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Characterization and Classification of Soils from Three Agro-climatic Zones of Belgavi District, Karnataka

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Belgavi district in Karnataka is characterized by three contrasting agro-climatic zones *viz*., a relatively dry semi-arid northern dry zone (Zone-3) with low rainfall, a somewhat higher rainfall area termed transitional zone (Zone-8) nestling between the Western Ghats and Eastern Plains, and a heavy rainfall area comprising part of Western Ghats called hilly zone (Zone-9). This situation provided an opportunity to compare the properties of pedons occurring in these agro-climatic zones. Nine pedons, three each from the three micro-watersheds *viz*., Yadawad (Zone-3), Hukkeri (Zone-8) and Khanapur (Zone-9) were characterized for their morphological, physical and chemical properties with an objective of comparing their properties which have an implication on their use and behaviour. Pedons from Yadawad micro-watershed (Zone-3) were deep, alkaline, calcareous and contained considerable amount of salts and are rich in clay content. The pedons of Hukkeri micro-watershed (Zone-8) were shallow to moderately deep, neutral, non-calcareous and contained low amount of salts and are somewhat coarse textured. Despite similar parent rock (basalt) in these two micro-watersheds, the variation in depth and texture are a direct result of erosion and deposition due to topographic variations. The pedons from Khanapur micro-watershed (Zone-9) were acidic, highly leached, and moderately fine textured. The variation in the soil properties of soils of Khanapur watershed sharply contrasted with soils of both Yadawad and Hukkeri watersheds due to high rainfall at the former compared to the latter. The soils of Yadawad micro-watershed classify as Typic Calciusterts, those of Hukkeri micro-watershed as Lithic and Typic Ustorthents and the soils of Khanapur micro-watershed as Oxic Dystrustepts and Kanhaplic Haplustalfs reflecting the leaching regime and erosion of sediments during soil formation.

Key words: Agro-climatic zones, basaltic landscape, Calciusterts, Kanhaplic Haplustalfs, watersheds, erodibility

To enhance or at least maintain the present level of productivity, management of land resources on scientific principles, soil resource inventory provides the needed information on their potential and limitations relative to optimum utilization through characterization and evaluation of land resources. Soil resources inventory requires a good understanding of the properties and processes of different soils (Walia and Rao 1996) in a given area so that their mapping becomes easy. Study of soils within a watershed has been increasingly been attempted as it offers diverse soils to form due to the topographic variation present in a watershed. Arun Kumar *et al*. (2002) studied soils of Palar-Marimuthar watershed in Tamilnadu, while Thangasamy *et al*. (2005) studied soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh. Belagavi district in Karnataka has three distinct agro-climatic zones (Zones 3, 8 and 9) and provided an opportunity to study the soils along the climatic gradient between the three agro-climatic zones. Further, the topographic variations within a watershed helped to evaluate the topographic influence within a agro-climatic zone. Such studies are seldom reported in recent past, except the one dealing with fertility gradient across these zones (Prabhavathi *et al.* 2015). Keeping this in view, the present study was undertaken to characterize the soils in three watersheds representing the three agro-climatic zones of Belagavi district, Karnataka.

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Table 1. Particulars of watersheds studied

Sl. No.	Micro-watershed and code	Area (ha)	Elev. (m)	Agroclimatic zone	MAR (mm)	Geology	Land use
1.	Yadawad 4D7D3I1a*	572.9	595-627	Northern dry zone (zone-3)	507.6	Basalt	Entirely agriculture
2.	Hukkeri 4D7D7D2a*	498.3	632-675	Northern transition zone (zone -8)	658.4	Basalt	40% agriculture 60% open scrub
3.	Khanapur 4D7C9L1c*	586.2	646-716	Hilly zone (zone -9)	1859.1	Peninsular gneiss	69% agriculture 26% forest

MAR=Mean Annual Rainfall
*As per Micro-watershed Atlas supplied by Karnataka Remote Sensing Application Centre, Bangalore (unpublished document)

Materials and Methods

Site conditions

The Belagavi district is situated in the north-western part of Karnataka. Three micro-watersheds *viz*., Yadawad representing zone-3 (northern dry zone), Hukkeri representing zone-8 (northern transitional zone) and Khanapur representing zone-9 (hilly zone) were selected. The location of micro-watersheds is shown in fig. 1 and the salient features of those are presented in table 1. A detailed Google image of the watersheds studied is presented in fig. 2.

