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ESTIMATION OF WOODY CARBON DENSITY BY ALLOMETRIC METHOD IN THE SELECTED SAL FORESTS OF BANGLADESH

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ABSTRACT

Estimation of Carbon (C) density in different Sal forests of Bangladesh has not yet been done for exploring their potentials in storing C. The present study compared the woody C density among three selected Sal forests located in Madhupur, Lalmai and Singra of Bangladesh in order to examine the effects of management intensities on C stocks. A total of 19 plots (each with 10 m × 10 m in size), 9 from Madhupur forest and each 5 from other two forests were placed to collect data on vegetation structure, plant diameter and woody C density. Allometric method was used to estimate C density for both aboveground and belowground parts of juvenile and adult tree plants of the selected plots. Woody biomass was converted into C content by multiplying the value with van Bemmelen factor (1.724). Results showed that woody C density was significantly (p = 0.0156) higher in Lalmai (552.46±64.09 ton/ha) and Singra forests (547.13±62.43 ton/ha) than the Madhupur Sal forest (354.03±38.43 ton/ha). Mean diameter of Sal tree plant at breast height was significantly (p = 0.022) higher in Lalmai (38.84±2.12cm) and Singra (37.36±1.97 cm) forests than Madhupur forest (30.72±1.93 cm). Results clearly demonstrated that forest trees with high average diameter had the high woody biomass content. This study thus suggested that long term forest conservation could be an effective approach to increase C stock in the forest ecosystems.

Keywords: Allometric method, biomass carbon, protected area, Sal forest

Introduction

Global warming has created enormous concerns for its multifaceted problems including climate change. Elevated concentrations of carbon dioxide (CO_2) in the atmosphere is playing the major role in global warming (Nunes 2023). Exploring the options for the mitigation of this environmental problem is, therefore, important to stop further deterioration of the current alarming situation. Among the various approaches, role of forest conservation in reducing CO_2 in the atmosphere is well recognized. As per UNFCCC (United Nations Framework Convention on Climate Change) and Kyoto Protocol, forest ecosystems can contribute to mitigating greenhouse gas emissions (Somogyi *et al*. 2008). Because, extant plant is one of the important pools that act as a sink for C storage. Therefore, reliable estimates of C density in woody plants is the fundamental to determine C stocks in forest ecosystems.

C storage by trees can be calculated from the biomass of the same species. Therefore, biomass estimation is a prerequisite to the calculation of C content stored by various tree species. As per the Kyoto Protocol, C should be assessed from different pools like aboveground and belowground biomass, dead wood, litter and soil (Santilli *et al.* 2005).

Several methods including destructive and non-destructive approaches and mean tree method are available for the estimation of biomass. Although destructive methods provide more accurate data, it has some limitations such as sacrifice of live plants and vast time. On the other hand, non-destructive method requires less time and labor. Allometric model is a non-destructive mathematical tool to estimate tree forest biomass (Picard *et al*. 2015). This model is the mathematical functions of tree variables including diameter at breast height, total height and wood density.

Estimating C content from the extant live plants in non-destructive approach is important from the aspects of conservation. Use of allometric regression models to convert forest inventory data to estimate aboveground biomass is commonly used method to quantify C stocks in the forest (Van Breugel *et al*. 2011). The use of allometric models implies decisions on the selection of extant models or the development of a local model, the predictor variables included in the selected model, and the number of trees and species for destructive biomass measurements.

Forests are predominant global C sinks as they restore 70-90% of biomass C (Houghton *et al*. 2009, Brienen *et al*. 2015). REDD (Reducing Emissions from Deforestation and Forest Degradation) under IPCC programs have also stressed on the importance of forest conservation and afforestation to scale back the atmospheric C levels (Skutsch *et al*. 2007; Angelsen 2008; Keith *et al*. 2009; IPCC 2003). In Bangladesh, Sal forests (dominated by *Shorea robusta* Gaertn.) cover an area of about 121,000 ha (Banglapedia 2021). These forests, distributed over different geographical locations, vary in management intensities such as protected, reserve and buffer forest zones.

Although some studies compared C density and stocks among several different forests of Bangladesh (Mukul *et al.* 2014; Mahmood *et al*. 2019), few attempts were taken so far to estimate biomass C in the Sal forests with different management intensities, though such information is very important for better management and conservation of forest for C storage. The specific objectives of the present study were to compare woody biomass C density among Singra Sal forest, Madhupur Sal forest and the Lalmai Sal forest with different management intensities in Bangladesh.

