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Wetland soil and nutrient variability in Haors of Sunamganj District, Bangladesh

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Abstract
The study was carried out at three different haors of Sunamganj district to evaluate the status and variability of the Physico-chemical properties of soil. The properties of soil such as moisture content, texture, pH, electric conductivity, organic carbon and organic matter, available N, P, K, Mn and Fe were determined and analyzed following standard method and the soils from three different haors showed nutritionally fertile. The studied soil was dominated by Loam along with Clay loam and slightly acidic with a mean pH value 5.93±0.42. The N content was low and ranged from 0.025 to 0.392%, but the organic carbon (0.61±0.09%) and organic matter (1.05±0.16%) seemed higher. Accumulation of organic matter is an indication of a functional wetland. Concentration of available P, Mn, K and Fe was 0.82 μgg^{-1}, 57.84 μgg^{-1}, 115.03 μgg^{-1} and 261.85μgg^{-1} respectively. The nutrients of the soils seemed to be at a balanced condition with a variation among sites, seasons and haors for the successful growth of the plant.

Keywords: Physico-chemical properties of soil, nutrient variability, wetland, Haor

Introduction

Most important freshwater wetlands of Bangladesh occur in the *haor* basin. The *haor* is a freshwater wetland ecosystem in the north-eastern part of the country which physically is a bowl or saucer-shaped tectonic depression and located between the natural levees of rivers. There are about 373 *haor*s/wetlands located in the districts of Sunamganj, Habiganj, Netrokona, Kishorganj, Sylhet, Moulvibazar and Brahmanbaria covering about 1.99 million ha of area and accommodating about 19.37 million people (MoWR 2012) [6].

Compared with other major natural forms of landscape, a wetland is young, dynamic and physically unstable and the key to vegetation development and community dynamics here is hydroperiod, affected by topography, flooding and flood type, precipitation, and water table fluctuations (Bennett *et al*. 1995) [1]. Once the *haor*s harboured to high plant diversity, but it has been depleting gradually. Though the floral diversity of *haor*s is subjected to such severe disturbances, we do not have any comprehensive scientific studies on the vegetation as well as its edaphic factors. Research on the vegetation as well as its relationship with the edaphic factors of *haor*s could provide important information, which would be desirable to ensure their conservation and improvement. Soil clay content and, consequently, water retention capacity of the soil could have contributed to the occurrence of species. Likewise, Whited *et al.* (1999) [9] recently suggested that, in addition to return of hydrology, plant communities, and wildlife use, some soil properties could be used as criteria for assessing wetland restoration success.

The objective of the study was to see the the status and variability of the Physico-chemical properties of the soil of three unique ecosystems of haors.

Materials and Methods

The study was carried out at three different haors of Sunamganj districtnamely Tanguar Haor of Tahirpur upazila (H-1), Pagnar Haor of Jamalganj upazila (H-2) and Dekhar Haor of Sunamganj sadar upazila (H-3). Each haor was divided as three experimental sites. Each site had some specific differences from topography and interference point of view. The investigation was consisted of two basic methodological approaches, viz.: soil sample collection and laboratory analysis of sample to find out major physico-chemical status of soils. The Soil sample were collected throughout the year at three months intervals. Thus, the four sampling times were as follows: October-2011, January-2012, April-2012 and July-2012 and design them as post-monsoon, winter, summer and monsoon respectively.

Soil samples were obtained from two different depths such as topsoil (1 – 25 cm) and subsoil (26 – 50 cm) and put into separate polythene bags. These soil samples were tagged separately and preserved for analysis in laboratory.

After that these soil samples were dried in sun, grounded and passed through a 2mm sieve. The sieved soil samples were then stored in a cool dry place in the laboratory for further analysis. Physical properties of soil e.g. Moisture content at field condition and soil texture distribution were determined from the soil samples. pH and Electrical conductivity were determined with an electronic digital pH meter (Model TOA, Japan) and a conductivity meter (WPA-CM 25 model) respectively from the soil suspension. Organic carbon and organic matter content were Determined by following "Wet oxidation method" [Waldey and Black, 1934]. Available nitrogen of soil (N) was determined by Standardization, Digestion, extraction and Distillation process. Available P, Mn, K and Fe were measured from soil extraction by an Atomic Absorption Spectrophotometer (AAS, Model: iCE 3500, Origin: USA/EU, Source: Thermo Fisher Scientific).

Result and Discussion

Physical attributes of soils

The Physical properties such as moisture content at field condition and textural classes of the studied soil have been presented in Table 1 and Table 2. These properties of the soil were determined in soil samples obtained from two different profiles depth during October-2011 to July-2012.

Table 1: Distribution of textural classes in the studied soil of three different *haor*s of Sunamganj, Bangladesh.

Se	SP	H-1			H-2			H-3		
		Site-1	Site-2	Site-3	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3
PM	TS	CL	L	L	L	CL	L	CL	CL	SaC
	SS	CL	L	L	SiL	L	SiL	SaCL	CL	SaC
W	TS	SiL	SaCL	SaL	SaC	L	L	SaC	CL	L
	SS	CL	CL	L	L	L	SiL	L	SaL	CL
S	TS	L	L	SaL	L	L	L	L	CL	SaL
	SS	L	L	L	L	L	L	SaCL	L	L
M	TS	L	L	L	L	L	L	CL	L	L
	SS	L	L	L	L	L	L	L	SaCL	L

Note: H-1= Tanguar Haor, H-2= Pagnar Haor, H-3= Dekhar Haor. SP= Soil profile, TS = Topsoil,
SS= Subsoil. Se= Season, PM= Post-monsoon, W= Winter, S= Summer, M= Monsoon. L= Loam,
CL= Clay loam, SiL= Silty loam, SaCL= Sandy clay loam, SaL= Sandy loam, SaC= Sandy clay.

