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Characterization, Classification and Productivity Potential of Vertisols and Associated Soils of Bihar

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Abstract: *The fine textured soils of sedentary and old alluvial origin are characterized by uniform colour (brown to very dark grey), mottles of various shades and intensities, neutral to slightly alkaline reaction, low organic carbon and high clay content and high CEC and SiO_2 content. They have developed on varied types of parent materials at different physiographic levels under basic environment and impeded drainage. The Chour land soils of young alluvial region are characterized by various shades of grey colour, clay to loam texture with lithological discontinuity, lower CEC and high SiO_2 content. They have developed in bowl shaped physiography on alluvium. The decrease in CEC, cations and clay with depth is suggestive of their younger origin. The sedentary soils have been classified as Udic Chromusterts, old alluvial soils as Udorthentic chromusterts and chour land soils as Vertic Ustorthents. These soils have an average productivity and good potentiality. The productivity can be raised by 1.8 to 2.0 times by adopting appropriate measures.* (**Key Word** : *Classification, genesis, potential, CEC, pedoturbation*).

Vertisols and associated soils of sedentary as well as alluvial origin are of common occurance in the districts of Nawadah, Gaya, Patna, Rohtas, Bhojpur and Begusarai in Bihar. An adequate information on characterization, classification and productivity potential of these soils is lacking. In view of this the investigation was undertaken.

MATERIAL AND METHODS

The study area lies between 24°31' and 25°13'N Lat. and 84°11'59" and 86°10'10"E Long. covering parts of Nawadah, Rohtas, Bhojpur and Begusarai districts. The elevation varies from 40 to 116 m MSL. The topography appears to be almost flat (< 1 % slope). The soils are poorly drained, and in rainy season, are almost flooded and inundation continues from 2 to 4 months.

The climate is subtropical, subhumid with well expressed summer (March to June), rainy season (June to October) and cold season (November to February). The mean annual precipitaion varies from 1097 to 1258 mm, receiving 84 to 89 per cent during June to September. The highest annual temperature ranges between

41.7 and 45.2^{o}C and lowest around 7^{o}C. The mean annual (air) temperature (MAT) varies form 25.3 to 26.7^{o}C. The annual precipitation covers 63 to 70 per cent of the potential evapotranspiration. The control section of soils may remain moist in some parts for more than 180 cumulative days and dry for 60 consecutive and / or more than 90 cumulative days in a year. It qualifies for ustic moisture regime and hyperthermic temperature regime.

The five pedons representing most common series; sendua (sedentary), Pithwaiya (old alluvial soils) and Aurahi (chour land soil) were studied (Table 1) and morphology was described (Soil Survey Staff 1951). The total elemental analysis of soils were done by fusing soils with anhydrous Na_2CO_3 at 850^{0}C. Soils were classified as per Soil Taxonomy (soil Survey Staff 1975). The soil productivity (p) and potentiality (p') indices were evaluated on the basis of Riquier *et al.* (1970) by considering important soil characteristics.

RESULTS AND DISCUSSION.

The morphological characteristics (Table 2) indicated that almost all the soils except chour landsoil (Pedon 5) have charateristics of typical Vertisols viz. uniform soil (Pedon 5) have characteristics of typical Vertisols viz. uniform colour ranging from brown of various shades to very dark grey. The sedentary soils (Pedons 1 &2) and old alluvial soils of Sone Command (Pedons 3 &4) have lower organic carbon content (0.3 to 0.5%). The soils are poorly drained and remain moist for longer period providing conditions for reduction of the ions consequently leading to darker colour. Subdued shades like grey indicate higher degree of hydration and reduction of Fe and Mn. Yellow tinge of colour might be due to hydrated iron oxide (Fe_2O_3, $3H_2O$). The role of organic matter and smectite clay minerals is evident in chour land soils (Pedon 5) where colour has changed from darker to lighter side with decreasing organic matter and clay content. Mottles and concretion have been generally noted in these soils. Periodic wetting and drying appears to be essential for the concretion formation, whereas more permanent wetness leads to mottling. In poorly drained hydromorphic soils, Fe and Mn are mobilised by reduction and after wards concentrated in various forms, among which mottles and concretions are the most frequent (Schwertmann & Fanning 1976). In these soils (sedentary and old alluvial) distinct horizonation is

