				
	Bss4	H	fi	msmp				
				Kamalapur series (KMPiC2g0)				
P2	Ap	Sh	fr	sssp	1–5	Moderate	Moderately well	Lower prediplain
	Bw1	Sh	fr	sssp				
	Bw2	Sh	fr	sssp				
	Cr	Sh	fr	sssp				
				Bhimnalli series (BMNiB2g0)				
P3	Ap	Sh	fr	sssp	5–10	Moderate	Moderately well	Pediments
	Bw	Sh	fr	sssp				
	Cr	Sh	fr	sssp				
				Margutti series (MRGiD3g1S1)				
P4	Ap	Sh	fr	sssp	5–10	Severe	Well	Pediments
	Bw	Sh	fr	sssp				
				Margutti series (MRGiC3g1)				
P5	Ap	L	I	ssmp	5–10	Severe	Well	Pediments
	Bw	H	I	ssmp				
				Gutti series (GUTmB2g0)				
P6	Ap	H	fr	msmp	5–10	Slight	Well	Lower prediplain
	Bw	Vh	fi	vsvp				
	Bw1	Vh	fi	vsvp				
				Bachanal series (BHNhB2g0)				
P7	Ap	H	fi	msmp	5–10	Severe	Excessive	Foot slope
	Bt1	Vh	fi	msmp				
				Bachanal series (BHNhC3g1S1)				
P8	Ap	Sh	fr	sssp	5–10	Severe	Excessive	Foot slope
	Bt1	Sh	fr	sssp				
	Cr	Sh	fr	sssp				
				Kurkota series (KKThE3g1S1)				
P9	Ap	Vh	fi	msmp	10–25	Severe	Excessive	Side slope
	Bt	H	fi	sssp				
	Bt1	H	fi	sssp				
				Ratnagutti series (RTGhC2g0)				
P10	Ap	Vh	fi	msmp	5–10	Moderate	Well	Hill top
	Bt	H	fi	sssp				

Table 2. Physical properties of Dongaragaon micro-watershed. sc–Sandy clay, c–Clay, sl–Sandy loam, scl–Sandy clay loam, BD–Bulk density, PD–Particle density, MWHC–Maximum water holding capacity.

