Dhaka Univ. J. Biol. Sci. **30**(1): 115-124, 2021 (January)

ASSESSMENT OF CARBON STORAGE AND NUTRIENT CONTENTS IN SOME WETLAND SOILS OF THE NORTHEASTERN REGION OF BANGLADESH

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Key words: Wetlands, Soil characteristics, Soil C storage

Abstract

An investigation was carried out in four designated wetlands to assess soil organic carbon (SOC) storage and evaluate soil nutrients of the northeastern Sylhet basin of Bangladesh. SOC storage was the highest in the Nikli wetland (4.1 Tg), followed by Hakaluki (4.0 Tg), Hail (2.8 Tg) and Balai wetland soils (2.6 Tg) at 100 cm depths. It is found that the total soil C storage across the medium low land (MLL) and low land (LL) sites covering the four wetlands of the Sylhet basin is about 13.5Tg. C storage across the MLL and LL sites at 100 cm depths was estimated about 5.1Tg and 8.4Tg respectively. It is found that SOC storage was higher in the low land sites in contrast to medium low land sites. The soil property varies depending on land types, soil depths and spatial distributions. Among the investigated wetland soils, Hakaluki wetland stored higher amount of SOC in the deeper soil layers whereas an inverse relationship between soil depth and SOC storage was noted for rest of the wetlands. It is apprehended that SOC storage thus gradually lessening in greater magnitude due to climate change and other anthropogenic reasons. An integrated management approach should be developed to restore the SOC sink.

Introduction

Carbon stock in wetland soils has received much attention worldwide because of its key role in the biogeochemical carbon cycles and its potential feedback on global warming. Information on global and regional soil organic carbon (SOC) pool in the topsoil is generally available for a variety of land use and climatic conditions[(1,2)]. It is widely accepted that carbon sequestration is most active in topsoil horizons, but growing evidence explains that deeper soil layers can sequester high amounts of stabilized SOC[(3,4,5)] and this should be considered for SOC emission-storage analysis. The importance of SOC sequestration in sub-soils regarding the mitigation of the greenhouse

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DOI: https://doi.org/10.3329/dujbs.v30i1.51815

effect is related to the fact that subsoil SOC occurs in fairly stable and highly recalcitrant forms to bio-degradation[3,6]. The SOC stocks surveys usually consider a fixed soil depth, typically 1 meter[2]. Carbon sink potentiality of the soil through proper proactive practices, carbonaceous gas emissions can be reduced to a great extent[7]. The inundation land is a unique feature in Bangladesh and has taken into account in land management where five categories of inundation land types were identified[8]. Out of the five, the medium low land (MLL) and low land (LL) contains a significant proportion of basin soil properties [8,9].

The relative importance of the edaphic factors as drivers or constraints of spatial heterogeneity of SOC content in these wetland soils is not well understood. Possibly due to the decrease of inundation level in the wetland sites of Bangladesh and consequent intensive agricultural and other anthropogenic activities, the basin soils are losing their carbon contents, and thus wetland basin ecosystems are degrading. So, exploring carbon storage as well as their sustainable usage is very much important in recent days. The present study aimed at (i) to estimate carbon storage throughout 1 m depth of both medium low and low land soils (ii) to evaluate some wetland soil properties at different soil depths.

