



Biomass estimation and carbon storage in tree species of the Chandra Sal Forest Ecosystem at Gazipur, Bangladesh

Sadia Jannat Mim, Mohammad Mahfuzur Rahman, Gazi Mosharof Hossain, M d Asaduzzaman

Department of Botany, Plant Ecology and Environment Laboratory, Jahangirnagar University, Savar, Dhaka, Bangladesh

DOI: <https://doi.org/10.66856/ijeec.2026.8.2.8044>

Abstract

Estimation of biomass and carbon stored by the tree species in the Chandra Sal forest ecosystem at Gazipur district, Bangladesh, was conducted during 2024 to 2025. Present study included the estimation of aboveground tree biomass (AGTB), belowground tree biomass (BGTB), total tree biomass (TTB), and total tree carbon (TTC) across five selected sites of the said forest ecosystem. The recorded values of AGTB, BGTB, TTB, and TTC were 144.99 tonh⁻¹, 28.99 tonh⁻¹, 173.99 tonh⁻¹ and 81.78 tonh⁻¹ respectively, in Site A; 55.39 tonh⁻¹, 11.08 tonh⁻¹, 66.48 tonh⁻¹ and 31.25 tonh⁻¹ respectively, in Site B; 44.35 tonh⁻¹, 8.87 tonh⁻¹, 53.22 tonh⁻¹ and 25.02 tonh⁻¹ respectively, in Site C; 41.33 tonh⁻¹, 8.27 tonh⁻¹, 49.59 tonh⁻¹ and 23.31 tonh⁻¹ respectively, in Site D; and, 37.22 tonh⁻¹, 7.44 tonh⁻¹, 44.66 tonh⁻¹ and 20.99 tonh⁻¹ respectively, in Site E. The results showed remarkable variation, with AGTB ranging from 37.22 tonh⁻¹ to 144.99 tonh⁻¹, BGTB from 7.44 tonh⁻¹ to 28.99 tonh⁻¹, TTB from 44.66 tonh⁻¹ to 173.99 tonh⁻¹, and TTC from 20.99 tonh⁻¹ to 81.78 tonh⁻¹. The highest AGTB value of 144.99 tonh⁻¹ was recorded from Site A, whereas the lowest value of 37.22 tonh⁻¹ was recorded from Site E. Similarly, the highest BGTB value of 28.99 tonh⁻¹ was recorded from Site A, whereas the lowest value of 7.44 tonh⁻¹ was recorded from Site E. Furthermore, the highest TTB value of 173.99 tonh⁻¹ was recorded from Site A, whereas, the lowest TTB value of 44.66 tonh⁻¹ was recorded from Site E. Thus, the highest TTC value 81.78 tonh⁻¹ was recorded from Site A, whereas, the lowest TTC value of 20.99 tonh⁻¹ was recorded from Site E. Chandra Sal forest ecosystem exhibited comparatively lower biomass and carbon storage than other previously studied Sal forest ecosystems of Bangladesh, primarily due to the prevalence of trees with smaller diameter and height, as well as habitat degradation, deforestation, and increasing encroachment by local inhabitants living in the vicinity of forest areas. Despite these lower values, the forest still demonstrates considerable potential as a natural green carbon sink, highlighting its importance in forest-based local climate mitigation planning. Improvement of stand structure through natural regeneration and reducing anthropogenic pressure are strongly recommended to enhance biomass accumulation and carbon storage through carbon sequestration in the studied forest areas.

Keywords: Tree biomass, carbon storage, Chandra Sal forests, Bangladesh

Introduction

Biomass refers to the mass of living organisms present within a specific area or ecosystem at a given time. It may represent the biomass of a particular species (species biomass) or the combined biomass of a habitat or biological community (community biomass) (IUPAC, 2006) [19]. Biomass is commonly expressed as fresh weight or, more accurately, dry weight per unit area or volume. It serves as a key indicator for assessing ecosystem productivity, carbon storage capacity, and energy transfer across trophic levels (Chapin *et al.*, 2011) [12]. Forest biomass refers to the total organic matter present in a forest ecosystem, including both living and dead plant materials such as trees, branches, leaves, roots, and stumps. The largest proportion of biomass in forest ecosystems is typically stored in standing trees, which may account for approximately 62–97% of the total biomass. Tree biomass includes both aboveground components (such as stems, branches, and foliage) and belowground components (such as root systems) (Brown, 1997) [9].

Carbon stock refers to the total quantity of carbon stored within a specific pool at a given time (FAO, 2011; IPCC, 2000) [14, 16]. In forest ecosystems, carbon is primarily sequestered through photosynthesis, whereby atmospheric carbon dioxide (CO₂) is converted into organic compounds and subsequently stored in plant biomass and soil (Alexandrov, 2007) [2]. Forests are widely recognized as

major carbon sinks, with the capacity to sequester 20–100 times more carbon per unit area than crop lands (Brown and Pearce, 1994) [7]. Consequently, forest vegetation and soils play a critical role in mitigating global climate change by reducing atmospheric CO₂ concentrations (Bajracharya *et al.*, 2018; Lal, 2004) [4, 21]. Forest ecosystems store substantial carbon pools in aboveground and belowground biomass as well as in soil organic matter (Brown and Lugo, 1992) [8]. Globally, forest vegetation and soils together account for nearly 60% of terrestrial carbon stocks (Winjum *et al.*, 1992) [36]. In addition to acting as carbon reservoirs, forests actively participate in the carbon cycle by exchanging carbon with the atmosphere through processes such as photosynthesis and respiration (Brown and Pearce, 1994) [7].

