__Original Research Article__

Characterization of Rice Growing Soils of Lower Brahmaputra Valley Zone (LBVZ) of Assam, India

Abstract

An experiment was conducted to characterize and classify the physico-chemical properties of different rice growing soils namely *Ahu*, *Sali* and *Boro* rice of Boko block of Assam. A total of sixty (60) geo-referenced and representative (0-15 cm) samples of soil were collected from the three different rice growing soils (20 each) *viz., Ahu, Sali* and *Boro*. The soils were then tested for their different physico-chemical properties. Soil textural classes varied from sandy loam to clay loam for *Ahu* and *Sali* rice while clay loam in *Boro* rice with strongly acidic to moderately acidic in their reactions (pH 4.52 to 5.85). Soil organic carbon was found to be medium to high in *Ahu* and *Sali* rice but high in *Boro* rice growing soils. The clay content was found to be significantly more in Boro rice growing soils as a contrary to *Ahu* and *Sali* rice growing soils. The EC values represented the non-saline nature of the soils and the CEC of all the rice growing soils of Boko block was invariably low with the mean values of 8.66 cmol (p+) kg^{-1} for *Ahu* rice growing soils, 8.80 cmol (p+) kg^{-1} for *Sali* rice growing soils and for *Boro* rice growing soils it was 8.90 cmol (p+) kg^{-1}. All the available primary nutrients were medium in their status except available phosphorus which was low to medium. Exchangeable Ca^{2+} was the dominant basic cation followed by Mg^{2+}.

INTRODUCTION

The history of agriculture in India runs down the memory lane to the neolithic era. If statistical reports are to be believed it states that more than 50% of the Indian workforce is engaged in agriculture and contributing 17-18% to the country’s GDP. India is also the second largest producer of wheat and rice, the world’s major food staples. Rice management often hastens the soil forming processes and have a considerable impact on soil forming processes compared to non-rice growing soils (Gholami *et al.,* 2017). Indian farming is a mix of modern techniques and traditional age-old practices which influences considerably the soil quality.

According to data it also shows that Assam being one of the most rice producing state in the Indian subcontinent has low to average agricultural productivity with very low productivity in some of the districts. Rice growing soils is often characterized as unique anthropogenic type of soils that is formed under long term hydro-agric management with seasonal submergence (Gong, 1999).

The success rate of higher crop production relies on testing of the soil for its various physical and chemical properties to know better the soil health as the growth and development of any crop requires adequate nutrient supplying capacity of the soil and its ability to sustain the various developmental activities from time to time. One of the critical constraints hindering rice cultivation in Assam is lack of site specific information on soil characteristics. Appropriate information on soil characteristics is fundamental to obtain optimum soil productivity. The attributes of yield are dependent on the soil and its characteristics. Modern agricultural practices need site specific management of soil nutrients and its various properties governing the quality of soil. In order to adopt good management practices and higher productivity, a systematic study of the soils is highly essential. Hence, the present investigation was taken up to characterize and classify the soils of lower Brahmaputra valley of Assam more specifically of Boko block (Fig 2) of Kamrup(R) district (Fig 1) to give a clear view of the rice growing soils of this area.

MATERIALS AND METHOD

The present study was conducted by collecting samples from different rice growing soils *viz., Ahu, Sali* and *Boro* rice in Boko block (Fig 2) which comes under Kamrup(R) district (Fig 1) of Lower Brahmaputra Valley Zone (LBVZ), Assam. Major part of Kamrup district is covered by younger and older alluvium of Quaternary Period. The climate of the study area is humid sub-tropical. The mean annual rainfall of the area is 1566 mm, major portion of which is received during April-September (1484 mm).

The soil samples were air dried, grounded and passed through a 2 mm sieve. The sieved soil samples were stored in plastic bags and subsequently used for analysis of various soil parameters. The particle size analysis was done as per international pipette method as described in ISSS (1929) using sodium hexameta phosphate as dispersing agent. The textural classes were determined as per the USDA system. The pH was determined by 1:2.5 soil: water suspension menthod using pH meter (Jackson, 1973). Organic carbon was determined by wet digestion method determined by (Walkey and Black, 1934). Available nitrogen was estimated by alkaline potassium permanganate method (Subbiah and Asija, 1956). Available phosphorus was determined by Bray's I method (Bray and Kurtz, 1945). Available potassium was estimated by neutral normal NH_4OAc method as outlined by (Jackson,1973). Exchangeable Ca and Mg was estimated by complexometric titration method as described by (Schwarzenbach *et al.*

(1946). The Cation Exchange Capacity (CEC) was determined following neutral normal ammonium acetate saturation method (Jackson, 1973).