Pedon no.	Horizon	Depth (cm)	Coarse sand	Fine sand	Total sand %	Silt	Clay	Textural class	BD	PD	Porosity	MWHC
									Mg m^{-3}		%	
					Black soil							
					Dongaragaon series (DGNiB2g0)							
P1	Ap	0-30	19.4	34.7	53.1	4.5	42.4	sc	1.24	2.31	42.0	51.2
	Bw	30-58	17.3	30.0	47.3	7.1	45.6	c	1.28	2.37	41.8	53.4
	Bss1	58-82	14.5	24.7	39.1	12.4	48.5	c	1.37	2.45	40.0	55.4
	Bss2	82-109	9.6	16.5	26.1	17.5	56.4	c	1.42	2.48	38.7	56.9
	Bss3	109-148	7.4	12.6	20.0	12.7	67.3	c	1.47	2.53	37.9	59.4
	Bss4	148-185	6.6	11.3	17.9	9.2	72.9	c	1.52	2.57	37.0	61.5
					Kamalapur series (KMPiC2g0)							
P2	Ap	0-22	19.3	33.0	52.3	8.2	39.5	sc	1.27	2.34	41.5	47.5
	Bw1	22-32	16.2	27.6	43.8	13.4	42.8	c	1.31	2.38	40.8	49.1
	Bw2	32-61	12.8	21.8	34.6	15.2	50.2	c	1.33	2.46	41.9	52.5
	Cr	61-96	9.7	16.7	26.4	11.8	61.8	c	1.35	2.51	42.2	55.5
					Bhimnalli series (BMNiB2g0)							
P3	Ap	0-10	16.9	28.9	45.8	11.0	43.2	sc	1.29	2.29	39.3	52.4
	Bw	10-30	16.0	27.1	43.1	10.6	46.3	c	1.33	2.35	39.1	55.9
	Cr	30-35	12.5	21.5	34.0	10.0	56.0	c	1.39	2.41	38.2	58.4
					Margutti series (MRGiD3g1S1)							
P4	Ap	0-10	17.8	30.4	48.2	10.4	41.4	sc	1.27	2.41	43.2	51.2
	Bw	10-22	17.5	29.7	47.2	9.1	43.6	c	1.33	2.45	41.6	54.8
					Margutti series (MRGiC3g1)							
P5	Ap	0-6	19.0	32.3	51.3	7.6	41.1	sc	1.26	2.42	43.8	51.4
	Bw	06-26	16.0	27.3	43.3	10.3	46.4	c	1.37	2.57	43.1	45.7
					Gutti series (GUTmB2g0)							
P6	Ap	0-13	19.0	32.3	51.0	8.0	40.5	c	1.27	2.35	41.7	53.5
	Bw	13-39	14.4	24.6	39.0	13.0	48.0	c	1.32	2.37	40.1	56.8
	Bss1	39-68	12.5	21.3	33.8	10.3	55.9	c	1.37	2.39	38.5	59.3
					Red soil							
					Bachanal series (BHNhB2)							
P7	Ap	0-17	43.2	25.4	68.5	15.4	16.1	sl	1.44	2.34	34.2	37.1
	Bt1	17-46	36.7	21.6	58.2	19.5	22.3	scl	1.49	2.39	33.5	29.1
					Bachanal series (BHNhC3g1S1)							
P8	Ap	0-10	38.6	22.7	61.3	20.5	18.2	sl	1.43	2.31	33.8	38.2
	Bt1	10-32	33.9	19.9	53.8	23.6	22.6	scl	1.47	2.39	34.3	35.0
	Cr	32-41	31.3	18.4	49.7	24.9	25.4	scl	1.51	2.43	33.7	30.8
					Kurkota series (KKThE3g1S1)							
P9	Ap	0-32	41.1	24.2	65.2	16.3	18.5	sl	1.39	2.29	34.9	40.1
	Bt	32-48	35.8	21.0	56.8	18.5	24.8	scl	1.45	2.35	34.0	32.5
	Bt1	48-82	30.9	18.2	49.1	21.4	29.5	scl	1.55	2.41	31.5	25.5
					Ratnagutti series (RTGhC2g0)							
P10	Ap	0-26	43.9	24.4	68.2	14.4	17.5	sl	1.33	2.36	39.4	40.2
	Bt	26-79	36.8	21.7	58.5	19.2	22.3	scl	1.40	2.46	39.0	28.7

slightly hard to very hard, loose to friable, slightly sticky to very sticky and slightly plastic to very plastic in black soils (Dongaragaon, Kamalapur, Bhimnalli, Margutti and Gutti series). Increase in stickiness and plasticity may be due to predominance of clay minerals and their content. Whereas, in red soil pedons consistence varied from slightly hard to very hard (Bachanal series), firm to friable (Kurkota series), slightly sticky and slightly plastic to moderately sticky and moderately plastic (Ratnagutti series) in dry, moist and wet condition, respectively (Pulakeshi et al. 2014). The slope of Dongaragaon micro-watershed varied from gently sloping to very steep sloping having shallow (22 cm depth in Margutti series: MRGiD3g1S1) to very deep (185 cm depth in Dongaragaon series) in depth. Similar, observations were made by Kanthraj et al. (2015) in the soils of Patapura micro-watershed.

Physical and chemical properties

High clay content was observed in subsurface depths of all the pedons of both black and red soils (Table 2). However, black soils had high clay content (39.5–72.9%) than red soils (16.1–29.5%). Black soil pedons were clay (c), sandy clay (sc) in texture while red soil pedons were sandy clay (sc) and sandy loam (sl) in texture. This variation in texture was mainly because of deposition of finer fractions. Prominent slickensides (ss) and abundant accumulation of $CaCO_3$ nodules were observed in black soil pedons. Similar observation were noticed by Naveen et al. 2018 in Dotikol micro-watershed of Karnataka state.

