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Estimation of soil organic carbon storage in different depths of the Kaptai national park, Bangladesh

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Abstract:
Soil is the important and the largest carbon pools in the terrestrial forest ecosystems. Soil is a major source of organic carbon in a forest. Soil contains 4-5 times more organic carbon than all living things three to fourfold greater than plantation. The present study was conducted to estimate the soil organic carbon in the Kaptai National Park, Kaptai, Rangamati Hill Tracts district, Bangladesh. A systematic method was used to identify each sampling point through the Global Positioning System. The study was explored soil pH, soil organic carbon, bulk density and soil organic matter. Soil samples were collected from 0-15, 15-30, 30-45, 45-60, 60-75 and 75-90 cm depth for the estimation of the above parameters. Soil organic carbon (SOC) was determined by Walkley-Black method. Bulk density was calculated the ratio between the dry (105^0C) weights of the core sample divided by the volume of the sample. SOC distribution was influenced by land use, soil type, elevation, and the bottom flatness. The highest average SOC content of 31.08 Mg C ha^{-1} was reported for 0-15 cm depth soil, whereas there was on average 4.87 Mg C ha^{-1} at 75-90 cm depth soil. SOC and bulk densities were decreased with the increase of soil depth. In total the soil stored 75.58 Mg C ha^{-1}. The findings of the study can be directed to researchers and administrators to analyze for global carbon which can be helpful to improve the forest resources and environmental sectors like Bangladesh and other tropical countries with similar conditions.

Keywords: *GPS, bulk density, depth, oxidation method, organic matter, organic carbon,*

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I. Introduction

Soil organic carbon (SOC) is strongly influenced by climate conditions and SOC stocks are determined by the balance between the total amount of carbon released to the atmosphere in the form of CO_2 and the total amount withdrawn from the atmosphere (Janssens *et al.*, 2005).The carbon pools in forest depend on soil characteristics, climate and anthropogenic activities. The ability of soil to stabilize soil organic matter (SOM) and the relationship between soils structures are key elements in soil carbon dynamics (Six *et al.*, 2002). Physical properties as in silt and clay content or the micro aggregation of soil are considered to protect organic matter from decomposing organisms (Kaiser and Guggenberger, 2003). Soil organic carbon (SOC) is an ideal and primary indicator of sustainable land management (Doran, 2002; Karlen *et al*., 1997). Carbon dioxide (CO_2) is assimilated by plants through photosynthesis process and store carbon in biomass and soil (Trexler and Haugen, 1994; Brown *et al.*, 1996; Watson *et al*., 2000). All kinds of growth and distribution of vegetation depend on soil physical and chemical properties (Cao *et al.*, 2007). The distribution of SOC Changes across the landscape and it also varies by depth. In most soils, SOC is higher in the surface layers and it decreases with the increase of depth gradually. Soil organic carbon depends on bulk density and organic matter. SOC storage in the tropical forests is an important response option for global warming in the tropical developing countries such as Bangladesh (Moura-Costa, 1996; Myers, 1996). Carbon stored in soils is the largest carbon pool in most terrestrial ecosystems holding approximately 1500pg carbon in the top one meter (Batjes, 1996), roughly twice the amount of carbon in the atmosphere and three times the amount in vegetation (Lal, 2004). Keeping this point in mind, the present work was conducted to estimate the soil organic carbon in the Kaptai National Park. Such studies have not yet been found in the southeastern part of Bangladesh due to the absence of research. For this reason, the main aim of the research was find out the SOC storage of this Park. There is no comprehensive base line information about the soil characteristics of this Park. Considering the fact an attempt has been taken to estimate the soil organic carbon of the Kaptai National Park. The study was based on field-data collection through physical measurement, field observation and laboratory chemical analysis. This research will help to investigate the general status of the SOC storage in the tropical forest, based on the soil organic carbon storage with special attention to the Kaptai National Park.