Soil sampling and characterization

Three pedons in each micro-watershed representing different landscape positions were selected for the study. The pedons 1, 2 and 3 were from Yadawad micro-watershed, pedons 4, 5 and 6 were from upland, mid-land and lowland positions of Hukkeri micro-watershed; and pedons 7, 8 and 9 were

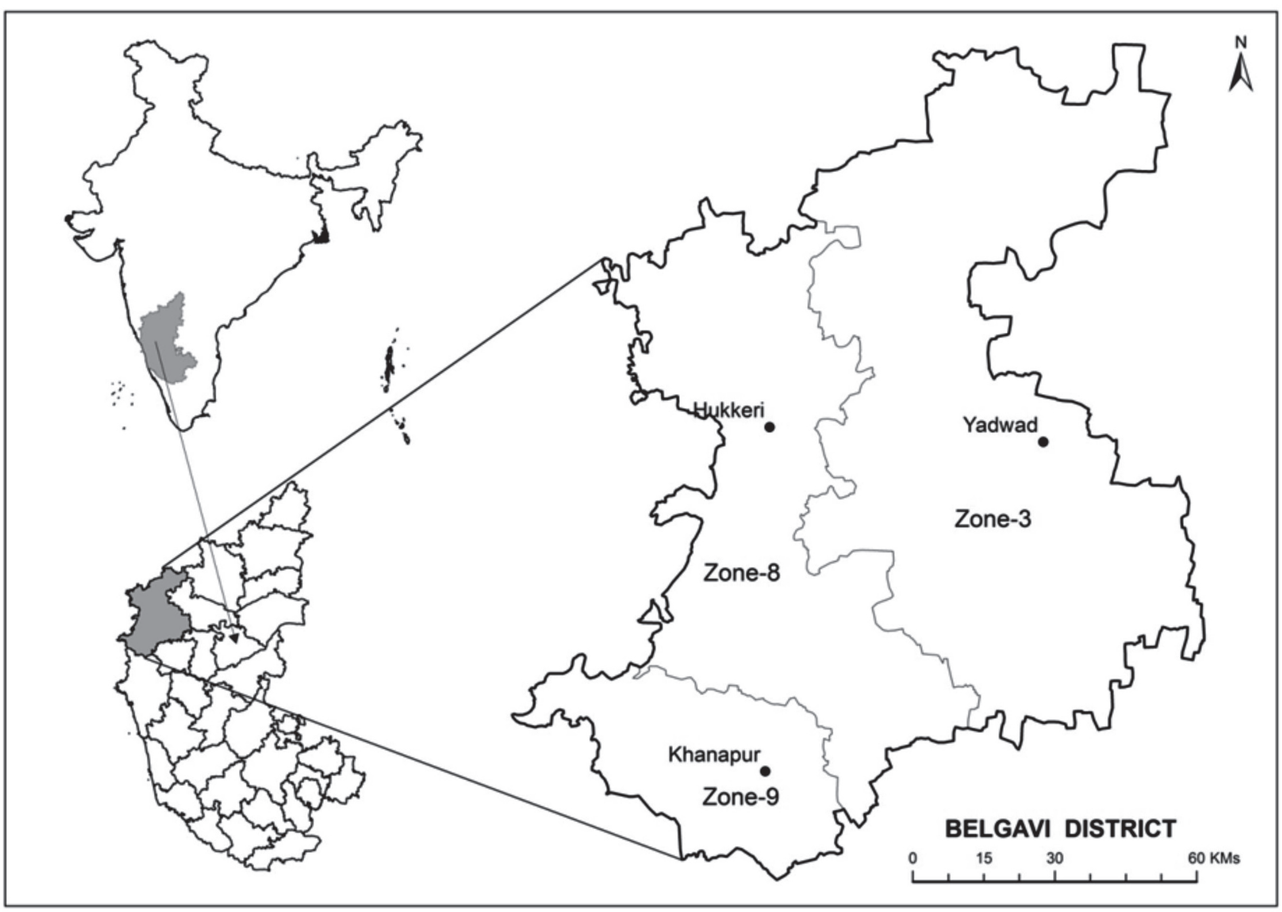

Fig. 1. Map showing the location of micro-watersheds

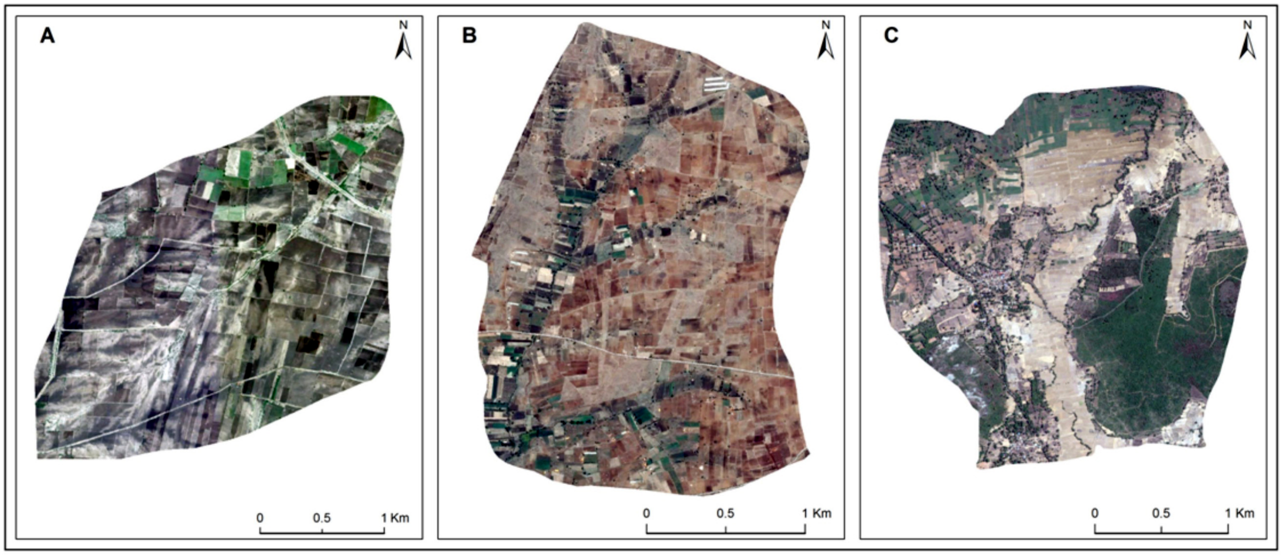

Fig. 2. Google image of Yadawad (A), Hukkeri (B) and Khanapur (C) micro-watersheds

from upland, mid-land and lowland positions of Khanapur micro-watershed. Morphological features of the pedons were described as per soil survey manual (Soil Survey Staff 1993). Soil samples representing each horizon of the pedons were collected, processed and their physicochemical properties were determined using standard procedures (Black 1965). Maximum water holding capacity of the soils was determined by using Keen Raczkowaski brass cup as described by Sankaram (1960). Dispersion ratio was calculated using the relationship described by Middleton (1930) by the equation: dispersion ratio = (silt + clay dispersible in water)/ (total silt + clay). Erosion Index was computed from the relationship described by Sahi *et al*. (1977) using the equation, erosion index = dispersion ratio/ (clay/0.5 water holding capacity).

Results and Discussion

Soil Morphology

All the three pedons of Yadawad micro-watershed were very deep and exhibited 10 YR hue throughout the pedon (Table 2). The chroma was two or less indicating poor internal drainage (Dasog and Hadimani 1980). The soil colour (Table 2) varied from very dark grey (10 YR 3/1) to dark grey (10 YR 4/1) in pedon 1 and 3 and to greyish brown (10 YR 5/2) in pedon 2. The texture was clay in the surface horizons of