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SHORT COMMUNICATION

SOIL ORGANIC CARBON ESTIMATION THROUGH PARTICIPATORY APPROACH IN A SELECTIVE VILLAGE COMMON FORESTS IN CHITTAGONG HILL TRACTS

Climate change is a burning issue because of the increasing concentration of CO_2 in the atmosphere imposing global warming and, consequently, global climate change. Excessive use of fossil fuel and deforestation is contributing to global warming at an alarming rate. The Reducing Emissions from Deforestation and forest Degradation and supporting the role of conservation, sustainable management of forests and enhancement of forest carbon stocks (REDD+) concept was proposed in The United Nations Framework Convention on Climate Change (UNFCCC) which includes a new initiative led by developing countries by providing economic incentives for reducing deforestation in developing countries and maintaining carbon emission under a baseline (Seymour and Busch, 2016).

There is an excellent potential scope of implementing REDD+ program in Bangladesh for managing forest conservation with great success (Miah *et al.*, 2014). A pilot project of REDD+ in Masito Ugalla ecosystem area in western Tanzania worked on enhancing the capability of community people to conserve high bio-diversity value (Norway, 2014). On the other hand, Miah *et al.*, (2014) found that the alternative livelihoods and appropriate cash compensation to the forest-dependent people can reduce the traditional forest use in Rangamati of Chittagong Hill Tracks (CHT).

Among the six most crucial carbon pools, the soil is considered as the largest terrestrial pool of the carbon (Pearson *et al.*, 2013; Islam and Weil, 2000). A study conducted in Northeastern China showed that 69.5 to 77.8% of carbon was estimated in soil compared to the total carbon sink in the forest (Yawei *et al.*, 2014). Jobbagy and Jackson (2000) from the world soil database estimated that 2344000 million tons of carbon are stored in the top 3 m of soil from global soil organic carbon storage. Soil carbon stock in the natural forest was higher than the cultivated land which is greatly influenced by land uses (Islam and Weil, 2000).

The engagement of local people in organic carbon measurement based on their knowledge and background is the primary concern in the participatory carbon measurement (Cornwall and Jewkes, 1995). The expert base carbon accounting is more costly while participatory carbon measurement could be more cost-effective in terms of transaction cost (Casarim *et al.*, 2013). In the participatory carbon measurement, it is a crucial issue in REDD+ to build a well-trained and managed the team for maintaining activities in carbon sequestration and to disseminate knowledge to local communities (Subedi *et al.*, 2011).

Participatory carbon measurement by local non-professional community people reduces the transaction cost of carbon estimation (Casarim *et al.*, 2013). Many studies estimated soil carbon stock in natural forests, plantation, agricultural land, grassland, etc. all over the

world (Degryze *et al.*, 2004; Islam and Weil, 2000; Lasco and Cardinoza, 2005; Miah *et al.*, 2009; Stolbovoi, 2002; Tschakert, 2004; Wit *et al.*, 2006), but no study was done so far on soil organic carbon estimation of natural forest by a participatory approach in Bangladesh. So, the specific objectives of this study were to estimate soil organic carbon stock in Komolchari Village Common Forests (VCF) under the Khagrachhari district of CHT; to engage the local community ethnic people in carbon measurement, and to compare the estimated organic carbon between forestry experts and local participants. The study, enriching the knowledge pool about the involvement of the local community in soil organic carbon measurement, will play a vital role in the implementation of national REDD+ programs in Bangladesh.

