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Characterization and classification of soils of Kokarda micro watershed in relation to landform and soil properties

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Abstract
The soil survey was conducted and eight typifying pedons were selected for detailed investigations representing major landforms, which are distinctly different from one another in their slope form and composition *viz.,* summit crests, shoulder slopes, escarpments, foot slopes, toe slopes, interfluves slopes and entrenched valley floors. In general, these soils are non saline and alkaline in nature owing to the calcareous nature of the parent material. The soils developed on toe slopes and main valley side slopes are deep, showed comparatively thicker horizons, where deposition predominates erosion (P4 and P5), characterized by deep, wide cracks and well developed slickenside. These soils were classified under the order *Vertisols*. The soils of shoulder slopes and foot slopes (lower) (P1, P3 and P6) were classified as *Ochrepts* within the order *Inceptisols*. The soils developed on summit crests, shoulder slopes, foot slopes (upper) and escarpments (P2, P7 and P8) lack diagnostic surface and subsurface horizons and hence they qualified for *Entisols* soil order.

Keywords: Landforms, parent materials, slickenside, soil order

1. Introduction

The success of soil management to maintain soil quality depends on understanding the responses of soils to land uses and management practices overtime. The changes induced due to the changes in land management often modify soil properties and in turn agricultural productivity. Periodic assessment of important soil properties and their responses to changes in land management is necessary in order to improve and maintain the fertility and productivity of soils. To enhance or at least maintain the present level of productivity, management of land resources on specific principles, soil resource inventory provides the needed information on their potential and limitations relative to optimum utilization through characterization and evaluation of land resources (Prabhawati *et al,* 2017).

Soil resources inventory requires a good understanding of the properties and process of different soils in a given area so that their mapping becomes easy (Walia and Rao, 1996) [22]. As we have to meet the challenges of this country, new understandings and new technologies will be needed to protect the environment and at the same time produce food and biomass to support society (Brady and Weil, 2004) [2]. Systematic study of morphology and taxonomy of soils provides information on nature and type of soils, their constraints, potentials, capabilities and their suitability for different uses (Sehgal, 1999) [11]. Watershed management practices change the land use, vegetative cover and other non-structural and structural actions that are taken to achieve the management objectives. Watershed is an area in which runoff resulting from precipitation, flows and passes through a single point into a large stream, a river, a lake or an ocean (Murthy, 1988) [8]. Keeping this in view, the present study was carried out to study the potentiality and limitations of soils of Kokarda micro watershed for agricultural activities. In this study, an attempt was made to characterize and, classify the soils of the area.

2. Materials and Methods

2.1 Study area

The village Kokarda in Kalmeshwar tehsil of Nagpur district in Maharashtra state lies between $21^{0}10'18''$ N latitude and $78^{0}10'28''$ E longitude. The area falls under Agro ecological sub region (AESR) 10.2 represented by Eastern plateau, hot sub humid ecosystem with 180-210 days length of growing period (LGP). The area is characterized by sub-tropical, subhumid with well expressed weather summer March to May, rainy season June to October and a mild winter November to February. The mean annual temperature varies from 18.67 to 31.29 ^{0}C and rising to 45^{0}C in summer. The area receives mean annual rainfall ranges from 800 to 1200 mm which is mostly received during south-west monsoon period. The natural vegetation of the watershed comprises of dry deciduous tree species and some grasses. Babool (*Acacia arabica*), Palas (*Butea frondosa*), Neem (*Azadirachta indica*), Teak (*Tectona grandis*), Imli (*Tamarindus indica*), Ber (*Zizipus jujuba*) are the predominant species among the natural vegetation. Based on the slope analysis of Kokarda microwatershed eight typifying pedons were selected in such a way that they represent most of the landform units. Soil profiles were positioned in the centre of each geomorphological site and were studied for their morphological characters (Soil Survey Staff, 1993) [14] and samples were collected horizon-wise. The soil samples were analysed for physical and chemical properties using the established standard analytical methods. The studied pedons were classified tentatively using USDA system of Soil Taxonomy (Soil Survey Staff, 1998) [14].

