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Characterization and classification of soils under different land use systems in the upper Brahmaputra valley of Assam

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ABSTRACT

For characterization of soils, soils were collected from Jorhat and a Golaghat district during 2016-2017under different land uses systems i.e. bamboo, sugarcane, tea and rice. Results indicated that surface soils of different land use systems varied from greyish brown (10YR 5/2) to brownish yellow (10YR 6/8).The structure was found predominantly sub-angular blocky and loam to clay loam in texture. The soil soils of all horizons of bamboo, tea plantation and rice were extremely acidic (pH <4.5) except sugarcane horizons (strongly acidic pH 5.0-5.50).Soil cation exchange capacity(CEC) in bamboo, sugarcane, tea plantation and rice varied from 6.20 to 7.29 cmol (p+)/kg, 8.19 to 9.92 cmol (p+)/kg, 5.54 to 6.88 cmol (p+)/kg, and 6.99 to7.58 cmol (p+)/kg, respectively due to variation in clay content. Sugarcane and tea plantation soils showed clay alleviation with more than 1.2 times in sub-surface horizon over surface horizon with low base saturation <35%to place them in the Ultisol and classified as fine-loamy, mixed, hyperthermic family of Typic Hapludults.In bamboo plantation, the soil had cambic horizon with base saturation <35%and classified as coarse loamy, mixed, hyperthermic family of Typic Dystrudepts, whereas, in case of rice soil, the gleyed sub-surface horizon was observed with base saturation <35% and classified as loamy, mixed, hyperthermic, Typic Endoaquepts.The correlation coefficient (r) among physico-chemical of soil properties in profiles under different land use systems in upper Brahmaputra valley of Assam showed organic carbon was positively and significantly correlated with base saturation. The pH showed positive and significant correlation with CEC and clay content.

Key words: Brahmaputra valley, classification, characterization, hyperthermic, land use

INTRODUCTION

The soil is the most important basic natural resource which determines the ultimate sustainability capacity of any agricultural system. A comprehensive and proper knowledge of the soils morphological, physical and chemical characteristics offers further insight into the soil's dynamics. The North Eastern Region (NER) of India is characterized by very complex geological and geomorphic formations with heavy rainfall, which is commensurate with various types of soils formed on different landforms. The Brahmaputra valley comprises of majorly alluvial soils formed on recent river deposits called “new alluvium”. Inside the valley, there are few isolated pockets of Pleistocene deposits called “old alluvium” found along the foothills and in parts of Bangladesh (Goswami and Das, 2003). A cropping system is defined as the sequence of crops grown over a specific piece of cultivated land in order to enhance the benefits from the available physical resources. Therefore, the basic approach in an efficient cropping system is to increase production and accordingly the economic returns. A flexible cropping system helps in capturing economic opportunities and environmental realities (Gangwar*et al.*, 2004). It also ensures balanced farm growth at the regional level. Hence, selection of component crops needs to besuitably planned for efficient utilization of resources available and to attain higher overall productivity (Anderson, 2005). Inclusion of crops like cereals, oilseeds, pulses, vegetables, and fodder crops improve the economic condition of small and marginal farmers owing to higher price and higher volume of their major and by-products. Apart from this, wheat and maize also have gained popularity among the farmers of the study area. Characterizing and classifying soils is important for understanding the nature of soil resources. The data generated on the basis of the profile characteristics will serve as a benchmark for monitoring and evaluating the probable changes in soil characteristics in different crop systems periodically due to the introduction of different soil management techniques (Sahoo *et al.*, 2019).Therefore, keeping in view this importance present research

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work was carried out to classify the soil based on their morphological, physical and chemical characteristics of soils according to soil taxonomy (USDA) under different land use systems in the Brahmaputra valley of Assam.

