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Variation in sediment organic carbon stock in Bhitarkanika wetlands, India

K Banerjee*, G Bal, K Mallik & R Paul

Department of Biodiversity and Conservation of Natural Resources, Central University of Odisha, Landiguda, Koraput, Odisha – 764 021, India

*[E-mail: banerjee.kakoli@yahoo.com]

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Wetlands are known to sequester atmospheric CO_2 in biomass and sediments, often referred to as “blue carbon” of the ocean. The present research has tried to focus on depth-wise (0-10, 10-20, 20-30, 30-40 and 40-50 cm) profile of sediment organic carbon (OC) along with temperature, pH, electrical conductivity (EC) and bulk density (BD) seasonally in Bhitarkanika wetlands at five different locations for two years 2016-17 and 2017-18, respectively. Variation of sediment temperature with depth ranged from 21.32±0.76 to 34.13±0.58 °C, pH ranged from 4.8±0.28 to 6.6±0.75, EC ranged from 0.167±0.08 to 1.814±1.89 Sm^{-1}, BD ranged from 740±0.06 to 125±0.17 kg m^{-3} and OC ranged from 0.24±0.14 to 3.57±0.80 %, respectively. Variation of OC between season, depth and stations has been proved through ANOVA analysis. The study revealed approximately 22.45±11.24 to 63.51± 37.84 t ha^{-1} CO_2 equivalent is being absorbed by the sediment compartment in this mangrove ecosystem, confirming the potentiality of mangrove sediment as a sink of carbon dioxide.

[**Keywords**: CO_2 equivalent, Mangrove sediment, Organic carbon, Physico-chemical variables]

Introduction

Wetland plays a significant role in global carbon cycling because of their high primary productivity[1,2]. Among the wetlands, floral communities - mangroves are the most dominant and its vegetation occupies and covers approximately 1,38,000 to 1,80,000 km^2 of global landscapes[3-6]. Coastal wetlands are the most active regions of the biosphere in terms of biological and geological pathways[7]. Owing to their extensive root system they are known to coagulate and assemble sediments to large extent through their integrated root system. This leads to an anoxic and acidic environment. Litter and detritus in the sediments play a pivotal role in increasing the potential for large amount of carbon deposition[8]. Data on the contribution of mangrove wetland as a global carbon sink in tropical and subtropical areas are limited, although the rate of carbon accumulation in mangrove sediments is quite high. It has been estimated that the mangrove ecosystem can sequester 174 g C m^{-2} y^{-1} on average which is also known as “Blue carbon” of the ocean[8,9].

Mangrove ecosystem usually stores organic carbon which originates from industrial and domestic waste, agriculture and aquacultural outfalls, accidental oil spillage and also from the decomposition of organic material like marine organisms[10]. This deposited organic carbon depends on the soil texture distribution over the wetlands and is either resuspended and disturbed by the waves, tides and currents[11,12]. Organic carbon in the mangrove sediments determines the redox potential and pH in the sediments which are responsible for the growth and sustenance of the mangrove ecosystem. Sediments in mangrove forests act as a reservoir of carbon because of their physical, chemical and biological composition making it a high storehouse of carbon[13-15]. Research on mangrove ecosystem focusing on carbon cycle dynamics and sequestration has been carried out for the last 20 years[15]. These forests are located in the transition zone, providing a unique combination of sediment carbon. Most pioneering work in the field include Duarte *et al.*[16] and Jannerjaha & Ittekot[17] on the global extent of mangroves representing < 2 % of the marine environment and accounting for 10-15 % of total organic carbon.

Several studies have been published on species composition and structure of tropical mangrove forests. However, the basic component of sediment is often ignored which is also a sink of carbon because of the role they play in regulation of anthropogenic and natural factors. The present study is therefore an attempt to understand the seasonal and depth-wise variation in organic carbon dynamics of Bhitarkanika wetland which is known for its highest reptile diversity and invertebrate fauna in India.

