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SPATIO-TEMPORAL VARIATION OF STORED CARBON IN *Porteresia Coarctata* ALONG THE EAST AND WEST COASTS OF INDIA

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ABSTRACT

We evaluated stored carbon in the above ground biomass (AGB) and below ground biomass (BGB) of *Porteresia coarctata* for 12 consecutive years (2001-2012) along the Hooghly estuary (in the north east coast) and Mandovi estuary (in the west coast) of India. In this salt marsh grass species, the BGB is more (~65%) compared to AGB (~35%). The AGB of the species is more in the Hooghly estuarine region (186.88 gm m^{-2} to 262.82 gm m^{-2}) compared to those sampled from the intertidal mudflats of the Mandovi estuary (98.66 gm m^{-2} to 173.66 gm m^{-2}). The BGB ranges from 238.61 gm m^{-2} to 293.12 gm m^{-2} in the Hooghly estuarine stretch and in the Mandovi estuary the BGB ranges from 116.52 gm m^{-2} to 273.67 gm m^{-2}. The above ground carbon (AGC) exhibit a similar trend as that of AGB and BGB with more carbon content in the Hooghly estuarine region (58.33 gm m^{-2} to 104.30 gm m^{-2}) compared to that of the Mandovi estuarine region in the west coast of India (32.57 gm m^{-2} to 63.82 gm m^{-2}). The below ground carbon (BGC) ranged from 47.81 gm m^{-2} to 63.49 gm m^{-2} in the mudflats of Hooghly estuary, where as in the Mandovi estuarine mudflats, the values ranged between 26.79 gm m^{-2} to 54.41gm m^{-2}. Significant spatio-temporal variations in AGB, BGB, AGC and BGC of the species were observed through ANOVA ($p < 0.01$). The present results suggest the potentiality of *P. coarctata* in sequestering carbon, which is primarily site specific because of different growth pattern and biomass.

KEYWORDS: *Porteresia coarctata*, Above ground biomass, Below ground biomass, Above ground carbon, Below ground carbon.

INTRODUCTION

Wetlands under tidal influence are an important constituent of coastal ecosystems for their ecological, socio-economic and aesthetic values. Mangrove habitats in the tropics particularly in the belt of 25ºN–25ºS are the most predominant wetlands. *Porteresia coarctata* [Roxb.] Tateoka, a perennial halophytic wild grass, relative of rice, member of Poaceae acts as a pioneer species in the succession process of mangrove formation along the estuaries of India (Jagtap, 1985; Chauduri and Choudhury, 1994; Mitra and Banerjee, 2005). The species establishes on the newly deposited sediments and helps enhance sedimentation, developing favourable substratum for the growth of mangroves (Fig. 1). The C: N ratio of 21.31 (Bhosle, 2003) in *P. coarctata* leaves indicates it as an excellent source of energy for benthic fauna and cattle. It is one of the natural fodders for camels in the dry and arid northwest regions of India such as Gulf of Kutch in the state of Gujarat. In Sundarban deltaic complex, *P. coarctata* is an important food for the deer. The C: N ratio in *P. coarctata* further indicates that it could be used as compost, organic fertilizer and in aquaculture, similar to some of the other angiosperms (Bauersfeld et al., 1969). *P. coarctata*, though of great significance to estuarine and deltaic environments, is very poorly understood ecologically, compared to other marine and estuarine vegetation. Here we present the temporal and spatial patterns in biomass production and carbon content of *P. coarctata* at selected stations along the banks of Hooghly estuary and Mandovi estuary in the east and west coasts of the Indian sub-continent respectively. The present investigation enriches existing information of *P. coarctata* and is significant to the development of the blue carbon register of the Indian sub-continent.

MATERIAL AND METHODS

Study Site Description

The mighty River Ganga emerges from a glacier at Gangotri, about 7,010 m above mean sea level in the Himalayas and flows down to the Bay of Bengal covering a distance of 2,525 km. At the apex of Bay of Bengal a delta has been formed which is recognized as one of the most diversified and productive ecosystems of the tropics and is referred to as the Indian Sundarbans. The western sector of the deltaic lobe receives the snowmelt water of mighty Himalayan glaciers after being regulated through several barrages (like Farakka barrage) on the way. In Indian Sundarbans, out of seven major estuaries, the Hooghly is the westernmost estuary. Four sampling sites were selected along the Hooghly estuarine stretch in the east coast of India *viz*. E_1 (21°52'26.50"N and 88°08'04.43"E), E_2 (21°47'01.36"N and 88°04'52.98"E), E_3 (21°39'58.15"N and 88°10'07.03"E) and E_4 (21°38'54.37"N and 88°03'06.17"E) for the present study.

