



P-ISSN: 2349-8528

E-ISSN: 2321-4902

IJCS 2020; 8(1): 1008-1013

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Received: 19-11-2019

Accepted: 23-12-2019

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Characterization and classification of soils of Bemetara under rice and soybean based cropping systems

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DOI: <https://doi.org/10.22271/chemi.2020.v8.i1m.8378>

Abstract

A study was conducted on the soils under rice and soybean based cropping systems in Bemetara block of Bemetara District, Chhattisgarh in order to characterize and classify them. The investigation revealed that the rice growing soils were very deep, dark grayish in color (10 YR 3/2) and clayey in texture throughout the depth, with presence of slickensides in the sub-surface layers. During the summers, the soils exhibited wide spread cracks on the surface, extending to the surface of the slickensides. Periodic opening and closing of cracks, clay content more than 30% rich in smectites and the presence of slickensides thicker than 25 cm in these soils qualify them to Vertisols. In absence of slickensides and wedge shaped soil structure in the sub-surface and clay content less than 35% below the surface, the soybean growing soils could not qualify for Vertisols and placed in the other soil order, Inceptisols.

Keywords: Characterization, classification, soybean based, cropping systems

Introduction

Agriculture is the main occupation of nearly 75% of the population of the Chhattisgarh. Chhattisgarh is known as rice bowl of India. Chhattisgarh produces 7.98 million tonnes rice from 4.03 mha area with 1978 kg ha⁻¹ productivity. Bemetara district in Chhattisgarh is one of the premier districts known for producing rice and soybean. Rainfed agriculture is common with traditional practice in the district. Productivity of the district for paddy (17.08 q/ha), soybean (5.51 q/ha) and wheat crop (9.92 q/ha) are very low in comparison of the national productivity 23.91, 9.51 and 27.50 q/ha for rice, soybean and wheat crop, respectively (Agricultural Statistics, 2015) [1]. Degradation of the land resources is one of the major problems for raising the productivity. Blanket recommendation and uniform land use without considering the potentiality and problem of land resources are the major causes of low productivity and land degradation in the district.

There is urgent need to increase the production and the productivity of rice and soybean to feed the rising population and associated need for increased agricultural production, there is great necessity for improving management and sustainable utilization of the land resources specially the soils and water. Land evaluation is a prerequisite to achieve optimum utilization of available land for agricultural production in a sustainable manner. The detailed spatial information on land resources is essential for land evaluation (Burrough, 1989; Maji *et al.*, 2001, 2002; Reddy *et al.*, 2001, 2015) [5, 11, 12, 16] for following various approaches and methodologies developed (Storie, 1954; Ricquier *et al.*, 1970; FAO, 1976) [6, 17].

For successful execution of land evaluation programme, a comprehensive knowledge of soils with respect to their characteristics, classification, location, extent and distribution, potentials and problems is prerequisite (Thilagam and Sivasamy, 2013). Systematic study of morphology and taxonomy of soils provides information on nature and type of soils, their constraints, potentials, capabilities and their suitability for various uses.

The present investigation aims to evaluate the, soil and site characteristics to determine the degree of suitability for paddy and soybean in Bemetara block in Bemetara district of Chhattisgarh which has 1027 mm annual average rainfall and comes under the Agro Ecological Region (ICAR)-10 [J6C4(3)]

and described as hot sub-humid agro-eco region with moderately deep black soils (inclusion of red soils) and LGP 150-180 days. The agro-ecoregion covers eastern plateau of Satpura, Mahanadi basin and fringes of Maharashtra plateau and covers 15.2 mha areas (4.6% of the TGA) in Chhattisgarh, Madhya Pradesh and Maharashtra (NBSS&LUP, 1995) [13]. The region is the house of 38.39 million people and 17.50 m livestock (Indian livestock Census, 2012). Farmers of the region are resource poor. The Similar kind of study has been taken elsewhere in the country (Bobade *et al.*, 2010; Sharma *et al.*, 2011; Selvaraj and Naidu, 2013; Saroj *et al.*, 2014; Yadav and Hooda, 2014) [4, 18, 19].

