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ESTIMATION OF CARBON STOCK IN THE SYLHET BASIN SOILS OF BANGLADESH

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Abstract

Wetland basin soils are the major store houses of organic carbon where there is a scope to use this carbon in mitigating the climate change. A study was conducted in these basin soils at 100 cm depth regarding their carbon stock. The study showed that total soil organic carbon (SOC) stock in the Sylhet basin soils of Bangladesh is 0.094 Pg where the SOC stock was 0.044 Pg in medium low land sites and it was about 0.050 Pg in lowland sites. There was no previous study on SOC stock in the Sylhet basin soils of Bangladesh. These may act as benchmark SOC stock datasets for the future agricultural planning. The soil organic carbon stock is higher in the lowland than medium lowland sites. The contents of SOC are low is compared to its threshold levels. Moreover, it is apprehended that basin soils may lose their carbon due to the decrease of inundation level by climate change, and other eco-environmental changes. So, it is very much urgent to take steps in preserving the organic carbon of lowland basin soils.

Key words: Estimation, Carbon stock, Sylhet basin soils

Introduction

Soil organic carbon (SOC) is one of the main factors affecting soil quality and agricultural productivity. Being a source as well as storage of plant nutrients, SOC plays an important role in terrestrial C cycle (Freixo *et al.* 2002). Landuse has a significant effect on SOC storage, since it affects the amount and quality of litter input, litter decomposition rate, and stabilization of SOC (Bronson *et al.* 2004). Information on global and regional SOC pool in topsoil is generally available for a variety of landuse and climatic conditions (Batjes 1996). However, study on SOC storage in soils as affected by inundation of land is very scanty, particularly in Bangladesh. It is widely accepted that SOC is largely concentrated in the top 30 cm of the soil, but there is a growing evidence that deeper soil horizons have the capacity to sequester high amounts of SOC (Jobbagy and Jackson 2000, Swift 2001) and that this should be considered for SOC emission-storage analysis. The importance of SOC sequestration in sub-soils mitigating the greenhouse effect is related to the fact that subsoil SOC occurs in fairly stable and highly

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recalcitrant forms to biodegradation (Batjes 1996, Kogel-Knabner 2002, Nierop and Verstraten 2003). SOC surveys usually consider a fixed soil depth, typically 1 meter. Global surveys based on vegetation units (Post *et al.* 1982) and soil taxonomic units (Eswaran *et al.* 1993, Batjes 1996) indicated that soil stores 1500-1600 Pg C in the top one meter depth. However, soil carbon can be underestimated in its global budgets by fixing a lower boundary at 1 m depending on the vertical distribution of SOC. A very important aspect of such studies would be in the area of mitigating the effects of global climate change, which has a direct relationship to agriculture and specifically to organic carbon management in soils (Johnson and Kerns 1991).

There are a few studies on the estimation of carbon stocks in the wetland basin soils of Bangladesh. Wetland basin soils are the major storehouse of organic carbon where there is a scope to use this carbon and energy in mitigating climate change. In Bangladesh, exploration of this research area may provide valuable information regarding their usage by estimating their storage. On the other hand, possibly due to the decrease of inundation level in Bangladesh and consequent intensive agricultural usage (Brammer 2002), the basin soils are losing their carbon contents, and thus lowland basin ecosystems are degrading. So, exploring the carbon storage as well as their sustainable usage is very much important in the recent days. In this connection, an attempt was undertaken to estimate carbon stock in the Sylhet basin soils of Bangladesh under the present situation of climate change.

