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Physico-chemical properties and acidity components of some alluvial derived soils of the Brahmaputra valley of Assam

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Abstract
A study was carried out to investigate the profile distribution of phosphorus and its relation with pedogenesis of some alluvium derived soils of the Brahmaputra Valley of Assam. Three different locations of Jorhat district starting from Borholla at the extreme South of the District, at Koronga in midpoint and Alengmora located near the bank of Brahmaputra were selected for the purpose. From each area, two profiles were exposed, one from rice-ecosystem and another from adjacent non-rice ecosystem. Soil samples were collected from six profiles P1(Rice ecosystem, Borholla), P2((Non-rice ecosystem, Borholla), P3(Rice-ecosystem, Koronga), P4(Non-rice ecosystem Koronga,), P5(Rice-ecosystem, Alengmora) P6 (Non-rice ecosystem, Alengmora) with twenty seven numbers of horizons. The soils are dark brown to brownish yellow in colour with a dominant hue of 10YR. value ranged from 4 to 6,while chroma varied widely from 2 to 8 and varied widely in texture (sandy loam to clay), structure (single grain to moderately strong sub-angular blocky), clay content (7.5-44.5%), pH(4.3-6.9)was lower in the surface horizon and it tends to increase with soil depth and surface horizons of all the pedons recorded the highest organic carbon (OC) content(0.1-1.81%) within a profile and it decreased regularly with the soil depth except in P5 and P6 where an irregular depth distribution pattern was observed. Cation Exchange capacity (CEC) of the soils ranged from (4.7-12.3)and the bulk density ranged from(1.31Mg m^{-3}-1.81 Mg m^{-3})which first increased with depth in P1, P2, P3 and P4 and thereafter it showed either a decreasing trend or irregular pattern. But it showed a regular increasing pattern with depth in P5 and P6. Different acidity components which includes the values of Exchange acidity that ranged from (0.50 to 3.25) cmol (p^+) kg^{-1}. The values of exchange acidity were lowest in the surface horizon of P1 to P4 which increases with depth but in P5 and P6 it decreases with depth of the profile where total potential acidity was found higher in the surface of P1, P2 and P5 and thereafter it decreased with depth. The rest of the soils did not show any definite depth distribution pattern and similar kind of distribution trend was also observed in pH dependent acidity of the soils which varied from 4.00 to 11.05 cmol (p^+)kg^{-1}. The soils were classified in the order Alfisols (P1 and P2), P2 (Non Rice) as Inceptisols, (P3 and P4) and as Entisols (P5 and P6) respectively.

Keywords: Characterization; classification, alluvium-derived soils, land uses

Introduction
The study area comprises of Jorhat district which is a part of upper Brahmaputra valley zone of Assam. The district is located in between the latitude of 26 ^{0}20' to 27 ^{0}10' N and longitude 93 ^{0}57' to 94^0 37'E.Total geographical area of the district is 2,859.35 sq km, equivalent to 3.63 percent of the state. The area consists of both old and new alluvial plains, char lands and some highlands. On the basis of physiography, climate, soil, flood proneness, socio economic condition and cropping pattern, the district is classified into six Agro-Ecological situations. The region experiences hot and wet summer and dry and cool winter and the climate that prevails in this region is humid subtropical. Mean annual temperature of the area is 23.2 ^{0}C with maximum temperature and minimum temperature 31.35 ^{0}C and 15.05 ^{0}C. The average annual rainfall of the district is about 2000 millimetres. Hence the area qualifies for hyperthermic soil temperature and udic soil moisture regime.

Six soil profiles at three different locations of Jorhat district, starting from extreme south of the district to near bank of Brahmaputra were exposed for the study (Fig 1). From each location, two profiles were exposed, one from Rice Ecosystem and other from adjacent Non-Rice Ecosystem. Horizons were demarcated and the morphological characteristics of each horizon such as colour, texture, structure, consistency, mottles, presence of cutans etc. were studied in the field itself following Soil Survey Manual (NBSS and LUP, 2009). The details of the location of the profiles and other site characteristics are described in Table 1. Horizon-wise soil samples were collected, air dried under shade and processed.

