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Biomass and Carbon Estimation of the Four Major Tree Species in Ratargul Swamp Forest, Bangladesh.

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Tahasina Chowdhury, A. Z. M. Manzoor Rashid*, Md. Tareq Khan Tipu

Department of Forestry and Environmental Science, Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh.

*Corresponding author's email: pollen_forest@yahoo.com

Abstract

Wetland forests– a major ecosystem of Bangladesh, is still being neglected despite of having enormous potentials particularly in case of ecosystem balancing and CO_2 accumulation. Under this purview, the present study aimed at estimating the biomass and carbon stock of four major tree species namely *Pongamia pinnata*, *Barringtonia acutangula*, *Syzygium fruticosum* and *Lagerstroemia speciosa* at Ratargul swamp forest under Sylhet Forest Division. Thirty sample plots (20 m × 20 m) were taken to enumerate biomass and carbon stock of the selected tree species. Tree biomass was estimated using a pan-tropical allometric biomass equation widely known as Brown's equation. Loss on ignition method was followed to determine the carbon concentration of four studied species. Species selection was done based on the value determined through IVI (Importance Value Index). The study revealed that 191.53 ton/ha biomass and 93.76 ton/ha carbon are held by *P. pinnata* in this forest where the other three species occupied only 22.88 ton/ha biomass and 12.19 ton/ha carbon altogether. *P. pinnata* held the highest biomass (61374.55 kg) within 38–48.9 cm DBH class whereas most of the biomass in *B. acutangula* (9868.50 kg), *L. speciosa* (721.49 kg) and *S. fruticosum* (708.10 kg) is held between 13–20.9 cm, 19–25.9 cm and 10–14.9 cm DBH class respectively. In addition, 50968.09 tons of atmospheric CO_2 have been accumulated by these four tree species in this forest. The findings of the study can be used as baseline information for developing future conservation and management planning in fresh water swamp forest and in wetland areas of Bangladesh.

Keywords: Biomass estimation; Carbon stock; Wetland forest; Climate change.

1. Introduction

Tropical forests have the biggest potentials in counteracting climate change through protection of the current carbon pools, extension of carbon sinks, and substitution of inexhaustible wood products for fossil fuel [1]. Forests can serve as an effective means in battling climate change, securing people and their livelihood. Forests preserves higher amount of carbon in trees, under-story vegetation, and soil. Plants take CO_2 from the air during the procedure of photosynthesis and store it through carbon sequestration process. Tropical forests can intake and store carbon at a more significant rate than boreal forests [2]. Forest degradation, forest-fires and agricultural burning make an extraordinary contribution for the outflow of ozone harming substances. Literature shows that up to 20% of aggregate net anthropogenic carbon outflows originate from land utilization and land utilization changes, particularly deforestation and degradation of forest [3,4]. The greater part of this deforestation and degradation happens in tropical developing nations [5]. The best measures for relieving the pressure brought to by climate change are the protection of existing carbon stocks [6]. A standout amongst the most noticeable current strategies worldwide is the execution of REDD+ (Reducing Emissions from Deforestation and Forest Degradation) mechanism. REDD+ gives a carbon-effective, cost-efficient, and even-handed instrument for decreasing outflows from deforestation and forest degradation while enhancing local livelihoods and upscaling biodiversity conservation [7–9]. Several tropical developing countries have recognized REDD+ as one of their Intended Nationally Determined Contributions (INDCs) to climate change mitigation as a major aspect of the Paris Climate Agreement [10,11]. Wetlands are considered as the "Natural Supermarket" on account of its rich biodiversity on the planet [12–14]. Ratargul swamp forest (RSF) is one of the most important fresh-water wetland in the north eastern part of Bangladesh. This forest is a very important habitat for a large variety of floral and faunal diversity [15,16]. Besides, it serves several ecological functions in terms of carbon sequestration, hydrological cycle, water storage and discharge, flood control and regulation, biodiversity protection etc. for the whole fresh water ecosystem and many economic functions (fodder, fuel wood, fish management etc.) for the community as well [16–18]. Wetlands can sequester significant amount of carbon and have been perceived worldwide as a profound carbon storage [19]. However, in absence of adequate management efforts, this amount of carbon will leak out and become a source of greenhouse gases [17,19]. Currently, world carbon storage has been emerged as a potential business, which can contribute to socio economic development as well as environmental amelioration too. However, due to lack of estimation, inadequate and weak policy and decision-making process, Bangladesh is far behind in the global carbon market [20]. Very limited studies have been conducted to evaluate the roles and potentials of wetlands in carbon sequestration [19]. Wetland forests serves a critical function in the worldwide carbon cycle because of their significant role in C sink with respect to other ecological systems [21]. Moreover, swamp forests are considered as a major driver of spatial variability in C storage. Despite their importance for ecosystem and human services, biomass storage and dynamics, swamp forest's contribution in Global carbon cycle remain poorly understood [22]. Therefore, precise estimation of biomass stock and C storage of these wetland species will form the base for understanding the role of swamp forest in C sink management [23]. Unfortunately, only a small number of studies have been conducted on the carbon sequestration potentiality and biomass estimation of tree species of swamp forest [24,25]. Moreover, RSF was not covered during the last national forest inventory by Bangladesh Forest Department. Hence, considering the wetland tree carbon sequestration potentiality, this study was conducted in RSF of Bangladesh to estimate the total amount of biomass, carbon stock and accumulated carbon dioxide of four major wetland tree species.