Materials and methods

Study site description: Three Sal forests namely Madhupur Sal forest, Lalmai Sal forest and the Singra Sal forest were selected in this study. Madhupur forest is situated in the Madhupur Sub-district under the district of Tangail. It is located at 24°41′22.0992″N to 24°41′22.1784″N latitude and 90°8′10.896″E to 90°8′10.4856″E longitude. The Lalmai forest, situated in the district of Cumilla, lies between the latitudes 23°25′18.8472″N to 23°25′20.9424″N and longitudes 91°8′12.0084″E to 91°8′12.444″E. Singra Sal forest, situated in the Birganj upazila of Dinajpur district, belongs to the tropical dry deciduous forest. Geographically, it is located from 25.8876682°N to 25.889277°N axis and 88.563593°E to 88.560535°E longitude. A part of this forest was declared as National Park in 2010. The area of Madhupur forest, Lalmai forest and Singra forest was 18,439.57 ha, 202.34 ha and 355 ha, respectively.

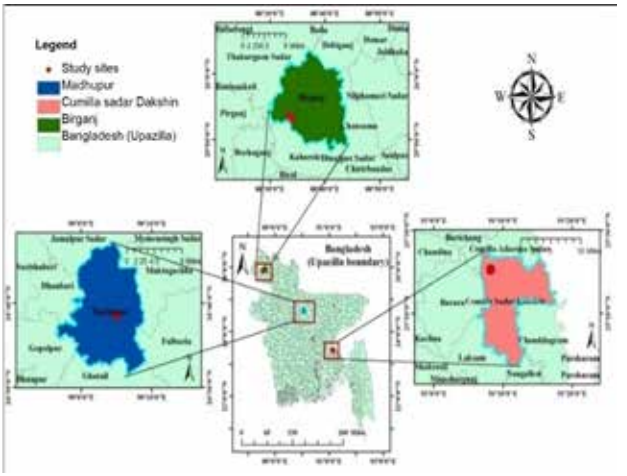


Figure 1. Map showing the study areas of Madhupur Sal forest, Lalmai Sal forest and Singra Sal forest of Bangladesh.

Vegetation analysis: Vegetation data were collected by following quadrat methods. A total of 19 quadrats (10 m × 10 m) were placed randomly at the three selected forests of which 9 were placed in the Madhupur forest while each 5 were in other two forests. Quadrats placed in the Singra forest were in the protected Area. Plant species were identified within the quadrat and recorded. The height of the tree species was determined by applying the general rules of trigonometry as follows:

Tree Height, h = Tan A x d, where h is the tree height, d is the distance from tree, and A is the angle to the top of the tree.

To measure the DBH (Diameter of Breast Height) of the tree species, GBH (Girth of a tree at Breast Height) was taken with a tape at a height of 1.37 m of a tree (Hossain 2022). DBH was determined from the GBH measurement using the formula $D = G / \pi$.

Determination of tree biomass and C density: Tree biomass and C density (ton/ha) of woody vegetation were assessed using the non-destructive allometric method. The aboveground biomass (AGB) of adult (≥30 cm GBH) tree species was estimated following the allometric equation of (Chave *et al.* 2005).

$AGB = \exp(-2.187+0.916 \times \ln(\rho \times D^2 \times H))$

Aboveground biomass of juvenile tree population (>10cm-<30 cm GBH) was estimated using allometric equation by following (Chaturvedi *et al*. 2012).

$AGB = 3.344+0.443 \times \ln(D^2)$

The wood specific gravity of each tree species was taken from the available published literature (Gisel *et al.* 1992; Cordero and Kanninen 2002; Mani and Parthasarathy 2007; Wiemann and Green 2007; Sundarapandian *et al*. 2014).

Belowground biomass (BGB) of trees was calculated following (Cairns *et al*. 1997).

$BGB = \exp(-1.0587 + 0.8836 \times \ln(AGB))$

The belowground biomass of juvenile tree population was calculated by multiplying the aboveground biomass value with 0.26 (Cairns *et al*. 1997, IPCC 2003).

Total carbon stock (TCS) was calculated by multiplying the Total biomass (AGB+BGB) value with 0.4453 (Prado-Junior *et al*. 2016).

$TCS = (AGB + BGB) \times 0.445$

For adult plants, GBH was considered >30 cm. The juvenile stage was considered when the sprout continued to grow but had not yet reached the stage of complete maturity and GBH was considered >10 cm to <30 cm.

Results and Discussion

There was no significant difference in species richness and Shannon's diversity index among the three selected forests although the values were relatively lower in Lalmai forest than the other two forests (data not shown). Mean DBH value of Sal plant was significantly (p = 0.022) higher in Lalmai (38.84±2.12cm) and Singra **(**37.36±1.97 cm) forests than that of the Madhupur **(**30.72±1.93 cm) forest (Figure 2). These results indicated that the trees of the Singra and Lalmai forests were older than the Madhupur forest. Dey *et al*. (2017) also reported that plant age and DBH were significantly positively correlated in a sugar-maple dominated forests of Menominee Indian Reservation in northeastern Wisconsin, the USA.

