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Characterization of soils of Jagdalpur in a topo-sequence

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Abstract
A study was conducted on the soils of Jagdalpur in a topo-sequence in order to characterize and classify them. The investigation revealed that the soils of the study area belong to Alfisols. The soils on subdued hills were very shallow and moderately deep on side slopes. These were well drained, gravely clay loam on the surface to clay loam in the sub-surface with redder hue (2.5YR 6/4) on summit and on the side slopes, and soils were grayer in colour together with yellower hue in the sub-surface. The soils were moderately deep to very deep well drained, with redder hue on undulating land to grey colour in the upper valley together with sandy clay loam to clay loam in texture and medium moderate sub-angular blocky structured. Soils were slightly acidic to moderately acidic soil reaction increased down the profile. CEC of surface horizon was 6.8 and 11.9 cmol (P+) kg^{-1} on the summit and the side slopes and almost comparable between 9 to 10 cmol (P+) kg^{-1} at undulating upland, and upper valley.

Keywords: Characterization, Jagdalpur, topo-sequence

Introduction
Land is a finite and one of the prime natural resources of a country for agriculture and all other developmental activities. Land use change, including land conversion from one type to another and land cover modification through land use management has greatly alter a large proportion of the earth land surface to satisfy mankind's immediate demand for natural resources (Meyer and Turner, 1992). Further, Global warming resulting from green house effect has threatened the sustainability of natural resources and agriculture in many regions over the earth's surface. Agricultural production systems in different regions are highly vulnerable to changes in climate, soil and topography.

Chhattisgarh state has very diverse landforms, soil mineralogy and sociality and divided into three agro-climatic zones namely, Chhattisgarh plains, Bastar plateau and Northern hills, 45.8% area of the state is covered under forest and remaining 54% under agriculture. The problem of resource poor tribal farmers and the unabated degrading resources in Bastar district of Chhattisgarh is more precarious. The disadvantaged area with lateritic acidic soils, undulated topography is very prone to soil erosion and other kinds of associated soil degradations. Surprisingly fortunate in its water resources, Bastar region receives high rainfall associated with rapid runoff due to the undulating terrain. The economic condition of tribal farmers is very poor, in general and most of them are small farmers with fragmented land holdings coupled with ignorant about technical know-how of modern agriculture and proper land use planning. Rice is the major crop and is commonly grown in all land situations (landforms). Irrigation facilities are negligible (about 20% of the cultivated area) hence; mono-cropping "rice-fallow" is prevalent.

To maintain the present level of soil productivity and to prevent soil/ land degradation, management of soil resources on scientific principles is essential which requires precise and comprehensive information on land resources. Therefore, in recent years increasing attention is laid on characterization of soils, correct mapping of different kinds of soils and developing rational and scientific criteria for land evaluation and interpretation of soils for multifarious land uses.

Therefore, the detailed knowledge on soil resources, their spatial distribution, physical and chemical properties and limitations/capabilities is pre requisite for any agricultural land use planning. Keeping the above facts in the background and for developing capsules of sustainable agriculture in Chhattisgarh state on watershed scale, soils in a toposequence was studied to characterize it.

Material and Methods

Study area

Study area covers a part of Dandakaranya region of Eastern Ghats hill range. We attempted to concentrate our study at the Bastar plateaus which is dominated by socially and economically backward tribal population, and most of them are small farmers with fragmented land holdings. A Watershed Goriyabahar Nala in Jagdalpur block, Bastar district of Chhattisgarh state lies between 18º 55′ 17.54″ to 19º 06′ 2.82″ N latitude and 81º 57′ 41.32″ to 82º 07′ 18.67″ E longitude represent most of the geomorphic units of Dandakaranya upland is sampled for characterizing the natural resource (Fig.1).

Soil survey and soil site characterization

Four profiles in a toposequence were studied (Figure 2). Profiles of size 1.5m x 1.0 m with depth of 1.5 m or up to murum layer were dug and examined for various morphological properties as suggested in the USDA Soil Survey Manual (Soil Survey Staff, 1998) [11]. Various site and soil characteristics like slope, stoniness, erosion, colour, texture, structure *etc*. were recorded in standard format. Soils were classified according to Keys to Soil Taxonomy (Soil Survey Staff, 2003) [9].