The tropical moist deciduous forest in Bangladesh is commonly referred to as “Sal forest” due to the dominance of Sal or Gojari (*Shorea robusta* Gaertn. f., family: Dipterocarpaceae). These forests are mainly distributed in the plainland areas of the central and north-western regions of the country. Approximately 86% of the total forest area is located in the central region, particularly in the districts of Dhaka, Mymensingh, Tangail, and Comilla, while the remaining 14% occurs in the north-western districts of Rangpur, Dinajpur, and Rajshahi (Alam *et al.*, 2008) [1].

Sal forests play a significant ecological role in capturing, transforming, and storing atmospheric carbon dioxide (CO₂)

in the form of biomass and soil organic carbon, thereby acting as important terrestrial carbon sinks. Through the process of photosynthesis, the dominant species *Shorea robusta* effectively sequesters atmospheric carbon and stores it in aboveground and belowground biomass pools. Consequently, Sal forest ecosystems contribute substantially to climate change mitigation and the reduction of global warming impacts (Brown and Lugo, 1992; Lal, 2004) [8, 21]. Due to their relatively high biomass accumulation potential, Sal forests are considered efficient carbon-storing ecosystems compared to many other tropical forest types, particularly in well-stocked stands (Pandey and Bhusal, 2016; Siddiqui and Lodhiyal, 2023) [24, 34]. However, anthropogenic activities including deforestation, forest degradation, urbanization, and fossil fuel consumption have significantly increased atmospheric carbon emissions. Notably, deforestation alone contributes approximately 20% of global carbon emissions (IPCC, 2006) [15], making it the second-largest source after fossil fuel combustion (Campbell *et al.*, 2008) [11]. Given their critical ecological functions, Sal forests not only contribute to carbon sequestration but also provide a wide range of ecosystem services, including timber, fuel wood, fodder, and biodiversity conservation. Therefore, the conservation and sustainable management of Sal forest ecosystems are essential for enhancing carbon sequestration potential and mitigating climate change at local, regional, and global

scales. However, limited information is available on its biomass and carbon storage potential, and no comprehensive inventory has been conducted to establish this baseline. Therefore, the present study aims to estimate the biomass and carbon storage potential of trees in the Chandra Sal forest ecosystem.

Materials and methods

Description of Study Area and Designing

The Chandra Sal Forest is situated in Gazipur District, approximately 40 km north of Dhaka, within the Madhupur Tract of central Bangladesh. This forest represents a significant portion of the country's Sal (*Shorea robusta*) forest ecosystem and falls under the administrative jurisdiction of the Chandra and Bowali Beats within the Kaliakair Range of the Dhaka Forest Division. Geographically, the study area extends between latitudes 23°58' to 24°15' N and longitudes 90°14' to 90°26' E (Islam *et al.*, 2021) [17]. The region is characterized by a tropical monsoon climate, with hot and humid summers and relatively mild winters. The mean annual rainfall ranges from 2,030 to 2,290 mm, and the average annual temperature is approximately 25°C (Anonymous, 1994; Shapla *et al.*, 2015) [3, 32]. On the basis of different administrative and ecological perspectives the study area was divided into five representative sites recognized as Site A, Site B, Site C, Site D, and Site E (Fig 1).