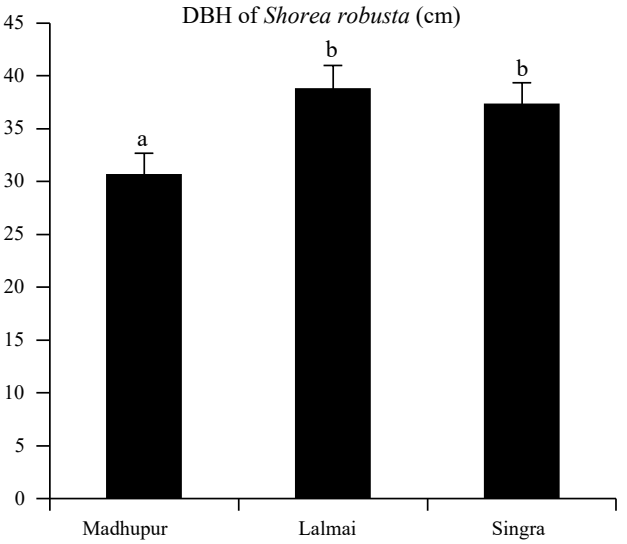


Figure 2. Diameter at Breast Height (DBH) of *Shorea rabusta* Gaertn. of Madhupur Sal forest, Lalmai Sal forest and Singra Sal forest of Bangladesh.

Significant differences appeared in aboveground (p = 0.0161), belowground (p = 0.0146) and total biomass (p = 0.0159) C density of the adult woody plants among the three selected forests (Figure 3). Aboveground, belowground and total biomass C density of the adult plants were significantly higher in Lalmai **(**547.8±63.6 ton/ha**)** and Singra **(**510.1±57.98 ton/ha**)** forests than Madhupur Sal forest. In case of juvenile tree, woody biomass C showed significant difference in aboveground (p = 0.0001), belowground (p = 0.0001) and total woody biomass (p = 0.0001) C density among the three selected forest (Figure 4). Data showed that the highest value was found in Singra forest **(**37.02±6.82 ton/ha**)** and the lowest in Lalmai forest **(**4.67±0.8 ton/ha**)** and the intermediate was in the Madhupur Sal forest **(**15.84±2.27 ton/ha**)** (Figure 4). When aboveground and belowground biomass C values were summed together then the woody C density was significantly (p = 0.0156) higher in Lalmai (552.46±64.09 ton/ha) and Singra forests (547.13±62.43 ton/ha) than that of the Madhupur Sal forest (354.03±38.43 ton/ha) (Figure 5).

Data of the present study clearly demonstrated that woody biomass C density was significantly higher in Singra and Lalmai Sal forests than the Madhupur Sal forest. Singra forest with an area of 305.7 ha was declared as Protected Area in 2010 by the government of Bangladesh. Wood logging and other disturbances were prohibited as per the Protected Area act. As a result forest tree plants could continue to grow till maturity. In Lalmai forest, Sal plants were found relatively taller and older. Mature and old plants could store more C than the relatively younger plants in the forest ecosystems. Other studies also reported similar results (Melillo *et al.* 2016; Tian *et al.* 2023). Estimation of woody C density is the fundamental and primary step in determining C stocks in forest ecosystems. The findings of the present study suggested that allometric method could be appropriate for determining woody C density. Results of the study are relevant for the estimation of C stocks of these forests by selecting more sampling sites.

