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Soil Morphological, Physical and Chemical Characteristics of Chandan River System

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Abstract: Nine pedons representing tal and upland physiography were selected for detailed investigation of the soils under Chandan river system of Banka and Bhagalpur district of south Bihar. Tal soils were light gray to dark gray in color, clay to clay loam in texture and old alluvium soils were gray to grayish yellow in color, heavy textured with wide cracking fall under the watershed of Chandan river. The upland physiography of old alluvial soils under immediate influence of the river Chandan are characterized by Yellowish brown in colour, sandy loam to sandy clay loam in texture, presence of low organic carbon, neutral to slightly alkaline reaction (pH 6.4 -7.7), very slow to slow hydraulic conductivity, lower CEC, while the soils on upland, under immediate influence of Chandan river are light olive in colour, sandy loam to sandy –clay- loam.

Additional keywords: River Chandan, saturated hydraulic conductivity, CEC, soil physico- chemical properties

Introduction

The Chandan river originates from the northern part of Deoghar hills and terminates in the river Ganga in the lower regions. Chandan river system occupies major areas of Banka and Bhagalpur districts of South Bihar covering an area of approximately 64 thousand ha. Soils of this region are alluvial; among the group of most fertile soils of the country. The clayey texture of such soils is either from the basic nature of parent materials in the mountain regions or from the sedimentation process in wide flood plains. The Chandan river, being the largest hill stream in south Bhagalpur, this river system has a topographical variability which has contributed greater extent to soil formation in respect to soil depth, textural classes, fertility status, water retaining character and several other physical and chemical characters. Present investigation has been undertaken to characterize and classify the soils of Chandan river system which is considered to be useful for improving agriculture livelihood of this area by the means of providing information about soil and its scientific management. The main factors affecting utilization of irrigation water in Chandan irrigation project are unpredictable supply of water, improper maintenance, inadequate micro-distribution system and lack of coordination.

Materials and Method

The study areas lies between 24°48' - 25°16' N latitudes and between $86^0$45' - 87°04' E longitudes situated under Chandan Command area. This geographical location belongs to Bhagalpur and Banka districts of South Bihar and covers an area of 64,000 ha approximately. The climate of the area is sub-tropical and sub-humid with annual precipitation of around 1200 mm covering 63 to 70 per cent of the potential evapotranspiration. The minimum and maximum temperature ranges between 10.2 and 36.5°C. The rainfall varies from 1135 mm to 1200 mm. The mean annual temperature (MAT) varies from 28.8 to 36.5°C. Natural vegetation varied considerably with altitude and aspect. The soils may remain moist in some parts of control section for more than 180 cumulative days and dry for 60 consecutive and/or more than 90 cumulative days in a year (Table 1).

Table 1. Site characteristics

Pedons	Location	Altitude (meter)	Slope (%)	Erosion	Natural vegetation
P1	Khiri Pagar, $24^0$48'N Latitude, $86^0$48'E Longitude	70	2-3	Nil	Doob (*Cynodon dactylon*), Tetar (*Launea pinnutifolia*), Bathua (*Chenopodium album*), Mango (*Mangifera indica*)
P2	KVK, Banka, $24^0$55'N Latitude, $86^0$55'E Longitude	67	1-2	Nil	Doob (*Cynodon dactylon*), Bathua (*Chenopodium album*), Babool (*Acacia Arabica*)
P3	Karma, $24^0$57'N Latitude, $86^0$57'E Longitude	64	0-1	Nil	Doob (*Cynodon dactylon*), Tetar (*Launea pinnutifolia*), Bathua (*Chenopodium album*), Mango (*Mangifera indica*)
P4	Baniyachak, $24^0$48'N Latitude, $86^0$48'E Longitude	50	0-1	Nil	Doob (*Cynodon dactylon*), Tetar (*Launea pinnutifolia*), Bathua (*Chenopodium album*), Mango (*Mangifera indica*)
P5	Rutpai, $25^0$03'N Latitude, $86^0$45'E Longitude	46	0-1	Nil	Doob (*Cynodon dactylon*), Babool (*Acacia Arabica*), Neem (*Melia aradirachata*), Gumma (*Leucas aspera*), Peepal (*Ficus religious*)
P6	Akarbarnagar, $25^0$13'N Latitude, $86^0$50'E Longitude	35	0-1	Nil	Doob (*Cynodon dactylon*), Gumma (*Leucas aspera*), Palm (*Borassus flabellifer*), Gorkhul (*Tribulus terrestris)*
P7	Rajpur, $25^0$14'N Latitude, $87^0$04'E Longitude	39	0-3	Nil	Doob *(cynodon dactylon*), Tetar (*Launea pinnutifolia*), Babool (*Acacia Arabica*), Mango *(Mangifera indica*)
P8	English Farka, $25^0$14'N Latitude, $87^0$04'E Longitude	37	0-1	Nil	Doob (*cynodon dactylon*), Babool (*Acacia Arabica*), Kataiya (*Argemone mexicana*)
P9	Kasil Kharwa, $25^0$16'N Latitude, $87^0$04'E Longitude	40	0-5	Nil	Doob (*Cynodon dactylon*), Mango (*Mangifera indica*)