Materials and Methods

Forty soil samples were collected from eight profiles of Balai, Hakaluki, Hail and Nikli wetland areas at different soil depths. The different soil depths were 0-20cm, 20-40cm, 40-60cm, 60-80cm, and 80-100cm. The samples were collected from medium low land (MLL) and low land (LL) of the selected sites. The sampling at different soil depths was used to assess soil carbon storage and distribution as affected by soil depths and inundation land types[2,4]. By using fixed depth (1 meter) of the soil profile, the sampling was performed in a topo- sequence arrangements e.g. two profile samples from the Balai wetland at the Zakiganj border near Barak river where Surma and Kushiyara coincide, four profile samples from the Hail and Hakaluki wetland sites of Moulvibazar district and the other two profile from the wetland site of Nikli under the district of Kishoreganj. In order to calculate the area of the studied wetlands, Google Earth Pro and ArcGIS 10.3 software were used. First, the area of the wetlands has been visually interpreted in the dry season with International Union for Conservation of Nature (IUCN) resources maps and then, the shape files were digitized in Google earth pro. With the help of ArcGIS, the shape files are geo-referenced and projected and then, the areas were calculated using polygon attribute tables (PAT) files. The calculated value of the studied wetlands was 17,390 hectares for Balai wetland, 23,501 hectares for Hakaluki wetland, 21,318 hectares for Hail haor, and 22,562 hectares for Nikli wetlands. All these soils comprises moderately to very deeply flooded, very poorly drained, fine-textured soils which are generally developed in the Surma-Kushiyara valley of the Sylhet basin[8,9]. Soil samples from each wetland were collected in thick polythene bags. The samples were air-dried, ground and sieved through 2 mm and 0.5 mm sieve, respectively, and mixed thoroughly. The samples were then preserved in plastic containers for laboratory analysis. Soil organic carbon (SOC) was determined using the Walkley and Black wet oxidation method[10]. The soil pH was measured in a 1 : 2.5 soil-water ratio. Total soil Nitrogen was determined by using Micro-Kjeldahl distillation method[11]. Bulk density was measured by the core method[12]. It may be noted that the bulk density and SOC concentration (%) are the two prerequisites for estimating SOC stock or storage. Thus, the SOC storage were calculated using the following equations[1,13].

Total soil organic carbon (TSOC) = $SOC_i \times BD_i \times D_i$; Where SOC_i is the SOC content in the i^{th} layer (g/kg soil), BD_i is the bulk density in the i^{th} layer (g/cc) and D_i represents the thickness of the i^{th} layer (cm).

Results and Discussion

Soil pH: The soil pH values in the studied sites MLL in the Balai, Hakaluki, Hail and Nikli wetlands varied from 5.88 to 6.81, 5.45 to 6.44, 6.65 to 7.72, and 5.98 to 6.38, respectively (Tables 1-2). The pH is low in the upper soil layers and it increases with depth in Balai wetland (Fig. 1). In Hakaluki wetland, the pH markedly increased with depth while the fluctuation in pH was most prominent at the depth 0-40 cm. Similar trend was also found in Hail wetland. In Nikli and Balai wetland, the variation of soil reaction was found in the lower depths. In LL sites, the pH was found to be highest in the deeper soil layers in Balai wetland. In Hakaluki wetland, pH fluctuated with the increase in depths whereas it was unchanged in the deeper soil layers. Similar observation on soil pH was reported in cropland soils[13]. The soil reaction status was gradually higher with depths and is presented in Fig. 1.

Bulk density: The distribution of bulk density in MLL sites was ranged from 1.12 to 1.43 g/cc for Balai haor soils, 1.29 to 1.56 g/cc for Hakaluki soils, 0.91 to 1.19 g/cc for Hail soils and 1.10 to 1.32 g/cc for Nikli haor soils respectively. The bulk density has been observed as the highest in Hakaluki haor soils in contrast to other sites (Table 2). In MLL sites, the peak value of bulk density was found in the upper soil (0-20 cm) and then gradually decreased with the increase in depth in both Balai and Hakaluki wetland soils (Fig. 1). Hail wetland also exhibited decreasing pattern of bulk density with an exception in 40- 60 cm depth, where bulk density increased slightly in comparison to its immediate upper layer in MLL. The fluctuation in bulk density was most prominent in Nikli haor soils (Fig. 1). In case of LL sites, the values of bulk density were ranged from 1.09 to 1.31 g/cc for Balai, 1.29 to 1.48 g/cc for Hakaluki, 1.15 to 1.32 g/cc for Hail and 1.13 to 1.37 g/cc for Nikli haor soils (Tables 1-2). The highest bulk density has been observed in the deeper layer of Hakaluki haor soils. Bulk density was highest in the layer depth 20-40 cm for Balai wetland, and then with the increase in depth, the bulk density was decreased gradually.

