RESEARCH ARTICLE

Carbon Sequestration Potentials for Conservation of Sheikh Russel Aviary and Eco-Park, Rangunia, Chittagong

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Received: 02 May, 2024, Accepted: 23 June, 2024, Published: 27 June, 2024

Abstract

The study investigates the carbon sequestration potential of tree species in the Sheikh Russel Aviary and Eco-Park, situated in diverse natural settings. Utilizing quadrate sampling, the study selected plot sizes of 26*26 m based on tree species diversity. Employing a Randomized Block design with nine blocks, three plots were laid out for each block, categorized as Top, Middle, and Bottom according to hill altitude. Soil samples were collected at depths of (0-15cm) and (15-35cm) for calculating soil organic carbon and moisture content through the loss of ignition method. Enumerating 781 trees from 27 families within 27 quadrates, the survey revealed total volume, basal area, biomass, and carbon sequestration potential, with *Acacia auriculiformis* displaying the highest Importance Value Index (IVI). Notably, *Acacia auriculiformis*, *Tectona grandis* and *Gmelina arborea* exhibited the highest carbon sequestration potentials, contributing significantly within specific diameter and height classes. The study further assessed soil organic carbon content and moisture levels, providing a comprehensive overview of the ecological contributions of the studied area.

Keywords: Carbon Sequestration; Sheikh Russel Aviary; Eco-Park; Allometric Model; Importance Value Index

Introduction

The ongoing industrial revolution and escalating urbanization in the modern world are contributing to the heightened concentration of greenhouse gases (GHGs), notably methane (CH_4) and carbon dioxide (CO_2), in the atmosphere (Hangarge et al., 2012 and Nowak & Crane, 2002). The escalating carbon emissions stand as a paramount concern in today's context, a concern that was comprehensively addressed in the Kyoto Protocol, recognizing it as a primary causal factor for global warming (Ullah & Al-Amin, 2012). Forest ecosystems, encompassing 62% to 78% of the total terrestrial carbon, play a pivotal role in influencing the response to rising atmospheric CO_2 concentrations, thereby impacting the global carbon cycle (Hagedorn et al., 2002). International studies (Aryal et.al, 2020), particularly by the Intergovernmental Panel on Climate Change (IPCC, 2007), extensively document evidence linking climate change to human-induced increases in GHG concentrations. In this context, the role of green trees becomes imperative, given their high potential for tapping atmospheric carbon through photosynthesis (Hangarge L.M et al., 2012). The sequestered carbon, stored in plant tissues(Siddique et al., 2024), facilitates growth (Grogan & Matthews, 2002). Forests are accredited as natural brakes on climate change due to their ability to sequester and store carbon (Islam et al., 2016). Global estimates from the Forest Resources Assessment indicate that the world's forests alone store 289 Gigatons of carbon in their biomass.

Recognizing the crucial role of forests in mitigating climate change(M.S. et.al, 2020, Nelson. et al.,2008;NOAA,2008), many countries have initiated assessments to enhance and maintain carbon sequestration in their forest resources (Kaul et al., 2010).The Food and Agriculture Organization (FAO, 2001) proposes three strategies for forest carbon management(Nowak et. al.,2002; Ram Oren et al.,2001; Ravindranath et. al.,2007):creating carbon sinks, (Miah et al., 2011; Mignone et al.,2008) minimizing carbon release rates, and reducing fossil fuel demand. The Kyoto Protocol involves Bangladesh in an atmospheric greenhouse gas reduction regime through its Clean Development Mechanism (CDM) concept (Schlesinger et al., 2001; Schnell.et.al, 2014; Scotcher, 2005). This allows for the generation of carbon credits from natural forests and afforestation/reforestation activities in developing countries(Yong Shin et al., 2007;Simon et al.,2018; Chowdhury et al., 2023, 2024).However, challenges exist in Bangladesh, where a significant portion of forest land lacks satisfactory tree cover (Talukdar et al., 2020). Hilly forests face severe degradation due to overpopulation, shifting cultivation, and agricultural expansion, leading to a substantial loss of natural forest (Yong Shin et al., 2007).Despite these challenges, Bangladesh, with its substantial pool of existing bare hills, has the potential to play a major role in mitigating global warming and earning carbon credits (Simiele et al., 2022).Additionally, communities can derive various benefits from forests, such as adapting to climate change, conserving natural resources (Srinivasan et. al.,2008; US EPA,2015), and promoting sustainable development. Integrating existing forest management strategies with climate change through carbon sequestration becomes crucial at this juncture (Islam et al., 2016; Yong Shin et.al, 2007).