Fig No 1. Study area is shown in Assam map

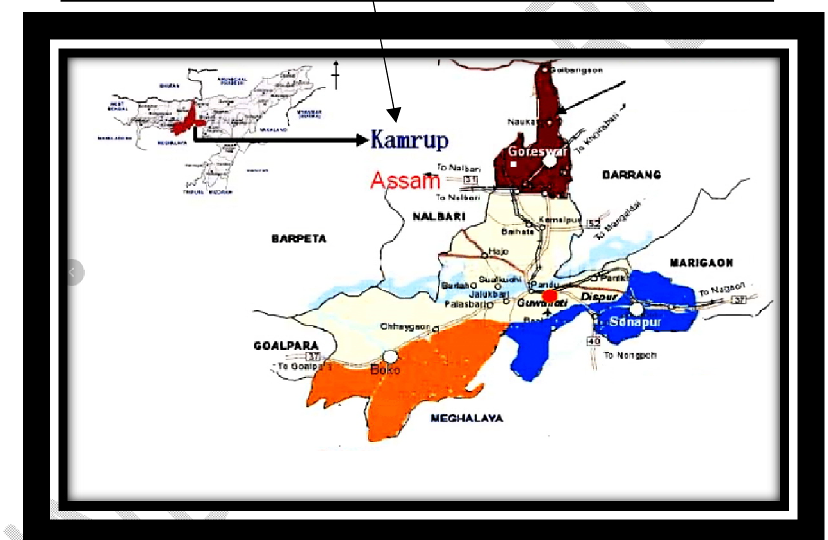

Fig No 2. Study area is shown in map with large version

RESULTS AND DISCUSSIONS

Mechanical composition of soil

The mechanical aggregates of the *Ahu* rice growing soils, namely, sand, silt and clay are presented in table 1 which showed their variation as 22.20% - 56.00%, 23.50% - 47.30% and 16.00% -38.60%, with an average of 39.59%, 33.05% and 27.37%, respectively. Likewise, for *Sali* rice growing soils, the sand, silt and clay varied from 26.30% - 59.00%, 18.00% - 35.20% and 18.00% - 40.00% with average values of 40.33%, 26.95% and 33.18%, respectively (Table 3). The higher content of sand was observed compared to silt and clay content which can be due to the fluviatile characteristics of the soil (Karmakar and Rao, 1999a). For *Boro* rice growing soils, the sand, silt and clay content varied from the range as 21.80% - 42.00%, 20.00% - 41.60% and 32.80% - 40.00% with the mean values of 34.09%, 29.11% and 36.81%, respectively (Table 5). The texture of the soils varied as sandy loam, loam and clay loam for *Ahu* and *Sali* growing soils whereas clayey loam for *Boro* rice growing soils. The average values of mechanical composition of the soils reveals that the soils under *Boro* rice contained the highest amount of clay followed by *Sali* and *Ahu* rice growing soils. This variation can be a consequence of the influence of parent material rather than management practices. These results are in conformity with the findings of Satish *et al.* (2018) and Singh *et al.* (2019).

Soil pH

Data presented in table 1, 3 and 5 showed that pH for *Ahu* rice growing soils varied from 4.52-5.85, with an average value of 5.27 which indicate that the soils are medium acidic in nature. Similarly, for *Sali* rice, pH of the soils was found to range between 4.61-5.50, with the mean value of 4.94 which showed that it is strongly acidic to medium acidic in nature and for *Boro* rice growing soils, the pH values ranged from 4.85-5.28 having average value of 5.07 which showed that these soils are also strongly acidic to medium acidic in nature. The highest value for pH was found to be 5.85 which were observed under *Ahu* rice whereas the lowest value was found to be 4.61 observed under *Sali* rice growing soils. Thus, it can be predicted that the soils for the block under study was acidic in nature. Development of acidic pH with slight variation among the soils from strongly acidic to moderately acidic was due to high rainfall in Assam that leads to the leaching out of the basic cations from soil system. Similar results were also observed by Kandali *et al.* (2016). Besides rainfall, the degree of development of soil was also responsible for increasing the acidity of the soils of Assam (Raychoudhuri *et al.*, 1963; Chakravarty, 1977) or seasonal saturation of water for paddy soils (Dolui and Bhattacharjee, 2003).

Electrical Conductivity (EC)

The EC is used to measure the amounts of salt present in the soil which is a measure of salinity in general. Data presented in table 1, 3 and 5 representing the soils for *Ahu*, *Sali* and *Boro* rice growing areas respectively varied from lowest value of 0.04 dS m^{-1}found in *Sali* rice to 0.12 dS m^{-1} found in *Boro* rice growing soils. The values ranged from 0.08-0.10 dS m^{-1}, average value 0.09 dS m^{-1} for *Ahu* rice growing soils which are non-saline in nature while for *Sali* rice growing soils values ranged from 0.04-0.09 dS m^{-1} with average value of 0.06 dS m^{-1}. For *Boro* rice growing soils the EC values ranged from 0.07-0.12 dS m^{-1}, average value 0.09 dS m^{-1} which clearly describes the non-saline nature of the soils of Boko block of Kamrup district.

Soil Organic Carbon (SOC)

The values of soil organic carbon as expressed in percentage are shown in the tables 1, 3 and 5 for *Ahu*, *Sali* and *Boro* rice growing soils, respectively. From table 1 it was observed that the highest amount of organic carbon in *Ahu* rice growing soils was 1.12% while the lowest was 0.52%. The mean value was 0.77%. Similarly, under *Sali* rice growing soils the highest SOC was 1.20% and the lowest was 0.82% with an average of 1.02%. Likewise, the range of SOC with a mean in *Boro* rice growing soils 1.00% to 1.20% and 1.09%, respectively. Examining the results of organic carbon of the soils indicates their high status in *Boro* rice compared to *Ahu* and *Sali* rice. This kind of variation can arise because of scarce availability of FYM as well as differences in biomass addition and differential rate of decomposition in the vicinity under different rice growing soils (Nayak *et al.*, 2002) as the degradation of organic matter depends on the nature of the plant materials and soil microbes. Comparatively, higher soil organic carbon under *Boro* rice growing soils may be the result of accumulation of organic matter at the low-lying areas in a natural topographic configuration. *Boro* rice is generally cultivated in low-lying areas of Assam.