all the pedons of Yadawad micro-watershed due to good profile development through weathering over long time and might be due to less difference in elevation among pedon locations also. The texture of surface horizon in upland pedon of Hukkeri micro-watershed was sandy loam whereas, mid-land and lowland pedons were sandy clay loam and clay loam in texture, respectively. Similar trend was observed in pedons of Khanapur micro-watershed also. The texture of surface horizons of upland and mid-land pedon was sandy clay, whereas, the lowland pedon was clayey in nature at its surface. This variation in texture is mainly attributed to the deposition of finer fractions transported from uplands to mid-lands and lowlands. Similar transportation of finer soil fractions were reported by Arun Kumar *et al*. (2002).

The structure in pedons 1 and 2 of Yadawad micro-watershed was moderate, medium and sub-angular blocky at surface, but in sub-surface horizons (22-36 and 15-57 cm depth in pedon 1 and 2, respectively), the structure was angular blocky due to high clay content and slickensides formation. In pedon 3 of Yadawad micro-watershed, the structure was weak, fine, and granular in the surface horizon due to greater frequency of shrink-swell at the surface. The structure of upland pedon of Hukkeri micro-watershed was weak, fine and granular whereas, mid-land and lowland pedons had moderate, fine and sub-angular blocky structure, which is the reflection of their sandy loam and sandy clay loam to clay loam texture, respectively. The structure of surface horizons of all the pedons of Khanapur micro-watershed was some what well developed irrespective of physiography, being moderate, medium and sub-angular blocky as reported by Patil and Dasog (1999). The lime concretions and slickensides were observed only in