The fine earth fraction (<2 mm) was analyzed for mechanical composition (Piper 1950; Jackson 1956), pH (in water and 1N KCl in 1:2.5 ratio) Organic carbon and CEC following standard procedures (Jackson 1973). Bulk density (BD) was determined by clod (Black 1965). Exchangeable H^+ and Al^{3+} were determined in 1N KCl (Page *et al*. 1982). Exchange Acidity was determined Sokolov as described by (1939) and McLean (1965). Total Potential Acidity as described by Black (1965). pH Dependent Acidity was determined by subtracting total dependent acidity from exchange acidity.

Table 1: Site characteristics of the soil Profiles

Pedon No	Location	Ecosystem	Order
P1 (Rice)	Borholla	Rice	Alfisols
P2 (Non Rice)	Borholla	Non-rice	Alfisols
P3 (Rice)	Koronga	Non-rice	Inceptisols
P4 (Non Rice)	Koronga	Non-rice	Inceptisols
P5 (Rice)	Alengmora	Non-rice	Entisols
P6 (Non Rice)	Alengmora	Rice	Entisols

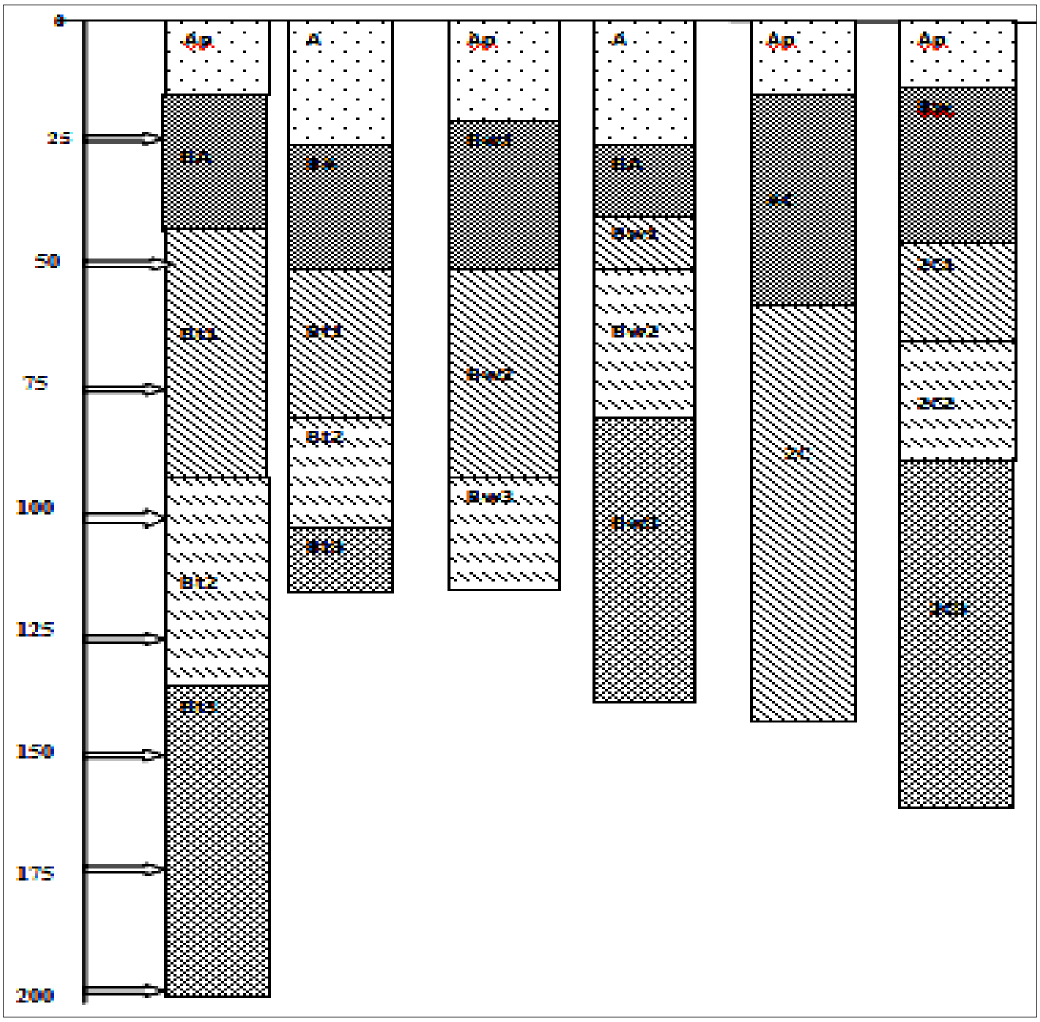


Fig 1: Horizonation of Profile

Results and Discussion

Morphological Characteristics

The horizon differentiation and profile development trend of the soils under each land use is shown in Fig.1 The morphological characteristics of the soils are presented in Table 2. The colour of the studied profiles ranged from dark brown to brownish yellow with a dominant hue of 10YR. The 10YR hue might be due to hydrated oxides of iron formed under humid condition (Dutta and Karmakar, 1995) [6]. The low chroma of the soils in P6 under rice ecosystem is attributed to the reducing condition of the soil in some part of the year (Chakravarty, 1977) [7]. A wide textural variation ranging from sandy loam to clayey was observed in the studied soil profile which becomes heavier with depth because of higher degree of translocation of clay to lower horizons (Dutta *et al*., 1995) [6]. The structural development of soils was quite similar with mostly weak to moderate sub-angular blocky type structure. Similar observations was also made by Dutta *et al*., (1999) [8] and Karmakar and Rao (1999) [8] in soils of Assam. Reddish yellow mottles have been observed in the lower horizons of all profiles except P5 and P6. The presence of these mottles indicated an alternate oxidation and reduction caused by fluctuating ground water table. In P1 and P2 under rice and non-rice ecosystem clay cutans are also observed in the horizons below a depth of 40 cm from the surface. The formation of clay skins on the ped faces reflected the maturity of these soils. The paddy soils have massive structure in the surface horizon. This is the result of mechanical breakdown of soil structure caused by puddling and subsequent drying. Puddling causes destruction of aggregates due to mechanical disturbance (Padma Raju and Deb, 1968; Tarasawa, 1975) [9].

Physicochemical properties and acidity components of soil