Nearly 2.0 kg of representative soil samples from each horizon of all the representative profiles were collected in cloth bags and properly labeled for the laboratory analysis. Some soil clods from the each soil horizon were also collected for the determination of bulk density.

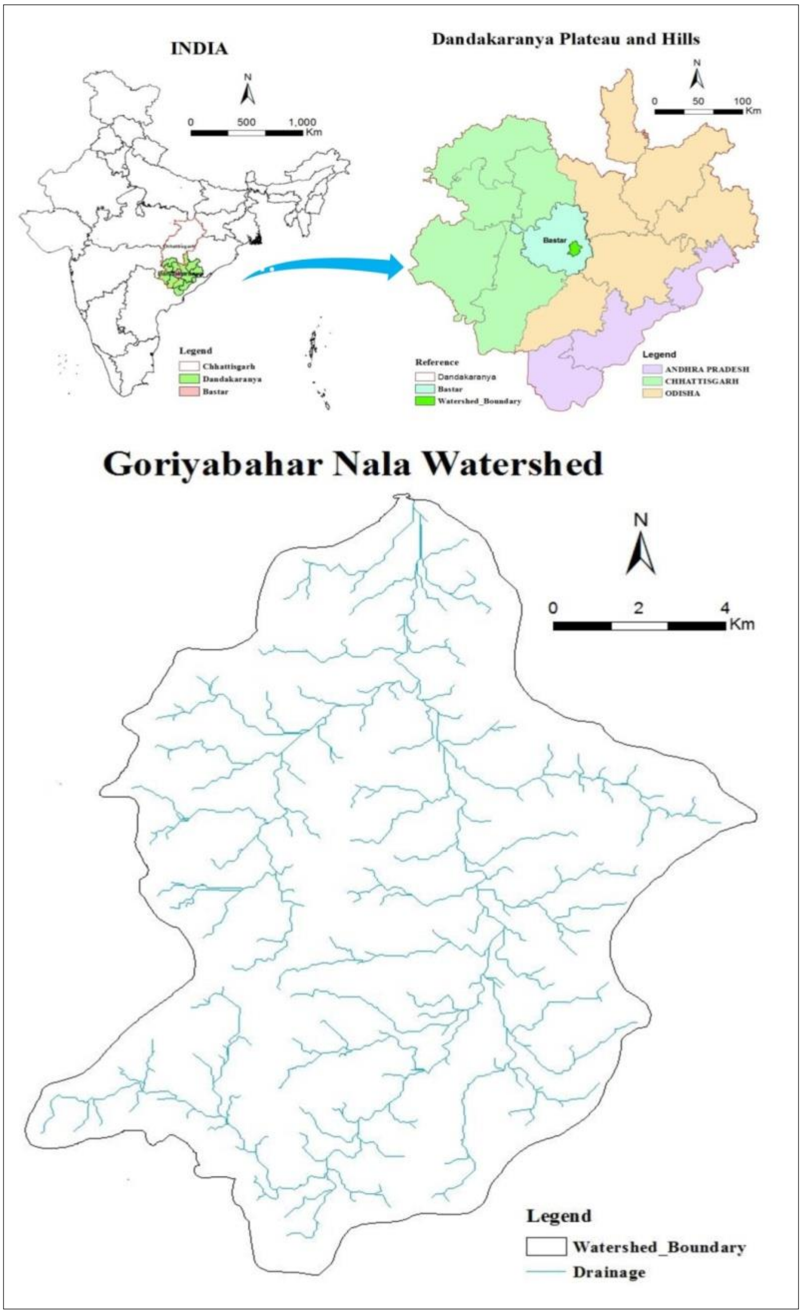

Fig 1: Location of the study area

Fig 2: The toposequence and the soil profile locations.

Morphological characterization of soil profiles

The soil profiles were examined in the field for morphological characteristics of as per the procedure given in USDA Soil Survey Manual (Soil Survey Staff, 1998) [11]. Morphological characteristics of each of the horizons like depth, colour, texture, volume of gravel, structure, consistence, calcareousness, roots, pores, *etc*. were recorded. Additional information about coarse fragment content in soil expressed on volume basis (%) *etc*. was also noted.

