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Pedological variabilities and classification of some dominant soils of Aravallies-Yamuna river transect in semi-arid tract of Haryana

G.S. Sidhu, S.K. Ghosh[1] and K.M. Manjaiah[1]

National Bureau of Soil Survey & Land Use Planning, Regional Centre, IARI Campus, New Delhi 110 012

[1]Nuclear Research Laboratory, Indian Agricultural Research Institute, New Delhi 110 012

Abstract

Characteristics and elemental composition of soils representing Aravallies - Yamuna river transect in south Haryana was investigated. The soils of lower piedmont and old flood plain are loam to clay loam, moderately to strongly alkaline with low to medium organic carbon content. Further, the fineness of texture and intensity of salinity/sodicity increased from higher to lower elevation of old flood plain. The soils showed the formation of structural (cambic) and argillic horizons and classified as Inceptisols and Alfisols. The soils on recent/active flood plain and sand dunes are stratified without any diagnostic horizons and classified as Entisols. The soils on hill top are shallow due to severe erosion. The soils on upper piedmont are deep but without any pedogenic development due to their recent deposition. The study shows that the soils are in their various stages of pedogenic evolution depending on the physiography and parent material as modified by time.

Additional keywords : Elemental composition, physiography, soil morphology, parent material.

Introduction

The soils derived from the Aravalli system constitute major agricultural area in the states of Haryana, Delhi and Rajasthan. Some information pertaining to mapping and characteristics of these soils was reported by Bali (1952) and Anonymous (1984). However, comprehensive information about their characteristics and genesis in relation to landform is still very scanty. The present study reports on the pedological variabilities and classification of soils developed in a landform sequence in Central Aravalli hill - Yamuna river transect of southern Haryana.

Materials and methods

The study area comprises of major part of Faridabad and some parts of Gurgaon districts of Haryana state. It lies between 28°12'30" to 28°18'20" N latitudes and 77°05'15" to 77°30'00" E longitudes. It represents semi-arid type of monsoon climate. The area qualifies for 'hyperthermic' temperature regime. The mean annual rainfall of the area is about 705 mm. The moisture regime is 'ustic' and 'aquic' (in patches). Dominant natural vegetation and grasses on hill top and upper piedmont plain are Khair (*Acacia catecheu*), Babul (*Acacia arabica*), Ber (*Zizyphus jujuba*), Dhak (*Cassia tora*), Amla (*Phyllanthus emblica*), Dub (*Cynodon dactylon*). The *lower piedmont* plain are inhabited by Babul, Jand (*Prosopis specigera*), Pipal (*Ficus religiosa*), Motha (*Cyperus rotundus*), Dub. etc. However, Shisham (*Dalbergia sissoo*), Pipal, Babul, Sarkanda (*Saccharum munja*), Dub, Motha, Dhak, etc. are associated with flood plain area. Babul, Jand, Sarkanda, etc. are dominant vegetation in the area of sanddune.

Based on reconnaissance soil survey of the area, ten pedons representing dominant soils of seven physiographic units, viz. hill top, upper piedmont, lower piedmont, old, active and recent-flood plain and sand dune were studied (Fig. 1). Morphology of soils was described using Soil Survey Staff (1951). Horizonwise soil samples were analyzed for pH and EC in 1:2.5 extract, cation exchange capacity, ammonium acetate (pH 7) extractable bases, organic carbon, particle size distribution and elemental analysis following standard procedures. Calcium carbonate equivalent was determined by rapid titration method (Puri 1930). The soils were classified according to Keys to Soil Taxonomy (Soil Survey Staff 1992).

