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Morphology, Physico-Chemical Characteristics and Classification of Lateritic Soils of a Part of Ajoy Catchment in West Bengal

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Abstract : *Based on detailed soil survey, four soil series namely Modhudanga, Jamuria, Churulia and Rakhakura were identified. These soils have acidic surface with pH values ranging from 5.95 to 6.80. The acidity decreases with depth. Organic carbon is low. Clay content of the surface soil ranges from 26.0 to 41.3 per cent. This value gradually increases with depth in all the pedons. CEC value of these soils are low, varying from 8.5 to 17.5 Cmol(+) kg^{-1}. Calcium is the dominant exchangeable cation, followed by magnesium, sodium and potassium. The exchange acidity and exchangeable Al and Fe are low. Illuviation of clay is prominent in the pedons from crest and upper side slopes, and clay cutans are also prominent in these pedons. The low molar SiO_2/R_2O_3 ratio, ranging from 1.8 to 3.70, and moderately active iron ratio (Feo/Fed) indicate moderate weathering of the soils. According to Soil Taxonomy, the soils were classified as: Modhudanga and Jamuria Series - (Typic Haplustalfs), Churulia Series - (Typic Ustochrepts) and Rakhakura Series - (Aeric Haplaquepts).* (**Key Words :** *Laterites, soil series, physico-chemical characteristics, soil taxonomy, active iron ratio, weathering).*

Laterities and Lateritic soils are one of the problematic soil groups in India. Low nutrient supplying capacity, the continuous erosion through run off during monsoon, and the undulating topography are considered to be some of the major limitations for their productivity and management (Bennama 1963). It covers 8 per cent of the total geographic area of the country. The morphology and genesis of these soils have been reported by several workers (Roy 1976; Roy & Rudra 1978; Gowaikar 1972). However, the information on soils of the Ajoy and Damodar basin in West Bengal is limited. In this paper, an attempt has been made to study the soils for their morphology, physical and chemical properties and soil classification.

MATERIAL AND METHODS

Study area is a part of a mini watershed and erosional plains of the Ajoy Catchment comprising three villages : Churulia, Modhudanga and Rakhakura in Burdwan district representing a stretch of undulating land of south-western West Bengal. North and south west part of this areas are highly eroded. The elevation of the area ranges from 120 to 140 m above MSL. The general slope is about 3 to 5 percent and is directed towards the valley both from the north and the south west (Fig. 1).

It has tropical sub-humid monsoonal climate. Mean maximum summer temperature is 39°C in May. In some years, it rises to as high as 43°C. Mean minimum temperature is 10°C, sometimes it goes down as low as to 5°C. The mean annual temperature is 26.3°C. The difference between mean summer and mean winter temperature is more than 5°C. The total annual rainfall is 1336 mm, of which about 87 per cent is received from middle of June to middle of October. Though the total precipitation is high, the evaporation in the entire year exceeds precipitation. The soil moisture regime is 'Ustic'.

Detail soil survey was carried out and soil map was prepared (Fig. 1). Four soil series i.e. Modhudanga, Jamuria, Churulia and Rakhakura were identified, and one pedon from each series