Goa is a maritime state in the west coast of India and has ~120 km coastline. The coastal strip is highly indented with sea-cliffs, notches and promontories alternating with rivers and estuaries, and bounded by the Arabian Sea on the west and by the Sahyadri ranges on the east. The steep topography has formed fringes of intertidal zones in the study area (12°28′–15°52′N and 73°46′–73°54′E). The coastline of Goa is indented with seven major estuaries including Mandovi, the site of the present programme. Four stations along the Mandovi estuary namely W_1 (73°46'57.3"E and 15°30'49.3"N), W_2 (73°52'10.6"E and 15°30'42.7"N), W_3 (73°54'06.5"E and 15°30'33.5"N) and W_4 (73°59'08.9"E and 15°30'26.4"N) were selected on the basis of availability of the species.

Sampling

Yearly samplings for biomass estimation of *P. coarctata* were carried out at ebb during every March from 2001 to 2012 in the intertidal mudflats along the Hooghly estuary (in the east coast) and Mandovi estuary (in the west coast). A perpendicular belt (~50 m width) transect to the shore was laid on the *Porteresia* beds from low tide to high tide mark at each station. The length of transect varied from 20 to 250 m depending upon the horizontal extent of beds to the shore. Each transect was divided into three zones, namely, low tide (LT), mid-tide (MT) and high tide (HT). Sampling interval varied at different stations from 5 to 50 m, depending upon the transect length. At each station, two to three perpendicular transects were laid down, depending upon the extent of beds parallel to the shore. The biomass was estimated by removing all the plants along with roots, rhizomes and shoots from five quadrants (each of $1m^2$ size), from each tidal zone. Plant material was thoroughly washed in the ambient water immediately after collections, as well as with tap water, to remove adhering debris and sediments. The various vegetative parts (above and below ground) were separated and sun dried and weighed and the results were expressed as gm m^{-2} on an average basis for different tidal zones.

Carbon estimation

Direct estimation of percent carbon in the AGB and BGB was done by *Vario MACRO elementar* CHN analyzer, after grinding and random mixing, the oven-dried above ground and below ground structures separately. This exercise was performed for the samples of eight stations collected from both the coasts.

STATISTICAL ANALYSIS

Analysis of variance (ANOVA) was performed to assess whether biomass and carbon content varied significantly between (i) stations of each coast, (ii) the two coasts and (iii) years; possibilities ($p < 0.01$) were considered statistically significant. All statistical calculations were performed with SPSS 14.0 for Windows.

RESULT AND DISCUSSION

The recent thrust on global warming phenomenon has generated tremendous interest in the carbon-storing ability of coastal vegetation. The carbon sequestration in this unique producer community is a function of biomass production capacity, which in turn depends upon interaction between edaphic, climate, and topographic factors of an area. Hence, results obtained at one place may not be applicable to another. Therefore region based potential of storing and sequestering carbon by coastal vegetation on different land types or substratum characteristics needs to be worked out. In the present study spatio-temporal variations of stored carbon have been worked out separately for AGB and BGB of *P. coarctata*.

Above Ground Biomass (AGB)

In the Hooghly estuarine region, the AGB values ranged from 186.88 gm m^{-2} (in 2002 at E_1) to 262.82 gm m^{-2} (in 2006 at E_4), whereas, in the Mandovi estuary, the AGB ranged from 98.66 gm m^{-2} (in 2001 at W_3) to 173.66 gm m^{-2} (in 2008 at W_1) (Fig. 1). The decadal survey indicates an average AGB of 215.00 gm m^{-2} and 128.08 gm m^{-2} in the east and west coasts respectively. The spatial variation between stations in each coast (Table 1 and 2) as well as between coasts (Table 3) are statistically significant as reflected through ANOVA ($p < 0.01$).

Below Ground Biomass (BGB)

Fig. 2. shows the BGB in *P. coarctata* in the estuarine stretches of east and west coasts. In the Hooghly estuary, the values ranged from 217.18 gm m^{-2} (in 2006 at E_4) to 293.12 gm m^{-2} (in 2002 at E_1), whereas, in the Mandovi estuary, the values ranged from 116.52 gm m^{-2} (in 2006 at W_4) to 273.67 gm m^{-2} (in 2006 at W_2). The average BGB in the east and west coasts are 265.37gm m^{-2} and 178.96 gm m^{-2} respectively. ANOVA results also confirm significant spatial variations in BGB between stations in each coast (Table 1 and 2) and between coasts (Table 3) and ($p < 0.01$).