2. Materials and Method

2.1 Study area

The study was conducted in the Ratargul fresh water swamp forest under the Ratargul forest beat, north Sylhet range-2, Goainghat, Sylhet. The study area is located between 25° 0′ 30″ to 25° 1′ 0″ N latitude and 91° 55′ 0″ to 91° 55′ 30″ E longitude (figure 1). Total area of this swamp forest is about 204 ha, of which 118.50 ha was declared as a reserve forest under the Assam Forest Act 1932. The climatic condition of this forest is generally sub-tropical. The average yearly precipitation is around 4162 mm. May and October are the warmest months having the highest temperature around 32°C, while January is the coldest month with the lowest temperature of 12°C. Relative humidity is about 74% during December that goes over 90% during July-August [16]. Soils of the study area are gray, heavy, silt-clay loam with clays that predominates [26]. Majority of this forest area are plain lowland and the remaining area consists of river basin, forest and small hillocks. The elevation of this forest area is about 35 feet above from the sea level. The top story of this forest is mostly composed of *P. pinnata* and *B. acutangula*. The canopy height is about 15m and canopy coverage is about 80% [16].

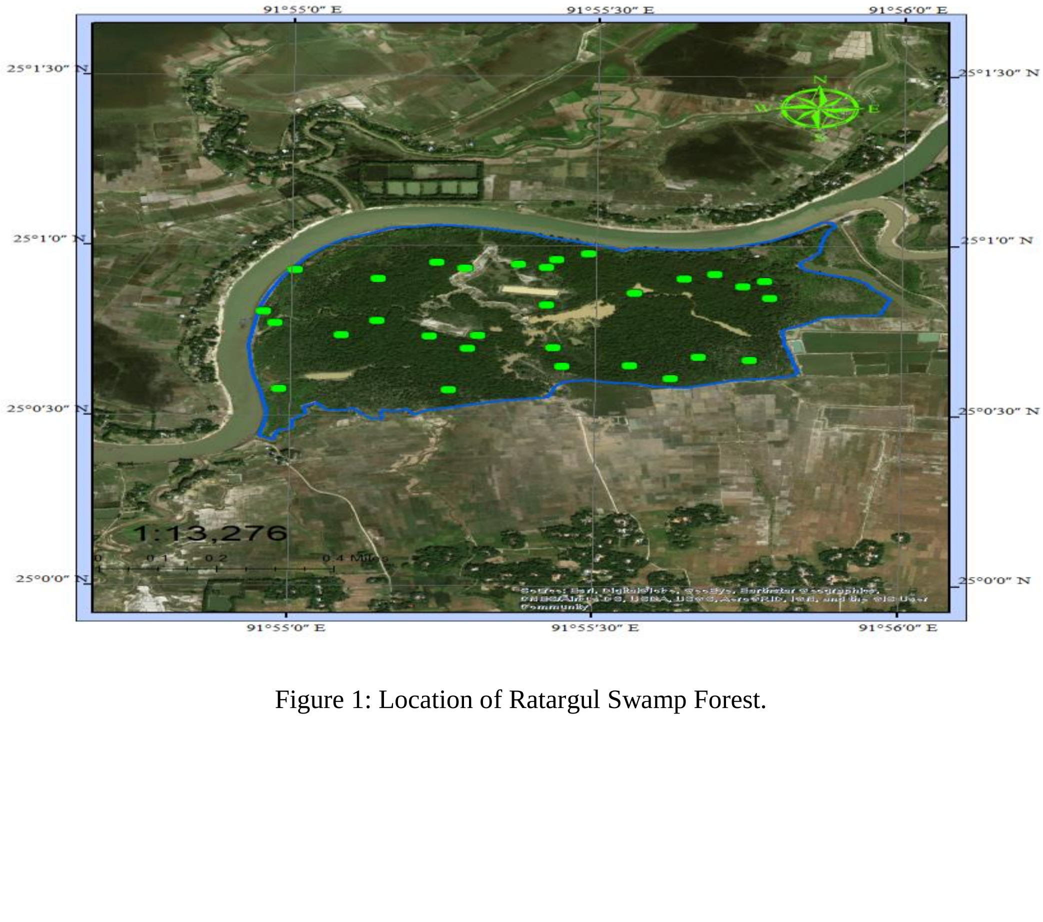


Figure 1: Location of Ratargul Swamp Forest.

2.2 Brief ecological description of the studied species

Pongamia pinnata (L.) Pierre, which belongs to *Fabaceae* family, is a small sized evergreen tree with a spreading crown. It is also known by the synonym *Millettia pinnata* as it was moved to the genus *Millettia* only recently. The tree species is popularly known as karmuj in Bengali, Karach in Sylhet region and Indian beach in English. It usually grows along the river side, canal and stream. Historically, this plant has long been used in Bangladesh and in neighboring regions as animal fodder, green manure, timber, fish poison and fuel. Extract of the plant possesses significant anti-diarrhoeal, anti-fungal, anti-inflammatory and analgesic activities.

Barringtonia acutangula (L.) Gaertn, which belongs to *Lecythidaceae* family, is a small to medium-sized evergreen, glabrous tree with spreading crown, locally known as hijal and the leaves are alternate, obovate or oblanceolate in shape, flowers are red in color while the fruits are oblong, glabrous and one seeded. Generally, this tree species occurs in freshwater swamp forests of Sylhet areas and is found along the ditches and canal side too throughout the country. Bark is a source of tannin and poison used for fish bait.