The particle size distribution data revealed a wide variation in sand, silt and clay content of the soils (Table 3) Sand fraction of soils ranged from 35.0-73.2 per cent and the particle size distribution of the studied soils showed a decreasing trend of sand with depth at Borholla and Koronga under both rice and non-rice conditions. But soils of Alengmora area (P5 and P6) sand increased with depth. The clay content showed a completely reverse trend in all the soils (Fig 2) The highest amount of clay (44.5%) was observed in Bw2 horizon of P4 (Non-rice, Karanga) and lowest (8.9%) being recorded in 2C horizon of P5 (Rice field, Alengmora). This might be attributed to the differences in the maturity of the soils. A highly significant and negative correlation between sand and clay fraction (r = -0.967**) in these soils suggested that appreciable amount of clay has been formed due to weathering of sand. Similar observation was also reported by Dutta and Karmakar (1995) [6] and Dutta *et al*. (2016). Bulk density of these soils was found to be mostly influenced by texture of the soils as highly significant relationship was observed between these physical properties and sand and clay content of these soils (Table 5). The pH range (4.3-6.9) indicated very strongly acidic to neutral condition of the soils. The overall low pH of the soils might be due to leaching of exchangeable bases under high rainfall condition (Dutta *et al*., 1999) [8]. Lower pH in the surface horizon of most of the soils irrespective of land use might be attributed to high rate of biochemical weathering at the surface of soil that causes release of more amount of proton to the soil solution. The increasing trend of pH with depth might be attributed to the deposition of exchangeable bases in the subsurface horizons of the profiles. The organic carbon content was found to be higher in the surface horizons of all the profiles which might be due to the incorporation of plant biomass in the form of weeds and crop residues in the studied soils or due to the addition of other organic source especially in rice fields. The observation was in good agreement with the finding of Dutta *et al*., (2016). The presence of higher amount of divalent cations (Ca^{2+} and Mg^{2+}) than the monovalent cations (Na^{+} and K^{+}) in the soils were in conformity with the Jenny's, (1931) view which implies preferential loss of monovalent ions and at the same time greater losses of Na^{+} and K^{+} by leaching. The variation of CEC in the studied soils was found to be mainly governed by amount of clay as indicated by a significant and positive relation (r =0.609**) between these two properties. Exchange acidity was observed that exchangeable aluminium had contribution towards exchange acidity suggesting that exchangeable acidity in soil is mostly due to monomeric Al^{+3}ions.Total potential acidity decreased with depth due to deposition of exchangeable bases with increasing soil depth. The higher values of total potential acidity in some soils might be due to higher content of organic carbon.