In black and red soil pedons, the bulk density (BD) varied from 1.24 to 1.52 Mg m^{-3} and 1.33 to 1.55 Mg m^{-3}, respectively (Table 2). In general, the BD of the lower solum was more than the upper solum and could be attributed to clogging of pores by dispersed clays in sub-soil layers that caused reduction in total porosity and organic carbon (OC) content with increasing depth. Maximum water holding capacity (MWHC) of all the soil series ranged from 25.5 to 61.5%. Clay content greatly influenced water retention capacity of all the pedons Kanthraj et al. (2015) and particularly in black soils increasing WHC with increasing soil depth was observed.

Chemical properties of Dongaragaon micro-watershed are presented in Table 3. Soil pH of surface depths of black soil pedons were ranged from neutral (7.4) to slightly saline (8.2) whereas in red soils it was slightly acidic (6.5) to neutral (6.9). Comparatively well drainage in red pedons might be the reason for acidic nature that caused leaching of bases to under depths. Whereas, high pH in black pedons was due to their calcareous nature and the accumulation of bases in the solum as they were poorly leached. In black soil series and red soil series, the electrical conductivity (EC) values of the soils ranged from 0.1 to 0.5 and 0.1 to 0.4 d Sm^{-1}, respectively. In the soils studied, the EC generally increased with depths in black soils. The upper solum was relatively low in salts than in the lower solum in black soils and might be due to leaching of salts from the soil surface to lower depths along with irrigation water and their subsequent accumulation in lower depths. Status of OC in soils of black and red pedon series ranged from 0.52% to 0.64% and 0.51% to 0.62%, respectively, which in general accumulated in surface layers. The lower contents of OC apparently resulted because of tropical climate characterized by high temperature (average maximum temperature > 40°C) prevailing in these areas which certainly induced organic matter decomposition at a rapid rate. Comparatively $CaCO_3$ content was higher in pedons of black soils (Dongaragaon, Kamalapur, Bhimnalli, Margutti and Gutti series) ranging from 4.3 to 6.5%, whereas, in red soil pedons (Bachanal, Kurkota and Ratnagutti series) ranging from 3.5–5.1% and shown increasing trend with depth. These observations of $CaCO_3$ content were in accordance with results observed in Bundi district of Rajasthan by Meena et al. (2014).

The pedons of all the soil series in Dongaragaon MWS were low to medium in available N content (134 to 336 kg ha^{-1}), medium to high (10.1 to 89.1 kg ha^{-1}) in available P_2O_5 content (Table 3) and availability of K_2O of pedons of all soil series ranged low to high (50 to 530) kg ha^{-1} and the content fallows the irregular pattern with the depth. Wide variation in available sulfur status was across all soil pedons ranging from 0.39 to 8.86 mg kg^{-1}. The low amount of S in surface samples in most of the soil series is mainly because of acid soil reaction and low EC values. The DTPA extractable Fe, Mn and Cu were in optimum range in all the pedons while Zn content was below the critical

Table 3. Chemical properties of pedons of Dongaragaon micro-watershed.

Pedon no.	Horizon	Depth (cm)	pH (1 : 2.5) (soil:water)	EC (d Sm^{-1})	OC (%)	Free $CaCO_3$ (%)
			Black soil			
			Dongaragaon series (DGNiB2g0)			
P1	Ap	0–30	8.2	0.1	0.64	5.5
	Bw	30–58	7.3	0.2	0.61	5.8
	Bss1	58–82	7.3	0.4	0.58	6.0
	Bss2	82–109	7.5	0.4	0.54	6.1
	Bss3	109–148	8.3	0.4	0.39	6.2
	Bss4	148–185	7.2	0.5	0.29	6.5
			Kamalapur series (KMPiC2g0)			
P2	Ap	0–22	7.4	0.1	0.63	5.1
	Bw1	22–32	7.6	0.2	0.60	5.4
	Bw2	32–61	7.7	0.4	0.57	5.9
	Cr	61–96	8.0	0.4	0.26	5.9
			Bhimnalli series (BMNiB2g0)			
P3	Ap	0–10	7.4	0.2	0.59	5.5
	Bw	10–30	7.6	0.4	0.53	5.9
	Cr	30–35	7.8	0.4	0.49	5.9
			Margutti series (MRGiD3g1S1)			
P4	Ap	0–10	7.8	0.5	0.53	4.3
	Bw	10–22	7.9	0.5	0.44	5.0
			Margutti series (MRGiC3g1)			
P5	Ap	0–6	7.5	0.3	0.52	4.9
	Bw	06–26	7.7	0.4	0.41	5.2
			Gutti series (GUTmB2g0)			
P6	Ap	0–13	7.7	0.4	0.61	4.9
	Bw	13–39	7.8	0.5	0.56	5.1
	Bss1	39–68	8.1	0.5	0.21	5.3
			Red soil			
			Bachanal series (BHNhB2g0)			
P7	Ap	0–17	6.9	0.2	0.57	4.8
	Bt1	17–46	7.1	0.1	0.44	4.9
			Bachanal series (BHNhC3g1S1)			
P8	Ap	0–10	6.8	0.4	0.51	4.5
	Bt1	10–32	7.1	0.2	0.48	5.0
	Cr	32–41	7.2	0.2	0.41	5.1
			Kurkota series (KKThE3g1S1)			
P9	Ap	0–32	6.6	0.4	0.62	3.5
	Bt	32–48	6.9	0.3	0.58	3.8
	Bt1	48–82	7.2	0.1	0.47	4.2
			Ratnagutti series (RTGhC2g0)			
P10	Ap	0–26	6.5	0.1	0.54	3.8
	Bt	26–79	6.8	0.1	0.44	3.9