Syzygium fruticosum (Roxb. DC) belongs to *Myrtaceae* family. It is a small to medium-sized glabrous evergreen tree. In Bengal, it is called nail-jam. Flowers are white and the fruits are globose berry. It generally occurs in the semi-evergreen and patch of the deciduous forest and also in Sundarban’s mangrove. Fruits are edible and mostly used as fuel wood.

Lagerstroemia speciosa (L.) Pers. belongs to *Lythraceae* family which is a medium-sized to large sized much branched tree. Locally known as jarul whose flowers are large in size and the seeds are laterally expanded into a oblong wing. It commonly grows at the edge of the forest stream, ditches and river banks and generally occurs in the semi-evergreen forests of Chattagram, Cox,s Bazar, Chattagram Hill Tracts , Sylhet and Dinajpur. Doors, windows and house post manufacturing are the common uses of jarul [27].

2.3 Sampling and Data collection

A total of 30 (20 m × 20 m) sample plots were taken randomly using randomization tool in ArcGIS version 10.3. Total studied area was 131.067 ha. Height and diameter at breast height (1.37 m) of trees in sample plots were recorded. Wood samples from the sampled trees were collected using wood borer at tree breast height. Vigorous, disease and knot free trees were selected for sample collection. One wood core and adequate amount of bark, branch-parts and leaves were taken from one sample tree of each species from each plot. The vegetative sample parts were further taken for laboratory analysis to estimate organic carbon.

2.4 Data analysis

Importance Value Index (IVI) was obtained to identify the major forest tree species in RSF by adding the values of relative density, relative dominance and relative frequency according to Shukla and Chandel [28].

2.5 Biomass estimation of trees

Pan-tropical allometric biomass equation of Brown et al. [29] was used to determine above ground biomass of each sample tree. So far literatures have showed that this method is one of the most suitable methods for biomass estimation in tropical forests [30–32].

$$Y = \text{Exp}\ \{-2.4090 + 0.9522\ \text{Ln}\ (D^2 * H * S)\} \qquad (1)$$

Here, Y = above ground biomass (kg); D = diameter (cm) at breast height; S = wood density (kg/m^3) for specific species and H = height of the trees (m). Table 1 shows the wood density for selected tree species were taken from Sattar [33] and ICRAF database [34].