MATERIALS AND METHODS

Present study was conducted during 2016-17 in Jorhat and Golaghat districts comes inthe upper Brahmaputra valley of Assam under different land use systems *i.e.* Bamboo field, Jorhatdistrict(26° 44′ 58.6″ N latitude and 94° 08′ 35.1″ E longitude), Sugarcane field, Golaghat**(**26° 37′ 39.5″ N latitude and 93° 56′ 41.1″ E longitude), Tea field, Jorhat district**(**26° 45′ 27.5″ N latitude and 94° 08′ 46.7″ longitude E) and Rice, Jorhat district (26° 55′ 29.5″ N latitude and 94° 04′ 41″ E longitude). The climate of the upper Brahmaputra valley part is humid, sub-tropical having an annual rainfall of 2250 mm. The moisture regimes was udic with hyperthermic soil temperature regime (STR) as mean winter and summer soil temperature differs by 5°C or more). Four land use systems were selected having nearly level plain (0-1% slope) to floodplain (1-3 % slope) for conducting research work (Table 1). The morphological characteristics of the soils of the studied land use systems were studied in the field. Horizon-wise composite soil samples were collected and the soil samples were processed and used further for analysis of physico-chemical parameters. Particle size distribution of the soils of the studied pedons was determined by International pipette method (Piper 1966). The soil pH in1: 2.5 soil water ratios was determined by Richards's method (1954), organic carbon by Walkley and Black method (1934), KCl extractable Al^{3+} by Mclean method 1965.CEC(Jackson 1973), exchangeable calcium and magnesium were determined by EDTA titration method (Carr and Frank 1956). The exchangeable bases (K and Na) were determined using 0.1 M barium chloride ($BaCl_2.2H_2O$) as an extractant by (Hendershot and Duquette, 1986). Base saturation was calculated as sum of bases divided by CEC and multiplied by 100.The soils were classified based on intrinsic properties *viz.,* morphological characteristics, and physico-chemical properties (Soil Survey Staff 2010).

Table 1: Site characteristics under different land use systems of soil profiles

Land use systems	Drainage	Soil slope		Erosion	Run off	Ground water depth (m)	Landform
		Gradient (%)	Length (m)				
Bamboo plantation	Mw	1-3	0-50	m	mw	2-5	Floodplain
Sugarcane	Mw	1-3	50-150	sm	m	5-10	Very gently sloping upland
Tea plantation	Mw	1-3	50-150	m	m	2-5	Very gently sloping upland
Rice	P	0-1	0-50	sm	s	1-2	Nearly level plain

mw- medium well, p-poor, m-moderate, sm-slightly moderate, s-slow

RESULTS AND DISCUSSION

Morphological Properties

The soils of the studied profiles of four different land use systems in the upper Brahmaputra valley of Assam were very deep (150 cm depth) except rice field profile (Table 2).The surface soils of different land use systems varied from greyish brown (10YR 5/2) to brownish yellow (10YR 6/8) whereas iron mottles were noticed in lower horizons of profiles except bamboo plantation due to high rainfall and water fluctuations (Bhattacharyya *et al.*, 1996). Moreover, gleyed horizon with mottles was observed in lower horizons under rice profile. This may be due to the prevalence of excessive wet environment under fluctuating ground water condition which is a common phenomenon in waterlogged soils of NER (Bhattacharyya *et al.*, 2003). The structure of soil profiles under all different land use systems was predominantly sub-angular blocky which may be attributed to the presence of higher quantities of clay fraction (Sharma *et al.*, 2004). The texture of the surface horizons varied from loam to clay loam. Identification of relatively well-developed structure in the sub-surface horizon (compared to the surface horizons) supported by enriched clay distribution indicated the presence of cambic horizon (Bw) in bamboo plantation. Increase in clay content in the lower layers of sugarcane and tea plantation is attributed to clay illuviation.