Table 2: Morphological characteristics of the collected soil samples

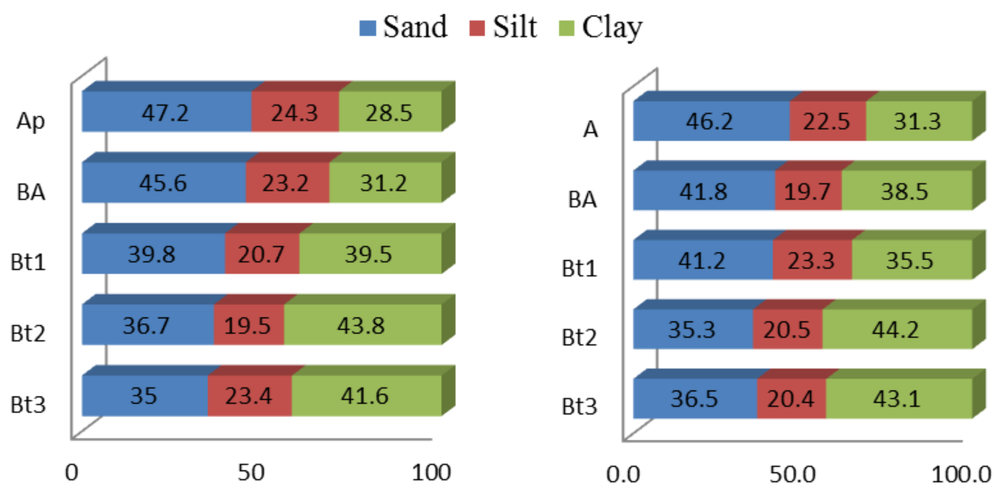
[a]Horizon	Depth	Colour(moist)	Texture	structure	Mottles(colour)	Cutans	Roots
Pedon 1(P1):Rice field (Borholla)							
Ap	0-15	10YR5/6	scl	massive	-		m-f
BA	15-40	10YR6/6	scl	m2sbk	5YR6/8		m-f
Bt1	40-95	10YR6/8	cl	m2sbk	5YR6/8	f-f-d	f-f
Bt2	95-140	10YR6/8	c	m2sbk	5YR6/6	f-f-d	f-f
Bt3	140-200	10YR6/8	c	m2sbk	5YR6/6	f-f-d	-
Pedon 2(P2):Non-rice (Borholla)							
A	0-25	10YR5/4	scl	f1sbk	-		m -m
BA	25-50	10YR5/6	cl	m1sbk			m-f
Bt1	50-80	10 YR6/6	cl	m2sbk		f-f-d	f-f
Bt2	80-115	10YR6/8	c	m2sbk	7.5YR6/8	f-f-d	f-f
Bt3	115-120	10YR6/8	c	m2sbk	7.5YR6/8	f-f-d	
Pedon 3(P3):Rice field (Koronga)							
Ap	0-20	10YR5/3	scl	massive	-		m-f
Bw1	20-50	10YR6/8	cl	m1sbk	5YR6/8		f-f
Bw2	50-90	10YR6/6	cl	m2sbk	5YR6/8		f-f
Bw3	90-120	10YR6/6	c	m2sbk	5YR6/8		
Pedon 4(P4):Non-rice (Koronga)							
A	0-25	10YR5/4	scl	f1sbk	-		m-f
BA	25-35	10YR5/3	scl	f1sbk	7.5YR6/8		f-f
Bw1	35-50	10YR6/6	cl	m1sbk	7.5YR6/8		f-f
Bw2	50-85	10YR6/6	cl	m2sbk	7.5YR6/8		f-f
Bw3	85-140	10YR6/6	c	m2sbk	7.5YR6/8		
Pedon 5 (P5):Rice field (Alengmora)							
Ap	0-15	10YR4/3	scl	massive	-		f-f
AC	15-55	10YR4/3	sl	f1sbk	-		f-f
2C	55-140	10YR5/3	sl	sg	-		
Pedon 6(P6):Non-rice(Alengmora)							
Ap	0-14	10YR4/3	l	f1sbk	-		m-f
Bw	14-40	10YR5/4	scl	f1sbk	-		f-f
2C1	40-72	10YR5/3	sl	sg	-		f-f
2C2	72-90	10YR4/3	sl	sg	-		
2C3	90-160	10YR5/2	sl	sg	-		

