ESTIMATION OF CARBON STOCK IN THE PEAT SOILS OF BANGLADESH

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Abstract

There are a very few study on the estimation of carbon stocks in the peat soils of Bangladesh. There are three categories of peat soils in Bangladesh: Sapric peat, Hemic peat and Fibric peat. A study was conducted in these three kinds of peat soils at 100 cm depths regarding their stock. The study shows that the carbon in peat soils is about 0.12 Pg whereas it was about 0.25 Pg during 1970s. So, it was found that soil organic carbon loss is alarming and it has been reduced by half during 50 years of agricultural intensification in Bangladesh. These peat soils are losing their carbon due to the decrease of inundation level by climate change, intensive agricultural use and even fuel use for cooking purposes by the local stakeholders. So, it is very much urgent to take steps in preserving the peat soils of Bangladesh.

Key words: Estimation, Carbon stock, Peat soils

Introduction

Peatlands occupy approximately 3% of global land area, but this storage is roughly 30% of the world's soil carbon (Gorham 1991, Bridgham *et al.* 1995, Limpens *et al.* 2008). Therefore, peatlands represent an important long-term sink for atmospheric carbon dioxide (CO_2) some of which is released following drainage and land use change. The restoration of peatland ecosystem functions has been suggested as one of the most cost-effective ways of reducing greenhouse gas (GHGs) and mitigating the effects of climate change.

Tropical wetland forests containing organic soils - mangroves and freshwater peat swamps- are significant global carbon stores (Donato *et al.* 2011). Page *et al.* (2011) estimated 88.6 Pg are stored in tropical peatlands worldwide, with 68.5 PgC (77%) occurring in Southeast Asia. Similarly, Donato *et al.* (2011) estimated mangroves may contain up to 20 Pg C globally. Tropical wetland forests are susceptible to large scale C losses, due to their high C storage and rapid rates of deforestation (Langner *et al.* 2007, Miettinen and Liew 2010 a, b). Further concern is the vulnerability o f tropical wetland

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C pools exacerbated by predicted consequences of global climate change: ENSO-related droughts and subsequent fires, altered precipitation patterns, increasing frequency and severity of tropical cyclones and sea level rise (Ellison and Stoddart 1991, Li *et al.* 2007, Field *et al.* 2009).

Land conversion on peatlands results in immediate massive C fluxes to the atmosphere due to drainage, deforestation and burning followed by longer-term oxidative losses contingent on hydrological conditions (Hooijer *et al.* 2010, Murdiyarso *et al.* 2010, Hergoualc'h and Verchot 2011). Murdiyarso *et al.* (2010) estimated that 25% of all C emissions from converting peat forest to industrial plantation (a dominant land use transition of tropical peatlands in Indonesia; Miettinen *et al.* 2012) occur from initial burning to clear land. Each year, large areas of peatlands burn throughout Indonesia with fire recurring frequently in areas where peat is drained and degraded. During the unusually severe fire season of 1997, drought conditions prompted opportunistic and uncontrolled burning which eventually affected over 2 Mha of wetland ecosystems throughout Indonesia, resulting in C losses commensurate with the 1.5 Pg C average annual flux from global land use change from 1990 - 2005 (Taconni 2003, Page *et al.* 2002, Langmann and Heil 2004).

There are a very few study on the estimation carbon stocks in the peat soils of Bangladesh. Peat soils are the major store house of organic carbon where there is a scope to use this carbon and energy in mitigating climate change. In the developed countries, peat soils are used in various ways of climate change mitigation. In Bangladesh, exploration of this resource may provide valuable information regarding its usage by estimating the storage. On the other hand, possibly due to the decrease of inundation level in Bangladesh and consequent intensive agricultural usage (Brammer 2002), the peat soils are losing its carbon contents, and thus peat land ecosystems are degrading. So, exploring the carbon storage as well as its sustainable usage is very much important in the recent days. In this connection, an attempt has been undertaken to estimate carbon stock in the peat soils of Bangladesh under present situation of climate change.

