Agropedology, 1997, 7, 22-31.

Characteristics and classification of some alluvium derived paddy and associated non-paddy soils of Assam

J. K. Dey and J. L. Sehgal***

*Regional Agricultural Research Station, Assam Agricultural University.
Diphu 782460,India
** Krishi Anusandhan Bhawan, New Delhi 110012, India.

Abstract

Traditional paddy and the associated non-paddy soils developed in alluvium of Brahmaputra and Barak valleys of Assam were studied for their physical and chemical characteristics and classification. The paddy soils were characterized by aquic feature such as low chroma (<2) and distinct mottling throughout the profile. Massive surface structure and subsurface plowpan reduced water intake in paddy soils as compared to non-paddy soils which had well developed soil structure. Plowpan was, however, absent in poorly drained fine textured paddy soils. Paddy soils were enriched with divalent cations and had higher base saturation and soil pH as compared to non-paddy associates. Calcareous paddy soils had low amount of free calcite, exchangeable bases, base saturation and soil pH as compared to non-paddy associate. There was enhanced eluviation of free Fe and Mn in paddy soils with distinct zone of subsurface illuviation. Organic carbon content and CEC: clay ratio were lower in the surface horizons of fine- textured paddy soils as compared to non-paddy associates. In terms of taxonomic classification, paddy and non-paddy soils differed either at suborder or at great group level. A new subgroup 'alfic' was suggested.

Additional key words: Brahmaputra valley, Barak valley. Soil Taxonomy

Introduction

Rice is traditionally grown in fine-textured soils with restricted internal drainage. Temporary or permanent impounding of water associated with paddy cultivation creates conditions which are markedly different from associated non-paddy soils. These were first recognised by the Chinese workers (Chu *et al.* 1938). Since then, considerable works were undertaken to understand the physical and chemical behaviour of soils influenced by characteristic hydrology of paddy soils. In Assam, rice is predominantly grown in the alluvial plains of Brahmaputra and Barak Valleys. Pedogenesis of soils of Assam have been studied by various workers (Chakravarty *et al.* 1978; Chakravarty and Baruah 1984:, Dutta *et al.* 1981; Sen *et al* 1997; Singh and Chamuah 1991). However, information on paddy soils of this region, with respect to morphology, physical and chemical characteristics and taxonomy is scanty. The present study was, therefore, conducted to make indepth pedological investigation on some traditional paddy and associated non-paddy soils of Assam with an objective to study the difference in soil characteristics and classification under two different land utilization.

Mateials and methods

Situated between the latitudes of $24^0 29'$ to 27^0 $14'$N and the longitudes of $92^0 48'$ to $94^0 7'$E, three sites were selected from the Brahmaputra valley and one from Barak valley of the state of Assam. Soils with a record of more than 50 years of paddy cultivation, were selected. The pedons P1 and P2, P3 and P4, P5 and P6 were located in North Lakhimpur, Titabor and Kaki respectively in the Brahmaputra valley and pedons P7 and P8 were located in Cachar in the Barak valley. Pedons P1, P3, P5 and P7 represented paddy soils and the pedons P2, P4, P6 and P8 the associated non-paddy soils. The non-paddy soils were either grassland or under tea plantation. The pedons in the selected sites were exposed to a depth of 150 cm and were described in the field (Soil Survey Staff 1951). The soil sample from various horizons were collected, air dried and passed through 2 mm sieve. Relevant characteristics were analysed following standard analytical methods (Piper 1950, Jackson 1958, 1969). Iron and manganese were analysed by atomic absorption spectrophotometer.

With mean annual rainfall ranging from 1169 mm to 2936 mm and mean annual temperature ranging from 23.1^{0}C to 26.0^{0}C, the region qualifies for humid moisture and hyperthermic temperature regime. Geology of the area is comprised of different rock types such as gneisses, granites, sandstone, mudstone, shale and argillaceous beds belonging to the Archean to the Tertiary age. The alluvium of both the valleys was of Pleistocene to recent geologic origin.