Cation Exchange Capacity (CEC)

A critical observation of CEC values in table 1 showed that for *Ahu* rice growing soils it ranged from 7.50 cmol p(+) kg^{-1} to 10.40 cmol p(+) kg^{-1} with mean value of 8.66 cmol p(+) kg^{-1} whereas for *Sali* rice growing soils the CEC values ranged from 7.10 cmol p(+) kg^{-1} to 10.30 cmol p(+) kg^{-1} with average value of 8.80 cmol p(+) kg^{-1} (table 3). Conversely, the CEC varied from 7.00 cmol p (+) kg^{-1} to 10.00 cmol p (+)

kg^{-1} with average value 8.90 cmol p (+) kg^{-1} in the soils under *Boro* rice cultivation (table 5). In general, the cation exchange, of soils under all the rice growing soils of Boko block were found to be invariably low which might be due to the presence of low activity clays (Kaolinite) in these soils. Similar observations were made by Karmakar and Rao (1998) and Dutta and Shanwal (2006) who reported that alluvium derived soils of Assam are related to the dominance of low activity clay like Kaolinite.

Table 1: Physico-chemical properties of *Ahu* rice growing soils of Boko block of Kamrup (rural) district

Sample No.	Particle size distribution (%)			pH	EC (dS m^{-1})	SOC (%)	CEC {cmol(p^+) kg^{-1}}	Textural class
	Sand	Silt	Clay					
1	54.0	28.0	18.0	5.50	0.08	0.52	7.60	sl
2	39.3	30.2	30.6	5.36	0.10	0.81	8.90	cl
3	45.2	23.5	31.4	5.38	0.09	0.79	8.90	cl
4	40.0	24.0	36.0	5.07	0.10	0.90	9.04	cl
5	49.0	35.0	16.0	4.62	0.08	0.52	7.50	l
6	29.0	50.0	21.0	5.58	0.09	0.69	7.90	l
7	46.2	24.5	29.3	5.85	0.08	0.82	8.40	cl
8	29.0	52.0	19.0	4.75	0.10	0.65	7.80	l
9	37.0	25.0	38.0	5.05	0.08	0.86	9.10	cl
10	46.0	26.0	28.0	5.06	0.09	0.69	8.70	cl
11	38.0	33.7	28.3	5.35	0.10	0.69	8.80	cl
12	22.7	39.8	37.5	5.38	0.09	1.02	10.2	cl
13	54.0	28.0	18.0	5.09	0.09	0.70	7.70	sl
14	22.5	47.2	30.3	5.38	0.10	0.82	9.60	cl
15	55.0	26.0	19.0	4.65	0.08	0.65	7.80	sl
16	30.0	32.0	38.0	5.85	0.09	1.04	10.20	cl
17	48.0	31.0	21.0	5.68	0.08	0.70	7.80	l
18	22.2	47.3	30.5	5.43	0.08	0.82	9.00	cl
19	28.6	32.8	38.6	5.78	0.09	1.12	10.4	cl
20	56.0	25.0	19.0	4.52	0.09	0.61	7.8	sl

Table 2: Range, Mean, SD and Skew for different physico-chemical properties (*Ahu* rice growing soils)

Properties	**Range**	**Mean ± SD**	**Skew**
Sand (%)	22.20-56.00	39.59 ± 11.53	-0.13
Silt (%)	23.50-47.30	33.05 ± 9.29	0.98
Clay (%)	16.00-38.60	27.37 ± 7.86	0.03
pH	4.52-5.85	5.27 ± 0.41	-0.38
EC (dS m^{-1})	0.08-0.10	0.09 ± 0.01	0.19
SOC (%)	0.52-1.12	0.77 ± 0.16	0.53

CEC {cmol(p^+)kg^{-1}}	7.50-10.40	8.66 ± 0.92	0.53

Table 3: Physico-chemical properties of *Sali* rice growing soils of Boko block of Kamrup (rural) district

Sample No.	Particle size distribution (%)			pH	EC (dS m^{-1})	SOC (%)	CEC {cmol(p^+) kg^{-1}}	Textural class
	Sand	Silt	Clay					
1	26.3	35.2	38.5	4.63	0.08	1.12	9.30	cl
2	27.0	33.0	40.0	5.07	0.07	1.02	10.20	cl
3	34.0	28.0	38.0	4.69	0.09	1.03	9.20	cl
4	36.4	24.8	38.8	4.92	0.07	0.92	9.30	cl
5	31.3	32.3	36.4	4.79	0.06	1.08	7.80	cl
6	38.0	27.0	35.0	4.76	0.04	0.99	7.10	cl
7	42.7	19.0	38.3	4.61	0.09	1.12	9.40	cl
8	42.0	20.0	38.0	5.50	0.06	0.94	9.30	cl
9	44.0	21.0	35.0	4.96	0.04	0.90	7.40	cl
10	43.0	22.0	35.0	4.88	0.06	1.11	8.90	cl
11	44.0	18.0	38.0	5.29	0.06	1.11	9.90	cl
12	30.0	30.0	40.0	5.33	0.05	1.19	10.30	cl
13	59.0	23.0	18.0	4.78	0.06	0.91	7.20	sl
14	47.0	35.0	18.0	5.02	0.04	1.10	7.60	l
15	39.0	29.0	32.0	5.06	0.04	0.82	9.40	cl
16	40.0	25.0	35.0	4.88	0.08	1.04	9.40	cl
17	48.0	32.0	20.0	5.00	0.04	1.01	7.40	l
18	48.3	28.7	23.0	4.82	0.09	1.10	8.10	l
19	38.1	28.1	33.8	4.92	0.05	1.02	9.40	cl
20	39.4	27.8	32.8	4.90	0.04	0.91	9.30	cl