Materials and Methods

Study area

The study was carried out in Bhitarkanika Wildlife Sanctuary (BWLS). It is situated in the maritime state of Odisha, east coast of India on the western side of Bay of Bengal. It extends from 20°04' to 20°08' N latitude and 86°45' to 87°05' E longitude with an area of 672 km^{2}(ref. 18). The sanctuary is encircled with river Hansua on the west, river Dhamra in north and Bay of Bengal in the east and south. The sanctuary is crowned with three feathers namely, Wildlife Sanctuary in 1975, National Park in 1998 and Ramsar wetland in 2002. The area is characterized by 35 km long coastal stretch comprising of Gahirmatha Marine Sanctuary (1435 km^2) declared in 1997 for the conservation of marine turtle (*Olive ridley*) and marine and estuarine life. The area is influenced by tropical climate with three seasons *viz*. post-monsoon (October to January), premonsoon (February to May) and monsoon (June to September). The region experiences an average temperature and rainfall of 15-30 °C and 1670 mm, respectively. Five stations were selected in the study area *i.e*. stn. 1: Dangmal, stn. 2: Bhitarkanika, stn. 3: Gupti, stn. 4: Habalikhati and stn. 5: Ekakula (Fig. 1).

Sediment sampling and analysis

Mangrove sediment sampling was carried out seasonally from all the sampling stations at 5 different