Table 1: Wood density of the selected tree species (based on BFRI and ICRAF database).

Species	Wood Density
Barringtonia acutangula	0.58
Pongamia pinnata	0.54
Syzygium fruticosum	0.60
Lagestroemia speciosa	0.51

Root shoot ratio (RSR), an indicator of physiological processes affecting the carbon allocation, is of significant importance in providing the estimation of BGB and TB. Multiplying AGB by RSR is the method used to estimate BGB and carbon stocks. In a study of Kumar and Sharma [35], RSR of 0.24 for *P. pinnata* and 0.2 for *B. acutangula*, *L. speciosa* and *S. fruticosum* were used to measure BGB. BGB for individual tree was calculated by using following formula:

BGB of individual tree = Above ground biomass of individual tree × RSR

2.6 Carbon stock estimation

Fresh weight of collected vegetative samples (wood core, bark, branch-parts and leaves) were taken and then dried at 65°C in the oven for 48 hours to take dry weight. Oven dried grind samples were taken (1.00 g from each collected vegetative component of tree) in a pre-weighted crucible for burning in the furnace at 550°C for 1 hour. After cooling, the crucible with ash were weighted and the percentage of carbon was calculated according to Allen [36] and Mahmood et al. [37].

$$Ash\ (\%) = \frac{W3 - W1}{W2 - W1} \times 100$$

C (%) = (100-Ash) × 0.58 (considering 58% carbon in ash-free litter material)

Where,

C = Biomass carbon stock, W1 = Weight of crucible, W2 = Weight of oven dried grind sample and crucible, W3 = Weight of ash and crucible.

To determine above ground carbon stock for individual plant, measured carbon percentage through loss on ignition method was multiplied with individual trees' above ground biomass. Below ground carbon stock for individual tree was obtained by multiplying the below ground biomass of individual tree with carbon factor 0.5 according to Brown [32]. Total above ground carbon stock and total below ground carbon stock were summed up to get total carbon stock. The carbon stock value of specific species was estimated as ton per hectare. In order to estimate CO_2 accumulation by the selected tree species, total carbon stock of selected tree species were converted into tons of CO_2 equivalents by multiplying 3.67 [38].

3. Result and Discussion

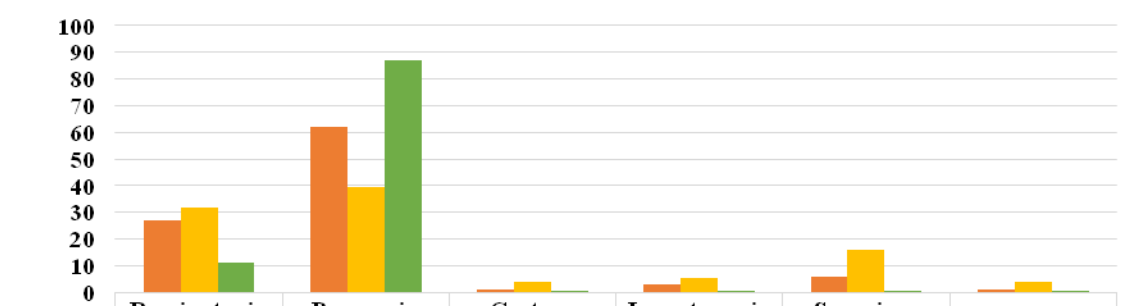
3.1 Results

The study identified six tree species in RSF. It reveals that *P. pinnata* (Koroch) poses the highest relative density (R_D) which is about 61.94% followed by *B. acutangula* (27.18%), *S. fruticosum* (6.09%), *L. speciosa* (2.80%), *C. magna* (1.15%) and *G. cowa* (0.82%). In terms of relative frequency (R_F), *P. pinnata* (39.47%) stands on top of *B. acutangula* (31.57%), *S. fruticosum* (15.78%), *L. speciosa* (5.26%), *C. magna* (3.94%) and *G. cowa* (3.94%). Again, in terms of relative dominance (R_Do), *P. pinnata* (86.83%) still holds on its position on top of *B. acutangula* (10.97%), *S. fruticosum* (0.69%), *L. speciosa* (0.73%), *C. magna* (0.54%) and *G. cowa* (0.20%). According to the result, *P. pinnata*, *B. acutangula*, *S. fruticosum* and *L. speciosa* have been found having greater importance value index (IVI) than the rest as showed in table 2. Therefore, these four species had been considered to be selected for estimation of their biomass and carbon stock in addition.