Physical characterization of soil profiles

The bulk soil samples collected from the soil horizons of the soil profiles were allowed to dry in the air and then prepared for the physical and chemical analysis in the laboratory. A wooden mortar and pestle was used to crush soil aggregates to pass a 2 mm sieve. Soil material passing through the sieve was placed in labeled boxes. The bulk density was determined by clod coating method (Black *et al*. 1965) [1]. Air dried clods collected from soil profiles were weighed and their bulk volume was determined by water displacement by clod coated with melted paraffin wax. The bulk density (Mg m^{-3}) was expressed on oven dry basis. Particle size distribution was determined as per the international pipette method. Soil was initially treated with H_2O_2 (30%) for the removal of organic matter and further treated with HCl (1N) to remove $CaCO_3$ using sodium hexametaphosphate as dispersing agent. Sand (2.0-0.05 mm), silt (0.05-0.002 mm) and, clay (< 0.002mm) were separated using the procedure described by Jackson (1967) [3]. The textural class was determined using the USDA textural triangle as given in Soil Survey Manual (Soil Survey Division Staff, 2000, Kumar et al., 2018).

Chemical characterization of soil profiles

Soil pH was determined in soil suspension (1:2.5 soil: water) by a glass electrode pH meter after equilibrating soil with water for 30 minutes with occasional stirring as per the method given by Jackson (1958). The supernatant liquid of soil water suspension (1:2.5) prepared for measuring pH was also used for measuring electrical conductivity. It was measured by conductivity bridge (Jackson 1973). Organic carbon was determined by wet oxidation (rapid titration) method (Walkley and Black, 1934). Ground soil sample passed through a 0.5 mm sieve were used for estimating organic carbon. Soil samples were oxidized by potassium dichromate (1 N) and the conc. H_2SO_4 was used to generate the heat of dilution. The amount of dichromate unutilized was determined by back titration with standard ferrous ammonium sulphate solution (0.5 N). The calcium carbonate was determined by rapid titration method (Piper 1966). The soil was treated with a known volume of 0.5N HCl to neutralize all the carbonates and the unutilized (excess) HCl acid was back titrated with standard NaOH solution of 0.25N using phenolphthalein as an indicator. CEC (cmol (p+) kg^{-1}) of soil was determined by saturating the soil with 1N sodium acetate (pH 8.2 for calcareous soil and pH 7.0 for non- calcareous soil). Excess sodium acetate was removed by washing with 95% methanol till supernatant has an EC of 40- 55 umhos/cm. The adsorbed sodium ions was then replaced and extracted by washing with 1N ammonium acetate (pH 7.0) solution and the leachate was made upto known volume. Na^+ present in the leachate was determined with a flame photometer and CEC was calculated (Jackson 1967). Exchangeable calcium and magnesium were determined by using 1NKCl Triethanolamine buffer solution (pH 8.2) and titrating the leachate with standard EDTA solution using murroxide and EBT as an indicator (Jackson 1967). Exchangeable sodium and potassium were determined by leaching the soil with 1*N* ammonium acetate (pH 7) solution. Na^+ and K^+ from the leachate were estimated by using flame emission spectrophotometer (Jackson, 1967). Base saturation was calculated (Black *et al*, 1965) [1] as sum of exchangeable cations- $Ca^{++,}$ Mg^{++}, Na^+, and K^+(cmol (p+) kg^{-1}) divided by CEC (cmol (p+) kg^{-1}) and multiplied by 100.

Results and Discussion

Morphological characteristics of soils

The soil depths

It is apparent from the data presented in table-1 that the soils on the subdued hills were very shallow and gradually became deeper down the slope, shallow to moderately shallow on the undulating lands. Further down the slope in the upper valley, soil depth was moderately deep. It is obvious to understand that very shallow soils on the summit part of subdued hills due to thin forest cover and excessive runoff leading to severe erosion. Further rolling materials would have deposited on the side slopes and foot slopes giving the impressions of moderately deep soils. Other soils from undulating upland to valley were noted as perceived from soil-landform relationship. Typifying pedons are shown in fig. 3.

Soil colour

Soils were noted with redder hue on the subdued hills and greyer hue on the foot slopes with yellower hue in the sub-surface. Further down the slopes, soils had redder hue on the undulating upland and became greyer hue in the valleys Excessive drainage and oxidative environment on the hills and on the uplands could be the reason for oxidation of iron and its oxide, imparting redder hue, whereas reductive environment in the valleys would have been the reason for greyer hues.