Table 3. Continued.

Pedon no.	Horizon	Available nutrients N	P_2O_5 kg ha^{-1}	K_2O	S mg kg^{-1}	DTPA extractable micro-nutrients Zn	Fe mg kg^{-1}	Cu	Mn
				Black soil					
				Dongaragaon series (DGNiB2g0)					
P1	Ap	213	46.0	530	5.2	1.0	5.5	4.8	13.2
	Bw	168	64.7	242	0.4	0.5	6.2	2.9	13.5
	Bss1	190	53.2	188	1.0	0.4	5.0	2.6	13.5
	Bss2	179	33.1	417	1.3	0.6	9.0	3.3	26.8
	Bss3	190	74.8	520	8.9	0.6	4.0	4.4	9.1
	Bss4	134	50.3	271	3.0	0.3	4.8	1.5	4.6
				Kamalapur series (KMPiC2g0)					
P2	Ap	146	44.6	469	1.2	0.8	14.6	5.2	31.8
	Bw1	179	27.3	240	1.3	0.5	12.9	3.8	26.5
	Bw2	168	69.0	239	1.6	0.3	9.0	4.0	19.5
	Cr	146	25.9	335	1.3	0.3	7.8	3.1	16.7
				Bhimnalli series (BMNiB2g0)					
P3	Ap	280	70.5	236	1.4	1.5	32.7	8.4	32.9
	Bw	213	67.6	92	3.0	0.7	26.3	7.0	29.8
	Cr	213	77.7	74	1.0	0.6	23.7	6.7	29.2
				Margutti series (MRGiD3g1S1)					
P4	Ap	246	73.3	157	3.1	1.0	37.5	6.6	38.4
	Bw	336	30.1	59	1.4	0.5	32.2	6.0	37.3
				Margutti series (MRGi C3g1)					
P5	Ap	168	89.1	169	4.6	0.5	10.5	3.9	18.4
	Bw	179	80.5	79	4.7	1.2	25.0	8.3	34.4
				Gutti series (GUTmB2g0)					
P6	Ap	246	10.1	466	2.4	0.9	25.3	5.3	37.9
	Bw	168	13.5	254	0.7	0.7	16.8	4.1	31.9
	Bss1	168	18.7	230	2.0	0.5	13.6	4.6	28.8
				Red soil					
				Bachanal series (BHNhB2g0)					
P7	Ap	302	61.8	255	1.3	1.2	26.8	6.0	36.2
	Bt1	257	64.7	104	0.7	0.5	17.4	6.4	22.8
				Bachanal series (BHNhC3g1S1)					
P8	Ap	255	66.5	313	1.8	1.4	24.4	6.7	29.3
	Bt1	240	61.1	289	1.4	1.1	19.5	6.1	24.7
	Cr	225	60.4	255	1.0	0.7	16.9	5.4	23.4
				Kurkota series (KKThE3g1S1)					
P9	Ap	291	66.2	148	0.8	0.9	30.4	7.0	34.1
	Bt	202	93.5	89	1.8	0.2	14.3	4.0	17.8
	Bt1	213	63.3	62	1.2	0.1	9.1	3.1	11.9
				Ratnagutti series (RTGhC2g0)					
P10	Ap	246	71.9	50	2.2	0.2	11.1	2.5	11.1
	Bt	258	56.1	115	0.7	1.0	21.5	3.6	29.6

Table 4. Exchangeable cations in the pedons of Dongaragaon soil series.