The study found that the entire forest is dominated by *P. pinnata* having the highest stocking rate which is about 313 tree per hectare followed by *B. acutangula* (138 tree/ha.), *S. fruticosum* (30 tree/ha.) and *L. speciosa* (14 tree/ha.). DBH class distribution and total biomass according to DBH class of the studied species in the sampled area are given in figure 3 and 4. From figure 5, it is clear that *P. pinnata* stands far above other three species in terms of total biomass as well as carbon stock per hectare. On the contrary, this amount is quite low in case of *B. acutangula*, *L. speciosa* and *S. fruticosum* compared with *P. pinnata*. Figure 6 shows that *P. pinnata* accumulated the highest amount of CO_2 from the atmosphere when calibrated for the entire RSF and it is far greater than the other three species altogether.

Table 2: Structural information of the forest stand.

Tree species	Average diameter (cm)	Average height (m)	Relative abundance (%)	Importance value index (IVI)
Pongamia pinnata	37.816	8.621	40.76	188.25
Barringtonia acutangula	19.692	7.530	22.36	69.74
Lagerstroemia speciosa	17.647	7.470	13.82	8.8
Syzygium fruticosum	10.986	6.459	10.02	22.57
Crateva magna	19.966	7.777	7.59	5.64
Garcinia cowa	18.733	10.000	5.42	4.97



	Barringtonia acutangula	Pongamia pinnata	Crateva magna	Lagestroemia speciosa	Syzygium fruticosum	Garcinia cowa
R_D%	27.183	61.944	1.153	2.801	6.096	0.824
R_F%	31.579	39.474	3.947	5.263	15.789	3.947
R_Do%	10.979	86.837	0.547	0.736	0.694	0.207

Figure 2: Stand characteristics of the studied area.

