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Characterization and classification of sodic soils of the Gangetic alluvial plains at Banthra, Lucknow

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Abstract

In order to monitor morphological, physical and chemical changes that occurred during the last thirty five years of biological reclamation, five pedons belonging to sodic landscape of the Gangetic alluvial plains at Banthra (NBRI), Lucknow, were studied for their characterization and classification. Soils of pedon 1 and 2 show the presence of argillic horizon but pedon 1 soils qualified for the natric horizon but soils of pedon 2 are free from sodicity throughout the profile. Soils of pedon 3, 4 and 5 have ochric epipedon and cambic sub-surface horizons. Soils of pedon 3 are strongly alkaline throughout the profile but exhibited higher chroma at lower depth. However, soils of pedon 4 are free from sodicity in upper half (50 cm) of the profile and remain saturated for maximum period depicting low chroma at lower depths. Soils of pedon 5 have low organic matter content and higher pH showing sodic characteristics throughout the profile. These soils are classified as Typic Natrustalfs, Typic Haplustalfs, Aeric Halaquepts, Aeric Endoaquepts, Typic Halaquepts, respectively.

Additional keywords : Salt-affected soil, biological reclamation.

Introduction

Soil sodicity is one of the major problems of land degradation in irrigated area of the world. In India sodic soils are commonly found in arid and semi-arid regions largely confined to the Indo-Gangetic plains of Punjab, Haryana and Uttar Pradesh. In Uttar Pradesh alone about 1.25 m ha soils are sodic in nature and are lying barren (Abrol and Bhumbla 1971). A great deal of information on morphological, physical and chemical characteristics of such land is available in the literature (Bhargava *et al.* 1976; Tiwari et al. 1983; Yadav 1993; Ved Prakash et al. 1995). However, information is not available on the sodic soils of Banthra Research Station (BRS) of NBRI, Lucknow (Garg 1987). Thus, an attempt is made here to characterize and classify them as per 'Soil Taxonomy' in order to achieve full utilization potential for crop production and to undertake research programmes accordingly.

Materials and methods

The Banthra Research Station comprised of about 50 hectares area near village Banthra. It is situated 23 km away from National Botanical Research Institute on the Lucknow-Kanpur highway at an elevation of 129 m above M.S.L. It stretches from 26°40' to 26°45' N latitude to 80°45' to 80°53' E longitude. This Centre was established in 1956 and it covers an area of more than 50 m ha which was then a barren land bereft of any vegetation except sparse growth of some grasses and plants of *Calotropis procera*. Since then considerable efforts were made to reclaim this land for plantation with the biological measures which includes incorporation of organic matter and unwanted weeds in bulk into the soil (Khoshoo 1987). Initially paddy (*Oryza sativa*), dhaincha (*Sesbania aculeata*) followed by wheat/barley were cultivated as being the most tolerant and adaptable in such stress soil conditions. In general, five different land use systems were consistently followed during the last 35 years. These were : (i) paddy - shrubs - bulbous plants (ii) paddy - fruit trees - bulbous plants (iii) paddy - fuelwood trees - shrubs (iv) paddy - mono or mixed cropping of different trees (v) paddy - sporadic planted with eucalyptus trees - uncultivated (presently).

The meteorological parameters indicated that the climate of the farm is semi-arid, subtropical and monsoonic. It receives an average annual rainfall of 872 mm. Mean maximum temperature of 39.1°C in the month of May and the mean minimum temperature of 7.6°C in month of January indicate a seasonal climate. The mean annual temperature was recorded as 26.5°C whereas the mean annual soil temperature (MAST) was 27.5°C. The mean summer soils temperature (MSST) and the mean winter soil temperature (MWST) were 32°C and 18.6°C, respectively. Thus, its temperature regime is hyperthermic. The moisture regime of the soils on upland is ustic (pedons 1 & 2) and those of midland to lowland physiographic position is aquic (pedons 3, 4 & 5) which remain saturated for maximum period of the year i.e. >180 days. These pedons exhibit reducing conditions in many horizons having chroma 2, but in some horizons it is >2 indicating the presence of ground water at lower depth. A schematic diagram showing physiographic position is presented in figure 1.