Khagrachhari district is situated in the southeast of Bangladesh (Figure 1). The geographical location is between latitude $22^0$38' to $23^0$44'N and longitude $91^0$42' to $92^0$11' E. Khagrachhari district is bordered by Tripura (Indian state) to north, Rangamati and Chittagong district to the south, Rangamati district to the east, Chittagong district, and Tripura to the west. The population of the Khagrachhari district is 6, 13,917, including male and female sex ratio 105:100, tribal and non-tribal ratio 52:48. The average literacy rate in the district is 26.3%. Khagrachhari is a valley that has three rivers, and most of the land is hilly, including the total area of 2,749.16 km^2. The mean annual rainfall is 3031 mm with a mean annual temperature maximum of 34.6^0C, and minimum 13^0C. The study was conducted in semi-evergreen forests in Komolchari VCF in Buarchari Mouza (Mouza no-264), Khagrachhari Sadar, which is of 128 ha managing by the local ethnic community. The VCF is about 5 km away from the village of Komolchari. This study was conducted from March 2014 to August 2015.

One VCF and the representative selected members from the community were engaged for the estimation of organic carbon stock and the capacity building of the local community member for carbon measurement. The VCF was selected purposively as a medium growth natural forest.

The 15 local trainees were selected for the study purposively with minimum literacy and without any knowledge of forest inventory. After selecting the participants, a short training scheme was undertaken. The plots were randomly selected through the local peoples' participation using the superimposed grids on the VCF map. 1-meter radius plot was demarcated in the center of each mother plot for collection of the soil sample, and the minimum distance of each other was more than 10 meters.

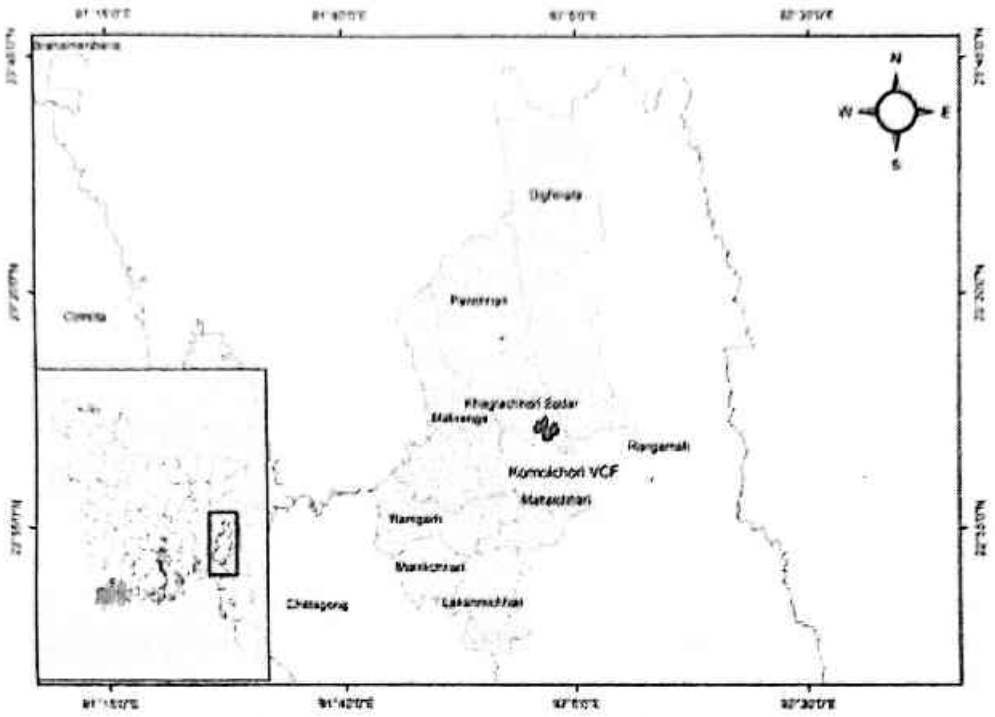

FIGURE1: LOCATION OF KOMOLCHARI VILLAGE COMMON FOREST IN KHAGRACHHARI DISTRICT UNDER CHITTAGONG HILL TRACTS.

Three soil samples were collected from each soil depth of 0 - 10 cm and 0 - 30 cm by the soil core of a known volume from each plot of the 1m radius. A total of 342 (=57*3*2) soil samples were taken from the 57 permanent mother plots where half of the samples were collected by the local trainees and another half by the forestry experts.

