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SOIL ORGANIC CARBON STOCKS IN THE BLUE CARBON HABITATS OF BANGLADESH

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Key words: Soil organic carbon stocks, Blue carbon habitats

Abstract

A study was conducted in the coastal blue carbon habitats of Bangladesh regarding soil organic carbon (SOC) stocks. Fifty soil samples covering 10 soil profiles at five different depths level up to 1 m was considered to complete the above research. In the salt marsh sites, SOC ranged from 13.1 to 45.7 g/kg with a mean value of 27.5 g/kg. In the mangrove sites, SOC varied from 14.1 to 46.3 g/kg with a mean value 26.4 g/kg. In Mangrove ecosystem soils, clay contents showed a very strong positive correlation with SOC ($r = 0.901$ and $p < 0.01$) whereas silt showed a significant positive correlation with the SOC ($r = 0.691$ and $p< 0.05$) in the salt marsh sites. As the mangrove ecosystem holds more clay than the salt marsh ecosystem so it may be said that mangrove soils are more potential for carbon storage than salt marsh soils. The study revealed that both of these ecosystems hold more carbon than the threshold level (20.0 g/kg). It is suggested to protect and regenerate the blue carbon habitats in the coastal ecosystem considering the present findings to tackle climate change and other sudden disasters.

Introduction

The coastal region of Bangladesh covers 710 kilometer coastline covering three distinct geographical parts: western, central and eastern. This lies between 21°30' to 22°30' north latitudes and 88°01' to 92°00' east longitudes. It comprises the most active portion of Ganges-Brahmaputra-Meghna River system in Bangladesh. It is reported that about 2.4 billion tons/year sediments flows in the Bay of Bengal through the major River channels[(1)]. As a result, erosion and accretion games are more common phenomenon in the coastal regions and coast line movement towards the Bay of Bengal[(2,3)]. The impact of climate change aggravates the situation of sediment transportation and deposition in a serious turn. To mitigate climate change and enhance blue economy, soil carbon sequestration strategies are getting priority in developing and formulating delta plan 2100. Knowledge of soil organic carbon (SOC) dynamics in deeper soil profiles is essential to understand the SOC sequestration rate[(4)].

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It is apprehended that, coastal habitats are degrading globally, raising fears that blue carbon habitats could largely disappear by the end of this century[5] unless significant protection and restoration efforts are enacted[6]. It is evident that coastal vegetation sequesters carbon far more effectively and permanently than the terrestrial ecosystem which is often referred to as 'blue carbon'[7]. There is a very few study on the SOC stocks and sequestration in the blue carbon habitats of Bangladesh. Bangladesh is facing a new challenge in the context of climate change, food security issues and identification of blue economies etc. To meet these challenges, it is very much vital to estimate SOC stocks and their sequestration potentials in the blue carbon habitats of coastal ecosystem of Bangladesh.

Materials and Methods

Total 50 soil samples from 10 soil profiles at five different soil depths (0-20, 20-40, 40-60, 60-80 and 80-100 cm respectively) up to 1m were collected covering the mangrove and salt marsh coastal eco-zones of Bangladesh (Fig. 1). The salt marsh sites were Char Kukri Mukri Island, Reju Khal estuary of Ramu Upazila, Bakkhali estuary of Cox's Bazar district, and Rangi Khali Khal of Teknaf Upazila. On the other hand, the mangrove sites were Munshiganj area of Shymnagar Upazila, Magurkhali area of Dumuria Upazila, Char Kukri Mukri Island, Reju Khal estuary of Ramu Upazila, and Boroitoli area of Teknaf Upazila. During soil sampling, soil bulk density for the individual depths were measured which were used in the estimation of SOC stocks. The collected soil samples were processed and preserved in plastic bottles for subsequent laboratory analysis. Particle size distribution was determined by hydrometer method after pre-treatments[8]. SOC was determined by the wet oxidation method[9]. Bulk density was measured by core method[10]. The total SOC stock or storage was calculated using the equations[11,12]. It may be noted that the bulk density and SOC contents are the two prerequisites for estimating SOC stock or storage. Thus, the soil organic carbon storage was calculated using the following equations:

$$\text{Soil Organic Carbon (TSOC)} = SOC_i \times B_i \times D_i$$

Where, SOCi is the SOC 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).