Table 1: Ranged morphological characteristics of soils at various landform units

Landform	Horizon	Thickness	Matrix colour	Texture	Structure	Nodule Conir (S,Q)
Subdued Hills	Ap	0-13 (13.0)	10YR4/3d	g-cl	m2sbk	f-m, f
	Bt	13-33 (20.0)	10YR4/3d	g-c	m2sbk	f, c
	BC	33-68 (35.0)	5YR4/4d	g-c	m2sbk	f, f
Undulating uplands	Ap	12-19 (15.8)	5YR4/6d	scl, l, cl	m2sbk	f-m, f
	Bw	17-30 (20.8)	5YR3/4d	c	m2sbk	f, f
	Bt	18-35 (24.0)	2.5YR3/6d	c	m2sbk	f,f
	BC	40-54 (46.8)	2.5YR3/6d	c	m2sbk	f, f
Undulating lowlands	Ap	13-15 (14.0)	10YR5/3d	scl, cl	m2sbk	f, f
	Bw	12-15 (13.5)	10YR5/4d	cl, c	m2sbk	f, c
	Bt	12-39 (25.5)	10YR5/4d	c	m2sbk	f, m
	BC	34-47 (40.5)	7.5YR4/4d	c	m2sbk	f, m
Upper valley	Ap	14-22 (18.0)	10YR5/4d	cl, c	m2sbk	f, f
	Bw	21-30 (26.25)	10YR4/6m	c	m2sbk	f-c, c
	Bt1	17-26 (21.75)	10YR5/2m	c	m2sbk	f-m, f
	Bt2	20-28 (23.25)	10YR5/2m	c	m2sbk	f-m, f
	BC	30-61 (48.25)	10YR5/1m	cl, c, sic	m2sbk	f-m, f