The center of the plot was recorded by the Global Positioning System (GPS) as the global coordinates (latitude, longitude). The GPS proximity alarms were set in the system for further monitoring of the same plot. A nylon rope of 6.28 m length was used for a convenient demarcation of the boundary of a 1 m radius plot for the collection of soil samples. Plots were distributed between the latitudes ranging from N 23°05.006' to N 23°05.988' and longitudes from E 92°01.774' to E 92°02.206'.

From the VCF, a total of 57 permanent sample plots were studied (Figure 2) for biomass and carbon estimation. The same plots were undertaken as mother plots for soil study also. The plots were selected randomly using the superimposed grids on the VCF map through the local peoples' participation. The plots were circular. The total number of permanent mother plots was estimated using the formula of MacDicken (1997) as follow;

$N = (CV*t)^2/E^2$

Where

N = maximum number of sample plots

CV = Coefficient of variation of biomass

T = value of t obtained from the student's t-distribution table at n-1 degrees of freedom of the pilot study at 10% probability

E= sampling error at 10%.

The 15 local participants consisted of three groups. Each group had five persons. The participation of local persons was included in the demarcation of plot boundary, GPS handling, soil sample collection, and data recording and marking on poly-bag. They had no participation in laboratory works. Professional records were enrolled by the experts from the Institute of Forestry and Environmental Sciences, Chittagong University (IFESCU), who had standard knowledge on forest inventory.

Bird-eye view of the study area indicating the waypoints of 57 permanent mother plots and whole covered area by connecting the border waypoints is presented in Figure 2.

The soil samples collected by the soil core were weighed in the field and then brought to the soil laboratory for organic carbon measurement. The wet oxidation method was used for the determination of the soil organic carbon in the laboratory.

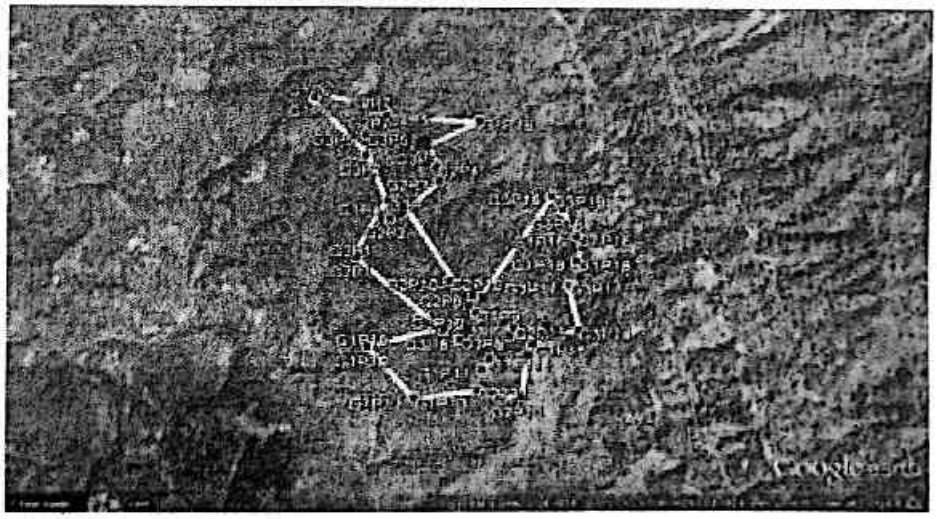

FIGURE 2: SATELLITE VIEW OF THE VILLAGE COMMON FOREST INCLUDING SAMPLING PLOT IN KHAGRACHHARI UNDER CHITTAGONG HILL TRACTS.

For measuring organic carbon, the following equation was used described by Pearson *et al.* (2007).