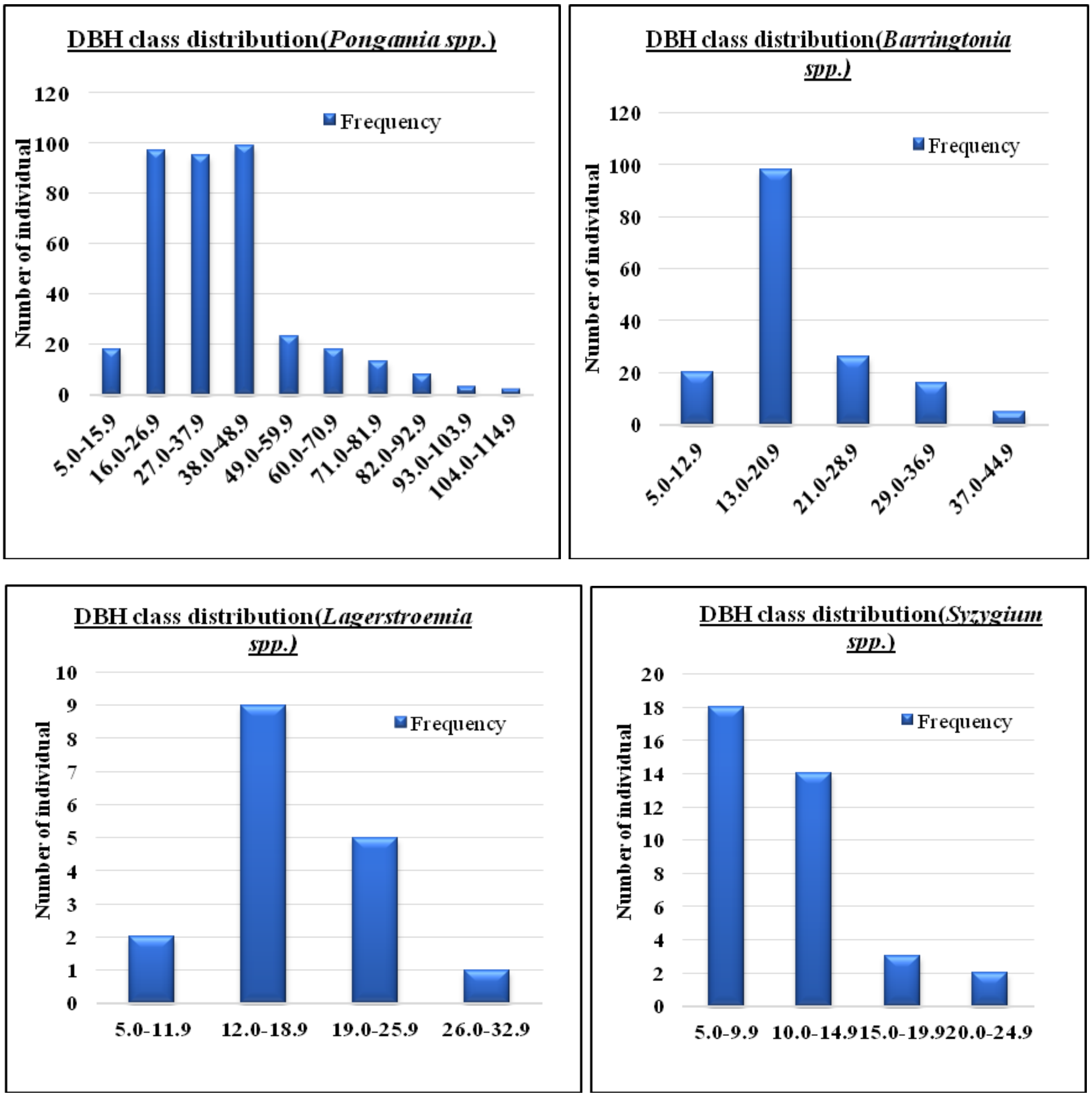


Figure 3: Diameter class distribution of four major species.