[a]Texture: sl – sandy loam; scl – sandy clay loam; cl – clay loam; c – clay. Structure: f – fine, m – medium; 1 – weak, 2 – moderate; m – massive, sbk – subangular blocky. Mottles Abundance: f – few, m – many; Size: 1 – fine, 2 – medium; Contrast: f- faint, d – distinct

Table 3: Physicochemical properties of the soils

Horizon	Depth (cm)	PSD			pH (1:2.5)		OC (%)	BD (Mg m^{-3})	TEC	CEC
		Sand (%)	Silt (%)	Clay (%)	H_20	KCl			(cmol(P^+)kg^1)	
	Pedon 1(P_1):Rice field (Borholla)									
Ap	0-15	47.2	24.3	28.5	4.3	3.8	1.24	1.31	3.35	7.6
BA	15-40	45.6	23.2	31.2	5.5	4.2	0.26	1.43	3.77	8.2
Bt1	40-95	39.8	20.7	39.5	5.7	4.3	0.15	1.51	4.97	9.8
Bt2	95-140	36.7	19.5	43.8	5.9	4.2	0.16	1.42	4.73	9.9
Bt3	140-200	35.0	23.4	41.6	6.0	4.6	0.12	1.47	2.93	6.7
	WM	38.9	21.8	39.2	5.7	4.3	0.24	1.45	4.03	8.5
	Pedon 2(P_2):Non-rice (Borholla)									
A	0-25	46.2	22.5	31.3	4.7	4.4	1.71	1.31	3.35	9.1
BA	25-50	41.8	19.7	38.5	4.9	4.0	0.78	1.43	3.48	8.7
Bt1	50-80	41.2	23.3	35.5	5.4	3.8	0.52	1.51	3.53	8.2
Bt2	80-115	35.3	20.5	44.2	5.4	3.9	0.52	1.42	4.12	7.5
Bt3	115-120	36.5	20.4	43.1	6.0	4.2	0.50	1.47	4.40	7.2
	WM	40.5	21.4	38.1	5.1	4.0	0.82	1.45	3.69	8.28
	Pedon 3(P3):Rice field (Koronga)									
Ap	0-20	46.2	24.5	29.3	5.7	4.2	1.81	1.43	3.77	7.7
Bw1	20-50	44.5	23.9	31.6	5.4	4.2	0.93	1.53	3.55	8.1
Bw2	50-90	42.5	22.3	35.2	5.0	4.0	0.67	1.46	4.34	8.9
Bw3	90-120	40.6	18.3	41.1	5.4	4.0	0.67	1.32	5.21	9.6
	WM	43.1	22.1	34.7	5.32	4.06	0.93	1.44	4.27	8.68
	Pedon 4(P4):Non Rice field (Koronga)									
A	0-25	49.5	22.2	28.3	5.2	4.5	1.66	1.58	3.98	9.7
BA	25-35	45.5	24.4	30.1	5.5	4.2	1.55	1.57	3.15	8.7
Bw1	35-50	42.2	22.3	35.5	5.8	4.7	1.29	1.51	2.76	10.2
Bw2	50-85	39.9	23.2	36.9	5.7	4.1	0.81	1.47	4.19	12.3
Bw3	85-140	36.2	19.3	44.5	5.7	3.8	0.47	1.32	3.94	10.5
	WM	40.8	21.4	37.7	5.59	4.14	0.93	1.44	3.83	10.65
	Pedon 5(P5):Rice field (Alengmora)									
Ap	0-15	46.4	26.9	26.7	6.6	4.5	0.78	1.48	4.81	10.2
AC	15-55	53.7	27.4	18.9	6.7	4.8	0.34	1.62	3.40	4.7
2C	55-140	73.2	19.3	7.5	6.9	5.3	0.41	1.79	3.30	5.1
	WM	64.7	22.7	12.8	6.82	5.06	0.43	1.71	3.49	5.53
	Pedon 6(P6):Non-rice(Alengmora)									
Ap	0-14	50.4	28.7	20.9	6.5	5.2	1.03	1.55	5.89	7.7
Bw	14-40	47.5	26.7	25.8	6.8	4.2	0.52	1.57	5.15	8.1
2C1	40-72	70.8	20.1	9.1	6.8	5.0	0.41	1.79	2.72	7.2
2C2	72-90	61.7	25.1	13.2	6.7	4.7	0.52	1.71	2.74	5.7
2C3	90-160	72.6	18.5	8.9	6.5	3.7	0.58	1.81	2.73	6.1
	WM	64.9	21.7	13.2	6.65	4.27	0.57	1.73	3.40	6.74

