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CARBON STORAGE CAPACITY OF DIFFERENT FOREST TREE SPECIES AND THEIR ROLE IN MITIGATING CLIMATE CHANGE

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Abstract

Carbon dioxide is the most important atmospheric component, as it traps heat and creates conditions that are adverse to all living organisms. Only plants can capture CO_2 from the atmosphere and help reduce it through photosynthesis. The determination of carbon sequestration capacity is crucial for assessing the ability of each tree species to mitigate global warming. The research was conducted in an artificially planted forest area to determine biomass and carbon storage capacity. A systematic sampling and non-destructive method were followed to determine the carbon sequestration capacity of five tree species. The present research revealed that carbon storage ranged from 215.62 kg tree^{-1} to 669.82 kg tree^{-1} at 25-year-old established orchards. The highest biomass was found in *Albizia procera,* and the lowest in *Lagerstroemia speciosa* Statistical analysis revealed that carbon storage varied significantly ($p < 0.05$) among the five tree species.

Introduction

Forests are essential to the regional and global carbon cycle, as they can store significant amounts of organic carbon in their flora and soil. Quantifying carbon stocks enhances understanding of forests' contributions to the global carbon cycle. Tropical forests play a particularly important role in global carbon fluxes (Mendes *et al.* 2020). By absorbing atmospheric CO_2, forest ecosystems help maintain ecological balance and mitigate climate change (Charman *et al.* 2013, Ghosh *et al.* 2021). Younger forests generally exhibit higher carbon sequestration potential than mature forests, highlighting the importance of selecting suitable high-capacity tree species for plantation programs. Plantations also improve soil health and ecological stability while enhancing carbon storage (Darmesh *et a*l. 2014, Sheikh *et al.* 2021, Thakur *et al.* 2021, Tamang *et al.* 2021).

Tree biomass, comprising aboveground and belowground components, is a key factor in forest productivity and the carbon cycle (Liu *et al.* 2019). Biomass is influenced by ecosystem characteristics, vegetation type, stand age, site conditions, altitude, slope, soil properties, and management practices (Gupta and Kumar 2014, Pragasan 2014, Pragasan 2015). Belowground biomass is commonly estimated from aboveground biomass, while total biomass depends on tree density, diameter, height, wood density, and basal area (Joshi and Ghose 2014). Hardwood species generally grow more slowly than softwoods (Rahman *et al.* 2019). Indigenous species are typically hardy and well-adapted to local environments, whereas exotic species often exhibit faster growth. Therefore, plantation forestry remains an effective strategy for increasing forest resources and mitigating global warming (Kumar *et al.* 2022).

Bangladesh is home to numerous established orchards featuring both native and exotic tree species. About 150 tree species are estimated to be cultivated in various natural and man-made forest areas (Rahman *et al.* 2025). Although some studies reported biomass and carbon storages of mangrove tree species (Ahmed *et al.* 2021) and carbon stock of different forest soils (Propa *et al*. 2021 and Alam *et al*. 2024), previous studies have not examined the biomass and carbon storage

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capacities of different forest tree species within the same age groups. Understanding these capacities is crucial for assessing the contributions of indigenous and exotic species toward climate change mitigation. Therefore, this study focuses on evaluating the carbon storage potential of five planted timber species across different locations in Rajshahi and Natore districts in Bangladesh.

Materials and Methods

The research was conducted across various planted areas, including the Rajshahi University campus in Rajshahi and Natore Sadar Upazila in the Natore district, Bangladesh. The study spanned from September 2024 to May 2025. The campus is located near the Padma River, about 5 kilometers east of Rajshahi City Corporation. It lies between 24.370° North latitude and 88.637° East longitude. The rainy season runs from the end of June to September. Humidity averages around 77%, with December, January, April, and July being the driest, coldest, warmest, and wettest months, respectively. Annual rainfall in Rajshahi ranges from 1542.10 to 2235.80 mm. Hot temperatures range from 24.5 to 40.10 °C, with an average yearly temperature between 26 and 36 °C. Natore Sadar Upazila is located between 24°07′ and 24°43′ North and 88°17′ and 88°58′ East. It belongs to the tropical zone and is known as Bangladesh's hottest district. Temperature fluctuations show an average annual range of about 26 ° to 36 °c. Average winter temperature varies between 9° and 14°C, while summer temperatures ranged from 25.50° to 40.70°C (Weather Office, Rajshahi, 2024).