Materials and Methods

Three soil profiles were selected covering the peat land soils of Bangladesh. There are a total of 9 profiles of peat in Bangladesh (Table 1). The selection of the soil profiles were done based on the sapric peat, hemic peat and fibric peat. Soil color study in the field recognized the nature of peat (Table 2). It may be noted that out of 9 profiles, 3 cover Sapric peat or (well decomposed peat with fibre content less than 15%) profiles

representing 3 soil series: Hakaluki, Satgaon and Sarail etc. Similarly; Hemic peat or (half decomposed peat with fibre content 15 - 75%) profiles cover the 3 soil series: Rajoir, Satla and Mohonganj; and the fibric peat (immature peat with fibre content greater than 75%) or profiles cover the 3 soil series: Harta, Juri and Tarala etc.

Table 1. A list peat basin soils of Bangladesh along with their areas and USDA names.

Soil series	Areas (ha)	USDA names
Hakaluki	4,953	Fluvaquantic Haplosaprists
Sarail	595	Typic Haplosaprists
Satgaon	722	Fluventic Haplosaprists
Rajoir	18,412	Typic Haplohemists
Satla	48,505	Typic Haplohemists
Mohanganj	4,930	Hydric Haplohemists
Harta	44,273	Typic Haplofibrists
Juri	2,035	Hydric Haplofibrists
Tarala	604	Hydric Haplofibrists

Source: Rahman 2005, Hussain *et al.* 2003.

Table 2. Indicators used for differentiating peat maturity in the field.

Indicators	Fibric (immature) peat	Hemic (medium maturity) peat	Sapric (mature) peat
Decomposition stage	Peat at early decomposition stage, with its original materials still recognizable.	Half-decomposed peats, with some original materials are still recognizable.	Decomposed peat in which the original materials are no longer recognizable.
Colour	Brown-light brown	Brown	Dark-brown-black
When squeezed in the palm, the amount of fiber remained	More than two-thirds of the initial amount.	One-to-two-thirds of the initial amount.	Less than one-third of the initial amount.

Soil samples from a depth of 1 m of all three profiles were collected in thick polythene bags. The soil samples were air dried under shade. The samples were then gently ground with rolling wooden rod 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 C analysis.

Soil organic carbon was determined by the wet oxidation method of Walkley and Black (1934) as described by Nelson and Sommers (1982). Bulk density was measured by core method as described by Blake and Hartge (1986). The total soil organic carbon (TSOC) stock or storage was calculated using the equations of Batjes (1996), Chen *et al.* (2007), Zhang *et al.* (2013). 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 was calculated using the following equations (Batjes 1996, Chen *et al.* 2007, Zhang *et al.* 2013).

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

where, SOC_i is the SOC content on the ith layer (g/kg);

B_i is the bulk density of the ith layer (g/cc), and D_i is the depth of the ith 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 organic soils and peatlands are seriously lacking (IPCC 2006). The close relationship between C density and bulk density allows for a reasonably accurate estimation of peat C stocks for tropical organic soils.

Eswaran *et al.* (1995) estimated soil organic carbon contents in the soil orders at global level. From the above data sets, Hussain (2002) estimated that the soils of Bangladesh have a total of 2.2 Pg of organic carbon. The Histosols in Bangladesh occupy an area of slightly more than a million ha and it contains 0.25 Pg organic C (Table 3). Possibly, this is the base line data sets of organic carbon mass in the soils of Bangladesh. There is a serious lacking of SOC stock or storage data sets in Bangladesh even for peat soils. This quantity of organic carbon present in the Histosols may be significant as C sink. But at present, these peats are used for agriculture as well as fuel where C is released to the air after the decomposition of peat. In the tropics, most Histosols are still under forest, though most of them are cleared for agriculture and other purposes.