It may be noted that the area of the mangrove and salt marsh eco-zones were delineated using the International Union for the Conservation of Nature (IUCN) resources map and the respective shape files were extracted and digitized in Google Earth Pro. The shape files were then geo-referenced, projected and subsequently, the areas were calculated using the respective polygon attribute tables (PAT) in ARC/GIS 10.3.

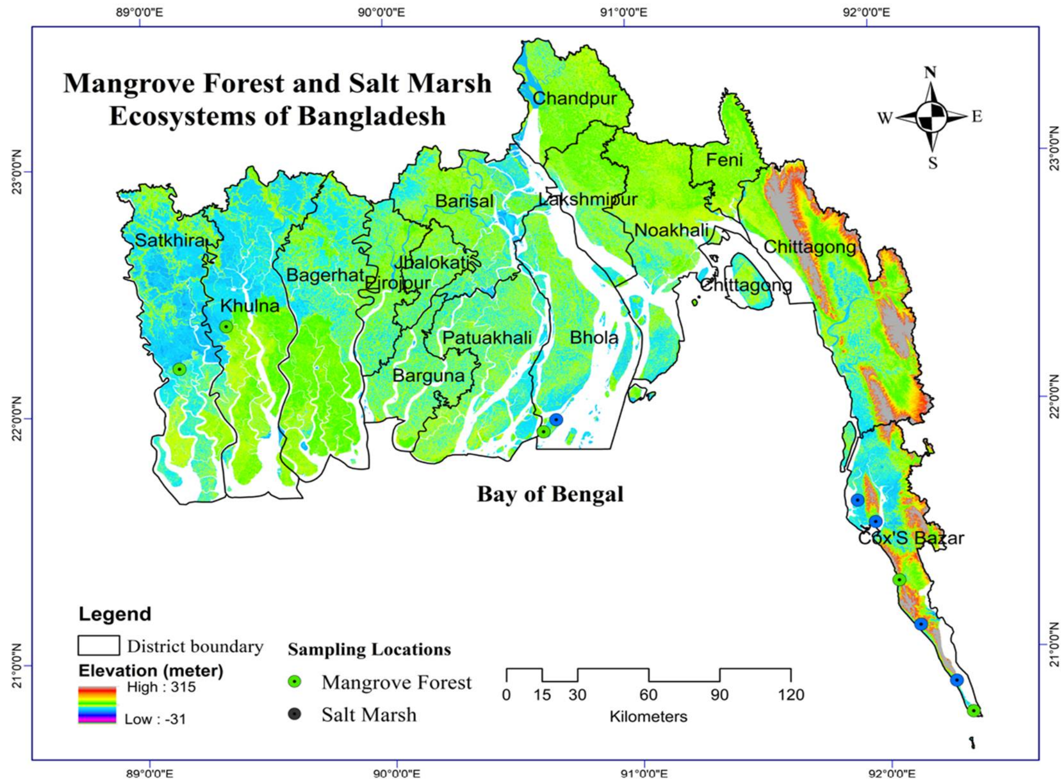


Fig 1. Sampling locations of the mangrove forest and salt marsh habitats of Bangladesh coast

Results and Discussion

In the salt marsh sites, SOC ranged from 13.1 to 45.7 g/kg with a mean value of 27.5 g/kg (Table 1). SOC storage in the same habitats varied from 19.01 to 61.53 kg/m^2 with a mean value of 41.53 kg/ m^2 at 100 cm depths (Table 1). Distribution pattern of SOC in the salt marsh sites have been given in figures 2-6. The highest level of SOC was found in Rangi Khali Khal of Teknaf, Cox's Bazar salt marsh site (Fig. 6) and the lowest level was recorded in Reju Khal, Ramu, Cox's Bazar site (Fig. 3). The reason behind the fact that Rangi Khali Khal of Teknaf site belongs between the border line of Myanmar and Bangladesh –The Naf Estuary where the River Naf flows downward in the Bay of Bengal with high sediments. It may be mentioned that SOC contents in the salt marsh sites varied widely and may be due to the greater capacity for carbon storage. It is reported(13) that blue carbon sequestration takes place in seafloor sediments by burial phenomenon in saltmarsh ecosystem.