In Hakaluki wetland, the bulk density was highest in the deeper soil layers (80-100 cm) in LL whereas the fluctuation was most remarkable in Nikli wetland soils (Fig. 1). A recent study evaluated the fitness of bulk density as proxy SOC storage in grassland converted to cropland afforestation[13].

Table 1. Soil properties of Balai, Hakaluki, Hail and Nikli wetlands depending on land types.

Wetland sites	Soil properties	Mean ±SD (MLL)	Range (MLL)	CV(%) (MLL)	Mean ±SD (LL)	Range (LL)	CV(%) (LL)
Balai wetland	pH	6.47±0.37	5.88-6.81	5.72	5.84±0.15	5.57-5.94	2.57
	Bulk density (g/cc)	1.29±0.12	1.12-1.43	9.30	1.19±0.09	1.09-1.31	7.56
	SOC content (%)	0.99±0.07	0.94-1.11	7.07	1.31±0.08	1.22-1.45	6.11
	C/N ratios	10.60±0.85	9.80-12.00	8.02	8.95±2.75	6.63-13.56	26.72
	SOC storage (kg m^{-2})	2.56±0.37	2.15-3.17	14.45	3.12±0.29	2.81-3.43	9.29
Hakaluki wetland	pH	6.01±0.38	5.45-6.44	6.33	7.19±0.11	7.02-7.28	1.53
	Bulk density (g/cc)	1.41±0.10	1.29-1.56	7.09	1.35±0.08	1.29-1.48	5.93
	SOC content (%)	1.26±0.16	1.05-1.49	12.69	1.25±0.07	1.14-1.32	5.60
	C/N ratios	11.02±1.68	8.75-13.44	15.25	10±1.93	7.60-12.60	19.3
	SOC storage (kg m^{-2})	3.58±0.69	2.88-4.64	19.27	3.37±0.32	2.95-3.73	9.49
Hail wetland	pH	7.42±0.44	6.65-7.72	5.94	7.80±0.17	7.50-7.92	2.17
	Bulk density (g/cc)	1.05±0.11	0.91-1.19	10.48	1.24±0.06	1.15-1.32	4.84
	SOC content (%)	1.02±0.18	0.81-1.21	17.65	1.13±0.23	0.84-1.42	20.35
	C/N ratios	9.09±1.18	8.07-10.90	12.98	9.61±1.60	8.40-12.25	16.64
	SOC storage (kg m^{-2})	2.18±0.58	1.48-2.88	26.60	2.81±0.64	2.03-3.75	22.77
Nikli wetland	pH	6.25±0.16	5.98-6.38	2.56	7.06±0.34	6.69-7.50	4.82
	Bulk density (g/cc)	1.22±0.09	1.10-1.32	7.38	1.25±0.09	1.13-1.37	7.2
	SOC content (%)	1.00±0.17	0.82-1.25	17.00	1.74±0.11	1.61-1.90	6.32
	C/N ratios	10.04±1.10	8.80-11.36	10.95	12.23±3.24	9.05-16.10	26.50
	SOC storage (kg m^{-2})	2.45±0.30	2.16-2.80	12.24	4.37±0.54	3.93-5.20	12.35

Nitrogen contents and C/N ratios: The Nitrogen contents of the studied wetland soils are higher in LL sites (Table 2) compared to MLL sites except for Hail wetland soils. The C/N ratios of LL sites ranged from 6.63 to 13.55 for Balai, 7.60 to 12.6 for Hakaluki, 8.40 to 12.25 Hail and 9.05 to 16.10 for Nikli haor soils, respectively (Tables 1- 2). It was observed that C/N ratios are higher in deeper soil layers. It may be noted that the increased mineralization of N in topsoil because of high SOC and microbial activity may be one of the possible reasons for lower C/N ratios (Table 1). Similar findings were reported in different layers of a Mollisol after long-term mineral fertilization in Northeast China[5]. Application of crop residues to soil instead of using it as an energy source has a positive effect on the improvement of soil fertility and OC stabilization and its turnover, carbon restoration and mitigation of climate change[14].