Table 4: Range, mean, SD and Skew for different physico-chemical properties (*Sali* rice growing soils)

Properties	Range	Mean ± SD	Skew
Sand (%)	26.30 – 59.00	40.33 ± 8.13	0.12
Silt (%)	18.00 – 35.20	26.95 ± 5.23	-0.13
Clay (%)	18.00 – 40.00	33.18 ± 7.30	-1.33
pH	4.61 – 5.50	4.94 ± 0.23	0.89
EC (dS m^{-1})	0.04 – 0.09	0.06 ± 0.02	0.38

SOC (%)	0.82 – 1.20	1.02 ± 0.10	-0.35
CEC {cmol(p^+)kg^{-1}}	7.10 – 10.30	8.80 ± 1.03	-0.44

Table 5: Physico-chemical properties of *Boro* rice growing soils of Boko block of Kamrup (rural) district

Sample No.	Particle size distribution (%)			pH	EC (dS m^{-1})	SOC (%)	CEC {cmol(p^+)kg^{-1}}	Textural class
	Sand	Silt	Clay					
1	37.2	25.8	37.0	4.85	0.09	1.00	9.10	cl
2	39.0	22.0	39.0	4.87	0.12	1.12	9.90	cl
3	37.0	25.0	38.0	5.09	0.08	1.00	9.20	cl
4	26.5	38.8	34.7	5.10	0.07	1.10	7.20	cl
5	29.4	37.8	32.8	5.08	0.08	1.14	7.00	cl
6	33.6	32.2	34.2	5.21	0.10	1.16	7.80	cl
7	33.6	30.8	35.6	5.15	0.09	1.20	8.40	cl
8	42.0	22.0	36.0	5.28	0.07	1.02	8.80	cl
9	42.0	20.0	38.0	4.99	0.09	1.00	9.20	cl
10	41.0	20.0	39.0	5.11	0.07	1.16	10.00	cl
11	40.0	22.0	38.0	5.22	0.08	1.02	9.80	cl
12	42.0	23.0	35.0	4.92	0.12	1.09	8.80	cl
13	25.5	35.6	38.9	4.88	0.11	1.14	9.00	cl
14	31.0	31.0	38.0	4.99	0.09	1.12	9.00	cl
15	36.2	26.0	37.8	4.89	0.09	1.08	8.80	cl
16	27.0	38.5	34.5	4.95	0.08	1.10	7.90	cl
17	32.0	28.0	40.0	5.12	0.10	1.09	9.90	cl
18	33.0	29.0	38.0	5.32	0.08	1.06	9.60	cl
19	21.8	41.6	36.6	5.19	0.07	1.10	9.30	cl
20	32.0	33.0	35.0	5.28	0.09	1.14	9.20	cl

Table 6: Range, mean, SD and Skew for different physico-chemical properties (*Boro* rice growing soils)

Properties	**Range**	**Mean ± SD**	**Skew**
Sand (%)	21.80 – 42.00	34.09 ± 6.03	-0.33
Silt (%)	20.00 – 41.60	29.11 ± 6.81	0.33
Clay (%)	32.80 – 40.00	36.81 ± 1.97	-0.35
pH	4.85 – 5.32	5.07 ± 0.15	-0.01
EC (dS m^{-1})	0.07 – 0.12	0.09 ± 0.02	0.77

SOC (%)	1.00 – 1.20	1.09 ± 0.06	-0.24
CEC {cmol(p^+) kg^{-1}}	7.00 – 10.00	8.90 ± 0.86	-0.88

Available Nitrogen

From table 7 it was found that available nitrogen content varied from 272.61 kg a ha^{-1} to 320.99 kg ha^{-1}in *Ahu* rice growing soil which was medium in their status. Here, the average value was found to be 294.29 kg N ha^{-1}. Similarly, the available nitrogen content of *Sali* and *Boro* rice growing soils was found to be 406.28 kg ha^{-1}– 460.78 kg $ha^{-1}$and 415.32 kg ha^{-1}– 448.12 kg $ha^{-1}$with their mean values being 431.61 kg $ha^{-1}$and 427.64 kg ha^{-1}, respectively (Table 9 and 11). From these values it was observed that the area under investigation had medium status of available nitrogen and was seemed to be concomitant with soil organic carbon for respective rice growing system. Despite undergoing continuous crop removal in paddy field, the amount of available N in soils is still high which might be attributed to regular external application of fertilizers as well as high organic carbon content in the surface soils. The incorporation of weed biomass as well as left over stubbles during ploughing operation in rice cultivation also contributed in accumulation of high organic matter resulting in higher amount of available nitrogen in these soils. The present observation corroborates the findings of Lyngdoh and Karmakar (2018).