The mean bulk density distribution in the Hakaluki and Rajoir soil (ranges from 0.62-0.63g/cc) is more or less same where as in Harta soil (0.53 g/cc), it is lower than the other two soils (Table 4). Agus *et al.* (2011) noted that the range of peat soil bulk density is generally about 0.02 - 0.30 g/cc depending on the maturity, compaction as well as the ash

contents. They also reported that on average bulk density for Southeast Asia peatlands indicates a broad range and considerable variation depending on its land uses. In Bangladesh, peatlands are mostly used for Boro rice, shrimp and vegetable where there is a little scope of soil carbon sink.

Table 3. 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	14.2	148	19	0.14
Inceptisols	21580	4565	97.5	352	60	1.59
Ultisols	11330	9018	0.89	105	85	0.08
Histosols	**1745**	**286**	**1.2**	**357**	**100**	**0.25**
Alfisols	18283	6411	1.2	127	30	0.03
Misc. land	7644	1358	24.0	18	2	0.05
Total	-	-	147.0	-	-	2.20

*Pg = Petagram = 1×10^{15} (Source: Eswaran *et al.* 1995); Hussain 2002**

Table 4. Bulk density distribution (g/cc) at different soil depths across the peat soils.

Depths (cm)	Harta	Hakaluki	Rajoir
0 - 20	0.88	0.91	0.90
20 - 40	0.65	0.85	0.90
40 - 60	0.60	0.65	0.52
60 - 80	0.28	0.40	0.50
80 - 100	0.28	0.30	0.35
Mean	0.53	0.62	0.63

Soil organic carbon (SOC) distribution in the Harta soils ranges from 10.09 to 21.53 per cent from surface to 100 cm depth and the mean organic carbon is 15.03 per cent (Table 5). Soil organic carbon distribution in the Hakaluki soils ranges from 6.63 to 15.01 per cent from surface to 100 cm depths and the mean organic carbon is 11.18 per cent. Soil organic carbon distribution in the Rajoir soils ranges from 12.10 to 28.20 per cent from surface to 100 depths and the mean organic carbon is 20.66 per cent. So, the soil organic carbon distribution in the peat soils of the study site ranges from 11.18 to 20.66 per cent (Table 5).

Agus *et al.* (2011) reported that peat soils contain 18 - 58% carbon. They also reported that in Southeast Asia, soil organic carbon in peat lands varies in a broad range and

considerable variation depends on their local land uses, land covers and land conditions. In Bangladesh, peatlands are mostly used for agricultural purposes where there is a considerable loss of organic carbon rather than sink. On the other hand, there is no forest cover in the peatlands of Bangladesh as such diversified use of peatland is limited.

Table 5. Soil organic carbon distribution (%) at different soil depths across the peat soils.

Depths (cm)	Harta	Hakaluki	Rajoir
0 - 20	10.09	6.63	12.10
20 - 40	11.24	8.83	12.59
40 - 60	12.21	10.54	24.20
60 - 80	20.12	14.91	26.21
80 - 100	21.53	15.01	28.20
Mean	15.03	11.18	20.66

Soil organic carbon storage in the Harta soils varies from 11.27 to 17.76 kg/m^2 and the total storage is about 14.07 kg/m^2 up to 100 cm depth of the soil (Table 6). Harta soils are mainly dominated by the rice-shrimp integrated cultivation. Soil organic carbon storage in the Hakaluki soils varies from 9.00 to 15.01 kg/m^2 and the total storage is about 12.34 kg/m^2. Hakaluki soils are used for the cultivation of Boro rice and in the dry season these are used for grazing grass land. Soil organic carbon storage in the Rajoir soils varies from 19.75 to 26.21 kg/m^2 and the total storage is about 23.11 kg/m^2. Rajoir soils are used for the cultivation Boro rice and it remains waterlogged almost for the whole year. So, it was found that soil organic carbon storage in the study sites varies from 12.34 to 23.11 kg/m^2 (Table 6). The variation in the soil organic carbon storage possibly due to the land use, inundation level and land cover variations.