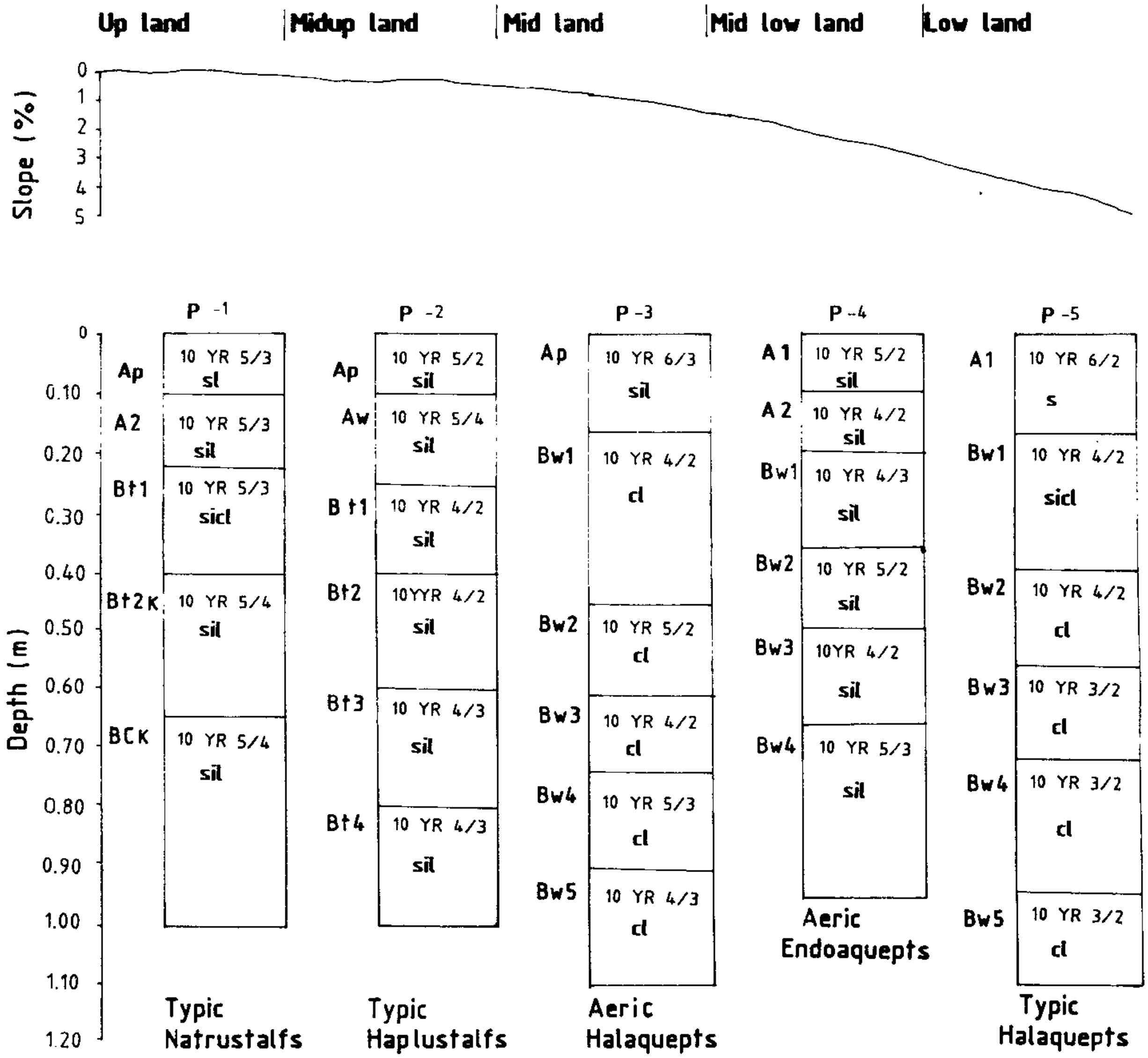

Fig. 1. Schematic diagram and physiographic setting of identified soils of Banthra Research Station, NBRI, Lucknow.

The detailed soil survey was conducted using cadastral maps (1:4000 scale). Extensive field survey was carried out using 5 x 5 cm grid which represented an area of 4 ha on the ground. A total of 20 auger bores were studied. Depending on the variability in physiographic units of the farm supporting different types of vegetation 5 representative pedons were selected and studied for morphological characteristics following the techniques outlined in Soil Survey Manual (1970). The horizonwise soil samples were collected for detailed analysis. Standard methods of analysis were followed for determining mechanical composition, pH, organic carbon, ECe, $CaCO_3$, exchangeable cations and exchangeable sodium percentage (ESP) (Richards 1954; Jackson 1967). The soils were classified according to Soil Taxonomy (Soil Survey Staff 1998).