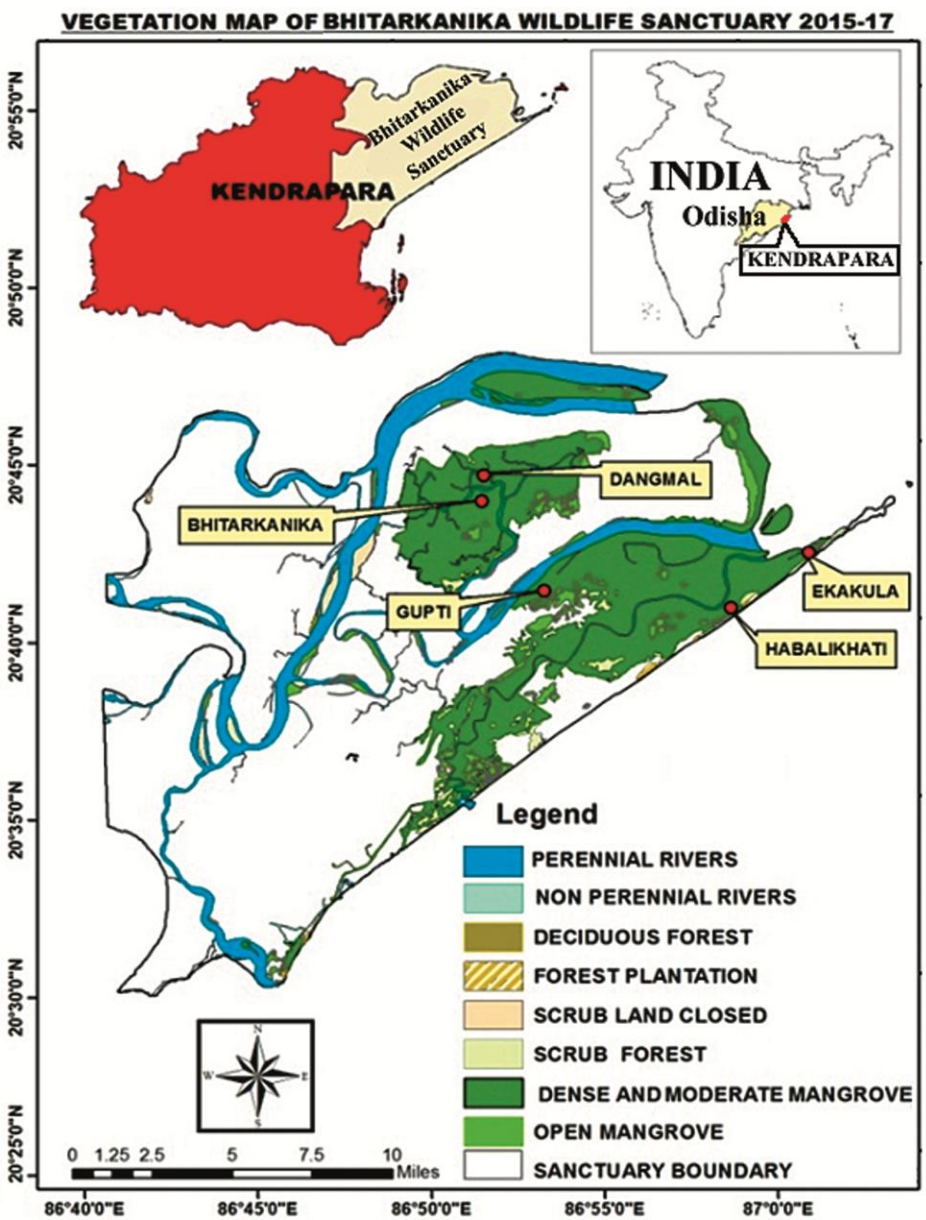

Fig. 1 — Map of Bhitarkanika Wildlife Sanctuary with sampling stations

sampling depths (0-10, 10-20, 20-30, 30-40 and 40-50 cm) during 2016-2018 randomly in clean polythene bags. The samples were cleaned for litter and were then analyzed for *in-situ* temperature, pH, electrical conductivity, bulk density and organic carbon, respectively. Sediment temperature was monitored with the help of digital thermometer (Model: Sigma), sediment pH was measured with the help of soil pH meter (Model: ZD-05) with sensitivity ±0.02 and electrical conductivity was measured with soil EC meter (Model: EC tester).

For estimation of bulk density and organic carbon, sediments were brought to the laboratory after collecting it through soil corer, dried in a hot air oven and was then estimated as per the formula.

$$\text{Bulk density (kg/m}^3\text{)} = \frac{\mathrm{Md}}{\mathrm{V}}$$

Where, M_d = Dry biomass and V is the volume of the cylinder.

For soil organic carbon (SOC), modified Walkley and Black method[19] was used after titrating it with ammonium ferrous sulphate solution as per the formula.

$$\text{SOC (\%)} = \frac{3.951}{\mathrm{g}} \times \left(1 - \frac{\mathrm{S}}{\mathrm{B}}\right)$$

Where, g = weight of soil taken, S = Mohr salt consumed for sample, and B = Mohr salt consumed for blank.

The conversion of carbon percentage to carbon ton per hectare (t C ha^{-1}) and equivalent atmospheric CO_2 (CO_2e) was also done using the standard formula of Homann *et al.*[20].

$$\text{SOC (t ha}^{-1}\text{)} = \text{Bulk density (kg m}^{-3}\text{)} \times \text{depth of soil (0.1 m)} \times \text{SOC (\%)}$$

$$CO_2e\text{(t ha}^{-1}\text{)} = 3.67 \times \text{SOC (t ha}^{-1}\text{)}$$

Results and Discussion

Mangrove sediments are characterized by the saline, anoxic, acidic and waterlogged system, which are continuously inundated by tidal action and sporadically by floodwaters during cyclones[21,22]. Mangrove sediment properties are valuable parameters influencing the floral and faunal assemblage of the mangrove community. A sound physical and chemical quality of the sediment ensures good health of the mangrove forest. Sustenance and productivity of sediment depend upon SOC and bulk density. Mangrove sediments are characterized by a lot of mangrove litter, because of which sediments are usually black and produces strong odour due to presence of hydrogen sulphide resulting from anaerobic sulphur reducing bacteria (*Desulfovibrio* spp.), which thrive in this anoxic conditions[23]. The physical, chemical and biological properties of sediments in mangrove forest differ widely to different forest sites, which is a result of various intricate interactions between biotic and abiotic factors. In the present study similar variation in sediment temperature, pH, electrical conductivity, bulk density and SOC has shown specific trends with depth, space and time. All these parameters play a vital role in the regulation of SOC chemistry in the mangrove sediments. This directly or indirectly is responsible for huge reptilian diversity in the sanctuary.

Sediment temperature

The temperature of the soil varied from 21.32±0.76 °C at stn. 1 in post-monsoon 2017 to 34.13±0.58 °C in premonsoon 2017 at stn. 5. Higher sediment temperature was recorded from 0 to 10 cm depth in comparison to the other depths down below up to 50 cm, although no significant trend was observed with depth at the selected stations. At depth of 10 cm minimum and maximum temperature ranged from 22.12±0.45 °C at stn. 2 in post-monsoon 2017 to 34.13±0.58 °C in premonsoon 2017 at stn. 5; at depth of 20 cm the sediments temperature values ranged from 21.54±0.47 °C in post-monsoon 2017 at stn. 2 to 34.08±1.39 °C at premonsoon 2017 at stn. 5; at 30 cm depth it ranged from 21.32±0.76 °C in post-monsoon 2017 at stn. 1 to 33.99±0.27 °C in premonsoon 2017 at stn. 5; at 40 cm depth it ranged from 21.94±0.84 °C in post-monsoon 2017 at stn. 2 to 34.0±0.46 °C in premonsoon 2017 at stn. 5 and at depth of 50 cm it ranged from 22.11±0.86 °C in post-monsoon 2017 at stn. 2 to 33.89±0.43 °C in premonsoon 2017 at stn. 5, respectively (Fig. 2). There was a significant difference ($p < 0.05$) in temperature between seasons and between stations which may be attributed to the fact that the stations being located at different geographical and physiographical locations and distinct seasonal variation in temperature at the selected stations. Similar anomalies with depth and season were also observed by Das *et al.*[24].