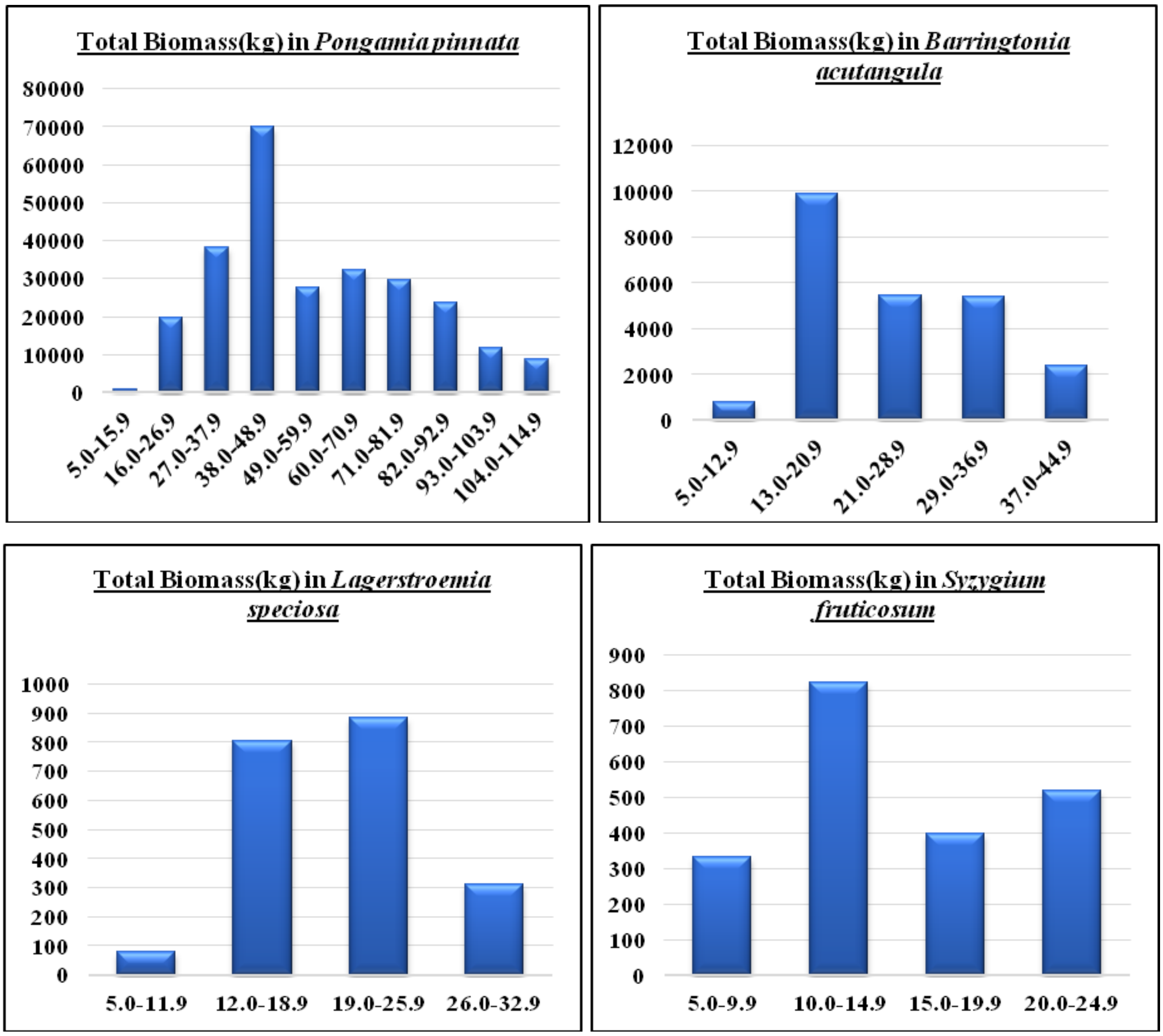


Figure 4: Biomass according to DBH classes of four studied species.

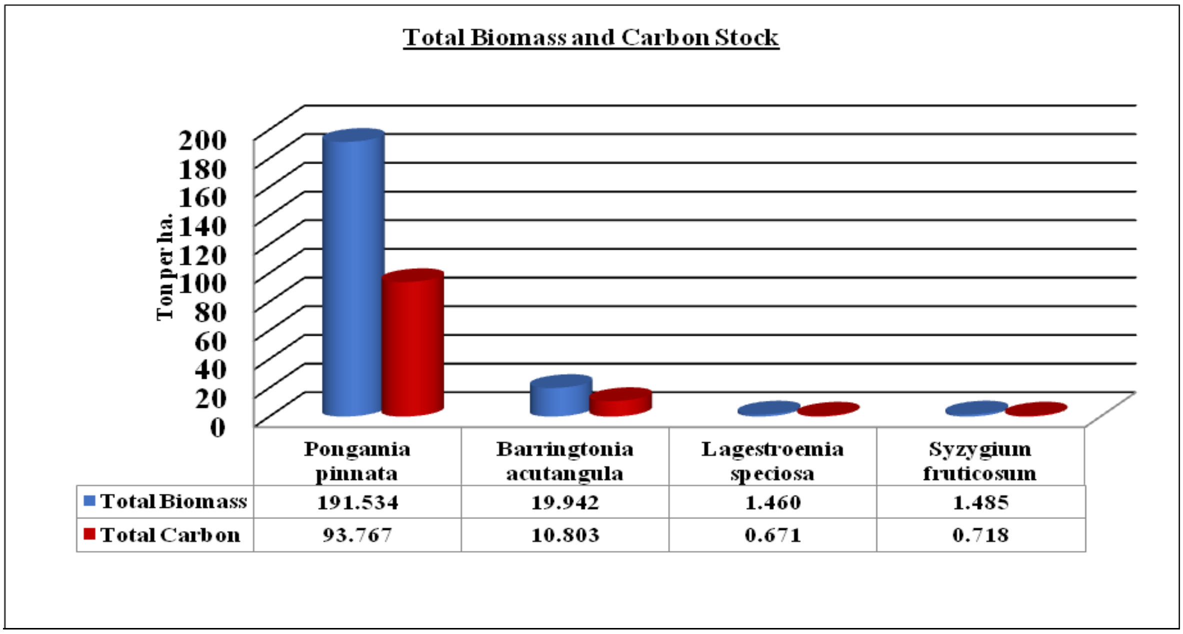


Figure 5: Total biomass and carbon stock of four major species per ha.

