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Estimation of Aboveground and Belowground Carbon in *Dipterocarpus turbinatus* (Garjan) Plantations in Chittagong University Campus, Chittagong, Bangladesh

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Abstract: Climate change scenario is now an alarming issue because of increasing CO_2 concentration which is a prominent cause of global warming and deforestation and forest degradation are the main causes of this burning issue. The study was therefore conducted on *Dipterocarpus turbinatus* (*D. turbinatus*) (locally known as Garjan) plantations in Chittagong University campus, Chittagong to estimate the aboveground (trees, herbs and grasses) and belowground (soil) carbon. Total biomass density and carbon density of trees estimated in *D. turbinatus* plantation were 131.2628 t/ha and 65.63142 tC/ha, respectively. Furthermore, the percentage of organic carbon and organic matter at 0-10 cm soil depth in *D. turbinatus* plantations was 1.19102 and 1.78043%, respectively while the concentration of carbon at 0-10 cm and 0-30 cm of soil depth was 13.12551 tC/ha and 39.37007 tC/ha, respectively. In the case of herbs and grasses, estimated biomass and carbon in herbs and grasses were 0.19501 t/ha and 0.09168 tC/ha, respectively. This study confirms that *D. turbinatus* plantation can store a significant amount of carbon in different carbon pools as trees, soil, herbs and grasses. *D. turbinatus* plantation can be spread in bare areas of Chittagong University campus to store the significant amount of carbon with a proper management as well as enrich the forest status. These findings will help administration panel and researcher in Chittagong University to think to spread *D. turbinatus* plantations as well as carbon trade experts and climate change mitigation practitioner, policy makers in native and board scale.

Key words: Aboveground and Belowground Carbon · *D. turbinatus* · Garjan · Plantation

INTRODUCTION

Greenhouse gasses play a vital role in climate change. The greenhouse effects can be mitigated by reducing the concentrations of these gasses in the atmosphere by reducing their emissions and increasing the sequestration or storage of carbon. Carbon sequestration is the absorption of CO_2 from the atmosphere by photosynthesis organisms which has tended to be equated to tree planting both in natural forests and plantation aspects.

Trees play the role of major reservoirs of carbon containing 80% of all carbon stored in land-based vegetation but when forest lands are degraded the stored carbon is released into the atmosphere [1] while storing rate depends on the age and growth rate of the forest. Trees are considered as the most important carbon sink and biomass source in the world including various uses such as food, fuel wood, domestic and other industrial uses etc. Management of carbon sequestration means the increasing of the amount of carbon stored in vegetation. One ton carbon in the wood or forest biomass represents 3.67 tons of atmospheric carbon dioxide [2]. The carbon absorption rate by the tree depends on the type of tree species and site conditions. On an average tree can remove about 22 kilograms CO_2 from the atmosphere per year [3]. Forest varies considerably in their capacity to absorb and store carbon [4]. Plantation has higher annual

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carbon sequestration rates. Conventional carbon accounting methods refer that the conservation of natural forests to the plantation is very likely to produce any carbon benefits [5].

Soil contains approximately three times more carbon than the atmosphere and four and half times more carbon than all living things [6]. Sequestrating carbon by increasing the amount of organic matter in the soil is both a source of greenhouse gasses and a sink for carbon. Following the Kyoto protocols, a forest may be the best land use as sink and source of atmospheric carbon. Growing trees and other vegetation capture CO_2 from the atmosphere and mix with water to produce carbohydrates. The concentration of atmospheric carbon has increased from 352 ppm to 367 ppm and without terrestrial, oceanic carbon sinks the CO_2 concentration due to burning of fossil fuels could have been 382 ppm during the late 1990s [7]. Furthermore, it has been estimated that approximately half of this total carbon sink releases from land ecosystems and major part of this sink is situated within forests in northern latitudes [7]. Managed forests provide the scope for improving forest growth rates while a young forest holds less carbon including additional carbon sequestration over time and an old forest may not capturing any new carbon but can continue to hold huge olumes of carbon as biomass over long periods of time. Tree cover alone is not enough to protect degradation of soil as well as the environment, basically in hilly areas. Undergrowth vegetation not only protects soil erosion but also absorb carbon from atmosphere [8].