TABLE 1. General descriptions of the area

Variables	Pedon-1	Pedon-2	Pedon-3	Pedon-4	Pedon-5
Soil Series :	Sendua	Sendua	Pithwajya	Pithwaiya	Aurahi
Locations :					
Lat. :	$24^0$32' N	24^0 31' N	25^0 12'30" N	25^0 12'31" N	25^0 05'40" N
Long. :	85^0 24' 30" E	$85^0$23'30"E	$84^0$12" E	$84^0$11'59" E	$86^0$10'10" E
Elev. :	110 M	116 m	105 m	107 m	40 m
Land Use :	Paddy, Wheat, Paddy-Paira Sugarcane-fallow (Rainfed)	Virgin	Paddy-Paira/ Wheat (two crops)	Paddy-paira/ Wheat (two crops)	Wheat, Gram, Rai, etc. (mono cropped)
Slope(5) :	0-1	0-1	0-1	0-1	0-1
Aspect :	WE	WE	WE	WE	SN
Land form :	Lower fringe of the upland rolling physio-graphy	Upland with subnormal relief	Low land with normal relief	Medium upland with normal relief	Low land (depression)
Permeability :	Very slow	Slow	Very slow	Very slow	Moderate
Erosion :	Slightly sheet erosion	Moderately sheet erosion	Very slow Nil	Very slow Nil	Moderate Nil
Depth of water table					
Wet season :	300-450 cm	300-450 cm	150-210 cm	150-210 cm	Flodded
Dry season :	1200-1350 cm	1200-1350 cm	300-450 cm	300-450 cm	200-350 cm
Rivers :	-	-	Sone, Dharm-auti	Sone, Goria	Gandak and rain water
Soil Classification :	Udic Chromusterts	Udic Chromusterts	Udorthentic Chromusterts	Udorthentic Chromusterts	Vertic Ustorthents

lacking due to haplodization by argillipedoturbation.This is also evident from the uniform distribution of organic carbon and high clay content within the pedons. Shining-pressure faces and intersecting slickensides are the results of high shrink-swell potential of the soils. The parallel epipeds with their long axes tilted at angle between 25 and 50^0 from horizontal plane denote the dominance of haploidization inhibiting horizon differentiation leading to the development of AC pedons (Buol *et al.* 1973). Vertic character of lower degree has also been noted in upper layers of Chour land soils (Pedon 5).