Bulk density (gm/cm^3) = mass (gm)/core volume (cm^3)

t Cha^{-1} = [soil bulk density (gm/cm^3) × soil depth (cm) × C] ×100

(C must be expressed as a decimal fraction, for example, 2.2% is expressed as 0.022 in the equation; bulk density must be expressed as gm/cm^3)

Finally, the density of organic carbon t Cha^{-1} was found for the Komolchari VCF. All of the data were analyzed by using the SPSS statistical software along with the use of Microsoft Excel.

After collecting the data by the local participants' group and the forestry experts, a comparison by the 't' test among the results was conducted. Results were based on two-sided tests assuming equal variances with significance level 0.05. Tests were adjusted for all pair-wise comparisons within a row of each innermost sub-table using the Bonferroni correction.

The average soil organic carbon percentage, organic matter percentage and bulk density estimated from the data of forestry experts and local participants were 1.39 ± 0.02% and 1.40 ± 0.02, 2.36 ± 0.04% and 2.04 ± 0.04%, and 1.47 ± 0.1 gm cm^{-3} and 1.45 ± 0.01 gm cm^{-3}, respectively (Table 1).

TABLE 1: SOIL PARAMETERS OF KOMOLCHARI VILLAGE COMMON FORESTS IN THE CHITTAGONG HILL TRACTS.

Soil parameters	**Measuring group**	
	Forestry experts	Local Participant
Organic carbon in soil (%)	1.39 ± 0.02	1.40 ± 0.02
Organic matter in soil (%)	2.36 ±0.04	2.04 ± 0.04
Bulk density of soil (gm cm^{-3})	1.47 ± 0.1	1.45 ± 0.01

In Figure 3, the horizontal straight line in the boxes represents the organic carbon and organic matter percentages, which were obtained from the data collected by forestry experts and local participants. The line for both of the groups remains inside the box, indicating the measurements by forestry experts and local participants were almost similar. It was also evident by the paired t-test.

In Figure 4, the horizontal straight line in the boxes represents the soil bulk density, which was obtained from the data collected by the forestry experts and local participants. The line for both of the groups remains inside the box, indicating the measurements by forestry experts and local participants are almost the same. It is also evident by the paired t-test.