2.2 Analysis of soil samples
Particle size analysis was undertaken by International Pipette Method as described by Black *et al.*, 1965 [1]. Soil Bulk density was determined by dry clod coating technique described by Black *et al.*, 1965 [1]. The soil reaction was determined in 1:2.5 suspension using standard pH meter (Jackson, 1967) [7]. Calcium carbonate was determined by rapid titration method given by Piper, 1966. The method described by Jackson, 1958 [6] was used for estimation of cation exchange capacity (CEC). Soil organic carbon (OC) was estimated using the wet oxidation method given by Walkley and Black, 1934 [21]. Soil suitability evaluation was carried out as per criteria laid down by Sys (1985) [16].

3. Results and discussions
3.1 Soil Characteristics
The geological formation of the area mainly consists of basalt. Summit crests, shoulder slopes, escarpment slopes, foot slopes, toe slopes, interfluves slopes and entrenched valley floor are the main geomorphic units identified in the study area. The soils occurring on summit crests, shoulder slopes, escarpments, upper and lower foot slopes are very shallow to shallow having depth 10 to 40 cm, while those occurring on the toe slopes and main valley slopes were deep (150 cm). The colour of soil vary according to their physiographic position and drainage conditions. The soil colour ranged from very dark gray (2.5 YR) to very dark grayish brown (10 YR). The soils of main-valley side slopes and shoulder slopes exhibited 10 YR hue throughout all the pedons. The chroma was low due to reduction of iron under the influence of relatively drainage and stable landform (Gaikawad *et al.*, 1974) [5]. It is observed that, the soil developed on the erosive surface are shallower due to less percolation of rain water and more runoff favouring soil loss, while deep soils are found where deposition occurs. The same was reported by Tamgadage *et al.* (1984) [17] and Srivastava *et al.* (1991) [15]. The secondary units are characterized and classified on the basis of size, shape and degree of distinctness into classes, types and grades respectively. The surface soils showed moderate, medium, sub angular blocky structure, while the sub surface horizons have developed strong, coarse, angular blocky structure due to high clay content. The soils of main-valley side slopes found well developed wedge shaped structural aggregates in the subsoil may be due to swell-shrink phenomenon of smectite clay which results in development of slickensides. The highest amount of coarse fragments observed in soils of shoulder slope shows irregular trend of increase down the profile related to topographic position. Hence, more calcium carbonate accumulated in lower layers. Similar results were reported by Sharma and Roychoudhary (1988).

The texture was clay in the surface and subsurface horizon of all the pedons of Kokarda micro-watershed, being the parent material of these soils is known to produce higher amount of clay (Eswaran *et al.*, 1988). The texture of summit crests, shoulder slopes and main valley-side slopes are relatively finer in texture as compared to those in the escarpments, foot slopes (upper and lower) indicating that the soils become finer and finer as one moves from higher to lower relief. The clay content increased with increasing in depth. This may be due to partly caused by beating action of fine soils from surface. The surface soil showed moderate, medium, sub angular blocky structure, while, the sub surface horizon have developed strong, coarse, angular blocky structure due to high clay content. The soils of main valley side slopes found well developed wedge shaped structural aggregates in the sub soil may be due to swell-shrink phenomenon of smectite clay which results in development of slickenside. The sand content ranges between 3 to 55 per cent in the escarpments and foot slopes (upper) whereas, the sand content was observed up to 50 per cent in the main valley side slopes and plain areas. The clay content varies from 56 to 78 per cent being highest in summit crest, shoulder slopes and main valley side slopes while lower in escarpments, foot slopes (upper and lower) varying from 26 to 33 per cent. The increase in clay content down the slope may be due to migration of finer fractions and their deposition down the slope. The bulk density of the air-dry clod ranges from 1.37 to 1.89 Mgm-3 and found to increase down the slope due to the increase in clay content. The bulk density increases with depth which may be due to overburden pressure causing compaction in the subsurface horizon, while, the surface soils are less compacted due to high amount of organic matter and plant roots. Similar findings were also reported by Virmani *et al.* (1982) [19] and Coughlan *et al.* (1986) [3].