The particle size distribution (Table 3) shows that the soils are of

TABLE 2. Morphological descriptions of the soils

Horizon depth	Colour (moist)	Texture	Structure	Consistancy	Efferv. (HCL)	Boundry	Mottles	Remarks
Sedentary Soils: Pedon 1, Shahpur, low land								
Ap (0-35)	10YR 5/4	C	m2 abk	mfi	eo	gs	fif 10YR 5/6	2 to 7 cm wide and 80 cm deep,
A11 (35-62)	10YR 5/4	C	m3 abk	mvfi	eo	gs	cif 10YR 5/6	Polygonal cracks, wedge blocks,
A12 (62-88)	10YR 5/3	C	c3 abk	mvfi	eo	cs	c2d 10YR 5/6	slicken sides, conca and consirs
AC (88-135)	10YR 5/2	SiCl	c3 abk	mvfi	es	-	m2d 10YR 5/6	
Pedon 2, Uparidih, upland								
A (0-22)	10YR 5/3	C	m2 abk	mfi	eo	gs	nil	2 to 5 cm wide and 100cm deep,
A11 (22-73)	10YR 5/3	C	m3 abk	mefi	eo	ds	c2f 10YR 5/4	Polygonal cracks, wedge blocks,
A12 (73-130)	10YR 5/3	C	c3 abk	mefi	eo	-	c2f 10YR 5/4	slicken sides, conca and consirs
Old alluvial soils: Pedon 3, Karmaini, lowland								
Ap (0-20)	2.5YR 4/2	C	m2 abk	mfi	eo	cs	nil	2 to 7 cm wide and 60 cm deep,
A11 (20-60)	2.5YR 4/2	C	c3 abk	mfi	eo	gs	nil	polygonal cracks, wedge blocks,
A12 (60-107)	2.5YR 4/2	C	m2 abk	mfi	eo	ds	fif 10YR 5/4	slicken sides, conca and consirs
AC (107-155)	2.5YR 3/2	C	m2 abk	mfi	eo	-	fif 10YR 5/4	
Pedon 4, Karmaini, Upland								
Ap (0-30)	10YR 4/4	C	m2 abk	mfi	eo	cs	ccd 7.5YR 4/4	2 to 7 cm wide and 90 cm deep,
A11 (30-57)	10YR 4/3	C	c3 abk	mvfi	eo	gs	fif 10YR 5/4	Polygonal cracks, wedge blocks,
A12 (57-92)	10YR 4/3	C	m2 abk	mfi	eo	gs	fif 10YR 5/6	slicken sides, conca and consirs
A13 (92-130)	10Yr 4/2	C	ml abk	mfi	eo	as	fif 10YR 5/4	
AC (130-155)	10YR 4/3	Cl	massive	mfi	es	-	c3p 10YR 4/6	
Young alluvial soils: Pedon 5, Kushmnaut chour, low land								
Ap (0-21)	5Y 3/4	C	m2 abk	mfi	eo	cs	nil	vertical and hori-
A1 (21-44)	5Y 3/1	C	ml abk	mfi	eo	eo	nil	zontal cracks upto
IIC (44-62)	5Y 4/1	C	m2 abk	mfi	eo	cs	cld 10YR 5/4	third layer, clay skins
IIIC (62-91)	5Y 5/1	Cl	massive	ml	eo	cs	c2d 10YR 5/6	
IVC (91-120)	5Y 5/1	L	massive	ml	eo	-	nil	

TABLE 3. Organic carbon and $CaCO_3$ contents in soils and particle size distribution

Horizon & depth cm	OC (%)	$CaCO_3$ (%)	Sand		Silt (<0.02-0.002mm)	Clay	
			Coarse (>0.2,)	Fine (0.2-0.02 mm)		Coarse (<0.002-0.001mm)	Fine (<0.001 mm)
Sedentary soils: Pedon 1, Shahpur, lowland							
Ap (0-35)	0.27	0.5	1.2	14.9	35.0	15.6	33.3
A11(35-62)	0.26	1.0	1.4	15.8	34.6	18.5	29.7
A12 (62-88)	0.23	1.0	1.2	15.2	35.5	14.6	33.6
AC (88-135)	0.18	7.3	1.4	17.3	36.3	8.2	36.8
Pedon 2, Uparidih, upland							
A (0-22)	0.42	0.5	3.5	15.7	33.0	12.9	34.9
A11(22-73)	0.30	0.5	2.5	16.2	33.8	10.4	37.1
A12 (73-130)	0.27	0.5	2.4	16.0	32.7	10.3	38.5
Old alluvial soils: Pedon 3, Karmaini, lowland							
Ap (0-20)	0.39	0.5	1.5	21.3	22.1	11.7	43.4
A11(20-60)	0.33	0.2	1.5	24.9	21.0	11.6	41.9
A12 (60-107)	0.29	0.5	1.3	23.3	21.0	11.6	42.8
A13 (107-155)	0.23	0.5	1.3	23.3	20.0	11.4	44.1
Pedon 4, Karmaini, upland							
Ap (0-30)	0.33	0.4	1.3	24.9	21.3	12.4	40.2
A11(30-57)	0.30	0.4	1.2	23.8	20.7	10.9	43.4
A12 (57-92)	0.29	0.4	1.3	26.4	20.4	8.7	43.2
A13 (92-130)	0.22	0.2	1.2	27.2	21.8	8.9	41.0
AC (130-155)	0.08	4.1	1.2	34.4	24.4	9.9	30.1
Pedon 5, Kushmhaut Chour, lowland							
Ap (0-21)	0.59	0.4	nil	12.8	32.4	13.5	41.3
A1 (21-44)	0.43	0.4	nil	13.6	32.5	13.7	40.2
IIC (44-62)	0.34	0.3	nil	22.1	35.1	13.4	39.4
IIIC (62-91)	0.21	0.2	nil	31.5	34.3	13.4	39.4
IVC (91-120)	0.10	0.2	nil	35.2	41.6	12.1	11.1

