Original Research Article

Estimation of Carbon Sequestration in a Forest: A case study of Bhawal National Park, Gazipur

ABSTRACT

Carbon sequestration is a global strategy of reducing atmospheric carbon to tackle global warming and climate change. Since the industrial revolution, the atmospheric carbon concentration has been increasing, therefore, global warming is speeding up and ecosystems are destroyed which increases the threat for global environmental sustainability. To limit global warming to 1.50 C, COPs recommendation to be implemented particularly halt and reverse forest loss, and align the financial sector with net-zero by 2050. Also, the Kyoto protocol explore the opportunity of carbon trading for developing countries like Bangladesh which is also reinforced by the net zero strategy of IPCC. To assess the forest carbon sequestration potentials, Bangladesh needs to accurately measure its storage carbon using statistical validated methods. Compared to ideal situations considering size and population, forest land is inadequate in Bangladesh as a result, to get global benefit, the country should manage the carbon pool by assessing periodically and managing accordingly. This study follows the randomized block design for sampling and data collection from 9 plots of 100 m2 each. Each individual tree of a sample plot measured and recorded and a total 240 trees measured to get its GBH and individual height. Study area covers the core area of Bhawal National Park which is a planted forest dominated by Sal tree (*shorea robusta*). From the study it has been observed that 3.345-million-ton Carbon sequestrate (equivalent to 12.276-million-ton CO2) in the core area of Bhawal National Park which is 940 hectares. Very few older plants are found in the Bhawal national park, most of them are coppicing plants. This study report might be beneficial to estimate the Carbon sequestration potential of forest in Bangladesh and to achieve net zero of carbon emission also, create a foundation of carbon trading, therefore, the country might be benefited.

Keywords: sequestration, global warming, climate change, net zero strategy, IPCC, Kyoto protocol etc.

1. INTRODUCTION

Carbon sequestration is a global emerging concern as strategy of reducing atmospheric carbon to tackle global warning and climate change. Since industrial revolution (1750) the increase in atmospheric concentration of CO_2 by 31% from fossil fuel combustion and land use change as a result necessitates identification of strategies for mitigating the threat of global warming (Lal, 2004). Likewise, there is a scientific consensus that global climate is changing in part as a result of human activities (IPCC, 2001; Ravindranath et al., 1997; Negi et al., 2002) and those the social and economic costs of abating and of responding to its impacts will be big (OECD, 2000). Forests plays an important role in the global climate system. In the meantime, deforestation contributes 18% all forms of CO_2 emissions worldwide (Stern, 2006). Developing countries like Bangladesh are mostly affected by the consequences of “Global Warming” (Anon, 2000).

Bangladesh is a signatory of the Kyoto Protocol to reduce global greenhouse gas emissions by specified targets below a 1990 baseline level during the first commitment period, 2008 to 2012. Several provisions of the Kyoto agreement may affect how forestry is practiced in Bangladesh. Verifiable changes in carbon sequestration from afforestation, deforestation, and reforestation since 1990 could be counted as credits or debits if the result directly from anthropogenic activities. Other articles establish mechanisms for trading carbon credits among parties to the protocol (Coeli M. Hoover, 2000).