3.2 Chemical properties
The soil reaction ranges from 5.5 to 8.6 which are moderately acidic to moderately alkaline in nature. The pH increases from soils of summit crest to lower sections of main valley side slopes in all soils due to the removal of bases and calcium carbonate form the upslope position and its deposition to the down slope. Similar results were also reported by Sharma *et a.l* (1996) [12]. It was also observed that the pH increases in soil with depth due to accumulation of calcium carbonate and bases in the lower horizons. Electrical conductivity of the soils found to be low which was ranged from 0.05 to 0.11 d Sm^{-1} within the safe limit for growing of crops. Organic carbon content of the soils ranges from 0.23 to 0.75 per cent. In surface layer of pedon 5, organic carbon was observed 1.05 per cent which was high may be because of the soils only occasionally cultivated which favours more addition of organic matter and less oxidation of carbon due to tillage operations. Cation exchange capacity (CEC) showed variation in all the soil profiles and ranged from 29.76 to 63.36 cmol (P^+) kg^{-1}. The CEC values largely influenced by the high clay

content in black soils are attributed to their smectite clay mineralogy (Pal and Deshpande, 1987) [9]. Base saturation ranges from 32.49 to 99.27 per cent which was found to increase down the slope as well as showed increasing trend with depth. This may be attributed to the removal of bases by water. In general, base saturation percentage increases with increase in the pH and considered to be an indicator of soil fertility (Tan, 1989) [18]. The relatively higher base saturation in surface layer could be attributed to the recycling of basic cations through vegetation.

3.3 Soil classifications

The dominant soils of the study area belong to *Vertisol*, *Inceptisol* and *Entisol* orders. The pedon 4 and 5 quantify to be *Vertisols* and *Usterts* and classified as *Typic Haplusterts* due to very deep in nature, dark coloured, clayey (> 50 % clay), wide cracks and well developed slickensides. The *ochric* epipedon was observed in pedon 1, 3 and 6 underlain by a *cambic* horizon and have been classified as *Ochrepts* within order *Inceptisol*. These soils was placed under great group *Ustochrepts* due to prevailing *ustic* moisture regime. At sub group level soils of pedon 1 and 3 classiefied as *Vertic Haplustepts* as they have *vertic* properties within 50 cm of the mineral soil surface. The soils of pedon 2, 7 and 8 developed on eroded surface and lack diagnostic surface and subsurface horizon and hence they were qualify for *Entisols*. In view of lithic contact within 50 cm of surfaces, these soils belong to the subgroup *Lithic Ustorthents*.

Table 1: Morphological characteristics of the soils of study area.