II. Materials and Methods

Study area

The present study was carried out in the south-eastern part of Bangladesh, the Chittagong Hill Tracts (CHT), which lies at 21°25'N to 23°45' N latitude and 91°54' E to 92°50' E longitude. The CHT borders Myanmar on the southeast, the Indian state of Tripura on the north, Mizoram on the east and Chittagong district of Bangladesh on the west. The study area, however, lies between $22^{0}27'$ and $22^{0}32'$N latitudes and from $92\,^{0}30'$ to $92\,^{0}16'$ E longitudes (Figure 1). The mean annual rainfall ranges from 1725 to 2513 mm, and about 90% rainfall occurs during May to September. The maximum humidity is 84% in June and, the minimum humidity is 76% in January. The mean annual humidity is around 82% (Meteorological Station, Kaptai Power Development board Records of 2016). The maximum, minimum and mean temperatures are 25.3^{0}C, 14.7^{0}C and 24.1^{0}C respectively (Rangamati Weather Station Records of 2016). About 90% land of the area is hilly, settlers occupy 4%, and 6% land is arable. Most hills in CHTs are of Tertiary age and contain hills of varying elevations including high hill ranges (350m->1000 m above mean sea level). The hills comprise the higher parts of major anticline and frequently possess steep slopes (>40% to over 100%). In the hills, rocks are mainly shale, siltstone, sandstone and some conglomerate, and considerably folded, faulted and uplifted; the anticlines form the hills and the synclines form the valleys (NRCS-USDA 1999). The soils are mainly yellowish brown to reddish brown sandy loams to clay loams, locally sand and clay depending on parent materials which grade into broken shales or sandstones as well as mottled sand at variable depths. The soils are very strongly acidic. These 'Brown Hill Soils' (Hussain 1992) are broadly classified as dystric cambisols according to the FAO-UNESCO system and World Reference Base for Soil Resources (FAO 2006). These soils fall mainly in the orders of Alfisols, Entisols, Inceptisols, and Ultisols of Soil Taxonomy (NRCS-USDA 1999).

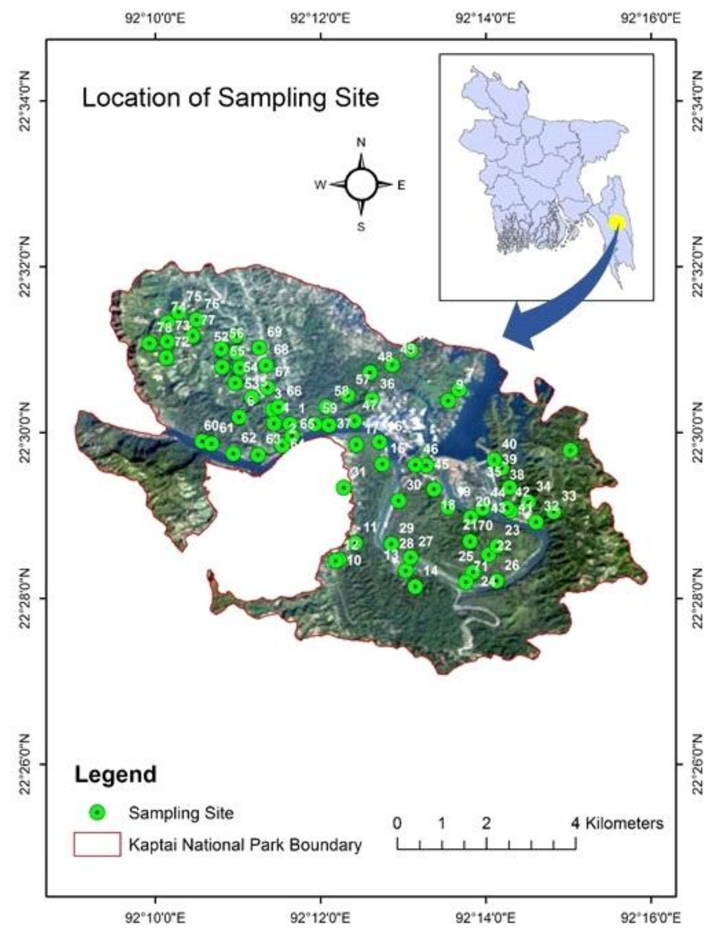

Figure 1: Map showing the location of the study area in Kaptai National Park, Bangladesh.