However, such kind of study is yet to be attempted in this part of the state. Therefore the present investigation was carried out in some part of Bemetara tehsil of Bemetara district, Chhattisgarh to evaluate the soils for paddy and soybean based cropping system.

Methods and Materials

Location

Bemetara block belongs to Bemetara district of Chhattisgarh and is located in the centre of Mahanadi basin. Geographically, it is located between 21° 58' to 22° 00' N latitude and 81° 28' to 81° 32' E, covering an area of 2841.65 ha (Fig 3.1-1). The study area is part of the Mahanadi Basin which is the 8th largest basin in the country with a catchment area of 139681.51 sq. km between 80° 30' to 86° 50' E longitude and 19° 21' to 23° 35' N latitude covering the states

of Chhattisgarh and Odisha and comparatively smaller spread in Jharkhand, Maharashtra and Madhya Pradesh. In the state of Chhattisgarh, Mahanadi basin is associated with Baghelkhand plateau, Chotanagpur plateau, Dandakaranya, which all are the constituents of eastern plateau (Singh *et al.* 2016). Thus the study area was classified as the part of eastern plateau (E) at the physiographic level. Further the study area was classified as the part of Mahanadi basin at sub-physiographic level (Em). It has been taken down as a part of sedimentary deposits (EmS_d) at the level of broad landforms. EmS_d was further classified into upland and flood plains. The first landform represents the basalt flow and its aggregation, whereas flood plains represent the junction of basalt and purana sedimentary basin of Chhattisgarh. Srivastava *et al.* (2016) also reported basaltic flow and its aggregation in the part of Chhattisgarh state.

Climate

The study area comes under the Agro-Climatic Zone -7, Eastern Plateau and Hills Region (Planning Commission) and represents Agro Ecological Region (ICAR) – 10 [J6C4(3)]: Hot sub-humid agro-eco region with moderately deep black soils (inclusion of red soils) and LGP 150-180 days. The climate of the area is tropical, sub-humid with well-expressed summer (April to May), monsoon season (June to September), post-monsoon season (October to December) and winter season (January to March).