Houghton and Nassikas (2018) emphasized on protecting deforestation and allowing the secondary forests to grow to reduce global carbon emissions by about 120 PgC between 2016 and 2100. As forests, trees, or vegetation acts as the carbon storage, these could be used in devising mechanisms to cope with the undesirable impact of global climate change (Rahman, Sarker, & Hossen, 2013; Shin, Miah, & Lee, 2007). To achieve full carbon mitigation potential requires estimation of country-based carbon stocks through statistically valid methods (Mahmood, Siddique, & Akhter, 2016). As a cosigner of the Kyoto protocol, Bangladesh needs accurate estimations of carbon stocks throughout the country comprehensively to implement carbon trading CDM projects (Saatchi et al., 2011). Accordingly, the Government of Bangladesh took initiative to meet up nation-wide carbon stock data and prepared the REDD+ Readiness Roadmap (BFD, 2018). The reliable quantification of vegetative carbon sequestration will help the researcher, entrepreneur and policy makers of Bangladesh to sell certified emission reduction to developed countries (Ahammad, Hossain, & Husnain, 2014; Ahmed & Glaser, 2016) in global carbon markets under REDD+ and CDM (Al-Amin, 2016; Shin, Miah, & Lee, 2008) as they need to counterbalance their higher per capita carbon emission. Carbon stock estimation includes quantification of soil organic carbon, carbon in living trees, undergrowth vegetation, woody debris, and litters of forest floor in form of above-ground carbon and below-ground carbon (Gibbs, Brown, Niles, & Foley, 2007; Patra et al., 2013). In Bangladesh, researchers have estimated carbon stocks using different methods in the different parts of the country and have developed allometric models. However, most of the estimation is limited to few variables that miss the enormous pools of ecosystem carbon (Donato et al., 2011).

Existing forests of Bangladesh absorbs more carbon than the total carbon produced in the country. As a cosigner party of ‘Kyoto Protocol’ the country could be asked for compensation from the developed countries for their extra carbon absorbed by country’s forest (Mukul, 2007). According to Forest Department (FD) and some other sources (Hossain, 2005; Khan et al., 2007; Mukul et al., 2008) the area of forest land is about 2.53 million ha which is approximately 17.5% of the country’s total surface area but according to Forest Resource Assessment 2005 this figure is only about 0.871 million ha (FAO, 2006; 2007).

Sal forests covers huge area of central and eastern part of Bangladesh which constitute a unique biological diversity. They constitute 70- 75% "Sal" trees (*shorea robusta*) including several other valuable trees and herbaceous species (Ahmed, 2005). Agriculture is the main land-use in Bangladesh, comprising nearly 65% of the country’s land area, followed by forests (17.5%), urban/built-up areas (7.9%), and water (9.6%) (Dey et al. 2012). Forests occupy about 2.53 million hectares (10.53% of the country’s total land) in Bangladesh (Khan et al. 2007). Of these, 1.53 million hectares are under the jurisdiction of the Forest Department (FD) (Alamgir and Turton 2014) and remaining are unclassed state forests (0.73

million hectares) under the control of district administration and homestead forests (0.27 million hectares) owned by smallholder landowners (Khan et al. 2007). Most of the sal forests of Bangladesh are regenerated secondary forests (53%), followed by primary forests (30%) and planted (17%) forests (Mongabay 2014). The deciduous Sal forests are located on relatively plain lands in the central districts of Bangladesh and are dominated mainly by Sal (*Shorea robusta*). The sal forest covers 0.12 million ha which is 7. 9% of total country forest and 0.8% of total country land.

Accurate tree biomass estimation is critical and vital for calculating carbon stock as well as for studying climate change, monitoring of forest health, productivity, nutrient cycling and budget etc. (Mohammad Raqibul Hasan Siddique, 2021). The IPCC default emission factors was applied, where it is assumed that soil and dead organic matter do not change with forest management practice, type of forest, or disturbance regime (Sun Jeoung Lee, 2018). Sources and sinks of carbon associated with forests depend strongly on the management regime and spatial patterns in potential productivity (DAVID P. TURNER, 2004).

The number of specific allometric equations for Bangladesh has increased, among them half of the models lack statistical validity, Mahmood et al. (2016) concluded that only 5% tree species and shrubs in Bangladesh have allometric equation to estimate the biomass (Chanda et al., 2016). Carbon sequestration rate under the same environment exclusively depends on the species (Nahiyan, Baidya, Dip, Sultan, & Ahmed, 2017) which prescribed the need to develop species-specific localized allometric equations (Aysha et al., 2015; Mukul et al., 2014). Most of the studies, counted below-ground carbon stock as 15% of above-ground carbon stock (Miah, Uddin, Bhuiyan, Koike, & Shin, 2009; Ullah & Al-Amin, 2012), but in another study, it was found 14% in real field (Rahman et al., 2015) which added further errors into the estimates.