Results and discussion

Morphological characteristics : The morphological observation (Fig. 1) indicated that the non- paddy soils from all locations except that of Kaki(P6) are brown to dark brown (10 YR 3/3 to 10YR 5/3) at the surface, and yellowish brown (10 YR 6/8 to 10 YR 5/3) at lower horizons with faint reddish yellow/yellowish red to dark, reddish brown (5 YR 5/8 to 5 YR 3/3) mottles, were observed between 5 to 53 cm depth suggesting moderate drainage conditions of these soils . The corresponding paddy soils from these locations had acquired grayish colour (chorma ≤ 2) throughout the proflies. Colour of surface horizons of soils under paddy was dark gray to gray (10 YR 6/1 to 5 YR 5/1). Distinct mottles, varying from red/yellowish red to strong brown (5 YR/2.5 YR 5/8 to 7.5 YR 5/6) were observed throughout the profiles of paddy soils.

Both paddy and non-paddy soils from Kaki (Pedons P5 and P6) had grayish matrix colour (chroma ≤ 2) because of their lower topographic position in low lying old channel. However, paddy soils had dominant yellowish hue (2.5 Y to 5Y) as against reddish hue (10 YR to 5 YR) in non-paddy soils in the subsurface horizons, which suggested greater segregation of iron as hydrous oxides in paddy soils. The uniform grayish matrix colour in all paddy soils irrespective of locations suggested strong influence of characteristic hydrology of paddy soil on soil colour.

The paddy soils under study had in general, massive structure at the surface which broke to moderate, medium and coarse subangular blocky structure. The non-paddy counterparts had strong, medium, granular and subangular blocky structure. Variation in grade, strength and shape of soil structure of surface horizon were the result of mechanical breakdown caused by puddling and subsequent drying in paddy soils (Wilding and Rehage 1985). Paddy soils in general, had angular blocky and columnar structure of coarser grade, against subangular blocky structure of medium grade in the associated non-paddy soils in their B horizons.

Physical characteristics : Soils from Kaki and Cachar (P5, P6, P7, P8) had higher clay content (Table 1) than that of North Lakhimpur and Titabor (P1, P2, P3, P4). The higher clay content in Kaki and Cachar is due to the fact that alluvium of these soils are derived from argillaceous beds of Assam plateau and Barail Range (Chakravarty *et al.* 1978; Goswami 1960). Soils from Titabor and Cachar (P3, P4, P7, P8) had clay cutans in