Pedon no.	Horizon	Depth (cm)	Ca	Mg	Na	K	CEC	BS	ESP
				cmol (p^+) kg^{-1}					(%)
				Dongaragaon series (DGNiB2g0)					
P1	Ap	0–30	37.91	13.41	1.12	1.37	56.89	94.55	1.97
	Bw	30–58	35.12	14.82	1.65	0.31	54.96	94.36	3.00
	Bss1	58–82	30.01	16.13	1.83	0.24	51.27	93.95	3.57
	Bss2	82–109	38.21	16.71	2.30	0.54	60.84	94.90	3.78
	Bss3	109–148	33.11	25.44	2.65	1.15	65.40	95.26	4.05
	Bss4	148–185	30.92	35.23	2.80	0.35	72.35	95.72	3.87
				Kamalapur series (KMPiC2g0)					
P2	Ap	0–22	28.21	14.02	1.32	0.60	47.22	93.44	2.80
	Bw1	22–32	26.33	17.41	1.87	0.31	48.98	93.67	3.82
	Bw2	32–61	19.22	10.93	2.07	0.31	35.58	91.29	5.82
	Cr	61–96	30.24	25.82	2.23	0.43	61.76	94.98	3.61
				Bhimnalli series (BMNiB2g0)					
P3	Ap	0–10	25.11	9.81	0.63	0.30	38.93	92.04	1.62
	Bw	10–30	28.32	13.72	0.91	0.12	46.13	93.28	1.97
	Cr	30–35	24.23	14.63	1.08	0.10	43.08	92.80	2.51
				Margutti series (MRGiD3g1S1)					
P4	Ap	0–10	33.81	11.44	1.69	0.20	50.19	93.82	3.37
	Bw	10–22	32.23	15.44	2.51	0.08	53.29	94.18	4.71
				Margutti series (MRGiC3g1)					
P5	Ap	0–6	27.82	18.32	1.54	0.22	50.96	93.92	3.02
	Bw	06–26	33.71	17.11	2.21	0.10	56.21	94.49	3.93
				Gutti series (GUTmB2g0)					
P6	Ap	0–13	36.91	24.71	1.14	0.60	66.44	95.33	1.72
	Bt	13–39	34.12	15.02	1.65	0.33	54.18	94.28	3.05
	Bt1	39–68	38.93	28.03	2.12	0.30	72.42	95.72	2.93
				Bachanal series (BHNhB2g0)					
P7	Ap	0–17	29.81	21.81	1.84	0.33	56.87	94.55	3.24
	Bw1	17–46	30.62	22.42	2.63	0.13	58.86	94.73	4.47
				Bachanal series (BHNhC3g1S1)					
P8	Ap	0–10	27.98	18.31	1.34	0.34	51.06	93.93	2.62
	Bt1	10–32	28.14	21.33	1.45	0.23	54.24	94.28	2.67
	Cr	32–41	31.67	22.52	1.98	0.21	59.43	94.78	3.33
				Kurkota series (KKThE3g1S1)					
P9	Ap	0–32	30.71	21.51	0.93	0.19	56.42	94.51	1.65
	Bt	32–48	27.12	15.02	1.38	0.11	46.69	93.36	2.96
	Bt1	48–82	29.33	12.01	1.97	0.08	46.45	93.33	4.24
				Ratnagutti series (RTGhC2g0)					
P10	Ap	0–26	29.21	19.81	1.86	0.06	54.02	94.26	3.44
	Bt	26–79	17.02	8.42	1.58	0.15	30.23	89.74	5.23

Table 5. Soil classification of Dongaragaon micro-watershed as per USDA soil taxonomy, 1999.