2. MATERIAL AND METHODS

2.1 Description of the study site

The study area “Bhawal National Park” was established in 1974 which officially declared as National Park in 1982 under the Wildlife Act of 1974. By origin, it is a planted forest and was the part of Madhupur forest under the rule of Bhawal Estate. It is located between 24°5′45″N 90°24′14″E in Gazipur, Dhaka Division of Bangladesh. The core area of the Bhawal national park covers 940 hectares but extends to 5,022 ha of surrounding forest. Most of this area was covered by forests fifty-five years ago and the dominant species was Sal (Shorea robusta). The purpose of this forest is to maintain important habitats as well as to provide opportunities for recreation. It has been kept under IUCN Management Category V, as a protected landscape.

2.2 Biomass sampling and sampling size determination

The object of sampling is to secure a sample which will be represented the entire population and reproduce the important characteristics of the population as closely as possible. A sampling plots is determined by the size of sampling units, number of sampling units, the distribution of the sampling units over the entire area, the type and method of measurement in the selected units and the statistical procedures for analyzing the collected data.

Under this study, selected 3 spots within the core area of Bhawal National Park through transect walk at least 100 meter inside from road site. Then, demark serially 5 plots in a straight-line each plot size will be 10 mX10 m= 100 m2. Through lottery, select 3 plots among 5 plots for primary data collection. Likewise, collect data from 3 sites and 3 plots from each spot therefore, measure DBH and tree heights from total 9 plots of 100 m^2 size each.

In each plot, count the number of trees (sal) and other species. Also count DBH and height of each individual tree of the plot. Likewise, counted 3 random plots of each 3 sites.

2.3. Research Approach

This research is based on quantitative approach as we take sample plots and trees for further calculation, measurement of DBH, and height. It is the general approach to estimate above ground biomass before statistical analysis. There are several research works have already done by using that approach. This approach is used because this is more convenient and easier to handle into a forest cover area moreover identifying sample and trees are also easy to count.

2.4 Data Collection

To complete this project, we required two types of data, one is primary data and another is secondary data. Data and its collection methods are discussed below

2.4.1 Primary Data

Data, those are collected from direct field level and those were not used before is called primary data. To complete study, tree diameter, tree height, GPS reading is needed that's why we collect those data from this site by manually. By using diameter tape, we measure diameter at breast height (1.32 m above from the ground) of trees in cm, height is measured by Michael Kuhn's Stick method in meter, measurement tape is used to measure the plot size and an Android GPS is also used to get geographic location like altitude, latitude, elevation etc.

2.4.2 Secondary Data

The secondary data like total area of plantation, tree species, history of management by which we can get to determine the age of tree and by this way we can easily know about growth and height relationship, height and biomass relationship and the growth and development of those site. I have collected official data from the forest office of Dhaka division, online resources through internet browsing, collect opinion of local denizens and forest villagers, etc.

2.5 Biomass Calculation

2.5.1 Biomass and Carbon calculation

Indeed, tree biomass includes above ground biomass including shoots, branch, twigs etc. and the below ground biomass includes roots biomass.

Calculation of Estimation of carbon of above ground biomass: The above ground tree biomass (AGTB) was estimated for carbon estimation by multiplying the bio-volume with the green wood density of particular tree species. Tree bio-volume (TBV) value was calculated by multiplying of DBH and height of tree species to factor 0.4 (Pandya et al., 2013). Wood density (WD) was fround from the Global wood density database (Zanne et al., 2009). The height of trees was measured by Michael Kuhn's Stick method, while the DBH was determined by measuring tree girth at breast height (GBH), approximately 1.32m from the ground. The GBHs of trees was measured directly from tree using measuring tape. The DBH of the tree was measured by dividing GBH by π (3.14) value i.e., GBH/3.14.

