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Spatial variation of mangrove seedling carbon with respect to salinity: A case study with *Bruguiera gymnorrhiza* seedling

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Abstract

We present evidence that the Indian Sundarbans, a mangrove dominated ecosystem in the lower Gangetic delta at the apex of Bay of Bengal is experiencing the effects of salinity on the biomass and stored carbon in the vegetative parts of a 3-month old seedling of *Bruguiera gymnorrhiza.* Observations on above ground biomass (AGB, comprising of stem and leaves) and below ground biomass (BGB, comprising of the root system) indicate pronounced spatial variations with highest value in the eastern sector followed by western and central sectors. Similar trend is also observed for stored carbon in AGB and BGB. These observed changes could possibly be attributed to a combined effect of salinity and human interventions; the later cause is not a subject of the present study.

Keywords: Above ground biomass (AGB), below ground biomass (BGB), above ground carbon (AGC), below ground carbon (BGC), spatial variations.

Introduction

Bay of Bengal and its adjacent estuaries are less studied regions of world oceans in context of the impact of salinity fluctuation on mangrove floral community although the region sustains the 5th largest mangrove chunk in the world together with Bangladesh Sundarbans. This mangrove chunk sustaining some 34 mangrove species is noted for its carbon sequestering potential (Donato *et al*., 2011; Mitra *et al*., 2011; Banerjee *et al*., 2012; Mitra, 2013; Raha *et al*., 2013; Mitra and Zaman, 2016). However, there is very limited data bank on biomass and stored carbon in mangrove seedlings and the present study is the first attempt from this part of the Indian sub-continent.

Bruguiera gymnorrhiza, a true mangrove species reaches up to 10 m high and belongs to the family Rhizophoraceae. It is found on the seaward side of mangrove swamps, often in the company of Rhizophora. Its bark is rough and reddish-brown. The tree develops short prop-roots rather than long stilt-roots. Flowers are creamy-white soon turning brown. The sepals are persistent, narrow and slightly tapered. When mature, the spindle-shaped fruits drop and become embedded in the mud in an upright position, where they rapidly develop roots.

