Original Research Article

Characterization and classification of soils in atoposequence of the semi-arid basaltic landscape of western India

Abstract

The pedological investigations were carried out on a soil toposequence of the semi-arid region on the basaltic landscape of western Indiaand landform-soil relationship was established. In the study, seven soil profiles, representative of the summit, escarpment, lower pediment, undulating lands, plains and valley in a toposequence were studied. The study indicated that the soil development and its properties were following the toposequence. The profile development was least at the summit and best in the plains of the toposequence. The horizon sequences observed from the summit through plains of the toposequence are A-R, Ap-Bw-Cr, Ap-Bw1-Bw2-Bw3-Bw4-Crk, Ap-Bw1-Bw2-Bss1-Bss2-Bss3,Ap-Bw-Bss1-Bss2-Bss3-Bc and Ap-Bw1-Bw2-Bw3-Bw4. The soil colour is brown to very dark greyish brown down the toposequence. The solum depth varied from extremely shallow to very deep. An increasing trend was observed in clay content, cation exchange capacity, soil reaction, electrical conductivity, base saturation and exchangeable cations from summit to plains. The soils of summit, pediments and plains were classified as Entisols, Inceptisols and Vertisols, respectively.

Keywords: Landform-soil relationship, Basaltic landscape, Toposequence, Soil classification

1. Introduction

Soil is the most precious basic natural resource, on which depends the security of food, nutrition, income, biodiversity, livelihood, and environment and whose proper use depends on the life-supporting systems of a country and the socio-economic development of its people (Sahu*et al.*, 2014). The continuous use, misuse and exploitation of land resources have resulted in its degradation and destruction. In order to sustain developmental processes in the long-term, it is necessary to have a judicious allocation of land for various activities according to its sustainability and capability (Bajpai, 2013; Sahu*et al.*, 2014). Soil characterization plays a key role in the management of natural resources. The slope is a key factor for the analysis and mapping of landforms (Reddy, 2018) as it influences surface flow, soil properties and water content, as well as the erosion potential of an area. Management of soil resources on scientific principles is essential to maintain the present level of soil productivity and to prevent soil degradation (Sahu*et al.,* 2014).Study of various geomorphological processes provides inferences to understand landscape evolution (Manjare*et al.,* 2022), pedology (Reddy *et al.,* 1999, 2002, 2013), hydrology (Reddy *et al.,* 1994) and status of land degradation (Reddy *et al.,* 2002; Nagaraju*et al*., 2011). Soil survey provides an accurate and scientific inventory of different soils, their kinds and nature, and extent of distribution so that one can make predictions about their characters and potentialities (Reddy *et al*., 1993; 2004; Kaduand Kharche, 2017).Variations in most of the soil properties in the study area are closely related to their position on the landscape (Singh *et al*., 2006).

The present study selected a part of the basaltic terrain of Rahuri tehsil of Ahmednagar district, Maharashtra, which falls under agro-ecological zone 6 (semi-arid region). The Rahuri tehsil has an elevation of 511 m above mean sea level (MSL) with flat and undulating lands and the average rainfall of the study area is 585 mm. Varying combinations of elevations and climatic regimes have resulted in a large number of contrasting physiographic elements and conditions for agricultural production. The major part of Rahuritehsil isunder sugarcane cultivationassociated low rainfall and high soil salinity, which influence crop yield. Characterization of soil properties and their distribution over an area has become essential for the efficient management of soils for developing non-degrading cropping systems and associated management practices of sustained productivity. Keeping this in view seven soil profiles were studied and characterized in a toposequence of Rahuri tehsil of Ahmednagar district, Maharashtra and established the landform-soil relationship.

2. Materials and Methods

2.1 Geographical settings

RahuriTehsil in Ahmednagardistrict,Maharashtra is located between 19^{0} 15' to 19^{0} 34' North latitude and 74^{0} 23' to 74^{0} 50' East longitudeat an elevation of 511 m above MSL in the semi-arid region of Western Ghats in Mulaand Pravara basin. The tehsil has a monsoon type of climate with an annual rainfall of 585 mm and 94 % of which falls during the period from June to October. May is the hottest month, temperature varies from 33 °Cto 41 °Cand December is the coldest month of the year with the mean daily maximum temperature at 28.5 °C and the mean daily minimum temperature at 11.7 °C. The relative humidity varies from 73 % in the rainy season to 33 % during winter. Physiographically, the