For each area of study, a systematic sampling method was used to select each plot (Pearson *et al*. 2007). Each plot was 100 meters apart from the other plots. Each plot was circular and covered 10 meters. The total number of plots was 408. The total study area was 305 hectares, and the sampling area was 12.81 hectares. Several scientists have recommended that a sampling area of at least 1% is required for terrestrial areas (Rana *et al*. 2012). However, the present study area covered more than 4.20%. The number of trees in each plot was counted, identified, and recorded. Diameters were measured (1.30 m above ground level) of all trees in each plot using a tape measure. Heights were measured with a Hega altimeter. A tree is included if >50% of its basal area fell within the plot and excluded if <50% of its basal area fell outside the plot.

A non-destructive method was used to measure the biomass and carbon content of the trees (Brown *et al*. 1989, Schroeder *et al*. 1997, Mac Dicken 1997).

Analysis of variance (ANOVA) was done with different forest tree species. Duncan's multiple-range tests were used to determine the significance of differences in mean values. Statistical Package for the Social Sciences (SPSS) version 28 was used to perform these analyses.

Results and Discussion

The research was conducted on five planted forest tree species, approximately 25 years old, in two different areas of northern Bangladesh. The diameter at breast height and the total height of *Albizia procera, Delonix regia, Lagerstroemia speciosa, Syzygium cumini,* and *Terminalia arjuna* were measured for the determination of biomass and carbon storage capacity. The findings revealed that the diameters at breast height (DBH) and the total heights (H) were 35.70, 40.47, 21.45, 30.02, and 31.35 cm, and 18.77, 14.69, 7.87, 13.07, and 17.83 m for 25-year-old planted tree species, respectively (Table 1). The highest diameter and height were observed in *D. regia*, while the lowest diameter and height values were recorded in *L. speciosa*. The statistical analysis revealed that the diameters and total heights of the five tree species varied significantly ($p < 0.05$) at the same ages.

Table 1. Diameter at breast height and height of five tree species at 25 years old.

Name of species	DBH (cm)	H (m)	MADI (cm)	MAHI (m)
Albizia procera	$35.70 \pm .52^{b}$	18.77 ± 1.25^{a}	1.42 ± 0.09^{b}	0.75 ± 0.06^{a}
Delonix regia	40.47 ± 0.41^{a}	14.69 ± 4.04^{b}	1.90 ± 0.11^{a}	0.59 ± 0.14^{b}
Lagerstroemia speciosa	21.45 ± 3.02^{d}	7.87 ± 2.21^{d}	0.86 ± 0.67^{d}	0.34 ± 0.48^{d}
Syzygium cumini	30.02 ± 2.19^{c}	13.07 ± 1.02^{c}	1.21 ± 0.07^{c}	0.52 ± 0.05^{c}
Terminalia arjuna	31.35 ± 3.29^{c}	17.83 ± 2.09^{a}	1.25 ± 0.49^{c}	0.71 ± 0.19^{a}

The present study revealed that the mean annual diameter increment (MADI) and mean annual height increment (MAHI) of five tree species were 1.42, 1.90, 0.86, 1.21, and 1.25 cm and 0.75, 0.59, 0.34, 0.52, and 0.71 m, respectively, found in *A. procera, D. regia, L.speciosa, S. cumini*, and *T. arjuna,* respectively (Table 1). The maximum mean annual diameter increment (MADI) and mean annual height increment (MAHI) were found in *A. procera* and *T. arjuna.* The statistical analysis revealed that the values varied significantly ($p < 0.05$) among the five tree species at the same age.

The main objectives of the study were to determine the biomass and carbon content of the following species. The total biomass and carbon of five selected timber species at the same ages are shown in Table 2. The results revealed that the total biomass values were 1339.64, 1006.12, 431.24, 1051.52, and 1240.85 kg for *A. procera*, *D. regia*, *L. speciosa*, *S. cumini*, and *T. arjuna*, respectively (Table 2). The highest biomass was observed in *A. procera*, and the lowest in *L. speciosa*. The results showed that the total carbon storage values were 669.82, 503.06, 215.62, 525.76, and 620.43 kg for *A. procera*, *D. regia*, *L. speciosa*, *S. cumini*, and *T. arjuna,* respectively (Table 2). The highest total carbon was found in *A. procera*, while the lowest in *L. speciosa*. All trees were similarly aged (25 years), biomass variation among species was significant ($P < 0.05$).

Table 2. Aboveground, belowground, total biomass, aboveground, belowground, and total carbon of five tree species.