clay in texture. In old alluvial soils of Sone Command (Pedons 3 & 4), coarse and fine sand fractions are present with higher amount of clays, as these soils have developed on alluvium brought by the river Sone, which brings even coarse sand with it. However, the influence of parent material is also visible in the depthwise distribution of clay and sand fractions in sedentary soils (Pedons 1 & 2) developed on micaceous schist and granite gneiss. The textural variation in lower layers of Chour land soils (Pedon 5) suggest lighological break. This may be due to change in fluvial nature of the soils.

The physiochemical characteristics (Table 4) show that these soils are neutral to slightly alkaline in reaction (pH 6.8 to 7.7). In old alluvial soils of Sone Command and Chour land soils, the pH increases with depth. This may be due to loss of bases from upper layers by rain and flood water.

The CEC may be attributed to high content of fine clay and dominance of smectite mineral. The higher values and small variation in CEC with depth (Pedon 1 to 4) is due to haploidization as reported by Raychaudhury *et al.* (1943), Das and Das (1966), Challa and Gaikawad (1986) and Diwakar and Singh (1992) for Vertisols of India. Among the exchangeable cations, Ca was dominant followed by Mg, Na and K. The highly significant correlation was observed between clay content and exchangeable Ca, Mg and K ($r = 660$; 0.468 and 0.748); and of pH with exchangeable Ca and Na ($r = 0.642$ and 0.443), respectively. The soils are highly base saturated (91 to 97%).

The chemical compositions of the soils (Table 5) suggest that the soil forming processes operative are varied. On the basis of SiO_2 content, these soils can be put under different groups, i.e. sedentary soils having high SiO_2 content (68.3 to 74.2%), old alluvial soils of Sone region with low (62 to 69.1%) and Chour land soils with variable SiO_2 content (61.9 to 72.2%). The parent material seems to have influenced the SiO_2 content. Contrary to the silica content, sesquioxide appears to be highest in Chour land soils. These soils have high Fe_2O_3 (2.1 to 3.6%), CaO (2.87 to 5.81%), MgO (1.03 to 2.63%) and K_2O (2.34 to 4.22%). This is in conformity with the findings of Diwakar and Singh (1992) in Tal land soils of Bihar.

The sedentary soils (Pedons 1 &2) have developed on a mixed type of parent materials like granite-gneiss, mica-schist, etc., and fit well in the general observation made by a host of worker in relation to the genesis of Vertisols of Peninsular India. It is further seen that the sedentary soils