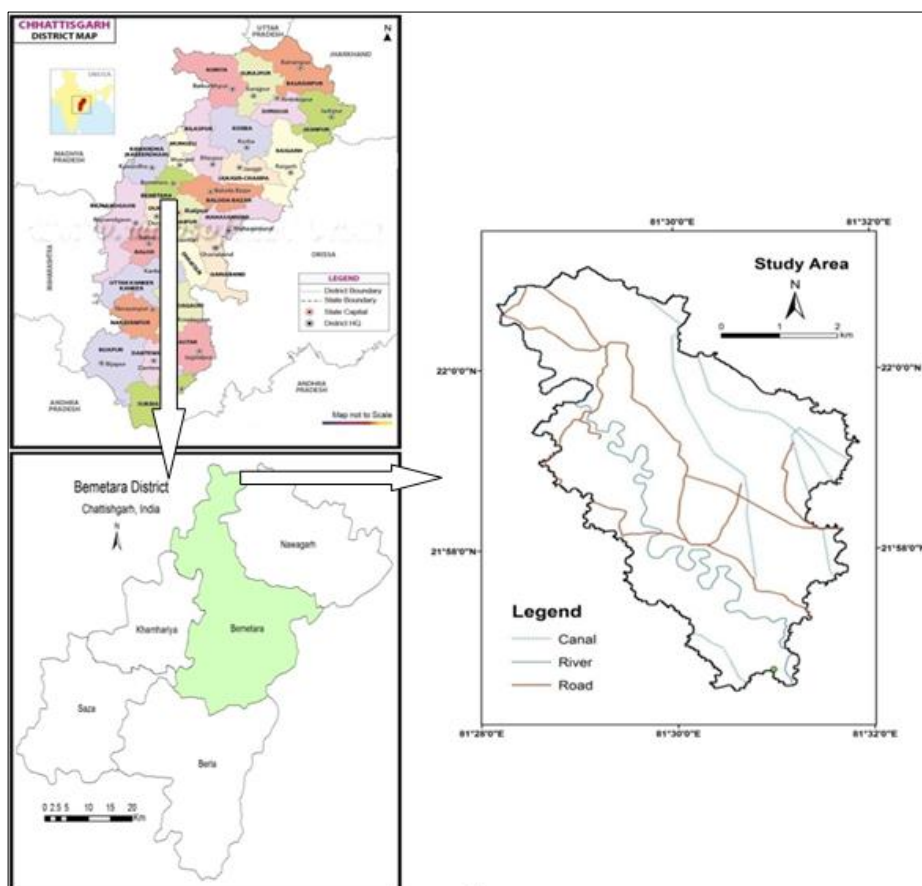


Fig 1: Study area location

The study area receives rainfall mainly from south-west monsoon. It sets in third/fourth week of June and continues till mid-August/September with heaviest showers in the months of July and August and nearly 95% of the annual rainfall is received during this period. The average annual

rainfall for the study area is around 1076.9 mm (District Survey Report, Bemetara, 2016). Monthly rainfall data (mm) of Bemetara district during 2012 -2016 was given in the table-3.1.3.

Soil survey and soil site characterization

To understand the soil variability in the study area, representative soil profiles were studied. Based on the interpretation of satellite data, landform, and cropping systems adopted in the area, representative 16 soil profiles were selected for the study. 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) [24]. Special observations regarding the depth and width of cracking and also the extent of slickensides were also recorded. 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) [25].

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.

Morphological characterization of soil profiles

The soil profiles were examined in the field for morphological characteristics of as per the procedure given in IARI Manual (1971) and USDA Soil Survey Manual (Soil Survey Staff, 1998) ^c. 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 pressure faces/slickenside, depth and width of cracks, 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) [3]. 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 ($< 0.002\text{mm}$) were separated using the procedure described by Jackson (1967) [8]. 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) [11].

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) [7]. 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) [9]. Organic carbon was determined by wet oxidation (rapid titration) method (Walkley and Black, 1934) [28]. 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 $\mu\text{mhos/cm}$. 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) [8]. Exchangeable calcium and magnesium were determined by using 1NKCl Triethanolamine buffer solution (pH 8.2) and titrating the leachate with standard EDTA solution using murexide and EBT as an indicator (Jackson 1967) [8]. Exchangeable sodium and potassium were determined by leaching the soil with 1N ammonium acetate (pH 7) solution. Na^+ and K^+ from the leachate were estimated by using flame emission spectrophotometer (Jackson, 1967) [8]. Base saturation was calculated (Black *et al.*, 1965) [3] 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

The present study was carried out on soils used for paddy and soybean- based cropping system with the objectives to characterize and evaluate the soils. A total of 16 soil profiles were studied based on the landforms. The profile locations are depicted in the figure 2. After systematic study (Soil Survey Division Staff 2000) of soils' range of characteristics typifying pedons were studied and classified (Soil Survey Staff, 2014). Soil series was tentatively established. Here in the text soils are described cropping system form wise for easy and lucid presentation.

Morphological and physical properties

All the pedons were deep to very deep with mean thickness of surface horizon varied from 14 cm to 18 cm. out of 16 soil profiles studied, 13 exhibited dark grayish colour (10 YR3/2) throughout the soil profile and resemble to the color pattern known for deep black cracking soils derived from basalt and basaltic alluvium due to the chelation effect of organic matter on the surface of smectite type of clay minerals (Kumar *et al.*, 2019). Soil texture was clayey throughout the soil profile. It moves the texture known from deep cracking black soils of India and elsewhere. Well developed slickensides tilting an angle of 20 to 60°C were prominently seen. The slickensides were breaking to medium moderate to strong angular blocky soil structure. Consistency was friable (moist), very sticky and very plastic (wet) at the surface and firm (moist) very sticky and very plastic (wet) in the sub surface. During the summers, the soils exhibited wide spread cracks on the surface, extending to the surface of the slickensides. Sometimes, cracks used to bisect slickensides vertically. Three soils studied in the flood plains were similar in properties to the other soils in the surface horizons. However, the colour was slightly different and was registered with

chroma and value of 4 in 10 YR in the subsurface. The texture of soils of flood plain in subsurface was noted silty clay with clayey texture on the surface. No slickensides were observed in these soils, and structure was moderate sub-angular blocky. Stickiness and plasticity in the sub-surface horizon was comparatively of lower order than that of other soils. The cracking pattern was not that much profuse in these soils. Typifying pedons of the two kinds of soils are seen in figs 2.