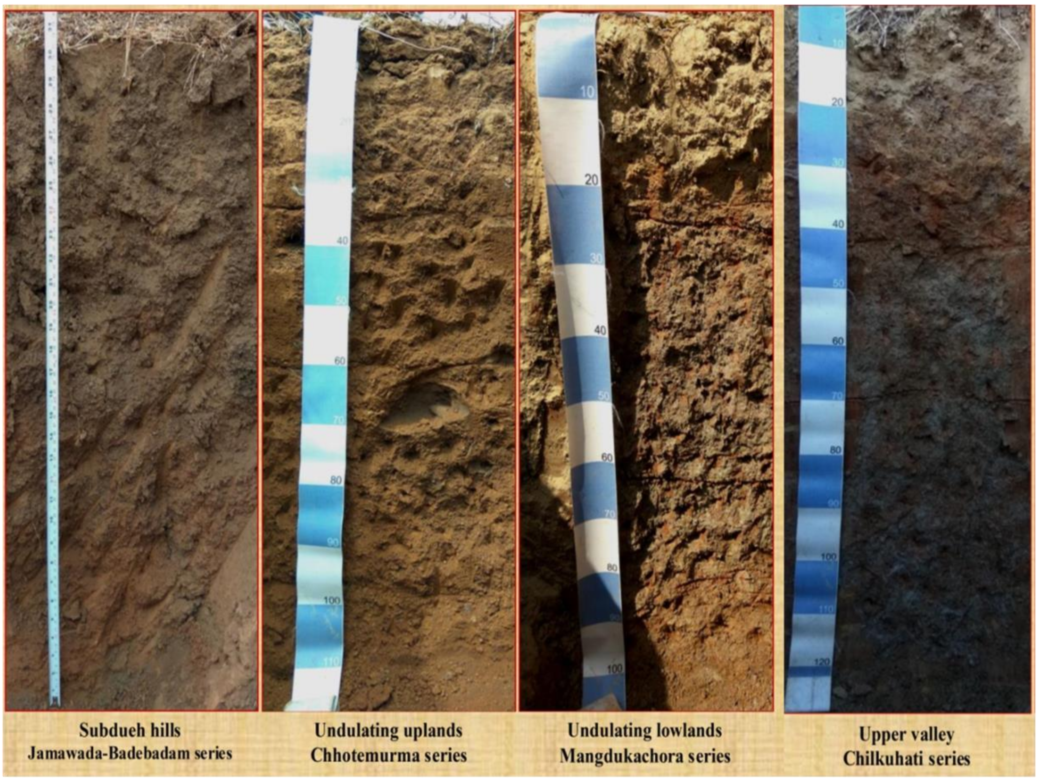

Fig 3: Profile pictures for the toposeuence

Soil texture

A close examination of data presented in table-2 that surface soil texture was gravelly clay loam on the subdued hills and on the associated side and foot slopes. Further down the slope, sandy clay loam to clay loam texture was noted on the uplands and further moving in the valley, soil texture was noted clay loam. The variation in the soil texture from subdued hills to alluvial plains could be explained on the basis established soil-landform relationship illustrating coarser soils on the high slopes and finer in the valleys and alluvial plains. In the sub-surface, texture was uniformly clayey except gravelly clays on the subdued hills, perhaps matching with the kind and nature of parent material utilized for the development of landscape.

Soil structure

Medium, moderate sub-angular blocky structure was prominently appeared on the undulating uplands, lowlands and upper valley both at the surface and in the sub-surface.

Diagnostic Horizons

Elluvial and illuvial horizons (Bt) were prominently marked in the soils of undulating upland and the upper valley. Mean thickness of argillic horizon was 24 cm in the soils of undulating upland and 47 cm thick in the upper valley. The prominent presence of argilic horizons in these soils might have been related to the contrasting wetting and drying cycle.
Mean thickness of cambic horizon was 20.8 cm in the soils of undulating upland, and 26 cm in the soils of upper valley. This could be seen as thickness of argillic horizon increased, there was decreased in the mean thickness of cambic horizons. This leads to infer that cambic horizon was developed initially and a part of it converted into argillic horizons with the progress of Pedogenesis.

Physical properties of soils

The physical properties of different profiles are presented in figure 4 and discussed in following sections.

Particle size distribution

Clay content at the surface (Ap horizon) was around 32% each at the undulating upland in the watershed and increased topographically down the slope by 39% each in upper valley. In Bw horizon, 46% clay content was noted in undulating upland; increased to 54 % in upper valley. In Bt horizon, clay content was 46% on the side slope further increased to 49 % in undulating upland. Clay content in the upper valley was almost parallel to the undulating low land. In BC horizons, clay content was 54 on the side slope, 55% each in undulating upland and low land. In the upper valley, the corresponding clay content was 60. The trend of higher clay content in BC horizons than others revealed that this was the actual weathering front largely influenced by the topography. However increased clays in Bt horizons from side slopes of hills to upper valley suggested that in the contrasting situation of wet and dry period, clays were moved from upper to the lower horizons.

