

Spatio-Temporal Variation of Stored Carbon in *Sonneratia apetala*: a Case Study from Indian Sundarbans

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ABSTRACT: Considering 24 stations, distributed in three contrasting salinity regimes in Indian Sundarbans, we carried out a survey on Above Ground Biomass (AGB) and Above Ground Carbon (AGC) of *Sonneratia apetala* for two decades (1996-2015). We focused on three sectors of Indian Sundarbans namely western, central and eastern sectors that have contrasting salinity profile. In the western sector, the average AGB of the species were 36.85 tonnes ha⁻¹, 43.17 tonnes ha⁻¹ and 49.04 tons/h during 1996, 2005 and 2015 respectively. In the central sector, the mean AGB of the species were 0.84 tonnes ha⁻¹, 2.74 tonnes ha⁻¹ and 7.83 tonnes ha⁻¹ in similar years. In the eastern sector, the mean AGB values were 9.16 tonnes ha⁻¹, 14.76 tonnes ha⁻¹ and 20.21 tonnes ha⁻¹ during the same years. The AGC values synchronized with the AGB values. The present study indicates that the stored carbon in the AGB of the species is significantly more in the hyposaline environment of Indian Sundarbans (western sector) compared to the hypersaline central sector of the deltaic complex ($p < 0.05$).

KEYWORDS: Indian Sundarbans, *Sonneratia apetala*, AGB, AGC, Salinity.

I. INTRODUCTION

Mangroves occupy less than 0.1% of the Earth's surface, but they are responsible for 8-15 % of the carbon deposited in coastal sediments and 10-11 % of the total export of terrestrial carbon to the ocean [1]. Many studies have shown the importance of mangroves ability as carbon sinks [2-5]. However, they have mostly focused on carbon quantity import, export and production per year instead of researching the mangroves capability to trap carbon [1].

According to earlier research [6] *Sonneratia apetala*, a non-native species in China has a very high biomass carbon accumulation rate compared to other native species. However, such baseline data on stored carbon is not available in Indian Sundarbans although the region supports a luxuriant growth of the species particularly in the western sector. *Sonneratia apetala* is a member of the Lythraceae family. The species is native in India, Bangladesh and Myanmar, and has been introduced to southern parts of China. Even the species is fast growing in nature its relative abundance is decreasing from the central Indian Sundarbans on account of the hypersaline condition of the environment [3-5, 7-10].

II. MATERIALS AND METHODS

Sampling

The study was carried out at an interval of a decade during a span of 20 years (1996-2015). Above Ground Biomass (AGB) in this species refers to the sum total of stem, branch and leaf biomass that are exposed above the soil. The AGB of the species was evaluated for the individuals, which were almost of similar ages (approximately 22 years in the final year of investigation).

We selected 24 stations distributed in the three sectors of Indian Sundarbans (Figure 1). In each station, 15 sample plots (10m × 10m) were laid (in the river bank) through random sampling. The random sampling accounts for the largest variability in the biomass range. Samplings were carried out in low tide period during postmonsoon season in the selected years and the same plots (as fixed by GPS) were monitored during the three observation years.

Above Ground Stem Biomass (AGSB) estimation

The stem volume of five individuals of the species in each of the 15 plots per station ($n = 5 \times 15 = 75$ for each station) was estimated using the Newton’s formula.

$$V = h/6 (A_b + 4A_m + A_t)$$

Where V is the volume (in m³), h the height measured with laser beam (BOSCH DLE 70 Professional model), and A_b, A_m, and A_t are the areas at base, middle and top respectively. Specific gravity (G) of the wood was estimated taking the stem cores, by boring 7.5 cm deep with mechanized corer. This was converted into stem biomass (B_S) as per the expression B_S = GV. The stem biomass of individual tree was finally multiplied with the number of individuals of the species in 15 selected plots. This exercise was carried out for all the 24 stations distributed in three sectors of Indian Sundarbans.