Table 2. Soil properties of Balai, Hakaluki, Hail and Nikli wetlands depending on land types and their corresponding depths.

Wetland sites	Depths (cm)	pH values		Bulk density (g/cc)		Org C content (%)		C/N ratios		SOC storage (kg/m^2)	
		MLL	LL	MLL	LL	MLL	LL	MLL	LL	MLL	LL
Balai haor	0-20	5.88	5.57	1.43	1.17	1.11	1.45	10.10	7.25	3.17	3.39
	20-40	6.42	5.89	1.34	1.31	0.96	1.31	12.00	9.36	2.57	3.43
	40-60	6.48	5.9	1.32	1.25	0.94	1.22	10.44	13.55	2.48	3.10
	60-80	6.77	5.94	1.25	1.13	0.98	1.26	9.80	6.63	2.45	2.85
	80-100	6.81	5.89	1.12	1.09	0.96	1.29	10.67	8.06	2.15	2.81
Hakaluki haor	0-20	5.45	7.02	1.56	1.36	1.49	1.32	10.64	8.80	4.64	3.60
	20-40	5.88	7.27	1.45	1.30	1.31	1.30	10.92	10.02	3.80	3.38
	40-60	5.98	7.13	1.38	1.29	1.25	1.14	11.36	7.60	3.45	2.95
	60-80	6.28	7.25	1.37	1.31	1.05	1.21	8.75	11.00	2.88	3.17
	80-100	6.44	7.28	1.29	1.48	1.21	1.26	13.44	12.6	3.13	3.73
Hail haor	0-20	6.65	7.50	1.19	1.32	1.21	1.42	8.07	8.88	2.88	3.75
	20-40	7.48	7.82	1.06	1.15	1.15	1.30	8.85	10.00	2.44	2.99
	40-60	7.53	7.88	1.10	1.25	1.09	1.11	10.90	8.54	2.40	2.77
	60-80	7.68	7.89	0.98	1.28	0.86	0.98	9.55	12.25	1.69	2.51
	80-100	7.72	7.92	0.91	1.21	0.81	0.84	8.10	8.40	1.48	2.03
Nikli haor	0-20	5.98	6.69	1.10	1.37	1.25	1.90	11.36	9.05	2.75	5.20
	20-40	6.25	6.81	1.27	1.29	1.10	1.78	10.05	9.36	2.80	4.59
	40-60	6.28	7.02	1.26	1.13	0.88	1.74	8.80	11.53	2.25	3.94
	60-80	6.35	7.30	1.32	1.26	0.82	1.66	9.11	15.09	2.16	4.18
	80-100	6.38	7.50	1.16	1.22	0.98	1.61	10.88	16.10	2.27	3.93

Soil organic carbon (SOC) distribution: The primary sources of organic matter input into the subsoil are roots and root exudates, dissolved organic matter, and topsoil SOC translocated by bioturbation[15]. SOC distribution in the soils of MLL sites was recorded as 0.94 to 1.11% for Balai, 1.05 to 1.49% for Hakaluki, 0.81 to 1.21% for Hail and 0.82 to 1.25% for Nikli wetland soils respectively (Tables 1-2). The SOC content was found to be the highest (1.26%) in MLL of Hakaluki haor soils. SOC distribution patterns are given for MLL as Hakaluki wetland (1.26%)>Hail wetland (1.02%)>Nikli wetland (1.01%)>Balai wetland (0.99%). On the other hand, SOC distribution in the soils of LL sites in the Balai, Hakaluki, Hail and Nikli wetlands was found as 1.22 to 1.45%, 1.14 to 1.32%, 0.84 to 1.42%, and 1.61 to 1.90%, respectively (Tables 1 & 2). The SOC content was found highest (1.74%) in the LL of Nikli haor. SOC distribution patterns are given for LL as Nikli wetland (1.74%)>Balai wetland (1.31%)>Hakaluki wetland (1.24%)>Hail wetland (1.13%).