In the mangrove sites, SOC varied from 14.1 to 46.3 g/kg with a mean value 26.4 percent (Table 2). SOC storage ranged from 18.85 to 46.76 kg/m^2 with a mean value of 31.64 kg/ m^2 at 100 cm depths in the same habitats (Table 2). Distribution pattern of SOC in the mangrove sites have been given in figures 7-11. The highest level of SOC was found in Munshiganj, Shyamnagar, Satkhira mangrove site (Fig. 8) where the lowest level was recorded in Char Kukri Mukri, Bhola mangrove site (Fig. 9). The reason behind the fact may be due to the maturity and biomass production in the forest habitats of the Satkhira mangrove site is higher than the other sites. It is also found that the mean SOC storage in the mangrove forest ecosystem at 100 cm depths was recorded 31.64 kg/m^2 (Table 2).

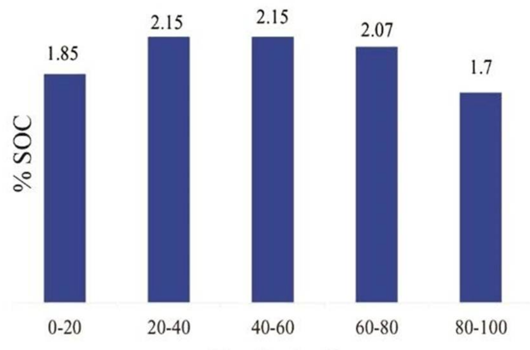
Table 1. SOC storage (kg/m^2) in the salt marsh sites at 100 cm depths in the coastal areas of Bangladesh

Salt Marsh Sites	Geo-Coordinates & Elevation (m)	SOC (g/kg)	Areas (ha)	SOC storage (kg/ m^2)
Char Kukri Mukri, Bhola	21° 55' 51.5'' N; 90° 40' 062'' E E= -1m	19.8	272	30.77
Reju Khal, Cox's Bazar	21° 17' 52.2'' N; 92° 03' 16.1'' E E= -2m	13.1	239`	19.01
Bakkhali Estuary -1	21° 28' 16.68'' N; 91° 58' 21 88''E E= 2 m	27.2	106	42.92
Bakkhali Estuary -2	21° 28' 54.01'' N; 91° 58' 44.59'' E E= 5 m	31.9	108	50.70
Rangi Khali Khal, Teknaf, Cox's Bazar	21° 00' 11.6'' N; 92° 15' 48.6'' E E= 8 m	45.7	281	61.53
Mean SOC	-	27.5 g/kg	1006	41.53

Table 2. SOC storage (kg/m^2) in the mangrove sites at 100 cm depths in coastal areas of Bangladesh.

Mangrove Sites	Geo-Coordinates & Elevation (m)	SOC (g/kg)	Areas (ha)	SOC storage (kg/ m^2)
Magurkhali, Dumuria, Satkhira	22° 41' 69.8'' N; 89° 21' 59.4'' E E= 5 m	18.4	19	24.46
Munshiganj, Shyamnagar, Satkhira	22° 15' 85.8'' N; 89° 11' 69.4'' E E= 7 m	46.3	8,000	38.76
Char Kukri Mukri, Bhola	21° 55' 67.6'' N; 90° 39' 54.3'' E E= 8m	14.1	2763	18.85
Reju Khal, Cox's Bazar	21° 17' 62.4'' N; 92° 03' 17.2'' E E= -2m	20.0	376	29.41
Boroitoli, Teknaf, Cox's Bazar	20° 53' 29.3'' N; 92° 17' 44.7'' E E= 9m	33.6	535	46.76
Mean SOC	-	26.4 g/kg	11,693	31.64