Understory layer consists of all the plants of lower canopy levels of a forest ecosystem mainly herbs and grasses. Small to medium-sized woody plant distinguished from a tree by its multiple stems and shorter height, usually less than 6 m (20 ft.) tall is termed as a shrub. In a forest, herbs and grasses are considered as a small component of the overall carbon budget, estimated as 2% of total forest carbon [9]. Understory layer may not sequester much carbon to the land but it added a valuable amount of carbon to the soil. Herbs, grasses, shrub and other understory growth can be the major source of carbon for the forest floor and soil. The need for accurate estimation of carbon from herbs and grasses will become even more vital in the future, as land use by the human being and the result of global climate changes increasingly alter both the forested and non-forested ecosystems.

According to Land use and Land-use change and Forestry projects (LULUCF) activities the most important six carbon pools are above-ground trees, above ground non-trees, belowground roots, litter, dead wood and soil organic matter [10]. In the world, because of extreme disturbances in climate, forest tree biomass is decreasing and it is a matter of risk that the resultant increasing rate of forest biomass degradation will release more carbon to the earth [11]. In the case of storing atmospheric carbon, trees play an important role while storing rate depends on the age and growth rate of the forest. In Bangladesh, higher annual carbon sequestration rates are noticed in plantation forests while natural forests are maintaining higher long term capacities for carbon sequestration [2].

The study was conducted in eight plantations site of *Dipterocarpus turbinatus* (locally known as Garjan) in the Chittagong University campus to estimate the aboveground carbon in trees, herbs and grasses and belowground carbon and organic matter in the soil. *Dipterocarpus turbinatus* is a species of tree in the family Dipterocarpaceae native to western India, Bangladesh and mainland Southeast Asia and cultivated in surrounding areas [12]. The trees of *Dipterocarpus turbinatus* are lofty, growing 30-45m tall. The bark is gray or dark brown and is shallowly longitudinally fissured and flaky. Branch-lets are glabrescent.

In Bangladesh, some research works was done to estimate organic carbon in the mixed plantations [13, 14] and in *Aphanamixis polystachya* plantations in the Chittagong [15] while the study was conducted in *Dipterocarpus turbinatus* plantations. This study will help Researchers, administration of Chittagong University and students to get information on carbon sequestration from trees, soil, herbs and grasses in the plantations of *Dipterocarpus turbinatus* which will enrich and conserve the plantations with the objectives of carbon sequestration and development in the national and international level.

MATERIALS AND METHODS

The study was conducted in Chittagong University campus. Chittagong University lies between 22°27'30" and 22°29'0" North latitudes and 91°46'30" and 91°47'45" East longitudes [8]. The campus stretches about 1300 acre landscape of green hills; undulating valleys, grassland and lush forests. Topographically the campus is lodged at a safe, elevation from seasonal flooding [16]. The Chittagong University campus occurs on the South-Eastern edge of the Sitakundu hill range of Tertiary Sedimentary rocks and the rest by valleys underlined by recent and sub-recent piedmont alluvial and colluviums sediments. They are underlain by coarse to moderately