Horizon	Depth (cm)	Boundary		Martix colour (Munsell notation)		Texture	Structure			Consistence			Porosity		Roots		Nodules		Effervences	Other features
		D	T	D	M		S	G	Ty	D	M	W	S	Q	S	Q	S	Q		
Typifying Pedon 1-Shoulder Slopes																				
A	0-5	a	s	5YR3/3	5YR3/3	C	f	1	sbk	s	fr	sp	vf-f	m	vf	f	-	-	-	-
Bw1	5-20	a	w	10YR3/2	10YR3/3	C	c	3	abk	h	fi	vsvp	f	c	vf	f	-	-	-	-
Bw2	20-42	a	w	10YR3/2	10YR3/3	C	c	3	abk	h	fi	vsvp	f	c	vf	f	-	-	-	-
Cr	42-65	-------------------Weathered basalt------------------																		
Typifying Pedon 2-Escarpments																				
A	0-12	a	w	7.5YR3.5/4	7.5YR3/3	sicl	m	2	sbk	sh	fi	sp	vf-f	m	vf	c				
Cr	12-50	-------------------Weathered basalt------------------																		
Typifying Pedon 3-Foot Slopes (Lower)																				
Ap	0-5	c	s	7.5YR3/2	7.5YR3/2	c	vf	2	sbk	sh	fr	sp	f-m	m	vf	f	vf-f	m	es	-
Bw1	5-22	c	w	10YR3/2	10YR2/2	c	m	3	sbk	h	fr	vsvp	f-m	c	vf	c	vf	c	es	-
Bw2	22-37	a	w	10YR3/1	10YR3/1	c	m	3	abk	-	fi	vsvp	vf	m	vf	f	vf	m	es	pf
Cr	37-70	-------------------Weathered basalt------------------																		
Typifying Pedon 4-Toe Slopes																				
Ap	0-15	c	s	10YR3/2	10YR3/2	C	f	1	sbk	s	fr	sp	f-m	m	vf	f	vf-f	m	es	-
Bw	15-48	c	s	10YR3/2	10YR3/2	C	m	2	sbk	h	fr	vsvp	vf	m	vf	c	vf-f	m	es	-
Bss1	48-67	a	s	10YR3/1	10YR3/1	C	m	2	abk	vh	vfr	vsvp	vf	m	vf	m	vf-f	m	es	ss
Bss2	67-93	a	s	10YR3/2	10YR3/2	C	c	3	abk	eh	vfi	vsvp	vf	m	vf	f	vf-f	m	ev	ss
Bss3	93-117	a	w	10YR3/2	10YR3/2	C	c	3	abk	eh	fi	vsvp	vf	m	-				ev	ss
Cr	117-170	-------------------Weathered basalt------------------																		
Typifying Pedon 5-Main Valley-side Slopes																				
Ap	0-24	c	s	10YR3/2	10YR3/2	C	m	2	sbk	sh	fr	sp	vf	m	m	c	vf	f	e	-
Bw1	24-42	c	s	10YR3/3	10YR3/3	C	m	2	sbk	sh	fr	sp	vf	c	-	-	vf	f	e	-
Bw2	42-67	c	s	10YR3/2	10YR3/2	C	m	2	abk	sh	fi	vsvp	vf-f	c	-	-	vf-f	c	es	-
Bw3	67-89	a	s	10YR3/2	10YR3/2	C	m	3	abk	h	fi	vsvp	vf-f	c	-	-	vf-f	c	es	-
Bss1	89-104	a	s	2.5Y3/2	2.5Y3/2	C	c	3	abk	vh	vfi	vsvp	vf	f	-	-	vf-f	c	ev	ss
Bss2	104-126	a	s	2.5Y3/2	2.5Y3/2	C	c	3	abk	vh	vfi	vsvp	vf	f	-	-	vf-f	c	ev	ss
Bss3	126-155	-	-	2.5Y3/2	2.5Y3/2	C	c	3	abk	vh	fi	vsvp	vf	f	-	-	vf-f	m	ev	ss
Cr		-------------------Weathered basalt------------------																		
Typifying Pedon 6-Shoulder Slopes																				
Ap	0-10	c	s	5YR3/2	5YR3/4	C	f	2	sbk	h	fr	vsvp	vf	m	vf	f	-	-	-	-
A2	10-25	a	w	5YR3/3	5YR3/3	C	m	2	sbk	h	fr	vsvp	vf	m	vf	-	-	-	-	-
Cr	25-35	-------------------Weathered basalt------------------																		
Typifying Pedon 7-Summit Crests																				
Ap	0-20	a	s	10YR3/2	5YR3/2	C	m	2	sbk	sh	fr	sp	f	f	vf-f		-	-	-	-
Cr	20-36	-------------------Weathered basalt------------------																		
Typifying Pedon 8-Foot Slopes (Upper)																				
Ap	0-15	a	w	10YR5/3	10YR3/3	Scl	m	1	sbk	sh	fr	sp	vf	m	vf-f	f	-	-	-	-
Cr	15-25	-------------------Weathered basalt------------------																		

Table 2: Physical properties of soils of the study area.