Therefore, it qualifies for Ustic moisture regime and Hyperthermic temperature regime. Natural vegetation in the study varied considerably with altitude and aspect. A field investigation of the area was conducted as per procedures outlined by AIS&LUS (1970). Representative nine pedons (P_1 to P_9) at each site were studied for their site characteristics (upland, middle and lower areas) and morphological properties (boundary, colour (moist), texture, structure and consistence (moist/dry) (Table 1) following standard procedures (Soil Survey Staff 1966) and sampled depth-wise (0-100 cm) for laboratory characterization as per standard analytical techniques (Black 1965; Jackson 1973). The soils were studied and described in the field for their morphology as per the soil survey manual (Soil Survey Staff 1951). Colour of the horizons was noted by using Munsell Colour Notations. The mechanical analysis of each soil layers was done by International pipette method followed by using International textural triangle. The water stability of aggregates was worked out with the wet sieving method (Tiulin 1928). Total porosity was calculated by determining the particle density and bulk density of soil by using the formula (Hillel 1971). Infiltration rate (by using double ring Infiltrometers, Bertrand 1965); Soil penetration rate (with the help of cone Penetrometer - Davidson 1965) and others were also determined *in situ*. Core samples were also collected for determination of hydraulic conductivity (Klute 1965) and using formula of Richards (1954) and bulk density in lab (Biswas *et al.* 1961). Soil pH was determined with the help of glass electrode pH meter (Jackson 1978). Electrical conductivity was determined with the help of conductivity bridge (Jackson 1978). Free $CaCo_3$ was determined by the rapid titration method by Piper (1950). Organic carbon was determined by Walkely and Black (1934) rapid titration method (Jackson 1978). The total CEC of soil was determined by Schollenberger and Simon's method, 1945. Exchangeable Ca^{++} and Mg^{+++} were determined by versenate titration (EDTA) method (Jackson 1978). Exchangeable Na^+ and K^+ were determined separately in the ammonium acetate leachate of the soil with the help of flame photometer (Jackson 1978).

Results and Discussion

Soil morphology

The data revealed (Table 2) that under moist condition, the colour of the soils from pedon I to III varied from brown to yellowish brown; pedon IV to VI, varied from dark grayish brown to light olive brown and pedon VII to IX; varied from dark yellowish brown to dark grayish brown. This difference in colour may be attributed to the organic matter, high clay content, presence of sufficient iron and manganese compounds and their hydration (Diwakar and Singh 1992).

The lower boundaries of surface horizons of these soils were clear and smooth indicated relatively well defined stratification of these soils and thus suggesting somewhat imperfect horizonation as affected solely by pedo-chemical processes, where as the lower boundaries of sub-surface horizons were generally gradual and smooth with few exceptions of the lower layers of pedon V, where they were diffused and smooth and pedon VI where they were abrupt and wavy.

The structure of these soils was angular to sub-angular blocky with variable grades (moderate, week to strong) in general except in bottom layers of pedon V where it was platy (coarse). The relative distribution of cations like Ca^{2+}, Fe^{2+} etc. along with organic matter appear to be influencing the development of mostly angular blocky structures (Diwakar and Singh 1992; Diwakar 2005).

The consistence of the soils was generally very hard, very sticky and plastic and very firm, under dry, wet and moist conditions with extremely hard and extremely firm in the lower layers of the pedons. All these soils have been found to be very plastic. It might be attributed to the dominance of smectite group of clay minerals along with the clayey texture of the soils. (Diwakar and Singh 1992).