TABLE 4. Physicochemical characteristics of the soils

Horizon	pH	EC	CEC	Exch. cations (c mol(P$^+$) kg^{-1})				BS (%)
		(dSm^{-1})	(c mol(p$^+$) kg^{-1})	Ca	Mg	Na	K	
Sedentary soils: Pedon 1, Shahpur, lowland								
Ap	7.3	0.07	44.1	33.3	7.6	0.3	0.8	95
A11	7.4	0.09	45.5	35.5	7.5	0.5	0.7	97
A12	7.5	0.05	55.9	40.2	10.9	0.4	0.7	93
AC	7.6	0.11	62.8	43.8	13.4	1.2	0.8	94
Pedon 2, Uparidih, upland								
A	7.5	0.06	41.0	32.7	5.3	0.6	0.8	96
A11	7.4	0.06	42.4	32.9	5.4	0.5	0.7	93
A12	7.4	0.09	42.4	32.8	5.4	1.0	0.8	94
Old alluvial soils: Pedon 3, Karmaini, lowland								
Ap	7.1	0.03	39.9	23.7	12.1	1.3	0.8	95
A11	7.3	0.03	43.9	28.4	10.8	1.8	0.7	94
A12	7.2	0.17	41.6	29.0	7.8	2.5	0.8	97
A13	6.9	0.17	41.5	28.9	7.7	2.5	0.8	96
Pedon 4, Karmaini, upland								
Ap	7.0	0.12	34.6	22.2	7.5	1.7	0.6	92
A11	7.2	0.09	35.2	22.2	7.5	2.1	0.6	92
A12	7.4	0.17	38.6	22.1	10.7	1.6	0.6	91
A13	7.4	0.17	34.9	22.1	10.7	1.5	0.6	94
AC	7.7	0.20	47.6	30.9	11.6	1.3	0.6	93
Young alluvial soils: Pedon 3, Kushmhaut Chour lowland								
Ap	6.9	0.14	34.2	21.3	8.6	0.8	0.9	92
A1	6.8	0.14	33.6	21.1	8.4	0.5	0.9	92
IIC	7.0	0.19	30.8	17.7	10.2	0.5	0.7	94
IIIC	7.1	0.17	20.4	11.6	6.5	0.3	0.5	93
IVC	7.2	0.18	16.2	8.8	6.1	0.2	0.2	94

have been found to develop irrespective of physiographic situation. It maybe presumed that the formation of heavy (fine) soils may take place at different physiographic levels provided the soil forming environment is basic and drainage impeded .This becomes still clear when we observe the morphology of pedons 1 (lowland) and 2 (upland), where

TABLE 5. Chemical composition of the soils

Horizon depth (cm)	SiO_2 (%)	R_2O_3 (%)	Al_2O_3 (%)	Mn_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	K_2O (%)	P_2O_5 (%)
Sedentary soils: Pedon 1, Shahpur lowland									
Ap	72.24	15.01	11.66	0.07	3.26	3.62	2.09	2.54	0.02
A11	69.99	15.39	12.12	0.10	3.12	2.90	2.62	2.40	0.05
A12	70.40	16.15	13.05	0.09	2.96	3.63	1.57	2.47	0.05
AC	68.31	18.59	15.55	0.07	2.90	4.38	2.62	2.53	0.08
Pedon 2, Uparidih, upland									
A	74.23	21.30	18.50	0.05	2.70	5.81	2.10	2.37	0.05
A11	71.73	19.27	15.98	0.05	3.16	5.09	1.57	2.48	0.09
A12	73.08	16.03	12.97	0.06	2.96	5.11	2.11	2.35	0.04
Old alluvial soils: Pedon 3, Karmaini, lowland									
Ap	62.06	21.51	18.19	0.05	3.22	3.71	1.60	2.67	0.05
A11	61.98	24.66	21.23	0.05	3.32	3.62	1.05	2.54	0.06
A12	62.23	19.53	16.17	0.04	3.26	4.36	1.05	2.34	0.06
A13	63.87	20.50	17.19	0.05	3.42	3.62	1.05	2.50	0.06
Pedon 4, Karmaini, upland									
Ap	67.64	17.13	13.55	0.05	3.47	3.61	1.04	2.46	0.06
A11	67.14	20.62	17.36	0.04	3.16	3.61	1.05	2.60	0.06
A12	69.14	19.66	16.16	0.04	3.42	3.60	0.51	2.73	0.04
A13	65.48	16.13	12.40	0.05	3.62	2.87	2.07	3.06	0.06
AC	66.77	15.73	12.85	0.05	2.76	4.99	1.03	2.70	0.07
Young alluvial soils: Pedon 3, Kushmhaut Chour lowland									
Ap	65.12	24.52	21.53	0.05	2.90	4.51	1.54	4.22	0.04
A1	62.84	27.47	24.52	0.05	2.90	3.86	1.43	4.16	0.05
IIC	61.91	27.65	24.51	0.04	3.10	3.92	1.97	4.30	0.16
IIIC	68.75	21.87	19.07	0.04	2.76	4.45	1.04	3.85	0.14
IVC	72.18	18.28	16.11	0.04	2.13	4.40	1.38	3.52	0.14