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Materials and Methods

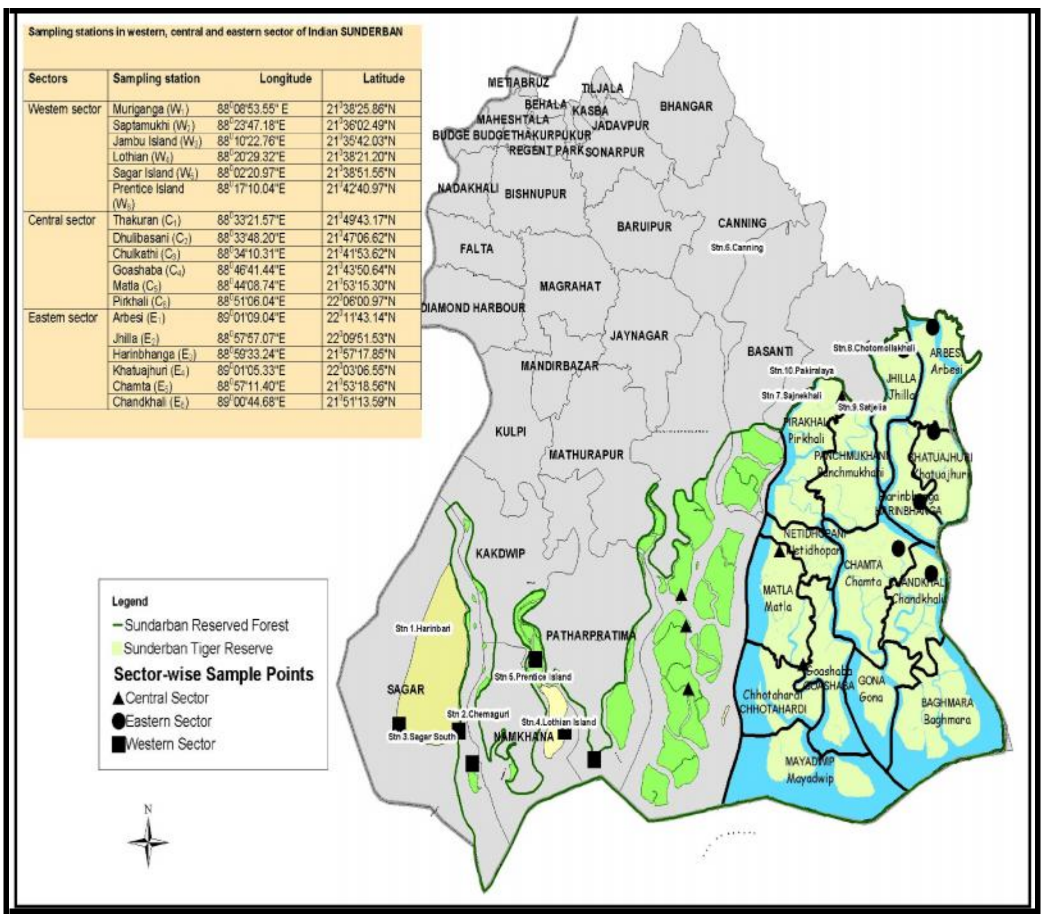
Study Site Description

The glacier Gangotri which is about 7010 m above sea level in the Himalayas is the origin of the mighty River Ganga. After emanating from the Himalayas the River Ganga flows south east through a number Indian cities and towns covering a distance of 2,525 km and finally drains into the Bay of Bengal. The delta that is formed at the apex of Bay of Bengal is known as the Indian Sundarbans and is recognized as one of the most diversified and prolific ecosystems of the tropics (Alongi, 2002). The deltaic complex houses about 102 islands covering an area of 9,630 sq. km (Mitra, 2000). Eighteen sampling sites were selected, six each in the eastern, central and western sectors of Indian Sundarbans (Figure 1). The eastern sector of Indian Sundarbans receives the fresh water from the River Raimangal and also from the Padma - Meghna - Brahmaputra river system of Bangladesh Sundarbans through several creeks and inlets because it is adjoining the Bangladesh Sundarbans (which comprises 62% of the total Sundarbans). The central sector on the other hand, is fully deprived of fresh water supply due to heavy siltation and clogging of the Bidyadhari channel since the 15th century (Chaudhuri and Choudhury, 1994). The western sector of the deltaic lobe also receives the snowmelt water of mighty Himalayan glaciers after being regulated through several barrages on the way. Samplings in these sectors were carried out in low tide period during June, 2016.

Biomass Estimation

Quadrate sampling technique was used in each site which contained 3 to 4 months old seedlings of *B. gymnorrhiza.* 15 sample quadrates (1.0 m × 1.0 m) were established (on the river bank) through random sampling.

Above Ground Biomass (AGB) is the sum total of stem and leaves of the seedlings and Below ground Biomass (BGB) comprises the roots of the seedlings. The seedlings of the species after collection from each quadrate were thoroughly washed with double distilled water to remove any sticking debris, dried at 70°C and the average values of 15 quadrates from each site were finally converted into biomass (gm/m^2) in the study area.



Sampling stations in western, central and eastern sector of Indian SUNDERBAN

Sectors	Sampling station	Longitude	Latitude
Western sector	Muriganga (W_1)	88°06'53.55" E	21°38'25.86"N
	Saptamukhi (W_2)	88°23'47.18"E	21°36'02.49"N
	Jambu Island (W_3)	88°10'22.76"E	21°35'42.03"N
	Lothian (W_4)	88°20'29.32"E	21°38'21.20"N
	Sagar Island (W_5)	88°02'20.97"E	21°38'51.55"N
	Prentice Island (W_6)	88°17'10.04"E	21°42'40.97"N
Central sector	Thakuran (C_1)	88°33'21.57"E	21°49'43.17"N
	Dhulibasani (C_2)	88°33'48.20"E	21°47'06.62"N
	Chulkathi (C_3)	88°34'10.31"E	21°41'53.62"N
	Goashaba (C_4)	88°46'41.44"E	21°43'50.64"N
	Matla (C_5)	88°44'08.74"E	21°53'15.30"N
	Pirkhali (C_6)	88°51'06.04"E	22°06'00.97"N
Eastern sector	Arbesi (E_1)	89°01'09.04"E	22°11'43.14"N
	Jhilla (E_2)	88°57'57.07"E	22°09'51.53"N
	Harinbhanga (E_3)	88°59'33.24"E	21°57'17.85"N
	Khatuajhuri (E_4)	89°01'05.33"E	22°03'06.55"N
	Chamta (E_5)	88°57'11.40"E	21°53'18.56"N
	Chandkhali (E_6)	89°00'44.68"E	21°51'13.59"N

Figure 1. Location of sampling stations in Indian Sundarbans

Carbon Estimation

The stems and leaves of the seedlings were oven dried at 70°C and were randomly mixed separately and grinded to pass through a 0.5 mm screen for stems and 1.00 mm for leaves. These samples were used in the *Vario Macro elementar* CHN analyzer for direct estimation of percent carbon in the AGB. The same process was followed for the roots of the seedlings which gave us the percent carbon in the BGB.