Sampling procedure

The study was based on field-data collection through physical measurement, field observation and laboratory analysis. The field study was conducted between December -2014 and November- 2016. Soil samples were collected from the field and chemical analyzed in the laboratory. The geo-position of the study area was determined by using Global Positioning System (GPS). Distant of each track was 500 meter from another track and it was marked (Figure 2).

Collection of soil samples

A total of 77 tracks and 308 plots were selected and track size was 100 x 20m. Each track contains four plots. To estimate soil carbon in the selected geo-position, 4 plots were selected in a track and soil samples were collected from each plot the following four depths, i.e., 0-15, 15-30, 30-45, 45-60, 60-75 and 75-90 cm . The size of the sample plots were 1meter (m) x 1meter (m). Each sample was a composite of three subs - samples. Core samples were also collected from each depth. A total of 308 x 4 soil samples were collected. Soil samples were collected using by soil auger. Each of the samples were kept separately on a brown paper and mixed thoroughly. Then about 1 kg of soil was collected from each paper to give a representative sample which placed in sealed polythene bags and leveled including collection of date, location and code number. The samples were carefully taken to the laboratory for chemical analysis through the Walkley-Black oxidation method.

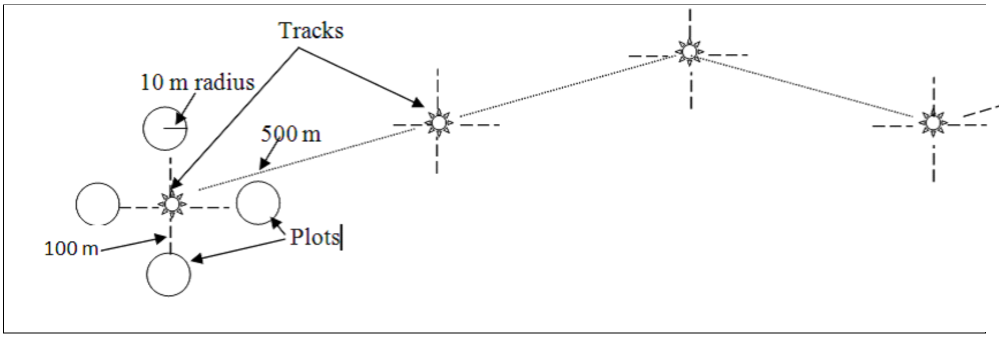

Figure 2. Schematic representation of the arrangement of sampling plots.

Preparation of soil samples

The soil sample was placed in a thin layer on a clean piece of paper on a shelf in the room and left until it is air dry. Visible roots and plant fragments were removed from the soil sample and discarded. For the preparation of the soil sample, soil was passed through the grinder and subsequently, a 2 mm stainless steel sieve. Then the soil samples were kept in a clean polythene bag for chemical analysis.

Estimation of organic stock in soil

Soil organic carbon was determined by Walkley and Black's (1934) wet oxidation method. Collected soil samples were dried in the air, and then all clods, stones, or other undesirable materials were separated. Then soil samples were dried in an oven at 105^0C for 72 hours. Dried soils were ground and then exactly 2 g soil sample was taken in a 500 ml conical flask. Exactly 10 ml 1N $K_2Cr_2O_7$ solution was added to it and shaken well. Then 10 ml conc. H_2SO_4 was added to it. The contents were thoroughly shaken occasionally for half an hour. After cooling, 150 ml distilled water, 5 ml conc. H_3PO_4 and about 0.5 g NaF were added. Diphenylamine indicator was added drop wise until the color became deep violet. This was then titrated against 1Nferrous sulfate solution until the color turned to bottle green at the end point.

Calculation

% Organic carbon in soil= (B-T) × f ×0.003 ×1.3 × 100/W

Where,

B = Blank titration reading

T = Soil titration reading

f = normality factor of ferrous sulfate solution, and

W = weight of soil.