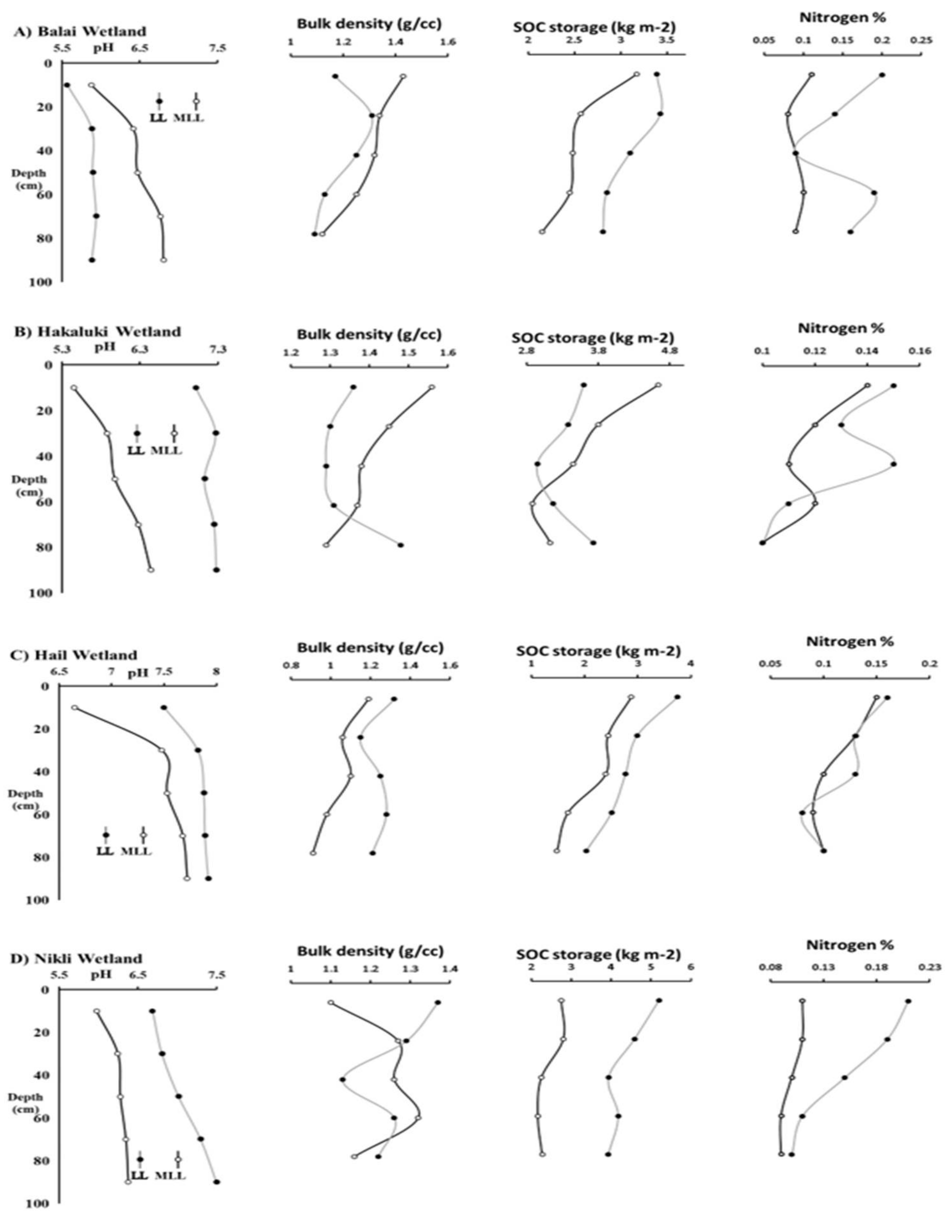

Fig. 1. Distribution of soil pH, bulk density, SOC storage, and soil N contents (%) with depths in MLL and LL sites of A) Balai, B) Hakaluki, C) Hail and D) Nikli wetlands.