Horizon	Depth (cm)	Coarse fragments (%)	pH (1:2.5) Soil:Water	Ec (1:2.5) Soil:Water	OC (%)	Particle size distribution (mm)			Textural class	Bulk density (air dry Mgm-3)	CEC cmol (p⁺) kg⁻¹	BS (%)
						Sand (mm)	Silt (mm)	Clay (mm)				
Typifying Pedon 1-Shoulder Slopes												
A	0-5	30.0	7.1	0.10	0.75	2.6	19.9	77.5	c	1.87	54.72	96.76
Bw1	5-20	10.0	6.9	0.09	0.64	2.9	20.1	77.0	c	1.85	55.68	74.94
Bw2	20-42	-	7.4	0.11	0.57	5.3	16.2	78.5	c	1.89	56.64	75.79
Typifying Pedon 2-Escarpments												
A	0-12	20.0	7.0	0.06	0.70	19.6	47.4	33.0	Sicl	1.42	30.72	90.26
Typifying Pedon 3-Foot Slopes (Lower)												
Ap	0-5	10.0	8.2	0.15	0.70	19.1	22.3	58.6	c	1.67	56.64	99.77
Bw1	5-22	5.0	8.2	0.13	0.57	16.1	10.4	73.5	c	1.82	62.30	98.49
Bw2	22-37	5.0	8.2	0.15	0.53	22.6	10.3	68.0	c	1.81	63.36	87.70
Typifying Pedon 4-Toe Slopes												
Ap	0-15	10.0	8.3	0.12	1.05	19.7	24.8	55.5	c	1.61	52.80	100.43
Bw	15-48	5.0	8.3	0.14	0.80	18.4	20.0	61.6	c	1.72	58.56	98.65
Bss1	48-67	10.0	8.4	0.14	0.70	20.3	20.7	59.0	c	1.72	62.40	100.86
Bss2	67-93	5.0	8.4	0.19	0.62	13.3	19.5	67.2	c	1.80	63.36	96.95
Bss3	93-117	10.0	8.4	0.19	0.55	30.6	17.4	52.0	c	1.57	47.04	98.72
Typifying Pedon 5-Main Valley-side Slopes												
Ap	0-24	15.0	8.1	0.17	0.66	11.6	32.4	56.0	c	1.49	53.76	100.48
Bw1	24-42	10.0	8.2	0.15	0.52	14.8	28.7	56.5	c	1.51	58.68	93.70
Bw2	42-67	15.0	8.3	0.16	0.46	36.9	4.1	59.0	c	1.70	56.64	94.42
Bw3	67-89	15.0	8.4	0.17	0.44	6.0	38.0	56.0	c	1.60	52.80	91.57
Bss1	89-104	10.0	8.5	0.19	0.43	17.0	21.0	62.0	c	1.77	65.64	78.64
Bss2	104-126	15.0	8.5	0.25	0.41	18.0	17.5	64.5	c	1.79	57.60	91.28
Bss3	126-155	20.0	8.6	0.24	0.33	20.9	18.5	60.5	c	1.72	68.56	94.65
Typifying Pedon 6-Shoulder Slopes												
Ap	0-10	10.0	5.8	0.16	0.77	8.5	25.0	66.5	c	1.69	45.12	87.16
A2	10-25	10.0	6.8	0.04	0.73	9.2	24.3	66.5	c	1.62	47.04	89.22
Typifying Pedon 7-Summit Crests												
Ap	0-20	30.0	7.1	0.07	0.61	15.7	25.8	58.5	c	1.58	50.58	90.42
Typifying Pedon 8-Foot Slopes (Upper)												
Ap	0-15	20.0	7.2	0.05	0.23	54.6	17.5	27.9	Scl	1.37	29.76	98.42

4. Conclusion

Soils of different geomorphic units have varying profile development from almost no diagnostic horizon to well developed horizons. *Entisols* were observed on eroded surfaces like shoulder slopes, summit crests, escarpments and foot slopes (upper); *Inceptisols* are observed on shoulder slopes and foot slopes (lower). The soils of *Vertisols* occupied lower topographic position *viz.*, main valley side slopes. This revealed that there is a strong influence of landform on soil properties.

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