Table 2: Distribution of Moisture content (%) in the studied soil of three different *haor*s of Sunamganj, Bangladesh.

Se	SP	H-1			H-2			H-3		
		Site-1	Site-2	Site-3	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3
PM	TS	26.87	30.16	52.02	33.31	48.15	50.08	36.11	42.07	43.41
	SS	32.66	31.72	68.01	32.64	34.75	48.81	41.62	49.28	66.61
W	TS	25.24	59.07	40.48	22.71	37.19	38.39	27.65	39.45	34.89
	SS	28.98	28.75	30.01	26.73	36.48	44.87	25.54	35.58	61.72
S	TS	32.26	38.76	42.83	37.23	37.48	46.08	23.15	45.89	43.55
	SS	41.97	47.65	61.4	38.54	41.01	57.15	29.4	37.8	35.32
M	TS	51.51	63.8	63.6	64.99	61.47	67	60.52	74.14	73.88
	SS	60.14	62.3	70.23	63.31	64.89	51.33	60.5	68.14	59.88
Mean ±SD		37.45 ±12.62	45.28 ±14.91	53.57 ±14.6	39.93 ±15.82	45.18 ±11.88	50.46 ±8.6	38.06 ±15.06	49.04 ±14.41	52.41 ±14.95

Note: H-1= Tanguar Haor, H-2= Pagnar Haor, H-3= Dekhar Haor. SP= Soil profile, TS= Topsoil,
SS= Subsoil. Se= Season, PM= Post-monsoon. W= Winter, S= Summer, M= Monsoon.
SD= Standard Deviation.

Physical attributes in studied soil of three different haors varied in different sites and seasons. Moisture content varied from 74.14% to 22.71% (average 45.71±14.26%).

The texture varied from six different textural classes of soils such as Loam, Clay loam, Silty loam, Sandy clay loam, Sandy loam and Sandy clay but dominated by Loam along with Caly loam. In the other part of the Sylhet basin, Uddin *et al.* (2012) [7] found silt loam in the wetland of Balanganj (Sylhet dirstrict) and Nasirnagar (Brahmanbaria), whereas in the wetland of Nabinagar (Brahmanbaria) soil series was silty clay.

The texture classes did not show any systematic arrangement in their profiles in respect to any samples of the study area. Haor basin receives flood water during the onset of monsoon and is, therefore, enriched of the fresh deposit of sand and clay.

Chemical attributes of soils

Some chemical properties were determined in soil samples obtained from two different profile depth and on four different seasons during October-2011 to July-2012. The results of some chemical properties of soils are presented in tables 3 to 11.

pH value of soil

pH values in the studied soil as shown in Table 3 indicate that the values were different from site to site, season to season, profile to profile and ranged from 5.16 (site-2, topsoil, H-3, summer) to 6.85 (site-1, topsoil, H-1, monsoon), with a mean of 5.93±0.42.

The average values of individual site ranged from 5.84 ±0.51 (site-2, H-3) to 6.03±0.5 (site-1, H-1) (Table3). In all*haors*, topsoil showed slightly higher value than the subsoil and the value ranged from 6.04±0.51 (subsoil, H-3) to 6.04±0.35 (topsoil, H-1).

In terms of average pH value (both topsoil and subsoil), the *haor*s were ranked in the order of H-1>H-2>H-3. From these pH values it was evident that the soil of the studied *haors* is slightly acidic. There was no significant difference among the sites or profiles, except among seasons for the distribution of pH values.

Table 3: Distribution of pH value in the studied soil of three different *haor*s of Sunamganj, Bangladesh.

Se	SP	H-1			H-2			H-3		
		Site-1	Site-2	Site-3	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3
PM	TS	6.19	6.23	5.96	6.23	6.11	5.97	6.21	6.05	6.18
	SS	5.92	5.96	6.34	5.87	6.01	5.95	5.99	5.86	5.82
W	TS	6.12	5.98	6.01	6.08	5.96	6.05	6.01	6.15	5.98
	SS	5.92	5.96	5.95	5.99	5.76	5.95	5.96	5.88	5.86
S	TS	5.43	5.31	5.28	5.65	5.22	5.37	5.59	5.16	5.34
	SS	5.35	5.32	5.25	5.54	5.23	5.35	5.32	5.21	5.19
M	TS	6.85	6.74	6.42	6.45	6.52	6.75	6.38	6.72	6.45
	SS	6.46	6.25	6.25	6.24	5.95	5.83	6.23	5.68	6.16
Mean ±SD		6.03 ±0.5	5.97 ±0.48	5.93 ±0.45	6.01 ±0.31	5.85 ±0.44	5.9 ±0.44	5.96 ±0.35	5.84 ±0.51	5.87 ±0.43

Note: H-1= Tanguar Haor, H-2= Pagnar Haor, H-3= Dekhar Haor. SP= Soil profile, TS= Topsoil,
SS= Subsoil. Se= Season, PM= Post-monsoon. W= Winter, S= Summer, M= Monsoon.
SD= Standard Deviation.