Rahuri tehsil partly belongs to the Sahyadri hills and partly represents the Tapi and Purnavalleys. The Baleshwar range of hills of Sahyadri region traverses in the neighboring Sub-Division of Sangamner touching the west ends of South-West boundary of Rahuri tehsil. The plains in the Rahuri tehsil occur below the elevation of 600 meters from MSL belong to Tapi and Purna system of basaltic origin and are spread over in Mula valley.Potential evapotranspiration (PET) is higher than P (Precipitation) round the year and the growing season begins in the month of June and continues till December. Rahuri tehsil is classified with South Western Maharashtra and North Karnataka Plateau, hot dry semi-arid agro-ecological sub-regions (AESR) with shallow and medium loamy black soils (deep clayey black soils as inclusion), medium to high available water capacity (AWC) and associated with the irrigated area. In the revised AESR map, Rahuri tehsil is classified in the agro-ecological region (AER) 6, which is defined as a Deccan plateau, hot semiarid region ecoregion, with shallow and medium black soils and a growing period of 90-150 days. Three types of soils have been reported here belonging to mainly Entisols, Inceptisols and Vertisols. The total land area of Rahuri tehsil is 1035.11km^2 out of that agricultural land use is 766.09 km^2 (74.01%), forest land is 157.06 km^2 (15.17%) and other land is 111.96 km^2 (10.82%). Major crops of Rahuritehsil are sugarcane, onion, jowar, maize, wheat, pomegranate, etc.

2.2 Soil profile study

Seven soil profiles in atoposequence representing the Summit, Escarpment, Lower pediment, Undulating lands, Plains and Valley were studied. Soil profiles of 3x3x5 meter dimension were dug and morphological characteristics were studied and horizon-wise samples were collected for laboratory characterization and verification of field studies.

2.3 Morphological characterization of soil profiles

The soil profiles were examined in the field for morphological characteristics as per the procedure given in AIS&LUS (1971) and USDA Soil Survey Manual (Soil Survey Division Staff, 2000). The morphological characterization includes soil depth, soil colour, soil texture, soil structure, horizon setting, effervescence with normal 0.1*N*HCl, gravel content, quantity, the orientation of pores and root characteristics. The special features like pressure faces, cracking patterns and slickensides were studied and recorded in the field.

2.4 Physical characterization of soil profiles

The bulk soil samples collected during the fieldwork were initially air-dried in the laboratory at room temperature, grind using a wooden mortar and pestle, screened through a 2 mm sieve, properly labelled and stored in polythene bags for laboratory analysis. For certain soil characteristics like organic carbon, samples were further grounded and screened through 80 mesh sieve. The bulk density (BD) was determined by the clod waxing technique (Blake and Hartge, 1986). Air-dried clods collected from soil profiles were weighed and their bulk volume was determined by water displacement caused by clod coated with melted paraffin wax. The BD was expressed on oven dry basis. Particle size distribution was determined as per the international pipette method. The soil was initially treated with H_2O_2 (30%) for the removal of organic matter and further treated with HCL (1*N*) to remove $CaCO_3$ using sodium hexametaphosphate as dispersing agent. Sand (2-0.05 mm), silt (0.05-0.002 mm) and clay (<0.002 mm) were analysedby using the Robinson pipette method as described by Jackson (1967). The textural class was determined by using the USDA textural triangle as given in Soil Survey Manual (Soil Survey Division Staff, 2000).

2.5 Chemical characterization of soil profiles

Soil pH was determined in soil suspension (1:2 soil: water) by a glass electrode pH meter after equilibrating soil with water for one hour with occasional stirring as per the method given by (Jackson, 1958). The supernatant liquid of soil water suspension (1:2) prepared for measuring pH was also used for measuring electrical conductivity (EC) using Conductivity Bridge (Jackson, 1973). Modified Walkley and Black's rapid titration procedure was followed for estimating the organic carbon content. Organic carbon in the soil was oxidized by potassium dichromate-sulphuric acid and the amount of potassium dichromate remaining was determined by back titration against standard ferrous ammonium sulphate solution using ferroin as an indicator following the wet oxidation method (Nelson and Sommers, 1982). The calcium carbonate was estimated by the rapid titration method (Piper, 1966). The soil was treated with 0.5 *N*hydrochloric acid to neutralize all carbonates and the unutilized hydrochloric acid was back-titrated with standard sodium hydroxide (0.25 *N*) using phenolphthalein as an indicator. The CEC was determined by saturatingthe soil with 1 N sodium acetate (pH 8.2 for calcareous and pH 7.0 for non-calcareous soils). Excess sodium acetate was washed with 99% methanol till the supernatant has an EC of 40-55 dSm^{-1}. The absorbed sodium was then replaced by 1 *N* ammonium acetate (pH 7.0) solution and the sodium concentration in the leachate was determined by flame photometer and CEC was calculated (Richards, 1954).Exchangeable Na^+ and K^+ were determined by leaching the soil with neutral normal ammonium acetate (pH 7.0) and analysing by a flame photometer (Jackson, 1979). Exchangeable calcium (Ca^{2+}) and magnesium (Mg^{2+}) of soils were extracted by leaching the soil with 1 *N*KCltriethanolamine buffer solution (pH 8.2) and titrating the leachate with standard EDTA solution using murexide and EBT as an indicator. Base saturation was calculated (Black,1965) as the sum of cations (cmol (p+) kg^{-1}) divided by CEC (cmol (p+) kg^{-1}) and multiplied by 100. It is expressed as a percentage.