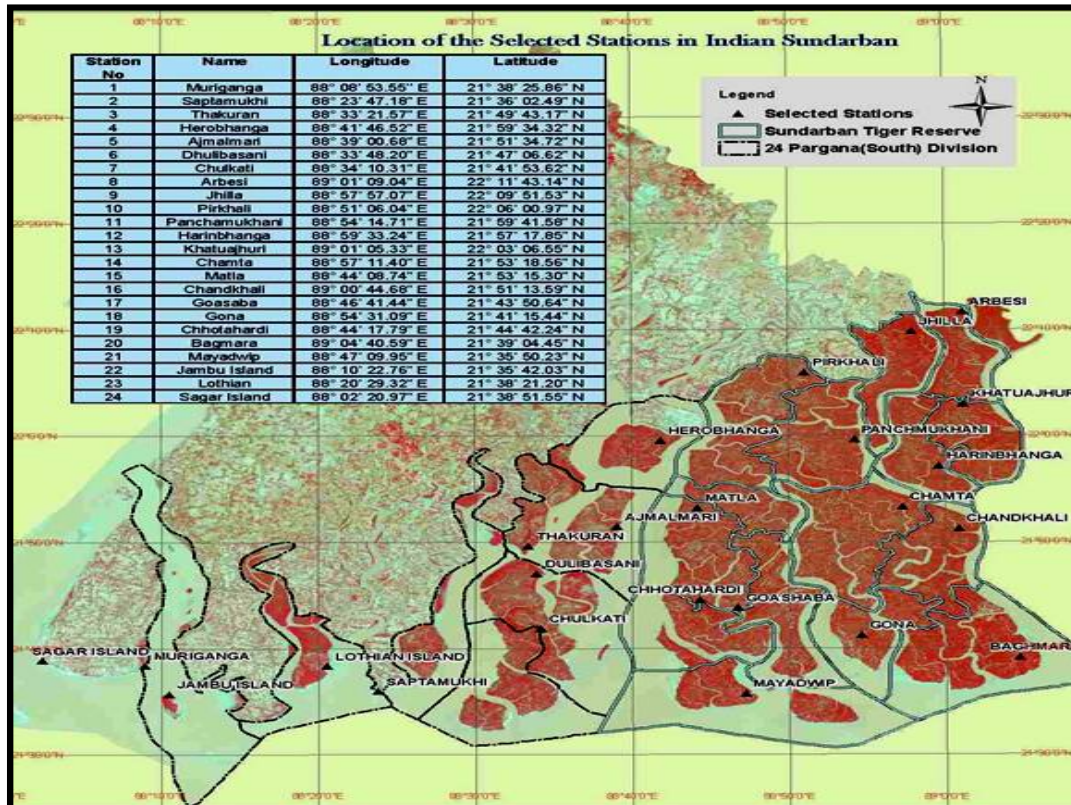


Fig. 1. Indian Sundarbans with 24 stations distributed in western, central and eastern sectors; Sagar Island, Muriganga, Jambu Island and Lothian Island are within the western sector; Herobhanga, Matla, Ajmalmani, Thakuran, Dulibasani, Chotahardi, Chulkati and Saptamukhi are within the central sector and Arbesi, Jhilla, Pirkhali, Katuajhuri, Panchmukhani, Harinbhanga, Chamta, Chandkhali, Goashaba, Gona, Bagmara and Mayadwip are within the eastern sector of Indian Sundarbans

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Above Ground Branch Biomass (AGBB) estimation

The total number of branches irrespective of size was counted on each of the sample trees. These branches were categorized on the basis of basal diameter into three groups, viz. < 6 cm, 6–10 cm and >10 cm. The leaves on the branches were removed by hand. The branches were oven dried at 70°C overnight in hot air oven in order to remove moisture content (if any) present in the branches. Dry weight of two branches from each size group was recorded separately using the standard equation as per the expression:

$$B_{db} = n_1bw_1 + n_2bw_2 + n_3bw_3 = \sum n_i b w_i$$

Where, B_{db} is the dry branch biomass per tree, n_i the number of branches in the i th branch group, b_{wi} the average weight of branches in the i th group and $i = 1, 2, 3, \dots, n$ are the branch groups. The branch biomass of individual tree was finally multiplied with the number of trees of the species in all the 15 plots for each station.

Above Ground Leaf Biomass (AGLB) estimation

One tree of each species per plot was randomly considered for estimation. All leaves from six branches (two of each size group) of individual trees of each species were removed and oven dried at 70°C and dry weight (species wise) was estimated. The leaf biomass of each tree was then calculated by multiplying the average biomass of the leaves per branch with the number of branches in that tree. Finally, the dry leaf biomass of the selected mangrove species (for each station) was recorded as per the expression:

$$L_{db} = n_1Lw_1N_1 + n_2Lw_2N_2 + \dots \dots \dots n_iLw_iN_i$$

Where, L_{db} is the dry leaf biomass of selected mangrove species per plot, n_1, \dots, n_i are the number of branches of each tree of the species, Lw_1, \dots, Lw_i are the average dry weight of leaves removed from the branches and N_1, \dots, N_i are the number of trees of the species in the plots.