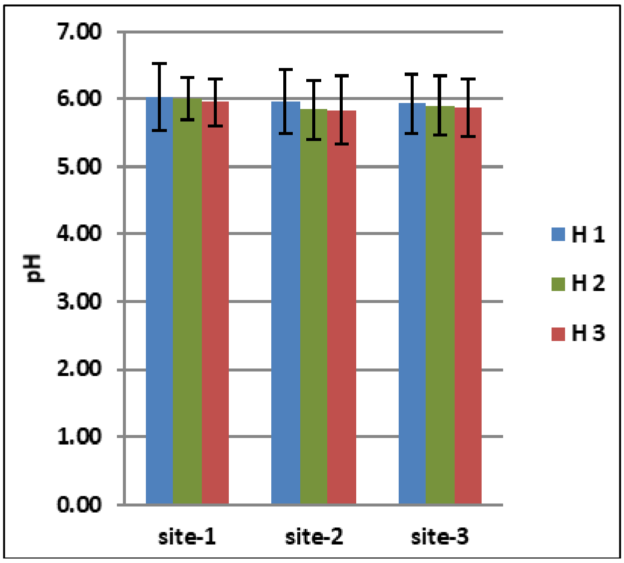


Fig A

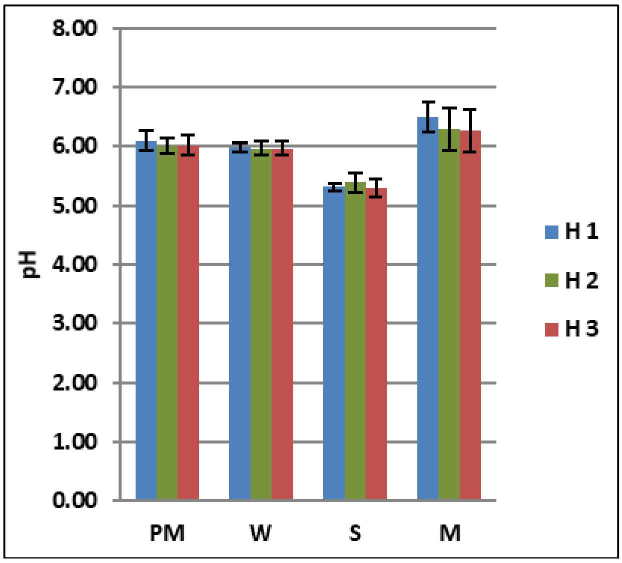
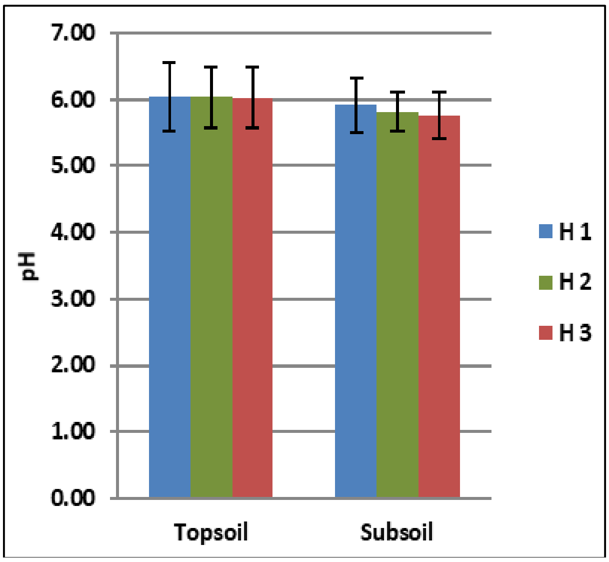
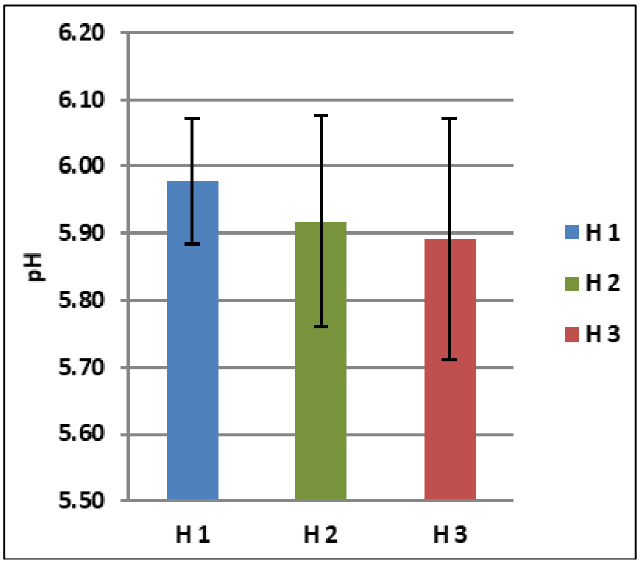


Fig B





Note: H-1= Tanguar Haor, H-2= Pagnar Haor, H-3= Dekhar Haor. PM= Post-monsoon, W= Winter, S=Summer, M=Monsoon.

Fig C

Fig D

Fig 1: Variation of pH in different (a). sites, (b). seasons, (c). profiles and (d). *haors* in the studied soil.