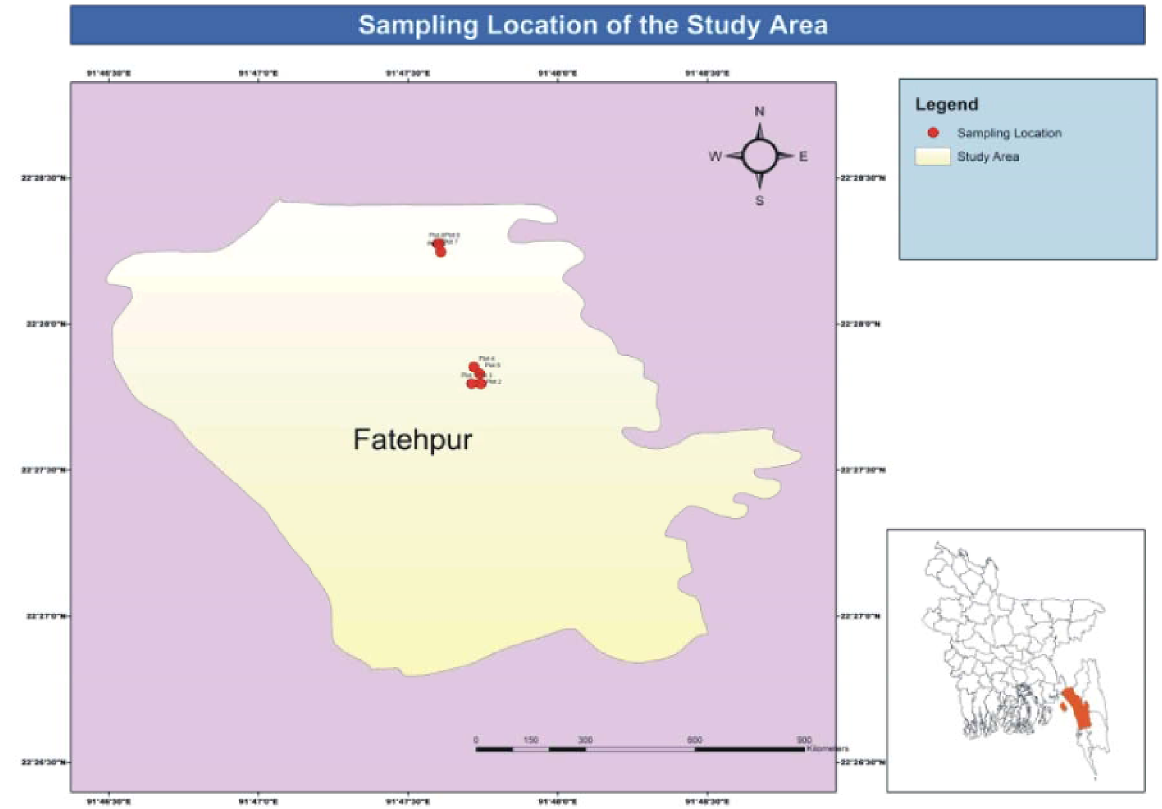

Fig. 1: Location of sample plots of *Dicterocarpus turbinates* (Garjan) in Chittagong University Campus, Chittagong

fine-textured recent and sub-recent alluvial and colloidal sediments [8]. Soil covering more than 60% of the campus area is formed in moderately coarse to moderately fine-textured, folded tertiary hill sediments and formation. The rest are formed in coarse to fine textured, recent mixed alluvial and colluviums piedmont sediments of valleys. The university area enjoys a tropical monsoon climate, characterized by hot, humid and cool, dry winter. The wind flows from south and west between March and May, from south and east between June and September and from North and West between October and February [17].

Selection and Sampling of Study Area: The study was carried out during July-September, 2015 and through physical measurement, field observation and laboratory analysis. The study area covered four *D. turbinatus* plantation sites. From the four plantation sites, total nine separate Garjan (*D. turbinatus*) plantation plots were taken as sample (Fig. 1).

Determination of Carbon in Trees: Total nine sampling plots of 10×10m were set up for tree species. In each sampling plots, Diameters at Breast Height (DBH) of trees were measured by using diameter tape. About 130 individuals of Garjan (*D. turbinates)* were measured in the sampling plots. The Aboveground Biomass Density (ABD) of trees was estimated using the Allometric model described by Pearson et al. (2005) [18]:

$ABD,\ kg/tree = \exp(-2.289+2.649*ln dbh-0.021*ln dbh^2)$, where *ln* is the natural logarithm.