Above Ground Carbon (AGC)

In the AGC of the species collected from the Hooghly estuary, the values of stored carbon range from 58.33 (at E_1 during 2002) to 104.30 gm m^{-2}, (at E_4 during 2011), whereas in the west coast (along the Mandovi estuary), the values are relatively less (32.57 at W_3 during 2000 to 63.82 gm m^{-2} at W_4 during 2011) (Fig. 3). The average carbon stored in the AGC at east and west coasts are 74.91gm m^{-2} and 44.48 gm m^{-2} respectively. ANOVA results also confirm significant spatial variations in AGC between stations in each coast (Table 1 and 2) and also between coasts (Table 3) ($p < 0.01$).

Below Ground Carbon (BGC)

Fig. 4. shows the carbon content in the root system of the species. The carbon content in BGC of *P. coarctata* follows the same trend as AGC with relatively more stored carbon in the samples from the mudflats in the Hooghly estuary in the east coast (47.81 at E_1 during 2008 to 63.49 gm m^{-2} at E_4 during 2009) compared to the Mandovi estuary in the west coast (26.79 at W_4 during 2006 to 54.41 gm m^{-2} at W_2 during 2006). The average carbon stored in the BGC at east and west coasts are 55.25 gm m^{-2} and 36.87 gm m^{-2} respectively. ANOVA results also confirm significant spatial variations in BGC between stations in each coast (Table 1 and 2) and also between coasts (Table 3) ($p < 0.01$).

DISCUSSION

Porteresia beds are commonly confined to polyhaline (18–30 psu) zones, but the species can also survive at ~ 35 psu salinity. The species prefers low salinity for its germination and early growth (Jagtap, 1985). This may be one of the reasons for better growth and biomass of *P. coarctata* in the east coast compared to the west coast. The average salinity of Hooghly estuary in March (as our team conducted the present study during March for 12 successive years) is ~ 20 psu, where as in Mandovi estuary the value is ~ 34 psu (range 30-35 psu) (Mitra et al., 2009; Menon and Sangekar, 2010 and Shetye, 2011).

The biomass and growth of *P. coarctata* also appeared to be strongly influenced by rich nitrite and nitrate contents along with lower salinity. Nutrients, particularly nitrogen enhance the plant productivity (Rigollet et al., 1998; Tamasko and Hall, 1999). The luxuriant growth and higher biomass of *P. coarctata* in the east coast could certainly be attributed to the high nutrient contents and lower salinity (Mitra and Banerjee, 2005). The relatively more biomass of the species in the east coast is the basic cause of more carbon storage in the AGB and BGB of *P. coarctata*.

It is noteworthy that AGC of *P. coarctata* is accounted considerably to AGB, unlike BGC that has minimum dependency on BGB. The carbon sequestration in the AGB in this salt marsh grass species, thus, is a function of biomass production capacity that depends on the interaction between edaphic, climate, and topographic factors. Hence, results or allometric model obtained at one location may not be generalized through out the coastal region.

The present study concludes that salt marsh grass system is a unique store house and sink of carbon. Although the present study left out the soil compartment in the study sites, but it has been established that each molecule of CO_2 sequestered in soils of tidal salt marshes and their tropical equivalents, mangrove swamps, probably has greater value than that stored in any other natural ecosystem due to the lack of production of other greenhouse gases. Contrary to the freshwater wetland soils, marine wetlands produce little methane gas, which is a more potent greenhouse gas than CO_2. The presence of sulphates in salt marsh soils reduces the activity of microbes that produce methane (IUCN Report, 2009). Considering the ecological significance of salt marsh grass system, policy must be implemented to preserve and restore the system, which have been destroyed and damaged in many parts of the globe by activities like dredging, tilling, draining, construction of roads and are now threatened by sea level rise.