The soil of the study area was slightly acidic. The pH of the studied soil varied from haor to haor even within the site and the values ranged from 5.16 to 6.85 with a mean of 5.93±0.42. Uddin *et al.* (2012) [7] reported that pH value was higher to near neutrality and ranged from 6.7 to 7.0 with a mean of 6.9 in the wetlands of south-eastern part of the Sylhet basin, where as in the wetland soil of central Florida, pH value was recorded 6.15 (Vimala *et al.* 2001) [8]. Wetland soil might be acidic or basic depending on location and other environmental factors. Acidic pH may be attributed to rain-fed run-off and organic acid production during the decomposition of organic matter within the wetland, while pH of many alluvial wetlands could be near neutral due to flooding by river water with high Ca content (Vimala *et al.* 2001) [8].

Electric conductivity (EC) of soil

The EC in the studied soil as shown in Table 4 indicates that the values were different from *haor* to *haor*, even within site to site and values ranged from 65 (site-1, topsoil, H-3, post monsoon) to 328 (site-2, topsoil, H-3, monsoon). The mean value of EC in studied soil was 173.2917±62.69. The average values of individual site (both subsoil and topsoil) ranged from 137 ± 27.75 (site-2, H-2) to 206.38 ± 56.57 (site-1, H-2). In H-1, topsoil showed the higher value than that of subsoils; on the other hand, in H-2 and H-3, subsoil showed the higher value. The average highest and lowest values of EC in topsoil were 184.5±76.16 (H-1) and 164.08±83.09 (H-3) and those of subsoil were 180.17±46.43 (H-3) and 162.5±39.28 (H-1) respectively.

The value of electric conductivity showed the following trend H-2>H-1>H-3; moreover, there were no significant differences among the sites or profiles, except among the seasons for the distribution of EC values. The EC value of H-2 in summer was significantly higher than the value of H-1 and H-2 in Post-monsoon.

Table 4: Distribution of Electric conductivity in the studied soil of three different *haor*s of Sunamganj, Bangladesh.

Se	SP	H-1			H-2			H-3		
		Site-1	Site-2	Site-3	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3
PM	TS	126	127	146	130	132	129	65	202	125
	SS	130	128	130	142	127	133	230	130	136
W	TS	165	235	123	221	117	99	93	186	163
	SS	211	167	145	201	133	113	121	134	231
S	TS	86	267	308	312	164	148	133	110	303
	SS	126	189	233	237	184	224	156	214	223
M	TS	277	112	242	210	94	324	182	328	79
	SS	214	148	129	198	145	265	191	244	152
Mean ±SD		166.88 ± 62.72	171.63 ± 55.35	182 ± 69.42	206.38 ±56.57	137 ± 27.75	179.38 ±81.75	146.38 ±54.3	193.5 ± 71.45	176.5 ± 71.43

Note: H-1= Tanguar Haor, H-2= Pagnar Haor, H-3= Dekhar Haor. SP= Soil profile, TS= Topsoil, SS= Subsoil. Se= Season, PM= Post-monsoon. W= Winter, S= Summer, M= Monsoon.
SD= Standard Deviation.

Organic Carbon (OC) of soil

The data of Table 5 indicate that the values of organic carbon content in the studied soil varied with the change of seasons, profiles as well as sites and ranged from 0.29% (site-3, subsoil, H-2, summer) to 1% (site-3, topsoil, H-3, post monsoon), with a mean of 0.61±0.17%. The average values of individual sites (both topsoil and subsoil) varied from 0.49±0.18% (site-3, H-2) to 0.72±0.22% (site-3, H-3). It was found that the average value of topsoil of all *haor*s had the highest values compared to those of subsoil. The highest value of OC in the topsoil was due to accumulation of forest litter on the topsoil rather than subsoil. The average value of carbon content in individual *haor*s varied from 0.59±0.03% (H-1) to 0.64±0.13% (H-3) and showed the following trend H-3>H-2>H-1. The values of organic carbon did not show any significant differences in different sites, seasons and Soil profiles. There was no significant difference among the sites or profiles or seasons for the distribution of OC values.

Table 5: Distribution of Organic carbon (%) in the studied soil of three different *haor*s of Sunamganj, Bangladesh.

sSe	SP	H-1			H-2			H-3		
		Site-1	Site-2	Site-3	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3
PM	TS	0.82	0.61	0.37	0.74	0.86	0.68	0.53	0.74	1
	SS	0.76	0.51	0.43	0.61	0.37	0.35	0.57	0.61	0.62
W	TS	0.6	0.57	0.86	0.99	0.86	0.49	0.7	0.6	0.47
	SS	0.66	0.45	0.53	0.94	0.68	0.37	0.62	0.51	0.41
S	TS	0.7	0.55	0.43	0.53	0.76	0.37	0.74	0.84	0.9
	SS	0.66	0.57	0.51	0.49	0.47	0.29	0.6	0.45	0.66
M	TS	0.84	0.55	0.49	0.7	0.37	0.82	0.45	0.82	0.96
	SS	0.53	0.7	0.57	0.6	0.45	0.55	0.49	0.35	0.74
Mean ±SD		0.7 ±0.11	0.56 ±0.07	0.52 ±0.15	0.7 ±0.18	0.6 ±0.21	0.49 ±0.18	0.59 0.10	0.61 ±0.18	0.72 ±0.22

Note: H-1= Tanguar Haor, H-2= Pagnar Haor, H-3= Dekhar Haor. SP= Soil profile, TS= Topsoil,
SS= Subsoil. Se= Season, PM= Post-monsoon. W= Winter, S= Summer, M= Monsoon.
SD= Standard Deviation.