Biomass holds a pivotal position in forest stand productivity, and understanding the relationship between biomass carbon and biodiversity parallels that of biodiversity and ecosystem function. Amid global efforts to reduce global warming(K. N. Islam et al., 2020), strategies aimed at absorbing CO_2 from the atmosphere and sequestering it in terrestrial ecosystems gain significant attention. Developing countries, facing challenges in supporting forest conservation and afforestation, can potentially benefit from ecotourism, which offers a sustainable approach to tourism accommodations(Ghale et al., 2022). Harnessing tourism to generate national and regional revenue, while simultaneously contributing to global warming mitigation, introduces new perspectives to various business sectors associated with tourism, such as transportation, entertainment, and accommodation(Mamun et al., 2022). Initiatives promoting tourism's contribution to global warming mitigation have been developed with the aim of establishing a mutually beneficial relationship between tourism and climate change (Bookbinder et al., 1998 and Kiper, 2013).

While discussions often focus on minimizing carbon emissions from tourism activities, few address the positive contribution of tourism activities to absorbing and storing carbon (Wabnitz et al., 2018). The overarching objective of this project paper is to quantify sequestered carbon, assess people's opinions, and evaluate the potential of eco-tourism at Sheikh Russel Aviary and Eco-park. The study aims to measure the total carbon sequestration of tree species and explore the relationship between carbon sequestration potential and tree species diversity.

Materials and methods

Experimental design for quantitative enumeration of tree species

"Sheikh Russel Aviary and Eco-Park, Rangunia" is situated at Nischintapur Mouza of Kudala beat in Rangunia Range, Chittagong district, under the jurisdiction of Chittagong South Forest Division, near the border of the hill tracts. Covering an area of 210.0 ha, it is positioned between 22°18' and 22°37' north latitudes and 91°58' and 92°08' east longitudes. The project is approximately 35.0 km east of Chittagong city, close to the Chittagong-Kaptai Highway, neighboring Chandraghona town, and the well-known Karnafuly paper mill and Kaptai hydroelectricity project (Rahman et.al. 2022). Data collection followed a Randomized Block design, as illustrated in (Figure 1). The study area was divided into 9 blocks (Mamun et.al.,2020), and three plots were established for each block, categorized as Top, Middle, and Bottom based on the altitude of hills(Hossain et al., 2020,2015; I. Islam et al., 2022; Uddin et al., 2020).Plot size determination utilized the quadrate sampling method, with a sampling plot size estimated at 26m * 26m (Figure 1).