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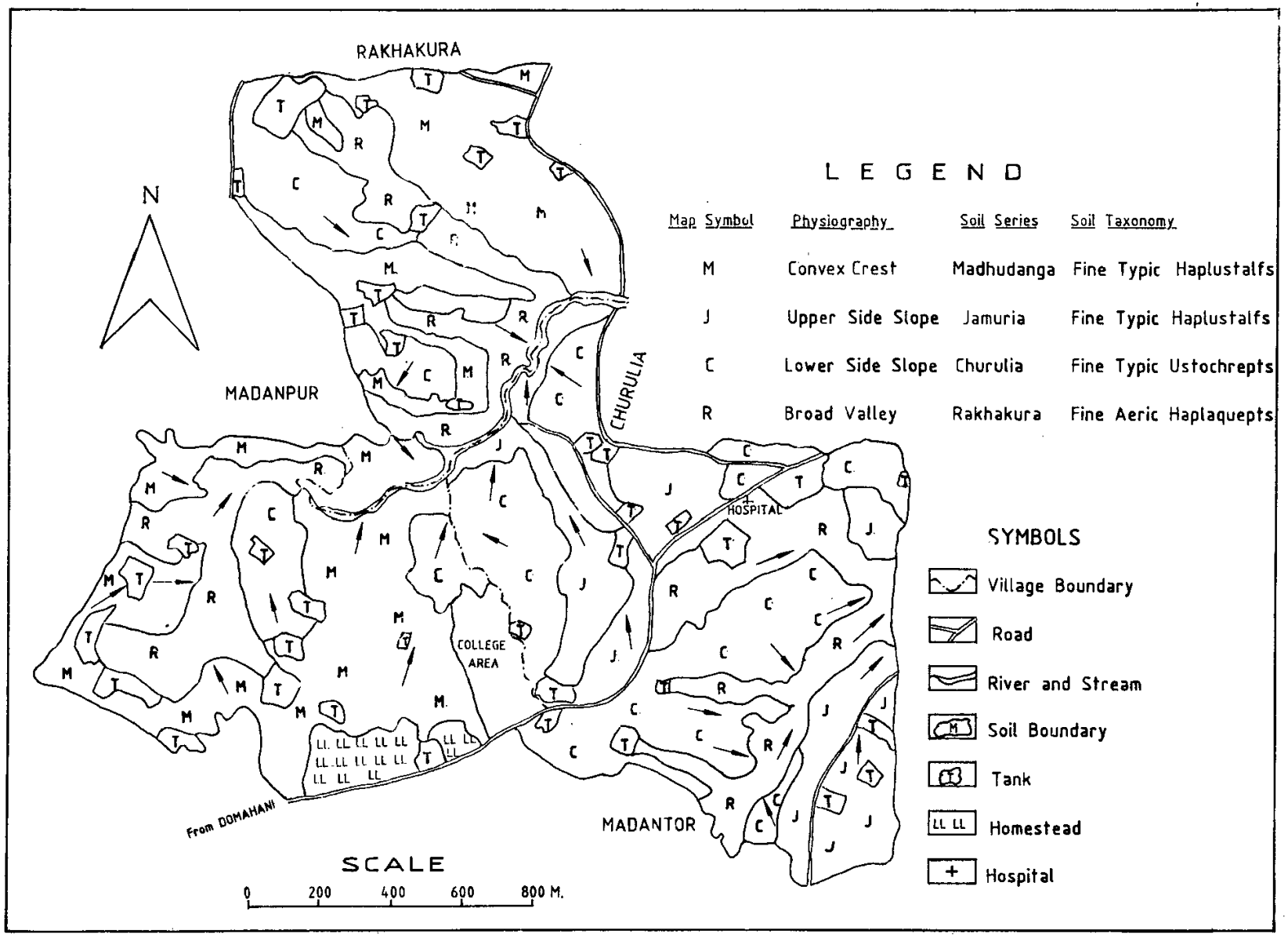

Figure 1. Physiography and soil map of part of Ajoy catchment

was selected for detailed characterization. They were described by following FAO (1965) guidelines. Mechanical composition, pH (1:2.5, soil:water suspension), organic carbon (wet oxidation), CEC and exchangeable cations were determined by standard procedures (Black 1965; Jackson 1973). For exchangeable Al, aluminon method (Coleman *et al.* 1959; Pratt & Bair 1961); and for Fe and exchangeable acidity, Orthophenanthroline method (Black 1965) were followed. Total soil analysis was also done. Amorphous Fe was determined by modified Tamm's acid oxalate method (Mckeague *et al* 1966). Total free iron oxidewas measured by dithionite method (Kilmer 1960).

RESULTS AND DISCUSSION

The soils of the area have been derived from ferruginous material and shales. The area is a fairly broad band running from east to west, from the Ajoy river, near Churulia through Raniganj coal field, up to Barakar, a tributary of river Damodar. The area belongs to coal bearing Damodar series of Lower Gondwana sediments of middle Precambrian (Gee 1932).

On the basis of relief, slope and erosion etc., four land forms units were identified, which were found to correspond to different pedogenic processes leading to the development of different soils. The units identified are: Convex Crest; Upper side slope; Lower side slopes and Broad valley.

Convex Crest : The soils of the crest are well developed, with argillic horizon. But because of convex topography and susceptibility to erosion, the soils have moderate depth. These are well drained soils and have been identified as Modhudanga series. Taxonomically, these soils belong to soil family of fine, mixed, hyperthermic Typic Haplustalfs. All these soils have subangular blocky structure at the surface and angular blocky in the subsurface horizons. Weathered parent material mixed with soil and iron concretions has been observed at a depth of 74 cm. The area is occasionally cultivated.