Materials and Methods

The Sylhet basin is located in the extreme north-eastern part of the main basin, surrounded by the Shillong plateau, Tripura hills, and the Madhupur terrace Pleistocene uplands. The south boundary is a major fault scarp. The basin has an average altitude of about 4.5 m above mean sea level (MSL) at its center. It was earlier considered as a part of the Ganges-Brahmaputra delta. The Old Brahmaputra River (the original channel of the Brahmaputra) passes through the westernmost part. The present Brahmaputra course has an elevation of about 15 m above mean sea level, which shows that the Sylhet basin has subsided about 10.5-12 m during the last couple of hundred years (Mukherjee *et al.* 2009). The cause is certainly tectonic, associated with movements of the fault systems. Holocene fossil wood fragments have been found at depths of 15-18 m below surface. The surface is inundated every year during monsoon season. Geomorphologically, the basin possesses natural, continuously meandering levees with dendritic drainage (Umitsu 1985). The sediment composition of the basin grades from sandy or silty near the surface to fine sand at a depth of about 12 m.

Forty soil samples from the eight profiles at different soil depths (0-20, 20-40, 40-60, 60-80 and 80-100 cm) were collected. The sampling covers the north-eastern *Haor* basin regions of Bangladesh covering the 4 districts of Sylhet, Moulvibazar, Habiganj and Brahmanbaria. These samplings at different soil depths were used for the purpose of SOC storage and distribution as affected by soil depths and inundation land types. The inundation land type is a unique feature in Bangladesh and has taken into account in land management. In Bangladesh, five categories of inundation land types were identified by FAO-UNDP (1988). These were highland (HL), medium highland (MHL), medium lowland (MLL), lowland (LL), and very lowland (VLL), as outlined in Table 1.

Table 1. Classification of land types of Bangladesh and Sylhet basin based on inundation flood level.

Land types	Flooding depth	Bangladesh (%)	Sylhet basins (%)
Highland (HL)	Land which is above normal flood level	18	6
Medium highland (MHL)	Land which normally is flooded up to about 90 cm deep during the flood season	32	20
Medium lowland (MLL)	Land which normally is flooded up to between 90 and 180 cm deep during the flood season	12	19
Lowland (LL)	Land which normally is flooded up to between 180 and 300 cm deep during the flood season	6	20
Very lowland (VLL)	Land which is normally flooded deeper than 300 cm during the flood season	2	11

Source: (FAO-UNDP 1988, SRDI 2010).

These inundated land types are regarded as the biophysical units of a landscape. The inundated land types, MLL and LL were considered here only. Because these land types bear the lowland basin properties. The samplings were done in a topo sequence arrangement e.g. 2 profile samples from Zakigang border of Barak river where Surma and Kushiyara coincide, 2 profile samples from the Hakaluki *Haor* of Moulvibazar district, 2 profile samples from the Hobigang *Haor* sites and the other 2 profile samples from the *Haor* sites of Sarail, Brahmanbaria. Thus, these samples reflect a whole scenario of the basin or *Haor* ecosystems.

Soil samples from each site up to 1 m depth were collected in thick polythene bags. The soil samples were air dried under shade. The samples were then gently ground with rolling wooden roller and also with a wooden hammer and passed through 0.5 mm sieve and mixed thoroughly. The samples were then preserved in plastic bags for soil organic carbon analysis.

Soil organic carbon (SOC) was determined by following the method of Walkley and Black (1934). Soil bulk density was determined by using the core method as described by Blake and Hartge (1986). Soil particle size analysis was determined by hydrometer method after pretreatments as described by Gee and Bauder (1986). It may be noted that the bulk density and SOC concentration (%) are the two prerequisites for estimating SOC stock or storage. Thus, the total soil organic carbon and total soil nitrogen storage were calculated using the following equations (Batjes 1996, Chen *et al.* 2007, Zhang *et al.* 2013).

Total soil organic carbon (TSOC) = $SOC_i \times B_i \times D_i$ Eq. (i)

Total soil nitrogen (TSN) = $TN_i \times B_i \times D_i$ Eq. (ii)

where, equation (i) represents TSOC; SOCi is the SOC content on the i^{th} layer (g/kg);

Equation (ii) represents TSN; TN_i is the total nitrogen content on the i^{th} layer (g/kg);

B_i is the bulk density of the i^{th} layer (g/cc), and D_i is the depth of the i^{th} layer (cm).