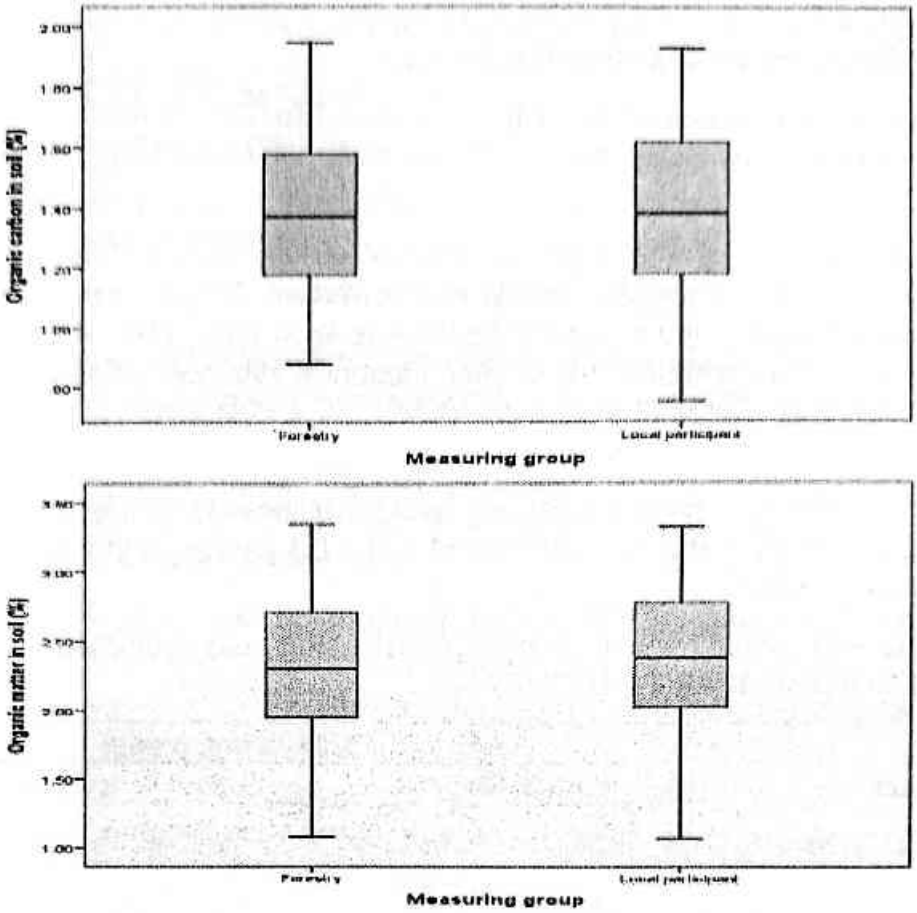

FIGURE 3: DATA DISTRIBUTION OF ORGANIC CARBON AND ORGANIC MATTER PERCENTAGE IN THE KOMOLCHARI VILLAGE COMMON FOREST IN THE CHITTAGONG HILL TRACTS.

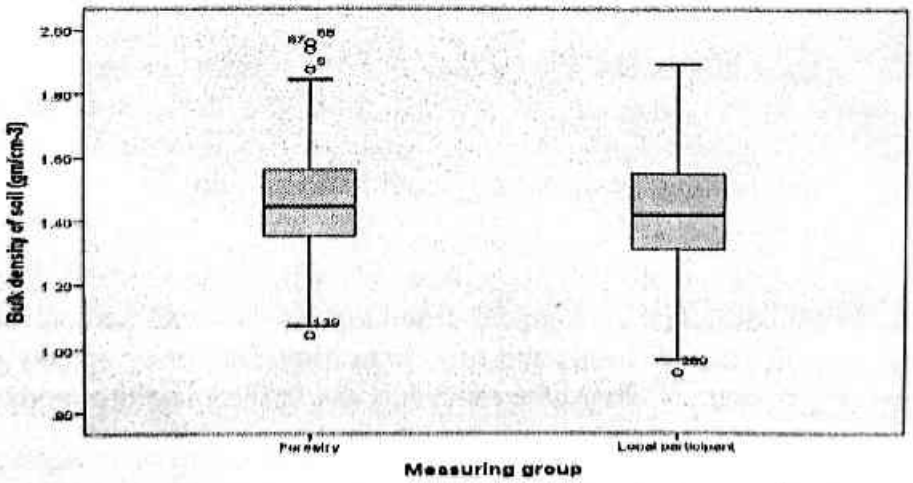

FIGURE 4: DATA DISTRIBUTION OF BULK DENSITY (gm cm^{-3}) OF SOIL IN THE KOMOLCHARI VILLAGE COMMON FOREST IN THE CHITTAGONG HILL TRACTS.

The percentage of organic carbon was found 1.39 ± 0.05 at 0 - 17 cm depth from the study on the natural forest in Bandarban (Haque 2013b). From another study on eight locations of the CHT, the percentage of organic carbon was found 1.55 at 0-15 cm depth for the forested site (Biswas *et al.*, 2012). From the estimation of Miah *et al.*, (2000), the percentage of organic carbon was found 1.34 ± 0.42 at 0-30 cm soil depth in *Aphanamixis polystachya* plantation in Chittagong region, Bangladesh.

The percentage of organic matter was found 1.10 at 0 - 20 cm depth of the soil in the broadleaves forest soil of Dulahazra in Bangladesh (Haque 2013a). Another study in Barkal Upazila, Rangamati district, showed that the percentage of organic matter in the soil of natural forest was 6.24 at 0 - 10 cm depth (Miah *et al.* 2010). The study conducted by Haque (2013b) on the natural forests in Bandarban, found organic matter percentage as 2.40 ± 0.09 at 0 - 17 cm depth of the soil. The percentage of organic matter from the estimation of Miah *et al.* (2000) was found 2.32 in the *Aphanamixis polystachya* plantation in the Chittagong region Bangladesh.