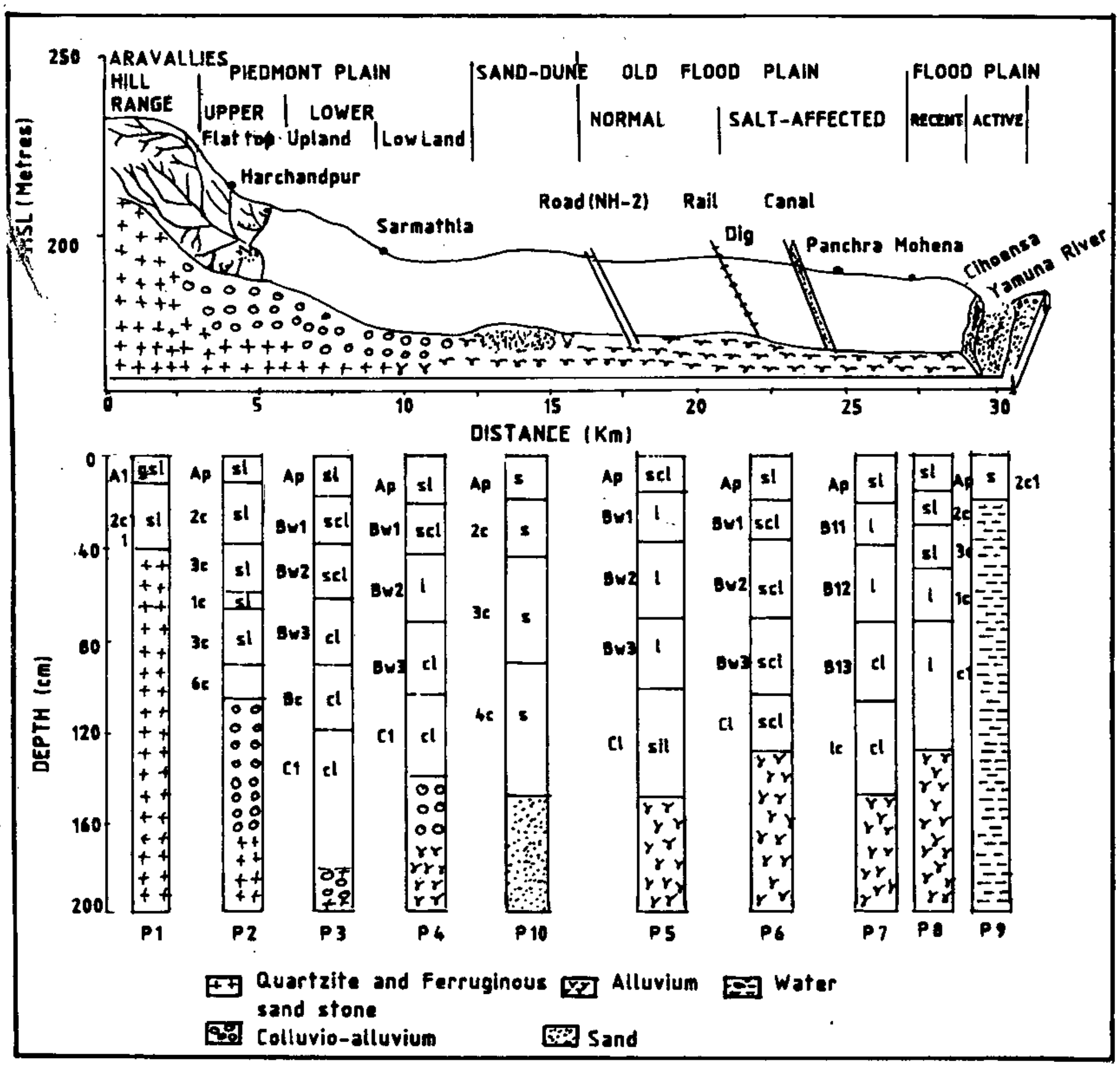

Fig. 1 : Schematic diagram of landform-soil relationship.

Results and discussion

Soil morphology : The morphological characters of the soils indicate that Bahalpa (P1) soils occurring on steep slopes are deep and highly eroded. The soils (P3, P4, P5 and P6) on lower piedmont and old flood plain have weak to moderate, medium to coarse subangular blocky structure. In P7 soils, the presence of thin to thick patchy to continuous clay coatings and increase in clay content by 20 per cent indicate the illuviation process. The inter fluvial layers and sand pockets were observed in pedon 8. The presence of river sand in P9 soils and aeolian sand deposit in P10 soils restricted the structural development. Data indicate that the soil colour values ranges from 3 to 7, chroma 2 to 6 with hue 10YR and 7.5YR except P4 soils. The colour of 2.5Y hue in P4 soils mottling and gleying may be ascribed to the reducing conditions and high content of clay (Sehgal *et al.* 1980).