Sediment pH

The pH of the sediments is depended on the chemical reactions of microbes which transform

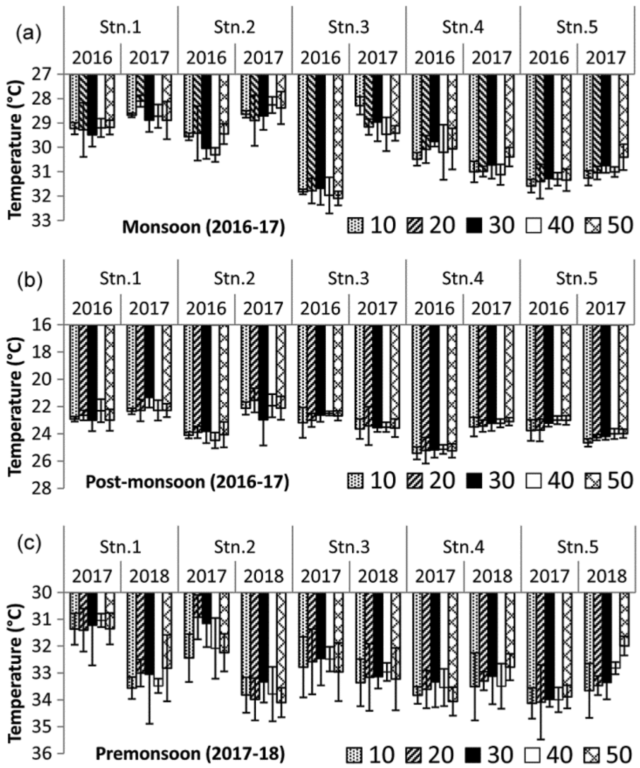

Fig. 2 — Seasonal depth-wise variations in temperature (°C) of the selected station: a) Monsoon (2016-17), b) Post-monsoon (2016-17), and c) Premonsoon (2017-18)

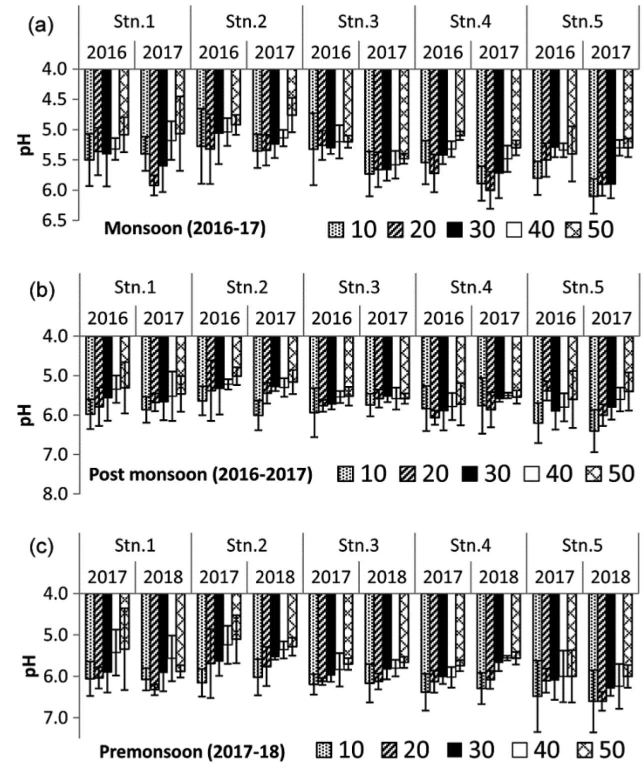

Fig. 3 — Seasonal depth-wise variations in pH of the selected stations: a) Monsoon (2016-17), b) Post-monsoon (2016-17), and c) Premonsoon (2017-18)