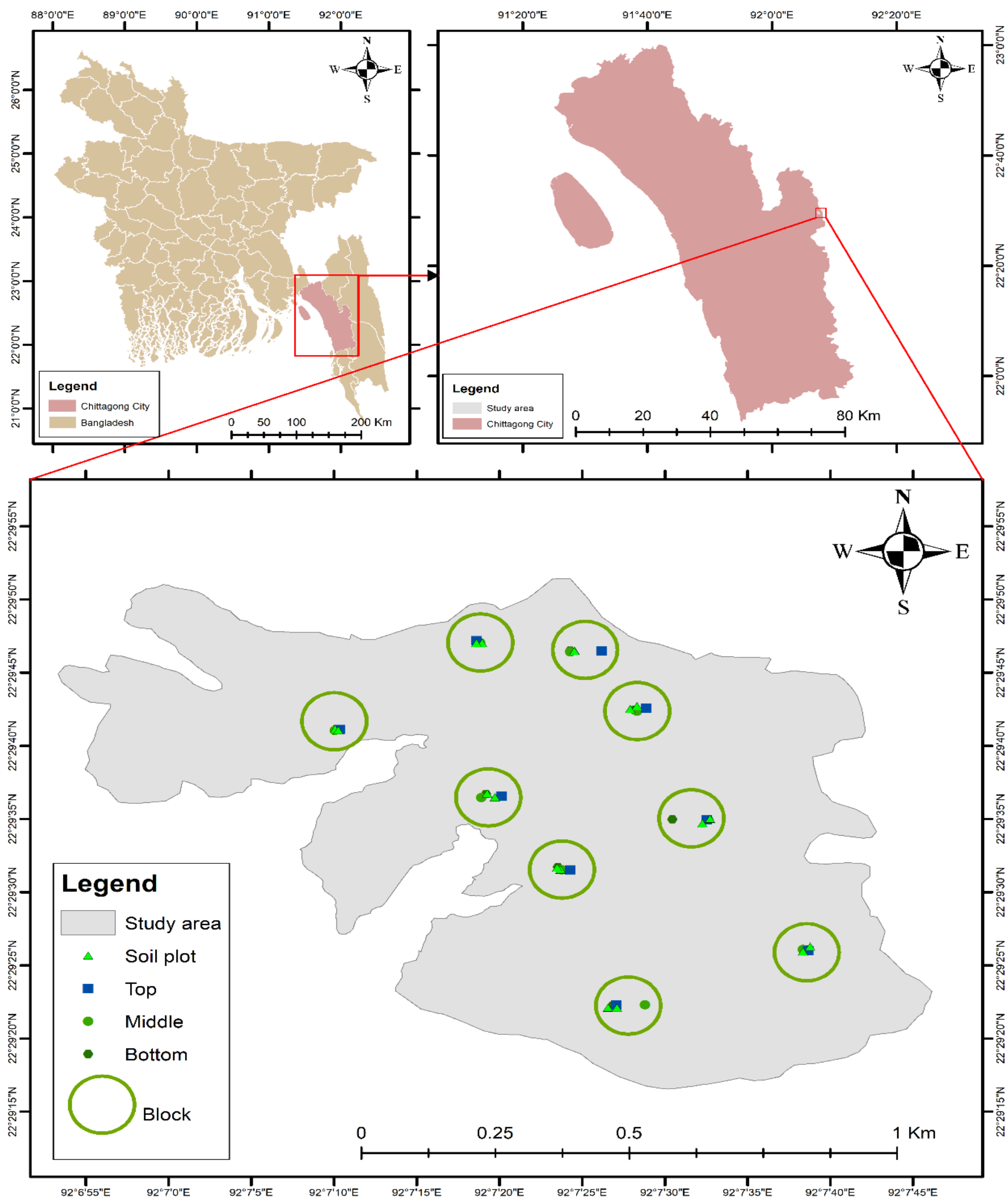

Figure 1: Map of blocks of Sheikh Russel Aviary and Eco-Park.

Soil data collection

Figure 01, From the 9 blocks, 18 plots were selected, and two soil samples were collected from each plot at depths of (0-15 cm) and (15-35 cm) from the top and bottom of the hills. Soil organic carbon was determined using washed silica crucibles, which were dried in an oven at 105°C for 20 minutes. Oven-dried soil was ground, and 5g of the ground soil was placed in silica crucibles and weighed using an electric balance (Mamun et.al.,2020). The crucibles with soil were then transferred to an electric furnace, ignited at 850°C for 3 hours, cooled in a desiccator, and reweighed to determine the percentage loss of ignition (%LOI). LOI was expressed relative to the weight of oven-dry soil, and the percentage of moisture was relative to the weight of field-moist soil, calculated according to the formula (Wang et al., 2013 and Ullah & Al-Amin, 2012).