Results and Discussion

Guidelines for estimating greenhouse gas (GHG's) emissions from agriculture, forestry, and other land uses are provided by the Intergovernmental Panel on Climate Change (IPCC). The IPCC guidance includes specific details for estimating C stocks of upland forest ecosystems, however, specific provisions for tropical wetland soils and peat lands are seriously lacking (IPCC 2007). The close relationship between C density and bulk density allows for a reasonably accurate estimation of C stocks for tropical wetland soils. Eswaran *et al.* (1993) estimated soil organic carbon contents in the soil orders at global level as well as tropical regions. From the above datasets, Hussain (2002) reported that the soils of Bangladesh have a total of 2.2 Pg organic carbons. The above report revealed that in Bangladesh, Inceptisols and Entisols orders contains about 1.73 Pg organic carbons (Table 2). Possibly, this is the base line datasets of organic carbon mass in the soils of Bangladesh. Idris and Uddin (2013) showed that Sylhet basin soils occupy the soil orders of Inceptisols and Entisols. There is a serious lacking of SOC stock or storage data sets in Bangladesh even in the Sylhet basin soils of Bangladesh. So, it is expected that the soil organic carbon contents in the study site may be within this range.

The bulk density distribution of medium lowland (MLL) site in the Zakiganj Upazila under Sylhet district varied from 1.37 to 1.59 g/cc and the mean bulk density is 1.47 g/cc. The particle size analysis showed that silt is the dominant size fraction that varied from 60 to 85 per cent and its mean value is 69 per cent. The bulk density value in the Hakaluki *Haor* under Moulvibazar district ranged from 1.61 to 1.82 g/cc and the mean bulk density is 1.71 g/cc. The particle size analysis showed that clay is the dominant size fraction that varied from 53 to 68 per cent and the mean value is 59 per cent. The bulk density distribution in the Hobiganj site varied from 1.31 to 1.41 g/cc and the mean bulk density is 1.36 g/cc. The particle size analysis showed that silt is the dominant size fraction that varied from 68 to 83 per cent and the mean value is 75 per cent. The bulk density distribution in the Sarail site under the Brahmanbaria district varied from 1.44 to 1.67 g/cc and the mean bulk density is 1.56 g/cc. The particle size analysis showed that silt is the dominant size fraction that varied from 75 to 88 per cent and the mean value is 83 per cent. The higher bulk density has been observed in the Hakaluki *Haor* site of Moulvibazar district than that of other sites (Table 3).

Table 2. Organic carbon mass in the soils of the world and of Bangladesh.

Soil orders	Area (10^3 Km^2)			Organic C (Pg)*		
	Global	Tropical	Bangladesh	Global	Tropical	Bangladesh**
Entisols	14921	3256	14.20	148	19	0.14
Inceptisols	21580	4565	97.50	352	60	1.59
Ultisols	11330	9018	0.89	105	85	0.08
Histosols	1745	286	1.20	357	100	0.25
Alfisols	18283	6411	1.20	127	30	0.03
Misc. land	7644	1358	24.00	18	02	0.05
Total	-	-	147.00	-	-	2.20