% Organic matter in soil= % of organic carbon × 1.72 (Van Bemmelen factor; assuming that organic matter of average soil contains 58% of organic matter)

Organic carbon, kg ha^{-1} = $\frac{\%\ Organic\ carbon}{100} \times \frac{A \times d \times D_b}{1000}$

Where,

A = Area of 1 ha soil = 10,000 cm x 10,000 cm,

d = Depth of soil, cm

D_b = Bulk density of soil, g cm^{-3}

Determination of bulk density

The bulk density of the soil was determined by the core method. Standard alluminium cores of known weight were pushed into the soil under pressure and a definite volume of soil was collected. The core with the soil was weighed before and after drying in an oven at 105^{0}C for 48 hours. The weight of the soil was divided by its volume to get the bulk density.

Calculations

Soil volume = Core volume

Core volume (cm^3) = 3.14 × r^2 × h

Where, r is the radius of the core (cm) and h is the height of the core.

So, bulk density (g cm^{-3}) =$\frac{W}{V}$,

Where W = weight of dry soil, and

V = Volume of soil

Statistical analysis

Statistical analysis was carried out using SPSS program version 23.00. To show the differences in soil properties among the different layers in the soil depths. One way analysis of variance (ANOVA) was carried out.

III. Results and Discussion

Soil organic carbon (SOC) is a very important component of forest soils and ecosystems. Soil organic carbon percentage is the essential elements for the estimation of the total soil organic carbon. The percentage of SOC in different depths of soils of forest under the present study varied from 0.34 to 1.52%. 0.30 to 1.43%, 0.11 to 1.33%, 0 to1.21%, 0 to 0.68%, and 0 to 0.42% in 0-15 cm, 15-30 cm, 30-45 cm,45-60 cm, 60-75 cm and 75-90 cm depths respectively. In almost all the tracks, soil organic carbon gradually decreased with increasing depth. The principal sources of soil organic carbon are the aboveground and belowground parts of vegetation and litter. According to Osman (2013), plants litters including dead leaves, stems, barks, flowers, fruits and logs are the major sources of forest soil organic carbon. Pradhan *et al* (2012) reported percentages of organic carbon and their distribution with depth of soil in different forest types of Nepal. There were higher organic carbon content always at the upper level of the soil. Their result showed that, *Shorea robust* forest, Pine-Shorea forest, *Schima-catanopsis* forest and degraded forest contained 0.94%, 00.76%, 2.33% and 0.58% organic carbon at the 0-20 cm depth soil respectively. While the corresponding values in the 80-100 cm depth were 0.26%, 0.11%, 0.21% and 0.16%. Yan et al. (2016) observed that the average SOC content in some forest soils of China was 1.755 which leads to an average SOC density of 124 Mg C ha^{-1} . The average forest SOC density in northeastern, middle-eastern and south-eastern China was 135, 99.50 and 133 Mg C ha^{-1}.Bulk density is the weight of dry soil per unit of its volume and it is expressed in g cm^{-3}. Bulk density is the most important indicator of soil porosity and soil compaction. Bulk density is determined for the estimation of soil organic carbon stocks. The bulk density of the present study ranged from 1.31 to 1.58 g cm^{-3}. Generally the bulk density increased with increasing depth of soil. In the present study bulk density was the highest in 75-90 cm depth and the lowest in 0-15 cm depth of soil (figure 3). It is indicated that soil porosity was higher in the surface soil due to higher biotic activity.

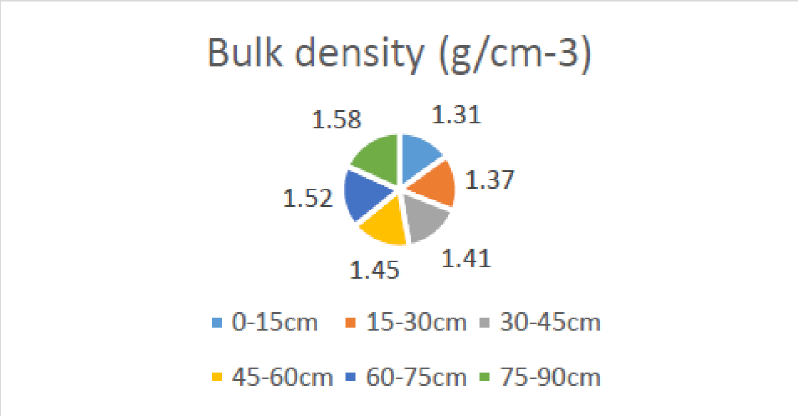

Figure 3. Bulk density variation in different depths of the soils.