3. Result and Discussion

The seven profiles were studied in a toposequence in the Rahuri tehsil of Ahmednagar district, Maharashtra representing landforms of the summit, escarpment, lower pediment, undulating lands, plains and valley. The photographs of the soil profile studied are shown in fig. 1. The detailed characteristics of the soils are presented in table 1 and discussed the following section.

3.1 Soil morphological properties

The morphological characteristics of the soils were extremely shallow (8 cm) to very deep (>150 cm) in depth and poorly to well drained. Inpedon 1 (P1) a 25 cm thick A layer was observed followed by hard basaltic R horizons. Pedon 2 (P2) had only 8 cm deep (extremely shallow) and A horizon underlying a thick R layer of hard basalt material (Table 1). In pedon 3 (P3) a 21 cm thick Ap horizon was observed followed by a 19 cm deep Bw horizon owing to a change in colour and structure. Weathered parent material (Cr) was observed after 40 cm depth. The 4thpedon (P4) and 7thpedon (P7)were represented by the horizon sequence of Ap-Bw1-Bw2-Bw3-Bw4-Crk. These horizons were assigned based on the change in colour, presence of cracks and increase in hardness down the profile. Weathered parent materials with $CaCO_3$ were observed after a depth of 150 cm in the 4thpedon. The pedon 5 (P5) and pedon 6 (P6) was having 20 cm thick Ap horizon followed by a cambic horizon (Bw) of 70 cm thickness owing to darker colour than the surface horizon. It was followed by deep 76 cm thick Bss horizons (Bss1-Bss2-Bss3) with the occurrence of slickensides. The horizons with slickensides (Bss) were identified below the depth of 76 cm in pedon P5 and 43 cm in pedon P6.The colour varied from brown to very dark greyish brown (7.5 YR4/3 to 10 YR 3/2). The value ranged from 3 to 5 and chromafrom 1 to 4. The colour in pedon 1 was observed as brown (7.5 YR 4/3) and pedon 2 was observed very dark greyish brown (10 YR 3/2). Brown dominant shades were also noted in the soils of upper and lower pediments (pedon3 and pedon4). The upper part of the undulating land exhibited a dark yellowish-brown to brownish shade, whereas its lower part registered a dark greyish-brown to very dark greyish-brown colour (Pedon 5).In the plains and the valley (Pedon 6 and Pedon5), soil colour was dark greyish brown to very dark greyish brown as the dominant shade (Fig. 1 & 2). However, brown shades were also noted occasionally.

It is well known that soils developed from basalt on the lower topographical position were dark to very dark greyish brown due to the chelation and complexation of organic matter on the surface of the smectites (Dudal and Eswaran, 1988). The colour shades and extensive cracking in soils of the lower part of the undulating land, plains and valley were in agreement with the given concept.Further, Singh and Baser (2020) and Duchaufour (1982) reported brown to dark brown colour in the intensively cultivated soils of basalt. The release of iron from the smectites was accounted for the variations. The concept supported the observations of brown and dark brown soils of undulating land and sometimes plains used for cultivating twice with the support of irrigation.Singh *et al.* (1995) developed an index of Dithionite extractable free iron oxide to clay. It was stated that the soils were grey with a narrower ratio and the colour shade was brown with a wider Dithionite extractable iron to clay ratio. Wider-free iron oxide to clay ratio suggested that bonding between organic colloids and smectites was not strong enough, and resulted in a redder hue and brighter chroma (Duchaufour, 1982).

This does not apply to the yellowish-brown to brown soils from summits to upper pediments, sparsely cultivated at places and dominantly left uncultivated under forest. The present climatic conditions with 584.97 mm mean annual rainfall of three to four months do not support the developmentof the formation of such soils. A climate consisting of high rainfall and temperature is needed for the development of such soils. Possibly the soils/ sediments associated with the upper part of the landscape were the part of Indian plate, which was once at the equator under equatorial climate, favorable for the development of yellowish-brown to reddish-brown soils. Probably these were the original colour of the soils before the collision of the Indian and Eurasian plates. After the collision, the present shape of topography was attended in the region. The lower part was occupied by the basaltic material that erupted during the Holocene period, while the upper part of the landscape was not affected by the basaltic alluvia. The presence of yellowish-brown to reddish-brown colour below the surface in the valley also supported our observation.