Table 2. Morphological characteristics of soils

Pedons	Depth (cm)	Boun-dary	Colour (moist)	Texture	Struc-ture	Consistence (Moist/Dry)
	0-10	cs	10YR 5/3	Sandy loam	sbk	mfi
	10-21	cs	10YR 5/4	Sandy loam	sbk	mfi
Pedon1	21-48	-	10YR 4/2	Sandy clay loam	sbk	mfi
	48-66	-	10YR 5/3	Sandy clay loam	sbk	mfi
	66-101	-	10YR 5/4	Sandy clay loam	sbk	mfi
	0-10	cs	10YR 5/3	Sandy Loam	sbk	mfi
Pedon 2	10-24	cs	10YR 5/4	Sandy clay loam	abk	dh, mfi
	24-36	cs	10YR 4/3	Sandy clay loam	abk	mfi
	36-52	gs	10YR 3/4	Sandy clay loam	sbk	mfi
	52-75	cs	10YR 4/3	Sandy loam	sbk	mfi
	0-16	cs	10YR 5/3	Sandy clay loam	m 2 abk	mfi
	16-32	cs	10YR 5/4	Sandy clay loam	abk	mvfi
Pedon 3	32-64	gs	10YR 3/4	Sandy clay loam	m 2 abk	mefi
	64-85	gs	10YR 3/4	Sandy clay loam	sbk	mefi
	85-130	-	10YR 5/4	Sandy clay loam	abk	mefi
	0-20	-	10YR 4/2	Clay	m 2 abk	mfi
Pedon 4	20-45	-	10YR 3/2	Clay	m 2 abk	mfi
	45-100	-	10YR 4/2	Clay	m 2 abk	mfi
	100+	-	10YR 4/2	Clay	m2abk	mfi
	0-20	cs	2.5Y 4/4	Clay	m 2 abk	dvh, wvs, wvp, mvfi
	20-55	gs	2.5Y 4/4	Clay	c 2 abk	deh, wvs, wvp, mefi
Pedon 5	55-95	gs	2.5Y 5/4	Clay	c 2 abk	deh, wvs, wv, pmefi
	95-120	ds	2.5Y 4/4	Clay	c 2 abk	deh, wvs, wvp, mefi
	120-150	-	2.5Y 4/4	Clay	c 2 pl	deh, wvs, wvp, mefi
	0-15	cs	2.5Y 5/2	Clay	c 3 abk	dvh, wvs, wvp, mvfi
	15-34	aw	2.5Y 4/2	Clay	m 2 abk	dvh, wvs, wvp, mvfi
Pedon 6	34-80	gs	2.5Y 7/4	Clay loam	f 2 sbk	dvh, wvs, wvp, mvfi
	80-115	gs	2.5Y 6/4	Clay loam	f 2 sbk	dvh, wvs, wvp, mfi
	115-150+	-	2.5Y 6/6	Clay	m 2 abk	dvh, wvs, wvp, mvfi
	0-30	cs	10YR 3/4	Clay	m 2 abk	dvh, wvs, wvp, mfi
	30-65	gs	10YR 3/4	Clay	m 2 abk	dvh, wvs, wvp
Pedon 7	65-90	cs	10YR 3/4	Clay	m 3 abk	dvh, wvs, wvp
	90-132	gs	10YR 3/3	Clay	m 3 abk	dvh, wvs, wvp
	132-172	-	10YR 3/2	Clay	m 3 abk	dvh, wvs, wvp
	0-20	cs	10YR 4/2	Clay	m 3 abk	dvh, wvs, wvp
	20-40	gs	10YR 4/2	Clay	m 2 3abk	dvh, wvs, wvp
Pedon 8	40-85	gs	10YR 4/2	Clay	f,m 2 abk	dvh, wvs, wvp, mfi
	85-125	gs	10YR 4/3	Clay	f,m 2 abk	dvh, wvs, wvp, mfi
	125-165	gs	10YR 3/2	Clay	f,m 2 abk	dvh, wvs, wvp, mfi
	0-20	cs	10YR 4/2	Clay	m 1 abk	dvh, wvs, wvp, mvfi
Pedon 9	20-54	cs	10YR 4/2	Clay	m 2 abk	dvh, wvs, wvp, mvfi
	54-100	gs	10YR 4/3	Clay	m cabk	dvh, wvs, wvp, mvfi
	100 +	-	10YR 4/2	Clay	m cabk	dvh, wvs, wvp, mvfi