Bio-volume (TBV) = 0.4 × (DBH)2 × H

AGTB = TBV × WD

Calculation of Estimation of below ground biomass: The below ground tree biomass (BGTB) was calculated by multiplying the above ground biomass (AGTB) by root-to-shoot ratio of 0.26 (Hangarge et al., 2012).

BGTB = AGB × 0.26

Calculation of Estimation of total biomass: The total tree biomass was then calculated as (Sheikh et al., 2011):

Total tree biomass (TTB) = AGTB + BGTB

Calculation of Estimation of carbon storage: Generally, for any plant species 50% of its biomass is considered as carbon (Pearson et al., 2005). Therefore, the total biomass carbon was calculated as:

Carbon storage = Biomass × 50% or Biomass/2

Calculation of estimation of CO_2 equivalent: The CO_2 equivalent was calculated as following equation (Johnson and Coburn, 2010):

1 ton of carbon = 3.67 tons of CO_2 equivalent.

The estimated data was then complied and tabulated and analyzed by statistically validated methods. The Microsoft Office Excel 2010 and SPSS software was used to analyze the data.

3. RESULTS AND DISCUSSION

There are two methods of carbon estimation in tree species, destructive method and non-destructive method approved by many researchers. The project employed the non-destructive method for carbon estimation, in this method the study doesn't need to harvest the entire bio-volume and sacrifice the tree.

A total 240 trees were recorded from 9 sampling plots of 100 m2 (10m x 10m) each of Bhawal national park. The study conducted in the core area of Bhawal National Park where 3 plots were located in the Plot 1 (P1)- Coordinate-24°05'26.3"N 90°24'04.1"E, Plot 2 (P2)- Coordinate- 24°05'31.9"N 90°24'11.2"E, and Plot 3 (P3)- Coordinate- 24°05'01.7"N 90°23'45.9"E.

3.1: Results on Biomass Estimation

The study collected data to calculate above ground biomass and below ground biomass to find total biomass. Both biomasses could contain carbon which the study estimated.

3.1.1 Estimation of Above Ground Tree Biomass (AGTB)

The graph shows the comparison of tree bio volume found in different sample plots. It represents a strong relationship between tree diameter, height and above ground biomass. Highest biomass found in the P1R1 (2278.35 kg/plant) and lowest in the P2R1 (1969.88 kg/plant). The diameter of individual plants was found higher in plot 1 than plot 2 with tree height because plot 1 was located inside the park and plot 2 was near the road side.

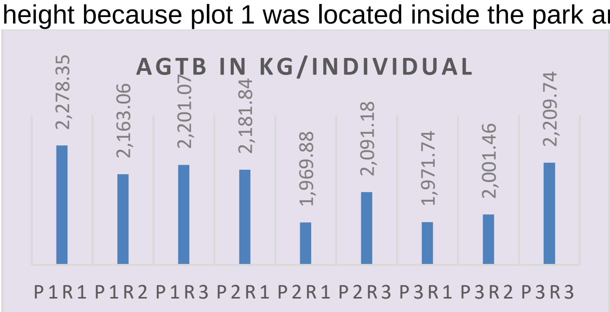

Figure 1: Graphical presentation of Average Above Ground Tree Biomass (AGTB) in different sample plots

3.1.2 Estimation of Below Ground Tree Biomass (BGTB)

The graph shows that the below ground biomass is higher in the P1R1 (592.37 kg/individual) and lowest in the P2R1(512.17 kg/individual). The cause behind the variation may be for the tree diameter and height, if any plant has higher girth and height that means the plant has more root biomass. Moreover, the below ground biomass calculated from the above ground biomass, therefore which plot has more AGTB, certainly that will have more BGTB.