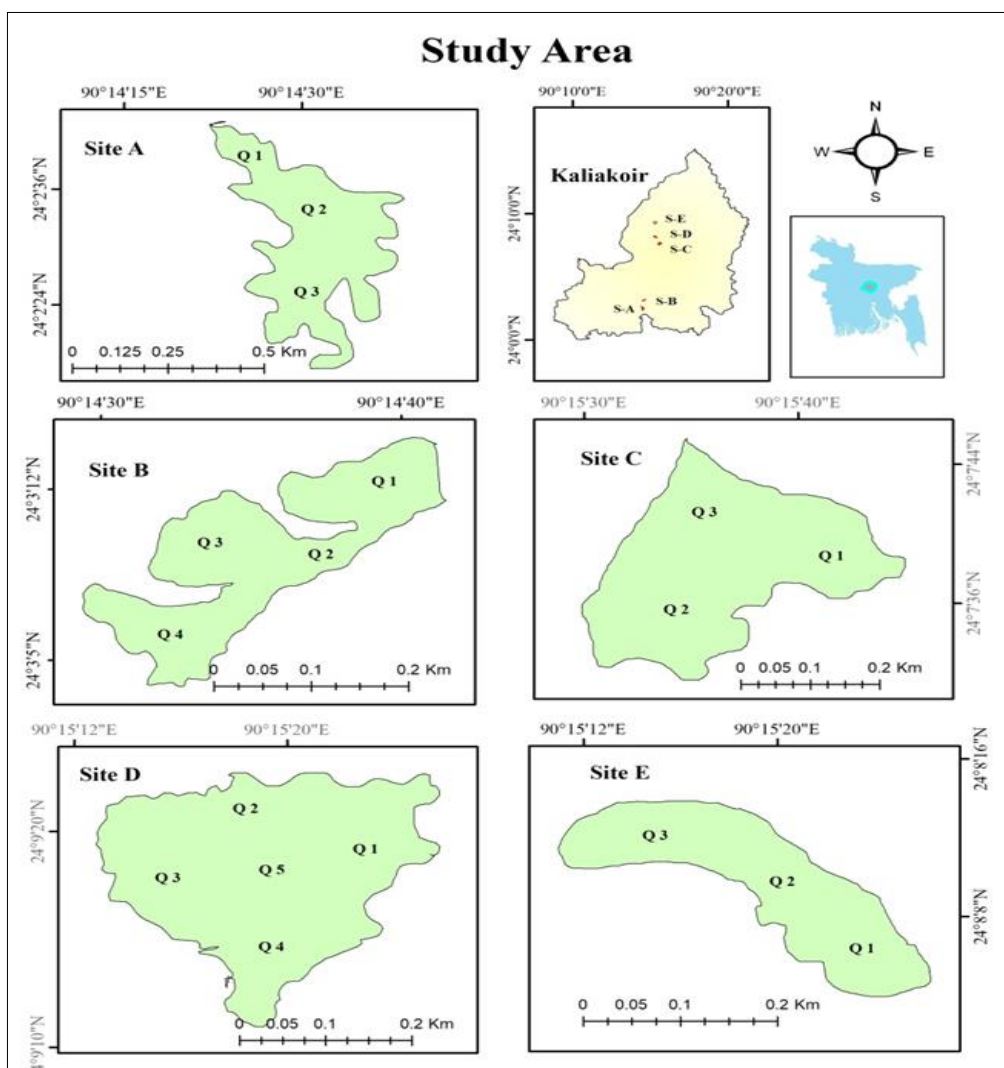


Fig 1: Map of the study area showing study sites of the Chandra Sal forest ecosystem

Data Collection and Analysis

Tree biomass data were collected using the standard quadrat method (Braun-Blanquet, 1932; Raunkiaer, 1934) [6, 27]. A quadrat size of 10 m × 10 m was selected based on the species–area curve method (Cain, 1938) [10] to ensure adequate representation of species composition. In this study, all individuals with a diameter at breast height (DBH) ≥ 5 cm were considered as trees. A non-destructive method was employed to measure key biophysical parameters, including DBH, total height, and stand density. Tree height was measured using a measuring pole or clinometer depending on tree size and field conditions, while diameter at breast height (DBH) was estimated from circumference at breast height (CBH). CBH of trees was measured directly by measuring tape. The DBH of the trees was then calculated by dividing the measured circumference by π (3.14), following the relation $DBH = CBH/3.14$. Measurements were taken for representative individuals within each sample plot. Species-specific wood density values (gcm^{-3}) were obtained from published databases and literature sources (i.e., Reyes, 1992; Sattar, 1981) [30, 31]. Aboveground biomass and carbon stock were subsequently estimated using established Allometric equations and standard procedures described in previous studies (i.e., Karki *et al.*, 2016; Mokany *et al.*, 2016; Ravindranath and Ostwald, 2008; Vashum and Jayakumar, 2012) [20, 22, 28, 35].

- Aboveground Tree Biomass (AGTB) = $0.0509 \times \rho D^2 H$
- Where, ρ = wood-specific density (kgm^{-3}); D = tree diameter at breast height (cm); H = tree height (m)
- Belowground Tree Biomass (BGTB) = $0.2 \times \text{AGTB}$
- Where, AGTB = Aboveground Tree Biomass
- Total Tree Biomass (TTB) = AGTB + BGTB
- Total Tree Carbon (TTC) = $\text{TTB} \times 0.47$

Results

Tree biomass data namely, diameter at breast height (DBH) and height (H) were documented from different geographical location of Chandra Sal Forest and wood specific density data were collected from literature to calculate the aboveground, belowground, total tree biomass, and total carbon storage. The calculated data were presented in Table 1, Fig 2 and Fig 3.

In Site A, a total of 12 tree species was recorded from the sampled quadrats for the estimation of aboveground, belowground, and total tree biomass. The accumulated data regarding total tree biomass and carbon storage at Site A have been presented in Table 1, Fig 2 and Fig 3. The total values of aboveground, belowground, total tree biomass, and total tree carbon storage at this site were recorded as 144.99 tonh^{-1} , 28.99 tonh^{-1} , 173.99 tonh^{-1} and 81.78 tonh^{-1} , respectively. The accumulated biomass data revealed that *Shorea robusta* Roxb. was the dominant species in terms of density and distribution within the sampled area, with a total tree biomass (TTB) of 36.12 tonh^{-1} . In contrast, several other species, including *Delonix regia* (Hook.) Raf., *Eucalyptus camaldulensis* Dehnh., *Peltophorum pterocarpum* (DC.) K. Heyne, *Senna siamea* (Lam.) H.S. Irwin & Barne exhibited considerable biomass accumulation despite being recorded in only a single quadrat. This

indicates a localized distribution pattern of these species within the study area. Although these species contributed measurable biomass at the quadrat level, their biomass estimates may not adequately represent the overall forest condition due to their restricted occurrence. Therefore, the biomass contribution of these species should be interpreted as site-specific rather than representative of the entire forest vegetation.

In Site B, a total of five tree species, were recorded within the sampled quadrats for the estimation of aboveground, belowground, and total tree biomass. The accumulated data regarding total tree biomass and carbon storage at Site B have been presented in Table 1, Fig 2 and Fig 3. The total values of aboveground, belowground, total tree biomass and total tree carbon storage at this site were recorded as 55.39 tonh^{-1} , 11.08 tonh^{-1} , 66.48 tonh^{-1} and 31.25 tonh^{-1} , respectively. The highest TTB was recorded for *Shorea robusta* Roxb. (65.23 tonh^{-1}), indicating that this species contributed most substantially to the total biomass at Site B.

In Site C, a total of eight tree species were recorded from the sampled quadrats for the estimation of aboveground, belowground, and total tree biomass. The accumulated data regarding total tree biomass and carbon storage at Site C have been presented in Table 1, Fig 2 and Fig 3. The total values of aboveground, belowground, total tree biomass and total tree carbon storage at this site were recorded as 44.35 tonh^{-1} , 8.87 tonh^{-1} , 53.22 tonh^{-1} and 25.02 tonh^{-1} , respectively. *Shorea robusta* Roxb. exhibited the highest total tree biomass (TTB) value of 37.82 tonh^{-1} and total tree carbon (TTC) values of 17.77 tonh^{-1} , indicating its dominance at this site in terms of biomass and carbon storage.