Organic Matter (OM) of soil

The data of Table 6 indicate that the values of Organic matter in the studied soil varied with seasons, profiles as well as with sites and ranged from 0.5% (site-3, subsoil, H-2, summer) to 1.72% (site-3, topsoil, H-3, post-monsoon), with a mean of 1.05±0.3%. The average values of individual sites (both topsoil and subsoil) varied from 0.84% ±0.32 (site-3, H-2) to 1.23% ± 0.38 (site-3, H-3). It is evident that the top soil of each *haor* had relatively higher value (1.25% ± 0.32, H-3) as compared to those of subsoils (0.88% ± 0.31, H-2). This is probably the consequence of the accumulation of forest litter on the topsoil. The highest value of organic matter content was found in winter (1.24% ±0.43, H-2) and the lowest value in summer (0.83% ± 0.28, H-2). The average value of OM content in individual *haor*s varied from 1.02% ±0.06 (H-1) to 1.1% ±0.21 (H-3) and showed the following trend H-3>H-2>H-1. There was no significant difference among the sites or profiles or seasons for the distribution of OM values.

Table 6: Distribution of Organic matter (%) in the studied soil of three different *haor*s of Sunamganj, Bangladesh.

Se	SP	H-1			H-2			H-3		
		Site-1	Site-2	Site-3	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3
PM	TS	1.41	1.04	0.64	1.27	1.47	1.17	0.9	1.27	1.72
	SS	1.31	0.87	0.74	1.04	0.64	0.6	0.97	1.04	1.07
W	TS	1.04	0.97	1.47	1.71	1.47	0.84	1.21	1.04	0.8
	SS	1.14	0.77	0.9	1.61	1.17	0.64	1.07	0.87	0.7
S	TS	1.21	0.94	0.74	0.90	1.31	0.64	1.27	1.44	1.54
	SS	1.14	0.97	0.87	0.84	0.8	0.5	1.04	0.77	1.14
M	TS	1.44	0.94	0.84	1.21	0.64	1.41	0.77	1.41	1.64
	SS	0.9	1.21	0.97	1.04	0.78	0.94	0.84	0.6	1.27
Mean±SD		1.2 ±0.18	0.96 ±0.13	0.9 ±0.25	1.2 ±0.32	1.04 ±0.36	0.84 ±0.32	1.01 ±0.17	1.06 ±0.30	1.23 ±0.38

Note: H-1= Tanguar Haor, H-2= Pagnar Haor, H-3= Dekhar Haor. SP= Soil profile, TS= Topsoil,
SS= Subsoil. Se= Season, PM= Post-monsoon. W= Winter, S= Summer, M= Monsoon.
SD= Standard Deviation.

Electric conductivity of studied soil varied from 65 to 328 with a mean of 173.29±62.69. Organic carbon content and organic matter of the studied soil varied from 0.29% to 1% (average 0.61±0.17%) and from 0.5% to 1.72% (average 1.05±0.3%) respectively. Almost similar observations were reported by Uddin *et al.* (2012) [7], who found that the organic matter content of the soils varied from 0.96 to 1.17 with a mean of 1.1% in the wetlands of other part of the Sylhet basin, where as Vimala *et al.* (2001) [8] found organic carbon 50 gKg^{-1} in the wetland soil of Central Florida. In the present study, almost all of the sites and seasons topsoil showed higher value of organic carbon and organic matter that of subsoil, due to accumulation of forest litter on the top soil rather than subsoil. Accumulation of organic matter is an indication of a functional wetland (Ervin *et al.* 1997) [2].

Available Nitrogen (N) of soil

The value of available Nitrogen content in the studied soil, shown in Table 7 exhibits that the nitrogen content varied from site to site, season to season as well as profile to profile. The value of N content ranged from 0.025% (site-2, subsoil, H-2, Monsoon) to 0.392% (site-1, topsoil, H-1, summer) with a mean of 0.11±0.07%. The average value of individual site (both topsoil and subsoil) varied from 0.067±0.02% (site-3, H-3) to 0.157±0.11% (site-1, H-1). In general, there was a decreasing trend in nitrogen values with the increase of depth. The average value of topsoils varied form 0.106±0.05% (H-3) to 0.161±0.11% (H-1) and those of subsoils from 0.072% ±0.04 (H-3) to 0.104% ±0.056 (H-1). The highest value of available N content was found in summer (0.249±0.092%, April, H-1) and lowest value in monsoon (0.049±0.01%, July, H-3). The average value of the individual *haor*s showed the following trend H-1>H-2>H-3. The result also indicates that there were significant differences among the seasons for the distribution of available N content in the studied soil, but there were no significant differences among the sites or profiles, except the value of site-2 in H-1, where it was significantly higher than the value of site-3 in H-3.

Table 7: Distribution of available Nitrogen (%) in the studied soil of three different *haor*s of Sunamganj, Bangladesh.