mottles have been observed under both the conditions. The soils of old alluvial region have developed on alluvium brought by the river Sone in bowl shaped physiography where water stagnates. The overall properties of these alluvial soils lead to believe that the heavy textured and dark coloured soils, classified later on as Vertisols may develop on alluvium provided there is a sufficient period for water stagnation. The paucity of leaching conditions signifies the calcification as the predominant process coupled with haploidization. However, this is not true fully in Chour land soil, which are neutral in reaction and pH increases down the depth and has got higher organic carbon content in the surface layers and fine sand fractions in the lower layers. CEC and exchangeable cations alongwith the clay content which do not increase with depth, are suggestive of their younger nature from origin point of view, although vertic characters have been noted in this pedon.

Soil Classification: The sedentary as well as old alluvial soils (Pedon 1 to 4) are marked by wide and deep cracks and sometimes gilgai microrelief on the surface and have been classified as Chromusterts because of the following considerations :

- Crack exceeding a width of 1.0 cm upto the depth of 50 cm or more which remain open for 90 or more cumulative days.
- Very fine to fine particle size class having more than 30 per cent clay at a depth of 100 cm and below.
- Intersecting slickenside forming parallel epipeds.
- No lithic or paralithic contact within 50 cm from the surface.
- Moist chroma more than 1.5 (2 to 4) through out the upper 30 cm layer.
- MAST more than 22^{0}C (27.1 to 28.3^{0}C).
- MSST (29.9 to 32.3^{0}C) and MWST (21.4 to 22.2^{0}C) differ by more than 5^{0}C.

The sedentary soils (Pedons 1& 2) differ from Typic Chromusterts in (a) colour value (moist) above 3.5 (5.0) (dry) alluvial soils of Sone Command (Pedon 3 & 4) differ from Typic Chromusterts in (a) Value (moist) above 3.5 (4.0) and (c) the cracks that remain open only from 70 to 150 cumulative days in a year and thus placed under Udorthentic Chromusterts.

The Chour land soils of young alluvial region (Pedon 5) are marked by their recent origin (lacking diagnostic horizons) and lithological discontinuity. These soils are classified as Vertic Ustorthents because of the following consideration :

- An ochric epipedon.
- Regular decrease in organic carbon content with depth.
- Fine particle size class having more than 30 per cent clay at a depth of 100 cm.

TABLE 6. Range of soil properties

Pedons	Soil moisture (below wilting (H)	Drainage (flooding) (D)	Effective soil depth (P)	Texture (T)	Nutrient A- horizon (% base saturation) (N)	Organic matter (%) (O)	CEC (cmol (+) kg^{-1}) (A)	Mineral suits in sand fractions Or	pl	Mu	Qu	Ot	Mineral derived from
Shahpur (Sedentary)	3 months	2-4 months	Very deep	Clay	93-97	0.31-0.46	73-76	5+	1+	3+	4+	2+	basic
Uparidih (Sedentary)	3 months	2-4 months	very deep	clay	91-95	0.46-0.71	72-75	5+	1+	3+	4+	2+	basic
Karmaini (Old alluvial)	3 months	2-4 months	very deep	clay	94-97	0.39-0.66	65-92	4+	2+	1+	5+	3+	basic rock
Karmaini (Old alluvial)	3 months	2-4 months	very deep	clay	91-94	0.14-0.56	66-87	4+	2+	1+	5+	3+	basic
Kushmhaut Chour (Young alluvial)	3 months	2-4 months	very deep	clay	88-95	0-17-1.00	55-70	1+	4+	5+	3+	2+	basic rock