Physical and chemical characteristics : The particle size data (Table 2) indicated that highly eroded P1 soils were gravely sandy loam on the surface and sandy loam in subsurface. Higher content of sand in the subsurface was due to in-situ weathering of sandstone. The sandy loam texture in P2 soils was observed throughout the depth of soil profile except in the last horizon which was loamy sand. The presence of thin layer of iron concretions below a depth of 60 cm indicated the different depositional cycles of the soils. The wide sand/silt ratios (7.3 to 23.9) indicated the deposition through different cycles and less of pedogenic weathering. Similar trend was also observed in silt/clay ratio (except in the last layer). The results indicated that two depositional cycles were operative i.e. 0–0.6 m depth and 0.63–1.05 m depth, which were separated by the presence of a thin layer (0.60-0.63 m) dominated by iron concretions. The high clay content in surface layer of P4 soils was due to cumulative process as a result of concave landform. In P5 soils the texture was sandy loam on the surface and loam to silty loam in subsurface. The increase in clay content with soil depth was low as compared to silt fraction. Consequently the sand/silt ratio was minimum in the cambic horizon which indicated eluviation and illuviation in these soils which lead to the formation of dark coloured cambic B horizon.

Table 1. Morphological properties of soils

Depth (m)	Horizon	Colour (moist)	Structure	Horizon Boundary	Clay cutans/ Mottlings
		P1 Hill top (Bahalpa)			
0–0.11	A1	10YR 4/4	m1sbk	cs	-
0.11–0.40	C	7.5YR 4/4	m1sbk	as	-
		P2 Upper piedmont plain, dissected (Harchandpur)			
0–0.11	Ap	7.5YR 3/4	m0 massive	cs	-
0.11–0.38	2C	7.5YR 3/4	m1sbk	as	-
0.38–0.60	3C	7.5YR 3/4	m1sbk	as	-
0.60–0.63	4C	7.5YR 3/4	m1sbk	as	-
0.63-0.91	5C	7.5YR 3/4	m1sbk	as	-
0.91+	6C	10YR 4/4	vfosg	-	-
		P3 Lower piedmont plain, upland non-dissected (Sarmathla)			
0–0.18	Ap	10YR 5/3	m1sbk	cs	-
0.18–0.38	Bw1	10YR 4/3	m2sbk	cs	-

0.38-0.62	Bw2	10YR 3/3	m2 sbk	gs	-
0.62-0.89	Bw3	10YR 3/3	m2 sbk	gs	-
0.89-1.20	BC	10YR 4/3	m2 sbk	gs	-
1.20-1.8	C1	10YR 4/3	m1sbk	-	-
		P4 Lower piedmont plain, lowland non-dissected (Sarmathla)			
0-0.21	Ap	2.5YR 4/2	m1 sbk	as	-
0.21-0.43	Bw1	10YR 4/3	m2 sbk	cs	10YR 3/1
0.43-0.73	Bw2	10YR 4/3	m2 sbk	gs	10YR 3/1
0.73-1.04	Bw3	10YR 4/3	m2 sbk	cs	10YR 3/2
1.04-1.51	C1	10YR 3/3	m1sbk	-	-
		P5 Old floodplain normal (Dig)			
0-0.16	Ap	10YR 4/3	m1sbk	as	-
0.16-0.38	Bw1	10YR 4/3	m2sbk	cs	-
0.38-0.71	Bw2	10YR 3.5/3	m2sbk	cs	-
0.71-1.02	Bw3	10YR 3.5/3	m2sbk	gs	-
1.02-1.50	C1	10YR3.5/3	m2sbk	-	-
		P6 Old floodplain salt-affected (Panehra)			
0-0.19	Ap	10YR 5/2	m1sbk	as	nil
0.19-0.37	Bw1	10YR 4/4	m2sbk	cs	nil
0.37-0.71	Bw2	10YR 4/3	m2sbk	cs	t,tn,p
0.71-1.04	Bw3	10YR 4/3	m2sbk	cs	t,tn,p
1.04-1.32	C1	10YR 4/3	m1sbk	as	-
		P7 Old floodplain salt-affected (Mohena)			
0-0.21	Ap	10YR 4/4	m1sbk	cs	nil
0.21-0.4	Bt1	10YR 3/3	m2sbk	gs	t,mth,p
0.4-0.73	Bt2	7.5YR 3/3	m3sbk	gs	t,mtk,p
0.73-1.07	Bt3	7.5YR 3/3	m3sbk	cs	t,mtk,p
1.07-1.50	1C	7.5YR 4/4	m1sbk	-	nil
		P8 Recent floodplain (Chhaensa)			
0-0.16	Ap	10YR 7/4	fosg	as	-
0.16-0.31	2C	10YR 5/3	m0massive	as	-
0.31-0.5	3C	10YR 4/3	m0massive	as	-
0.5-0.72	4C	10YR 4/4	m0massive	as	-
0.72-1.30	5C	10YR 4/4	m0massive	-	-
		P9 Active floodplain - Yamuna river bed (Chhaensa)			
0-0.20	2C	10YR 7/3	fm0sg	-	-
		P10 Sand dune (Baikera)			
0-0.20	Ap	10YR 6/6	fosg	as	-
0.20-0.45	2C	10YR 6/6	m0massive	gs	-
0.45-0.90	3C	10YR 6/6	m0massive	gs	-
0.90-1.50+	4C	10YR 6/6	m0massive	-	-