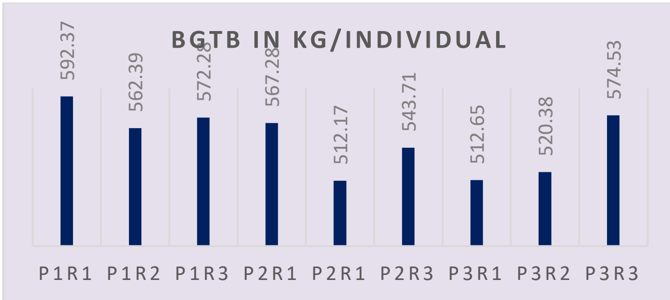

Figure 2: Average Below Ground Tree Biomass in different sample plots

3.1.3 Estimation of Total Tree Biomass (TTB)

The graph shows the total tree biomass found in the P1R1 (2,870.72 kg/individual) and lowest in the P2R1 (2,482.05 kg/individual). The reason may be the same that the growth of plot 1 trees is higher than plot 2 therefore, total biomass found higher in the plot 1.

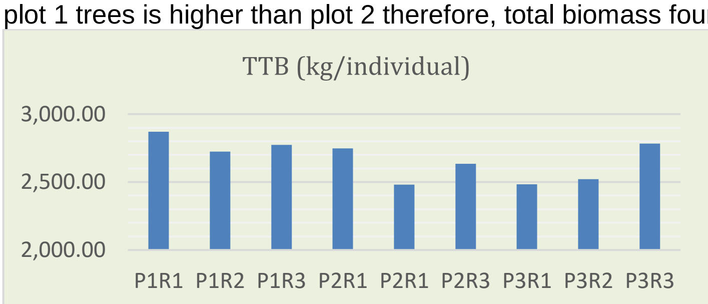

Figure 3: Total Tree Biomass (TTB) found in different sample plots

3.2 Results on Storage Carbon Estimation in different Plots

The study calculated total storage carbon in the total biomass found in the 240 trees of Bhawal National Park. Based on the primary data, the study estimated storage carbon per hector.

3.2.1 Carbon Storage Estimation of Above Ground Tree Biomass (AGTB)

The graph shows that the storage carbon found highest in the P1R1(1139.175 kg/plant) and second highest in the P3R3 (1104.87kg/plant) and lowest in the P2R1 (984.94 kg/plant). The storage carbon depends on the tree bio-volume and wood density therefore found more in the plot where biomass is also higher compared to other plots.

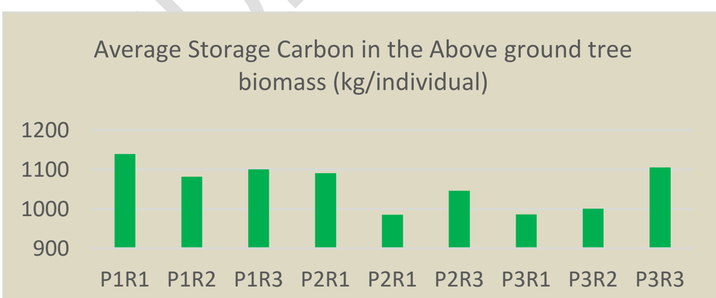

Figure 4: Storage carbon found in the above ground biomass in different sample plots

3.2.2 Carbon Storage Estimation of Below Ground Tree Biomass (BGTB)

The graph shows that the storage carbon in the below ground biomass is highest in the P1R1 (296.185 kg/tree), second highest the P3R3(287.265 kg/tree) and lowest in the P2R1

(256.085 kg/tree). It may be for the storage carbon calculated from the tree bio volume, where girth and height are major factors that are found highest in the plot 1, then plot 3 and then plot 2.

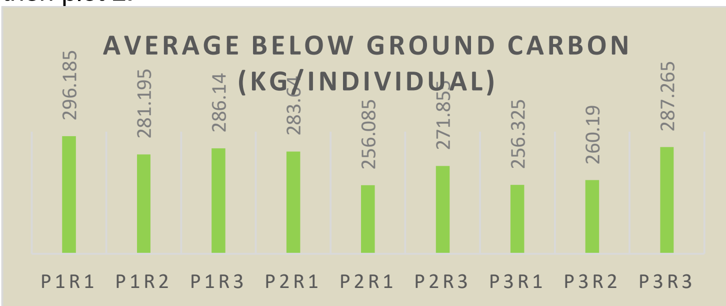

Figure 5: Storage carbon in the below ground biomass in different sample plots

3.2.3 Carbon Storage Estimation of Total Tree Biomass (TTB)

The graph shows that the total storage carbon is higher in the P1R1(1435.36 kg/tree) and second highest in the P3R3 (1392.135 kg/tree) and lowest in the P2R1 (1241.025 kg/tree). The wood density (0.73) is higher in the Sal (s*horea robusta)* compared to other forest trees as a result, storage carbon found higher in the plot 1.