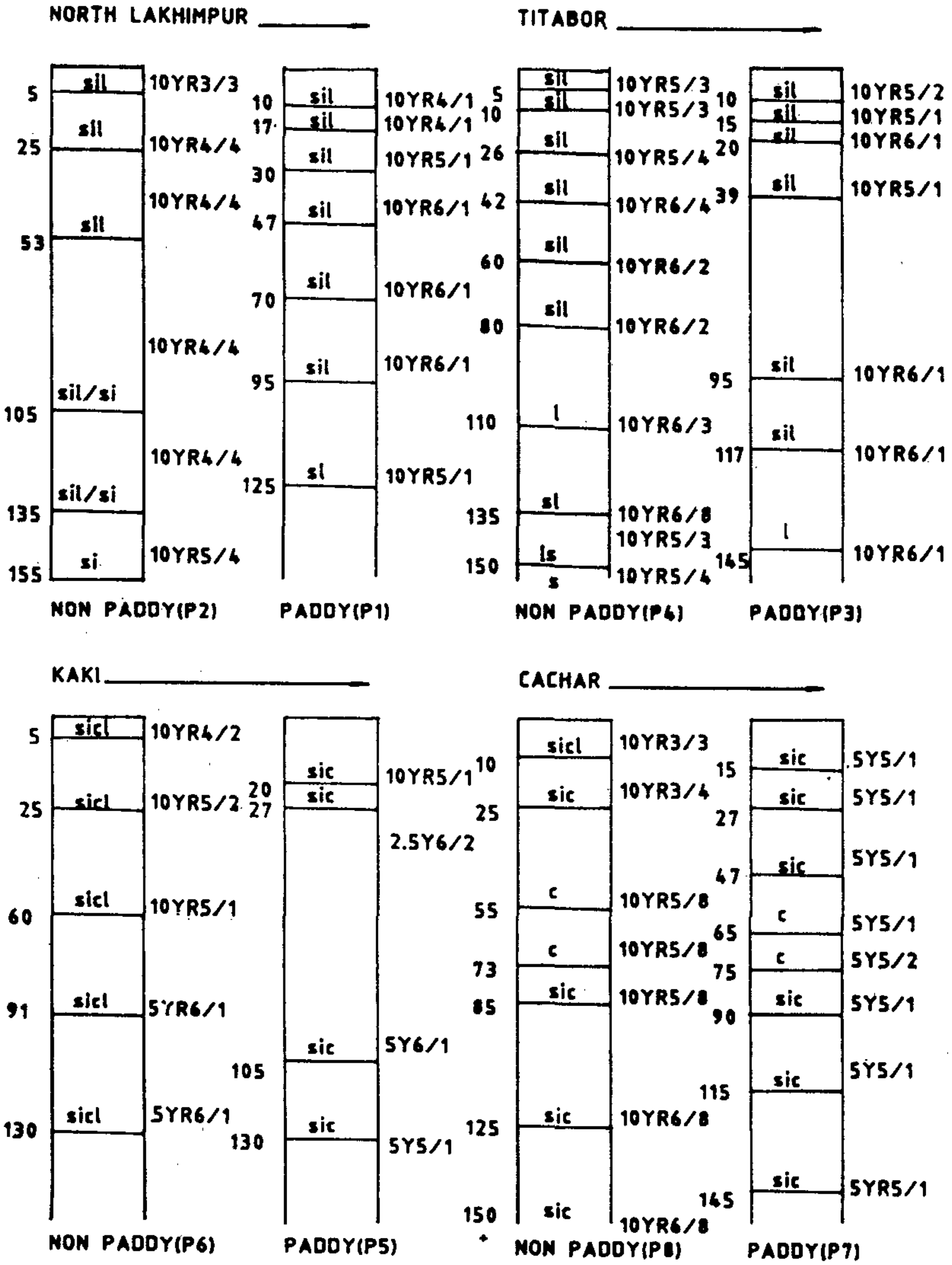

Fig. 1. Morphology of paddy and associated non-paddy soils of Assam

the B horizon and showed increase in content of fine and total clay with increase in depth which suggested that these soils are at advance state of development. However, formation of argillic horizon are observed only in Cachar soils (P7, P8). Lithological break as indicated by sand:silt ratio (Sidhu *et al.* 1976) was observed at 30 and 95 cm depth in P1 and between 80 to 117 cm depth in P3 and P4.

Table 1. Physical and chemical characteristics of paddy and associated non-paddy soils

Horizon	Depth (cm)	Clay Fine (%)	Clay Total (%)	Organic carbon (%)	pH (1:2)	Base saturation (%)	$CaCO_3$ (%)
Pedon 1 : Paddy Soil, North Lakhimpur							
Apg	0-10	2.	9.5	1.48	5.1	54	-
Bg1	10-17	4.0	10.1	1.00	5.4	64	-
Bg2	17-30	2.7	7.0	0.39	5.8	80	-
Bg3	30-47	2.1	9.0	0.27	6.0	93	-
Bg4	47-70	2.5	4.9	0.19	6.1	98	-
Bg5	70-95	1.3	4.8	0.26	6.0	100	-
BCg	95-125	1.8	3.0	0.16	6.4	100	-
Pedon 2 : Non-paddy Soil, North Lakhimpur							
A	0-5	4.4	13.2	1.87	4.9	44	-
BA	5.25	2.5	12.2	0.58	4.9	61	-
Bw1	25-53	3.8	10.6	0.33	4.7	63	-
Bw2	53-105	1.4	6.7	0.25	5.2	63	-
BC1	105-135	2.0	6.0	0.23	5.3	100	-
BC2	105-155	1.2	4.8	0.17	5.4	83	-
Pedon 3 : Paddy Soil, Titabor							
Apg1	0-10	1.1	8.4	1.09	5.5	69	-
Apg2	10-15	4.6	11.1	0.38	5.8	73	-
Bg1	15-20	6.3	10.3	0.23	5.5	65	-
Bg2	20-39	4.7	11.8	0.20	5.5	61	-
Bg3	39-95	5.0	11.0	0.15	5.7	60	-
Bg4	95-117	5.2	11.1	0.12	5.9	78	-
Bg5	117-145	3.2	9.2	0.13	5.9	85	
Pedon 4 : Non-paddy Soil, Titabor							
A1	0-5	3.2	8.8	1.17	4.7	43	-
A2	5-10	4.5	9.9	0.77	4.5	48	-
BA	10-26	5.5	10.8	0.64	4.4	41	-
Bw1	26-42	5.1	12.7	0.39	4.5	44	-
Bw2	42-60	4.3	12.9	0.56	4.6	58	-
Bw3	60-80	4.5	12.9	0.26	4.4	52	-
Bw4	80-110	4.9	12.2	0.28	4.8	71	-
BC1	110-135	3.2	6.6	0.15	4.9	72	-
BC2	135-150	3.0	3.7	0.04	5.1	75	-
C	150-155	0.3	0.5	0.00	5.0	86	-