Available Phosphorus

Perusal of data on available phosphorus in soil presented in the table 7 it was observed that for *Ahu* rice the values ranged from 19.68 kg P_2O_5 ha^{-1} to 24.90 kg P_2O_5 $ha^{-1}$with the mean value of 22.67 kg ha^{-1}which was low. Also, for *Sali* rice growing soils the available phosphorus content ranged from 19.20 kg ha^{-1} to 24.99 kg ha^{-1} and the average value was found to be 24.41 kg ha^{-1} while for *Boro* rice growing soils their values ranged from 19.12 kg ha^{-1} to 24.28 kg $ha^{-1}$and the average value was 20.49 kg P_2O_5 ha^{-1} (Table 9 and 11). The average values for available phosphorus indicate that they were mostly deficient; poor status of available phosphorus in the acid soils of north-eastern region of India has been reported by many workers (Gangopadhyay *et al*., 2001; Mandal *et al*., 2011; Bhagowati and Das, 2016). This might be due to presence of high amount of free Fe and Al oxides which fixed the soluble P and rendered it unavailable.

Available Potassium

Available potassium presented in table 7 exhibited that soils under *Ahu* rice cultivation ranged between 212.92 kg K_2O ha^{-1} to 245.45 kg K_2O ha^{-1} with a mean of 228.84 kg K_2O ha^{-1}. For *Sali* rice growing soils the highest value was found to be 251.50 kg $ha^{-1}$and the lowest was 142.67 kg ha^{-1} with the average value of 227.34 kg ha^{-1} (Table 9). Similarly, soils under *Boro* rice cultivation contained available potassium in the range of 202.72 kg K_2O ha^{-1} to 289.76 kg K_2O ha^{-1} and the mean value was found to be 244.77 kg K_2O ha^{-1} (Table 11). All the values for potassium were found to be medium in its availability. Comparatively higher amount of available potassium in soil was observed under *Boro* rice cultivation. The lower values of available potassium in soils under rice cultivation might be due to leaching of potassium from these soils. Fixation of added K may also take place in soils under rice cultivation which contains high amount of clay. It was reported by Baruah *et al*., (1991) that 28% to 90% of the added potassium was fixed in soils of Assam that tremendously fixed the plant available K.

Exchangeable calcium and magnesium

Results of exchangeable calcium and magnesium are presented in tables 7, 9 and 11 and it was found that in all the rice growing soils of Boko block of Kamrup (R) district of Assam, the dominant exchangeable cation was calcium. The dominance of calcium is in general agreement with the findings of earlier workers on soils of Assam (Karmakar, 2014 and Dutta *et al*., 2017). The preferential adsorption of Ca^{++} over Mg^{++} in soils dominated by low activity clay like kaolinite was also reported by Gatson and Selim (1991). Likewise, from table 9 it was found that for *Sali* rice growing soils its values ranged from 0.98 - 1.98 {cmol (p^+) kg^{-1}} with the average value of 1.33{cmol (p^+) kg^{-1}}. On the other hand, exchangeable magnesium content ranged between 0.21 - 0.87 {cmol(p^+) kg^{-1}} and the average value was 0.55 {cmol (p^+) kg^{-1}} which was quite low compared to exchangeable calcium. For *Boro* rice growing soils, exchangeable calcium ranged between 1.46 – 2.28 {cmol (p^+) kg^{-1}} with an average value of 2.04 {cmol (p^+) kg^{-1}} while exchangeable magnesium ranged from 0.84 – 1.48 {cmol (p^+) kg^{-1}} with an average value of 1.08 {cmol (p^+) kg^{-1}} (Table 9). Both exchangeable calcium and magnesium, in general, were found to be very low in these soils.

Table 7: Nutrient Status of *Ahu* rice growing soils of Boko block of Kamrup (rural) district

Sample No.	Available Nitrogen (kg ha^{-1})	Available Phosphorus (kg ha^{-1})	Available Potassium (kg ha^{-1})	Ex. Ca {cmol(p^+)kg^{-1}}	Ex. Mg {cmol(p^+)kg^{-1}}
1	272.61	23.64	212.92	2.45	1.17
2	302.60	24.48	244.76	2.56	1.34
3	295.85	23.20	220.12	2.34	1.35
4	309.66	22.48	221.22	2.45	1.67
5	273.61	20.53	218.12	1.17	1.07
6	285.50	22.74	219.34	2.61	1.67
7	302.85	21.53	214.42	2.62	1.67
8	280.29	24.82	245.16	2.25	1.18
9	306.26	21.68	216.54	2.01	1.15
10	286.85	22.22	215.66	2.56	1.78
11	287.85	19.68	245.45	2.09	1.56
12	310.71	23.15	242.56	2.67	1.08
13	287.74	20.85	234.46	2.45	1.65
14	301.99	26.34	243.78	2.39	1.67
15	281.76	23.15	218.20	1.34	1.09
16	312.41	22.43	230.34	2.65	1.88
17	288.24	22.53	239.78	2.43	1.85
18	300.76	21.76	242.80	2.32	1.35
19	320.99	22.90	224.64	2.23	1.27
20	277.17	23.21	226.54	2.30	1.25

Table 8: Range, mean, SD and Skew of nutrient status (*Ahu* rice growing soils)