Table 2: Morphological characteristics under different land use systems of soil profiles

Horizon	Depth (cm)	Soil colour	Soil texture	Soil structure	Soil consistency
Bamboo plantation: *coarse loamy, mixed, hyperthermic family of Typic Dystrudepts*					
A	0-20	Brown (10YR 5/3)	Sl	2msbk	sssp
AB	20-60	Brownish yellow (10YR 6/6)	Sl	2msbk	sssp
Bw1	60-100	Brownish yellow (10YR 6/8)	Sl	2msbk	sssp
Bw2	100-150	Brownish yellow (10YR 6/7)	Sl	2msbk	sssp
Sugarcane: *fine-loamy*, *mixed, hyperthermic family of Typic Hapludults*					
Ap	0-31	Greyish brown (10YR 5/2)	Cl	2msbk	sssp
Bt1	31-55	Pale brown (10YR 6/3)	Cl	2msbk	sssp
Bt2	55-76	Pale brown (10YR 6/3)	Cl	2msbk	sssp
Bt3	76-110	Pale brown (10YR 6/3) & mottles observed	Cl	2msbk	sssp
Bt4	110-150	Greyish brown (10YR 5/2) & mottles observed	Cl	2msbk	sssp
Tea plantation: *fine-loamy*, *mixed, hyperthermic family of Typic Hapludults*					
Ap	0-23	Light yellowish brown (10YR 6/4)	L	1msbk	sssp
AB	23-58	Light brownish gray (10YR 6/2)	L	1msbk	sssp
Bt1	58-95	Brown (10YR 5/3)& mottles observed	L	2msbk	sssp
Bt2	95-150	Pale brown (10YR 6/3)	Cl	2msbk	sssp
Ap	0-18	Grey (10YR 5/1)	L	1msbk	sssp
Rice: *loamy, mixed, hyperthermic, Typic Endoaquepts*					
Bg1	18-39	Grey (10 YR 6/1)	Loam	1msbk	sssp
Bg2	39-68	Brown (10YR 5/3)& mottles observed	sil	2msbk	sssp
Bg3	68-103	Grey (10YR6/1)& mottles observed	Sil	2msbk	sssp
Bg4	103-130	Grey (10 YR 5/1)	Sil	2msbk	sssp

2msbk-moderate medium sub-angular blocky, 1msbk-weak medium sub-angular blocky, ss-slightly stics, sp-slightly plastics, l-loam, sil-silty loam, cl-clay loam sl-sandy loam

Physical Properties

The mechanical fractionation reveals that the sand content in the soils of the studied profiles of the land use systems was decreased down the depth compared to surface horizon (Table 3). The sand content in soils of bamboo plantation was >50 % up to 60 cm depth. The silt content in tea plantation and rice land use systems was observed>35 %with irregular distribution in all depths. The erratic sand and silt distribution in soils of Brahmaputra plains were reported due to frequent seasonal floods that alter the mode of stratification within the alluvial profiles (Vadivelu *et al.*, 2004). The sub-soil clay content in sugarcane and tea plantation wasincreased1.2 times more to that of surface horizons to designate argillic horizon (Bt) with appearance of patchy clay skins on ped surfaces. The clay rich sub-soils in tea plantation have tremendous negative effect on proliferation of tea roots and soil productivity. The clay content was increased in sub-surface horizon over surface horizon under sugarcane and tea plantation which was due to illuviation of clay in the plateaus and lower valley regions. Irregular distribution of clay content was reported in soils of bamboo plantation whereas it was decreased with depth in rice. The more silt distribution in the soils of lower horizons of these land use systems of pedons and indicated lithological discontinuity. This may be attributed to topographical features of upper valley.

Table 3: Physico-chemical characteristics under different land use systems of soil profiles