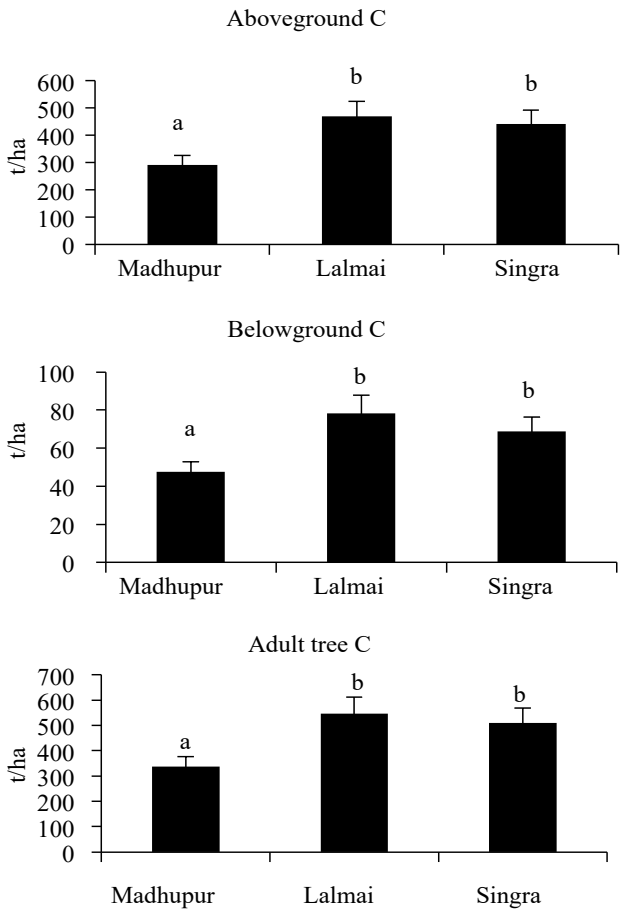


Figure 3: Carbon density (t/ha) of adult tree plants of the Madhupur Sal forest, Lalmai Sal forest and Singra Sal forest of Bangladesh.

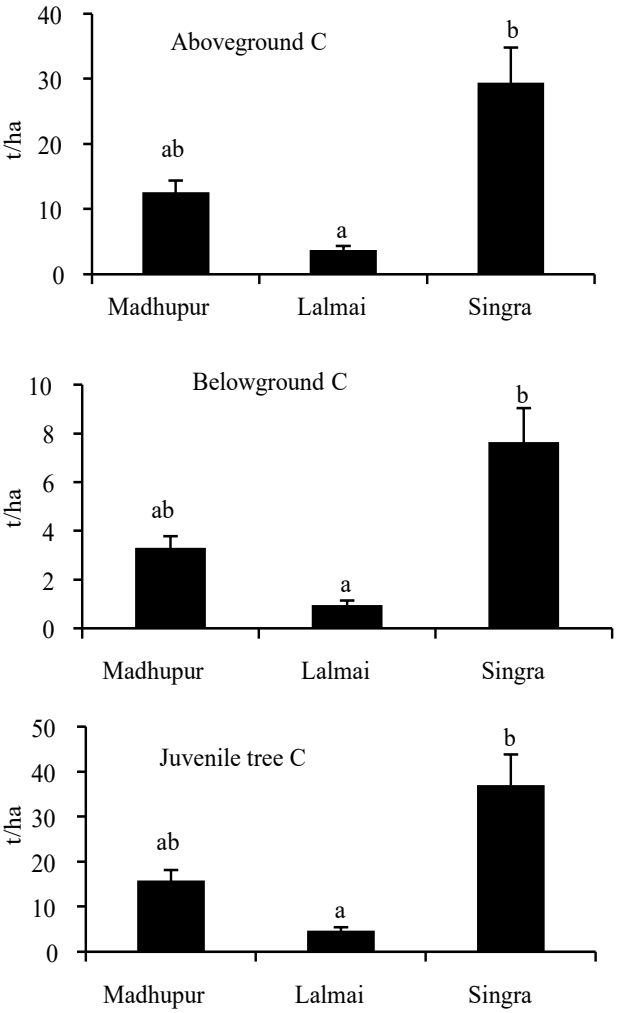


Figure 4: Carbon density (t/ha) of the aboveground, belowground and juvenile tree plants of the Madhupur Sal forest, Lalmai Sal forest and Singra Sal forest of Bangladesh.

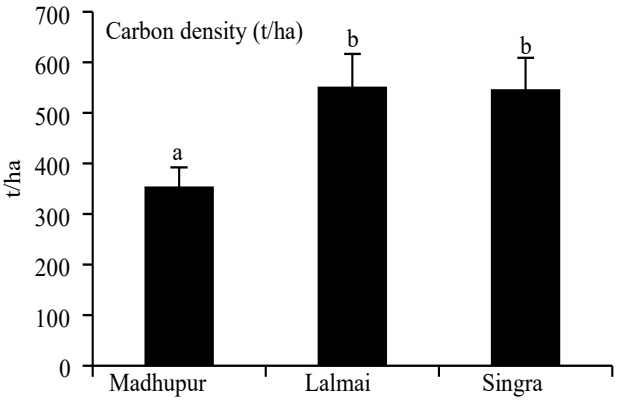


Figure 5: Carbon density (t/ha) of total woody plants of Madhupur Sal forest, Lalmai Sal forest and Singra Sal forest of Bangladesh.

Conclusion

The selected Sal forests differed significantly in woody C density where the values were higher in Singra and Lalmai forests than the Madhupur forest. Variation in plant growth as revealed by diameter of tree trunk at breast height might cause such difference in woody C density among the selected forests. Results of the study, therefore, suggested that long term forest conservation might have contributed to increase C stock in the forest ecosystem.

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