Upper Side Slope : These soils are also well developed, well drained, deep with argillic subsurface horizons, identified as Jamuria series. They belong to fine, mixed, hyperthermic family of Typic Haplustalfs. They are mostly cultivated for crops like paddy and wheat.

Lower Side Slopes : The soils of this unit are of less developed as that of crest and upper side slopes. They have cambic subsurface diagnostic horizons and are named as Churulia soils series. They belong to fine, hyperthermic family of Typic Ustochrepts. They are well drained, free from lime throughout the profile. The area is dominantly cultivated though subjected to severe erosion. Gravel and weathered parent material have been observed at 40 cm depth.

Broad Valley : The soils of this unit are poorly drained. The matrix colour is 10YR 4/2 (dark grayish brown) with mottles of 5 YR 4/6 (Yellowish red), and 10YR 4/6 (Yellowish brown) colour. Due to poor drainage, the soil physical conditions are not favorable for many crops, like cotton and wheat. These soils have been named as Rakhakura series. They belong to fine, mixed, hyperthermic family of Aeric Haplaquepts. Weathered shale parent material, mixed with soils have been observed at 122 cm depth. The ground water is at shallow depth and sometimes rises within one meter from the surface.

Physical and Chemical Characteristics : The morphological and physico-chemical properties are given in Tables 1 and 2 respectively. The clay content of the surface soil ranges from 26 to 41.3 per cent and increases with depth. Silt content is low but it is found almost uniform with depth. Clay and silt together constitute the major portion of the mechanical composition (59 to 74 %). Sand fraction, decreases with depth. Surface soils of all these pedons are acidic, (pH 5.95 to 6.80). The pH increases with depth. Soluble salt content is low. CEC varies form 8.5 to 17.5 Cmol (+) kg^{-1}. Calcium is the dominant exchangeable cation, followed by magnesium, sodium and potassium. The exchangeable bases (Ca+Mg)/exchange activity is low at the surface and

TABLE 1. Morphology of soils

Horizon	Depth (cm)	Colour	Notation	Mottles	Clay cutans
Modhudanga Series					
A	0-14	Dark yellowish brown	10YR 4/4	—	—
AB	14-30	-do-	-do-	—	—
Bt1	30-53	Brown	10YR 5/3	—	Thin Patchy
Bt2	53-74	-do-	-do-	—	Thick Patchy
C	74+	Weathered parent material with soil matrix and iron concretions			
Jamuria Series					
A1	0-14	Yellowish brown	10YR 5/4	—	—
A2	14-26	Dark yellowish brown	10YR 4/4	—	—
A3	26-40	-do-	-do-	—	—
Bt1	40-83	-do-	-do-	—	Thin Patchy
Bt2	83-107	-do-	-do-	—	-do-
Bt3	107-137	-do-	-do-		Thick continuous
Churulia Series					
A	0-10	Yellowish brown	10YR 5/4	—	—
Bw1	10-20	-do-	-do-	—	—
Bw2	20-40	Dark yellowish brown	10YR 4/4	—	—
C	40+	Gravel and weathered parent material mixed with iron concretions			
Rakhakura Series					
Ap	0-13	Dark brown	10YR 4/3	Strong brown	
A2	13-38	-do-	-do-	Light brownish grey	
A3	38-55	Dark greyish brown		light brownish grey yellowish Brown	
Bw1	55-81	-do-	-do-	Yellowish red	
Bw2	81-102	-do-	-do-	-do-	—
Bw3	102-122	-do-	-do-	-do-	—
C	122+	weathered shale parent material mixed with some soil.			

high in lower horizons, indicating the leaching of bases (Gowaikar & Dutta 1971). In all the series exchange acidity is low, base saturation is high, (> 60%) and organic carbon is low but, it changes with land forms; 0.51 to 0.56 per cent in the crest, and 0.87 per cent in the valley soils. This clearly shows that the variation of carbon content have topographic influence. (Allen & Fanning 1983). The higher value of organic carbon in valley soils is due to the deposition of eroded materials from upland soils.