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	OC (g kg^{-1})	pH	Ca	Mg	Na	K	EA	CEC	BS (%)
						cmol (p^+)/kg						
Bamboo plantation (*coarse loamy, mixed, hyperthermic family of Typic Dystrudepts)*												
0-20	54.0	29.4	16.5	7.2	4.24	1.23	0.50	0.04	0.15	0.96	6.20	31.0
20-60	52.0	32.3	15.6	6.1	4.19	1.15	0.45	0.04	0.10	1.50	6.52	26.9
60-100	44.8	34.9	20.2	3.6	4.23	1.02	0.58	0.05	0.08	1.69	6.71	25.8
100-150	41.1	37.6	21.1	3.2	4.41	0.73	0.60	0.06	0.06	1.98	7.29	19.9
Sugarcane (*fine-loamy*, *mixed, hyperthermic family of Typic Hapludults)*												
0-31	35.4	36.9	27.5	8.2	5.18	1.30	0.40	0.05	0.20	2.79	8.19	23.8
31-55	24.6	36.7	38.6	6.7	5.29	1.10	0.53	0.05	0.17	3.17	9.23	20.1
55-76	26.1	33.8	40.0	5.0	5.47	1.15	0.58	0.04	0.12	3.56	9.87	19.1
76-110	27.3	34.7	37.8	3.5	5.60	0.98	0.30	0.04	0.08	3.77	9.78	14.3
110-150	25.5	36.9	37.5	2.3	5.50	0.78	0.58	0.03	0.07	3.88	9.92	13.9
Tea plantation (*fine-loamy*, *mixed, hyperthermic family of Typic Hapludults)*												
0-23	46.8	36.0	17.1	6.8	4.29	1.22	0.57	0.05	0.17	1.52	5.54	36.2
23-58	39.5	39.1	21.3	4.7	4.52	1.08	0.48	0.07	0.14	1.79	5.49	32.3
58-95	38.4	36.7	24.8	3.3	4.63	0.83	0.70	0.06	0.11	1.92	6.33	27.0
95-150	34.3	37.5	28.1	2.4	4.66	0.67	0.52	0.44	0.08	2.06	6.88	19.3
Rice (*loamy, mixed, hyperthermic, Typic Endoaquepts)*												
0-18	33.6	48.0	24.0	7.1	4.31	1.02	0.77	0.10	0.21	1.77	7.02	29.7
18-39	29.6	54.2	21.6	4.3	4.58	0.87	0.83	0.11	0.16	1.98	6.99	28.2
39-68	24.2	58.2	18.5	3.4	4.73	0.70	0.60	0.10	0.13	2.29	7.39	20.7
68-103	23.7	62.5	15.2	3.5	4.69	0.67	0.42	0.08	0.11	2.54	7.47	17.0
103-130	24.1	60.6	14.3	2.6	4.64	0.85	0.50	0.06	0.09	2.71	7.58	19.8

EA= Exchangeable acidity

Chemical properties

The soils in all the horizons of bamboo, tea plantation and rice were having extremely acidic pH (<4.5) except in soils of sugarcane growing having strongly acidic (pH 5.0-5.50) (Table 3). These soils have an ideal soil pH rating for tea (pH 4.50 to 6.60) (Kacar 1984), and whereas extremely acidic conditions may have an adverse effect on tea growth and productivity. The extreme acidity of these soils can be explained by the oldness of the tea gardens and period of inappropriate fertilization methods (Ozyazici *et al.*, 2010). The low pH in all horizons is due to presence of organic carbon, whereas, low pH in B horizons of these soils is due to net negative charge of clay and extremely acidic to strong acid soils have high exchangeable aluminium in bamboo (0.96 to 1.74 cmol (p+)/kg, sugarcane (2.79 to 3.88 cmol (p+)/kg, tea plantation (1.52 to 2.06 cmol (p+)/kg and (1.77 to 2.71 cmol (p+)/kg with gradual increase with depth. The low concentration of exchangeable aluminium in surface horizons is due to mobilization of aluminium along with OC and its subsequent adsorption by clay minerals in sub-soils (Sahoo *et al.*, 2010).The OC content of the soil of bamboo, sugarcane, tea plantation and rice varied from 3.2 to 7.2, 2.3 to 8.2, 2.4 to 6.8 and 2.6 to 7.1 g kg^{-1} respectively with high at surface and decreased with soil depth. The highest amount of OC8.2 g $kg^{-1}$was observed in the sugarcane surface soil (Table 3).The high organic carbon content at the surface may be due to accumulation and decomposition of leaves, litter on the surface. Soil CEC in bamboo, sugarcane, tea plantation and rice varied from 6.20 to 7.29 cmol (p+)/kg, 8.19 to 9.92 cmol (p+)/kg, 5.54 to 6.88 cmol (p+)/kg, and 6.99 to7.58 cmol (p+)/kg, respectively. The CEC of < 10 cmol (p+)/kg throughout the profile in all different land use systems. The low CEC with depth indicates the occurrence of low activity clays and mixed mineralogy (Bhattacharyya *et al.* 2010). Among the extractable bases, Ca was found to be dominant cation followed by Mg in all different land use systems. The Na and K values however do not vary much within the pedons. The total extractable bases were high in surface soils and showed an irregular distribution with depth. This may be due to the accumulation of bases in the lower valley position by runoff water from the surrounding areas. These soils have low base saturation (< 35 %) in different land use systems.