*Pg = Petagram = 1×10^{15} (Source: Eswaran *et al.* 1993), Hussain 2002**

The bulk density distribution of lowland (LL) site in the Zakiganj site under Sylhet district varied from 1.56 to 1.74 g/cc and the mean bulk density is 1.66 g/cc. The particle size analysis showed that silt is the dominant size fraction that varied from 45 to 60 per cent and the mean value is 51 per cent. The bulk density in the Hakaluki *Haor* under Moulvibazar district ranged from 1.59 to 1.92 g/cc and the mean bulk density is 1.70 g/cc. The particle size analysis showed that clay is the dominant size fraction that varied from 45 to 65 per cent and the mean value is 56 per cent. The bulk density distribution in the Hobiganj site varied from 1.32 to 1.53 g/cc and the mean bulk density is 1.46 g/cc. The particle size analysis showed that silt is the dominant size fraction that varied from 75 to 88 per cent and the mean value is 81 per cent. The bulk density distribution in the Sarail site under the Brahmanbaria district varied from 1.43 to 1.75 g/cc and the mean bulk density is 1.56 g/cc. The particle size analysis showed that silt is the dominant size fraction that varied from 75 to 88 per cent and the mean value is 80 per cent. The higher mean bulk density has also been observed in the Hakaluki *Haor* site of Moulvibazar district than that of other sites (Table 4).

Table 3. Bulk density distribution (g/cc) at different soil depths in medium lowland sites across the Sylhet basin soils.

Depths (cm)	Sylhet Sadar site (Zakigonj site)	Moulvibazar site	Hobiganj site	Brahmanbaria site
0 - 20	1.49	1.65	1.37	1.49
20 - 40	1.59	1.77	1.36	1.52
40 - 60	1.37	1.70	1.32	1.67
60 - 80	1.44	1.82	1.31	1.44
80 - 100	1.50	1.61	1.41	1.65
Mean	1.47	1.71	1.36	1.56

Table 4. Bulk density distribution (g/cc) at different soil depths in lowland sites across the Sylhet basin soils.

Depths (cm)	Sylhet Sadar site (Zakigonj site)	Moulvibazar site	Hobiganj site	Brahmanbaria site
0 - 20	1.67	1.70	1.46	1.43
20 - 40	1.64	1.59	1.32	1.58
40 - 60	1.74	1.61	1.49	1.47
60 - 80	1.70	1.92	1.51	1.75
80 - 100	1.56	1.67	1.53	1.58
Mean	1.66	1.70	1.46	1.56

Soil organic carbon (SOC) distribution in medium lowland (MLL) soils in the Zakiganj site under Sylhet district varied from 0.81 to 0.96 per cent from surface to 100 cm depth and the mean organic carbon was 0.92 per cent (Table 5). SOC distribution in the Hakaluki *Haor* soils under Moulvibazar district ranged from 0.73 to 1.38 per cent from surface to 100 cm depth and the mean organic carbon was 0.97 per cent. SOC distribution in the Hobiganj site ranged from 0.73 to 0.88 per cent from surface to 100 cm depth and the mean organic carbon was 0.80 per cent. SOC distribution in the Sarail site under Brahmanbaria district varied from 0.49 to 0.77 per cent from surface to 100 cm depth and the mean organic carbon was 0.58 per cent. On the other hand, SOC distribution of lowland (LL) soils in the Zakiganj sites under Sylhet district varied from 0.81 to 1.28 per cent from surface to 100 cm depth and the mean organic carbon was 1.11 per cent (Table 6). SOC distribution in the Hakaluki *Haor* soils under Moulvibazar district ranged from 0.53 to 0.98 per cent from surface to 100 cm depth and the mean organic carbon was 0.76 per cent. SOC distribution in the Hobiganj site ranged from 0.61 to 0.98 per cent from surface to 100 cm depth and the mean organic carbon was 0.72 per cent. SOC distribution in the Sarail site under Brahmanbaria district varied from 0.40 to 0.89 per cent from surface to 100 cm depth and the mean organic carbon was 0.55 per cent. The highest SOC concentration was found in the topsoil (0 - 20 cm) across the eight land types (Tables 5-6).

Table 5. Soil organic carbon distribution (%) at different soil depths in medium lowland sites across the Sylhet basin soils.