Pedon 5 : Paddy Soil, Kaki							
Apg	0-20	18.3	57.0	1.32	5.7	81	-
Bg1	20-27	16.0	55.0	0.75	7.2	96	0.7
Bg2	27-105	14.2	53.0	0.26	8.0	100	0.8
Bg3	105-130	12.9	52.2	0.17	8.1	100	1.2
Pedon 6 : Non-paddy Soil, Kaki							
A	0-5	11.9	32.0	3.2	5.8	80	-
Bw1	5-28	9.7	34.6	1.19	6.9	90	-
Bw2	28-60	9.2	34.1	0.35	8.7	100	4.6
Bw3	60-91	9.0	35.2	0.23	8.8	100	2.2
Bw4	91-130	6.4	36.4	0.66	8.7	100	2.4
Pedon 7 : Paddy Soil, Cachar							
Apg	0-15	15.0	46.4	1.54	4.9	59	-
EBg	15-27	17.5	55.9	0.83	5.5	76	-
Bg	27-47	17.6	56.7	0.63	5.9	75	-
Btg1	47-67	14.7	56.8	0.39	6.3	87	-
Btg2	67-75	14.5	57.1	0.40	6.3	85	-
BCg1	75-90	10.3	45.4	0.40	6.5	93	-
BCg2	90-115	7.4	48.5	0.53	6.6	90	-
BCg3	115-145	13.1	42.1	0.36	6.7	84	-
Pedon 8 : Non-paddy Soil, Cachar							
A	0-10	12.0	38.4	1.83	5.3	62	-
E	10-25	16.1	50.6	1.04	5.0	50	-
Bt1	25-55	19.4	56.5	0.75	5.2	53	-
Bt2	55-73	16.3	55.4	0.42	5.5	55	-
BC1	73-85	10.4	44.8	0.40	5.5	67	-
BC2	85-125	11.9	47.8	0.35	5.7	70	-
BC3	125-150	15.9	45.2	0.53	5.8	69	-

There was no appreciable variation in respect of particle size distribution between paddy and non-paddy soils except in Kaki, where paddy soils(P5) because of lower topographic position in rolling landscape contained higher amount of clay than that of non-paddy soils (P6).

Surface horizon of all paddy soils except Titabor (P3) had higher bulk density and lower porosity than that of their non-paddy associate (Fig. 2). This effect was more pronounced in the fine- textured (Kaki and Cachar) than medium-textured soils (North Lakhimpur) which was due to the fact that dispersed clay in puddled soils tended to attain face to face orientation as soil dried leading to collapse of non-capillary pore thus, resulting in higher bulk density (Greenland 1981). Apparent deviation observed in Titabor is attributed to surface compaction in non- paddy soils (P4) under tea crop due to farm operation. All paddy soils except Kaki (P5) were marked by a zone of high bulk density and low porosity in the ploughsole. Absence of such compacted zone in fine-textured poorly drained paddy soils from Kaki (P5) could not be explained although there was similar report from Japan (Fukusi and Iwana 1982).