Results and discussion

Morphological characteristics : Salient features of morphological characteristics of pedons are presented in table 1. Pedons 1 and 2 occurring in the upland physiographic positions are moderately well drained soils. Soils of pedon 1 are brown to yellowish brown in colour. The texture is sandy loam (surface) and is dominantly silty loam in the subsoil. Soil structure is granular in surface horizon and subangular blocky in rest of the soil profile. Yellowish brown mottles, ferro-manganese concretions and calcrete are present in subsoils. Thin, discontinuous clay films were observed on lining of the pores and ped faces in the subsoil. Soil colour of pedon 2 was greyish brown to dark brown with yellowish brown mottles below 60 cm depth. There were thin continuous clay films on lining of the pores and ped faces in the subsoil. Soil texture was silty loam and structure was subangular blocky throughout the depth of the pedon. Ferro-manganese concretions were present throughout the profile.

Pedons 3 and 4 occurring on midland physiographic position were imperfectly drained with calcrete in subsurface horizons. Pedon 3 exhibited pale brown to dark brown colour with yellowish brown mottles below a depth of 45 cm. The surface texture is silty loam and clay loam in the subsoils. The structure of the soils is prismatic which breaks into angular and subangular blocky secondary structure. Ferro-manganese concretions were observed throughout the depth whereas calcrete were found below 74 cm. Pedon 4 has greyish brown to brown matrix colour with distinct yellowish brown mottles throughout the depth. Soil texture is loam throughout the profile. The surface structure was crumb and subangular blocky in subsurface. The soil is calcareous and alkaline below 50 cm depth.