In Site D, a total of 12 tree species were recorded from the sampled quadrats for estimating the aboveground, belowground, and total tree biomass. The accumulated data regarding total tree biomass and carbon storage at Site D have been presented in Table 1, Fig 2 and Fig 3. The total values of aboveground, belowground, total tree biomass and total tree carbon storage at this site were recorded as 41.33 tonh^{-1} , 8.27 tonh^{-1} , 49.59 tonh^{-1} and 23.31 tonh^{-1} , respectively. *Shorea robusta* Roxb. exhibited the highest total tree biomass (TTB) value of 47.13 tonh^{-1} and total tree carbon (TTC) values of 22.15 tonh^{-1} , indicating its dominance at this site in terms of biomass and carbon storage.

In Site E, altogether 18 tree species were recorded from the sampled quadrats for estimating the aboveground, belowground, and total tree biomass. The accumulated data regarding total tree biomass and carbon storage at Site E have been presented in Table 1, Fig 2 and Fig 3. The total values of aboveground, belowground, total tree biomass and total tree carbon storage at this site were recorded as 37.22 tonh^{-1} , 7.44 tonh^{-1} , 44.66 tonh^{-1} and 20.99 tonh^{-1} , respectively. *Shorea robusta* Roxb. exhibited the highest total tree biomass (TTB) value of 30.20 tonh^{-1} and total tree carbon (TTC) values of 14.19 tonh^{-1} , indicating its dominance at this site in terms of biomass and carbon storage.

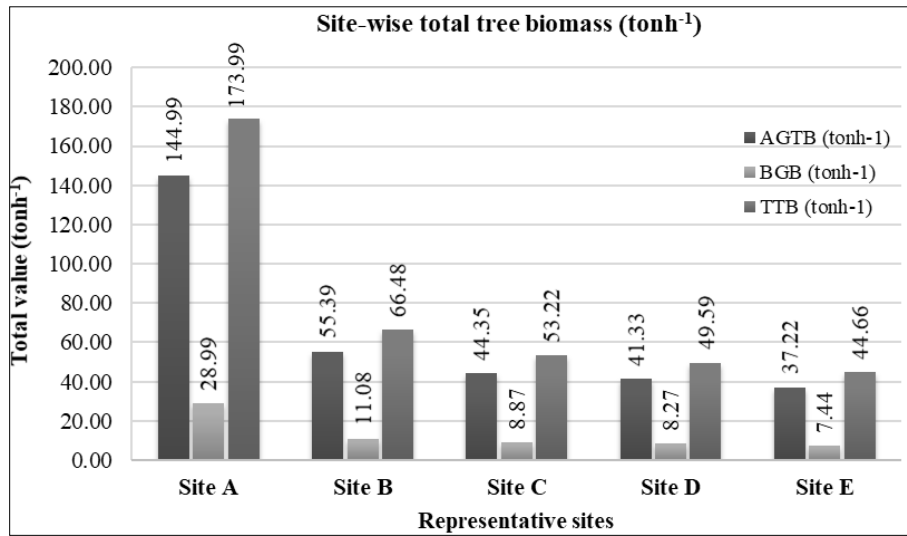


Fig 2: Site-wise aboveground, belowground and total tree biomass values (tonh⁻¹) recorded from the Chandra Sal forest ecosystem

Table 1: Values of aboveground, belowground, total tree biomass, and total tree carbon (tonh⁻¹) storage in the recorded trees at different selected sites of the Chandra Sal forest ecosystem during 2024-2025