The surface structure of these soils was medium, weak, and sub-angular blocky structure at the summits and Escarpment (pedon 1). These remained weak to moderate at the escarpment (pedon 2). During the journey from the summits to the upper pediment, the size of the sub-angular blocky structure remained medium. The medium moderate sub-angular blocky structure was also prominent in the lower pediments (pedon 3). In the upper of undulating land, medium-weak sub-angular blocky structure on the surface and medium moderate sub-angular blocky in the sub-surface were registered (pedon 4). Further, in the soils of plains (pedon 5 and pedon 6), the soils structure was identical in terms of size, grade, and shape as reported for the soils in the lower undulating land. In contrast, the soil structure in the valley (pedon7) could be seen dominantly as a medium, moderate sub-angular blocky both in the surface and sub-surface.The consistency of the soils varied from soft to hard (dry), friable to firm (moist) and slightly sticky to very sticky and slightly plastic to very plastic (wet). An increase in stickiness and plasticity might be due to a large amount of clay minerals down the profile (pedon 5, 6 and 7) whereas, the remainingpedons exhibited soft, friable, slightly sticky and slightly plastic.Few and fine nodules were present in all the profiles. Fine roots were observed in all the pedons as they were under agricultural use with many roots in the surface and few in the sub-surface layers.

3.2 Physical characteristics

Higher sand content was observed in the surface horizon than those of sub-surface horizons. Sand percentage varied from 17.8% to 43.7% in surface horizons (Fig. 3). Pedon 1, 2 and 3 represents the summit, escarpment and lower pediment were having higher sand content. Pedon 4, 5 and 6 observed lower sand percentage with increasing depth. Pedon 7 represents the valley,where sands are accumulated in the lower horizons. Silt ranged from 16.9% to 23.4% with an irregular trend with depth, which might be due to variation in weathering of parent material. Higher silt content was observed in pedons 6 and 7 than that of other pedons. The clay content varied from 38.0% to 58.8 %. The clay enrichment was observed in the Bw and Bss layers in the case of pedons 4, 5 and 6, whereas, the clay distribution showed a decreasing trend with depth in pedon 7. Clay content increased below the surface in the soils of undulating land and plains. The increasing clay with depth was primarily might be due to in-situ weathering of parent material or due to vertical migration of clay. Contrastingly, clay content was observed comparatively low in the sub-surface than their surface counterparts in the valley.The pedon representing the summit, escarpment and lower pediment observed clay loam texture and the pedon representing the undulating lands, plains and valley observed clay texture. The bulk density of different pedons varied from 1.36 to 2.87 Mg m^{-3}. The bulk density of all the pedons increased with depth. High clay content together with sodium on the exchange complex in the soils of undulating land and plains could be the factor for high bulk density(Table 1). Slickensides, a mark of high swelling pressure accentuated the influence of clays and sodium and imparted bulk density of very high order. In the soils of the valley, bulk density lower than plains and undulating land could be ascribed to the low clay content in the sub-surface, offering lower surface area to the sodium on the exchange complex. The phenomenon leads to restricted swelling pressure and the cumulative effect was manifested in terms of low bulk density.

3.3 Chemical characterization

The data revealed that pH of the soil varied from 7.1 to 9.0 categorizing them to slightly alkaline to strongly alkaline and exhibited an increasing trend with depth in all the pedons. The soil reaction down the profile was slightly alkaline to moderately alkaline in pedons 1, 2 and 3. Strongly alkaline soilsreaction were observed in pedons 4, 5, 6 and 7 due to the accumulation of soluble salts (Fig. 3). Soil EC varied from 0.06 to 0.92 dSm^{-1}. EC was observed lower in pedons 1, 2 and 3. EC increasing trend with depth in the pedons 4, 5, 6 and 7 due to accumulation of soluble salts.The organic carbon content in all the pedons showed a decreasing trend with depth, which varied from 0.07 % to 1.37 % and fell under the low to very high category. Low organic carbon in the soil might be attributed prevalence of higher temperatures in summer season causing a faster rate of degradation of organic matter, thereby leaving less organic carbon in the soil. The organic carbon followed a decreasing trend with depth in all the pedons.