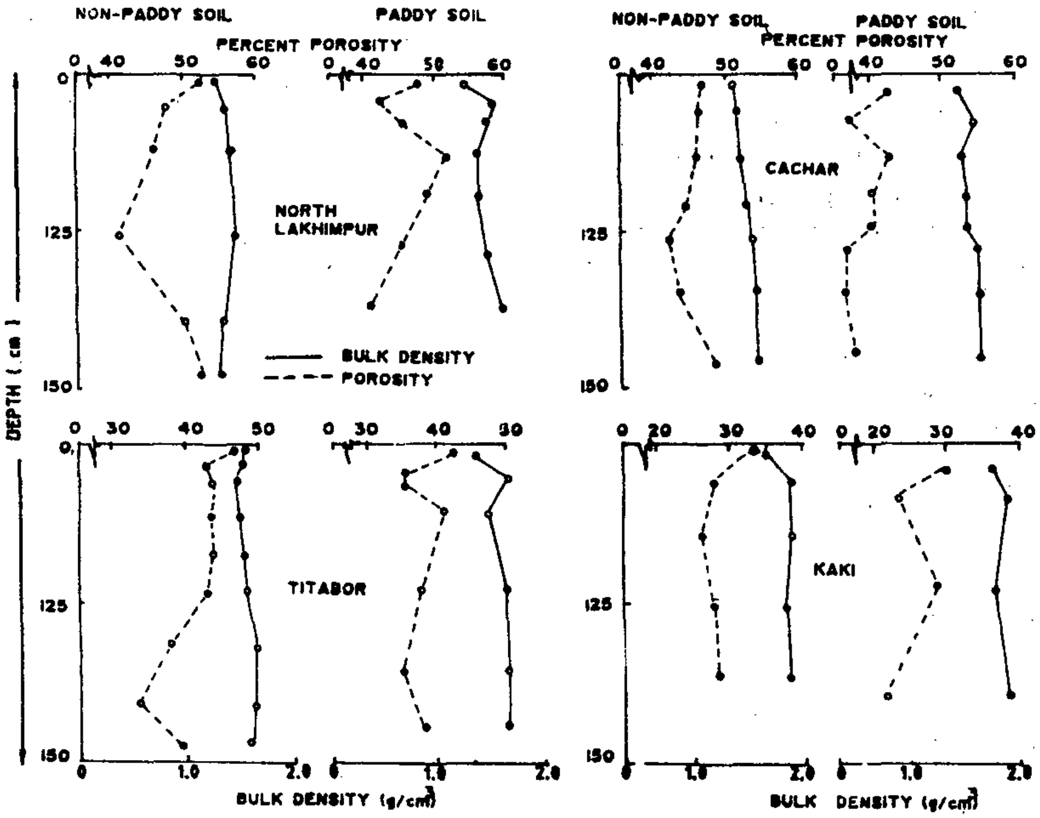

Fig. 2. Depth distribution of bulk density and porosity in paddy and non-paddy soils

Cumulative water infiltration rate and average water intake rate for a period of 6 hours was always lower in paddy soils (2.7 to 6.1 cm and 1.2 to 2.5 cm respectively) than in the non-paddy soils (4.2 to 7.7 cm and 1.5 to 2.9 cm respectively). Similar findings were recorded in the paddy and the non-paddy soils from Punjab (Swahney and Sehgal 1989). Lower porosity and poor physical condition in the upper horizons of paddy soils might account for their lower water intake as compared to non-paddy soils.

Chemical characteristics : In conformity with the observation of Chakravarty *et al* (1980), the present study indicated strong influence of rainfall on soil pH (Table 1). Thus soils from high rainfall locations of 2000- 3000 mm annual rainfall (P1, P2, P3, P4, P7, P8) were acidic to weekly acidic (pH 4.7 to 6.2) whereas that of low rainfall location with 1200 mm annual rainfall (P5, P6) were near neutral to alkaline (pH 7.6 to 8.3). In the high rainfall locations, paddy soils (P1,P3,P7) had higher soil pH, total bases and base saturation than that of non-paddy soils (P2, P4, P8) whereas in low rainfall location, calcareous paddy soils (P5) had lower soil pH and base saturation than that of calcareous non-paddy soils (P6). In high rainfall location, base enrichment in paddy soils through lateral flow from surrounding higher landscape (Wilding and Rehage 1985) might have led to increase in base saturation as well as pH, whereas, in calcareous soils solubilization of $CaCO_3$ by H_2CO_3 produced under higher partial pressure of CO_2 during the microbial decomposition of organic matter in the puddled soils, led to formation of soluble $Ca(HCO_3)_2$ which ultimately leached down leading to lower base saturation as well as pH in paddy soils (Ponnamperuma *et al.* 1966). In Kaki, the calcareous paddy soils (P5) had lower lime content (0.08%) than that of the non-paddy associate (P6).