The total soil carbon stock (sum of 0 to 90cm depths) varied from 11.9 to 120.62 Mg C ha^{-1} with an average soil organic carbon stock of 75.58 Mg C ha^{-1} (table 1). Miah *et al.* (2009) conducted a study in forest plantation on Chittagong University campus and observed an average soil carbon in soil of 53.96 Mg C ha^{-1}. Ullah and Al-Amin (2012) reported that carbon stock at 1 miter soil depth in Tankawati natural hill forest of Bangladesh was 168.15 Mg C ha^{-1}. In this case, our result showed that lower values than their values. The higher anthropogenic disturbances were observed in the present study area. The national average soil carbon stock in India was 182.94 Mg C ha^{-1} (Jha *et al.*, 2001). Soil organic carbon (SOC) stored in forest soils comprises about 73% of global soil carbon storage (Sedjo, 1993). Stendahl *et al.* (2010) reported that the national mean soil organic carbon stock was 92.00 Mg C ha^{-1} in spruce dominated stands and 57.00 Mg C ha^{-1} in dominated stands of Sweden. The total amount of soil organic carbon depended on species diversities and land management systems. The magnitude of soil carbon depletion in increased by soil degradation especially due to erosion. Land use and soil management practices can significantly influence soil organic carbon dynamics and carbon flux from the soil (Tian et al., 2003).

Table 1. Soil organic carbon storage at different depths in the study area.

Percentage of organic carbon (% OC)				Carbon stocks in soil (Mg C ha^{-1})		
Depths(cm)	Max.	Min.	Mean	Max.	Min.	Mean
0-15	1.52	0.35	0.97	31.07	6.48	20.50
15-30	1.33	0.27	0.85	28.50	2.63	17.70
30-45	1.33	0.11	0.66	26.50	2.08	13.80
45-60	0.80	0.10	0.50	18.68	2.38	10.79
60-75	0.55	0.08	0.36	16.01	1.97	8.08
75-90	0.42	0.06	0.21	9.90	1.76	4.87
0-90	1.52	0.06	0.57	113.34	14.56	75.58

Reforestation adds organic carbon to the soil, which usually increases with the increase of the plantation (Brady, 1996). Clearing of native vegetation for agricultural production often leads to reduce in soil organic carbon (Davidson & Ackerman, 1993). The chief source of organic carbon in forest's soil is derived from the fallen litter which is largely found on the surface area of the soil. The distribution of soil carbon storage was also varied among the forest species (Osman *et al.*, 2001). They concluded that soil organic carbon increases with the age of the plantation until canopy closure, but is dependent on the ability of the species to produce litter. In the study, it is clearly found that some forest species have a great role in the decomposition of litter which is enriched the carbon storage in the soil. The decomposition and release of carbon through litter fall and its decomposition was the highest in legume species, i.e. *Xylia xylocarpa A. auriculiformis*, *Albizia procera* and *A.lebbeck* (Singh *et al*., 2004 a). Teak *(Tectona grandis* -non legume) contributes poor carbon storage in the soil due to its deposition of less organic carbon (Singh *et al.,* 2004 b). The highest average soil carbon content was found in the forested lands while the lowest was found in the denuded area of the Kaptai national park.

Variation of soil carbon stocks with elevation.

The study locations were covered with hills and various types of evergreen and deciduous forest tree species. The highest elevation was 95 meter and the lowest elevation was only 5 meter. The amounts of soil organic carbon, however, should depend on many factors such as longitude, latitude, slope and elevation along with others. Elevation was the most important factor for the estimation of the soil organic carbon in the above parameters. The total soil organic carbon was found out on the basis of the elevation and variation was also found in the present study. The total study area was divided into three classes on the basis of the elevation. Data of soil carbon stock in the present study showed considerable variation with elevation of the forest lands. The maximum soil carbon was 78.26 t ha^{-1} in 00-35 m elevation class and the minimum was 71.80 t ha^{-1} in 65-95 m elevation class (Figure 4). The result of the study expressed that, the lowest elevation (00-35m) contained the highest amount of carbon and the following trends were found such as 00-35m>65-95m>35-65m.