Se	SP	H-1			H-2			H-3		
		Site-1	Site-2	Site-3	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3
PM	TS	0.098	0.086	0.079	0.091	0.09	0.087	0.088	0.094	0.072
	SS	0.084	0.065	0.072	0.045	0.067	0.065	0.074	0.048	0.038
W	TS	0.187	0.19	0.125	0.135	0.15	0.085	0.17	0.092	0.099
	SS	0.15	0.087	0.105	0.087	0.1	0.05	0.15	0.08	0.05
S	TS	0.392	0.298	0.265	0.262	0.179	0.195	0.199	0.182	0.096
	SS	0.214	0.195	0.128	0.156	0.162	0.175	0.087	0.137	0.083
M	TS	0.085	0.058	0.067	0.075	0.05	0.062	0.075	0.053	0.05
	SS	0.046	0.05	0.054	0.062	0.025	0.043	0.037	0.035	0.046
Mean ±SD		0.157 ±0.11	0.129 ±0.09	0.112 ±0.07	0.114 ±0.07	0.103 ±0.06	0.095 ±0.06	0.11 ±0.06	0.09 ±0.05	0.067 ±0.02

Note: H-1= Tanguar Haor, H-2= Pagnar Haor, H-3= Dekhar Haor. SP= Soil profile, TS= Topsoil,
SS= Subsoil. Se= Season, PM= Post-monsoon. W= Winter, S= Summer, M= Monsoon.
SD= Standard Deviation.

Available Nitrogen content in the studied soils ranged from 0.025% to 0.392% with a mean of 0.11±0.07%. Among the studied soil profiles, Tanguar Haor showed the highest contents of available N while Dekhar Hoar had the lowest. In general, there was a regular decrease in available N content from the surface downward. The available N in all the soils was higher in the surface horizons, probably due to addition of organic matter. However, the soil of the Ganges floodplain in Bangladesh, the available N in the studied soils ranged from 60 to 140 mgkg^{-}1(Hossain *et al*. 2009) [3], and similar results and distribution patterns of N were reported by Mazumder *et al.* (2003) [5] for some floodplain soils of Bangladesh. On the other hand available N content was found 9 gKg^{-1} in the soil of wetlands in central Florida (Vimala *et al.* 2001) [8]. The low N content in the studied soils may be indicates the loss through denitrification, which is occurred probably due to the poor drainage condition of soils.

Available Phosphorus (P) content of soil

Available Phosphorus content in the studied soil as shown in Table 8 indicate that the values were changed with profiles, seasons and sites and ranged from 0.08 µgg^{-1} (site-1, subsoil, Summer, H-3) to 1.68 µgg^{-1} (site-3, topsoil, winter, H-2) with a mean of 0.82±0.33 µgg^{-1}. In general, there was a decreasing trend in the values with the increase of depth and the highest value of topsoil was 0.95±0.35 µgg^{-1} (H-2) and those of subsoil was 0.58± 0.26 µgg^{-1}(H-3). The average value of available P content of individual *haor* ranged from 0.88±0.03 µgg^{-1}(H-1) to 0.71± 0.18 µgg^{-1} (H-3) and showed the following trend H-1>H-2>H-3. There was no significant difference among the sites or profiles or seasons for the distribution of available P content.

Table 8: Distribution of available Phosphorus (µgg^{-1}) in the studied soil of three different *haor*s of Sunamganj, Bangladesh.

Se	SP	H-1			H-2			H-3		
		Site-1	Site-2	Site-3	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3
PM	TS	1.44	0.72	0.56	1.04	1.12	1.25	1.04	0.96	1.44
	SS	0.8	0.96	0.64	0.96	0.96	0.62	0.96	0.4	0.64
W	TS	1.28	1.12	0.8	1.04	1.28	1.68	0.88	0.64	0.8
	SS	1.2	1.52	0.32	1.44	0.8	0.58	0.72	0.56	0.64
S	TS	0.96	0.72	0.64	0.64	0.88	0.72	0.72	0.48	0.72
	SS	0.8	0.64	0.64	0.72	0.8	0.64	0.08	0.64	0.56
M	TS	1.04	0.64	0.88	0.48	0.72	0.56	0.32	1.04	0.16
	SS	0.99	0.8	0.96	1.04	1.04	0.38	0.32	0.32	0.24
Mean ±SD		1.06 ±0.23	0.89 ±0.3	0.68 ±0.2	0.92 ±0.3	0.95 ±0.19	0.8 ±0.43	0.63 ±0.35	0.63 ±0.25	0.65 ±0.39

Note: H-1= Tanguar Haor, H-2= Pagnar Haor, H-3= Dekhar Haor. SP= Soil profile, TS= Topsoil,
SS= Subsoil. Se= Season, PM= Post-monsoon. W= Winter, S= Summer, M= Monsoon.
SD= Standard Deviation.

Available Phosphorus content in the studied soils ranged from 0.08µgg^{-1} to 1.68µgg^{-1} (mean value 0.82±0.33 µgg^{-1}). These values are slightly lower than those reported in some wetlands in the south-eastern part of the Sylhet basin, where Uddien *et al.* (2012) found available P content varied from 7.0 to 23.0 µgg^{-1} with an average of 16.25µgg^{-1}. The higher content of P in soils may be due to the presence of phosphorus containing minerals in the soil materials (Harris, 2002). Islam & Mandal (1978) [4] reported that the contents of P in soils of Bangladesh varied with the variation of organic matter, pH and clay contents.