The belowground biomass density (BBD) was found using the following Allometric equation described by Pearson *et al*. [18]:

$BBD = \exp(-1.0587+0.8836*ln ABD)$ where *ln* is the natural logarithm.

The biomass was then converted to carbon stock using the factor 0.5 for estimating both aboveground carbon density (ACD) and belowground carbon density (BCD) Pearson *et al.* [18].

Determination of Organic Carbon and Organic Matter in Soil: Soil samples at each site were collected from a depth of 0-15 cm. from each site three soil samples were collected randomly and each soil sample was put into

Table 1: Site locations including north latitude and east longitude and age of the plantation sites in the *Dipterocarpus turbinatus* Plantations in Chittagong University campus, Chittagong

			GPS location	
Plots No.	Site location	Age of the plantation (Year)	Latitude	Longitude
Plot 1	Behind the Girl's block of Master da Surjo Sen Hall	21	22.46325	91.79572
Plot 2	Memorial plantation of IFESCU 1	21	22.46324	91.79571
Plot 3	Memorial plantation of IFESCU 2	21	22.46325	91.7952
Plot 4	Right side of Teachers' quarters road	21	22.46421	91.79533
Plot 5	Left side of teachers' quarters road	21	22.46382	91.79565
Plot 6	Near main gate or Zero point	21	22.47077	91.79348
Plot 7	Behind the Shah Jalal Hall (1)	21	22.47124	91.7933
Plot 8	Behind the ShahJalal Hall (2)	21	22.47125	91.7934
Plot 9	Behind the Shah Jalal Hall (3)	21	22.47126	91.7934

All of these plots were selected randomly from the available *Dicterocarpus turbinates* (Garjan) plantation sites in Chittagong University campus (Fig. 1).

labeled polybag and brought to the laboratory. For determination of organic carbon and organic matter of soils, washed silica crucibles were dried in a furnace at 105°C for 30 minutes and cooled in a desiccator. In an electric balance exactly 5g of moist soil was accurately weighted in the electric balance and taken into crucibles and the soil with crucibles was then transferred into a furnace at 850°C for 1 hour, cooled in the desiccators and re-weighted in the electric balance to determine loss on ignition (LOI) %. LOI% was calculated as follows:

$$\%LOI = \frac{W1}{W2} \times 100$$

where W_1= loss in weight and W_2= weight of oven dry soil.

Percentage of carbon and organic matter were then calculated from the following relationship described by Hoque and Dider-ul-Alam as cited as [19]:

%Carbon = 0.476× (%LOI-1.87)
%Organic matter = %Carbon× 1.72

Furthermore, for estimating organic carbon, the following equation was used described by Pearson et al. (2005) at cited as [18].

Bulk density (gm/cm^3) = mass (gm)/core volume (cm^3)
C(t/ha) = [(soil bulk density (gm/cm^3) × soil depth (cm) × C)] ×100
where, Bulk density and Carbon (C) was presented as gm/cm^3 and a decimal fraction, respectively.

Determination of Carbon in Herbs and Grasses: From the nine plots, a total of nine sample plots (Table 1) were studied for collecting sample of herbs and grasses. The plots were circular in shape. 1m radius plot was taken from the center point of every 10×10m plot for measuring herb, shrub, grass and litter. For measuring carbon from the herbs and grasses, a destructive method was used. For that, one circular plot (1m radius) was allocated for measuring the total biomass from herbs and grasses. All the understory vegetation was cut down and then weighted in the field. A subsample of herbs and grasses weighted and brought to the laboratory for drying. The herbs and grass was oven dried at 105°C unless we got the constant weight. Fresh weight of total sample, sub-sample and dried weight was recorded in structured data sheet.

One fresh herb, shrub and grass samples were collected from each of the plot, in air-tight poly bag and weighted in the field and then brought to the laboratory for measuring dry mass.

For measuring dry mass, the following equation was used described by Pearson *et al*. as cited as [18].

Dry mass = [subsample dry mass/ subsample fresh mass]*fresh mass of whole sample.