Chemical properties

All the soils were found neutral in reaction. The organic carbon in the soils was medium to high with a decreasing trend with depth. Calcium carbonate was uniformly distributed in all the soils. Mean content varied from 5 to 6%. Calcium was the dominant cation in the exchange complex with slightly lower content in the three soils of flood plains. Magnesium was the next dominant cation following similar trend as in case of calcium. Sodium cations were very low. However, it was towards slightly higher side in case of the three soils of the flood plain. For the 13 high clay soils, the cation exchange was 42 to 49 C mol (p+) kg⁻¹ and increased down the depth with the corresponding figure of 54 to 57 C mol (p+)kg⁻¹ in the sub-surface. For the other three soils the mean cation exchange capacity was 38 and 40 C mol (p+)kg⁻¹ in the surface and just below the surface, respectively. The lowest value of cation exchange capacity was noted 27 to 21 in the lower part of the soil profile.

Soil correlations

A sequence of Ap, Bw and Bss horizons in the first 13 soil profiles with deep to very deep soil depth class, dark grayish uniform soil colour throughout the profile, clayey texture both at the surface and in the sub-surface and the presence of slickensides and wedge shaped soil structure breaking medium moderate angular blocky (Fig. 3) represent a group of soils. The other three soils at the flood plains with dark grayish colour for first 50 cm soils with slight variation in chroma and value of 4 than the soils of alluvial plains indicated other group of soils. The variations were also noted in sub-soil texture which was sandy clay loam to silty clay loam. The sequence of the genetic horizon was Ap-Bw- 2Bw.

Soil classification

Periodic opening and closing of cracks, clay content more than 30% rich in smectites and the presence of slickensides thicker than 25 cm in the soils of first group which resembled

to Vertisols soil order as described in soil taxonomy (Soil Survey Staff, 2014). In absence of slickensides and wedge shaped soil structure in the sub-surface and clay content less than 35% below the surface, the other group could not qualify for Vertisols and placed in the other soil order, Inceptisols. At the sub-order level based soil moisture regime soil of first and second group were classified into Ustert and Ustepts sub-order. Since these two soils did not have any other diagnostic characteristics, therefore soils of both groups were classified into Haplusterts and Haplustepts great groups in Vertisols and Inceptisols soil orders. Since Haplusterts present the central concept of Vertisol soil order therefore these were classified into Typic Haplusterts at sub-group level. The fluvial nature of soils of second group overshadowed the central concept of Inceptisols accordingly these were classified into Fluventic Haplustepts at subgroup of Inceptisol soil order at the sub-group level. At the family level, particle size class, mineralogy and soil temperature regime, the soils of vertisols series were classified into Fine, smectitic (cal.) hyperthermic family of Typic Haplusterts, whereas soils of inceptisols were classified into Fine over fine loamy, mixed hyperthermic family of Fluventic Haplustepts sub-group of Inceptisol soil order. The morphological, chemical, and physical properties of the typifying pedons of these two classes of soils are given in the table 1 and 2.

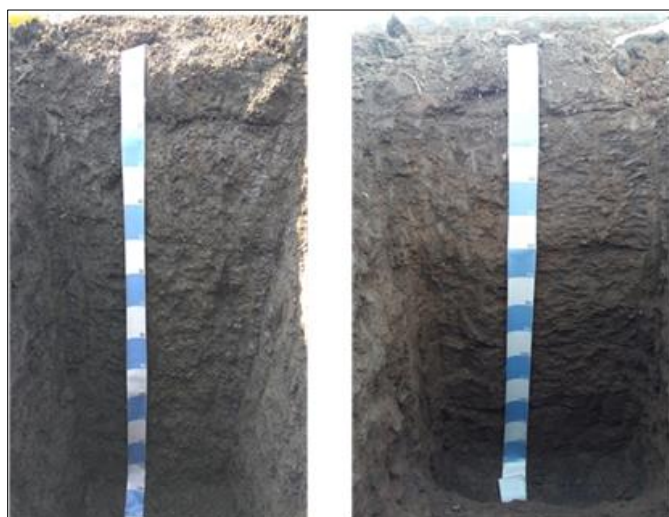


Fig 2: Soil profile pictures of the two typifying pedons, vertisol (left) and inceptisol (left)