The exchangeable Ca^{2+} and Mg^{2+} together dominated the exchange complex of both paddy and non-paddy soils (Table 2). Paddy soils in general contained higher amount of exchangeable Ca^{2+} and Mg^{2+} (3.50 to 27.6 cmol (p^{+}) kg^{-1}) than the non-paddy soils (2.30 to 24.5 cmol (p^{+}) kg^{-1}, indicating that paddy soils were enriched with divalent cations, which was also confirmed by higher ratio of divalent : monovalent cations in the paddy than the non-paddy soils.

Table 2. Exchangeable cations in paddy and non-paddy soils

Pedon	Exchangeable cations				$\frac{\text{Ex. }(Ca^{2+} + Mg^{2})}{\text{Ex. }(Na^{+} + K^{+})}$
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	
		(cmol (p^{+}) kg^{-1})			
North Lakhimpur					
Paddy (P1)	4.4	2.9	0.2	0.1	24.3
Non-paddy (P2)	5.8	1.3	0.2	0.1	23.7
Titabor					
Paddy (P3)	1.6	1.9	0.2	0.2	8.8
Non-Paddy (P4)	1.5	0.8	0.1	0.2	7.7
Kaki					
Paddy (P5)	19.2	8.4	1.1	0.6	16.2
Non-paddy (P6)	13.1	11.4	2.8	0.4	7.7
Cachar					
Paddy (P7)	3.7	10.5	0.4	0.3	20.3
Non-paddy (P8)	3.0	8.3	0.3	0.4	16.1

Cation exchange capcity of the studied pedons varied from 1.9 to 34.6 cmol (p^{+}) kg^{-1}. CEC mostly followed the clay content of soils. Although there was no consistent difference in CEC between paddy and non-paddy soils, the CEC per unit clay showed appreciable difference. The CEC per unit clay was appreciably lower in fine-textured paddy soils from Cachar and Kaki (P5, P7) as compared to the non-paddy associates (P6, P8), which was, however, noticed only in the upper horizon (0-27 cm) (Fig. 3) in Cachar (P7) and throughout the profile in Kaki (P5). The observed lowering in CEC : clay ratio indicated some change in surface characteristic of clay under paddy cultivations, particularly in fine-textured soils.

The organic carbon content in the pedons varied from 0.04 to 3.20 percent. Fine-textured soils (P5, P6, P7, P8) contained twice as much organic carbon as medium-textured soils. The organic carbon content in the surface horizon was invariably lower (1.09 to 1.54%) in the paddy than the non-paddy associates (1.17 to 3.20%). This difference, however, narrowed down with increase in depth (Fig. 4). The decrease in organic carbon in surface horizon of paddy soils was attributed to repeated cycle of wetting and drying which enhanced microbial decomposition of organic matter (Neue 1985).