Name of spp.	AGB (kg)	BGB (kg)	TB (kg)	AGC (kg)	BGC (kg)	TC (kg)
Albizia procera	267.93	1071.71	1339.64^{a}	133.96	535.86	669.82^{a}
Delonix regia	201.22	804.90	1006.12^{b}	100.61	402.45	503.06^{b}
Lagerstroemia speciosa	86.25	344.99	431.24^{d}	43.12	172.50	215.62^{d}
Syzygium cumini	210.30	841.22	1051.52^{b}	105.15	420.61	525.76^{b}
Terminalia arjuna	248.17	992.68	1240.85^{a}	124.09	496.34	620.43^{a}

*AGB; Aboveground biomass, BGB: Belowground biomass, TB: Total biomass, AGC: Aboveground carbon, BGC: Belowground carbon, and TC:Total carbon

The present study indicated that the average carbon storage values were 26.79, 20.12, 8.62, 21.03, and 24.82 kg tree^{-1}year^{-1} for *A. procera*, *D. regia*, *L. speciosa*, *S. cumini,* and *T. arjuna,* respectively, at 25-year-old trees (Table 3). A single *A. procera* captured 98.33 kg carbon dioxide tree^{-1}yea^{r-1} from the atmosphere and released 71.78 kg oxygen tree^{-1} year^{-1}, the highest amount of carbon dioxide captured and oxygen released in the atmosphere (Table 3). In this case, *L. speciosa* captured only 31.65 kg carbon dioxide per tree^{1} year^{1} from the atmosphere and released only 23.11 kg oxygen per tree^{-1} year^{-1}.

Table 3. Carbon storage, capturing CO_2 and releasing O_2 tree^{1}year^1 of five trees species.

Name of spp.	Carbon storage tree^{-1}year^{-1}(kg)	Capturing CO_2 tree^{-1}year^{-1}(kg)	Releasing O_2 tree^{-1}year^{-1}(kg)
Albizia procera	26.79^a	98.33^a	71.78^a
Delonix regia	20.12^c	73.89^c	53.91^b
Lagerstroemia speciosa	8.62^d	31.65^d	23.11^d
Syzygium cumini	21.03^c	77.18^c	56.34^c
Terminalia arjuna	24.82^b	91.08^b	66.49^b

The findings revealed that species significantly differed in carbon storage, carbon dioxide capture, and oxygen release at the same ages. The main aims of the research were to determine the carbon storage capacity of five planted tree species. Table 3 shows the carbon storage capacity of each tree species at the same age. Therefore, selecting high carbon-capturing tree species for large-scale plantation programmes should be prioritized, as they can play a crucial role in mitigating global warming. Typically, biomass variations were observed among species, with different values recorded within the same age groups of *Dipterocarpus turbinatus*, *Gmelina arborea*, *Acacia auriculiformis*, *Swietenia macrophylla*, *Lagerstroemia speciosa*, and *Tectona grandis* (Rahman *et al*. 2019). Another study on Bodamalai hill tree species indicated that the *Albizia amara* shared maximum carbon stock followed by *Ficus benghalensis*, *Euphorbia antiquorum*, *Tamarindus indica*, and *Strychnos potatorum* (Pragasan 2015). Variations in biomass values among tree species may result from factors such as site conditions and silvicultural management (Suryawanshi *et al*. 2014). Ecological factors, including significant differences in tropical deciduous and mixed deciduous forest trees, also influence biomass variation (Salunkhe *et al.* 2016). In addition, elevation plays a vital role in biomass variation (Thokchom and Yadav 2017). Several scientists have reported that biomass is significantly affected by stem size, distribution, soil fertility, and topography (Pragasan 2014, Murthy *et al*. 2016). Notably, the present findings also demonstrate considerable variations.

The present study examined five tree species to assess their biomass and carbon sequestration capacities at the same ages and under nearly the same environmental conditions. The highest biomass was observed in *A. procera*, while the lowest in *L. speciosa*. The findings suggest a significant potential for carbon storage in large plantations, which could help to mitigate the effects of global warming. Additionally, these results will aid researchers, scientists, and planners involved in implementing plantation programmes in Bangladesh. However, these findings are not sufficient to be generalized to the entire country. Further research is necessary to determine the carbon storage capacity of various tree species, which will inform future large-scale plantation initiatives. Planting high carbon-capturing tree species is vital for climate change mitigation, as it plays a key role in reducing environmental impacts and fostering sustainable development.

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