The biomass density (the number of tons of biomass per hectare) was calculated by multiplying the dry mass by an expansion factor calculated from the sample plot size.

Expansion factor= 10, 000m^2/ Area of plot (m^2)

For the forest floor (herbs, grass and litter), the amount of biomass per unit area was measured by using the following equation:

$$LHG = \frac{W_{field}}{A} \times \frac{W_{subsample,dry}}{W_{subsample,wet}} \times \frac{1}{10000}$$

where, LHG = Biomass of leaf litter, herbs and grass [t ha^{-1}]; W_{field} = Weight of the fresh field sample of leaf litter, herbs and grass, destructively sampled within an area of size A [g]; A= Size of the area in which leaf litter, herbs and grass were collected [ha]; $W_{subsample, dry}$= Weight of the oven-dry sub-sample of leaf litter, herbs and grass taken to the laboratory to determine moisture content [g]; $W_{subsample, wet}$ = Weight of the fresh sub-sample of leaf litter, herbs and grass taken to the laboratory to determine moisture content [g].

The carbon content in LHG, C (LHG) was calculated by multiplying LHG with the IPCC (2001) as cited as [7] default carbon fraction of 0.47.

RESULTS AND DISCUSSION

Trees

Biomass in Trees: The total biomass density in trees of *D. turbinatus* plantations in Chittagong University campus was 131.2628 t/ha (Table 2). From a study conducted in Ghana found that total biomass density in Rubber (*Hevea brasiliensis*), Oil palm (*Elaeis guineensis*) and Cocoa (*Theobroma cacao*) plantations was 61.5 t/ha, 45.3 t/ha and 65.0 t/ha, respectively [20]. From the discussion, it can be said that the *Dipterocarpus turbinatus* plantations in Chittagong University campus contained a formidable concentration of biomass in trees.

Carbon in Trees: The study found that, the total tree carbon density was 65.63142 tC/ha in the *Dipterocarpus turbinatus* plantations in Chittagong University campus (Table 3). From a study it is found that, the forests of Bangladesh can sequestrate 92 t/ha on average [21]. Furthermore, in another study in Kashmir Himalaya, India shows that the tree carbon stocks ranged from 45.4 to 135.6 t/ha [22]. From the analysis, it can be said that, the amount of total carbon in *D. turbinatus* plantations in Chittagong University campus is presented in a standard level compared to other studies.

Soil

Soil Parameters: The average soil organic carbon and average soil organic matter in *D. turbinatus* plantations was 1.19% and 1.78%, respectively at 0-10 cm depth (Table 4). Furthermore, the average bulk density was found 0.95 (gm/cm^{-3}) (Table 4). From a study conducted in *Aphanamixis polystachya* plantation in Chittagong University campus depicts that the average percentage of organic carbon at 0-30 cm was 1.34±0.42 [15]. Again, in the case of organic matter, a study conducted at natural forest in Bandarban Hill Tracts found 2.40± 0.09% at 0-17 cm depth [23] and another study in *Aphanamixis polystachya* plantation in Chittagong found 2.32% [15]. From the discussion it can be said that the percentage of soil organic carbon and organic matter in *D. turbinatus* plantations present in a good stock level.

Carbon in Soil: The study has found the carbon stock in the *D. turbinatus* plantations in the Chittagong University campus was 13.12551 tC/ha and 39.37007 tC/ha at 0-10 cm and 0-30 cm soil depth, respectively (Table 5). From a study conducted in plantation of afforested land in Michigan found that the organic carbon was 12.6 tC/ha at 0-7cm soil depth [24] and in the plantation of *Aphanamixis polystachya* in the Chittagong, the estimated carbon was 53.96 tC/ha at 0-30 cm soil depth [25]. From the analysis it is found that the carbon stock in the *Dipterocarpus turbinatus* plantations in the Chittagong University campus is decent.