Properties	Range	Mean ± SD	Skew
Available N (kg ha^{-1})	272.61 – 320.99	294.29 ± 14.02	0.13
Available P (kg P_2O_5 ha^{-1})	19.68 – 24.90	22.67 ± 1.52	0.36
Available K (kg K_2O ha^{-1})	212.92 – 245.45	228.84 ± 12.18	0.24
Exchangeable Ca {cmol(p^+) kg^{-1}}	1.17 – 2.67	2.29 ± 0.40	-1.94
Exchangeable Mg {cmol(p^+) kg^{-1}}	1.07 – 1.88	1.44 ± 0.28	0.16

Table 9: Nutrient Status of *Sali* rice growing soils of Boko block of Kamrup (rural) district

Sample No.	Available Nitrogen (kg ha^{-1})	Available Phosphorus (kg ha^{-1})	Available Potassium (kg ha^{-1})	Exch Ca {cmol(p$^+$)kg^{-1}}	Exch Mg {cmol(p$^+$)kg^{-1}}
1	446.06	23.43	240.80	1.76	0.65
2	432.92	24.66	251.50	1.78	0.84
3	436.30	23.80	249.90	1.09	0.43
4	415.72	23.62	242.80	1.07	0.21
5	440.64	24.21	249.50	1.07	0.25
6	426.24	24.15	146.00	1.07	0.23
7	445.78	24.99	241.50	1.87	0.48
8	416.84	27.23	251.50	1.98	0.87
9	412.32	24.20	149.20	0.98	0.45
10	444.74	23.46	246.00	1.03	0.49
11	443.04	25.60	250.50	1.96	0.78
12	450.48	25.53	248.90	1.96	0.85
13	414.52	24.93	142.70	1.12	0.45
14	440.36	24.15	246.90	1.12	0.56
15	406.28	22.91	247.30	1.08	0.47
16	438.42	25.27	149.90	1.05	0.67
17	434.56	23.95	247.30	1.14	0.45
18	439.46	23.48	248.40	1.17	0.48
19	434.00	23.93	249.50	1.21	0.76
20	413.56	24.66	246.90	1.17	0.67

Table 10: Range, mean, SD and Skew of nutrient status (*Sali* rice growing soils)

Properties	Range	Mean ± SD	Skew
Available N (kg ha^{-1})	406.28 – 460.78	431.61 ± 13.58	-0.54
Available P (kg P_2O_5 ha^{-1})	19.20 – 24.99	24.41 ± 0.99	1.18
Available K (kg K_2O ha^{-1})	142.67 – 251.50	227.34 ± 41.37	-1.61
Exchangeable Ca {cmol(p$^+$) kg^{-1}}	0.98 – 1.98	1.33 ± 0.38	0.94
Exchangeable Mg {cmol(p$^+$) kg^{-1}}	0.21 – 0.87	0.55 ± 0.20	0.00

Table 11: Nutrient status of *Boro* rice growing soils of Boko block of Kamrup (rural) district

Sample No.	Available Nitrogen (kg ha^{-1})	Available Phosphorus (kg ha^{-1})	Available Potassium (kg ha^{-1})	Exch Ca {cmol(p^{+})kg^{-1}}	Exch Mg {cmol(p^{+})kg^{-1}}
1	416.92	20.86	235.50	1.90	0.87
2	428.32	20.24	236.34	1.46	0.84
3	415.32	20.12	238.24	2.01	0.87
4	430.48	20.30	250.53	1.98	0.88
5	434.72	21.25	233.46	1.93	0.98
6	438.32	19.32	242.35	1.86	1.02
7	448.12	19.45	266.70	2.07	1.05
8	419.78	19.63	254.56	2.28	1.08
9	415.92	18.43	234.67	2.06	1.04
10	438.48	25.28	202.72	2.18	1.25
11	418.92	20.86	235.50	2.27	1.25
12	424.32	20.24	236.34	2.15	1.05
13	434.32	20.12	238.24	2.19	1.23
14	430.48	20.30	250.53	2.14	1.15
15	422.72	21.25	233.46	2.18	1.48
16	426.32	19.32	242.35	1.89	0.98
17	425.12	19.45	266.70	2.17	1.32
18	420.78	19.63	254.56	2.19	1.34
19	428.92	18.43	234.67	1.98	0.87
20	434.48	25.28	202.72	1.90	1.09

Table 12: Range, mean, SD and Skew of nutrient status (*Boro* rice growing soils)

Properties	Range	Mean ± SD	Skew
Available N (kg ha^{-1})	415 32 – 448.12	427.64 ± 8.71	0.51
Available P (kg P_2O_5 ha^{-1})	19.12 – 24.28	20.49 ± 1.82	1.92
Available K (kg K_2O ha^{-1})	202.72 – 289.76	244.77 ± 16.34	-0.68
Exchangeable Ca {cmol(p^{+}) kg^{-1}}	1.46 – 2.28	2.04 ± 0.19	-1.43
Exchangeable Mg {cmol(p^{+}) kg^{-1}}	0.84 – 1.48	1.08 ± 0.18	0.52