Symbols as per Soil Survey Manual (AIS&LUS, 1970)

Physical characteristics

The particle size distribution (Table 3) indicates varied amount of sand and clay particles depending upon the distance of pedon from the river of Chandan. The textural classes of upper three pedons varied from sandy loam to sandy clay loam but medium to lower pedons were clay in texture. In general, the top soils (0-15 cm) had higher sand (64.60%) as compared to the lower layers (14.17%). It might be due to canal irrigation water siltation at the nearest point and also due to sudden decrease in threshold velocity for sand particles. Similarly, the decrease in threshold velocity for silt and clay particles may result in deposition of soil separates. The movement of clay from upper layer may also be resulted in increasing the clay content in lower layers due to puddled rice cultivation.

There was increase in bulk density in lower layers (Table 3) as compared to top soil. The highest bulk density in lower layers may be due to contribution of higher pH and development of sodicity in lower layers of some of the profiles. Similar result was observed by Pandey and Pathak (1975). The values of saturated hydraulic conductivity (Table 3) were in the range of very slow to slow hydraulic conductivity. It seems to be due to high bulk density, low organic matter, high pH and high clay content in lower layers. Similar result was observed by Nayer and Shukla (1943 a,b,c).

Perusal of the data presented in table 4 revealed that there was an increase in total aggregates with depth. The depth wise variation of micro and macro aggregates was differential. The micro aggregate generally decreased whereas macro aggregates increased with soil depth. This might be accentuated that an extra pressure generated due to fracture along with the wetting front in the lower layers of the pedons, was conductive to the generation of macro-aggregate at fastest rate. The depth wise increasing of macro-aggregate was also reported by Kauraw *et al.* (1983) and Diwakar and Singh (1992). Taking all the nine pedons into consideration, it seemed that clay mineral played an important role in the aggregation as there was significantly positive correlation of clay with total aggregate and macro- aggregate. This also confirms the findings of Krishnamurti and Singh (1975).

It is evident that total porosity of top layer i.e. 0-15 cm in all profiles were having higher values (50.94%) as compared to lower layer (36.92%) of the profiles (Table 4). This might be due to the contribution of higher amount of organic matter content in the top layer because of well aggregate formation as compared to lower layers. With the increase in depth of soil, the porosity will decrease because of compactness in the subsoil. This may also be due to higher organic matter content of the surface soil which might have resulted in the higher rooting density, further their decay in rice-wheat cropping system in surface soil. The higher amount of per cent pore space in lower layer may be due to higher clay content of soil in lower layers. The lowest values of per cent of pore space in lower soil layers might be due to lower organic carbon content and higher clay content. Similar results were obtained by *Baver* (1956).

There was a slight variation in final infiltration rate (Table 5) but all were in under low to very low class of infiltration rate which may impose salinity hazardous in due course of time. It is evident from table 6, that the penetration resistance was lower in surface soil (0-15 cm) as compared to lower layers and it increases with depth. There was a tendency of compaction development in subsoil layers. The effect of higher pH in lower layers may be helpful in increasing the value of soil penetration resistance resulting in lesser root penetration for lesser volume of soil to be exploited for water and nutrient uptake resulting thereby lower yield of crops (*Ehlers et al.* 1983). They reported a linear decline in penetration resistance with increase in soil water content.