Representative sites	Species name	ATH (m)	DBH (cm)	ρ (g/cm ³)	AGTB (tonh ⁻¹)	BGTB (tonh ⁻¹)	TTB (tonh ⁻¹)	TTC (tonh ⁻¹)
Site A	<i>Alstonia scholaris</i> (L.) R.Br.	21.34	63.66	0.290	4.254	0.851	5.105	2.399
	<i>Delonix regia</i> (Hook.) Raf.	21.34	54.11	0.500	15.89	3.180	19.08	8.967
	<i>Diospyros malabarica</i> (Desr.) Kostel.	10.67	35.97	0.630	1.475	0.295	1.770	0.832
	<i>Eucalyptus camaldulensis</i> Dehnh.	24.59	31.83	0.820	24.26	4.852	29.11	13.68
	<i>Lagerstroemia indica</i> L.	19.05	26.89	0.640	10.48	2.095	12.57	5.908
	<i>Mangifera indica</i> L.	16.76	47.75	0.540	3.502	0.700	4.202	1.975
	<i>Peltophorum pterocarpum</i> (DC.) K. Heyne	23.62	38.99	0.620	22.67	4.533	27.19	12.78
	<i>Senna siamea</i> (Lam.) H.S. Irwin & Barn.	23.37	40.45	0.750	24.81	4.962	29.77	13.99
	<i>Shorea robusta</i> Roxb.	18.79	23.37	0.720	30.09	6.019	36.12	16.98
	<i>Syzygium fruticosum</i> DC.	18.29	20.69	0.690	0.917	0.183	1.100	0.517
	<i>Tectona grandis</i> L. f.	27.43	46.15	0.650	6.443	1.289	7.732	3.634
	<i>Zanthoxylum rhetsa</i> (Roxb.) DC.	9.754	13.37	0.330	0.195	0.039	0.234	0.110
Total					144.99	28.99	173.99	81.78
Site B	<i>Alstonia scholaris</i> (L.) R.Br.	7.620	18.00	0.290	0.121	0.024	0.146	0.069
	<i>Albizia lebbeck</i> (L.) Benth.	16.76	22.00	0.600	0.826	0.165	0.991	0.466
	<i>Lannea coromandelica</i> (Houtt.) Merr.	2.438	7.000	0.670	0.027	0.005	0.033	0.015
	<i>Samanea saman</i> (Jacq.) Merr.	7.620	11.00	0.410	0.064	0.013	0.077	0.036
	<i>Shorea robusta</i> Roxb.	21.96	21.96	0.720	54.36	10.87	65.23	30.66
	Total				55.39	11.08	66.48	31.25
Site C	<i>Artocarpus chama</i> Buch. -Ham.	15.24	16.55	0.510	0.722	0.144	0.867	0.407
	<i>Dipterocarpus turbinatus</i> Gaertn. f.	13.26	15.44	0.650	1.743	0.349	2.092	0.983
	<i>Elaeocarpus floribundus</i> Blume	6.096	14.64	0.620	0.137	0.027	0.165	0.078
	<i>Ficus benghalensis</i> L.	15.85	30.56	0.500	3.767	0.753	4.520	2.124
	<i>Mangifera indica</i> L.	6.706	10.19	0.540	0.064	0.013	0.076	0.036
	<i>Shorea robusta</i> Roxb.	20.39	25.15	0.720	31.51	6.303	37.82	17.77
	<i>Swietenia mahagoni</i> (L.) Jacq.	14.48	13.37	0.580	1.019	0.204	1.222	0.574
	<i>Terminalia arjuna</i> (Roxb. ex DC.) Wight & Arn.	16.26	19.42	0.740	5.388	1.078	6.466	3.039
Total				44.35	8.87	53.22	25.02	
Site D	<i>Acacia auriculiformis</i> Benth.	5.486	11.14	0.570	0.066	0.013	0.080	0.037
	<i>Artocarpus heterophyllus</i> Lam.	4.572	7.639	0.750	0.034	0.007	0.041	0.019
	<i>Azadirachta indica</i> A. Juss.	7.315	12.73	0.760	0.153	0.031	0.183	0.086
	<i>Bridelia retusa</i> (L.) A. Juss.	4.572	7.321	0.500	0.021	0.004	0.025	0.012
	<i>Butea monosperma</i> (Lam.) Taub.	3.048	9.868	0.480	0.048	0.010	0.058	0.027
	<i>Careya arborea</i> Roxb.	4.572	7.003	0.610	0.070	0.014	0.084	0.039
	<i>Litsea glutinosa</i> (Lour.) C.B. Rob.	6.706	11.54	0.500	0.606	0.121	0.727	0.342
	<i>Milusa velutina</i> (Dunal) Hook. f. & Thomson	6.198	7.634	0.690	0.212	0.042	0.254	0.119
	<i>Shorea robusta</i> Roxb.	21.12	17.45	0.720	39.27	7.855	47.13	22.15
	<i>Syzygium fruticosum</i> DC.	6.096	7.957	0.690	0.045	0.009	0.054	0.025
	<i>Terminalia bellirica</i> (Gaertn.) Roxb.	10.97	11.14	0.750	0.693	0.139	0.832	0.391
	<i>Zanthoxylum rhetsa</i> (Roxb.) DC.	7.315	8.169	0.330	0.109	0.022	0.131	0.062
	Total				41.33	8.27	49.59	23.31
Site E	<i>Acacia auriculiformis</i> Benth.	15.24	13.75	0.570	3.901	0.780	4.681	2.200

Acacia mangium Willd.	17.53	13.77	0.520	2.639	0.528	3.166	1.488
Aporosa dioica (Roxb.) Müll.Arg.	9.144	18.46	0.670	0.354	0.071	0.425	0.200
Artocarpus heterophyllus Lam.	9.144	15.92	0.750	0.295	0.059	0.354	0.166
Careya arborea Roxb.	4.572	9.867	0.610	0.046	0.009	0.055	0.026
Dillenia pentagyna Roxb.	12.19	20.05	0.630	0.524	0.105	0.629	0.296
Dysoxylum excelsum Blume	6.858	6.525	0.460	0.068	0.014	0.082	0.039
Ficus hispida L. f.	5.486	7.321	0.350	0.017	0.003	0.021	0.010
Grewia nervosa (Lour.) Panigrahi	6.909	9.761	0.500	0.335	0.067	0.402	0.189
Lepisanthes rubiginosa (Roxb.) Leenh.	6.096	7.003	0.390	0.020	0.004	0.024	0.011
Litsea glutinosa (Lour.) C.B. Rob.	16.76	23.55	0.500	0.789	0.158	0.947	0.445
Mangifera indica L.	15.24	22.28	0.540	0.693	0.139	0.832	0.391
Mitragyna parvifolia (Roxb.) Korth.	10.67	11.78	0.650	0.490	0.098	0.588	0.276
Senna siamea (Lam.) H.S. Irwin & Barn.	9.144	13.05	0.750	0.396	0.079	0.476	0.224
Shorea robusta Roxb.	21.34	23.83	0.720	25.17	5.033	30.20	14.19
Suregada multiflora (A. Juss.) Baill.	3.048	4.138	0.650	0.006	0.001	0.007	0.003
Terminalia bellirica (Gaertn.) Roxb.	8.230	14.64	0.750	0.673	0.135	0.808	0.380
Zanthoxylum rhetsa (Roxb.) DC.	10.97	20.85	0.330	0.801	0.160	0.961	0.452
Total				37.22	7.44	44.66	20.99