$CaCO_3$ content was around 3% on the surface at the summits, increased to 8.3% on the escarpments and 9.5% in the upper pediments. Mean $CaCO_3$ was about 8.0% in the Ap horizon of the lower pediment. Other Ap horizons associated with the lower part of the landscape showed $CaCO_3$ about 10% and also noted parallel in Bw horizons. However, the mean of $CaCO_3$ was slightly lower about 8.0% in other Bw of the valley. Bss other horizon typifying the soils of undulating land and plains mean $CaCO_3$ content similar to Bw. $CaCO_3$ distribution in the soil profile was largely uniform along with the depth with slight variations. Occasionally $CaCO_3$ increased slightly by 1 to 2% along with the depth. However, in the soils of the valley, $CaCO_3$ was decreased down the depth and maintained hardly 3 to 4%. Another distinct point of $CaCO_3$ distribution was its presence as soft powdery lime in soils of the lower part of the landscape.Cation exchange capacity (CEC) of the soil varied from 31.25

cmol (P^+) kg^{-1} to 55.29 cmol (P^+) kg^{-1} at the surface along the toposequence. The CEC of pedons were related to the content of cations on the exchange complex. The soils with low pH value contain less exchangeable bases, they have lower CEC. The CEC increase with depth in different horizons may be attributed to the higher clay content in the lower layers. Similar results were also reported by Ayam*et al.*, 2020 andKusro*et al*., 2002.The base saturation of the soils varied from 84.40 % to 92.22 % at the surface layer of pedons. Lower base saturation was observed in the soils of escarpment and higher base saturation were observed in the soils of plains(Table 1). Higher base saturation of the pedon indicated that the soil exchange complexes were saturated with basic cations. The base saturation increased with depth of all the pedons.

Table 1.Soil morphological, physical and chemical properties.

Pedon	Horizon	Depth	Matrix colour			Particle size (%)			BD	pH	EC	OC	CEC	BS
		(cm)	hue	Value	Chroma	Sand	Silt	Clay	(Mg m^{-3})		dS m^{-1}	%	Col(p+)kg^{-1}	%
P1	A	0-25	7.5YR	4	3	42.5	18.3	39.2	1.41	7.11	0.06	1.37	43.50	88.67
P1	R	25^{+}						Hard basalt						
P2	A	0-8	10YR	3	4	43.7	18.3	38.0	1.41	8.12	0.14	0.65	31.25	84.40
P2	R	8^{+}						Hard basalt						
P3	Ap	0-21	10YR	3	2	25.6	20.3	54.1	1.61	8.22	0.19	0.83	45.21	95.76
P3	Bw	21-40	10YR	3	1	41.2	22.1	36.7	1.46	8.48	0.15	0.63	41.25	92.82
P3	Cr	40^{+}						Weathered basalt + powdery $CaCO_3$						
P4	Ap	0-19	10YR	4	3	30.2	19.3	50.5	1.37	8.35	0.33	1.20	35.00	95.63
P4	Bw1	19-42	10YR	4	3	28.7	20.7	50.6	1.36	8.45	0.37	0.88	32.50	90.45
P4	Bw2	42-80	10YR	4	3	28.3	18.2	53.5	1.40	8.58	0.22	1.52	32.50	92.26
P4	Bw3	80-117	10YR	5	4	29.2	18.5	52.3	1.45	8.75	0.19	1.09	32.50	93.54
P4	Bw4	117-150	10YR	5	4	27.6	20.2	52.2	2.08	8.69	0.25	1.02	35.00	94.34
P4	Crk	150^{+}						Weathered basalt + $CaCO_3$						
P5	Ap	0-20	10YR	4	2	21.1	20.6	58.3	1.43	8.65	0.22	0.86	35.00	91.57
P5	Bw1	20-47	10YR	3	2	20.5	23.7	55.8	1.87	8.83	0.24	0.70	38.00	92.73
P5	Bw2	47-76	10YR	3	1	19.9	22.9	57.2	1.99	8.90	0.32	0.43	40.12	98.36
P5	Bss1	76-97	10YR	3	1	17.2	23.2	59.6	2.42	8.85	0.36	0.39	41.54	92.40
P5	Bss2	97-122	10YR	3	2	17.2	21.2	61.5	2.34	8.70	0.34	0.58	40.31	95.14
P5	Bss3	122-150^{+}	10YR	3	2	14.4	19.7	65.9	2.10	8.89	0.31	0.28	38.52	91.87
P6	Ap	0-19	10YR	4	3	17.8	23.4	58.8	1.48	8.73	0.32	1.10	55.29	91.66
P6	Bw	19-43	10YR	3	2	19.2	23.1	57.7	1.78	8.57	0.53	0.94	55.12	91.15
P6	Bss1	43-70	10YR	3	1	19.7	22.4	57.9	2.17	8.50	0.53	0.78	50.32	97.26
P6	Bss2	70-104	10YR	3	1	20.1	23.3	56.6	2.33	8.50	0.78	0.82	52.84	90.42
P6	Bss3	104-130	10YR	3	1	19.3	18.9	61.8	2.87	8.56	0.92	0.74	51.89	97.01
P6	Bc	130-150	10YR	3	3	20.2	23.1	56.7	2.85	8.61	0.87	0.36	42.17	109.46
P7	Ap	0-18	10YR	3	2	27.8	16.9	55.3	1.71	8.82	0.24	1.02	40.50	92.22
P7	Bw1	18-44	10YR	3	3	25.3	20.0	54.7	1.63	9.08	0.23	0.60	41.22	93.04
P7	Bw2	44-72	10YR	3	3	33.4	28.7	37.9	1.49	9.05	0.26	0.56	40.21	95.47
P7	Bw3	72-109	10YR	5	4	26.4	48.2	25.4	1.46	9.05	0.27	0.81	42.25	90.15
P7	Bw4	109-150^{+}	10YR3	3	4	58.2	23.6	18.2	1.42	8.64	0.67	0.07	40.00	93.98