The study, conducted by Islam and Weil (2000) on *Shorea robusta* natural forest of Gazipur district, Bangladesh, found bulk density 1.22 gm cm^{-3} at 0 - 15 cm soil depth. In comparison, another study showed that the bulk density of the soil was 1.48 gm cm^{-3} at 0 - 20 cm soil depth in the broadleaves forest soil of Dulahazra in Bangladesh (Haque 2013a). In the natural forest of Thilla Ounte, Senegal, the estimated bulk density at 0 - 20 cm soil depth was 1.67 gm cm^{-3} (Tschakert, 2004). The estimated average bulk density, from 8 locations of the CHT at 0 – 15 cm depth of the soils, was 1.38 gm cm^{-3} (Biswas *et al.*, 2012) while the study on the natural forest of Tonkawati, Chittagong showed the estimated bulk density at 0 - 4 m is 1.32 gm cm^{-3} (Haque, 2013b).

From this discussion, it can be said that the percentage of organic carbon, organic matter and bulk density estimated in Komolchari VCF showed a standard acceptable stock of the specified soil parameters.

The average soil organic carbon stock at 0 - 10 cm and 0 - 30 cm soil depth estimated from the data of forestry experts and local participants were 20.31 ± 0.03 t Cha^{-1}, 60.92 ± 0.90 t Cha^{-1} and 20.07 ± 0.31 t Cha^{-1} and 60.22 ± 0.93 t Cha^{-1}, respectively (Table 2).

TABLE 2: ESTIMATED ORGANIC CARBON STOCK IN THE KOMOLCHARI VILLAGE COMMON FORESTS IN THE CHITTAGONG HILL TRACTS.

Soil depth (cm)	Measuring group	
	Forestry experts (t Cha^{-1})	Local Participant (t Cha^{-1})
0 - 10	20.31 ± 0.03	20.07 ± 0.31
0 - 30	60.92 ±0.90	60.22 ± 0.93

In Figure 5, the horizontal straight line in the boxes represents the organic carbon stock (t Cha^{-1}), which was obtained from the data collected by forestry experts and local participants as well. The line for both of the groups remained inside the box, indicating the measurements by forestry experts and local participants are almost similar. It was also evident by the paired t-test.