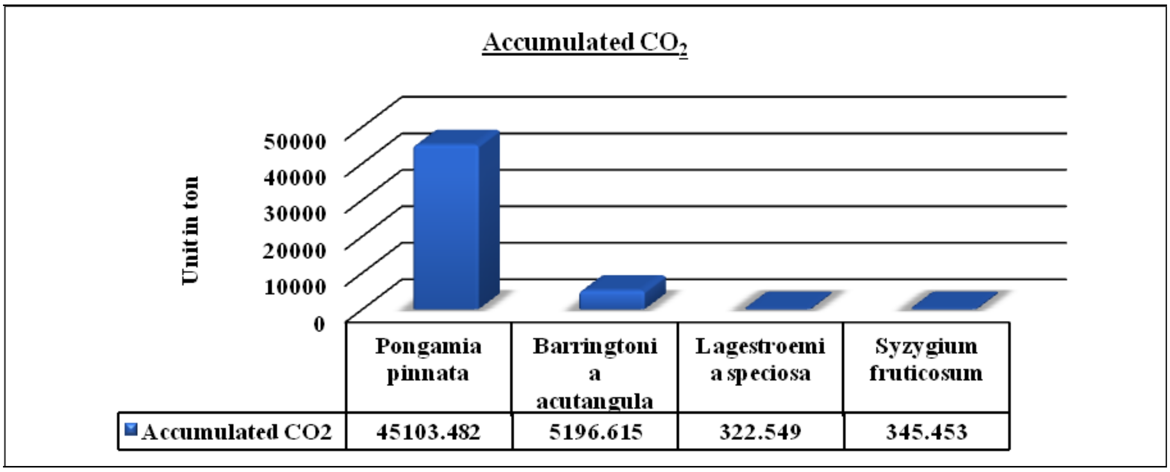


Figure 6: Total accumulated CO_2 held by four major tree species in Ratargul swamp forest.

3.2 Discussion

Wetland forests have a significant contribution in global carbon sequestration as well as greenhouse gas reduction. Tropical wetlands store 80% more carbon than temperate wetlands [19, 39]. Freshwater swamp forests are acting as an important carbon sink and contributing to climate change mitigation across the world. However, the factors on which its carbon storing capacity depends are the state of the forest, the current extent and the degree of disturbance in the forests [40]. In this context, RSF, the only remaining freshwater swamp forest of Bangladesh, has great carbon stock potentiality.

The study identified six tree species of which four were selected for biomass and carbon stock estimation according to their importance value index (IVI). Among those, *P. pinnata* poses the highest IVI value (188.25) followed by *B. acutangula*, *S. fruticosum* and *L. speciosa*, establishing *P. pinnata* as the dominant species of RSF. In addition, the value of relative dominance of *P. pinnata* (86.83%) showed how this species has taken out most spaces of the entire forest and playing an important role in regulating the forest structure. However, average height of tree species in this forest was only 8.621 m. According to Bohre et.al [41] the range of total biomass and total carbon held by *P. pinnata* was 3.92–936.44 ton/ha and 1.95–468.21 ton/ha for 2 to 18 year plantation. Our study also support the mentioned findings of Bohre et.al [41] as *P. pinnata* was found having 191.53 ton/ha total biomass and 93.76 ton/ha carbon stock in RSF. Coppice and tree density (trees/ha) could be the two main factors which had significant influence on biomass and carbon stock dominance of *P. pinnata* over others species [42]. Abeysekara et al. [43] revealed that both in natural and plantation forest around 50–60 ton/ha biomass are found within 40–49 cm DBH class. In our study, *P. pinnata*, occupying most of the part of the entire RSF, showed 70 ton/ha within almost same DBH class. Moreover, *L. speciosa* contains a total biomass of 1.460 ton/ha. and total carbon of 0.671 ton/ha which is almost similar with the study findings of Ullah and Al-Amin [44]. In RSF *S. fruticosum* and *L. speciosa* are in a very limited amount. Therefore, these two holds the least number of biomass and carbon stock in this forest.

The study revealed that 50968.09 ton of atmospheric CO_2 has been accumulated by these 4 major tree species in RSF. In addition, 105.95 ton/ha carbon was stored in these species. Hossain et al. [45] mentioned in his study that on average 92 ton of carbon is stored per hectare by the tree tissues in the forest of Bangladesh, which is quite similar with this study. Moreover, Muda et al. [46] quantified 236.51 ton/ha C in a tropical peat swamp forest. Several factors influence the variance of C stock in similar forests type. For instance, physiographic variety, stand characteristics, species composition, tree density, tree size, the age of the forest, climatic difference and allometric equation applied [29,46–48].

4. Conclusion

The study found *P. pinnata* and *B. acutangula* invading over other species in this forest in terms of storing biomass and carbon stock. These two species can be chosen in raising future plantation program in wetland areas. The study used common biomass estimation model for pan-tropical region due to resource limitation. Therefore, detailed further research including some species-specific biomass model is suggested to derive biomass and carbon stock data from this forest more precisely that can be applied in decision-making process of wetland management in Bangladesh.

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