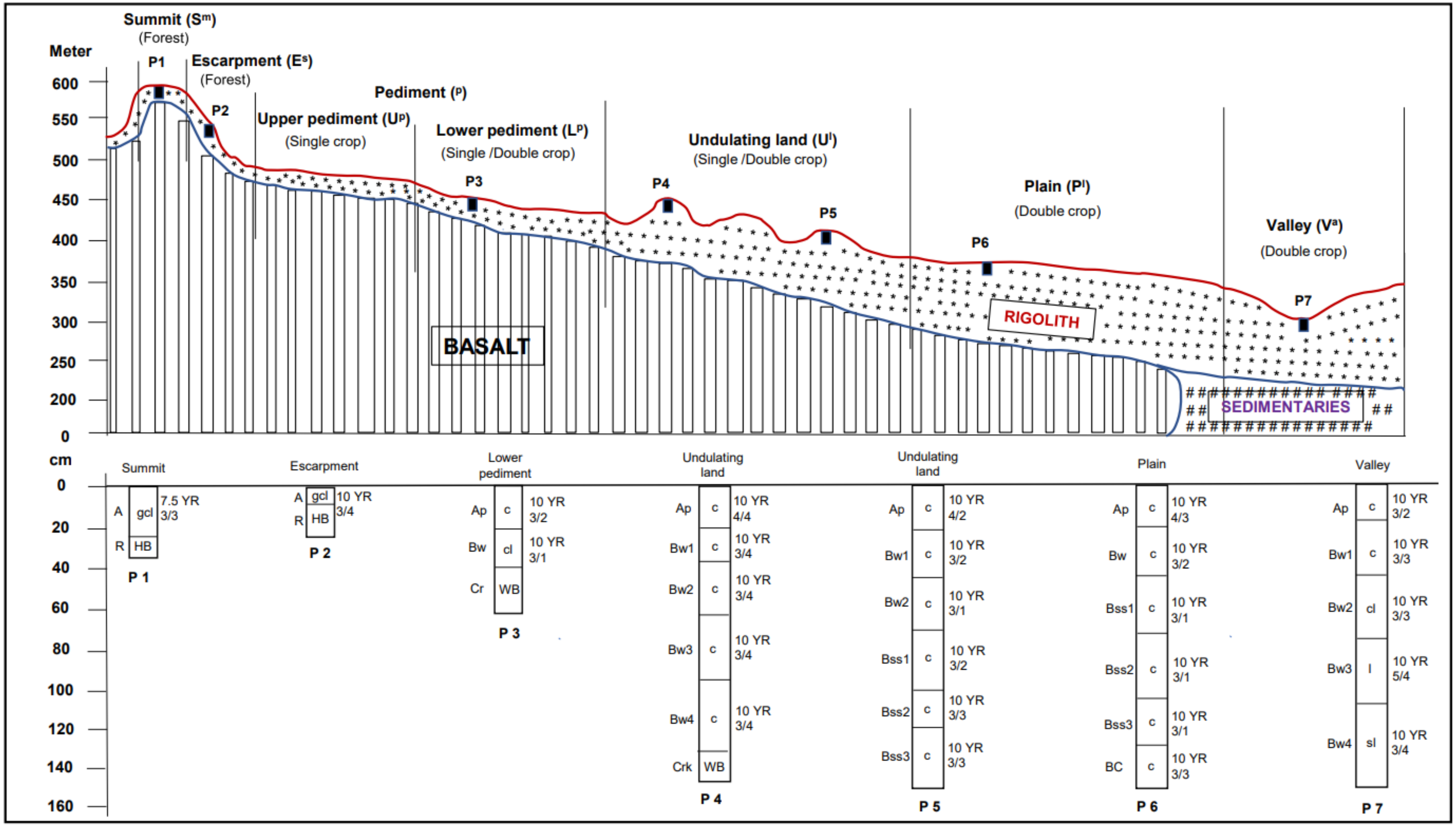

Fig 1: Soil-Landform Relationship of Typifying Pedons studied in different landforms in Rahuritehsil.