Results and discussion

Phytosociological characters of tree species

The study conducted at Sheikh Russel Aviary and Eco-Park in Bangladesh recorded a total of 50 tree species, highlighting a diverse range of flora within the area. Among these, *Acacia auriculiformis* exhibited the highest Importance Value Index (IVI) of 62.14, indicating its dominance in the ecosystem. This species was followed by *Tectona grandis* with an IVI of 44.01 and *Gmelina arborea* with an IVI of 30.54(Figure 2), underscoring their significant presence and ecological roles. The study also detailed the distribution of species among various botanical families. Families such as Verbenaceae (223 individuals), Mimosaceae (183), Combretaceae(62), Moraceae(83), Euphorbiaceae(28), Myrtaceae(40), and Tiliaceae (22) were particularly well-represented in the park. These families are noted for their adaptability to the local environment and their ability to sequester substantial amounts of carbon, contributing to the park's overall carbon sequestration capacity. A significant portion of the tree species (381 individuals) were found in the diameter at breast height (DBH) range of 5-15 cm, comprising approximately 48.8% of the total tree species recorded. This DBH class is crucial as it includes young to mature trees that play a vital role in carbon storage and the ecological stability of the area (Islam et al., 2016). The prevalence of trees in this DBH range suggests a relatively young forest structure, which is often indicative of active growth and dynamic ecological processes. In terms of height distribution, the majority of the tree species fell within the height class of 7.1 to 17 meters (Talukdar et al., 2020).

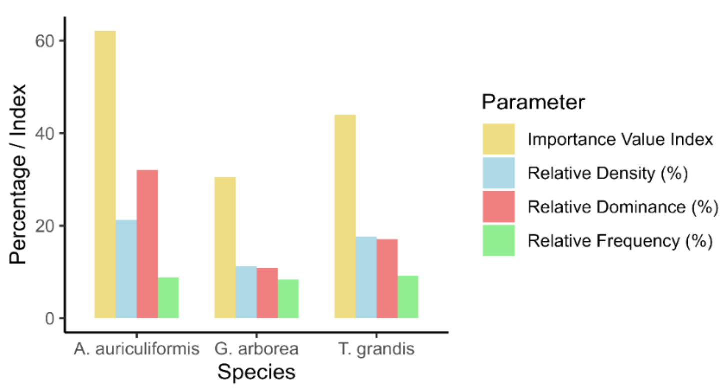

Figure 2: Importance value index (IVI) of the top three tree species in Sheikh Russel Aviary and Eco-park

This height class included 44 individual tree species and a total of 346 tree species, making up around 44.3% of the total tree population in the study area. The dominance of trees in this height range further emphasizes the park's role in carbon sequestration, as taller trees generally have a larger biomass and thus a greater capacity for carbon storage(Siddique et al., 2024). The study's findings underscore the ecological importance of Sheikh Russel Aviary and Eco-Park in terms of biodiversity and carbon sequestration. The presence of diverse species and significant numbers of trees in various DBH and height classes highlights the park's potential as a carbon sink, contributing to climate change mitigation efforts(Wang et al., 2013 and Ullah & Al-Amin, 2012). The data on IVI, DBH, and height distribution provide valuable insights into the structure and composition of the forest, which can inform conservation and management strategies aimed at enhancing the park's ecological functions. In addition to its role in carbon sequestration, the diversity of tree species and families within the park supports a wide range of ecological processes and services. These include habitat provision for various wildlife species, soil stabilization, water regulation, and nutrient cycling. The presence of species from different families also indicates a resilient ecosystem capable of withstanding environmental changes and disturbances (Talukdar et al., 2020). However, the study also points to the need for ongoing monitoring and management to maintain and enhance the ecological health of the park (Table 1). This includes efforts to protect and promote the growth of young trees, manage invasive species, and ensure sustainable tourism practices (Wang et al., 2013 and Ullah & Al-Amin, 2012). The high IVI values of certain species suggest that they are particularly well-suited to the local conditions and may be prioritized in future afforestation and conservation efforts(Siddique et al., 2024). Overall, the study provides a comprehensive overview of the tree species composition and structure within Sheikh Russel Aviary and Eco-Park, highlighting its significant role in carbon sequestration and biodiversity conservation. The detailed analysis of IVI, DBH, and height distribution offers a foundation for further research and management initiatives aimed at preserving and enhancing the ecological value of this important natural area.