Carbon sequestration potentials: In the carbon sequestration processes, the blue carbon habitats (e.g. mangroves, salt marshes and sea grasses, and coral reefs) uptakes more CO_2 from the atmosphere (Fig. 12) due to the C burial in soils and sediments with high turnover rate as the process is governed by the tidal sedimentation and deposition of finer particles[14]. The authors also noticed that the finer textured soil particles accumulate more organic C as the processes enhanced due to humification, aggregate occlusion of C, metal chelation and mineral attachment of C etc.



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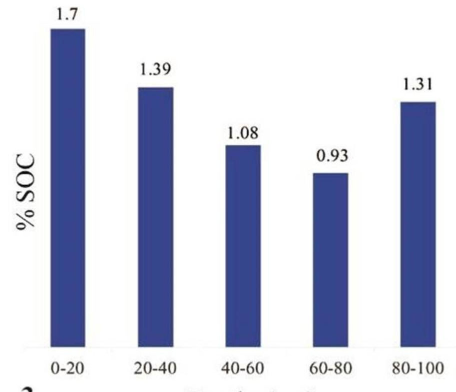

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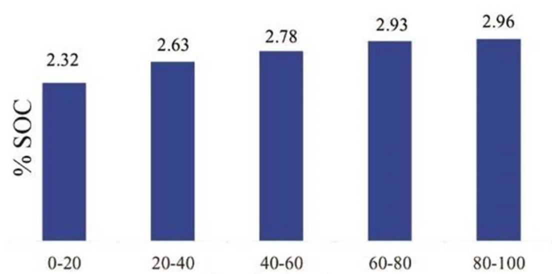

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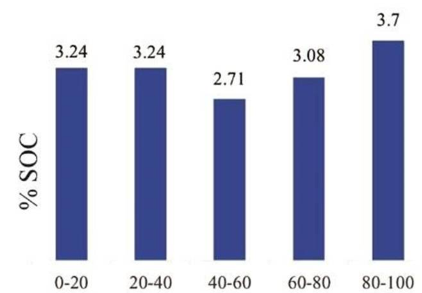

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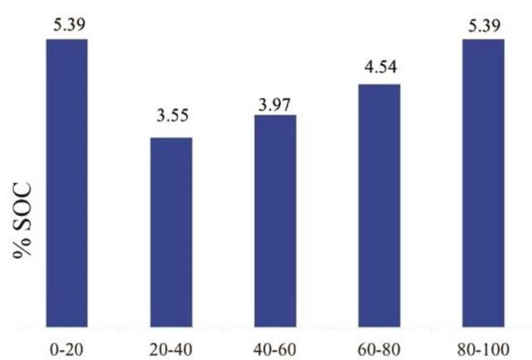