Symbols used are the same as those given by the Soil Survey Manual (1951).

Similar trend was also observed in P6 and P7 soils. There was no definite trend in sand/silt and silt/clay ratios in P8 and P9 soils indicating high instability in these soils due to different cycles of deposition of material from the Yamuna river.

The electrical conductivity was relatively low in these soils except in P6 and P7 soils which showed the EC (1:2.5) values of 0.15 to 0.66 dS m^{-1} indicating accumulation of salts due to the use of underground saline water for irrigation. The good quality of irrigation water from canals allowed the P5 soils to maintain low EC values. The increase of EC with soil depth was due to accumulation of salts with increased clay content. Consequently these soils (P6 and P7) showed high pH values (8.1–10.1) owing to high amount of exchangeable sodium which increased with the soil depth. The coarser fractions of the soils contain 5 to 10 per cent albites (Na-feldspars) which on weathering contributed to the exchangeable sodium in the soils (Bhargava 1978; Bhargava *et al.* 1981). The soils on active and recent flood plains showed higher pH values (8.3–8.5) due to high amount of exchangeable sodium in the soil. Similar results were also reported by Manchanda and Khanna (1981) and Sanwal (1984) in the lowlying areas of Yamuna alluvial plains due to deposition of salts. The cation exchange capacity and exchangeable bases are relatively low in these soils, which are closely related to distribution of clay and organic carbon content along the toposequence.

The organic carbon content was relatively more (0.69%) in the surface horizon of P1 soils due to grass cover and scrub forest, but in rest of the soils it was relatively low (0.04 to 0.30%). The low C:N ratio in the range of 10 to 12 (except in some horizons) indicated higher and constant rate of carbon mineralization in these soils.

The $CaCO_3$ content in P6 and P7 soils ranged between 0.2 to 1.4%. The $CaCO_3$ in recent flood plain (Chhensa) soils was comparatively high (1 to 2%) due to the calcareous nature of recent alluvium of Yamuna river as a result of washing down of $CaCO_3$ in these highly permeable sandy soils (Sanwal, 1984). In other soils, the distribution of $CaCO_3$ did not show any trend possibly due to deposition of alluvium in different cycles.

Elemental composition : The soils are siliceous in nature with SiO_2 content ranging from 66.5 to 82.5 per cent (Table 3). These variations in SiO_2 content are mainly associated with the nature of parent material and also the topography. The SiO_2 content was highest in P1 soils as these soils are developed from quartzitic sandstone. The SiO_2 content decreased with decreasing hill slope; viz. hill top (80.8 to 82.5%), lower piedmont P4 (67.8 to 74.9%), sand dune P10 (72.8 to 82.0%), recent flood plain P8 (72.8 to 82.0%) old flood plain P5 (70.7 to 74.6%). On the contrary the Al_2O_3 content increased from hill slope, hill top P1 (5.4 to 8.3%) to lower piedmont plain P4 (8.5 to 12.8%) and recent flood plain P8 (4.4 to 9.1%) to old flood plain P5 (8.3 to 15.0%). Less weathered sand dune soils (P10) also have relatively high content of SiO_2 (77.7 to 81.9%) and medium content of Al_2O_3 (9.5 to 12.1%). These findings indicate that weathering intensity of soils varied with the physiography and age of soils. The P1 soils also had higher amount of Fe_2O_3 (3.1-7.1%) as compared to other soils in the toposequence, indicating release and accumulation of iron from ferruginous quartzitic sandstone. The accumulation of Al_2O_3 and Fe_2O_3 in the cambic/argillic horizons in soils of old flood plain indicated the mobilization of these elements within the soil profile due to active soil forming processes. The soils showed the CaO content of 1.3–2.1 per cent which varied in narrow range and distributed uniformly in the profiles and the soils differed greatly in their Fe_2O_3 (1.4–7.1%) and MgO (0.5–2.5%) contents. This was due to variations in the mineralogical composition of Fe and Mg bearing minerals present in these soils (Sidhu 1991). The content of Na_2O varied in the range of 1.0 to 1.8 per cent, and the amount of K_2O (1.3–2.8%) was highest in old flood plain and recent flood plain soils due to the presence of K-bearing minerals, in the coarse fractions of these soils (Sidhu 1991). The soils vary considerably in their total base content (3.8 to 8.2%) depending upon the topography and parent material.