Table 3. Physical characteristics of soils

Pedons	Depth (cm)	Particle-size distribution (%)				Bulk density (Mg/m^3)	Saturated hydraulic conductivity (cm/hr)
		Sand	Silt	Clay	Soil Texture		
P1	0-10	64.60	20.43	14.25	Sandy loam	1.49	0.195
	10-21	63.10	21.15	16.47	Sandy loam	1.52	0.270
	21-48	57.90	22.10	20.00	Sandy clay loam	1.65	0.300
	48-66	52.20	26.30	21.50	Sandy clay loam	1.64	0.280
	66-101	50.15	27.60	22.25	Sandy clay loam	1.64	0.240
P2	0-10	60.15	20.55	19.30	Sandy Loam	1.50	0.203
	10-24	56.30	21.15	22.55	Sandy clay loam	1.54	0.168
	24-36	54.10	19.40	26.50	Sandy clay loam	1.60	0.152
	36-52	60.45	12.40	27.15	Sandy clay loam	1.64	0.145
	52-75	60.10	20.40	19.50	Sandy loam	1.52	0.298
P3	0-16	60.15	20.35	19.50	Sandy clay loam	1.32	0.165
	16-32	57.10	22.15	20.75	Sandy clay loam	1.48	0.145
	32-64	53.15	24.30	22.55	Sandy clay loam	1.45	0.142
	64-85	49.15	27.30	23.55	Sandy clay loam	1.43	0.131
	85-130	45.10	27.40	27.50	Sandy clay loam	1.45	0.152
P4	0-20	22.32	24.60	53.08	Clay	1.49	0.090
	20-45	21.25	23.40	55.35	Clay	1.51	0.081
	45-100	21.10	20.25	58.65	Clay	1.53	0.080
	100+	22.10	20.55	57.25	Clay	1.45	0.080
P5	0-20	23.50	25.70	50.80	Clay	1.30	0.131
	20-55	23.50	24.10	52.40	Clay	1.41	0.086
	55-95	23.00	23.80	53.20	Clay	1.42	0.072
	95-120	23.35	24.80	51.85	Clay	1.53	0.062
	120-150	22.20	23.70	54.10	Clay	1.54	0.052
P6	0-15	25.40	22..85	51.75	Clay	1.45	0.088
	15-34	27.10	22.40	50.50	Clay	1.45	0.072
	34-80	4.60	29.40	30.00	Clay loam	1.44	0.085
	80-115	42.40	28.50	29.10	Clay loam	1.41	0.080
	115-150+	33.30	24.40	42.30	Clay	1.52	0.062
P7	0-30	17.84	31.06	51.10	Clay	1.31	0.044
	30-65	16.69	28.65	54.66	Clay	1.33	0.041
	65-90	16.10	28.30	55.60	Clay	1.34	0.039
	90-132	15.90	27.82	56.28	Clay	1.40	0.035
	132-172	15.15	27.05	57.80	Clay	1.42	0.030
P8	0-20	15.32	30.06	54.62	Clay	1.30	0.031
	20-40	15.22	29.19	55.59	Clay	1.31	0.041
	40-85	15.15	27.52	57.33	Clay	1.31	0.045
	85-125	14.97	25.93	59.10	Clay	1.32	0.030
	125-165	14.71	25.69	59.60	Clay	1.30	0.035
P9	0-20	16.75	30.50	51.75	Clay	1.31	0.042
	20-54	16.45	29.14	54.41	Clay	1.34	0.034
	54-100	16.10	28.60	55.30	Clay	1.40	0.031
	100+	15.60	27.20	57.20	Clay	1.42	0.024

Table 4. Size of water stable aggregates of soils

Pedons	Depth (cm)	Macro-aggregates (>0.25 mm)(%)	Micro-aggregates (<0.25 mm) (%)	Total aggregates (%)	Total Pore space (%)
	0-10	24.72	18.92	43.64	43.12
	10-21	23.98	24.78	48.76	42.20
P1	21-48	25.22	29.48	54.70	37.26
	48-66	27.92	27.68	55.60	37.16
	66-101	30.65	27.34	57.99	36.92
	0-10	34.10	21.10	55.20	42.30
P2	10-24	34.24	19.32	53.56	40.99
	24-36	38.58	19.38	57.96	38.69
	36-52	32.84	19.44	52.28	37.64
	52-75	30.86	21.26	52.12	42.20
	0-16	21.18	16.08	37.26	50.18
P3	16-32	22.80	19.44	42.24	44.36
	32-64	26.85	21.25	48.10	45.48
	64-85	28.90	22.30	51.20	46.44
	85-130	30.30	26.35	56.65	45.69
	0-20	35.20	32.20	67.40	43.77
P4	20-45	32.34	27.52	59.86	43.23
	45-100	32.92	27.26	60.18	42.48
	100+	30.42	21.04	51.46	45.28
	0-20	33.58	19.32	52.90	50.94
P5	20-55	36.28	16.84	53.12	46.79
	55-95	27.36	30.12	57.48	46.82
	95-120	25.34	33.52	58.86	41.82
	120-150	28.25	31.94	60.19	41.44
	0-15	32.38	27.60	59.98	44.86
P6	15-34	30.20	21.16	51.36	45.07
	34-80	24.88	27.22	52.10	45.45
	80-115	26.62	25.04	51.66	46.79
	115-150+	30.60	29.50	60.10	42.20
	0-30	39.70	26.81	66.51	50.56
	30-65	36.20	20.68	56.88	50.00