Table 2. Morphological features of the pedons

Horizon	Depth	Colour (D)	Texture	Structure
		Yadawad		
Pedon 1				
Ap	0-22	10 YR 3/1	c	2 m sbk
AB	22-36	10 YR 3/2	c	2 m bk
Bss1	36-46	10 YRS 3/1	c	2 m sbk
Bss2	46-82	10 YR 3/1	c	2 m sbk
Bss3	82-97	10 YR 4/2	sc	2 m bk
BC	97-110+	10 YR 4/1	scl	2 m bk
Pedon 2				
Ap	0-14	10 YR 3/1	c	2 m sbk
AB	14-41	10 YR 3/2	c	2 m bk
Bss1	41-57	10 YR 4/2	c	2 m bk
Bss2	57-88	10 YR 5/2	c	2 m sbk
BC1	88-117	10 YR 5/2	c	3 m sbk
BC2	117-155+	10 YR 5/2	c	Massive
Pedon 3				
Ap	0-16	10 YR 3/1	c	1 f gr
AB	16-30	10 YR 3/2	c	2 m sbk
Bss1	30-43	10 YR 3/1	c	2 m sbk
Bss2	43-65	10 YR 4/1	c	2 m sbk
BC	65-110+	10 YR 4/1	c	2 m sbk
		Hukkeri		
Pedon 4				
Ap	0-15	5 YR 4/3	sl	1 f gr
AC	15-30	5 YR 5/4	Is	3 m sbk
Pedon 5				
Ap	0-10	5 YR 3/2	scl	2 f sbk
Bw1	10-20	5 YR 3/2	sl	2 m sbk
Bw2	20-30	5 YR 4/3	sl	2 m sbk
C	30-45	5 YR 5/6	ls	3 m sbk
Pedon 6				
Ap	0-15	10 YR 3/3	cl	2 f sbk
Bw1	15-30	5 YR 3/2	scl	2 m sbk
Bw2	30-50	5 YR 5/6	scl	2 m sbk
BC	50-70+	5 YR 5/6	sl	2 m sbk
		Khanapur		
Pedon 7				
Ap	0-20	5 YR 4/4	sc	2 m sbk
BA	20-35	5 YR 4/4	sc	2 m sbk
Bw1	35-55	5 YR 5/6	scl	2 m sbk
Bw2	55-85	5 YR 5/8	gsc	2 m sbk
Pedon 8				
Ap	0-20	7.5 YR 4/4	sc	2 m sbk
BA	20-40	7.5 YR 4/4	sc	2 m sbk
Bt	40-93	5 YR 3/4	sc	2 m sbk
BC	93-110+	5 YR 4/4	sc	2 m sbk
Pedon 9				
AP	0-20	10 YR 5/8	c	2 m sbk
BA	20-58	10 YR 5/6	c	2 m sbk
Bt	58-100	10 YR 6/8	c	2 m sbk
BC	100-130+	5 YR 5/6	gc	2 m sbk

pedons of Yadawad micro-watershed. The abundance of calcium carbonate ($CaCO_3$) nodules increased with depth in pedon 1 and pedon 2. The $CaCO_3$ concretions were observed commonly up to 43 cm depth in pedon 3 and thereafter few concretions were observed. The accumulation of $CaCO_3$ is due to less leaching and semi-arid climate (Dasog and Hadimani 1980). Abundance and intensity of slickensides was more in middle of solum because of maximum swelling pressure as reported by Dasog *et al*. (1987).

Physical Characteristics

The clay content was highest in Yadawad micro-watershed (31.3 to 59.5%) followed by Hukkeri among the basaltic landscape (Table 2). The Hukkeri micro-watershed is situated at an higher elevation with considerable relief within it compared to low relief in Yadawad watershed. In the pedons of Yadawad micro-watershed (pedon 1, 2 and 3), the sub-surface horizons exhibited higher clay content compared to surface horizons as it is commonly observed in black soils of Karnataka (Dasog and Hadimani 1980). Clay content at the surface increased from 17.9% in pedon 4 located in upland position, through an intermediary value in pedon 5 to 37.2% in lowland pedon (pedon 6) suggesting the severe erosion of upland soils in Hukkeri micro-watershed. Clay content of Khanapur upland pedon (pedon 7) varied in a narrow range of 34.2 to 36.3%. Higher clay content was observed in sub-surface horizon at 20-35 cm depth. The clay content in mid-land and lowland pedons of Khanapur micro-watershed (pedon 8 and 9) increased from surface to a maximum of 41.3% in the Bt horizon, thereafter it decreased slightly. High clay content with its accumulation in the intermediate layers indicates the degree of maturity of the profiles (Gowaikar and Datta 1971). Higher clay content in pedons of Khanapur micro-watershed may be due to high degree of weathering as a result of higher rainfall at Khanapur site. Silt content varied from 7.8 to 18.4, 9.6 to 23.5 and 8.4 to 15.0% in pedons of Yadawad, Hukkeri and Khanapur micro-watersheds, respectively with higher value observed in surface horizons of lowland pedons. Moreover, silt content decreased with depth in all the pedons, except in upland and mid-land pedons of Khanapur micro-watershed.

In general, in the pedons of Yadawad and Khanapur micro-watersheds, the very fine sand and fine sand content decreased with depth whereas, coarse sand and very coarse sand content increased with depth. Overall, total sand content increased with depth showing higher sand content of 60.9% in the BC horizon of pedon 1. The total sand content decreased with depth till 57 cm and then showed increasing trend thereafter in pedon 2. The pedon 3 had the highest total sand content in surface (39.0 %), which decreased in the sub-surface horizons. Sand fractions constituted bulk of the particle size composition in the pedons of Hukkeri micro-watershed. This might be due to severe erosion of top soil resulting in the shallow nature of the soils. Total sand fraction increased with depth and highest sand content (79.3 and 81.5%) was observed in BC horizon of pedon 4 and C horizon of pedon 5, respectively. The increase in total sand content was more prominent for coarse and very coarse sand fractions. Total sand content in all the pedons of Khanapur micro-watershed followed a decreasing trend up to certain depth and then slightly increased with depth. In upland pedon (pedon 7), The total sand content progressively decreased moving from upland pedon through mid-land pedon (pedon 8) to lowland pedon (pedon 9). This could be attributed to illuviation of clay and its consequent enrichment in relation to sand fractions.