Notes: ATH= average tree height, DBH= diameter at breast height, ρ = wood specific density, AGTB= aboveground tree biomass, BGTB= belowground tree biomass, TTB= total tree biomass, TTC= total tree carbon

The total values of aboveground tree biomass (AGTB) of the selected sites were found to show a range between 37.22 tonh^{-1} to 144.99 tonh^{-1} . The maximum AGTB value of 144.99 tonh^{-1} was recorded from Site A, which was followed by 55.39 tonh^{-1} , 44.35 tonh^{-1} and 41.33 tonh^{-1} , from Site B, Site C, and Site D, respectively. Whereas the minimum AGTB value of 37.22 tonh^{-1} was recorded from Site E. Similarly, the total values of belowground tree biomass (BGTB) of the selected sites were found to ranges from 7.44 tonh^{-1} to 28.99 tonh^{-1} . The highest BGTB value of 28.99 tonh^{-1} was recorded from Site A, followed by 11.08

tonh^{-1} , 8.87 tonh^{-1} , and 8.27 tonh^{-1} from Site B, Site C and Site D, respectively. Whereas the lowest BGTB value of 7.44 tonh^{-1} was recorded from Site E. Furthermore, the total values of total tree biomass (TTB) of selected sites were found to vary between 44.66 tonh^{-1} to 173.99 tonh^{-1} . The highest TTB value of 173.99 tonh^{-1} was recorded from Site A, followed by 66.48 tonh^{-1} , 53.22 tonh^{-1} and 49.59 tonh^{-1} , recorded from Site B, Site C, and Site D, respectively. Whereas, the lowest TTB value of 44.66 tonh^{-1} was recorded from Site E (Table 1, Fig 2).

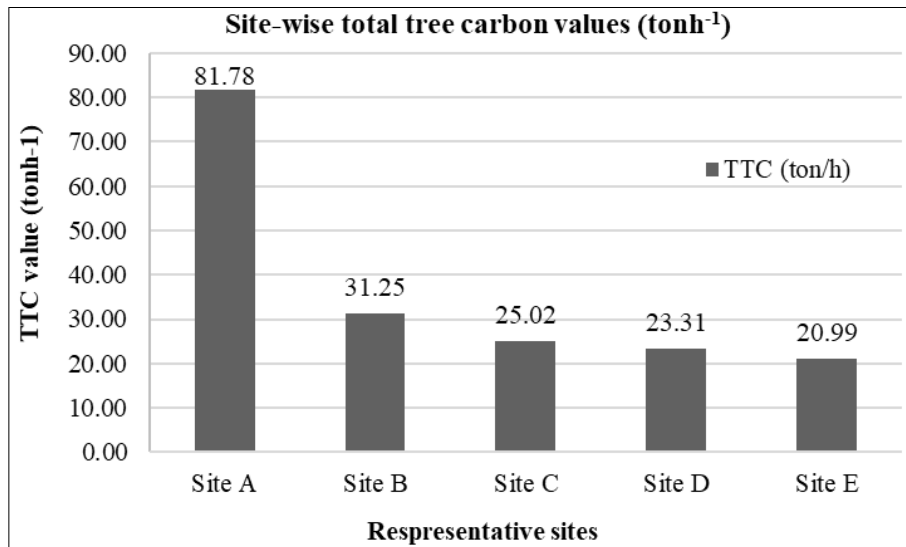


Fig 3: Site-wise total tree carbon values (tonh^{-1}) recorded from the Chandra Sal forest ecosystem

The values of total tree carbon (TTC) stored in selected sites were found to show a range from 20.99 tonh^{-1} to 81.78 tonh^{-1} . The maximum TTC value 81.78 tonh^{-1} was recorded from Site A, which was followed by 31.25 tonh^{-1} , 25.02 tonh^{-1} and 23.31 tonh^{-1} , recorded from Site B, Site C and Site D, respectively. Whereas the minimum TTC value of 20.99 tonh^{-1} was recorded from Site E (Table 1, Fig 3).

Discussion

Extensive research on total tree biomass (TTB) within Sal forest ecosystems across Bangladesh, India, and Nepal highlights significant structural variability (Banik *et al.*,

2018; Islam *et al.*, 2016; Pande *et al.*, 2010; Pandey *et al.*, 2023; Rahman *et al.*, 2022; Regmi *et al.*, 2021; Siddiqui and Lodhiyal, 2023) [5, 18, 23, 25, 26, 29, 34]. In the present study, observed biomass values align closely with the findings of Regmi *et al.* (2021) [29], who estimated a mean carbon stock of 99.02 tonh^{-1} in Dang District, Nepal. These similarities likely reflect comparable stand ages and disturbances in Sal tracts. Conversely, the biomass stocks in the present study are notably lower than the ranges reported for the Central Himalayas as 221.46 to 786.8 tonh^{-1} (Pandey *et al.*, 2023; Siddiqui and Lodhiyal, 2023) [25, 34] and for the Satpura Plateau as 190.53 to 406.27 tonh^{-1} (Pandey *et al.*, 2010) [23].

Furthermore, higher above-ground biomass (AGB) values of 301.70 to 458 tonh⁻¹ were documented by Rahman *et al.* (2022) [26] across various Sal forest sites in Bangladesh, including Bhawal National Park and Cumilla. Islam *et al.* (2016) [18], reported an average biomass of approximately 277.40 tonh⁻¹ in the Madhupur Sal Forest in Bangladesh. Similarly, Banik *et al.* (2018) [5] reported AGB values

ranging from 1.82 to 110.53 Mgh⁻¹ in natural Sal forests and 29.43 to 179.88 Mgh⁻¹ in plantations in Tripura, India. These discrepancies are primarily attributable to variations in stand maturity, canopy height, and site-specific productivity, as well as the prevalence of secondary growth stages compared to more mature forest stands.