Table 13. Correlation coefficient between physico-chemical properties of *Ahu* rice growing soils of Boko block Kamrup(rural) district

	pH	EC	SOC	CEC	Av N	Av P	Av K	Ex. Ca	Ex. Mg	Sand	Silt	Clay
pH	1	-0.462*	-0.462*	-0.237	-0.213	-0.244	-0.347	-0.175	0.145	0.279	-0.470*	-0.461*
EC		1	0.309	0.140	0.339	0.329	0.423	0.333	0.277	-0.378	0.399	0.226
SOC			1	0.531*	0.809**	0.409	0.467*	0.344	0.362	-0.376	0.441	0.687**
CEC				1	0.598**	0.236	0.506*	0.486*	0.462	-0.333	0.270	0.843**
Av N					1	0.475*	0.335	0.268	0.255	-0.295	0.342	0.585**
Av P						1	0.393	0.311	0.138	-0.406	0.379	0.255
Av K							1	0.244	0.086	-0.230	0.324	0.398
Exch.Ca								1	0.554*	-0.264	0.087	0.387
Exch.Mg									1	-0.038	-0.024	0.107
Sand										1	-0.867**	-0.719**
Silt											1	0.276
Clay												1

*Correlation significant at 0.05 level **Correlation significant at 0.01 level

Table 14: Correlation coefficient between physico-chemical properties of *Sali* rice growing soils of Boko block of Kamrup (rural) district

	pH	EC	SOC	CEC	Av N	Av P	Av K	Ex. Ca	Ex. Mg	Sand	Silt	Clay
pH	1	-0.459*	-0.470*	-0.335	-0.469*	-0.171	0.097	-0.092	0.153	0.036	0.208	-0.177
EC		1	0.352	-0.224	0.303	0.017	0.141	0.248	0.005	-0.117	-0.084	0.197
SOC			1	0.510*	0.662**	0.402	0.346	0.333	0.389	-0.411	-0.065	0.544*
CEC				1	0.485*	0.253	0.694**	0.583**	0.533*	-0.398	0.395	0.476*
Av N					1	0.494*	0.394	0.356	0.198	-0.324	-0.179	0.511*
Av P						1	0.390	0.327	0.379	-0.204	-0.336	0.400
Av K							1	.0382	.0390	-0.352	0.401	0.374
Exch.Ca								1	.0687**	-0.388	0.030	0.400
Exch.Mg									1	-0.257	0.171	0.349
Sand										1	-0.577**	-0.851**
Silt											1	0.061
Clay												1

*Correlation significant at 0.05 level **Correlation significant at 0.01 le

Table15: Correlation coefficient between physico-chemical properties of *Boro* rice growing soils of Boko block of Kamrup(rural) district

	pH	EC	SOC	CEC	Av N	Av P	Av K	Ex. Ca	Ex. Mg	Sand	Silt	Clay
pH	1	-0.537*	-0.536*	-0.205	0.170	-0.250	-0.082	0.290	0.139	0.052	0.260	-0.088
EC		1	0.371	0.218	-0.089	-0.322	0.305	-0.321	0.026	0.097	-0.488*	0.167
SOC			1	0.572**	0.678**	0.408	0.403	-0.151	0.055	-0.394	-0.081	0.590**
CEC				1	0.470*	0.205	0.664**	0.450*	0.480*	-0.393	0.010	0.532*
Av N					1	0.591**	0.217	0.233	0.098	0.173	0.026	0.553*
Av P						1	-0.408	0.143	0.333	0.288	0.033	0.414
Av K							1	0.218	0.306	-0.338	-0.090	0.418
Exch.Ca								1	0.684**	0.033	0.038	0.069
Exch.Mg									1	0.058	-0.109	0.013
Sand										1	-0.744**	-0.912**
Silt											1	0.404
Clay												1

*Correlation significant at 0.05 level **Correlation significant at 0.01 level

Correlation amongst different soil properties

Soil pH

The correlation coefficients of different soil properties are presented in table 13, 14 and 15 for *Ahu*, *Sali* and *Boro* rice growing soils respectively. From table 13 it is seen that for *Ahu* rice growing soils, soil pH was significantly and negatively correlated with clay (r = -0.461*), silt (r = -0.470*), soil organic carbon (r = -0.462*) while it has got fair positive correlation with cation exchange capacity (r = 0.237), available nitrogen (r = -0.213) and available phosphorus (r = -0.244). From table 14 it is evident that for *Sali* rice growing soils, pH was negatively and significantly correlated with EC (r = -0.459*), soil organic carbon (r = -0.470*) and available nitrogen (r = -0.469*) whereas rational correlation exhibited with cation exchange capacity (r = -0.335). From table 15 it can be observed that for *Boro* rice growing soils, soil pH was negatively and significantly correlated with EC (r = -0.537*) and soil organic carbon (r = -0.536*) while the correlation was positive but insignificant with cation exchange capacity (r = -0.205). The negative correlation between pH and OC could be due to production of organic acids during decomposition of organic matter that also increases soil acidity.

Soil organic carbon (SOC)

Observation of correlation coefficients in table 13 reveals that for *Ahu* rice growing soils, soil organic carbon existed with a positively significant correlation with clay (r = 0.687**), cation exchange capacity (r = 0.531*), available nitrogen (r = 0.809**) and available potassium (r = 0.467). Likewise, for *Sali* rice growing soils, soil organic carbon is positively and significantly correlated with clay (r = 0.544*), CEC (r = 0.510*), available nitrogen (r = 0.662**) (Table 14). For *Boro* rice growing soils, soil organic carbon seems to have positive and significant correlation with clay (r = 0.590**), CEC (r = 0.572**) and available nitrogen (r = 0.678**) (Table 15). The possible explanation could be that important functional processes in soil such as ability to store nutrients especially nitrogen was strongly influenced by the organic carbon content in the soil. The significant positive correlation could also be a result of the land use system that is followed for the area or the mean annual rainfall and temperature. Similar findings were also recorded by Wibowo and Kasno (2021). Clay content in the soil is another parameter contributing to reservation of soil organic carbon as clay particles can hold the soil organic carbon by stabilizing it from microbial mineralization