Table 1: Relative frequency (RF), relative density (RD), basal area/ha (BA in m^2), relative dominance (RDo) and importance value index (IVI) of trees at Sheikh Russel Aviary and Eco-park, Bangladesh.

Species Name	RD (%)	RF (%)	RDo (%)	IVI
Acacia auriculiformis A. Cunn.	21.25	8.79	32.09	62.14
Tectona grandis L.f.	17.67	9.21	17.14	44.01
Gmelina arborea Roxb.	11.27	8.37	10.90	30.54
Artocarpus heterophyllusLam	7.04	2.93	5.57	15.54
Terminalia arjuna (Roxb.ex DC.)	4.74	2.93	3.72	11.39
Artocarpus chama Buch.-Ham.	3.33	5.02	2.84	11.19
Syzygium cumini (L.) Skeels	3.46	5.02	1.81	10.29
Terminalia bellerica (Gaertn.)	2.94	3.35	2.81	9.10
Grewia nervosa (Lour.) Panigr.	2.56	3.77	2.70	9.03
Protium serratum (Wall. Ex Coelbr.) Engl.	2.30	2.93	1.71	6.95

Biomass and carbon sequestration potentials and relation with tree species diversity

A total of 781 trees were observed to estimate biomass and carbon sequestration potentials, with measurements of 102.774 (t/ha) for biomass and 51.387 (t/ha) for carbon sequestration (Table 02 and 03) in the surveyed area. The study delved into the relationship between carbon sequestration potentials within height and DBH classes of all tree species, identifying *A. auriculiformis* and Teak as dominant species in carbon sequestration (Table 2). An allometric model was utilized to calculate the biomass of individual tree species, ensuring a non-destructive and accurate method for biomass estimation (Talukdar et al., 2020). Carbon sequestration potential varied across DBH and height classes, with larger DBH and height classes demonstrating higher carbon sequestration potentials. The study also highlighted the dominance of *A. auriculiformis* and Teak in sequestering the highest carbon within specific DBH and height classes (Wang et al., 2013 and Ullah & Al-Amin, 2012).

Table 2: Total biomass and carbon sequestration potential for top 9 tree species at Sheikh Russel Aviary and Eco-park, bangladesh

Species	Biomass(kg)	TAGB(t/ha)	BGTB(t/ha)	TTB(t/ha)	CSP(t/ha)
Acacia auriculiformis A. Cunn.	166	28.49	7.41	35.89	17.95
Tectona grandis L.f.	138	16.05	4.17	20.23	10.11
Gmelina arborea Roxb.	88	7.41	1.93	9.33	4.67
Artocarpus heterophyllusLam	55	3.48	0.90	4.38	2.19
Terminalia arjuna (Roxb.ex DC.)	37	2.78	0.72	3.50	1.75
Artocarpus chama Buch.-Ham.	23	2.57	0.67	3.23	1.62
Syzygium cumini (L.) Skeels	26	2.15	0.56	2.71	1.35
Terminalia bellerica (Gaertn.)	13	1.85	0.48	2.34	1.17
Grewia nervosa (Lour.) Panigr.	20	1.78	0.46	2.24	1.12
Protium serratum (Wall. Ex Coelbr.) Engl.	18	1.57	0.41	1.98	0.99

Note: Tree above ground biomass calculated as following below formula (Mahmood et al., 2020), Ln (TAGB) = -6.6937+ 0.809*Ln (D2 *H*W). 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); (Islam et al., 2016): BGTB = AGB × 0.26. TTB) = AGTB + BGTB(Sheikh et al., 2011) and CSP = TTB × 50%(Pearson et al., 2005) and Islam et al., 2016)