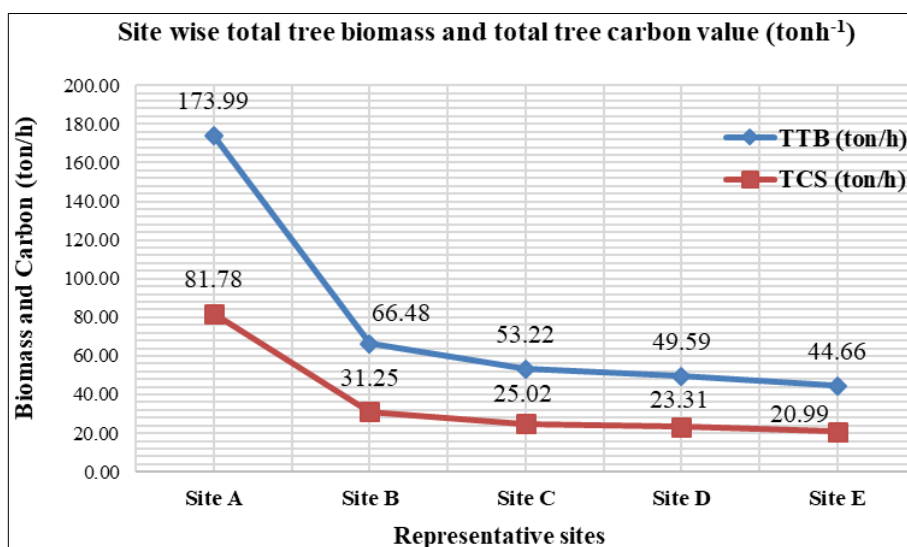


Fig 4: Relationship between total tree biomass and carbon storage in Chandra Sal forest ecosystem

Research on total tree carbon (TTC) storage within Sal forest ecosystems across South Asia reveals significant regional heterogeneity. In Nepal, tree carbon density varies markedly between the Terai region as 559.6 tonh⁻¹ and hill community forests as 115.22 tonh⁻¹ (Pandey and Bhusal, 2016) [24]. In the Indian Central Himalayas, TTC values have been reported to range from 116.91 to 244.82 tonh⁻¹ (Pandey *et al.*, 2023) [25], with other studies in the same region documenting stocks between 224.8 and 373.7 tonh⁻¹ (Siddiqui and Lodhiyal, 2023) [34]. Further variations are observed in the North Western Himalayas, where vegetation and ecosystem carbon densities reach up to 234.26 and 287.58 tonh⁻¹, respectively (Sharma *et al.*, 2025) [33]. In the lowland Sal tracts of Northeast India and Bangladesh, carbon stocks appear comparatively lower. For instance, Banik *et al.* (2018) [5] reported significantly higher vegetation carbon density in Sal plantations (19.65 to 219.68 tonh⁻¹) than in natural stands (16.73 to 167.64 tonh⁻¹) in Tripura. In Bangladesh, Islam *et al.* (2016) [18] estimated total carbon storage in the Madhupur Sal Forest at approximately 130.38 tonh⁻¹. The carbon storage values observed in the present study fall within this documented literature range; however, while our upper values are comparable to Himalayan estimates, and the lower values remain substantially below most regional averages, likely reflecting differences in stand maturity and anthropogenic pressure.

Conclusion

The present study provides a comprehensive estimation of total tree biomass and carbon storage within the Chandra Sal forest ecosystem of Gazipur district, Bangladesh. Based on the current critical tree biomass and carbon data, it is concluded that the Chandra Sal forest ecosystem possesses considerable biomass and carbon storage capacity, reflecting its role as an important carbon sink within plain land forest

landscape of Bangladesh. The significant spatial variation in these values highlights a dual reality: while certain sites exhibit high productivity and robust stand conditions, lower values in other areas underscore the need for targeted ecological restoration and management. Therefore, appropriate conservation and sustainable management practices should be strengthened to enhance forest productivity and carbon sequestration potential across all sites. This will not only improve biomass accumulation but also contribute to climate change mitigation and the long-term ecological stability of Sal forest ecosystems. Finally, the findings of this study may serve as a baseline for further detailed investigations on the complete carbon pools and long-term monitoring of this ecosystem.

Acknowledgements

The first author gratefully acknowledges the Ministry of Science and Technology of the Government of the People's Republic of Bangladesh for awarding the National Science and Technology (NST) Fellowship. The authors also extend their sincere appreciation to the Chief Conservator of Forests, the Conservator of Forests, and all field officials in the research area for their kind support and cooperation. In addition, the authors are also deeply thankful to the Chief Editor and the Reviewers of the Journal for their critical review of the manuscript.

References

1. Alam M, Furukawa Y, Sarker SK, Ahmed R. Sustainability of Sal (*Shorea robusta*) forest in Bangladesh: past, present and future actions. *International Forestry Review*, 2008;10(1):29-37.
2. Alexandrov GA. Carbon stock growth in a forest stand: the power of age. *Carbon Balance and Management*, 2007;2(1):4.