Table 1. Morphological characteristics of the soils

Horizon	Depth (cm)	Colour	Tex-ture	Structure	Consistence	Root	Pores	Mottles	Coarse fragments		Efferves-cence
									Fe-Mn	Lime	
					Pedon-1 Typic Natrustalfs						
Ap	0-10	10YR 5/3M	sl	f1 gr	vfr ss ps	c,m	cirr imped	--	--	--	e
A2	10-22	10YR 5/3M	sil	m2 sbk	sh fr ss ps	fm	cirr imped	--	--	--	e
Bt1	22-40	10YR 5/3M	sicl	c2 sbk	vh fi s p	ff	cmvert imped	--	ff conir	--	e
Bt2k	40-65	10YR 5/4M	sil	m2 sbk	h fr ss ps	ff	cmvert imped	mmd 10YR 6/6	fm conir	cm conc	es
BCk	65-100+	10YR 5/4M	sil	m2 sbk	sh fr ss ps	vff	cmvert imped	cmd 10YR 6/6	fm conir	cmconc	ev
					Pedon-2 Typic Haplustalfs						
Ap	0-10	10YR 5/2M	sil	m2 sbk	sh fr ss ps	cfm	ff irr imped	--	--	--	--
Bw	10-25	10YR 5/4M	sil	m2 sbk	sh fr ss ps	ff	ff vert imped	--	ff conir	--	--
Bt1	25-40	10YR 4/2M	sil	m2 sbk	h fr s p	ff	cm vert imped	--	cm conir	--	--
Bt2	40-60	10YR 4/2M	sil	m2 sbk	h fr s p	ff	cm vert imped	--	cm conir	--	--
Bt3	60-80	10YR 4/3M	sil	m1 sbk	sh fr ss ps	--	cm vert imped	mmd 10YR 5/6	cm conir	--	--
Bt4	80-100+	10YR 4/3M	sil	m1 pt	h fr s p	--	cf irr imped	mmd 10YR 5/6	cm conir	--	--
					Pedon-3 Aeric Halaquepts						
Ap	0-16	10YR 6/3D	sil	m2 sbk	h fr ss ps	cm	ff irr imped	--	--	--	--
Bw1	16-45	10YR 4/2D	cl	c3pr to m2sbk	vs fi s p	cm	cm vert imped	--	ff conir	--	--
Bw2	45-61	10YR 5/2D	cl	c3pr to m2 sbk	vs fi s p	ff	cfm vert imped	--	fm conir	--	--
Bw3	61-77	10YR 4/2D	cl	c3pr to m3 abk	vs fi vs vp	ff	cfm vert imped	fmd 10YR 5/8	cm conir	--	e
Bw4	77-90	10YR 5/3D	cl	c3pr to m3 abk	vh vfi vs vp	ff	cfm vert imped	cmp 10YR 5/8	cm conir	fm conc	es
Bw5	90-110+	10YR 4/3D	cl	c3pr to m3 abk	vh vfi vs vp	--	cfm vert imped	cmp 10YR 5/8	cm conir	cm conc	es
					Pedon-4 Aeric Endoaquepts						
A1	0-9	10YR 5/2D	sil	m2 cr	sh fr ss ps	cm	cf irr imped	--	ff conir	--	--
A2	9-19	10YR 4/3D	sil	m2 sbk	sh fr ss ps	fm	cm vert imped	fff 10YR 5/6	ff conir	--	e
Bw1	19-35	10YR 4/3D	sil	m2 sbk	sh fr s p	fm	cm vert imped	fff 10YR 5/6	fm conir	--	--
Bw2	35-48	10YR 5/2D	sil	m2 sbk	h fi s p	fm	cm vert imped	cmd 10YR 5/8	cm conir	fm conc	--
Bw3	48-66	10YR 4/2M	sil	m2 sbk	h fi s p	ffm	cm vert imped	cmd 10YR 5/8	cm conir	cm conc	--
Bw4	66-95+	10YR 5/3M	sil	m2 sbk	h fr s p	ffm	cm vert imped	cmd 10YR 5/8	cm conir	cm conc	--
					Pedon-5 Typic Halaquepts						
A1	0-16	10YR 6/2D	sil	m2 sbk	h fr ss ps	cm	ff vert imped	fff 10YR 5/6	ff conir	--	e
Bw1	16-39	10YR 4/2M	sicl	m2 sbk	h fi s p	cf	ff vert imped	fff 10YR 6/6	ff conir	--	e
Bw2	39-56	10YR 4/2M	cl	m2 sbk	h fi s p	cf	cfm vert imped	fmd 10YR 6/8	fm conir	--	e
Bw3	56-72	10YR 3/2M	cl	c3 abk	vh vfi vs vp	fvf	cm vert imped	cmd 10YR 6/8	cm conir	fm conc	es
Bw4	72-94	10YR 3/2M	cl	c3 abk	vh vfi vs vp	fvf	cm vert exped & imped	mmp 10YR 5/6	cm conir	fm conc	es
Bw5	94-100+	10YR 3/2M	cl	c2 abk	vh vfi vs vp	--	cf vert imped	mmp 10YR 5/8	cm conir	cm conc	es

Pedon 5 of lowland physiographic position is poorly drained. The colour ranges from light brownish grey to very dark greyish brown throughout the depth. There were common, medium, distinct yellowish brown mottles throughout the profiles. Calcrete were also commonly found in the subsoil which has a size of 2 to 15 mm and occupy about 15 per cent by volume. The surface soil texture is silty clay overlying clay loam subsoils. Soil structure was subangular blocky to angular blocky throughout the profile.

Physical and chemical characteristics : The physical and chemical characteristics of the different pedons are presented in table 2. Mechanical analysis indicates that the clay content in subsurface B2 horizons is 1.2 times higher than the overlying horizons in case of pedons 1 and 2. The evidence of pedogenic processes indicates the presence of the cambic horizons in pedons 3, 4 and 5.

The soil reaction is moderately to strongly alkaline in the surface (pH 7.8-9.5) and subsurface horizons (pH 7.9-11.0). A gradual increase in soil pH down the depth of every pedon is discernible except in pedon 2. The $CaCO_3$ in surface soil ranges from 0.13-8.4 g kg^{-1} which gradually increases with depth. However, in pedon 2 the contents of $CaCO_3$ was very low and thus no effervescence was observed in any horizon at the time of profile study. In pedon 4, second horizon only showed presence of $CaCO_3$ in field and pedons 1, 3 and 5 were calcareous throughout the profile. Electrical conductivity (ECe) ranged from 0.88-1.96 dS m^{-1} in the surface horizons of all pedons and showed an increasing trend with depth in pedons 1, 3 and 5 indicating the presence of salinity at lower depth. This trend is however, reversed in pedon 2 probably caused by leaching of soluble salts resulting in amelioration of soil profile due to adoption of biological measures i.e. cultivation of sodicity tolerant crops like paddy, dhaincha (*Sesbania aculeate*) and other deep rooted crops grown consistently for over three decades. The ECe of pedon 4 declined upto 48 cm depth because of the improvement in the soil profile due to plantation of different forest tree spp. such as *Acacia nilotica, Albizia procera, Cassia spp., Dalbergia sissoo, Dandroclamus strictus, Emblica officinalis, Ficus spp. Syzygium cumini, Terminalia arjuna* etc. for over three decades. Thereafter ECe increased at lower depths of pedon 4 showing accumulation of salts (Garg 2000).