The highest SOC concentration was found in the topsoil (0-20cm) in both land types. The topsoil layer is tilled and receives greater residue inputs which are subsequently mineralized. The top layer possesses higher SOC than the other soil layers. The topsoil layer may be able to sequester atmospheric CO_2 where nitrogen fertilization in topsoil of agricultural lands typically increases SOC concentrations due to increased biomass of residues returned to agricultural soils[5]. SOC concentration showed a decreasing trend from the topsoil to the bottom layer for both land types of the study area. It is noteworthy that LL contained higher SOC than the MLL. A study reported that MLL have lower SOC than soils in LL depositional areas[2]. The SOC threshold for sustaining soil quality is widely suggested to be about 2% (20 g/kg) below which deterioration in soil quality occurs[16]. Previous study reported that minimum and maximum thresholds of SOC, above or below which the effects of SOC on soil functions[17]. Thus it is found that the study sites belong to the minimum threshold of SOC level.

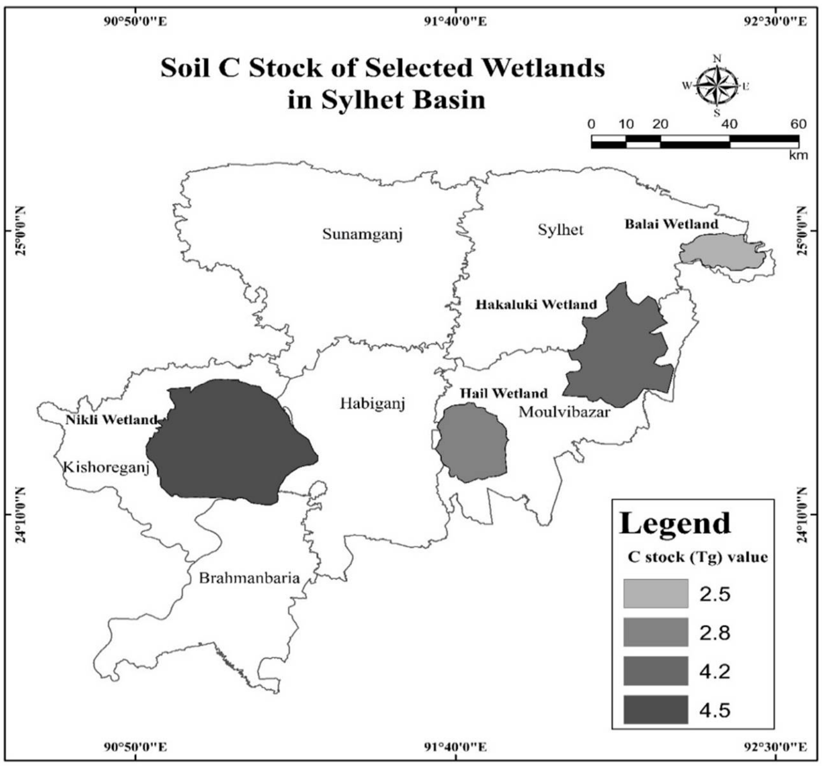

Fig. 2. Spatial distribution of soil C storage in Balai, Hakaluki, Hail and Nikli wetlands.

Soil Organic Carbon (SOC) Storage: The SOC storage in MLL sites of Balai, Hakaluki, Hail and Nikli wetland soils from the surface to 100cm depth was recorded as 12.82, 17.90, 10.89 and 12.23 kg/m^2 respectively (Table 2). In the topsoil layer i.e. 0- 20 cm, values of SOC storage were 3.17, 4.64, 2.88 and 2.75 kg/m^2 for Balai, Hakaluki, Hail and Nikli wetland, respectively. The SOC storage was found to be decreased with the increase in depth in Balai haor soils. It was highest in the topsoil layer, gradually decreased to 2.88 kg/m^2 in 60- 80cm depth and finally slightly increased to 3.13 kg/m^2 in the deepest layer