organic material into inorganic form leading to increase or decrease in acidity or alkalinity. According to Clarke[25] the pH of mangrove sediments usually ranges between 6 to 7. However, some soils may have pH as low as 5. In the present study, lower pH was observed at stn. 2 being a major mangrove chunk of this study area. The overall pH during the study period displayed a decreasing trend with depth and the values ranged from 4.8±0.28 in monsoon 2017 at stn. 2 to 6.6±0.75 in premonsoon 2018 at stn. 5. With respect to depth, at 10 cm minimum pH of 5.3±0.62 was observed during monsoon 2016 at stns. 2 and 3 and maximum pH of 6.6±0.75 was observed at stn. 5 during premonsoon 2018; at 20 cm depth the minimum pH of 5.3±0.58 was observed at stns. 2 and 3 during monsoon 2016 and maximum pH of 6.6±0.23 was observed during premonsoon 2018 at stn. 5; at 30 cm depth the minimum and maximum pH varied from 5.1±0.51 in monsoon 2016 at stn. 2 to 6.3±0.17 in premonsoon 2018 at stn. 5; at 40 cm it ranged from 5.0±0.23 in monsoon 2016 at stn. 2 to 6.2±0.54 in premonsoon 2018 at stn. 5 and at 50 cm it ranged from 4.8±0.28 in monsoon 2017 at stn. 2 to 6.0±0.27 in premonsoon 2017-18 at stn. 5, respectively (Fig. 3). Considering both the years, significant difference in pH was observed between stations, between depths and between seasons at 5 % level of significance, proving the fact that the difference in the quality and quantity of mangrove patch in the study sites has led to the features of a unique characteristics of decreased pH levels. The organic acids released from this vegetation displays actively metabolizing mangrove bacteria, which continuously releases CO_2 from the acidic soils. In addition to that, the amount of mangrove litterfall in the intertidal mudflats and their subsequent decomposition has led to the depthwise spatial and seasonal variation ($p < 0.05$) of pH in the study sites. Similar results of sediment pH were also observed by Biswas *et al.*[10] and Mitra *et al.*[26].

Sediment electrical conductivity (EC)

Soil salinity (expressed in terms of electrical conductivity) indicates the amount of discharge received by the different rivers in the sanctuary *viz.* the Bramhani, Baitarani and Bausagada and from other small distributaries along with anthropogenic outfall. The data reveals EC values to be lower at stn. 1 and stn. 2 compared to stns. 3, 4 and 5 owing to their proximity to the riverine discharge of Bramhani and Baitarani, respectively. The seasonal EC values varied from 0.167±0.08 Sm^{-1} in monsoon 2016 at stn. 2 to 1.814±1.89 Sm^{-1} during premonsoon 2018 stn. 5. Concerning the depth, all the EC values of mangrove sediment have shown an increasing trend at all stations and seasons, respectively. With depth at 10 cm, EC values varied from 0.167±0.08 Sm^{-1} in monsoon 2016 at stn. 2 to 1.581±0.60 Sm^{-1} during premonsoon 2017 at stn. 4; at 20 cm depth the values ranged from 0.246±1.19 Sm^{-1} during monsoon 2016 at stn. 2 to 1.492±1.89 Sm^{-1} during premonsoon 2017 at stn. 5; at 30 cm depth the values varied from 0.274±0.39 Sm^{-1} in monsoon 2016 at stn. 2 to 1.652±2.39 Sm^{-1} during premonsoon 2017 at stn. 5; at 40 cm depth it ranged from 0.559±2.08 Sm^{-1} during monsoon 2016 at stn. 2 to 1.763±1.84 Sm^{-1} during premonsoon 2017 at stn. 5 and at 50 cm depth it ranged from 0.517±2.40 Sm^{-1} during monsoon 2016 at stn. 2 to 1.814±1.89 Sm^{-1} during premonsoon 2018 at stn. 5, respectively (Fig. 4). The significant difference ($p < 0.05$) in EC values was observed with depth, seasons and stations, which proves that there is a considerable variation in the flow of river water, precipitation and temperature in the study sites. The tidal action of waters from Bay of Bengal has shown a significant effect on sediment EC because of which higher sediment EC was observed at stns. 4 and 5. The year 2016 had an effect of the flood because of which the values of sediment EC during 2016 were comparatively lesser than 2017. The difference in precipitation with the seasons and the run-off from the adjacent landmasses is a characteristic abiotic factor for the difference in EC values at the selected sites. The values of sediment EC which otherwise is a measure of soil salinity have increased with depth owing to percolation of tidal water beneath the sediment because of which *Rhizophora mucronata*, *Excoecaria agallocha* and *Avicennia marina* species are dominant at stns. 4 and 5, respectively. The dominancy of *Heritiera fomes* and *Avicennia officinalis* species at stns. 1 and 2 have proved the above facts. Similar observations of high salinity was also recorded by Biswas *et al.*[10] and Das *et al.*[29], respectively.