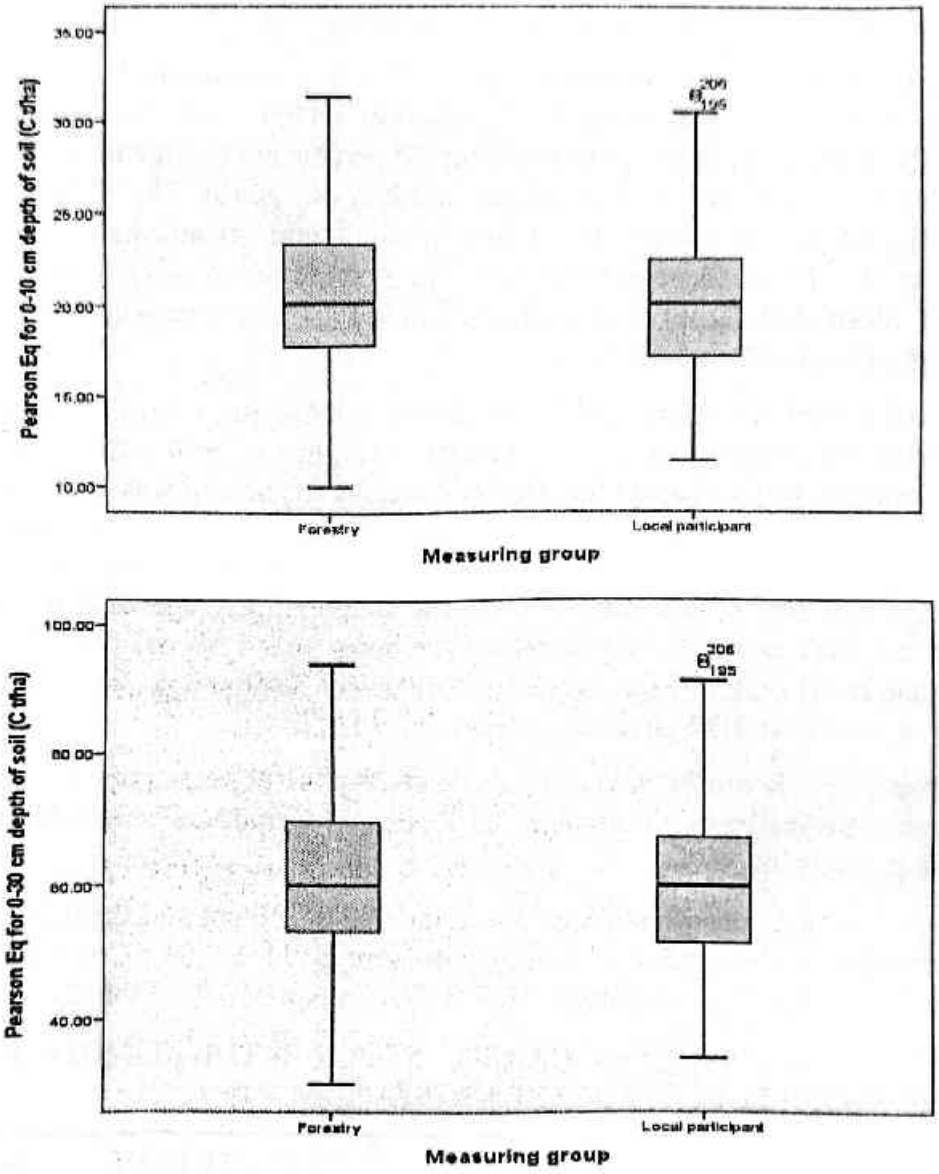

FIGURE 5: ESTIMATED SOIL CARBON STOCK IN 0-10 cm AND 0-30 cm SOIL DEPTHS FROM THE FORESTRY EXPERT AND LOCAL PARTICIPANTS' DATA IN THE KOMOLCHARI VILLAGE COMMON FORESTS IN THE CHITTAGONG HILL TRACTS.

The organic carbon in the soils represents 60 - 70% of the total carbon sequestration in the forests (Yawei *et al.,* 2014). It is also evident that natural forest possesses more organic carbon than the cultivated forests (Lal, 2005). Tundra, boreal/taiga, temperate, tropical and

wetland forest biomes are reported to have the soil organic carbon 115.74 t Cha^{-1}, 378.10 t Cha^{-1}, 105.82 t Cha^{-1}, 135.58 t Cha^{-1}, and 796.97 t Cha^{-1}, respectively (Adams *et al.* 1990, Dixon and Wisniewski 1995, Eswaran 2000, Malhi *et al.* 1999).

In a monoculture plantation of *Aphanamixis polystachya*, the average carbon stock in the soils at 0 – 30 cm depth was found 53.96 t Cha^{-1} in Chittagong, Bangladesh (Miah *et al.*, 2009). Baseline soil organic carbon levels were found 176.37 t Cha^{-1} in Laclubar and 77.17 t Cha^{-1} in Remexio in East Timor (Lasco and Cardinoza, 2007).

From the discussion, it is evident that the soil organic carbon stock estimation in the Komolchari VCF shows comparatively a lower concentration than the standard concentration found in the tropical forest biome. The massive degradation in the forests of Bangladesh can explain this (Islam *et al.*, 2001). However, the findings do not show any significant difference between the data collected by the forestry experts and the local participants.

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MD. DANESH MIAH * AND MD. ROBIUL HASAN

Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong 4331, Bangladesh.

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*Corresponding author: dansmiah@gmail.com; danesh@cu.ac.bd