Available Manganese (Mn) content of soil

The values of available Mn content in the studied soils shown in Table 9 indicate that the values varied with profiles, sites and seasons and ranged from 17.41 µgg^{-1} (Topsoil, site-2, H-1, in summer) to 89.59 µgg^{-1} (Subsoil, site-1, H-2, in winter) with a mean of 57.84±21.49 µgg^{-1}. The average value of individual site (both topsoil and subsoil) varied from 32±12.63µgg^{-1} (site-2, H-1) to 75.72±17.15µgg^{-1} (site-1, H-2). The average value of topsoil ranged from 49.52±22.37 µgg^{-1} (H-1) to 73.01±19.01 µgg^{-1} (H-3) and those of subsoil varied from 34.95±11.39 µgg^{-1} (H-1) to 62.3±18.02 µgg^{-1} (H-2). The average highest value of manganese content was found in winter (81.89±7.97 µgg^{-1}, H-3) and lowest value was in monsoon (32.46± 12.28, H-1). The mean value of individual *haor* ranged from 42.24±10.3 µgg^{-1} (H-1) to 66.31±9.48 µgg^{-1} (H-3) and showed the following trend H-3>H-2>H-1. Moreover, the result indicates that there were some significant differences among the sites, profiles, and seasons for the distribution of available Mn content; furthermore the value of H-1 was significantly lower than the value of H-2 and H-3.

Table 9: Distribution of available Manganese (µgg-1) in the studied soil of three different *haor*s of Sunamganj, Bangladesh.

Se	SP	H-1			H-2			H-3		
		Site-1	Site-2	Site-3	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3
PM	TS	87.19	46.76	66.55	89.3	53.47	75.87	89.11	86.53	86.94
	SS	59.54	39.72	49.32	88.45	53.47	50.88	65.29	83.45	72.57
W	TS	86.67	50.48	29.47	78.67	75.14	76.96	89.5	87.86	79.86
	SS	42.53	34.59	26.52	89.59	66.02	65.42	78.65	87.1	68.38
S	TS	35	17.41	56.16	83.8	66.12	51.64	78.67	70.14	43.87
	SS	32.15	22.75	36.1	53.65	44.89	73.76	43.78	53.71	54.14
M	TS	49.58	22.89	46.14	77.48	40.8	42.92	68.27	65.08	30.3
	SS	29.5	21.55	25.11	44.8	35.26	81.44	28.49	40.8	38.89
Mean ±SD		52.7±23.23	32±12.63	41.92±15.07	75.72±17.15	54.40±13.87	64.86±14.51	67.72±21.68	71.83±17.65	59.3±20.59

Note: H-1= Tanguar Haor, H-2= Pagnar Haor, H-3= Dekhar Haor. SP= Soil profile, TS= Topsoil, SS= Subsoil. Se= Season, PM= Post-monsoon. W= Winter, S= Summer, M= Monsoon. SD= Standard Deviation.

Likewise, the available Manganese content in the studied soils varied with profiles, sites and seasons and ranged from 17.41 to 89.59 µgg-1 (mean value 57.84±21.49 µgg-1) and higher concentration of available Mn was found in the upper horizon of the profiles in the study area. These results within the range reported by Uddin *et al.* (2012) [7] in some wetland soils of Sylhet basin, who found Mn content varied from 46.7 to 105.1 µgg-1 with an average of 76.52 µgg-1, while Vimala *et al.* (2001) [8] found Mn 18.2 mgKg-1 in the wetland soil in central Florida.

Available Potassium (K) content of soil

Available Potassium content in the studied soil as shown in Table 10 indicates that the values changed with profiles, sites and seasons. The values ranged from 2.95µgg-1 (site-2, topsoil, winter, H-3) to 248.03µgg-1 (site-1, topsoil, post-monsoon, H-3) with a mean of 115.03±60.48 µgg-1. The average value of individual site varied from 62.04±26.67 µgg-1 (site-3, H-1) to 183.08±55.98 µgg-1 (site-1, H-3). The highest value of available K was found in post-monsoon (211.64±28.13 µgg-1, H-3) and lowest value was in summer (47.94±13.97 µgg-1, H-1). The average value of K content of topsoil (combined of all sites and season) varied from 84.34±51.87 µgg-1 (H-1) to 154.81±72.2 µgg-1 (H-3) and those of subsoil varied from79.13± 44.23 µgg-1 (H-1) to 151.86±64.47 µgg-1 (H-3). The average value of individual *haor* varied form 81.74± 3.68 µgg-1 (H-1) to 153.34±2.09 µgg-1 (H-3) and showed the following trend H-3>H-2>H-1. However, the result also revealed that there were some significant differences among sites and seasons for the distribution of K, but not in any significant differences among the soil profiles; in addition the value of H-2 and H-3 were significantly higher than the value of H-1.

Table 10: Distribution of available Potassium (µgg-1) in the studied soil of three different *haor*s of Sunamganj, Bangladesh.

Se	SP	H-1			H-2			H-3		
		Site-1	Site-2	Site-3	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3
PM	TS	186.72	123.18	77.5	170.38	189.87	147.53	248.03	183.07	190.07
	SS	191.3	103.7	121.5	140.2	120.72	130.78	199.82	203.4	245.43
W	TS	153.47	133.98	54.5	151.43	175.45	78.37	237.02	2.95	207.73
	SS	80	97.33	60.7	157.63	149.72	72.2	201.52	245.33	158.28
S	TS	69.7	26.57	48.68	108.07	53.92	98.7	190.93	111.42	107.67
	SS	51.53	42.4	48.77	93.42	44.67	82.53	100.63	104.63	99.85
M	TS	56.62	41.43	39.75	105.85	58.67	87.57	189.03	105.63	84.18
	SS	67.3	40.12	44.92	104.63	39.08	78.93	97.68	102.13	63.6
Mean±SD		107.08±59.68	76.0±42.87	62.04±26.67	128.95±29.27	104.01±62.27	97.08±27.48	183.08±55.98	132.32±75.56	144.6±65.45

Note: H-1= Tanguar Haor, H-2= Pagnar Haor, H-3= Dekhar Haor. SP= Soil profile, TS= Topsoil, SS= Subsoil. Se= Season, PM= Post-monsoon. W= Winter, S= Summer, M= Monsoon. SD= Standard Deviation.