Carbon estimation

Direct estimation of percent carbon in the AGB was done by *Vario MACRO elemental* CHN analyzer, after grinding and random mixing the oven dried stems, branches and leaves separately for each station. The Above Ground Carbon (AGC) was finally determined in the species (for every station) by the product of percent carbon and Above Ground Biomass (AGB).

Statistical Analysis

To assess whether AGB and AGC varied significantly between sectors and years, ANOVA was performed considering the observed data sets of two decades. Possibilities less than 0.05 ($p < 0.05$) were considered statistically significant.

III. RESULTS

Above Ground Biomass (AGB)

In the western sector, the average AGB of the species were 36.85 tonnes ha⁻¹, 43.17 tonnes ha⁻¹ and 49.04 tonnes ha⁻¹ during 1996, 2005 and 2015 respectively. In the central sector, the mean AGB of the species were 0.84 tonnes ha⁻¹, 2.74 tonnes ha⁻¹ and 7.83 tonnes ha⁻¹ in similar years. In the eastern sector, the species exhibited AGB with mean values of 9.16 tonnes ha⁻¹, 14.76 tonnes ha⁻¹ and 20.21 tonnes ha⁻¹ during the same years. Figure 2 represents station-wise mean AGB of *Sonneratia apetala*.

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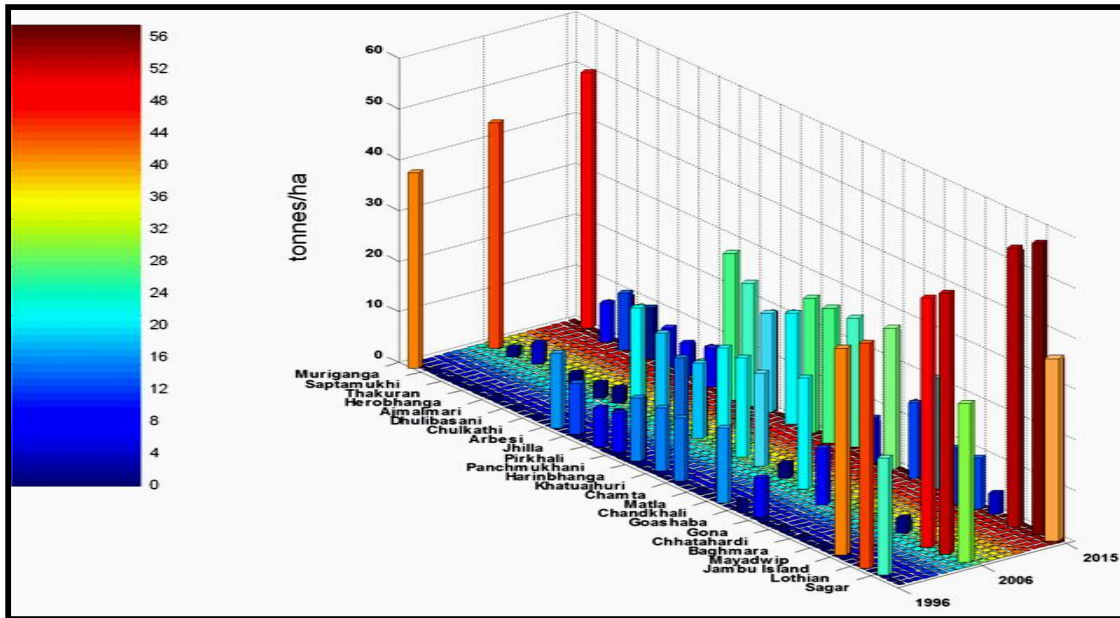


Fig. 2. Spatio-temporal variation of AGB in *S. apetala*

Above Ground Carbon (AGC)

The average AGC in 1996, 2005 and 2015 were 17.92 tonnes ha⁻¹, 20.97 tonnes ha⁻¹ and 23.96 tonnes ha⁻¹ respectively in the western sector. In the central sector of Indian Sundarbans, the average AGC were 0.38 tonnes ha⁻¹, 1.24 tonnes ha⁻¹ and 3.57 tonnes ha⁻¹ in the same years. In the eastern part, the average AGC were 4.35 tonnes ha⁻¹, 7.01 tonnes ha⁻¹ and 9.65 tonnes ha⁻¹ in the similar years. Figure 3 represents the spatio-temporal variation of AGC.