The bulk density of the pedons ranged from 1.27 to 1.54, 1.36 to 1.49 and 1.34 to 1.48 Mg m^{-3} in Yadawad, Hukkeri and Khanapur micro-watersheds, respectively. The surface horizons of all the pedons in the three micro-watersheds had lower bulk density values which could be attributed to relatively higher organic matter content and being subject to frequent tillage. In all the pedons, progressive increase in bulk density with depth was probably related to increase in coarse fragments and due to compaction. The maximum water holding capacity ranged between 31.2 and 51.3 per cent in Yadawad micro-watershed; between 16.1 and 34.7 per cent in Hukkeri micro-watershed; between 22.3 and 34.7 per cent in Khanapur micro-watershed and is related to clay content (Table 3).

Soil Erodibility Properties

According to Middleton (1930), soils having dispersion ratio >0.15 and erosion ratio >0.10 are susceptible to erosion and are termed erodible in nature. The soils of all the three micro-watersheds were found to be erodible as per the above criteria. Both dispersion ratio (DR) and erosion index (EI) values of surface soils were highest for Yadawad, intermediate for Hukkeri and lowest for Khanapur micro-watersheds following a climatic gradient (Table 3). High DR observed in Yadawad micro-watershed might be due to relatively high exchangeable sodium content observed in this soil. A significant positive correlation (r = 0.73**) between DR and exchangeable Na observed in these soils attests to this observation (Tabe 4). The soils of Yadawad micro-watershed exhibited higher value of DR and EI in lower depths as well in all the pedon locations, indicating their susceptibility to rill and gully erosion. These results are in conformity with the findings of Dabral *et al*. (2001). In pedons of Hukkeri micro-watershed, higher EI value was observed up to 30 cm depth, suggesting that these soils are prone to sheet erosion. Relatively lesser DR and EI values were observed in the soils of Khanapur micro-watershed. The DR and EI in all the pedons of Khanapur micro-watershed decreased with increasing soil depth. This may be attributed to higher clay content and better soil micro-aggregate content in the lower depths of the profile. A significant negative correlation was observed between erosion index and per cent clay (r = -0.47**).

Sand per cent exhibited a significant positive relationship (r = 0.45**) and per cent clay a negative relationship (r = -0.47**) with erosion index (EI) suggesting greater susceptibility of these soils to water erosion. Dispersion ratio (DR) was positively and significantly correlated with exchangeable sodium (r = 0.73**) and erosion index (r = 60*). The results are in conformity with those observed by Singh and Kundu (2008).

Chemical Properties

Chemical properties of the soils are presented in table 4. The pedons of Yadawad micro-watershed were slightly alkaline with pH varying from 7.94 to 8.77. Whereas, the pH values were in the neutral range (7.01 and 7.94) in Hukkeri pedons and were acidic in Khanapur pedons except in the lowland position. High pH values in pedons of Yadawad micro-watershed is due to their calcareous nature and the accumulation of the bases in the solum as they are poorly drained (Satyanarayana and Biswas 1970). In the Yadawad micro-watershed, pH decreased up to certain depth and thereafter increased at lower depths in pedons 1 and 2. This could be attributed to the downward movement of bases and their differential adsorption by different soil layers. Increasing trend in soil pH was observed with depth in pedon 3 of Yadawad micro-watershed and in all the pedons of Hukkeri micro-watershed, which could be attributed to increase in bases with depth. The lower pH values in surface horizons of all the pedons of Khanapur micro-watershed is mainly due to leaching of bases because of high rainfall at this site. The upland pedon of Khanapur has relatively lower pH value than that of lowland pedon. This increase in soil reaction down the slope could be due to leaching of bases from