Or- Orthoclase, Pl-Plagioclase, Mu-Muscovite, Qu-Quartz, Ot- others

- Ustic moisture regime and hyperthermic temperature regime.
- EC less than 2 dSm^{-1} at $25^{0}C$ (0.03 to 0.20 dSm^{-1}).
- Cracks at some period in most years that are 1 cm or more wide at a depth of 30 cm.
- Dominance of 2:1 lattice type of clay minerals.

Accordingly, these soils may be classified as Fine, montmorillonitic, hyperthermic, Udic Chromusterts (Sedentary soils); (old alluvial soils developed on Sone alluvium), and Fine, illitic, hyperthermic, Vertic Ustorthents (Chour land soils) upto the family level.

Soil productivity and potentiality: On the basis of the soil characteristics (Table 6), the productivity and potentiality ratings were worked out (Table 7). These soils have an average productivity and good potentiality which is attributed to low organic matter, high smectitic clay and poor drainage. These soils are monocrop-

TABLE 7. Productivity (P) and potentiality (P^1) index of the soils (Rating class with assigned values)

P/P^1	Coeff. of impt. (P^1/P)	H	D	P	T	N	O	A	M	X*	p/p^1 class
Shahpur (Udic Chromusterts)											
29.07	2.0	H4b(90)	D2b(50)	P6(100)	T5b(80)	N5(100)	O1(85)	A3(100)	M2C(95)	5.32	3/II
58.52		H5(100)	D3a(70)	P6(100)	T5b(80)	N5(100)	O3(100)	A3(100)	M2C(95)		
Uparidih (Udic Chromusterts)											
29.07	2.0	H4b(90)	D2b(50)	P6(100)	T5b(80)	N5(100)	O1(85)	A3(100)	M2C(95)	5.32	3/II
58.52		H5(100)	D3a(70)	P6(100)	T5b(80)	N5(100)	O3(100)	A3(100)	M2C(95)		
Karmaini (Udorthentic Chromusterts)											
32.30	1.8	H4C(100)	D2b(50)	P6(100)	T5b(80)	N5(100)	O1(85)	A3(100)	M2C(95)	5.32	3/II
58.52		H5 (100)	D3a(70)	P6(100)	T5b(80)	N5(100)	O3(100)	A3(100)	M2C(95)		
Karmaini (Udorthentic Chromusterts)											
32.30	1.8	H4C(100)	D2b(50)	P6(100)	T5b(80)	N5(100)	O1(85)	A3(100)	M2C(95)	5.32	3/II
58.52		H5(100)	D3a(70)	P6(100)	T5b(80)	N5(100)	O3(100)	A3(100)	M2C(95)		
Kushmhaut (Chour Vertic Chromusterts)											
20.52	2.0	H4C(100)	Dlb(30)	P6(100)	T5b(80)	N5(100)	O1(85)	A3(100)	M2C(95)	3.80	3/II
41.80		H5(100)	D2b(50)	P6(100)	T5b(80)	N5(100)	O3(100)	A3(100)	M2C(95)		

The symbols used according to Riquier *et al.* (1970)
H-Soil moisture content, D-drainage, P-effective depth of the soil, T-texture and structure of root zone, N-average nutrient content of A horizon, O-organic matter content in Al horizon, A-mineral exchange capacity and nature of clay, M-reserve of weatherable minerals in B horizon, X-10% of claculated potentiality; Coeff. impt- Coefficient of improvement.

ped due to long severe dry period in every year. The productivity of these soils can be reised by 1.8 to 2.0 times as is revealed from the doefficient of improvement (p^1/p).

This corroborates the findings of Raj Kumar *et al. (1984) for Vertisols and entisols.*

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