(WM: Weighted Mean of the profile)



(P1) **(P2)**

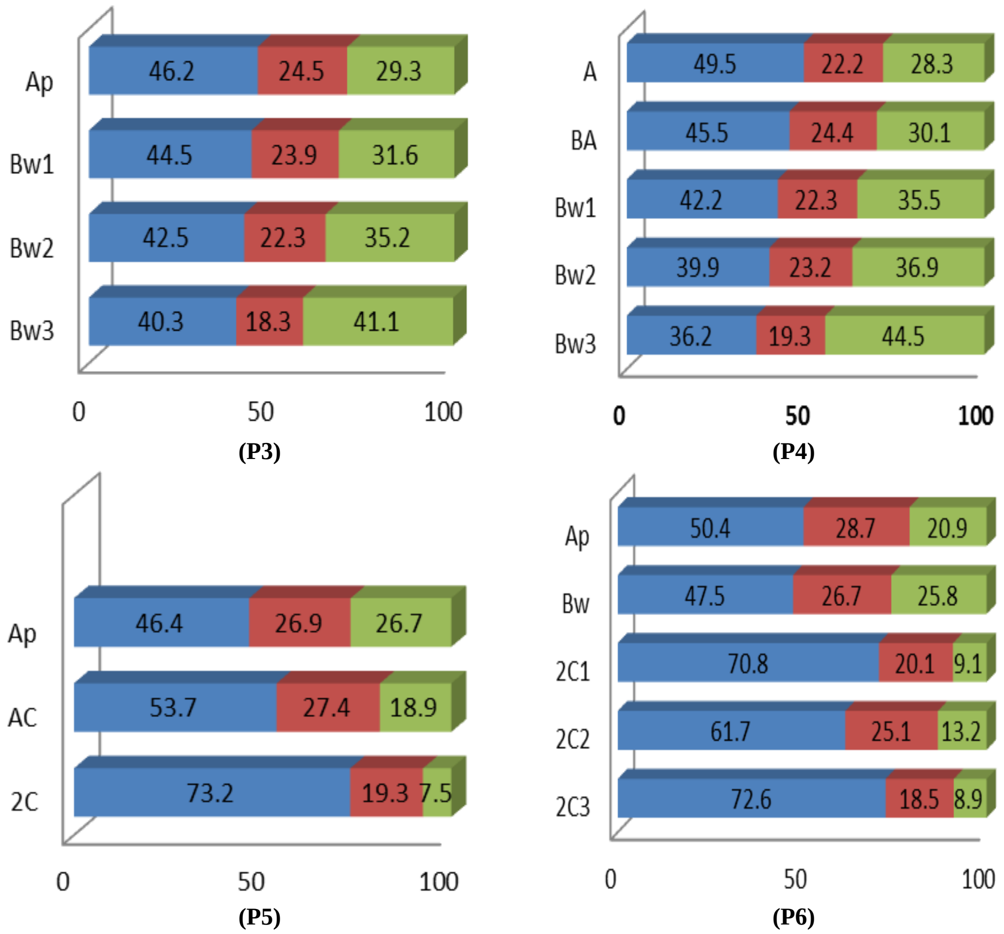


Fig 2: Depth distribution Pattern of Sand, Silt and Clay in the Profiles. (P1, P2, P3, P4, P5 and P6 represent the profiles)

Table 4: Acidity Components of the Soil samples

Horizon	Depth (cm)	Exch. H^+	Exch. Al^{3+}	Exchange acidity	Total Potential Acidity	pH dependent acidity
		(cmolp$^+$ kg^{-1})				
Pedon 1(P1):Rice field (Borholla)						
Ap	0-15	0.45	0.625	1.08	10.25	9.18
BA	15-40	0.39	0.87	1.26	11.68	10.42
Bt1	40-95	0.34	1.08	1.42	12.47	11.05
Bt2	95-140	0.39	1.21	1.60	9.95	8.35
Bt3	140-200	0.47	1.45	1.92	8.97	7.05
	WM	0.40	1.16	1.56	10.59	0.23
Pedon 2(P2):Non-rice (Borholla)						
A	0-25	0.56	0.79	1.35	11.10	9.75
BA	25-50	0.47	0.65	1.12	10.20	9.08
Bt1	50-80	0.46	0.96	1.42	8.50	7.08
Bt2	80-115	0.63	1.18	1.81	9.20	7.40
Bt3	115-120	0.52	1.09	1.61	7.50	5.89
	WM	0.53	0.93	1.46	9.56	0.32
Pedon 3(P3):Rice field (Koronga)						