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TABLE 1
ANOVA results showing variations of AGB, BGB, AGC and BGC of *P. coarctata* between years and stations in the Hooghly estuary

Variables	F_{cal}	F_{crit}
AGB		
Between Years	5.89	2.09
Between Stations	16.03	2.89
BGB		
Between Years	5.89	2.09
Between Stations	16.03	2.89
AGC		
Between Years	10.03	2.09
Between Stations	51.68	2.89
BGC		
Between Years	2.53	2.09
Between Stations	9.34	2.90

TABLE 2
ANOVA results showing variations of AGB, BGB, AGC and BGC of *P. coarctata* between years and stations in the Mandovi estuary

Variables	F_{cal}	F_{crit}
AGB		
Between Years	5.73	2.09
Between Stations	6.35	2.89
BGB		
Between Years	1.88	2.09
Between Stations	29.15	2.89
AGC		
Between Years	8.56	2.09
Between Stations	8.00	2.89
BGC		
Between Years	0.56	2.09
Between Stations	9.66	2.89

TABLE 3
ANOVA results showing variations of AGB, BGB, AGC and BGC of *P. coarctata* between the Mandovi and Hooghly estuarine stretches

Variable	F_{cal}	F_{crit}
AGB		
Between Years	8622.34	2.82
Between Coasts	1142122.00	4.85
BGB		
Between Years	14.02	2.82
Between Coasts	2162.65	4.85
AGC		
Between Years	223.33	2.82
Between Coasts	12728.77	4.85
BGC		
Between Years	1.77	2.82
Between Coasts	975.65	4.85