Elemental composition of soils is given in Table 3. The silica content ranges from 44.7 to 62.8 per cent and it decreases with depth. Al_2O_3 is moderately high and varies between 23.14 and 38.26 per cent. Fe_2O_3 is low in all these soils. High silica, moderately high Al_2O_3 and low Fe_2O_3 content, gave rise to higher SiO_2/Al_2O_3 molar ratios which ranges from 1.8 to 3.7. The SiO_2 ratio ranges from 2.13 to 6.55, indicating moderate weathering of these soils . The Al_2O_3/Fe_2O_3 ratio showed preferential leaching of Fe and Al, TiO_2 and P_2O_5 . Illite have also been observed in these soils. Similar observations have also been reported by Roy (1976), Roy and Rudra, (1978) and Govind Rajan and Dutta Biswas (1968).

Modhudanga and Jamuria soil series, situated on the crest and upper side slope, showed the presence of argillic horizon, which was formed due to percolating water and alternate wet and dry environment. Topography and rainfall are the main factors that influence the genesis of these soil. High intensity of rainfall during monsoon had caused the removal of much of top soil through erosion resulting in shallow solum and lower organic carbon. The organic carbon has also been influenced by the land forms and its value is higher in the valley (Table 3), suggesting the predominance of soil erosion in the crest and the side slopes. Although the annual prepitation is high (1336 mm), but it is confined to monsoon season (three to four months), much of which flows down as run off and only a portion of it goes into the soil. Thus undulating topography and restricted moisture for leaching through the profile had some limitation for pedogenic development and weathering of these soils (Allen & Fanning 1983). Thus, the pedons of crest and upper side slopes were fairly developed (Haplustalfs) as compared to pedon situated in the lower side slope. (Ustochrepts) and valley (Haplaquepts).

TABLE 2. Physico-chemical properties of soils

Depth (cm)	Coarse sand	Fine sand	Silt	Clay	pH H_2O	CEC Cmol(+) kg^{-1}	O.C.	Exchangeable cations Cmol(+) kg^{-1}				Exch. acidity Cmol(+) kg^{-1}	Exch. Al	Exch. Fe	Base sat
	<----------(%)---------->				1:2.5		(%)	Ca	Mg	Na	K		<---(ppm)--->		(%)
Modhudanga Series															
0-14	30.6	16.9	20.7	30.8	6.60	10.5	0.52	7.0	1.75	0.41	0.32	0.5	2.00	15.0	90
14-30	32.8	15.9	19.0	32.5	6.75	12.5	0.55	10.1	1.80	0.37	0.27	0.0	Tr.	15.0	100
30-53	20.4	3.7	19.4	56.5	6.85	16.0	0.12	12.1	1.81	0.38	0.28	0.0	-do-	10.0	91
53-74	21.4	2.1	21.5	55.0	6.85	17.5	0.10	12.1	1.91	0.44	0.33	0.0	-do-	10.0	84
Jamuria Series															
0-14	25.6	18.3	30.1	26.0	6.25	10.6	0.45	7.8	1.20	0.42	0.32	7.0	Tr.	15.0	93
14-26	23.6	15.7	32.2	28.5	6.55	10.5	0.23	7.0	1.30	0.90	0.99	6.0	- do-	10.0	97
26-40	19.3	18.0	34.8	27.9	6.95	15.5	0.17	9.0	3.50	0.88	0.30	3.0	0.18	20.0	88
40-83	15.5	19.0	22.8	42.7	7.85	13.0	0.13	8.7	2.75	0.44	0.46	2.5	0.35	20.0	95
83-107	9.9	18.0	23.8	48.8	7.65	13.1	0.11	10.1	1.30	0.40	0.39	2.5	0.10	5.0	92
Churulia Series															
0-10	40.0	14.1	10.3	35.6	5.95	8.6	0.78	5.0	1.20	0.82	0.75	3.0	0.18	22.5	90
10-20	40.1	13.2	9.4	37.5	6.85	10.1	0.50	7.5	1.50	0.49	0.38	2.5	0.50	17.5	98
20-40	25.8	12.5	39.1	22.6	7.00	9.7	0.51	7.0	1.65	0.85	0.19	4.0	0.37	5.00	100
Rakhakura Series															
0-13	7.4	26.5	25.8	40.3	6.20	9.5	0.87	7.5	1.10	0.48	0.29	5.0	Tr.	10.0	99
13-38	11.3	26.6	25.4	36.7	7.20	9.8	0.57	7.2	1.30	0.55	0.24	3.0	-do-	15.0	95
38-55	9.1	27.1	25.4	37.7	7.50	9.6	0.57	7.3	0.95	0.54	0.53	3.0	0.19	10.0	97
55-81	8.6	22.3	24.4	44.7	7.65	10.6	0.53	9.0	0.75	0.64	0.23	Tr.	0.19	11.0	100
81-102	4.3	25.6	23.4	46.7	7.60	11.7	0.51	9.7	0.85	0.65	0.30	0.8	0.86	11.5	98
102-122	7.4	22.1	24.3	45.7	7.70	11.0	0.40	9.7	0.95	0.62	0.20	Tr.	0.85	22.0	100