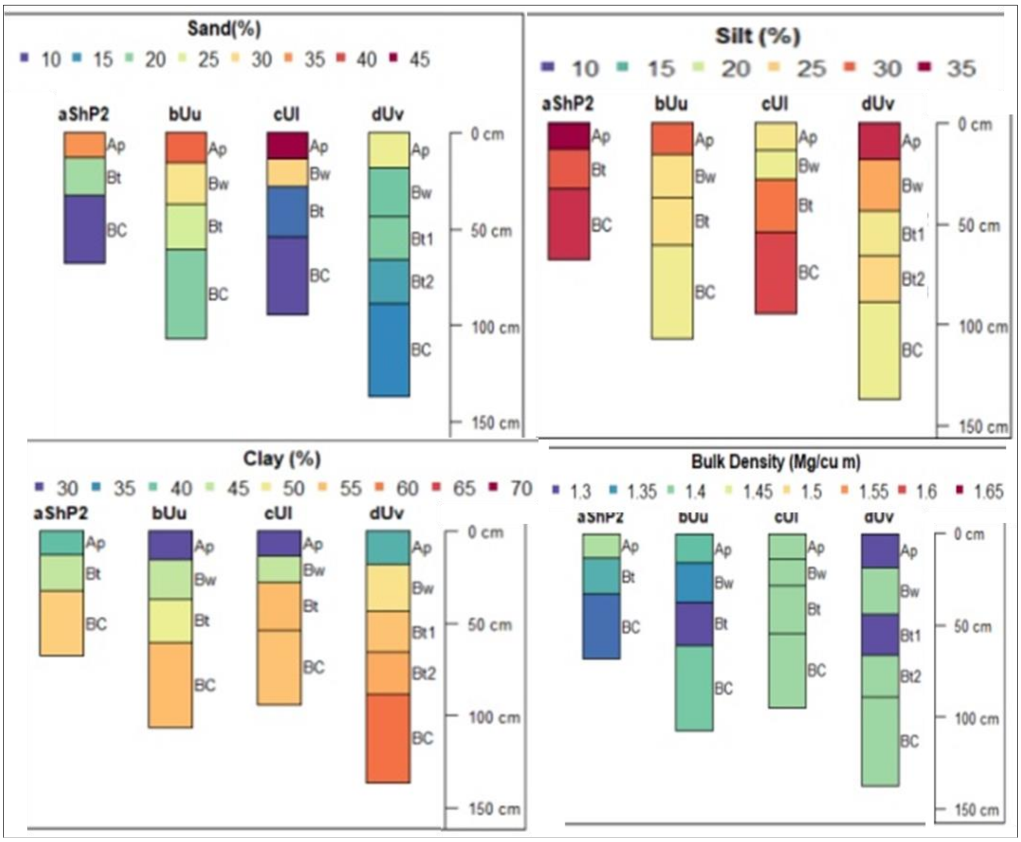

Fig 4: Physical properties of soils

In Ap horizons, silt content was 34% at the summit as well as on the side slopes, decreased to 29 and 23% at undulating upland and low land, respectively and was noted uniformly 32 % at the surface in the soils of upper valley. In Bw horizons, silt content was fairly uniform. No specific trend of sand distribution among the soils is associated with the landscape in the watershed. Thus dealing with the data of sand and silt content, particularly with the uniform pattern of distribution, this could be said that finer particles was affected with the weathering process operating on the landscape under the influence of varying soil-moisture conditions. The results are in agreement with findings reported by Murthy (1988) [6]; Maji *et al.*, (2005) [5] and Nasre *et al.*, (2013) [7].

Bulk density of the soil an index of workability of soil, soil moisture availability, aeration and root penetration. Bulk density at the surface was fairly uniform varying 1.3 to 1.4 Mg m^{-3} from the side slopes of subdued hills to the upper valley and touched to the mark of 1.5 at the subdued hills. In Bt horizons of course bulk density was uniform about 1.3 to 1.4 Mg m^{-3}.

Chemical properties

Soil reaction (pH)

In the light of data presented in fig. 5, it is noted that pH was uniformly below 5.5 in Ap horizons at the summit, side slope, undulating upland and low land, whereas it became 5.6 in the corresponding horizon of upper valley. In Bw horizons pH increased from the overlying Ap horizons, it was 5.8 in undulating upland, 5.5 in undulating low land, 6.0 in the upper valley. In Bt horizon, values were 5.5 on the side slope, 5.9 and 5.7 on the undulating upland and low land. pH in Bt horizon for upper valley was 6.3. pH in BC horizons was the higher than the overlying horizons. Values were 5.9 and 6.2 at the undulating upland and low land. It further increased in the narrow valley to 6.5.

Organic carbon (%)

In the soils of watersheds, Ap horizon was richer than Bw, Bt and BC horizons. On the summit and side slope of subdued hills, organic carbon was 0.64 and 0.86%, respectively. The content of soil organic carbon at the undulating upland, low land and upper valley was 0.8, 0.9 and 0.8 %, respectively. In Bt horizons, soil organic carbon was 0.47% at the side slope, decreased to 0.29 and 0.30 % in undulating upland and low land. SOC was 0.30% in Bt horizon associated with upper valley. Organic carbon in BC horizons was further decreased. It was 0.32 at the side slopes; 0.23 and 0.20 at undulating upland and low land, respectively. Thus the distribution of soil organic carbon revealed that soil organic carbon was higher on the elevated topography and decreased down the slopes with the change of land use from forest to agriculture. Decreasing SOC down the depth was related to the recycling and organic input which was higher on the surface than sub-surface.