Table 3. Salient physical and chemical properties of the soils studied

Horizon	Depth (cm)	V.C. sand (1.0-2.0 mm)	C. sand (0.50-1.0 mm)	M. sand (0.25-0.50 mm)	F. sand (0.10-0.25 mm)	V.F. sand (0.05-0.10 mm)	Total sand (0.05-2.0 mm)	Silt (0.002-0.05 mm)	Clay (<0.002 mm)	Bulk density (Mg m^{-3})	MWHC (%)	Suspension (%)	Dispersion ratio	Erosion index	pH	EC (dS m^{-1})	OC (g kg^{-1})	$CaCO_3$ (g kg^{-1})	CEC [cmol $(p^+)kg^{-1}$]	Exchangeable cations [cmol$(p^+)kg^{-1}$] Ca	Mg	K	Na
									Zone 3 (Yadawad micro-watershed)														
Pedon 1																							
Ap	0-22	5.0	5.8	2.8	3.0	10.9	27.5	16.1	56.4	1.31	40.1	54.2	0.75	0.27	8.61	0.31	4.30	100	35.3	23.8	5.2	0.5	3.7
AB	22-36	4.6	5.7	2.4	2.9	8.7	24.3	16.2	59.5	1.32	45.7	55.7	0.74	0.28	8.32	0.74	4.64	122	34.8	21.8	5.2	0.4	3.7
Bss1	36-46	13.8	9.9	3.0	2.2	5.5	34.4	14.2	51.4	1.39	37.1	52.6	0.80	0.29	8.26	1.33	2.74	179	32.4	21.0	6.5	0.3	3.3
Bss2	46-82	11.2	7.1	2.7	2.8	5.5	29.3	13.4	57.3	1.47	39.3	57.6	0.81	0.28	8.40	1.54	3.39	183	32.2	20.1	7.0	0.4	3.9
Bss3	82-97	22.1	8.2	4.3	2.5	4.3	41.4	10.7	47.9	1.48	31.2	53.7	0.92	0.30	8.51	1.32	2.35	201	28.2	17.2	4.7	0.3	3.5
BC	97-110+	28.1	21.4	6.7	1.9	2.8	60.9	7.8	31.3	1.45	nd	nd	nd	nd	8.77	0.93	1.29	246	20.8	11.1	3.4	0.2	2.9
Pedon 2																							
Ap	0-14	5.3	4.8	4.0	3.5	4.9	22.5	18.0	59.5	1.27	41.7	63.3	0.82	0.29	8.66	0.41	4.85	111	38.2	21.4	4.3	0.5	3.7
AB	15-41	2.7	3.9	2.8	3.3	6.3	19.0	15.3	65.7	1.34	47.4	65.0	0.80	0.29	7.99	3.04	4.75	141	44.2	31.2	6.5	0.5	4.3
Bss1	41-57	2.8	4.3	2.3	1.8	3.0	14.2	11.8	74.0	1.39	51.3	67.3	0.78	0.27	7.94	6.71	2.66	165	56.1	38.1	8.0	0.5	7.9
Bss2	57-88	9.1	4.3	2.3	2.1	5.2	23.1	13.4	63.5	1.40	nd	nd	nd	nd	8.21	3.67	1.23	220	42.9	22.1	5.9	0.5	5.3
BC1	88-117	11.5	4.5	1.5	1.4	6.5	25.3	11.4	63.3	1.41	nd	nd	nd	nd	8.11	3.71	1.66	274	41.4	21.8	9.0	0.5	5.2
BC2	117-155+	13.2	4.5	2.6	2.1	2.7	25.1	10.8	64.1	1.24	nd	nd	nd	nd	8.25	3.31	1.11	233	37.3	19.9	8.8	0.4	4.7
Pedon 3																							
Ap	0-16	8.5	13.7	7.1	2.4	7.3	39.0	11.6	49.4	1.37	39.7	52.6	0.86	0.35	8.18	0.18	4.76	109	29.6	20.1	3.9	0.6	0.9
AB	16-30	4.1	2.6	7.1	3.5	8.3	25.6	18.4	56.0	1.46	42.9	49.1	0.66	0.25	8.31	0.22	4.66	127	33.0	24.9	3.5	0.4	0.9
Bss1	30-43	14.4	13.5	7.0	1.9	0.6	37.3	12.1	50.6	1.44	39.9	41.9	0.67	0.26	8.37	0.27	3.37	116	30.4	16.8	3.8	0.3	1.7
Bss2	43-65	12.9	11.0	4.4	2.1	4.2	34.6	12.4	53.1	1.47	40.2	47.4	0.72	0.27	8.65	0.23	2.51	107	32.2	17.9	5.2	0.3	2.7
BC	65-110+	11.8	9.6	4.6	1.9	3.6	31.5	12.1	56.4	1.54	nd	nd	nd	nd	8.70	0.35	2.08	103	33.4	16.0	5.6	0.3	3.1
									Zone 8 (Hukkeri micro-watershed)														
Pedon 4 (upland)																							
Ap	0 - 15	7.0	12.0	25.7	15.4	10.6	70.6	11.5	17.9	1.41	24.2	17.9	0.61	0.41	7.01	0.08	3.33	np	12.0	7.1	3.4	0.1	0.8
AC	15 - 30	14.5	11.3	20.4	15.7	17.5	79.3	11.3	9.4	1.49	16.1	12.2	0.49	0.43	7.08	0.08	2.89	np	11.2	6.7	3.3	0.1	0.1
Pedon 5 (mid-land)																							
Ap	0-10	5.5	7.9	13.5	15.4	11.5	53.7	18.3	28.0	1.38	29.4	21.5	0.46	0.24	7.17	0.07	4.51	np	18.8	12.5	4.8	0.1	0.4
Bw1	10-20	9.3	12.5	25.1	14.3	9.5	70.8	12.2	17.0	1.42	25.2	16.3	0.56	0.41	7.41	0.19	4.49	np	16.2	10.3	4.6	0.1	0.5
Bw2	20 -30	11.6	16.0	27.4	12.0	5.3	72.2	11.4	16.4	1.42	23.8	15.8	0.57	0.41	7.46	0.24	2.58	np	15.4	9.9	4.2	0.1	0.6
C	30 -45	17.6	20.3	23.0	16.1	4.5	81.5	9.6	8.9	1.47	nd	nd	nd	nd	7.16	0.09	1.85	np	15.2	10.0	3.9	0.1	0.4
Pedon 6																							
Ap	0-15	5.5	7.0	10.1	7.5	9.2	39.2	23.5	37.3	1.36	34.7	24.6	0.41	0.19	7.61	0.11	5.71	np	25.0	17.7	5.8	0.1	0.6
Bw1	15-30	9.3	17.4	17.5	10.1	9.2	62.2	18.5	19.3	1.41	27.8	19.1	0.51	0.36	7.83	0.14	4.61	np	23.9	16.6	5.7	0.1	0.5
Bw2	30-50	11.6	17.4	27.5	13.5	3.6	68.0	12.1	19.9	1.44	nd	nd	nd	nd	7.94	0.13	2.48	np	20.3	13.9	4.7	0.1	0.4
BC	50 -70+	17.6	20.5	25.0	12.6	3.0	71.2	11.9	16.9	1.46	nd	nd	nd	nd	7.88	0.15	2.17	np	15.2	9.5	4.2	0.1	0.5