Pedon 1 Pedon 2 Pedon 3 Pedon 4 Pedon 5 Pedon 6 Pedon 7

Fig. 2. Landscape-soil relationship and soil profile development in a topsequence.

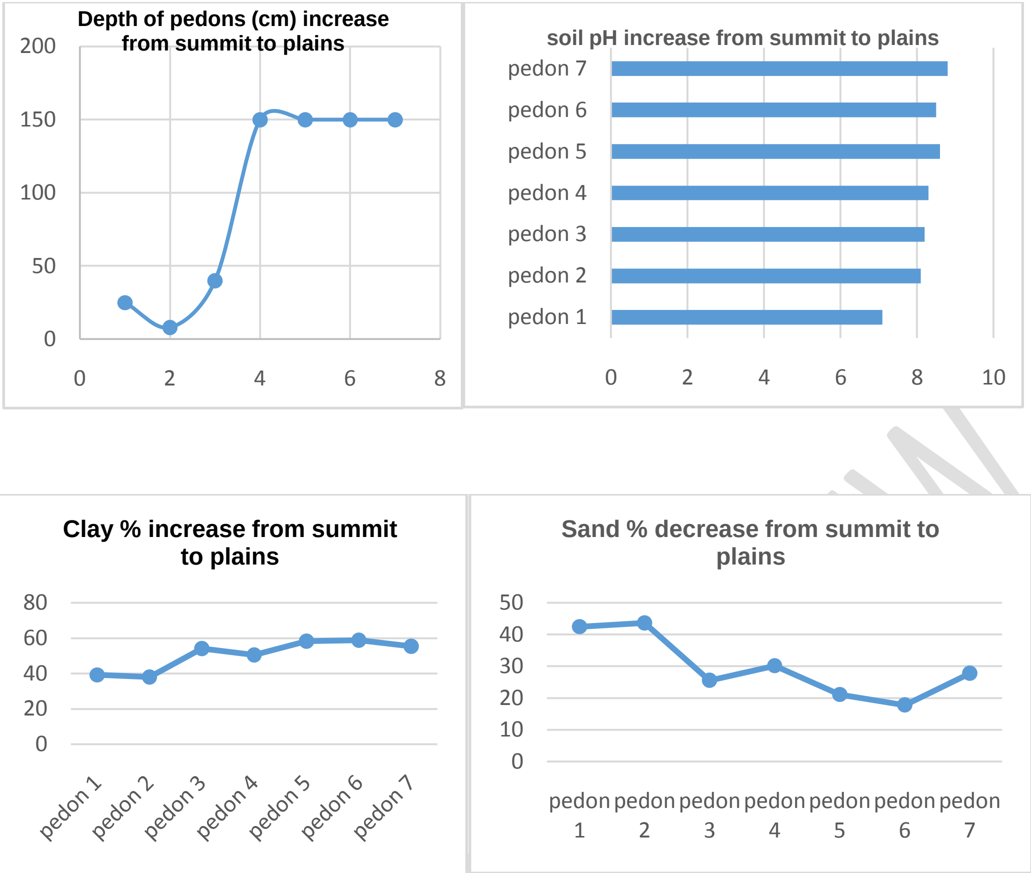

Fig. 3.Variation of soil physical and chemical properties across the landscape.

3.4 Soil classification

Based on the morphological, physical and chemical characterization, the soils from the summit and escarpment (pedon 1 and 2) were classified in Entisol soil order, owing to the absence of pedogenic horizons. These did not possess the soil properties to qualify for Aquents, Arents, Psamments, and Fluvents, therefore classified into Orthents sub-order. Ustic soil moisture regime was considered as diagnostic characteristics to classify Orthents into Ustorthents great group. The soil depth was $\leq$ 50 cm by the rock of the Dharwarsystem, therefore Ustorthents were placed as Lithic Ustorthents sub-group. Given the hyperthermic soil temperature regime and mixed mineralogy and loamy particle size class, the soils were classified as Loamy, mixed hyperthermic family of Lithic Ustorthents.Soils of pedon 3 were classified in the Ustepts sub-order under Inceptisols accounting alteration as medium moderate sub-angular blocky structure and Ustic soil moisture regime. Although these have only 12 and 7% calcium carbonate in the Bw horizon, however, these were rich in authigenic lime. The volume of authigenic lime was higher by 5% or more from the underlying horizon thus qualified for the calcic horizon. Therefore, the soils were classified as Calciustepts great group in Ustepts. Since the soils were represented the central concept of Calciustepts, therefore classified as TypicCalciustepts.