Ap	0-20	0.63	0.71	1.34	8.40	7.07
Bw1	20-50	0.50	0.86	1.36	10.10	8.74
Bw2	50-90	0.63	2.63	3.25	9.60	6.35
Bw3	90-120	0.63	1.88	2.50	9.80	7.30
	WM	0.59	1.68	2.27	9.58	0.24
Pedon 4(P4):Non Rice field (Koronga)						
A	0-25	0.35	0.65	1.00	6.90	5.90
BA	25-35	0.43	0.83	1.26	8.60	7.34
Bw1	35-50	0.49	1.03	1.52	11.20	9.68
Bw2	50-85	0.71	1.29	2.00	8.90	6.90
Bw3	85-140	0.50	1.15	1.65	9.10	7.45
	WM	0.52	1.06	1.58	8.85	0.26
Pedon 5(P5):Rice field (Alengmora)						
Ap	0-15	0.38	0.63	1.01	6.60	5.60
AC	15-55	0.21	0.45	0.66	5.10	4.44

2C	55-140	0.25	0.25	0.50	4.50	4.00
	WM	0.25	0.35	0.60	4.90	0.10
Pedon 6(P6):Non-rice(Alengmora)						
Ap	0-14	0.38	0.50	0.88	7.00	6.13
Bw	14-40	0.13	0.38	0.50	6.40	5.90
2C1	40-72	0.23	0.63	0.86	6.90	6.05
2C2	72-90	0.13	0.50	0.63	7.10	6.48
2C3	90-160	0.25	0.58	0.83	6.80	5.97
	WM	0.22	0.54	0.76	6.81	0.19

(WM: Weighted Mean of the profile)

Table 5: Correlation coefficient of Physicochemical and acidity components of soil