Table 3. Elemental composition of soils (expressed as per cent on oven dry basis)

Horizon	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total bases
				Pedon 1						
A1	80.8	5.4	7.1	12.5	1.6	2.4	1.8	1.1	0.07	6.8
2C1	82.3	8.3	3.1	11.4	1.9	0.9	1.0	1.0	0.04	3.8
				Pedon 2						
Ap	80.9	5.6	2.8	7.3	1.6	1.0	1.1	1.3	0.04	4.9
2C	80.2	11.7	4.7	16.3	2.0	1.2	1.7	1.6	0.05	6.4
3C	78.3	6.9	3.5	10.4	2.0	1.9	1.4	1.5	0.06	6.9
4C	81.9	10.3	2.4	12.1	1.8	0.9	1.4	1.6	0.05	5.7
5C	78.5	8.6	2.7	11.3	1.8	0.9	1.2	1.4	0.03	5.3
				Pedon 3						
Ap	79.7	10.7	2.8	13.5	1.9	1.8	1.3	1.6	0.05	6.7
Bw1	76.6	4.6	3.7	8.3	1.6	1.5	1.9	1.8	0.05	6.7
Bw2	79.8	6.0	4.0	10.6	1.6	1.9	1.5	1.5	0.06	6.5
Bw3	80.9	9.4	4.5	13.9	1.6	1.7	1.8	1.4	0.03	6.5
BC	79.1	8.5	4.9	13.5	1.7	1.9	1.7	1.6	0.04	7.0
C1	81.7	8.5	4.1	12.6	1.5	1.6	1.8	1.5	0.03	6.3
				Pedon 4						
Ap	67.8	9.6	6.5	46.2	1.4	2.5	2.0	1.3	0.07	7.1
Bw1	66.5	10.0	5.9	15.9	1.7	1.9	1.6	1.5	0.08	6.7
Bw2	73.5	8.6	4.8	8.4	1.9	1.7	1.3	1.6	0.04	6.5
Bw3	73.4	8.5	4.7	43.1	1.6	1.7	1.3	1.4	0.05	6.0
C1	74.9	12.8	5.2	18.0	2.0	1.9	1.7	1.5	0.05	7.1
				Pedon 5						
Ap	74.6	9.9	4.2	14.1	1.5	1.0	1.4	1.3	0.04	5.2
Bw1	73.8	14.9	4.7	19.6	1.7	1.8	1.9	1.4	0.04	6.7
Bw2	70.7	13.2	5.4	18.6	1.7	2.0	2.0	1.3	0.05	7.0
Bw3	72.1	15.0	6.3	21.4	1.6	2.0	2.1	1.4	0.06	7.0
C1	71.4	8.3	6.1	14.4	1.7	2.1	2.1	1.4	0.06	7.2
				Pedon 6						
Ap	69.7	20.0	2.3	22.2	1.8	1.1	1.3	1.5	0.03	5.7
Bw1	73.2	17.5	3.4	20.9	1.5	1.3	1.3	1.3	0.04	5.4
Bw2	73.3	17.2	3.8	20.9	1.5	1.4	1.4	1.4	0.05	5.7
Bw3	78.9	10.3	4.0	14.3	1.3	1.4	1.4	1.4	0.05	5.4
C1	74.2	8.9	4.5	13.4	1.5	1.6	1.6	1.5	0.06	6.2