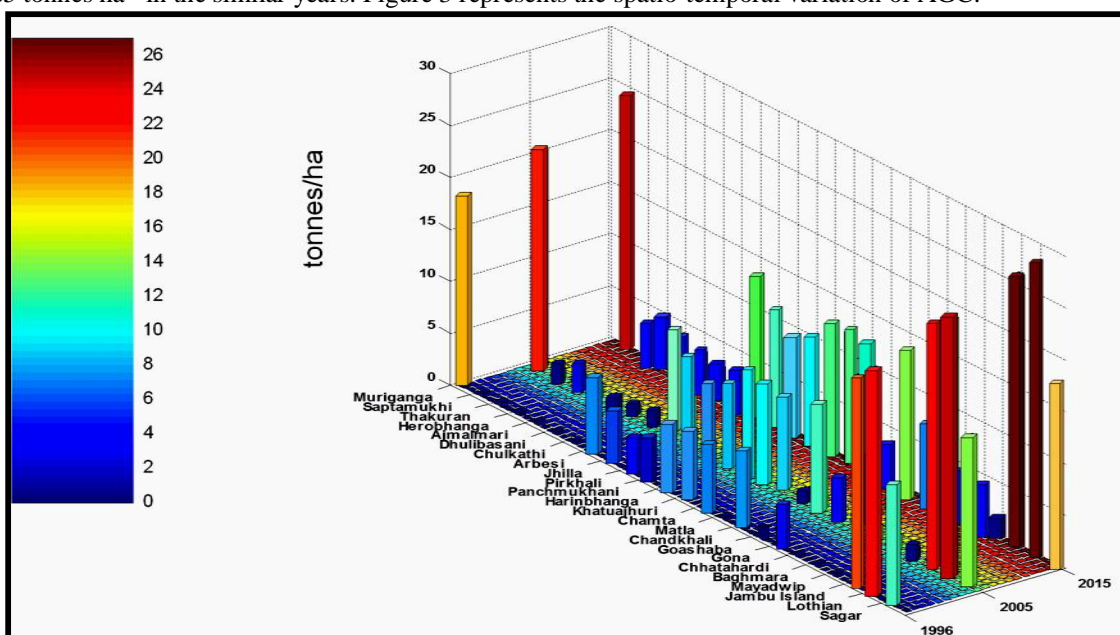


Fig. 3. Spatio-temporal variation of AGC in *S. apetala*

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Table 1: Seasonal and spatial variations of AGB of *S. apetala* from Indian Sundarbans

Source of Variation	SS	df	MS	F _{cal}	P-value	F _{crit}
Stations	14498.98	23	630.39	247.16	9.65×10 ⁻⁴¹	1.77
Years	1177.01	2	588.50	230.73	1.04×10 ⁻²⁴	3.19
Error	117.32	46	2.55	Comment: There are significant variations in AGB of <i>S. apetala</i> between years and stations (p < 0.05)		
Total	15793.31	71				

Table 2: Seasonal and Spatial Variations of AGC of *S. apetala* from Indian Sundarbans

Source of Variation	SS	df	MS	F	P-value	F _{crit}
Stations	3490.36	23	151.75	232.87	3.73×10 ⁻⁴⁰	1.766805
Years	267.89	2	133.95	205.55	1.16×10 ⁻²³	3.199582
Error	29.97	46	0.65	Comment: There are significant variations in AGC of <i>S. apetala</i> between years and stations (p < 0.05)		

IV. DISCUSSION

The Indian Sundarbans at the apex of Bay of Bengal is a complex region with numerous water masses [7]. The western Indian Sundarbans is relatively low saline as it receives the fresh water from the Farakka Barage. On contrary, the central Indian Sundarbans is hypersaline in nature due to lack of head-on discharge. The siltation of the Bidyadhari channel since the late 15th century has imparted such hypersalinity to the region [11]. The eastern Indian Sundarbans adjacent to Bangladesh is again hyposaline as it receives fresh water through Raimangal-Harinbanga River and also through several trans-boundary channels and creeks that supply fresh water from the Bangladesh Sundarbans region. Because of this variation in salinity the AGB and AGC of *S. apetala* has been pronouncedly affected (Tables 1 and 2) and it is of the order Western sector > Eastern sector > Central sector. The present study has great relevance as it pin points the most preferable salinity zone for survival and growth of *S. apetala*, which plays a key role in off-setting atmospheric CO₂ at local level.

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