	[a]S AND%	SILT%	CLAY%	BD	pH(H_2 0)	OC %	Ex Acidity	TPA	CEC	TEC
SAND%	1									
SILT%	-0.018	1								
CLAY%	-0.967**	-0.237	1							
BD	0.844**	0.004	-0.821**	1						
pH(H_2 O)	0.551**	0.211	-0.589**	0.653**	1					
OC(%)	-0.011	0.253	-0.054	-0.141	-0.440*	1				
Ex Acidity	-0.620**	0.328	-0.686**	-0.593**	-0.518**	-0.479**	1			
TPA	-0.606**	-0.263	0.655**	-0.620**	-0.720**	0.087	-0.520**	1		
CEC	-0.590**	-0.139	0.609**	-0.569**	-0.435*	0.240	0.418*	0.544**	1	
TEC	-0.414*	-0.179	0.357	-0.434*	0.031	-0.113	0.230	0.045	0.398*	1

[a]the * symbol indicates the level of significance. Single * indicates significant differences at $p< 0.05$ and double ** indicates significant differences at $p< 0.01$

Soil Classification

Based on the field morphology and physico-chemical characteristics, the soils of six pedons were classified upto sub-group level as per Soil Taxonomy (2014) There was evidence of presence of thin, patchy, clay cutans on ped surfaces of the lower horizons of P1 under rice ecosystem and P2 under non-rice ecosystem. Illuviation of clay was also prominent as indicated by higher clay content in the lower horizons. The amount of clay in these horizons was more than 1.2 times than the overlying horizons. Considering the amount of clay and presence of clay cutans, these horizons fulfilled the criteria of an argillic horizon and placed under the soil order Alfisols as per cent base saturation was more than 35 percent throughout the depth of profile. The soils does not exhibit any distinguish character except having an udic soil moisture regime and thus in the suborder level it was placed under Udalf. Under Great group level, the soils qualified for Hapludalf. The soils of P1, under rice ecosystem was generally saturated with water in one or more layers within 100 cm of mineral soil surface in normal years for either 20 or more consecutive days or 30 or more cumulative days and thus classified as Oxyaquic Hapludalf at subgroup level and the non-rice soils (P2) is classified as TypicHapludalf. The soils of Koronga (P3 and P4) showed considerable illuviation of clay but there was no evidence of development of clay cutans. Structural improvement with depth of the profile indicated the development of a cambic horizon in these soils. With a regular decreasing trend of organic carbon with depth and presence of cambic horizon these soils therefore qualifies for soil order inceptisols and udept at sub order level because of presence of udic soil moisture regime. At the greatgroup level these soils were placed under Dystrudepts as the soils have less than 60 percent base saturation throughout the profile. The soils of P3 qualifies for Oxyaquic Dystrudepts at the sub group level because of its saturation period with water which lasts for more than 20 consecutive days or 30 cumulative days under transplanted rice ecosystem and the non-rice soils (P4) is placed under Typic Dystrudepts. The soils of Alengmora (P5 and P6) showed erratic clay and organic carbon depth distribution pattern. There were also no evidences of structural improvement or presence of any diagnostic horizon. These soils therefore placed under the soil order Entisols and at suborder level they qualify for Fluvents. The soils were further classified as Udifluvents at the great group level due to presence of udic soil moisture regime and finally the soils under rice cultivation (P5) were classified as Oxyaquic Udifluvents because of its saturation period with water. The other soil (P6, non-rice) was classified as Typic Udifluvent.

Conclusion

The present study clearly demonstrates the influence of physicochemical properties and acidity components under Rice and non-Rice ecosystem in soils. The soils showed considerable variations in morphological and physicochemical properties due to variations in land uses particularly management practices remarkable changes in soil properties both in terms of morphological and physicochemical parameters were observed as affected by the stages of pedogenic development of these soils. Clay and Sand exhibited a definite depth distribution trend in all the areas under cultivation except in the areas which is located almost at the bank of Brahmaputra. The soils under the order Alfisols and Inceptisols formed from same kind of parent material but non uniformity of parent material was observed in the entisols as time is a limiting factor in soil development because of frequent flooding and silt deposition. Bulk density was found to be mostly influenced by texture of the soils as highly significant relationship was observed between these physical properties and sand and clay content of these soils.

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