Table 2. Physical and chemical characteristics of the soils

Depth (cm)	Sand	Silt	Clay	Texture	pH	ECe dS m^{-1}	O. C. g kg^{-1}	$CaCO_3$ g kg^{-1}	Exchangeable cations (cmol (+) kg^{-1})				ESP
	------	%	------						Ca^{++}	Mg^{++}	K^{+}	Na^{+}	
						Pedon-1							
0–10	67.2	17.0	15.8	sl	9.4	1.07	4.74	8.4	9.2	4.8	0.5	3.5	22.2
10–22	28.0	52.8	19.2	sil	10.0	3.44	1.03	7.2	6.0	2.8	0.4	9.6	52.4
22–40	11.7	53.8	34.5	sicl	10.2	4.19	0.91	9.3	2.8	0.4	0.5	14.8	73.9
40–65	25.8	53.7	20.5	sil	10.5	4.19	0.71	10.4	1.6	0.4	0.5	15.7	78.3
65–100+	38.5	52.0	9.5	sil	10.7	6.19	0.84	12.0	2.4	0.4	0.4	15.7	72.0
						Pedon-2							
0–10	22.5	61.7	15.8	sil	7.8	1.71	6.05	0.13	11.2	4.8	1.0	0.6	3.3
10–25	15.3	69.7	15.0	sil	8.1	1.22	2.58	0.09	10.8	6.0	0.5	0.5	2.9
25–40	11.2	69.3	19.5	sil	8.0	1.04	1.60	0.22	10.0	3.6	0.4	0.5	3.0
40–60	15.3	62.5	22.2	sil	8.1	1.08	1.68	0.26	9.2	5.2	0.4	0.4	2.1
60–80	13.3	71.5	25.2	sil	8.0	0.98	1.05	0.08	10.4	4.8	0.4	0.4	2.2
80–100+	9.5	68.5	22.0	sil	7.9	0.79	0.96	0.10	8.8	5.2	0.4	0.5	2.8
						Pedon-3							
0–16	30.0	51.0	19.0	sil	8.6	1.06	5.74	2.8	10.0	10.0	1.4	1.5	8.4
16–45	27.0	42.0	31.0	cl	10.0	2.48	1.32	4.0	9.3	8.8	0.8	11.4	61.7
45–61	27.0	42.0	31.0	cl	10.3	2.55	1.32	7.6	6.4	3.1	0.9	14.7	87.6
61–77	27.0	40.0	33.0	cl	10.4	2.61	0.58	5.4	4.6	4.9	0.9	14.0	90.3
77–90	27.0	40.0	33.0	cl	9.6	2.60	0.30	4.8	5.0	4.0	0.9	14.1	90.6
90–110+	27.0	38.0	35.0	cl	9.8	2.89	0.30	4.5	4.4	6.1	1.0	14.8	90.9
						Pedon-4							
0–9	20.0	62.0	18.0	sil	8.3	0.88	9.7	Nil	11.6	14.8	2.2	0.5	2.4
9–19	18.0	60.0	22.0	sil	8.5	1.06	1.17	2.9	14.8	15.6	2.0	1.6	8.8
19–35	22.0	54.0	24.0	sil	8.5	0.62	0.44	0.1	10.4	13.1	1.3	0.9	5.8
35–48	23.0	51.0	26.0	sil	8.9	0.65	0.44	Nil	9.8	13.1	0.8	1.9	11.7
48–66	23.0	52.0	25.0	sil	9.3	1.87	0.14	Nil	8.3	9.6	0.6	3.8	26.5
66–95+	24.0	54.0	22.0	sil	9.6	2.20	0.14	Nil	6.8	10.6	0.5	4.9	38.3
						Pedon-5							
0–16	27.0	50.0	23.0	sil	9.5	1.96	2.20	3.9	6.0	8.0	0.8	3.8	31.9
16–39	23.0	50.0	27.0	sicl	10.6	3.03	0.44	8.3	3.6	7.8	0.8	13.0	90.3
39–56	25.0	43.0	32.0	cl	10.9	4.76	0.29	8.0	2.3	2.3	0.8	14.7	90.3
56–72	25.0	38.0	37.0	cl	11.0	7.27	0.29	1.1	2.7	2.3	1.0	19.6	90.3
72–94	25.0	37.0	38.0	cl	11.0	9.26	0.14	1.1	3.0	1.5	0.9	19.0	91.3
94–100+	25.0	39.0	36.0	cl	–	9.45	0.14	1.0	3.3	3.3	0.9	14.7	67.5