Herbs and Grasses

Biomass in Herbs and Grasses: The estimated average biomass in herbs and grassed was 0.19501 t/ha in the plantation of *D. turbinatus* in the Chittagong University campus (Table 6). In 15 years old white pine stands of a temperate pine plantation forest, estimated biomass of herbs was 0.003 ± 0.005 t/ha indicating 0.3 tC/ha biomass in herbs and grasses [26]. The analysis shows that there is a significant concentration of biomass in herbs in *D. turbinatus* plantation in the Chittagong University campus, Chittagong.

Carbon in Herbs and Grasses: The study found 0.09168 tC/ha in herbs and grasses in *D. turbinatus* plantations in the Chittagong University, Chittagong (Table 7). A study was conducted in the Chinese cork oak forest of Qinling Mountains of China, estimated carbon in herbs was 0.19 ± 0.04 tC/ha [27] and in the Temperate pine plantation in Southern Ontario of China, the estimated carbon in herbs was 1.92± 1.85 t/ha [26]. Comparison among the conducted study in the *D. turbinatus* plantations in the Chittagong University and Chinese cork oak forest of Qinling Mountains, Temperate pine plantation in Southern Ontario of China shows that concentration of carbon in herbs is presented in good level.

Table 2: Biomass of trees in *Dipterocarpus turbinatus* Plantations in Chittagong University campus, Chittagong.

Parameters	Biomass (t/ha)
Aboveground biomass density	100.2146
Belowground biomass density	31.0482
Total biomass density	131.2628

Table 3: Carbon of trees in *Dipterocarpus turbinatus* plantations in Chittagong University campus, Chittagong.

Parameters	Carbon (t/ha)
Aboveground carbon density	50.10732
Belowground carbon density	15.52410
Total carbon density	65.63142

Table 4: Soil Parameters of *Dipterocarpus turbinatus* plantations in Chittagong University campus, Chittagong.

Parameters	Value
Organic carbon in soil (%)	1.19102
Organic matter in soil (%)	1.78043
Bulk density of soil (gm/cm^{-3})	0.95102

Table 5: Estimated carbon in soil of *Dipterocarpus turbinatus* plantations in Chittagong University campus, Chittagong

Soil depth (cm)	Carbon (tC/ha)
0-10	13.12551
0-30	39.37007

Table 6: Biomass of herbs and grasses in *Dipterocarpus turbinatus* plantations in the Chittagong University, Chittagong

Biomass pool	Biomass (t/ha)
Herbs and grasses	0.19501

Table 7: Carbon of herbs and grasses in *Dipterocarpus turbinatus* plantations in the Chittagong University, Chittagong

Carbon pool	Carbon (tC/ha)
Herbs and grasses	0.09168

CONCLUSIONS

The study estimated carbon amount from trees, soil, herbs and grasses which are representing important carbon pools of plantation carbon. The study found that the total biomass and carbon in *D. turbinatus* plantations in Chittagong University campus was 102.262±2.127 t/ha and 49.582±3.125 tC/ha, respectively. Furthermore, in the case of soil, estimated carbon in soil depth at 0-10 cm and 0-30 cm was 12.95±0.25 tC/ha and 38.68±0.60 tC/ha, respectively which reflects good stock of carbon in soil. Again, biomass and carbon in herbs and grasses in the *D. turbinatus* plantations in Chittagong University campus was 0.195±0.031 t/ha and 0.131±0.031 tC/ha, respectively. All of the findings revealed that, *D. turbinatus* plantations in Chittagong University campus had a good stock of carbon. Further study is needed to be carried out on the impact of *D. turbinatus* species plantation on other chemical, physical and biological properties of the soil of the plantation areas. All discussion and analysis in this study depicts that *D. turbinatus* plantations can store a good, obviously not negligible concentration of carbon if adequate protection is provided and through afforestation reforestation activities in the bared areas of Chittagong University areas with proper management implemented. It would be helpful for administration and researchers of Chittagong University to decide whether to increase *D. turbinatus* plantations in the area of Chittagong University to improve the carbon stocks which will help to minimize the environmental hazards.

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