Depths (cm)	Sylhet site	Moulvibazar site	Hobiganj site	Brahmanbaria site
0 - 20	0.96	1.38	0.88	0.77
20 - 40	0.90	1.02	0.77	0.61
40 - 60	0.81	0.81	0.73	0.53
60 - 80	0.94	0.90	0.81	0.49
80 - 100	0.98	0.73	0.85	0.49
Mean	0.92	0.97	0.80	0.58

Table 6. Soil organic carbon distribution (%) at different soil depths in lowland sites across the Sylhet basin soils.

Depths (cm)	Sylhet site	Moulvibazar site	Hobiganj site	Brahmanbaria site
0 - 20	1.28	0.98	0.85	0.89
20 - 40	1.10	0.81	0.77	0.61
40 - 60	0.81	0.77	0.73	0.49
60 - 80	1.22	0.73	0.65	0.40
80 - 100	1.14	0.53	0.61	0.40
Mean	1.11	0.76	0.72	0.55

Soil organic carbon concentration depends on the balance between organic carbon input and loss from soils (Zhuang *et al.* 2007). Topsoil layer (0 - 20 cm) is tilled and receives greater residue inputs which are subsequently mineralized. Thus this layer possesses higher SOC than the other soil layers. Chaplot *et al.* (2010) reported that the topsoil layer may be able to sequester atmospheric CO_2 and thus mitigate climate change effect where more biophysical activities take place. Xiao-Wei *et al.* (2012) noted that surface soils are rich in SOC due to being covered by highly productive vegetation or subject to long-term use of organic fertilizers or flooding conditions. SOC concentration showed a decreasing trend from the top soil layer to the bottom layer for all land types of the study sites. It is important to note that lowland (LL) sites contain higher SOC than the medium lowland (MLL) sites due to the nature of inundation depths. Roose and Barthes (2001) noted that SOC is lost from soils of higher topography level, through erosion, runoff and leaching where erosion and runoff contribute a large portion of carbon losses and these are highly accelerated in cultivated land compared to undisturbed land. Uddin *et al.* (2019) mentioned that land inundation influences the organic carbon levels in soils. SOC threshold for sustaining soil quality is widely suggested to be about 2% (20 g/kg) below which deterioration in soil quality occurs (Patrick *et al.* 2013, BARC 2018). Krull *et al.* (2004) discussed some of the minimum and maximum thresholds of SOC, above or below which the effects of SOC on soil functions are noticeable. However, Sparling and Schipper (2002) argued that other than defining such maximum values, it is reasonable if minimum SOC levels (e.g. 2% i.e. 20 g/kg) are established to inform the farming community on levels below which there would be a loss of important soil characteristics. Thus, it is found that the study sites belong to minimum threshold of SOC level.

Soil organic carbon storage of medium lowland (MLL) soils in the Zakiganj sites under Sylhet district varied from 2.21 to 2.94 kg/m^2 from surface to 100 cm depth and the total organic carbon storage was 13.57 kg/m^2 (Table 7). The dominant landuse types were transplanted Aman and Boro rice. SOC storage in the Hakaluki *Haor* soils under Moulvibazar district ranged from 2.35 to 4.55 kg/m^2 from surface to 100 cm depth and the total organic carbon storage was 16.54 kg/m^2. Hakaluki *Haor* soils are used for the cultivation of Boro rice and in the dry season these are used as grazing grassland. SOC storage in the Hobiganj site ranged from 1.92 to 2.41 kg/m^2 from surface to 100 cm depth and the total organic carbon storage was 10.93 kg/m^2. The dominant landuse of this study site is deep transplanted Aman rice and it remains waterlogged for most of the year. SOC storage in the Sarail site under Brahmanbaria district varied from 1.41 to 2.29 kg/m^2 from surface to 100 cm depth and the total organic carbon storage was 8.93 kg/m^2.