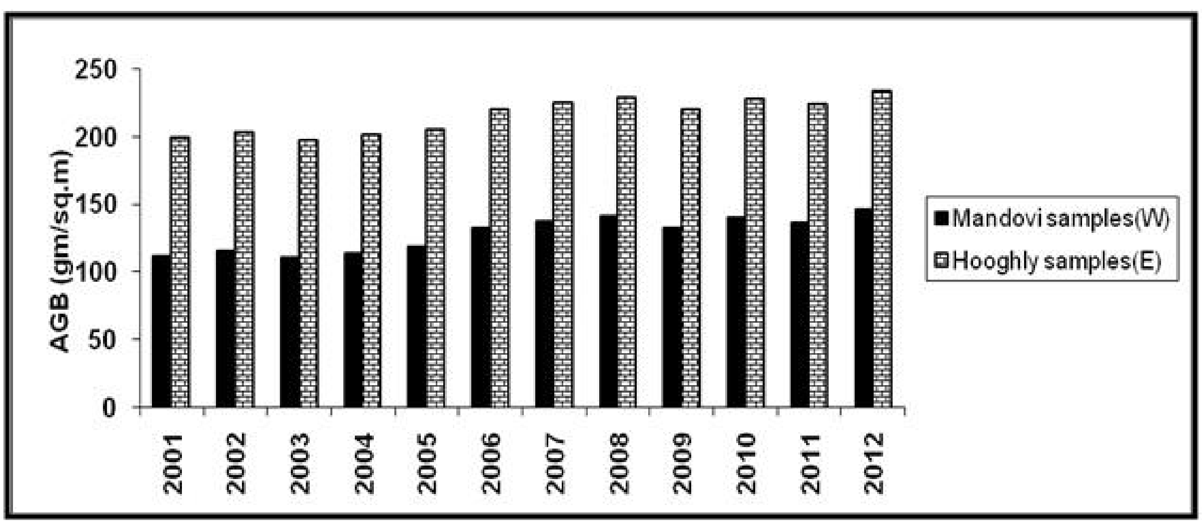

Fig. 1. AGB in *P. coarctata* samples from the Hooghly and Mandovi estuary

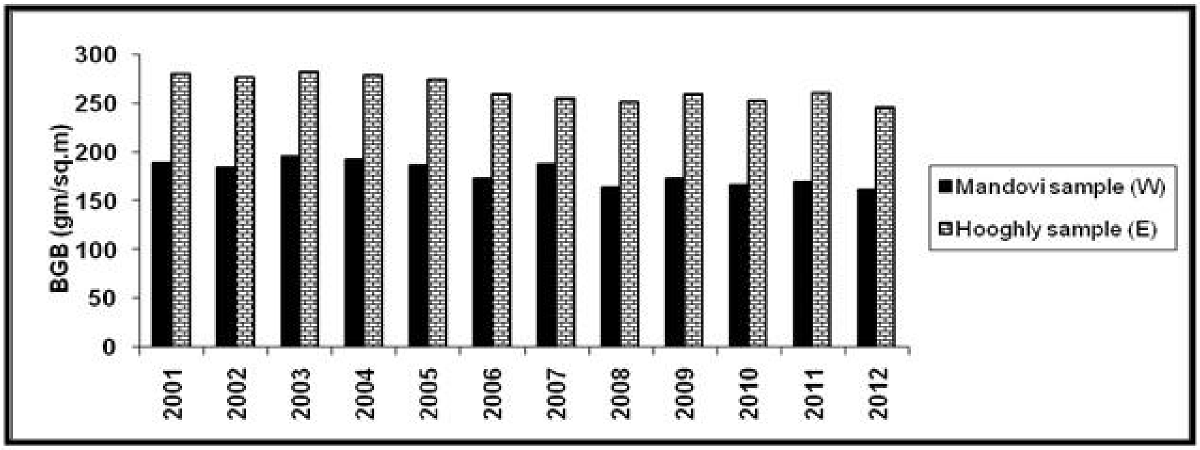

Fig. 2. BGB in *P. coarctata* samples from the Hooghly and Mandovi estuary

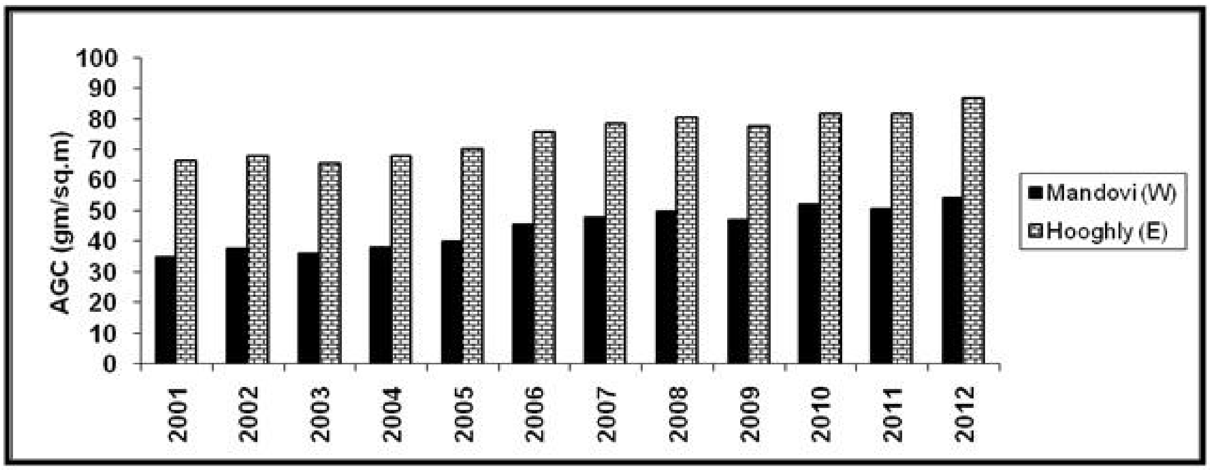

Fig. 3. AGC in *P. coarctata* samples from the Hooghly and Mandovi estuary

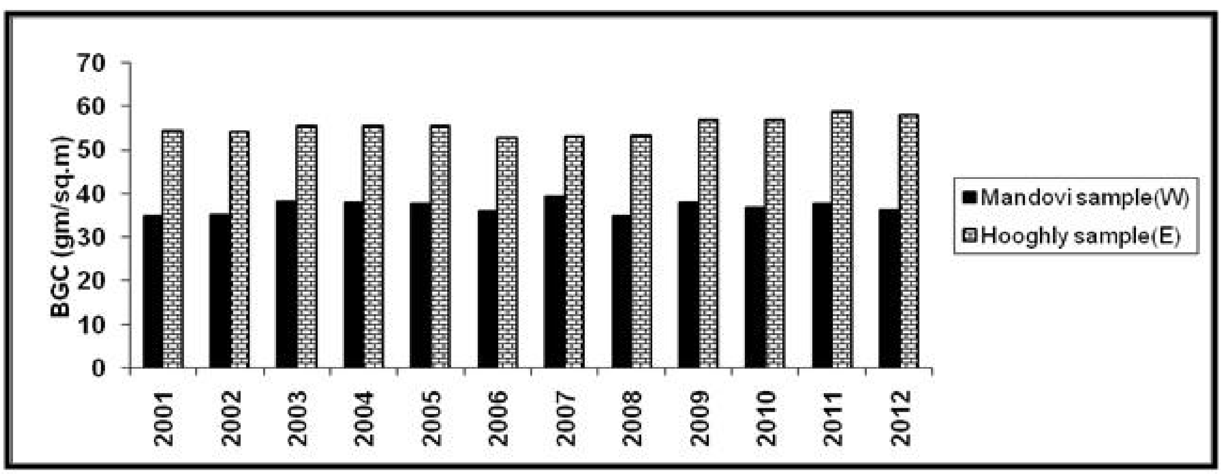

Fig. 4. BGC in *P. coarctata* samples from the Hooghly and Mandovi estuary