Tr. = Trace

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TABLE 3. Chemical composition (ignition basis) free iron oxides

Depth (cm)	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	P_2O_5	SiO_2/R_2O_3	SiO_2/Al_2O_3	CaO/MgO	Al_2O_3/Fe_2O_3	* Fe(d)	*Fe(O)	Ratio Fe(O)/Fe(d)
	<----------(%)---------->								<----------Ratio---------->				<-----(%)------->		
Modhudanga Series															
0-14	45.7	29.3	20.6	1.05	1.12	0.70	0.41	0.070	1.80	2.65	1.60	1.42	1.78	0.50	0.28
14-30	51.6	30.6	12.7	1.05	1.26	1.20	0.50	0.060	2.10	2.86	1.05	2.40	2.56	0.36	0.14
30-53	50.5	36.0	8.8	0.78	1.26	1.30	0.45	0.097	2.04	2.38	0.97	4.09	1.34	0.29	0.21
53-74	48.1	37.4	9.4	0.94	1.60	1.05	0.42	0.098	1.86	2.19	1.52	3.98	2.20	0.39	0.18
Jumuria Series															
0-14	66.6	23.7	6.2	0.78	1.12	0.60	0.47	0.126	4.11	4.74	1.87	3.85	0.67	0.57	0.89
14-26	68.4	21.3	6.2	0.78	2.10	0.30	0.34	0.096	4.56	5.48	7.00	3.44	2.39	0.32	0.80
26-40	63.6	24.6	7.6	0.63	1.54	0.80	0.36	0.207	3.66	4.39	1.92	3.24	1.00	0.29	0.29
40-83	63.9	12.3	20.4	0.68	1.40	1.00	0.34	0.230	4.24	8.79	1.42	0.61	0.33	0.25	0.78
83-107	48.3	26.9	21.2	0.71	1.68	0.90	0.41	0.240	2.05	3.04	1.86	1.27	0.48	0.25	0.50
Churulia Series															
0-10	57.0	24.3	15.0	0.43	1.54	0.70	0.48	0.110	2.88	3.98	2.20	1.62	0.95	0.50	0.52
10-20	52.4	27.4	15.0	0.47	2.20	1.12	0.40	0.046	2.42	3.25	1.96	1.83	0.95	0.29	0.30
20-40	47.1	30.1	18.4	0.44	1.40	0.40	0.43	0.110	1.85	2.66	3.50	1.64	1.14	0.35	0.30
Rakhakura Series															
0-13	62.8	24.5	7.7	1.10	1.54	0.60	0.50	0.060	3.70	4.52	2.57	3.12	0.74	0.57	0.77
13-38	55.9	27.5	11.2	1.09	1.54	1.16	0.49	0.049	2.74	3.44	1.40	2.45	0.97	0.43	0.54
38-85	60.0	25.6	9.6	0.85	1.40	1.12	0.48	0.063	3.22	3.99	1.25	2.67	0.70	0.46	0.65
55-81	61.6	25.1	9.0	0.78	1.68	1.40	0.58	0.046	3.43	4.12	1.20	2.79	0.77	0.29	0.37
81-102	59.5	27.3	8.0	0.78	1.26	1.30	0.55	0.176	3.30	3.01	0.97	3.41	0.48	0.36	0.73
102-122	58.2	27.7	10.1	0.78	1.20	0.98	0.44	0.064	2.73	3.70	1.22	2.73	1.17	0.43	0.37

* Fe (O) = Oxalate soluble Fe; Fe(d) = Dithionate soluble Fe

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