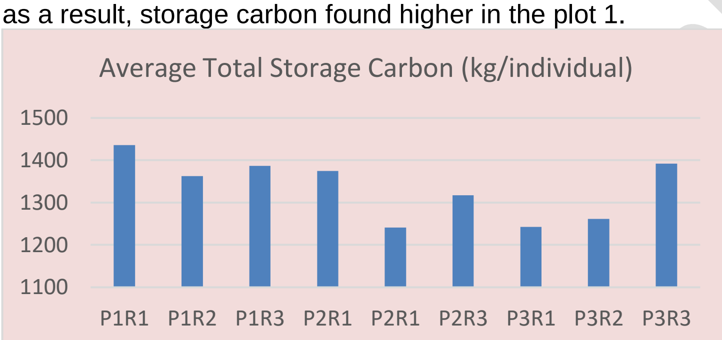

Figure 6: Total carbon storage in the sample plots

3.3 Estimation of CO2 Equivalent

The study calculated total storage carbon first, then convert into equivalent CO2.

3.3.1 Estimation of CO2 Equivalent of Above Ground Tree Biomass (AGTB)

The graph shows CO2 sequestrate highest in P1R1 (3839.02 kg/tree) and lowest in P2R1 (3319.248 kg/tree) in the above ground biomass of a tree. Those trees biomass is higher, they could sequestrate more carbon.

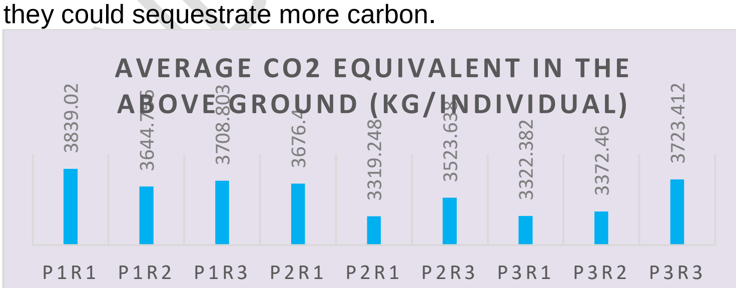

Figure 7: CO2 sequestration in the different sample plots

3.3.2 Estimation of CO2 Equivalent of Below Ground Tree Biomass (BGTB)

The graph shows that, CO2 sequestration found highest in the P1R1 (1086.999 kg/tree) and lowest in the P2R1 (939.832 kg/tree) in the below ground biomass. CO2 sequestration calculate from the below ground biomass, result which tree has higher biomass in the below ground they can sequestrate more carbon.

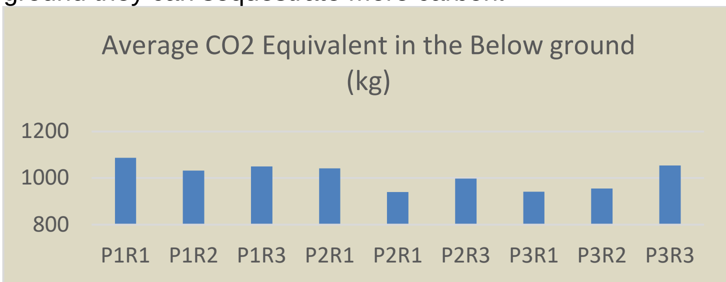

Figure 8: Graphical presentation of CO_2 sequestrate in the different sample plots in the below ground biomass

3.3.3 Estimation of CO2 Equivalent in the Total Tree Biomass (TTB)

The graph shows that, total CO_2 sequestrate in the P1R1 (5267.771 kg/tree) and lowest in the P2R1(5044.635 kg/tree). However, which trees biomass is higher, they could sequestrate more carbon.