Soil carbon sequestration, moisture, and organic carbon variability

In this study, we analyzed the carbon sequestration potential (CSP), soil moisture content (SMC), and soil organic carbon (OC) across various blocks, with measurements taken at different soil depths (Top, Middle, and Bottom). CSP, quantified in metric tons per hectare (t/ha), serves as an indicator of the soil's ability to sequester carbon dioxide (CO_2), thus contributing to climate change mitigation. SMC, expressed as a percentage, reflects the water content within the soil (Chowdhury et.al. 2007), which is critical for supporting plant growth and influencing both biological and chemical processes. OC, also expressed as a percentage, represents the concentration of carbon in the soil's organic matter, an essential component for maintaining soil fertility and overall soil health (Islam et al., 2016).Soil samples were systematically collected from 18 plots, with two samples taken from each plot at specified depths: Top (0-15 cm) and Bottom (15-35 cm). The determination of OC was carried out following a standard protocol: washed silica crucibles were initially dried at 105°C for 20 minutes, cooled in desiccators, and weighed (Talukdar et al., 2020). Oven-dried soil samples were then ground, and exactly 5 grams of the ground soil were placed in the crucibles (Barna, 2011), which were subsequently weighed (Islam et al., 2016). The crucibles containing the soil samples were transferred to an electric furnace, where they were ignited at 850°C for 3 hours(Siddique et al., 2024). After cooling (Table 3), the crucibles were weighed again to calculate the percentage loss of ignition (LOI). The OC was then calculated using the formula OC = 0.476 * (%LOI - 108), as referenced in studies by Wang et al. (2013) and Ullah & Al-Amin (2012).The results indicated significant variability in CSP, SMC, and OC across the different blocks and soil depths. CSP values ranged from 1.03 to 4.55 t/ha, highlighting differences in carbon storage capacity across the study area. SMC varied significantly between the Top and Bottom soil layers, reflecting differing moisture retention capabilities(Siddique et al., 2024). OC levels also showed considerable variation both within and between blocks, indicating differences in the soil's organic matter content. These findings underscore the importance of spatial and vertical variability in soil properties, which are critical for understanding and managing the potential for carbon sequestration and overall soil health in the study region.

Table 3: Carbon sequestration potential, Soil moisture content (%) and soil organic carbon (%) as Block wise

	CSP(t/ha)			SMC (%)		OC (%)	
	Top	Middle	Bottom	Top	Bottom	Top	Bottom
Block 1	1.11	1.17	2.74	16.39	19.57	0.57	1.67
Block 2	1.72	4.55	2.47	21.45	14.97	1.57	1.81
Block 3	2.68	1.51	2.82	16.94	18.12	1.71	1.71
Block 4	2.33	1.03	1.51	16.83	15.45	1.24	0.62
Block 5	1.09	1.60	1.54	17.08	20.37	2.05	1.95
Block 6	1.49	1.05	1.77	17.71	36.92	1.57	1.67
Block 7	1.61	1.89	1.94	19.97	19.71	1.48	2.05
Block 8	2.24	1.37	1.43	18.27	14.19	1.09	1.09
Block 9	1.99	2.06	2.70	17.28	15.98	1.19	1.38

Note: Carbon sequestration potential(CSP),Soil moisture content(SMC),Organic carbon(OC), For determine soil organic carbon, washed silica crucibles were dried in oven dry at 105◦ C for 20 minutes, cooled in desiccators and then weight were taken. Oven dry soil were grind by pistol and then exactly 5g of grind soil were kept in silica crucibles and weighted by electric balance. The crucibles with soil were then transferred to an electric furnace for igniting at 850◦C for 3 hours. Then crucibles with soil were cooled in a desiccators and reweight to determine the percent loss of ignition (%), Organic carbon=0.476*(%LOI-108) (Wang et al., 2013 and Ullah & Al-Amin, 2012). 18 Plots were selected for collection of soil sample. From each plots 2 soil samples were collected according to soil depth such as Top (0-15 cm) and Bottom (15-35 cm) to determine soil organic carbon.