Table 5. Infiltration rates of different pedons

Time interval (Minutes)	Cumulative time (Minutes)	Infiltration Rates (cm/hr)								
		Pedon I	Pedon II	Pedon III	Pedon IV	Pedon V	Pedon VI	Pedon VII	Pedon VIII	Pedon IX
5	5	5.4	4.2	5.4	5.4	4.2	4.2	6.0	5.5	5.4
10	15	2.4	2.1	2.4	2.1	1.8	1.8	2.4	2.2	2.4
15	30	2.0	1.8	2.0	2.0	1.6	1.6	2.0	2.1	2.0
15	45	1.6	1.6	1.4	1.4	1.4	1.4	1.6	1.5	1.6
30	75	1.0	1.2	1.2	1.2	1.1	1.2	1.1	1.3	1.2
30	105	0.6	0.9	0.9	1.0	0.9	0.8	0.9	1.0	0.9
60	165	0.4	0.6	0.5	0.6	0.6	0.4	0.5	0.7	0.5
60	225	0.3	0.4	0.4	0.5	0.3	0.3	0.3	0.4	0.3
60	285	0.3	0.3	0.3	0.3	0.25	0.2	0.2	0.3	0.25
60	345	0.25	0.25	0.3	0.2	0.2	0.2	0.15	0.2	0.2
60	405	0.25	0.23	0.28	0.13	0.12	0.13	0.11	0.20	0.14

Table 6. Soil penetration resistance at field capacity of different pedons

Depth (cm)	Penetration Resistance (Mpa)								
	PedonI	Pedon II	Pedon III	Pedon IV	Pedon V	Pedon VI	Pedon VII	Pedon VIII	Pedon IX
0-5	0.70	0.66	0.65	0.75	0.80	0.78	0.87	0.86	0.88
5-10	1.25	0.94	1.02	1.02	0.98	0.91	1.05	1.03	0.88
10-15	2.15	1.48	2.15	2.15	1.55	1.21	2.10	2.08	1.20
15-20	2.85	2.60	2.75	2.75	2.15	2.00	2.70	2.63	1.95
20-25	2.80	2.50	2.70	2.70	2.10	2.10	2.65	2.65	2.10
25-30	2.80	2.55	2.75	2.70	2.10	2.25	2.05	2.10	2.09

Chemical characteristics

The data (Table 7) revealed that the electrical conductivity varying between 0.03 to 0.17 dSm^{-1} indicated non-hazardous concentration of soluble soils in all the profiles. The soils have free $CaCO_3$ varying between 0.71 and 6.8 per cent. The medium to low organic carbon of these soils (0.64 to 0.15%) may be attributed to the oxidation loss of organic matter due to tropical climate condition (*Singh et. al.* 2000). The soils are slightly acidic to neutral (pH 6.4 to 7.7) in reaction which might be due to leaching of bases under well drained conditions. The higher pH in upland physiography may be due to the accumulation of soluble salts and sodium in saucer-shaped physiography under the influence of compact and hard layers formed due to high clay content. There is negative correlation with pH and organic carbon content of these soils.