Statistical Analysis

Analysis of variance (ANOVA) was performed to assess whether seedling biomass, seedling carbon varied significantly between sectors; possibilities ($p < 0.05$) were considered statistically significant. All statistical calculations were performed with SPSS 9.0 for Windows.

Results

Blue carbon is presently considered as a unique sink of carbon and its massive plantation is an eco-friendly approach to mitigate the local level carbon dioxide. However, the carbon storage potential of the blue carbon community is a function of population density, biomass and percentage of stored carbon in the vegetative and reproductive structures, which again is controlled primarily by salinity in the coastal and estuarine regions (Mitra *et al.*, 2004; Mitra and Zaman, 2015). The results of population density and biomass are presented here, which are the basic pillars for estimating stored carbon in the target species *B. gymnorrhiza.*

Population Density

Population density of *B. gymnorrhiza* seedlings was highest in the eastern sector (mean value =10 /m^2) followed by western sector (Mean value = 6.67 /m^2) and central sector (mean value = 3.17 /m^2). ANOVA results strongly confirm the significance of variation at 5% level.

Above Ground Biomass (AGB)

The AGB of the mangrove seedlings was highest in the eastern sector (mean value = 15.57 gm/m^2) followed by the western sector (Mean value = 13.38 gm/m^2) and central sector (mean value = 9.10 gm/m^2). ANOVA result confirms significant spatial variations ($p < 0.05$).

Below Ground Biomass (BGB)

The order of mean BGB in the study area is eastern sector (3.79 gm/m^2) > western sector (3.07 gm/m^2) > central sector (2.90 gm/m^2).These results are in accordance with the ANOVA that exhibit significant spatial variation in BGB.

Above Ground Carbon (AGC)

The mean value of stored carbon on the stem is 4.97gm/m^2 in the eastern sector followed by 3.78 gm/m^2 in the western sector and 2.42 gm/m^2 in the central sector. The stored carbon in the leaf followed the same trend with highest value in the eastern sector (2.78 gm/m^2) followed by western (2.76 gm/m^2) and central sector (1.96 gm/m^2). The results are further confirmed by ANOVA data which shows significant spatial variation in ABG

Below ground carbon (BGC)

The order of below ground carbon is eastern sector (1.63 gm/m^2) > western sector (1.27 gm/m^2) > central sector (1.196 gm/m^2). The pronounced variation in BGC is confirmed through ANOVA.

Discussion

It is observed that AGB and BGB exhibit significant spatial variations with highest value in the eastern sector followed by the western and central sectors. Similar trend is also observed in case of stored carbon (Table 1). The probable explanation behind such a trend may be attributed to aquatic salinity and human interventions.

Table 1. Spatial variations of Population density, biomass and stored carbon in vegetative structures of *B. gymnorrhiza* seedlings from Indian Sundarbans

	$F_{observed}$	$F_{critical}$
Population Density		
Between Sectors	10.8519	4.1028
Between Stations	1.2272	3.32584
AGB		
Between Sectors	68.2232	4.1028
Between Stations	3.3274	3.3258
BGB		
Between Sectors	41.5561	4.1028
Between Stations	0.8409	3.3258
AGC		
Between Sectors	76.3063	4.1028
Between Stations	3.3504	3.3258
BGC		
Between Sectors	29.7505	4.1028
Between Stations	0.7731	3.3258

The Indian Sundarbans exhibits three distinct regimes in terms of salinity according to long term studies conducted by many researchers (Figure.2).