(80- 100cm) observed in Hakaluki wetland (Table 2). The SOC storage was sharply decreased with depth (from 0-100cm) in Hail haor with an exception for layer 40-60 cm (Fig. 1). Nikli wetland followed a decreasing pattern with increasing depth with an exception for layer 80-100 cm (Fig. 1 and Table 2). The dominant land use types in Balai and Hail wetlands were transplanted Aman and Boro rice. Hakaluki soils are used for the cultivation of Boro rice and in the dry season, these grasslands are used for grazing cattle. The dominant land use is deep transplanted Aman rice and it becomes waterlogged for most of the year. Wetland rice cultivation represents the most complex system in relation to carbon sequestration(18) where residue management is an important method of sequestering C in soil and increasing the soil organic matter content(5). Thus, growing different crop types represents the variability of carbon storage in different locations of wetland soils. In LL sites, SOC storage in Balai, Hakaluki, Hail and Nikli wetland soils from the surface to 100cm depth was recorded as 15.58, 16.83, 14.05 and 21.84 kg/m^2, respectively (Table 2). In the topsoil layer i.e. 0-20cm, values of SOC storage were 3.39, 3.60, 3.75 and 5.20 kg/m^2 for Balai, Hakaluki, Hail and Nikli wetland, respectively (Table 2). In LL sites, the SOC storage tended to decrease in the deeper soil layers (Fig. 1). An inverse relationship between the soil depth and SOC storage was also noted for rest of the wetlands excluding Hakaluki (Table 2), where soil has an increasing carbon load in the deepest layer (80- 100 cm) (Fig. 1).

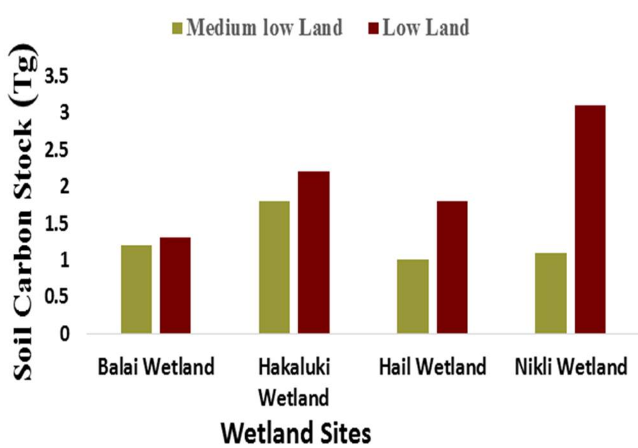

Fig. 3. Soil carbon storage (Tg) in MLL and LL sites of the four designated wetlands.

Soil carbon storage: It is found that the total soil C storage across the MLL and LL sites covering the four designated wetlands of the Sylhet basin is about 13.5Tg. In MLL sites, C storage was calculated as 1.2Tg for Balai wetland, 1.8Tg for Hakaluki wetland, 1.0Tg for Hail wetland and 1.1Tg for Nikli wetland soils. In LL sites, soil carbon storage was estimated as 1.3Tg for Balai, 2.2Tg for Hakaluki, 1.8Tg for Hail and 3.1Tg for Nikli haor soils. It is seen that C storage across the MLL and LL sites at 100 cm depths was estimated about 5.1Tg and 8.4Tg respectively. The estimated SOC storage in four wetlands and their spatial distributions are shown in Figs 2-3. Bangladesh predominantly consists of Inceptisols and the studied area belongs to Inceptisols as well. Previous investigations reported that the SOC stock of Inceptisols in Bangladesh is 1.59 Pg(19) where total SOC stock of Bangladesh is 2.2 Pg(20). In another study revealed that total soil organic carbon stock in the Sylhet basin soils of Bangladesh is 94Tg (21). The wetlands are the precious resources for the survival of mankind. The northeastern designated wetlands are the sources of carbon sink. The study showed that SOC storage remains below the critical level and is declining due to improper management. These carbon sources should be restored in an integrated way to tackle climate change and other issues.

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(Manuscript received on 10 November, 2020; revised on 15 January, 2020)