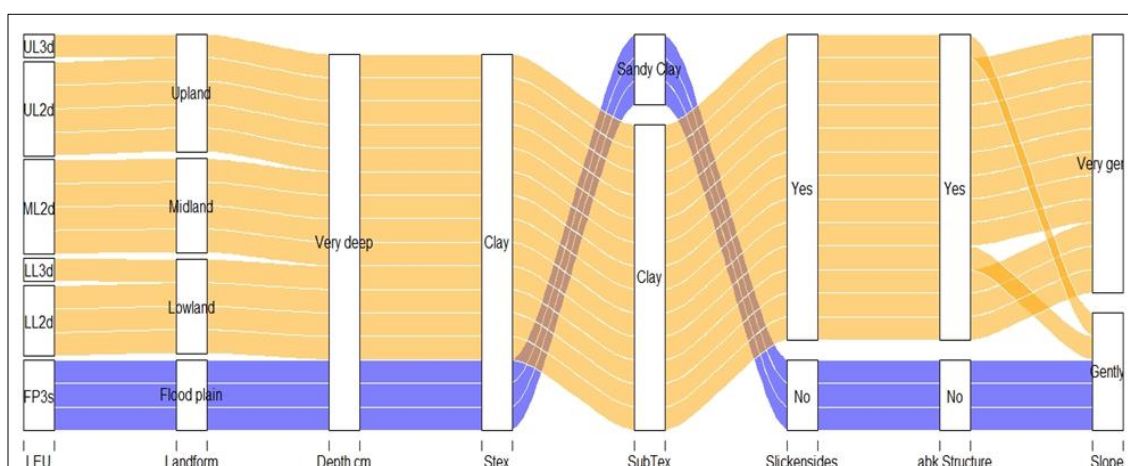


Fig 3: Alluvial diagram showing variations in important soil characteristics

Table 1: The morphological, physical and chemical characteristics of a typifying pedon of vertisol.

Pedon-04: Fine, Smectitic, Hyperthermic, Typic Haplusterts (Gently sloping Upland, Double crop)													
Morphological characteristics													
Horizon	Depth (cm)	Boundary DT	Matrix colour (m)	Texture	Coarse fragments SV%	Structure SGT	Consistence DMW	Nodule Conca SQ	Roots SQ	Effervescence	Other features-		
AP	0-14	cs	m 10YR 3/2	Clay		m 2 sbk	vh - vs vp	mc	Fm	e	-		
Bw1	14-28	cs	m 10YR 3/2	Clay		m 2 sbk	- fr vs vp	mm	Ff	e	-		
Bss1	28-40	cs	m 10YR 3/2	Clay		m 2 abk	- fr vs vp	mm	F-c f	es	ss		
Bss2	40-59	cs	m 10YR 3/3	Clay		m 2 abk	- fr vs vp	fm f	F-c vf	es	ss		
Bss3	59-109	cs	m 10YR 3/3	Clay		m 2 abk	- fr vs vp	fm f	c vf	ev	ss		
Bss4	109-150+	gs	m 10YR 3/3	Clay		m 2 abk	- fr vs vp	fm f	c vf	ev	ss		
Physical characteristics													
Horizon	Depth (cm.)	Texture			Water retention %				BD gm/cm ³				
		Sand %	Silt %	Clay %	Moisture at 1/3 bar	Moisture % at 15 bar	AWC %						
AP	0-14	30.40	26.80	42.80	33.20	15.48	17.72	1.60					
Bw1	14-28	25.80	25.40	48.80	30.22	14.61	15.62	1.59					
Bss1	28-40	23.60	26.20	50.20	30.68	15.94	14.75	1.60					
Bss2	40-59	21.00	25.40	53.60	30.38	15.00	15.38	1.64					
Bss3	59-109	17.00	27.80	55.20				1.65					
Bss4	150-109	14.80	28.60	56.60				1.64					
Chemical characteristics													
Horizon	Depth (cm.)	pH	EC mS/cm	OC %	CaCO ₃ %	Exchangeable Cations (me/100 gm soil)				Sum of cations	CEC cmoles P+/kg	% Base Saturation	ESP %
						Na	K	Ca	Mg				
AP	0-14	7.72	0.25	0.71	4.88	0.33	0.38	27.50	10.30	38.51	40.58	95.52	0.86
Bw1	14-28	8.07	0.22	0.52	5.58	0.28	0.32	28.10	9.90	38.60	44.78	87.14	0.73
Bss1	28-40	8.22	0.15	0.49	5.75	0.26	0.34	29.40	8.90	38.90	45.38	86.65	0.67
Bss2	40-59	8.29	0.2	0.43	5.83	0.2	0.3	28.60	11.40	40.50	50.98	80.35	0.49
Bss3	59-109	7.72	0.17	0.34	6.53	0.22	0.32	29.90	11.80	42.24	51.58	82.47	0.52
Bss4	150-109	8.17	0.19	0.27	6.85	0.22	0.34	27.50	12.70	40.76	52.18	78.61	0.54