The organic carbon content ranged from 2.2–9.7 g kg^{-1} in the surface soil showing minimum values in pedon 5 and the maximum value in pedon 4 probably due to higher accumulation of leaf litters from the tree stands in the latter (Garg 1998). Decreasing trends of organic carbon with depth in all the pedons was observed as found elsewhere in central alluvial region of U.P. (Tiwari *et al.* 1983).

In general, the exchangeable Ca^{2+} and Mg^{2+} were dominant cations followed by Na^+ and K^+ ions on the surface soils of almost all the pedons. However, comparatively a narrower Ca/Mg ratio was observed in the exchange complex of pedon 4 probably due to plantation of mixed forest species planted about three decades ago. Such variations have also been found in sodic soils of Bharatpur (Rajasthan) reported by Qureshi *et al.* (1996). The exchangeable Na^+ was higher than exchangeable Ca^{2+} and Mg^{2+} where ESP values were greater than 15 at lower depths in all the pedons except in pedons 2 and 4. The reversal of this shows the sign of soil improvement due to continuous cultivation for over three decades without any chemical amendments.

ESP of the soil was less than 15 in soil of pedon 2 showing complete replacement of Na^+ by Ca and/or Mg ions and is free from sodicity. Pedon 4 showed reduction in ESP upto about 0.5 m depth beyond which sodicity still persists. ESP of other pedons ranged from 22 to 90 at varying depths alongwith higher pH.

Thus, the results of five pedons representing five different land use systems discussed here have shown variation in soil characteristics and concluded that the sodicity tolerant species gave place to less tolerant species because of the amelioration of land itself.

Classification : Pedons 1 and 2 showed presence of an ochric epipedon with argillic subsurface horizon thus they qualify for the order Alfisols. Pedon 1 was classified as fine-loamy, mixed, hyperthermic family of Typic Natrustalfs because of a presence of natric subsurface diagnostic horizon. Pedon 2 was classified as fine-silty, mixed, hyperthermic family of Typic Haplustalfs due to the presence of an argillic horizon which is less than 35 cm thick and absence of paralithic contact within 100 cm. The soils of pedons 3, 4 and 5 show the presence of cambic horizon (Bw2) and thus qualify to be Inceptisols. These soils are classified under suborder 'Aquepts' due to aquic moisture regime and pedons 3 and 5 were classified under greatgroup Halaquepts due to the presence of more than 25 cm thick horizon with ESP >15.

Pedon 3 was further classified as fine-silty, mixed, calcareous hyperthermic, family of Aeric Halaquepts which have chroma 3 or more in 40 per cent or more of the matrix of one or more horizon at a depth between 15 and 75 cm from the mineral soil surface. The higher chroma is thought to be the result of lower ground water level. Pedon 5 was further classified as fine-silty, mixed, hyperthermic family of Typic Halaquepts which have chroma 2 or less and hue of 10YR or redder in all subsurface horizons between the depth of 75 cm represent aquic moisture regime. The soils of pedon 4 fall in other Aquepts i.e. Endoaquepts that have hue of 10YR or yellow in 50 per cent or more of the matrix either have a colour value (moist) 3 or more and chroma 2 or more qualifies to be Aeric Endoaquepts at subgroup level. Pedon 4 was thus classified as fine-loamy, mixed, calcareous, hyperthermic family of Aeric Endoaquepts.

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