Contd...

Horizon	Depth (cm)	V.C. sand (1.0-2.0 mm)	C. sand (0.50-1.0 mm)	M. sand (0.25-0.50 mm)	F. sand (0.10-0.25 mm)	V.F. sand (0.05-0.10 mm)	Total sand (0.05-2.0 mm)	Silt (0.002-0.05 mm)	Clay (<0.002 mm)	Bulk density ($Mg\ m^{-3}$)	MWHC (%)	Susp-ension (%)	Disper-sion ratio	Erosion index	pH	EC ($dS\ m^{-1}$)	OC ($g\ kg^{-1}$)	$CaCO_3$ ($g\ kg^{-1}$)	CEC [$cmol(p^+)kg^{-1}$]	Exchangeable cations [$cmol(p^+)kg^{-1}$]			
																				Ca	Mg	K	Na
Khanapur micro-watershed (Zone-9)																							
Pedon 7																							
Ap	0-20	5.3	9.7	15.0	14.1	10.0	54.0	10.9	35.1	1.39	25.5	22.1	0.48	0.17	5.72	0.05	4.18	np	2.4	0.4	0.2	0.1	0.2
BA	20-35	4.8	9.3	14.8	14.0	9.5	52.3	11.4	36.3	1.43	26.3	21.9	0.46	0.17	5.76	0.05	4.16	np	2.6	0.6	0.2	0.1	0.2
Bw1	35-55	8.7	9.7	13.5	14.0	8.5	54.4	11.4	34.2	1.41	22.3	19.5	0.43	0.14	5.27	0.05	4.14	np	2.0	0.5	0.2	0.1	0.1
Bw2	55-85	11.3	12.1	10.2	13.0	6.6	53.1	11.9	35.0	1.47	nd	nd	nd	nd	5.86	0.07	3.04	np	1.8	0.6	0.1	0.2	0.1
Pedon 8																							
Ap	0-20	9.4	8.7	11.7	13.5	7.6	50.9	11.8	37.3	1.37	29.1	20.1	0.41	0.16	5.67	0.04	4.64	np	3.1	0.8	0.6	0.2	0.4
BA	20-40	12.0	9.8	11.7	11.6	5.1	50.2	9.3	40.5	1.41	29.3	19.7	0.39	0.14	6.16	0.04	3.88	np	4.8	2.2	0.7	0.2	0.3
Bt	40-93	12.2	11.1	11.5	7.9	4.9	47.7	11.0	41.3	1.44	nd	nd	nd	nd	5.82	0.04	2.20	np	4.3	1.8	0.6	0.2	0.2
BC	93-110+	14.6	13.6	11.2	7.4	4.4	51.2	8.4	40.4	1.48	nd	nd	nd	nd	6.30	0.04	1.60	np	4.2	1.4	0.7	0.2	0.2
Pedon 9																							
Ap	0-20	9.7	7.0	5.9	13.3	8.6	44.5	15.0	40.5	1.34	31.8	18.4	0.33	0.13	5.82	0.03	5.78	np	4.1	1.9	0.5	0.1	0.3
BA	20-58	10.3	7.7	5.0	10.0	6.6	39.5	12.3	48.2	1.37	34.4	20.2	0.33	0.12	6.10	0.04	5.32	np	6.4	3.4	0.6	0.2	0.4
Bt	58-100	10.7	7.8	4.2	7.2	3.2	33.1	11.2	55.7	1.44	34.7	20.9	0.31	0.10	7.22	0.09	2.53	np	7.2	4.0	0.5	0.1	0.4
BC	100-130+	12.7	9.3	4.1	7.0	3.1	36.1	10.7	53.2	1.42	nd	nd	nd	nd	7.35	0.09	2.21	np	6.9	3.8	0.5	0.1	0.4

np= not present

Table 4. Correlation of dispersion ratio (DR) and erosion index (EI) of the soils studied

	Correlations co-efficients	
Soil parameter	Dispersion index	Erosion index
Clay	0.34	-0.47**
Sand	-0.34	0.45**
Dispersion ratio	1.0	0.60**
Erosion index	0.60**	1.0
Exch Na	0.73**	0.16
% Silt+Clay	0.34	-0.45**
OC	-0.26	-0.41*

**Significant at the 0.01 level; **Significant at the 0.05 level

upland situations and getting accumulated in lowlands.