Conclusion

The study identifies *Acacia auriculiformis*, *Tectona grandis*, *Gmelina arborea*, *Artocarpus heterophyllus*, *Terminalia arjuna*, and *A. heterophyllus* as key tree species in Sheikh Russel Aviary and Eco-Park, Bangladesh, for carbon sequestration, with rates ranging from 17.946 to 1.354 t/ha. These species are notably dominant in height classes of 12.1-17m and DBH classes of 15.1-25cm, playing a critical role in carbon storage and overall ecosystem health. With average soil organic carbon at 1.46% and moisture content at 18.73%, the study highlights the park's significant contribution to mitigating carbon emissions through afforestation and underscores the value of species diversity in enhancing carbon sequestration. It also suggests broadening research to include understory vegetation and soil carbon for a comprehensive understanding of the park's carbon storage potential, emphasizing the need for sustainable management that balances conservation with tourism. The selection of these species is strategic, considering their growth characteristics and adaptability to the local climate. *Acacia auriculiformis* and *Tectona grandis* are fast-growing species with high carbon sequestration potential, ideal for rapid afforestation. *Gmelina arborea* and *Artocarpus heterophyllus* not only store carbon but also support local biodiversity. The inclusion of *Terminalia arjuna*, known for its medicinal properties, adds ecological value by promoting a diverse habitat for various wildlife species.

The study's findings on soil organic carbon and moisture content are critical for understanding the broader ecosystem dynamics within the park. High levels of soil organic carbon indicate healthy soil, essential for sustaining plant growth and enhancing the forest's overall carbon sequestration capacity. The relatively high moisture content suggests favorable conditions for tree growth, supporting a dense and diverse canopy that enhances carbon sequestration. However, the study acknowledges several limitations that may affect the generalizability and completeness of its findings. One significant limitation is the exclusion of understory vegetation and soil carbon measurements. These components are crucial for understanding the total carbon sequestration potential, as they play significant roles in carbon cycling and nutrient turnover within forest ecosystems. Another limitation is the focus on specific tree species, potentially overlooking the contributions of less dominant species, which are important for maintaining ecosystem diversity and resilience. Additionally, the use of allometric equations for estimating carbon sequestration may introduce uncertainties, as these generalized models may not fully capture species-specific growth patterns and biomass accumulation. The study's emphasis on the park's carbon sequestration potential as a climate change mitigation strategy may also overlook other important ecosystem services, such as biodiversity conservation, water regulation, and soil protection. This focus could lead to management practices that prioritize certain species or approaches at the expense of overall ecological health. Future research should address these limitations to provide a more holistic understanding of the park's ecological contributions and to inform balanced conservation strategies.

Declaration

Acknowledgment: The Divisional Forest Officer, Cox’s Bazar Forest Division, Bangladesh provided necessary support during the field works.

Funding: Self-financed

Conflict of interest: No conflict of Interest

Ethics approval/declaration: This study did not involve human participants or animals, and ethical approval was not required. The research focused on plant carbon sequestration and was conducted in compliance with institutional guidelines for ecological and environmental research. All necessary permits for plant sampling and data collection were obtained from the relevant authorities where applicable.

Consent to participate: Not applicable. This research did not involve human participants, so no consent to participate was required.

Consent for publication: Not applicable. This study did not involve any individuals or identifiable data that would require consent for publication.

Data availability: Data sharing is not applicable to this article as no new data were created or analyzed in this study. The data that support the findings of this study are available from the author, [Mohd Imran Hossain Chowdhury], upon reasonable request.

Author’s contribution: Mohd Imran Hossain Chowdhury: Designed the study, performed data analysis, wrote the initial draft, and contributed to the final manuscript revision. Chinmoy Das: Conducted the experiments, contributed to data analysis, and reviewed the manuscript.

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