				Pedon 7						
Ap	82.5	8.9	3.0	6.9	1.6	1.3	1.8	1.6	0.04	6.2
Bt1	74.6	13.4	5.0	18.4	1.5	1.8	2.0	1.3	0.06	6.6
Bt2	77.7	8.3	5.2	13.5	1.3	1.8	1.8	1.2	0.06	6.2
Bt3	72.9	11.0	5.2	16.2	1.3	1.8	2.0	1.2	0.07	6.4
IC	82.2	1.8	5.6	7.4	1.5	2.0	1.9	1.1	0.07	6.5
				Pedon 8						
Ap	82.0	7.9	3.6	11.5	1.9	1.8	1.7	1.3	0.05	6.7
2C	80.6	9.1	3.5	12.6	1.7	0.8	1.3	1.4	0.34	5.3
3C	79.6	4.4	4.1	8.4	2.0	1.7	1.9	1.3	0.04	7.0
4C	72.8	7.8	4.2	12.1	2.1	1.8	2.2	1.3	0.04	7.4
5C	73.0	6.9	5.4	12.4	1.7	2.4	2.8	1.3	0.06	8.2
				Pedon 9						
2C	73.8	7.7	2.5	10.2	1.3	0.8	1.1	1.0	0.04	4.2
				Pedon 10						
Ap	80.8	12.1	2.6	14.7	1.6	0.6	1.2	1.4	0.03	4.8
2C	81.3	9.5	1.6	11.1	1.6	0.5	1.2	1.4	0.02	4.7
3C	77.7	11.7	1.5	13.2	1.7	0.7	1.4	1.6	0.02	5.2
4C	81.9	11.8	1.4	13.2	1.7	0.5	1.3	1.5	0.02	5.0

Classification : Based on the morphology, physical, chemical and elemental composition the soils occurring under different physiographic units were classified as per the criteria of Soil Survey Staff (1992). The soils of pedons 1, 2, 8, 9 and 10 have been put under the order Entisols due to the absence of any diagnostic subhorizons. P1 and P2 soils of hills and piedmonts were classifed into suborder-Orthents because of texture finer than loamy very fine sand (<85% sand) with regular decrease in organic carbon content and put into great group Ustorthents due to ustic moisture regime. The P1 soils were classified as Lithic Ustorthents (subgroup) due to lithic contact within 50 cm soil depth, and P2 soils put under subgroup Typic Ustorthents. The soils of pedons P8 were classified into suborder Fluvents due to fluventic characteristics (stratified layers) observed in the field and evidenced by erratic distribution of organic carbon and because of ustic moisture regime, these soils were put under great group Ustifluvents and subgroup of Typic Ustifluvents. The sandy soils of pedon P9 and P10 having more than 85 per cent sand (texture coarser than fine loamy sand) were classified as Psamments (suborder) and Ustipsamments (great group) and Typic Ustipsamments (subgroup). The soils of pedons 3, 4, 5 and 6 exhibit alteration in the form of colour with structural changes from weak to moderate subangular blocky structure from surface to subsurface horizons qualifying for the diagnostic cambic endopedon. Therefore, they qualify for Inceptisols. The soils of pedons P3, P5 and P6 were put under the suborder Ochrepts due to presence of ochric epipedon and these soils further classified into great group Haplustepts due to presence of ustic moisture regime. These soils qualify for subgroup Typic Haplustepts. Due to high ESP (>15%), the soils of pedons P3 and P6 were put under sodic phase of Typic Haplustepts. The P5 soils were placed into suborder Aquepts due to presence of aquic moisture as evidenced by colour of 2.5Y hue and reduced mottlings, and qualify for great group Haplaquepts because of absence of differentiating characteristics of other great groups of suborder Aquepts and placed under subgroup Typic Haplaquepts. The P7 soils have an argillic horizon, as evidenced by the presence of thick continuous clay cutans and supported by increase in clay content in adjacent argillic horizon than the overlying eluviated horizon by 20 per cent and these were classified as Alfisols. Since these soils have ESP >15 and and base saturation of >35%, these were keyout as Natrustalfs great group and qualify for Typic Natrustalfs (subgroup).

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