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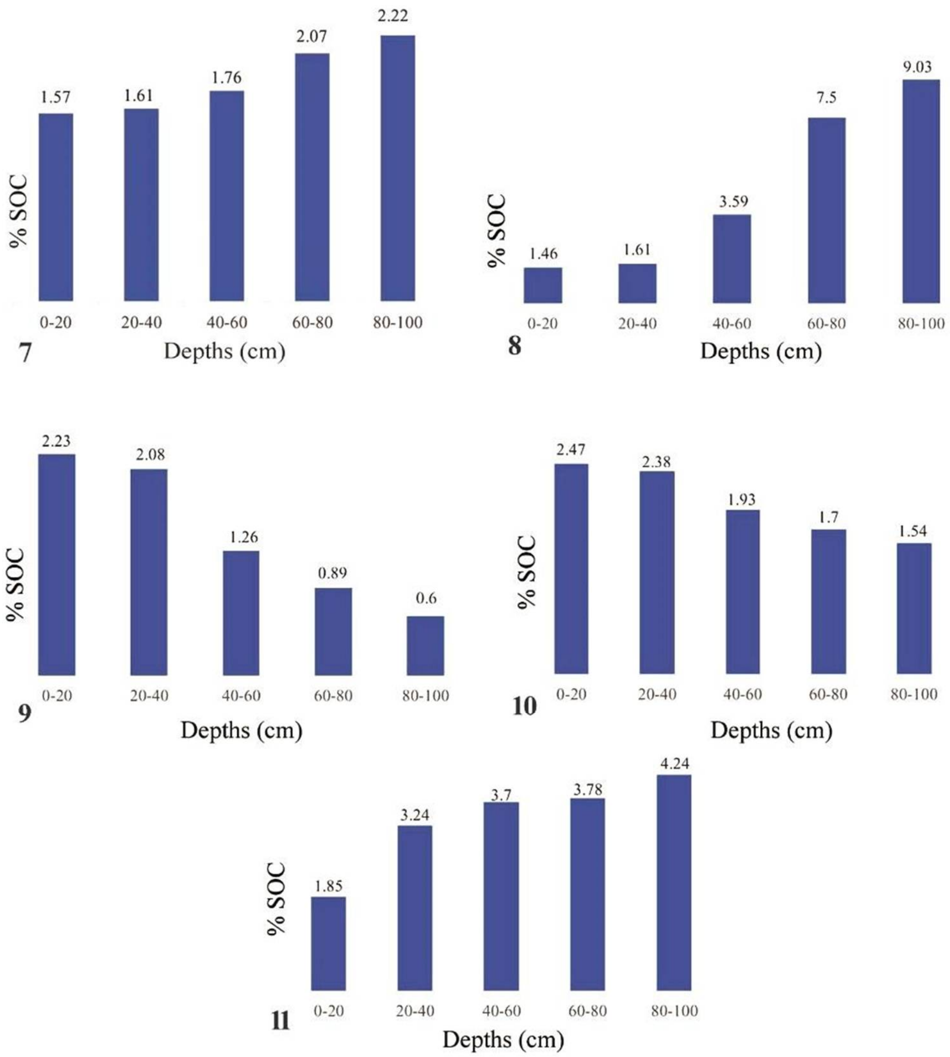
Figs 2-6. Distribution of SOC in different salt marsh ecosystem under blue carbon habitats at 100 cm depths: 2. Char Kukri Mukri of Bhola, 3. Reju Khal area of Ramu Upazila, 4. Bakkhali site 1 of Cox's Bazar, 5. Bakkhali site 2 of Cox's Bazar, 6. Rangi Khali Khal of Teknaf Upazila.



Figs 7-11. Distribution of SOC in different mangrove ecosystem under blue carbon habitats at 100 cm depths: 7. Munshiganj site of Shymnagar Upazila, 8. Magurkhalu site of Dumuria Upazila, 9. Char Kukri Mukri of Bhola, 10. Reju Khal of Ramu Upazila, 11. Boroitali area of Teknaf upazila.

The clay content in the mangrove forest soils ranged from 58 to 71 percent and the mean value was 64.5 percent. In mangrove ecosystem soils, clay percent showed a strong positive correlation with the carbon contents ($r = 0.901$ and $p < 0.01$). The clay content in the saltmarsh soils ranges from 28 to 43.5 percent and the mean value was 35.75 percent. The silt content in the saltmarsh ecosystem varied from 39.5 to 57.5 percent and the mean value was 48.5. Clay percent showed a negative correlation with the carbon contents ($r = -0.227$ and $p > 0.01$) in the salt marsh soils, but silt percent had a significant positive correlation with the carbon contents ($r = 0.691$ and $p < 0.05$). In this aspects, Arrouays *et* *al*[15] reported that there is a strong correlation of SOC stocks with clay contents. It is reported that dominance of finer particles with large surface area is one of the main reasons of high storing capacity of estuarine sediments[16]. As the mangrove ecosystem holds more clay than the salt marsh ecosystem so it may be said that mangrove soils are more potential for carbon reserve than salt marsh ecosystem.