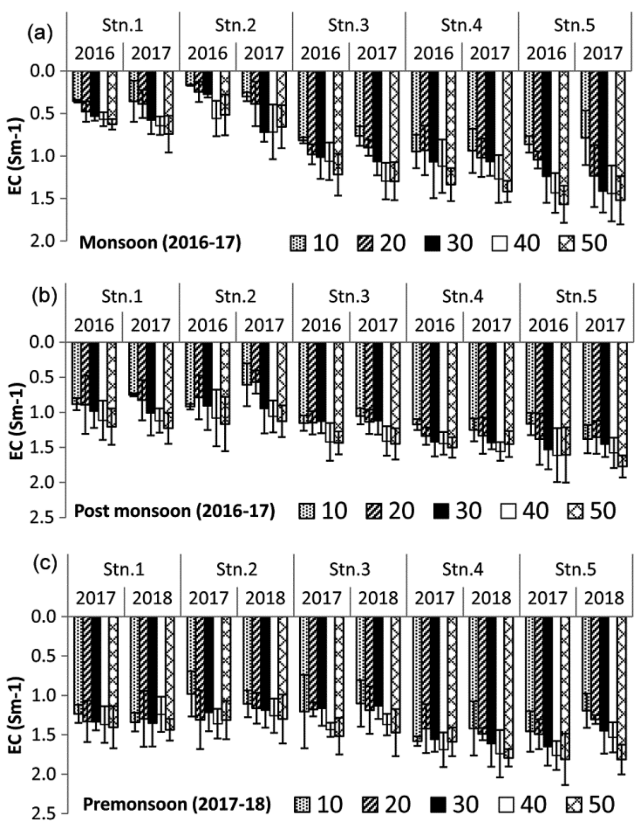

Fig. 4 — Seasonal depth-wise variations in electrical conductivity (Sm^{-1}) of the selected stations: a) Monsoon (2016-17), b) Post-monsoon (2016-17), and c) Premonsoon (2017-18)

Sediment bulk density (BD)

Bulk density (or in other words compactness of the soil), with respect to soil weight and volume, speaks about the amount of sand, silt and clay percentage of sediments. Lower BD is a characteristics of strong structure and coarse-textured forest soil which reflects high porosity[27]. The study area has observed low bulk density at all the selected stations being a mangrove soil, which is a characteristics of more percentage of silt and clay in comparison to sand. With respect to depth, there is an increasing trend of BD at all the stations and in all the seasons. However, with respect to seasons, monsoon has shown a higher BD than post-monsoon and premonsoon, respectively. The BD values at 0 to 10 cm depth ranged from 740±0.06 kg m^{-3} in premonsoon 2018 at stn. 5 to 1020±0.04 kg m^{-3} during monsoon 2017 at stn. 3; at 20 cm depth the values ranged from 750±0.02 kg m^{-3} during premonsoon 2018 at stn. 5 to 1070±0.10 kg m^{-3} during monsoon 2017 at stn. 3; at 30 cm depth it ranged from 760±0.08 kg m^{-3} during premonsoon 2017 at stn. 5 to 1180±0.20 kg m^{-3} during monsoon 2016 at stn. 4; at 40 cm depth it ranged from 780±0.08 kg m^{-3} during premonsoon 2017 at stn. 5 to 1210±0.10 kg m^{-3} during monsoon 2016 at stn. 4 and at 50 cm depth it ranged from 830±0.12 kg m^{-3} during premonsoon 2017-18 at stn. 5 to 1250±0.17 kg m^{-3}