Table 7. Some chemical characteristics of soils

Pedons	Depth (cm)	pH	EC (dSm^{-1})	Organic carbon (g /kg)	Free $CaCO_3$ (%)
P1	0-10	6.6	0.16	0.55	0.80
	10-21	7.4	0.13	0.29	0.78
	21-48	7.2	0.17	0.37	0.78
	48-66	6.8	0.13	0.31	0.77
	66-101	7.2	0.11	0.25	0.77
P2	0-10	7.4	0.15	0.64	0.74
	10-24	7.0	0.13	0.56	0.74
	24-36	7.2	0.11	0.32	0.73
	36-52	7.6	0.09	0.23	0.72
	52-75	7.7	0.09	0.59	0.71
P3	0-16	7.4	0.12	0.55	0.75
	16-32	7.4	0.13	0.41	0.73
	32-64	7.5	0.15	0.42	0.73
	64-85	7.6	0.14	0.35	0.72
	85-130	7.7	0.16	0.40	0.72
P4	0-20	6.6	0.13	0.63	1.60
	20-45	7.0	0.11	0.51	1.59
	45-100	7.2	0.09	0.34	1.59
	100+	7.2	0.07	0.41	1.58
P5	0-20	7.4	0.10	0.60	1.60
	20-55	7.6	0.09	0.39	1.58
	55-95	7.5	0.09	0.42	1.56
	95-120	7.5	0.11	0.39	1.55
	120-150	7.6	0.12	0.37	1.52
P6	0-15	7.4	0.10	0.56	1.60
	15-34	7.6	0.10	0.36	1.60
	34-80	7.7	0.12	0.20	1.58
	80-115	7.5	0.14	0.17	1.56
	115-150+	7.6	0.15	0.15	1.54
P7	0-30	7.0	0.05	0.68	3.10
	30-65	7.1	0.05	0.42	2.68
	65-90	7.1	0.05	0.41	2.74
	90-132	7.1	0.04	0.41	2.58
	132-172	7.3	0.03	0.40	2.57
P8	0-20	7.5	0.13	0.70	6.82
	20-40	7.5	0.13	0.45	5.76
	40-85	7.5	0.11	0.44	5.72
	85-125	7.6	0.11	0.44	4.64
	125-165	7.6	0.11	0.38	4.68
P9	0-20	7.3	0.11	0.58	3.10
	20-54	7.3	0.11	0.46	2.59
	54-100	7.4	0.09	0.43	2.58
	100+	7.4	0.07	0.41	2.58

The CEC varying between 11.30 to 52.22 cmol(p^+)kg^{-1} (Table 8) ranging medium to high in CEC. The higher values of CEC in upper layers might be due to high organic matter content and soil reaction (Diwakar 2005).The dominance of clay mineral being smectite appears to be responsible for higher CEC. The clay of these soils has positively significant correlation with macro, total, CEC, Ca^{2+}, Mg^{2+}, Na^{+}; whereas organic carbon has positive significant influence with Ca^{2+}, Mg^{2+}, Na^{+} and CEC and negative correlation with pH. These results were in conformity with the findings of Diwakar (1988) in fine textured soils of Bihar. Ram and Singh (1975) also reported positive correlation of exchangeable Ca^{2+} with the clay in the soils of Uttar Pradesh.

Table 8. Exchange properties of soils

Pedons	Depth (cm)	CEC [cmol(p$^+$)Kg^{-1}]	Exchangeable cations [cmol (p$^+$)Kg^{-1}]				Base saturation (%)
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	
P1	0-10	20.70	14.90	2.80	0.40	0.20	88.39
	10-21	24.50	16.40	3.60	0.60	0.18	84.79
	21-48	27.60	18.40	3.65	0.60	0.17	82.66
	48-66	26.70	17.30	3.70	0.55	0.17	81.32
	66-101	26.50	17.30	3.90	0.65	0.15	83.00
P2	0-10	17.50	12.40	2.60	0.20	0.10	87.41
	10-24	15.30	11.30	2.10	0.30	0.10	90.18
	24-36	14.10	11.30	1.90	0.32	0.10	95.15
	36-52	12.60	08.00	1.80	0.32	0.16	81.56
	52-75	13.60	10.60	1.40	0.30	0.15	91.53
P3	0-16	11.43	11.43	2.10	0.22	0.25	91.30
	16-32	12.49	12.49	2.72	0.42	0.29	88.22
	32-64	13.06	13.06	2.96	0.45	0.25	84.98
	64-85	12.08	12.08	2.70	0.50	0.22	92.95
	85-130	11.30	11.30	2.44	0.53	0.20	94.12
P4	0-20	26.92	26.92	12.80	1.13	0.44	86.86
	20-45	24.40	24.40	13.92	1.22	0.36	87.90
	45-100	21.45	21.45	15.62	1.09	0.32	87.28
	100+	20.45	20.45	14.65	1.35	0.28	83.83
P5	0-20	20.65	20.65	11.62	0.88	0.46	90.87
	20-55	18.80	18.80	10.44	0.96	0.38	92.71
	55-95	19.10	19.10	11.02	0.82	0.40	90.88
	95-120	19.10	19.10	9.84	0.90	0.40	87.81
	120-150	16.80	16.80	9.26	0.97	0.39	85.63
P6	0-15	43.65	26.90	12.20	0.97	0.45	92.81
	15-34	41.63	24.28	12.78	0.96	0.38	92.22
	34-80	26.63	14.76	9.30	0.82	0.35	94.72
	80-115	27.54	15.75	8.70	0.88	0.33	93.15
	115-150+	29.54	17.18	9.30	0.95	0.29	93.82
P7	0-30	45.44	27.90	12.86	0.71	0.90	93.23
	30-65	47.52	26.45	15.60	1.12	0.94	92.80
	65-90	46.65	26.44	15.68	1.12	0.90	94.60
	90-132	44.16	26.45	13.91	1.08	0.81	95.65
	132-172	46.75	26.45	14.70	1.35	0.79	92.56
P8	0-20	50.45	36.40	10.64	1.51	0.86	97.93
	20-40	52.22	34.91	13.24	1.51	0.83	94.75
	40-85	51.45	33.40	13.20	1.64	0.81	95.31
	85-125	50.10	32.10	12.60	1.30	0.78	93.35
	125-165	46.75	32.88	12.60	1.64	0.77	95.56
P9	0-20	49.47	27.67	12.67	0.73	0.81	84.64
	20-54	48.54	26.43	15.63	1.07	0.77	90.42
	54-100	48.66	26.43	15.70	1.11	0.72	90.32
	100+	46.80	26.33	13.91	1.32	0.74	90.38