Table 6. Soil organic carbon storage (kg/m^2) at different soil depths across the peat soils.

Depths (cm)	Harta	Hakaluki	Rajoir
0 - 20	17.76	12.06	21.78
20 - 40	14.62	15.01	22.66
40 - 60	14.65	13.70	25.17
60 - 80	11.27	11.92	26.21
80 - 100	12.05	9.00	19.75
Mean SOC Kg/ m^2	14.07	12.34	23.11

Soil organic carbon stock across the peat soils of Bangladesh at 100 cm depths was estimated to be about 0.12 Pg (Table 7) which is very low in relation to other tropical

countries. It was reported in 1970s that C stock across the peat soils of Bangladesh was about 0.25 Pg. The increasing demand for land resources has led to a high pressure for the use of peatlands for producing agricultural commodities. Thus, the conversion and draining of peat to create favorable conditions for aerobic crops, changed the role of peat land from C sink to C loss. Long-term drainage and conversion to farmland of peatlands has repeatedly caused major subsidence and carbon loss (Hutchinson 1980). On the other hand, peat fire for fuel purpose by the local stake holders in the dry season becomes more prevalent in some areas of Bangladesh which makes CO_2 emissions. Due to the long-term inundation, peat surface subsides; it loses its functions as the C storage and hydrological condition control which stores water during the rainy season and releases it gradually during the dry season. Thus, subsidence in the dry season is associated with peat compaction, and CO_2 emissions.

Table 7. Carbon stock (Pg) across the peat soils of Bangladesh at 100 cm depths.

Soil series	Areas (ha)	SOC stock (Pg)
Hakaluki	4,953	0.0031
Sarail	595	0.0003
Satgaon	722	0.0004
Rajoir	18,412	0.1202
Satla	48,505	0.0560
Mohanganj	4,930	0.0056
Harta	44,273	0.0315
Juri	2,035	0.0014
Tarala	604	0.0004
Total	1,25,029	0.1202

There are several factors that alter the function of peat land from a sink into a CO_2 source which are most common in Bangladesh.

1. Land clearing that increases the amount of sunlight onto the peat surface so that soil temperature and the activity of decomposing microorganisms increase. Water hyacinth and rice straw increases the availability of fresh organic matter that easily decomposes into CO_2 under aerobic, and CH_4 under anaerobic conditions.

2. Drainage that decreases the peat water table on the site and surrounding areas that are under agricultural crops/covers. Drainage changes the soil conditions from anaerobic to aerobic and increases CO_2 emissions.

3. Collection of peat in the dry season for fuel increases CO_2 emissions owing to burning or oxidation of one or a combination of plant biomass, and peat layers. Fires often occur during land-use change from forest to agriculture or other land uses in the tropical countries. Fires also occur during long drought periods. Under traditional farming practices, burning are done to reduce soil acidity and improving soil fertility. But, on the other hand, this practice increases the contribution of peat to CO_2 emissions.

4. The addition of fertilizers such as nitrogen fertilizers lowers the C/N ratio of soil and encourages the decomposition of organic matter by microorganisms, followed by the release of CO_2. Nitrogen fertilizer also contributes to N_2O emission. Fertilizing with manure or the addition of ameliorants that increase the pH of peat may also accelerate peat decomposition.

These soils can be improved by allowing sediments from the adjoining tidal rivers to settle on the peat basins. This sedimentation process should be continued for several years to develop the land for agricultural purposes. Peatland is an important carbon and water storage and the loss of these functions due to drainage has become a national and global concern. However, the activity of peat fire, loss of water table depth as well as carbon emission is hot issue now-a-days under recent situation of climate change. These strongly suggest research on this aspect. Technical, incentives and regulatory measures must be enhanced to make the best benefits of the use of peatland. Furthermore, exploration of economically competitive crops under un-drained system should also be prioritized.

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