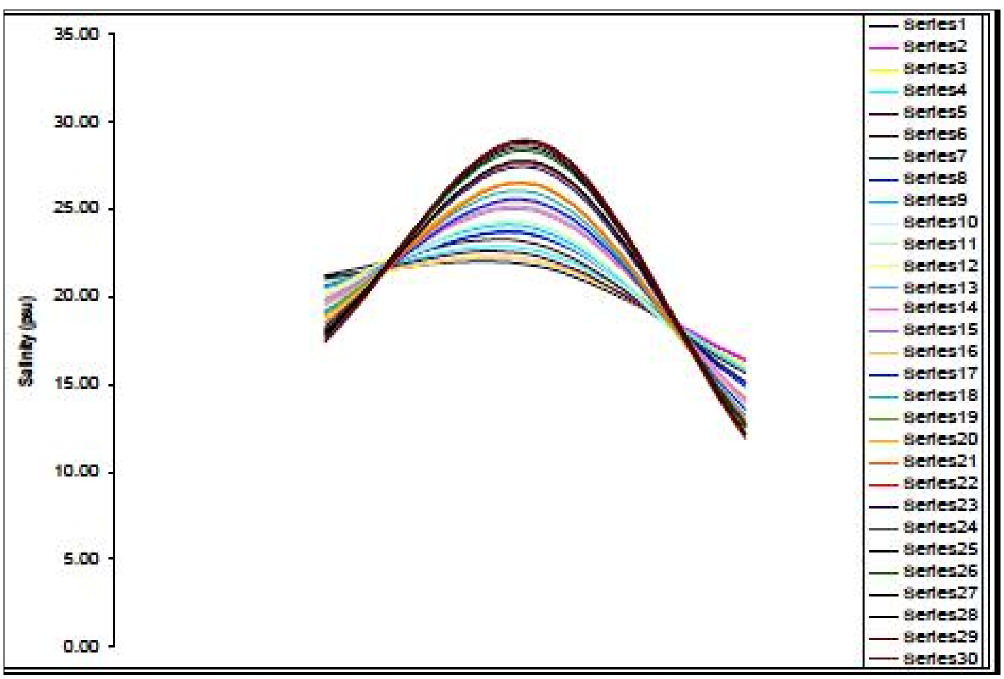


Figure 2. Bell-shaped nature of salinity profile of Indian Sundarbans based on 9200 readings; 30 series represent 30 consecutive years (1984-2013); Source: Trivedi *et al* (2016)

It was noted that the western sector is relatively low saline region owing to fresh water discharge from the Farakka Barrage. 15-year surveys (1999 to 2013) on water discharge from Farakka dam revealed an average discharge of (3.64 ± 1.10) × 10^3 m^3s^{-1}. Higher discharge values were observed during the monsoon with an average of (3.89 ± 1.30) × 10^3 m^3s^{-1}, and the maximum of the order 4568 m^3s^{-1} during freshet (September). Considerably lower discharge values were recorded during premonsoon with an average of (1.09 ± 0.08) × 10^3 m^3s^{-1}, and the minimum of the order 811 m^3s^{-1} during May. During postmonsoon discharge, values were moderate with an average of (1.88 ± 0.85) × 10^3 m^3s^{-1}.

The central sector, on contrary, exhibits hypersaline condition and an increasing trend in salinity through time. The central part of the Indian Sundarbans receives almost no fresh water because of heavy siltation and clogging of the Bidyadhari channel as well as the huge population living on the fringes of the Indian Sundarbans has resulted in high anthropogenic pressures on the mangroves and their resources in this sector (Chaudhuri and Choudhury, 1994). The eastern sector of Indian Sundarbans adjacent to Bangladesh Sundarbans receives fresh water from several channels and creeks from the Padma – Meghna - Brahmaputra river system and their tributaries.

The mangroves are salt tolerant species but under hypersaline condition they exhibit stunted growth (Mitra *et al*., 2004; Raha *et al*., 2013). The order of biomass and stored carbon in *B. gymnorrhiza* seedlings in the present study is basically the reflection of salinity, which is highest and exhibits an increasing trend in the central sector of Indian Sundarbans compared to the other two sectors. In the western and eastern sectors the salinity decreased by 21.91% and 16.35% respectively over a period of 24 years, whereas, in the central sector there has been a steady increase in the salinity by 9.32% during the same period (Mitra, 2013).

The degree of human intervention is also less in the eastern Indian Sundarbans as compared to western and central sectors. The human entry is highly restricted in this part of Indian Sundarbans because of its location. It is located in the Reserve Forest area which is not accessible without proper permission. This causes more natural growth rate and density of mangroves in the eastern sector compared to the western and central sectors, where the mangroves are mostly cut down for timber, fuel etc.

The overall discussion thus explains a congenial environment for the growth of *B. gymnorrhiza* in eastern Indian Sundarbans and also indicates the necessity of freshwater supply to accelerate the biomass and subsequently the stored carbon in *B. gymnorrhiza* seedling thriving in the Indian Sundarbans region in the lower Gangetic delta complex. Considering the abundance of the species and wide range of tolerance to variable salinity, it is of outmost importance to develop nursery of the species (Figure 3) and plant the seedlings in the vacant intertidal mudflats so as to reduce the atmospheric carbon dioxide at the local level.

Figure 3. Nursery of *B. gymnorhizza* in Indian Sundarbans

Conclusion

This study has demonstrated that biomass and stored carbon of the *B. gymnorrhiza* seedlings in the central Indian Sundarbans is a complex phenomenon influenced by a variety of hydro-edaphic conditions. Lack of fresh water supply from the upper catchments coupled with tidal influence from the Bay of Bengal has increased the salinity of central Indian Sundarbans over a period of time. The conditions in the western and eastern Indian Sundarbans are comparatively congenial for the growth of the mangrove species due to fresh water supply from the upstream region. These findings tend to support several other researches that point towards the necessity of dilution of saline water for proper growth and survival of mangrove seedlings.

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