Soil organic carbon storage of lowland (LL) soils in the Zakiganj sites under Sylhet district varied from 2.81 to 4.27 kg/m^2 from surface to 100 cm depth and the total organic carbon storage was 18.38 kg/m^2 (Table 8). The dominant landuse type is Boro rice. SOC storage in the Hakaluki *Haor* soils under Moulvibazar district ranged from 1.77 to 3.33 kg/m^2 from surface to 100 cm depth and the total organic carbon storage was 12.94 kg/m^2. Hakaluki *Haor* soils are used for the cultivation of Boro rice only and in the dry season these are used as grazing grassland. SOC storage in the Hobiganj site ranged from 1.86 to 2.48 kg/m^2 from surface to 100 cm depth and the total organic carbon storage was 10.51 kg/m^2. The dominant landuse of this study site is Boro rice and it remains waterlogged for most of the year. SOC storage in the Sarail site under Brahmanbaria district varied from 1.26 to 2.55 kg/m^2 from surface to 100 cm depth and the total organic carbon storage was 8.57 kg/m^2. The variation in the soil organic carbon storage possibly due to their landuse, inundation level and land cover variations.

Table 7. Soil organic carbon storage (kg/m^2) at different soil depths in medium lowland sites across the Sylhet basin.

Depths (cm)	Sylhet site	Moulvibazar site	Hobiganj site	Brahmanbaria site
0 - 20	2.86	4.55	2.41	2.29
20 - 40	2.86	3.61	2.09	1.85
40 - 60	2.21	2.75	1.92	1.77
60 - 80	2.70	3.28	2.12	1.41
80 - 100	2.94	2.35	2.39	1.61
Total SOC kg/m^2	13.57	16.54	10.93	8.93

Table 8. Soil organic carbon storage (kg/m^2) at different soil depths in lowland sites across the Sylhet basin.

Depths (cm)	Sylhet site	Moulvibazar site	Hobiganj site	Brahmanbaria site
0 - 20	4.27	3.33	2.48	2.55
20 - 40	3.60	2.57	2.03	1.92
40 - 60	2.81	2.47	2.17	1.44
60 - 80	4.14	2.80	1.97	1.40
80 - 100	3.56	1.77	1.86	1.26
Total SOC kg/m^2	18.38	12.94	10.51	8.57

Soil organic carbon stock across the study sites up to 100 cm depth was estimated for the medium lowland and lowland sites was about 0.024 Pg and 0.022 Pg, respectively. The total SOC stock in the study sites was about 0.046 Pg (Table 9). Similarly SOC stock calculation was done in other sites of Sylhet basin e.g. Netrokona, Kishoregang and Sunamganj districts using the mean SOC values. The result showed that in medium lowland (MLL) sites, the SOC stock was 0.020 Pg and in the lowland (LL) sites, the SOC stock was 0.028 Pg. So, the total SOC stock in the above two sites was 0.048 Pg. So, it is found that the total SOC stock in the Sylhet basin of Bangladesh was 0.094 Pg. There is no previous study on SOC stock in the Sylhet basin soils of Bangladesh. Lal (2004) estimated that SOC pool in India was 21.0 Pg up to 30 cm depth and 63.0 Pg up to 150 cm depth, respectively. He also reported that SOC concentration in most cultivated soils is less than 10g/kg, which is consistent with the present study. The prevalent low levels of SOC concentrations are attributed to excessive tillage, imbalanced fertilizer use, and little or no return of crop residues to the soil.

Table 9. Carbon stock (Pg) across the study sites at 100 cm depth.

Study sites	*Areas (ha) in MLL sites	SOC stock in MLL sites (Pg)	*Areas (ha) in LL sites	SOC stock in LL sites (Pg)	SOC stock in both MLL & LL sites (Pg)
Sylhet Sadar	74,315	0.010	68,688	0.012	0.022
Moulvibazar	29,019	0.004	16,149	0.002	0.006
Hobiganj	48,214	0.005	59,530	0.006	0.011
Brahmanbaria	58,844	0.005	28,614	0.002	0.007
Total SOC (Pg)		0.024		0.022	0.046

*Soil Resource Development Institute (SRDI) 2010.

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