In general, soils of lower and medium pedons were rich in bases (Ca^{2+} and Mg^{2+}) whereas soils of upper pedons were comparatively poor in bases. Soils of lower pedons were found to be high CEC and dominating in 2:1 type of clay minerals. Perusal of the data (Table 4) revealed that these soils showed high base saturation ranging from 81.32% to 97.93 % indicating them to be highly base saturated. As these soils received much of water as run-off from the vast areas and enriched with the basic ions. Calcium was the most dominating cation followed by magnesium, sodium and potassium. The exchangeable Na^{+} is within the non-hazardous range (0.20 to 1.64 [cmol(p^{+}) kg^{-1}]. It is interesting to note that exchangeable K^{+} is relatively low. This clearly indicates that most of the potassium is present in the form of primary as well as secondary minerals leading only a small fraction on the exchangeable site.

The clay of these soils has positive and highly significant correlation with macro, total, B.D., Ca^{2+}, Mg^{2+}, Na^{+}, CEC (Table 9) but has significant and negative correlation with Sat. H.C. whereas as organic carbon has positive and highly significant correlation with Ca^{2+}, Mg^{2+}, Na^{+} and CEC and negative correlation with pH and B.D.

Table 9. Correlation matrix of soils

	Macro	Total	B.D	O.C	Sat. HC	pH	Ca^{2+}	Mg^{2+}	Na^{+}	CEC
Clay	0.73**	0.76**	0.63**	0.27	-0.85**	0.03	0.87**	0.92**	0.86**	0.92**
Macro	-	0.83**	-0.50**	0.23	-0.59**	0.02	0.66**	0.57**	0.58**	0.64**
Total		-	-0.37**	0.17	-0.59**	0.04	0.77**	0.64**	0.71**	0.74**
B.D.			-	-0.38**	0.66**	-0.21	-0.64**	-0.56**	-0.54**	-0.59**
O.C.				-	-0.09	-0.30*	0.38**	0.22	0.10	0.32*
Sat.H.C.					-	0.16	-0.64**	-0.78**	-0.71**	-0.70**
pH						-	-0.07	-0.07	0.08	-0.11
Ca^{2+}							-	0.83**	0.88**	0.96**
Mg^{2+}								-	0.85**	0.94**
Na^{+}									-	0.90**
CEC										-

*Significant at 5% = 0.28755 & **Significant at 1% = 0.37213

Conclusion

Predominant influence of Chandan river system was observed on the soil formation and landscape which modified basic soil characters and as a consequent it influenced water regime and vegetation of these areas. Modification gradually and continuously occurring in the Chandan river system made the whole catchment area a vibrant soil system. Rice is pre dominant crop in kharif season, whereas in rabi diversification can be done with the inclusion of wheat, mustard, lentil as well as vegetable like cole crops and solanacious fruit can be taken in profitable manner, whereas in summer (zaid season) moong, cowpea, maize (cop purpose) and cucurbitaceous vegetables can be grown.

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