Soils of pedon 4 was observed in Ap-Bw-Crk sequence. In absence of another diagnostic horizon, the cracks, clay content of more than 30%, and the pressure faces were accounted as the pedogenic mark of alteration and placed them under Inceptisols soil order and subsequently Ustepts as sub-order. No secondary diagnostic pedogenic characteristics made them suitable to qualify under Haplusteptsin the Great group. The vertic characteristics like cracks, wedge-shaped structure, and ped faces were accommodated by placing the soils of pedon 4 into VerticHaplustepts sub-groups of Inceptisol soil order. Presuming hyperthermic soil temperature regime and smectites mineralogy, the soils were classified as a fine smectitichyperthermic family of VerticHaplustepts.Soils of pedon 5 were observed in Ap-Bw-Bss sequence were keyed out in Vertisols accounting cracks, pressure faces, slickensides, and clay content of more than 35%. Ustic soil moisture regime took the Vertisols into Usterts at the sub-order level. Calcic horizon defined based on authigenic lime which was 5% or more by volume from the underlying horizon, was considered as the secondary diagnostic horizon. Given to calcic horizon, these were placed under Calciusterts great group. Since the exchangeable sodium percentage was more than 15%, therefore Calciusterts were classified into the SodicCalciusterts sub-group. The soils also have ECe of 4 or more in the diagnostic Bss horizon, however, did not qualify for salic horizon, therefore exchangeable sodium percentage was given precedence over ECe. Given the hyperthermic soil temperature regime and smectites mineralogy, the soils of pedon 5 were classified as Fine, smectitichyperthermic family of SodicCalciusterts.

Soils of pedon 6 of Rahuri tehsils that were covered under the Ap-Bw-Bss-Bc sequence. These were separated on account of cracks, pressure faces, slickensides, and clay content of more than 30% at the order level, consequently, these were placed in Vertisol soil order. Owing to the Ustic soil moisture regime, Vertisols were placed into the Usterts sub-order. Therefore,Usterts were classified into the Calciusterts Great group. Further, ESP of more than 15% was the key property for qualifying Calciusterts into the SodicCalciusterts sub-group. Exchangeablesodium percentage was given preference over ECe for classification. Assuming, hyperthermic soil temperature regime and smectites mineralogy, the soils of pedon 6 were classified as fine, smectitichyperthermicfamily of

SodicCalciusterts. Based on the extensive stratification, the soils of pedon7, were classified as a fine loamy, mixed hyperthermic family of Typic Ustifluvents.

4. Conclusions

Seven soil profiles representing landforms of summit, escarpment, lower pediment, undulating land, plains and valley in a toposequence were studied, sampled and characterized in Rahuri tehsil of Ahmednagar district, Maharashtra. The soil characteristics were found to follow the landscape and toposequence. The soils were observedvery shallow, severely eroded, brownish, gravelly clay loam on the summit and very shallow yellowish-brown severely eroded and very shallow yellowish-brown moderately eroded soils on escarpment. Shallow brownish clay loam and shallow dark greyish brown clay loam soils of summit and lower pediment were covered lower pediments. Deep to very deep clayey cracking soils and deep to very deep clayey saline-sodic cracking soils of undulating land were grouped at undulating lands. Deep to very deep, imperfectly drain saline-sodic clayey cracking soils and deep to very deep, moderately well drained saline-sodic clayey cracking soils of undulating land were mapped at plains and valley. The clay content showed an increasing trend down the toposequence as well as down the profile in a particular pedon. The properties related to the clay content such as base saturation, CEC and exchangeable base showed the same trend. The soil organic carbon increased topographically and varied from the summits to plain and valley. Soil organic carbon content in the plain and valley was significantly different from others. The soils of Rahuri tehsil were classified in Inceptisols, Entisols, and Vertisols soil orders. Inceptisols engaged the highest area in Rahuritehsil,the soils from the summit with shallow to very shallow and no development of diagnostic horizon were noticed and classified them under Entisols.However, the soils representing the lower pediments were classified as Inceptisols owing to having no argillic or kandic horizons, whereas, changes in soil colour, structure and irregular distribution of soil particle size were observed and Vertisols occupied the lowest area with the presence of slickensides close enough to intersect in the sub horizons.

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