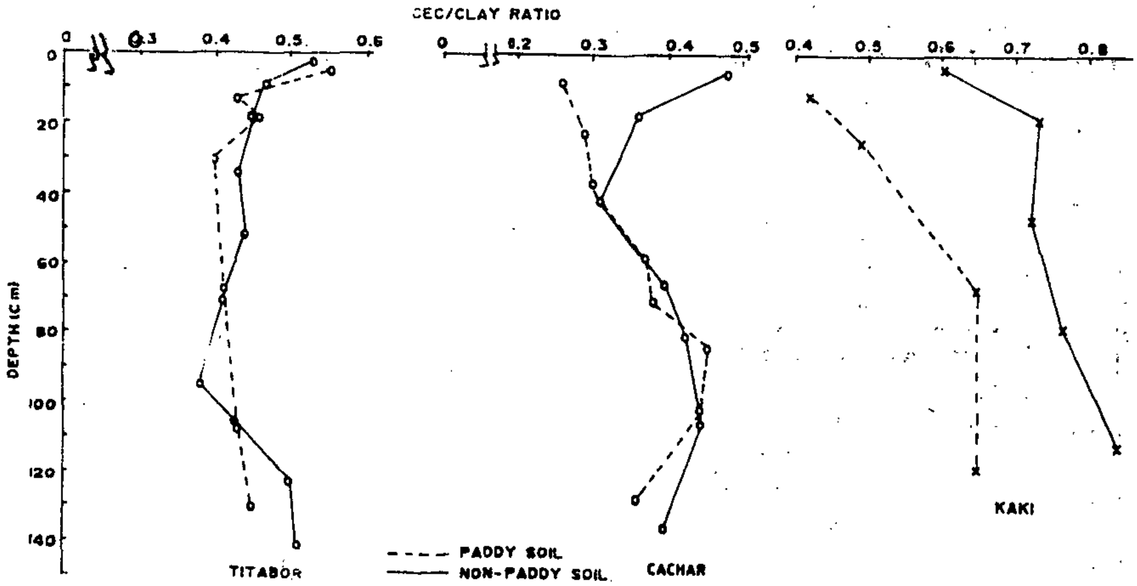

Fig. 3. Depth distribution of CEC / clay ratio in the paddy and the associated non paddy soils

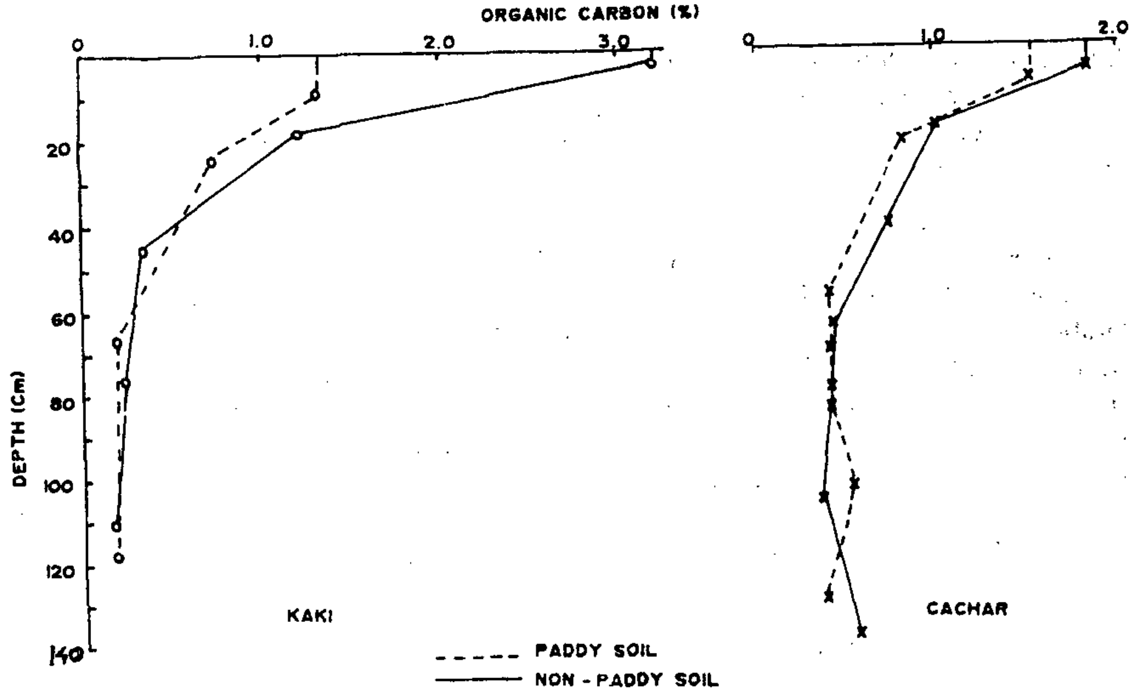

Fig. 4. Depth distribution of organic carbon in paddy and the associated non-paddy soils

The contents of free iron and manganese in the pedons varied from 0.4 to 4.0 per cent and 1.3 to 227.5 mg/g respectively. There was pronounced effect of age on the free iron content which was highest in the Cacher soils (P7, P8), being at advance state of development. Compared with non paddy soils, all paddy soils showed marked eluviation of both free iron and manganese from surface horizons (Fig. 5) with corresponding zone of illuviation in the B horizon (30 to 60 cm and 47 to 150 cm respectively). The zone of