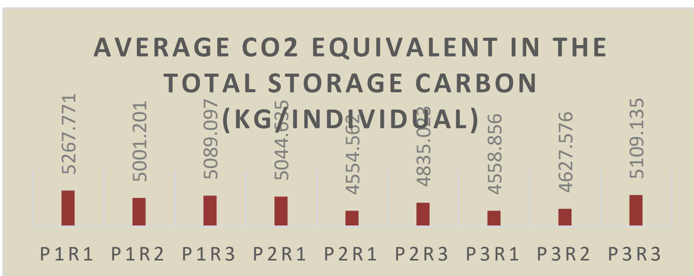

Figure 9: Total Carbon sequestrate in different sample plots

3.4 Carbon Stock Calculation per hectare Area of Bhawal National Park

A total 240 trees were recorded from 9 sampling plots of 100 m2 each in the Bhawal National Park Forest range. And the result and discussion chapter analyze the biomass and storage carbon for individual plants. Based on the individual tree data, the estimation of carbon storage are as follows

The project studied 3 plots in the different locations of Bhawal National Forest and recorded data from 9 plots of 100m2 each. Therefore, 240 trees were found in the 900 m2 and we know, 1 ha= 10000 m2. So, the average total number of trees in one-hectare is 2666. Average total tree biomass found per sal (*shorea robusta*) tree was 2669.56 kg, so total biomass found per hectare was **7117046.96 kg or 7117.04 ton/ha**.

Average storage carbon in individual Sal tree in the recorded plots (900m2) is 1334.782 kg/tree and the total number of trees in one-hectare is 2666, so total storage carbon found in the Bhawal National Forest is 3558528.812 kg or **3558.53 ton/ha.**

And we know One ton of carbon = 3.67 tons of CO_2 equivalent, therefore equivalent **CO_2 is 13059.80 ton/ha**.

The core area of Bhawal National Park is 940 ha, therefore total storage carbon estimated as **3.345 million ton and 12.276-million-ton CO_2.**

3.5 Correlation analysis of Tree Biomass, Tree height and Diameter

The correlation between tree biomass, tree height and diameter at breast height has analyzed using SPSS that found a significant correlation. The table showed the significant correlation (>0.5) between tree biomass, DBH (0.886) and height (0.711).

Correlations				
		Biomass	DBH	Height
Biomass	Pearson Correlation	1	.886**	.711*
	Sig. (2-tailed)		.003	.048
	N	8	8	8
DBH	Pearson Correlation	.886**	1	.350
	Sig. (2-tailed)	.003		.395
	N	8	8	8
Height	Pearson Correlation	.711*	.350	1
	Sig. (2-tailed)	.048	.395	
	N	8	8	8
**. Correlation is significant at the 0.01 level (2-tailed).				
*. Correlation is significant at the 0.05 level (2-tailed).				

Figure 10: Table of correlation analysis

4. CONCLUSION

The estimation of sequestrate carbon in each natural, planted or homestead forest of a country is becoming more important considering the global action of tackling global warming and climate change. If the global effort wants to limit global temperature increment by 1.5^{o} C, it needs to control emission of greenhouse gasses including carbon by any means. There are two ways to offset atmospheric carbon, one is reduced carbon emission from anthropogenic action at source and another is sequestration (creating a large reservoir of storage carbon) to balance emission. The sequestration strategies may be natural or mechanical, where Carbon sequestration in living forest may be a good strategy as natural. There are different types of natural or planted forest available in the earth, however, the study recommended increasing forest area with native species only and improving the management practice also to get large reservoirs of carbon. Still Bangladesh forest absorbed more carbon than total production in the country therefore, the country has good potential to earn foreign currency from carbon trading.

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