Cation exchange capacity (CEC)

CEC was 6.8 and 11.9 cmol (P+) kg^{-1} on the summit and the side slopes and almost comparable between 9 to 10 cmol (P+) kg^{-1} at undulating upland and upper valley. In Bw horizons, CEC was noted 11.4 and 10.3 cmol (P+) kg^{-1} at the undulating upland and low land further increased 15.3 at upper ow valley. The trend was by and large similar in BC horizons. Data suggested that process of ferrilization was proceeded rapidly at the elevated topography, whereas the process of silication adding silica into the system imparting higher CEC at the lower topography. Increased CEC in Bw horizons indicated that ferrilization was dominant on the surface whereas it was not that much effective in Bw horizons. Taking note further, trend for the distribution of CEC was inconsistent indicating differential pace of eluviation and illuviation process in response to varying micro-topographical conditions. Over all, lower cation exchange capacity was indicative of dominance of Kaolinite type of clay minerals together with the oxides of iron.

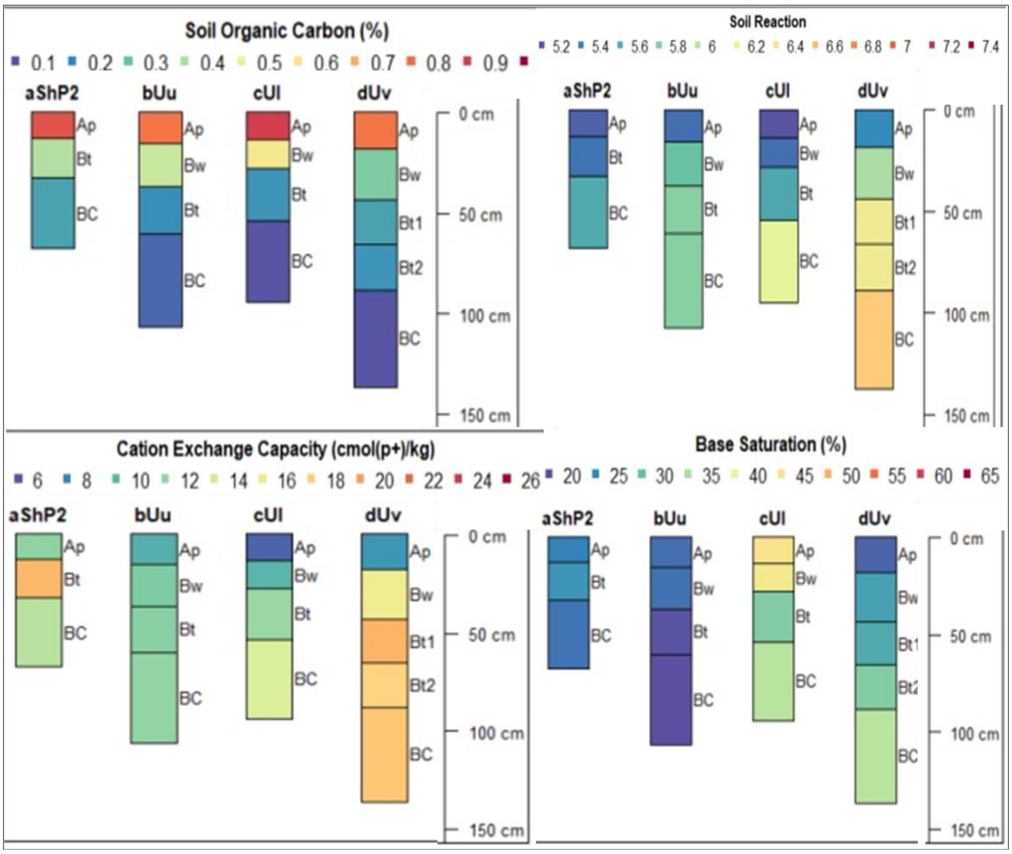

Fig 5: Chemical properties of the soils.

Conclusion

The soils on subdued hills were very shallow and moderately deep on side slopes. These were well drained, gravely clay loam on the surface to clay loam in the sub-surface with redder hue (2.5YR 6/4) on summit and on the side slopes, soils were grayer in colour together with yellower hue in the sub-surface. The soils were moderately deep to very deep well drained, with redder hue on undulating land to grey colour in the upper valley together with sandy clay loam to clay loam in texture and medium moderate sub-angular blocky structured. Soils were slightly acidic to moderately acidic soil reaction (pH 5.2 to 6.4) increased down the profile. CEC of surface horizon was 6.8 and 11.9 cmol (P+) kg^{-1} on the summit and the side slopes and almost comparable between 9 to 10 cmol (P+) kg^{-1} at undulating upland, and upper valley. The soils were classified as Typic Haplustalf.

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