3. Anonymous. An investigation into the ecology of Chandra Sal (*Shorea robusta* Gaertn.) forest, Gazipur, Bangladesh (Master's thesis). Jahangirnagar University, Dhaka, Bangladesh, 1994.
4. Bajracharya RM, Lal R, Kimble JM. Soil organic carbon distribution in aggregates and primary particle fractions as influenced by erosion phases and landscape position. In: Soil Processes and the Carbon Cycle,2018:353-367. CRC Press.
5. Banik B, Deb D, Deb S, Datta BK. Assessment of Biomass and Carbon Stock in Sal (*Shorea robusta* Gaertn.) Forests under Two Management Regimes in Tripura, Northeast India. Journal of Forest and Environmental Science,2018:34(3):209-223.
6. Braun-Blanquet J. Plant sociology: The study of plant communities. McGraw Hill, New York, 1932:439.
7. Brown K, Pearce D. The economic value of non-timber benefits of tropical forests: Carbon storage. In J. Weiss (Ed.), The Economics of Project Appraisal and the Environment,1994:102-123.
8. Brown S, Lugo AE. Aboveground biomass estimates for tropical moist forests of the Brazilian Amazon. Interciencia,1992:17(1):8-18.
9. Brown S. Estimating biomass and biomass change of tropical forests: a primer. Food & Agriculture Organization, 1997:134.
10. Cain SA. The species-area curve. American Midland Naturalist,1938:19:573-581.
11. Campbell A, Miles I, Lysenko I, Gibbs H. Carbon storage in protected areas: Technical report. UNEP-WCMC, 2008.
12. Chapin FS III, Matson PA, Vitousek PM. Principles of terrestrial ecosystem ecology. Springer, 2011.
13. FAO. Carbon sequestration options under the Clean Development Mechanism to address land degradation. Food and Agriculture Organization of the United Nations, 2000.
14. FAO. FAO glossary of terms. Food and Agriculture Organization of the United Nations, 2011.
15. IPCC. Guidelines for national greenhouse gas inventories. Intergovernmental Panel on Climate Change, 2006.
16. IPCC. Land Use, Land-Use Change, and Forestry: A Special Report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change, 2000.
17. Islam KK, Hyakumura K. The potential perils of Sal forests land grabbing in Bangladesh: an analysis of economic, social and ecological perspectives. Environment, Development and Sustainability,2021:23(10):15368-15390.
18. Islam MS, Tusher TR, Kabir MH, Hassan MR, Khan MNH. Carbon storage and sequestration potentiality of tree species in Madhupur Sal Forest of Bangladesh. Bangladesh Journal of Environmental Sciences,2016:30(2012):33-9.
19. IUPAC. Compendium of Chemical Terminology (the Gold Book). IUPAC, 2006.
20. Karki S, Joshi NR, Udas E, Adhikari MD, Sherpa S, Kotru R, *et al.* Assessment of forest carbon stock and carbon sequestration rates at the ICIMOD knowledge park in Godavari, Nepal, 2016.
21. Lal R. Soil carbon sequestration impacts on global climate change and food security. Science,2004:304(5677):1623-1627.
22. Mokany K, Raison RJ, Prokushkin AS. Critical analysis of root: shoot ratios in terrestrial biomes. Global Change Biology,2016:12(1):84-96.
23. Pande PK, Patra AK. Biomass and productivity in sal and miscellaneous forests of Satpura plateau (Madhya Pradesh) India. Advances in Bioscience and Biotechnology,2010:1(1):30.
24. Pandey HP, Bhusal MA. Comparative study on carbon stock in Sal (*Shorea robusta*) forest in two different ecological regions of Nepal. Banko Janakari,2016:26(1):24-31.
25. Pandey R, Bargali SS, Bargali K. Tree biomass and carbon stock in subtropical Sal forest of Central Himalaya, India. Vegetos,2023:36(4):1154-1164.
26. Rahman M, Hossain ME, Hoque S, Islam S. Variation in soil organic carbon stock and forest biomass carbon density at different locations of sal forest in Bangladesh. Journal of Tropical Forestry,2022:38:1-22.
27. Raunkiaer C. The life forms of plants and statistical plant geography. Oxford University Press, London, 1934.
28. Ravindranath NH, Ostwald M. Carbon inventory methods handbook for greenhouse gas inventory, carbon mitigation and roundwood production projects. Dordrecht: Springer Netherlands, 2008.
29. Regmi S, Dahal KP, Sharma G, Miya MS. Biomass and carbon stock in the Sal (*Shorea robusta*) forest of Dang District Nepal. Indonesian Journal of Social and Environmental Issues (IJSEI),2021:2(3):204-212.
30. Reyes G. Wood densities of tropical tree species. US Department of Agriculture, Forest Service, Southern Forest Experiment Station, 1992:88.
31. Sattar MA. Some physical properties of 116 Bangladeshi timbers. Bangladesh Forest Research Institute, 1981:15.
32. Shapla T, Park J, Hongo C, Kuze H. Agricultural land cover change in Gazipur, Bangladesh, in relation to local economy studied using Landsat images. Advances in Remote Sensing,2015:4(03):214-233.
33. Sharma A, Bhardwaj DR, Thakur CL, Katoch N, Verma S, Sharma JP. Assessment of biomass and carbon stock in subtropical Sal (*Shorea robusta* Gaertn. f.) forests in the North Western Himalayas. Scientific Reports,2025:15(1):37827.
34. Siddiqui F, Lodhiyal LS. Tree structure analysis, biomass and carbon stock of Sal forests in Central Himalayan region. Current World Environment,2023:18(1):107.
35. Vashum KT, Jayakumar S. Methods to estimate above-ground biomass and carbon stock in natural forests-a review. Journal of Ecosystem & Ecography,2012:2(4):1-7.
36. Winjum JK, Dixon RK, Schroeder PE. Estimating the global potential of forest and agroforest management practices to sequester carbon. Water, Air, and Soil Pollution,1992:64(1):213-227.