Table 4: Correlation among physico-chemical soil characteristics under different land use systems of soil profiles

	pH	*OC*	*Ca*	*Mg*	*Na*	*K*	*EA*	*CEC*	*BS*	*Sand*	*Silt*
pH	1										
OC	-0.15	1									
Ca	-0.01	0.85**	1								
Mg	-0.38	0.00	-0.17	1							
Na	-0.34	-0.10	-0.44	0.61**	1						
K	-0.10	0.83**	0.57*	0.29	0.34	1					
EA	0.95**	-0.29	-0.15	-0.36	-0.30	-0.23	1				
CEC	0.91**	-0.16	-0.07	-0.29	-0.34	-0.19	0.93**	1			
BS	-0.71**	0.57*	0.53*	0.41	0.20	0.57*	-0.80**	-0.81**	1		
Sand	-0.69*	0.41	0.49*	0.01	-0.29	0.05	-0.78**	-0.68**	0.70**	1	
Silt	0.00	-0.16	-0.32	0.10	0.42	0.03	-0.00	-0.01	-0.11	-0.26	1
Clay	0.86**	-0.03	0.09	-0.13	-0.36	-0.04	0.78**	0.81**	-0.52*	-0.46	-0.17

Classification of soils

The sub-soil clay increase in sugarcane and tea plantation was 1.2 times more to that of surface horizons to designate argillic horizon (Bt) and low base saturation (< 35%) to place them in the Ultisol and classified as *fine-loamy*, *mixed, hyperthermic family of Typic Hapludults*.The occurrence of deep soils belonging to Ultisols and Inceptisols on slopes of elevated landforms suggests that the materials displaced from the summits were not transported to long distances but deposited in the adjoining lower landscapes (Bhattachayya *et al.*, 2002). However, it is interesting that in the lower valley region the soils have argillic horizon may be due to stability of the landscape and uniform cropping system. In bamboo plantation on flood plain, the B horizons were cambic horizons and base saturation of less than 35 per cent so this classify as *coarse loamy, mixed, hyperthermic family of Typic Dystrudepts*. But in rice cultivated soil profile on nearly level plain, *gleyed* sub-surface horizon was observed and the soil was classified as *loamy, mixed, hyperthermic, Typic Endoaquepts.* The correlation coefficient (r) among physico-chemical of soil properties in profiles under different land use systems in upper Brahmaputra valley of Assam soil showed clay content was positively and significantly correlated with CEC that indication of illuviation in soil under sugarcane and tea plantation. The pH showed positively significant correlation with CEC and clay whereas base saturation showed positive significant correlation with organic carbon content in soil profiles (Table 4)

Four different land use systems in the upper Brahmaputra valley of Assam were characterized and classified in the subgroups of Inceptisols and Ultisols based on base saturation and clay illuviation. The formation of diverse group of soils could be attributed to the effect of topography, vegetation and climate leading to various pedogenic processes. The valley soils can be used for crop diversification with strategic agronomic measures and different land use systems soils that will help in taking effective measures for sustainable soils management. The information generated can also help the researchers, farmers and planners to comprehend the natural resources of upper Brahmaputra valley of Assam.

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