The available Potassium content in the studied soils ranged from 2.95 to 248.03 µgg-1 (mean value 115.03± 60.48 µgg-1). Slightly higher concentration of K was found in the upper horizon of the profiles in the study area. Black (1968) noted that the higher concentration of K in the surface in comparison to subsurface layer might be due to the action of plant roots in transporting K to the surface and also to addition of crop residues.

These high values of total potassium in the soils bear testimony to the fact that these soils are probably rich in K-bearing minerals like mica and feldspar (White 1985). In the soil of wetland of other part of Sylhet basin, K contents were found to vary from 0.31 to 0.85 cmol p+/kg with an average of 0.48 cmol p+/kg (Uddin *et al.* 2012) [7], and the contents of K in the soil of the Ganges floodplain in Bangladesh ranged from 100 to 260 mgkg-1(Hossain *et al*. 2009) [3]. Where as in the wetlands of central Florida, K content was 475 mgKg-1 (Vimala *et al.* 2001) [8].

Available Iron (Fe) content of soil

The data of Table 11 indicate that the values of available Fe content in the studied soil varied with the change of seasons, change of profiles as well as sites and ranged from 105 µgg-1 (site-1, topsoil, H-3, summer) to 498 µgg-1 (site-2, topsoil, H-1, monsoon) with a mean of 261.85±87.21 µgg-1. The average values of individual sites (both topsoil and subsoil) varied from 212.13±104.77µgg-1 (site-1, H-3) to 289.63±87.67µgg-1 (site-2, H-3). It was found that the average value of topsoil of each *haor* had the lowest values (ranged from 220.42±93.83 µgg-1, H-2 to, 268.92±99.94 µgg-1, H-1) compared to those of subsoil (ranged from 276.17±70.69 µgg-1, H-1 to 298.75±74.72 µgg-1, H-2). The highest value of Fe content (average) was found in monsoon (364.5±72.67 µgg-1, H-1) and lowest value was in summer (201.67±79.48 µgg^{-1}, H-3), these two values were significantly different from each other. The average value of iron content in individual *haor*s varied from 253.42±42.78 µgg^{-1} (H-3) to 272.55±5.13 µgg^{-1} (H-1) and showed the following trend H-1>H-2>H-3.

Table 11: Distribution of available Iron (µgg^{-1}) in the studied soil of three different *haor*s of Sunamganj, Bangladesh.

Se	SP	H-1			H-2			H-3		
		Site-1	Site-2	Site-3	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3
PM	TS	170	185	270	153	250	220	160	250	128
	SS	399	260	219	230	310	425	350	320	310
W	TS	310	178	206	107	327	205	209	180	402
	SS	350	280	240	199	356	370	210	254	290
S	TS	190	223	268	140	250	110	105	305	215
	SS	158	194	254	220	290	250	120	195	270
M	TS	360	498	369	333	155	395	153	244	327
	SS	310	360	290	370	346	219	390	320	375
Mean±SD		280.88±94.37	272.25±109.49	264.5±50.45	219± 92.16	285.5±66.03	274.25±110.09	212.13±104.77	258.5±53.75	289.63±87.67

Note: H-1= Tanguar Haor, H-2= Pagnar Haor, H-3= Dekhar Haor. SP= Soil profile, TS= Topsoil, SS= Subsoil. Se= Season, PM= Post-monsoon. W= Winter, S= Summer, M= Monsoon. SD= Standard Deviation.

The contents of available Iron in the studied soils ranged from 105 to 498 µgg^{-1} with a mean of 261.85±87.21 µgg^{-1}. These results varied with profiles, sites, and seasons. No definite sequence in the distribution of Fe with depth was noticeable probably due to young nature of these alluvial soils. However, this result corroborated well with the values reported by Uddin *et al.* (2012) [7] for some wetland soil of Sylhet basin, and they found Fe contents varied from 324 to 523µgg^{-1}. Hossain *et al*. (2009) [3] also reported that available Fe varied from 8 to 255 mgKg^{-1} in some alluvial soils of Bangladesh. On the other hand, in the wetlands of central Florida, Iron content was found 475 mgKg^{-1} (Vimala *et al.* 2001) [8]. No definite sequence in the distribution of Fe with depth was noticeable probably due to huge sedimentation in every monsoon.

Conclusion

In the studied soil, textural classes dominated by Loam and Clay Loam, average moisture content 45.71±14.26%, pH value ranged 5.16 to 6.85 with a mean of 5.93±0.42, mean value of electric conductivity 173.29±62.69, organic carbon and organic matter 0.61±0.17% and 1.05±0.3% respectively. Available N ranged from 0.025% to 0.392% with a mean of 0.11±0.07s%. Mean value available P, Mn, K and Fe content in the studied soil were 0.82±0.33, 57.84±21.49, 115.03± 60.48, 261.85±87.21 µgg^{-1} respectively. The nutrients of the soils seemed to be at a balanced condition with a variation among sites, seasons and haors for the successful growth of the plant.

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