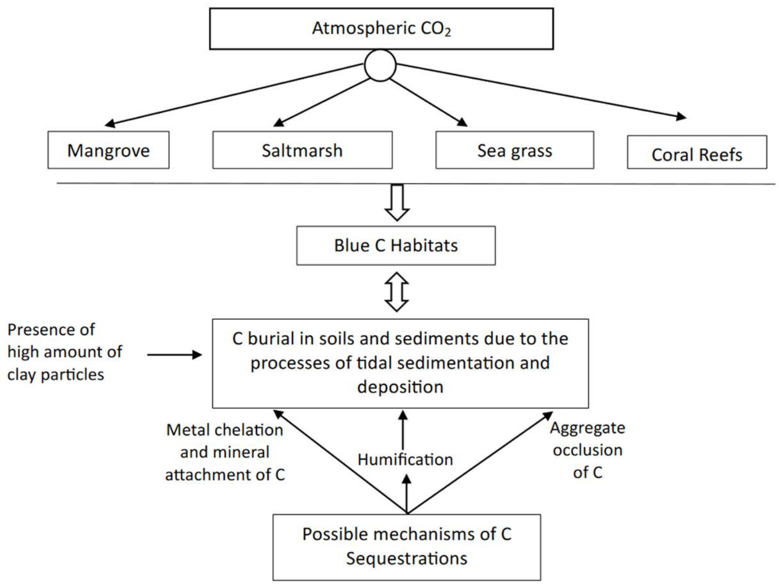


Fig. 12. Possible C sequestration mechanisms in the soils of coastal blue carbon habitats (Adopted)[14]

Miller *et al*[17] reported that saltmarsh ecosystem stores much carbon due to mainly the result of rapid accumulation of organic carbon rich sediments. They also reported that C accumulation rates are highest at young and expanding salt marsh edges. In the present study, we have noticed similar conditions where SOC contents were found higher in Rangi Khali Khal of Naf River estuaries. It was also noted[18] that in salt marsh habitats, the rapid vertical accretion of sediments is driven by eco-geomorphic feedbacks and thus maintains surface elevation in the tidal border by stimulating sediment accumulation at rates equivalent to relative sea-level rise. The mechanism of C stock and sequestration was explained by many authors in tidal marsh soils where saline seawater with high concentration of sulphate salts results predominance of sulphate reducing bacteria[19].These bacteria restrict soil C mineralization and suppress methane production[20]. Thus, the combination of high biomass input and slow turnover of C impacts on C stocks in tidal salt marsh soils[21]. Benner *et al*[22] reported that salt marsh soils are rich in organic carbon derived from dead plant material, and thus contain more carbon than tidal flat soils and getting accumulated in the deeper soil horizons. It was also reported that mangrove ecosystems store and sequester significant quantities of carbon[23]. The global mean SOC concentration of mangroves is 22 g C kg^{-1} [24] where it is higher value of C (26.4 to 27.5 g/kg) in the study sites than the stated value. Weiss *et al* [25] reported that SOC stocks in mangrove ecosystem vary from 27.1 to 57.2 kg C m^2 which is consistent with the present study. It is evident that SOC threshold for sustaining soil quality is widely suggested to be about 20 g/kg[26], below which deterioration in soil quality occurs. It is found that both mangrove and salt marsh habitats sequester more carbon beyond the threshold level. The mangrove habitats are interlinked with salt marshes and acts as a global potential for C sink due to their very high biomass productivity and continual deposition of C in soils and sediments[27].

Coastal mangrove and salt marsh ecosystem is the two major carbon hubs of terrestrial ecosystems where they contain more carbon than the threshold level. It is suggested to protect and regenerate the blue carbon habitats in the coastal ecosystem. Therefore, it is vital to formulate a policy of zoning mangrove and salt marsh ecosystem and to conserve wetland bio-resources and their carbon storage emphasizing climate smart eco-zones.

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