Cation exchange capacity (CEC)

The cation exchange capacity of soils under *Ahu* rice cultivation showed a positive and significant correlation with clay (r = 0.843**), available nitrogen (r = 0.598**), available potassium (r = 0.506*) and exchangeable calcium (r = 0.486*). Similarly, from table 14 for *Sali* rice growing soils it has been observed that CEC has a positive and significant correlation with clay content (r = 0.476*), available nitrogen (r = 0.485*), available potassium (r = 0.694**), exchangeable calcium (r = 0.583**) and exchangeable magnesium (r = 0.533*). From table 15 *i.e*., for *Boro* rice growing soils it has been found that cation exchange capacity has a significant and positive correlation with clay content (r = 0.532*), available nitrogen (r = 0.470*), available potassium (r = 0.664**), exchangeable calcium (r = 0.450*) and exchangeable magnesium (r = 0.480*). The CEC of soils is governed by the amount of inherent negative charged sites it contains as a result of the presence of organic matter and clay. These charged sites in turn electrostatically hold the positive cations which are mostly the plant nutrients. Hence, soils having more negative charged sites *i.e*., more organic carbon will retain more cations and increase the CEC of soils (McKenzie *et al*., 2004). The cation exchange capacity was also recorded to have a negative correlation with soil pH which can be attributed to the fact that soil organic carbon contains abundance of carboxyl groups which results in high density of ionized sites and liberation of H^+ resulting in lowering of soil pH. The results are in conformity with the findings of Johnson (2002)

Mechanical aggregates

From table 13 it can be observed that for *Ahu* rice growing soils sand was negatively and significantly correlated with silt (r = -0.867**) and clay (r = -0.719**). Similarly, for *Sali* rice growing soils it was found that sand has significant negative correlation with silt (r = -0.577**) as well as clay (r = -0.851**) (Table 14). For *Boro* rice growing soils also, the trend of relationship of sand with silt and clay was similar with ‘r’ values of (r = -0.744**) and (r = -0.912**) respectively. The high negative significant correlation in our study can be attributed to the formation of clay from sand and silt fractions due to alteration or neo transformation (Karmakar and Rao, 1999a; Satish Kumar and Naidu, 2012) under humid sub-tropical condition.

Exchangeable calcium and magnesium

Correlation amongst the exchangeable cations (Table 13, 14 and 15) revealed that exchangeable calcium has got a positive significant correlation with exchangeable magnesium only in all the rice growing soils studied [(r = 0.554*) for *Ahu*, (r = 0.687**) for *Sali* and (r = 0.684**) for *Boro* rice growing soils]. For rice growing soils exchangeable calcium and magnesium content is comparatively high than other land use systems (Kavitha and Sujatha, 2015) and can be sustained by an existence of significant positive correlation of calcium with magnesium.

Conclusion

The texture of the soils varied from sandy loam to clay loam for all the samples of *Ahu* rice and *Sali* rice while the textural class of *Boro* rice growing soils was found to be clay loam only. The pH of the soils varied from strongly acidic to moderately acidic irrespective of the rice growing soils. The maximum and minimum values for soil pH were observed in *Ahu* rice growing soils (5.85 and 4.52). The electrical conductivity values with a range of 0.04 - 0.12 (dS m^{-1}) revealed that all the rice growing soils of the study area are non-saline. The soil organic carbon status was found to be medium to high for soils under *Ahu* rice cultivation (0.52% -1.12%), and high for *Sali* (0.82% – 1.20%) and *Boro* (1.00% – 1.20%) rice cultivation. Soil organic carbon was found to be predominant in its content for all the samples collected from *Boro* rice growing areas. The cation exchange capacity of the soils showed a variation from 7.5 – 10.4 {cmol(p^+) kg^{-1}} for *Ahu* rice, 7.1 – 10.3 {cmol(p^+) kg^{-1}} for *Sali* rice and 7.0 – 10.0 {cmol(p^+) kg^{-1}} for *Boro* rice growing soils. On comparing means, the highest CEC was found in *Boro* rice growing [8.90 {cmol(p^+) kg^{-1}}] soils followed by *Sali* [8.80 {cmol(p^+) kg^{-1}}] and *Ahu* rice [8.66 {cmol(p^+) kg^{-1}}]. Amongst the primary nutrients, available N and K were medium in all the soils while available phosphorus was low to medium with overall respective means of 348.51 kg ha^{-1}, 233.65 kg K_2O ha^{-1} and 22.52 kg P_2O_5 ha^{-1}. Of the secondary nutrients exchangeable Ca was higher compared to exchangeable Mg with overall mean of 1.89 cmol(p^+) kg^{-1} and 1.02 cmol(p^+) kg^{-1}, respectively. Significant positive correlation was observed between soil organic carbon with available nitrogen, CEC and clay for all the rice growing soils. Significant positive correlation was found between CEC with available potassium, exchangeable calcium and clay content in all the rice growing soils. The correlation of soil pH with soil organic carbon and EC was found to be significantly negative irrespective of the rice growing soils.

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