Table 2: The morphological, physical and chemical characteristics of a typifying pedon of inceptisol.

Pedon-15: Fine mixed, Smectitic, Hyperthermic, Typic Haplustepts (Gently sloping Flood Plain, Double crop) CS													
Morphological characteristics													
Horizon	Depth (cm)	Boundary DT	Matrix colour (m/r)	Texture	Coarse fragments SV%	Structure SGT	Consistence DMW	Nodule Conca SQ	Roots SQ	Effervescence	Other features		
AP	0-17	cs	m 10YR 3/2	Clay	fg 1-3%	m 1 sbk	- fr sp	f-m f	f m	es	-		
Bw1	17-57	cs	m 10YR 3/2	Clay	-	m 2 sbk	- fr sp	f-c f	ff	es	-		
Bw2	57-92	cs	r 10YR 4/4	Clay loam	-	m 1 sbk	- fr vs p	ff	ff	-	-		
Bw3	92-120	cs	r 10YR 4/4	Sc	-	m1 sbk	- fr sp	--	v-f f	-	-		
Bw4	120-150+	cs	r 10YR 4/4	Sc	-	m 1sbk	- fr ss ps	--	v-f f	-	-		
Physical characteristics													
Horizon	Depth (cm.)	Texture			Water retention %				BD gm/cm ³				
		Sand %	Silt %	Clay %	Moisture at 1/3 bar	Moisture % at 15 bar	AWC %						
AP	0-17	22.20	35.80	42.00	25.34	14.39	10.95	1.58					
Bw1	17-57	21.00	34.40	44.60	24.59	13.59	10.99	1.64					
Bw2	57-92	19.20	35.60	45.20	22.78	12.51	10.27	1.65					
Bw3	92-120	40.80	38.80	20.40	16.95	8.87	8.08	1.64					
Bw4	120-150	38.00	40.40	21.60				1.66					
Chemical characteristics													
Horizon	Depth (cm.)	pH	EC mS/cm	OC %	CaC O ₃ %	Exchangeable Cations (me/100 gm soil)				Sum of cations	CEC cmoles P+/kg	% Base Saturation	ESP %
						Na	K	Ca	Mg				
AP	0-17	7.55	0.31	0.68	4.98	0.2	0.32	22.40	10.00	33.92	39.78	82.76	0.59
Bw1	17-57	7.61	0.12	0.43	5.05	0.14	0.26	23.10	9.00	32.50	40.38	80.49	0.43
Bw2	57-92	7.66	0.16	0.25	5.12	0.18	0.24	18.90	8.90	33.22	31.98	88.24	0.54
Bw3	92-120	7.72	0.14	0.21	5.36	0.14	0.2	12.80	5.10	34.24	19.58	93.16	0.41
Bw4	120-150	7.64	0.1	0.13	5.51	0.16	0.2	13.20	5.50	35.06	20.18	94.45	0.46

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