Sl. No.	Mapping units	Order	Subor-der	Great group	Subgroup	Family
			Dongaragaon series			
1	DGNiB2g0	Vertisols	Usterts	Haplusterts	Typic Haplusterts	Fine montmorillo-nitic, hyper-thermic
			Kamalapur series			
2	KMPiC2g0	Vertisols	Usterts	Haplusterts	Leptic Haplusterts	Fine montmorillo-nitic, hyper-thermic
			Bhimnalli series			
3	BMNiB2g0	Vertisols	Usterts	Ustortherts	Lithic Ustortherts	Fine mixed, hyperthermic
			Margutti series			
4	MRGiD3g1S1	Vertisols	Usterts	Ustortherts	Lithic Ustortherts	Fine mixed, hyperthermic
5	MRGiC3g1	Vertisols	Usterts	Ustortherts	Lithic Ustortherts	Fine mixed, hyperthermic
			Gutti series			
6	GUTmB2g0	Vertisols	Usterts	Haplusterts	Leptic Haplusterts	Fine montmo-rillonitic, hyperthermic
			Bachanal series			
7	BHNhB2g0	Alfisols	Ustalfs	Haplustalfs	Typic Haplustalfs	Fine skeletal, mixed, hyper-thermic
8	BHNhC3g1S1	Alfisols	Ustalfs	Haplustalfs	Typic Haplustalfs	Fine skeletal, mixed, hyper-thermic
			Kurkota series			
9	KKThE3g1S1	Alfisols	Ustalfs	Haplustalfs	Typic Haplustalfs	Fine skeletal, mixed, hyper-thermic
			Ratnagutti series			
10	RTGhC2g0	Alfisols	Ustalfs	Haplustalfs	Typic Haplustalfs	Fine skeletal, mixed, hyper-thermic

level (low in Zn status). It could be attributed to the high pH and calcareous nature of soil (Srikanth et al. 2008). The availability of micronutrients decreased with increase in pH and $CaCO_3$ content.

The exchangeable bases in all the pedons were in order of $Ca^{+2} > Mg^{+2} > Na^{+} > K^{+}$ on the exchange complex (Table 4). The exchangeable Ca + Mg dominated over the exchangeable Na and K. Higher cation exchange capacity was observed with increasing depth in the most of the soil series as cause of illuviation of clay from surface to subsurface horizons (Gill et al. 2012). Exchangeable sodium percentage (ESP) also followed the trend of CEC and all the pedons under study were free of sodicity problem. Base saturation percentage was low in red soils compared to black soils, because of leaching of bases and low amount of bases in its parent material in contrast to black soils. The ESP of both black and red soil series were in the range of 1.6 to 5.8% and 1.7 to 5.2%, respectively and indicated initiation of the process of sodiumization in a downward direction.

Soil classification

Based on morphological characteristics of the pedons, physico-chemical characteristics of the soils and climate of the area, ten pedons from the study area were classified up to the series level. As per USDA soil taxonomy, 1999 all the black soil series were classified as Vertisols at order level, as these pedon did not have lithic or paralithic contact within 50 cm of soil surface and had a weighted average of > 30% clay in all the horizon. All the red soil series were classified as Alfisols as they do not have plaggen epipedon and have arigillic horizon with > 35% of base saturation throughout the pedon (Table 5) (Pulakeshi et al. 2014). As the moisture regime is Ustic, the black soils (Dongaragaon series, Kamalapur series, Bhimnalli series, Margutti series and Gutti series) and red soils (Bachanal series, Kurkota series and Ratnagutti series) are classified as usterts and ustalfs respectively, at sub-order level.

The black soil serieses at great group level are classified as the *Haplusterts*. At sub-group level they are classified as *Typic*, *Leptic* and *Lithic* as they do not have *densic*, *lithic*, *paralithic* contact, duripan, hallic, sodic and petrocalcic horizon within 100 cm from mineral soil surface. The red soil series were key out as Haplustalfs at great group as they do not have duripan, plinthite, nastric, kandic and petrocalcic horizons. At sub-group level they are *Typic*.

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