A study was conducted in the Garhwal Himalayas (Mehraj *et al*., 2009) and the findings of their results were 185t Cha-1 in the 1600 1800m, 180.80 in the 1800-2000m and 160.80 t C ha-1 in the 2000-2200m altitude of the *Quercus leucotrichophora* forest. They also reported that, 141.60 t C ha-1 in the 600 -800 m, 126.40 t C ha-1 in the 800-1000m and 124.80 t C ha-1 in the 1000-1200m altitude of the *Pinus roxburghii* forest. Their results were gradually decreased with the increasing of altitude in the both forest areas and a negative relationship was found. The ethnic communities were chosen to build their houses in the middle part of the hills (35-65m elevation) and changed the forests lands to crops lands in the present study area. It is concluded that, the anthropogenic disturbances and land management are the most important parameter for the increasing of soil organic carbon.

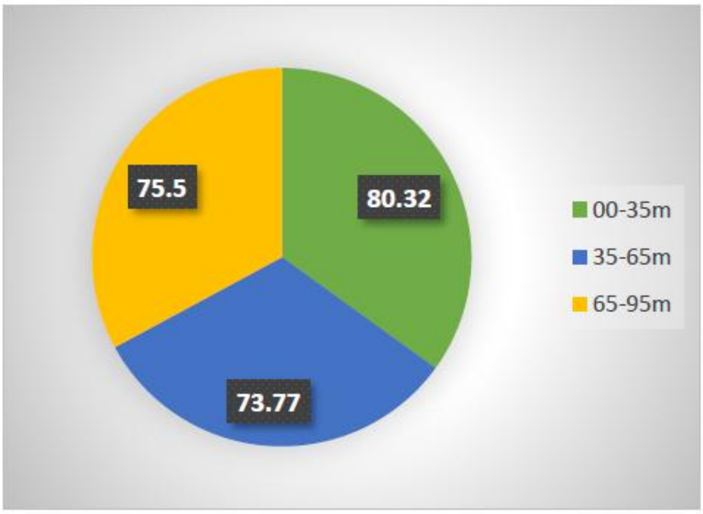

Figure 4: Average soil carbon stocks in different elevation classes.

Du *et al.* (2011) stated that on northern slope, soil organic carbon content increased with increasing altitude, and had significant negative correlations with soil bulk density and pH value. On southern slope, soil organic carbon content had no obvious variation pattern along the altitudinal gradient and had less correlation with soil bulk density and pH value, but soil organic carbon density decreased with increasing soil depth.

Table 2. ANOVA for soil carbon stocks among tracts.

Sources of variation	Degree of freedom	Sum of square	Mean sum of square	F-value	P
Treatment	76	5963.89	78.47	9.74	<0.01
Error	385	16496.85			
Total	461	22460.74			

One –way ANOVA showed that soil organic carbon contents were significantly depended on the different Tracts (table 2).

IV. Conclusion:

The Kaptai National park is the most important in Bangladesh. This park is situated at the foot of the hill and some parts of the park is covered with the Kaptai Lake, which is the most special criteria than other parks in Bangladesh. Hence, the authors of the present study have attempted to find out the soil organic carbon storage in the Kaptai National Park. This is the initial attempt of this kind of research works in the Kaptai National Park. The main focus of this study was to estimate the soil organic carbon in the Kaptai National Park. The study concludes that, the amount of soil organic carbon is gradually decreased on the basis of the depths. The highest amount of soil organic was found in forested land and the lowest amount of soil organic carbon was found in the denuded land. The present study is also revealed that, the amount of soil organic carbon was varied in the position of the slope. The findings of the study would be of importance for the estimation of the soil organic carbon in the whole of the world.

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