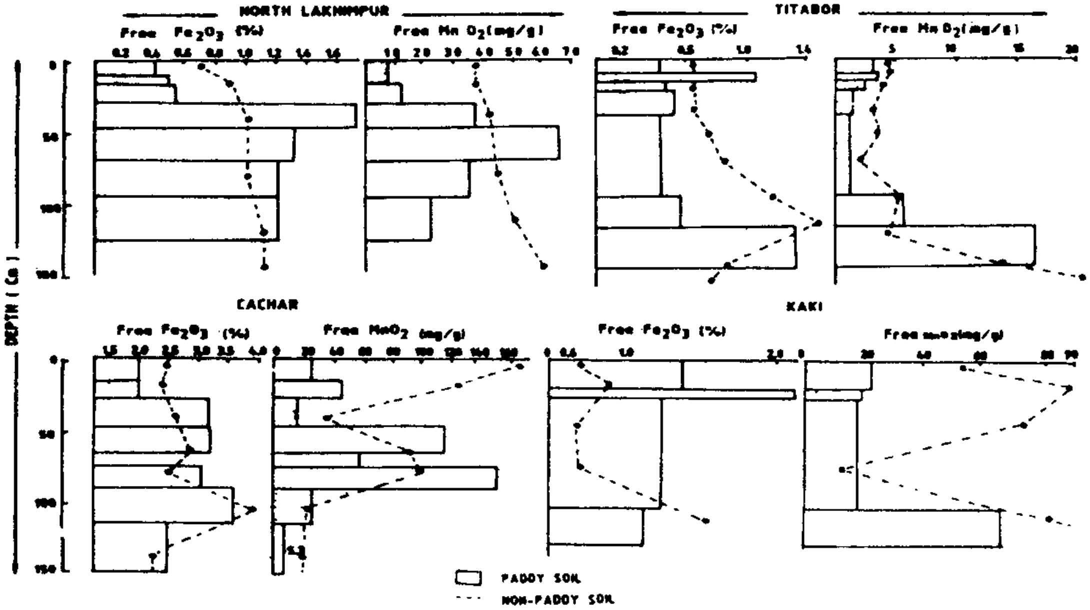

Fig. 5 Depth distribution of free iron and manganese in the paddy and the associated non-paddy soils

illuviation of free Mn was below that of free Fe suggesting greater mobility of Mn than Fe under submerged condition due to difference in redox system (Mitsuchi 1985). The present observation suggests that in evaluating free Fe as a weathering index, its content should be analysed atleast to a depth of 60 cm in traditional paddy soils of Assam.

Soil Taxonomy: The soils were classified on the basis of morphological, physical and chemical characteristics (Soil Survey Staff 1975). The locations where both paddy and non-paddy soils under natural condition were well drained (North Lakhimpur, Titabor, Cachar), there was change in soil classification at suborder level, whereas in poorly drained location (Kaki), there was change at subgroup level between two groups of soils. Soils of North Lakhimpur, Titabor and Kaki (P1, P2, P3, P4, P5, P6) belong to order Inceptisol because of presence of cambic horizon, whereas soils of Cachar (P7, P8), because of argillic horizon belong to the order Alfisol. A new sub-group 'alfic' is suggested to highlight development of subsurface horizon intermediate to cambic and argillic in Titabor (P3, P4). Soils were classified as follows :

North Lakhimpur : Pedon 1, Paddy Soil : Coarse loamy Typic Haplaquept
Pedon 2, Non-paddy soil : Coarse loamy Dystric Eutrochrept
Titabor: Pedon 3,Paddy soil : Coarse loamy Alfic Humaquept
Pedon 4, Non-paddy soil : Coarse loamy Fluventic-alfic Haplumbrept

Kaki : Pedon 5, Paddy soil : Fine Vertic Humaquept
Pedon 6, Non-paddy soil : Fine Typic Haplaquept
Cachar : Pedon 7, Paddy soil : Fine Vertic Ochraqualf
Pedon 8, Non-paddy soil : Fine Vertic Hapludalf

All soils had mixed mineralogy and hyperthermic temperature regime.

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