In pedon 1 and 2 of Yadawad micro-watershed medium to high electrical conductivity (EC) values were observed at lower depths. This is attributable to the accumulation of salts due to poor drainage condition of the soil. Whereas, the EC values are much less in pedon 3, probably due to greater leaching of the salts for being located in the vicinity of a stream. All the pedons of Hukkeri and Khanapur micro-watersheds had low EC values, indicating the non-saline nature of these soils. The well-drained nature of these soils might have favoured the removal of released bases by percolating water. The organic carbon (OC) content ranged from 1.11 to 4.85, 1.85 to 5.71 and 1.60 to 5.78 g kg^{-1} in pedons of Yadawad, Hukkeri and Khanapur micro-watersheds, respectively. The OC status of black soil pedons of Yadawad micro-watershed was relatively less. This probably was due to intense cultivation of crops without fully replenishing it with external organic inputs; and the occurrence of sheet erosion, which was evident from rather similar concentrations of OC content in the surface and immediate sub-surface layer. The lowland pedons of Hukkeri and Khanapur were relatively higher in OC content than other pedons. The distribution of OC is mainly associated with physiography. These findings are in conformity with those reported by Walia and Rao (1996). Relatively higher OC content in soils of Khanapur pedons is due to high rainfall and forest cover.

The CEC of all the pedons of Yadawad micro-watershed followed a similar trend as that of clay. The CEC of upland pedon of Hukkeri was low (11.2 to 12.0 $cmol(p^+)kg^{-1}$) compared to that of the lowland pedon (15.2 to 25.0 $cmol(p^+)kg^{-1}$), which could be due to higher clay content. The CEC in all the pedons of Hukkeri (pedons 4, 5 and 6) decreased with soil depth, which could be attributed to decreased OC and clay content in the lower depths of solum. The lower CEC values of Khanapur pedons is related to high rainfall, which resulted in intensive weathering and leaching of bases and relative dominance of kaolinite (Gowaikar and Datta 1971; Patil and Dasog 1999). The exchangeable bases in all the pedons followed the order: $Ca^{+2} > Mg^{+2} > Na^{+} > K^{+}$.

Pedogenesis

Though the parent rock is same between soils of Yadawad and Hukkeri watersheds, the low relief of the former and relatively higher relief of the latter through their influence on erosion and redistribution have brought out the contrasting changes in depth and texture of the soils of these two micro-watersheds. Whereas soils of Yadawad micro-watershed are very deep with clayey texture and 10 YR hue, those in Hukkeri are shallow in upland and mid-land and moderately deep in lowland, and are highly eroded with a predominantly sandy loam texture in pedons 4 and 5 and sandy clay in pedon 6. All pedons have 5 YR hue. This clearly brings out the role of topography as influenced by drainage and leaching in these two watersheds. This is evident in fig. 2. A and B as well. In a somewhat more humid climatic conditions of Central India, Maji *et al.* (2005) also have observed that soil depth decreased and hues were redder at higher elements of topography in basaltic landscape. The role of topography and to some extent climate have been responsible for the observed difference in soils of these two micro-watersheds despite basaltic parent rock. The intense leaching leading to formation of low activity clays has been the influence of climate in the Khanapur micro-watershed.

Soil Classification

All the three pedons of Yadawad micro-watershed qualify to be Vertisols and Usterts. Due to calcareous nature of these soils, all of them qualify at subgroup level as Typic Calciusterts (Soil Survey Staff 2014). The Hukkeri pedons do not exhibit altered horizon enough to be called cambic in the sub-soil and are shallow. Hence, all of them are grouped under Entisols, sub-order Orthents and at great group as Ustorthents. At sub-group level the pedons 4 and 5 would be Lithic Ustorthents and pedon 6 as Typic Ustorthents.

The pedon 7 in Khanapur micro-watershed can be barely put in Inceptisol as evidenced by some alteration and lack of carbonates. This would be Ustept at the sub-order level and Dystrustepts at the great group level and Oxic Dystrustepts at subgroup level because of low CEC in relation to clay. The other two pedons exhibit illuviation of clay and are grouped under Alfisols, sub-order Ustalfs and great group Haplustalfs and Kanhaplic Hapslustalfs at subgroup level because of low CEC in argillic horizon. There is a clear sequence of pedon development going from zone-3 through zone-8 to zone-9.

Conclusions

With three contrasting agro-climatic zones occurring within Belgavi district provided an opportunity to study the soil properties as influenced by rainfall in three selected micro-watersheds. The soils were more weathered and leached as evidenced by decreasing pH, EC and exchangeable bases going from zone-3 through zone-8 to zone-9. Within an agro-climatic zone, however, topographic influences were evident as seen from depth and surface texture variations. The predominantly shallow soils (Entisols) observed in zone-8 in comparison with Vertisols in zone-3 should not be construed as characteristic of that zone. It just happened that the site in zone-8 was at an higher elevation. A study consisting of more than one watershed at different elevations within zone-3 or zone-8, both of which are basaltic, will throw more light on topographic influence within a zone.

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