during monsoon 2016-17 at stns. 3 and 4, respectively. The overall BD values in the study sites ranged from 740±0.06 kg m^{-3} at stn. 5 during premonsoon 2018 to 1250±0.17 kg m^{-3} during monsoon 2016-17 at stns. 3 and 4, respectively (Fig. 5), proving that the monsoon season is the season for more deposition of fine sand, silt and clay as a result of high precipitation and outwelling from the adjacent habitations. This is a characteristics phenomenon in the tropical evergreen forests. Significant variation ($p < 0.05$) of BD has also been proved through ANOVA analysis between depths, seasons and stations, respectively. Similar observation on BD has also been observed by Sah *et al.*[28], Ukpong[29] and Biswas *et al.*[10].

Sediment organic carbon (SOC)

SOC is a major concern for tropical soil because of its importance in the global carbon cycling process. The SOC is dependent on the climate of the area, the amount of litterfall, abundance and distribution of vegetation, as well as on the anthropogenic activities[24]. The seasonal variation of OC in the present study showed higher values in post-monsoon season and slightly lower values in monsoon and pre-monsoon, respectively at all the stations.

The overall SOC percentage varied from 0.24±0.14 % during monsoon 2016-17 in stns. 4 and 5 to 3.57±0.80 % during post-monsoon 2016 at stn. 2. With respect to depth, minimum and maximum values of SOC at 10 cm depth ranged from 0.58±0.18 % in monsoon 2017 at stn. 5 to 3.57±0.80 % in post-monsoon 2016 at stn. 2; at 20 cm depth the values varied from 0.57±0.21 % in monsoon 2017 at stn. 4 to 1.61±0.60 % in post-monsoon 2016 at stn. 2; at 30 cm depth, it varied from 0.50±0.16 % in monsoon 2016 at stn. 1 to 1.0±0.32 % in post-monsoon 2016 at stn. 2; at 40 cm depth it varied from 0.34±0.07 % in monsoon 2017 at stn. 5 to 0.80±0.32 % in post monsoon 2016 at stn. 3 and at 50 cm depth the values of SOC ranged from 0.24±0.15 % during monsoon 2016-17 at stns. 4 and 5 to 0.50±0.24 % during post monsoon 2016 at stn. 2, respectively (Fig. 6).

The station wise variation in SOC has found the highest OC load at stn. 2 during 2016-17 and stn. 1 during 2017-18, which has proved that these areas are

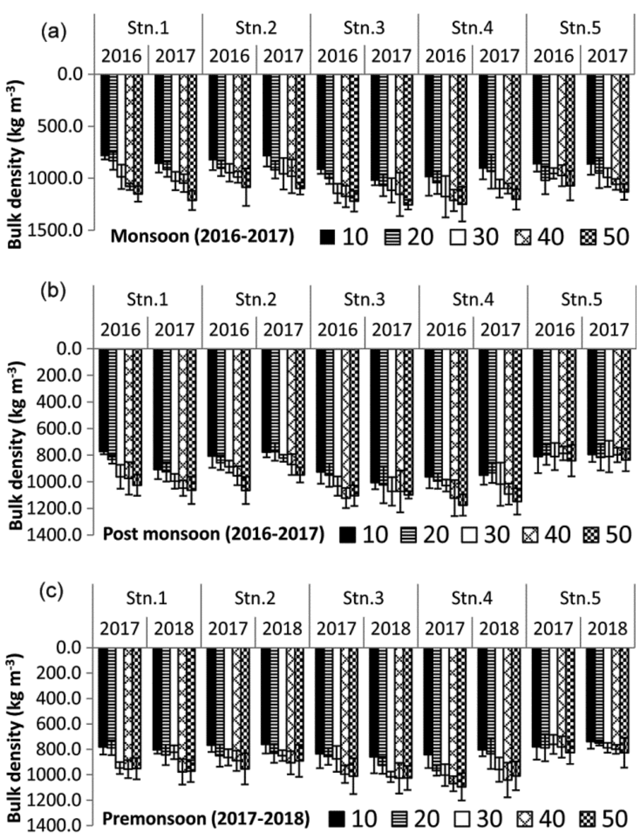

Fig. 5 — Seasonal depth-wise variations in bulk density (kg m^{-3}) of the selected stations: a) Monsoon (2016-17), b) Post-monsoon (2016-17), and c) Premonsoon (2017-18)

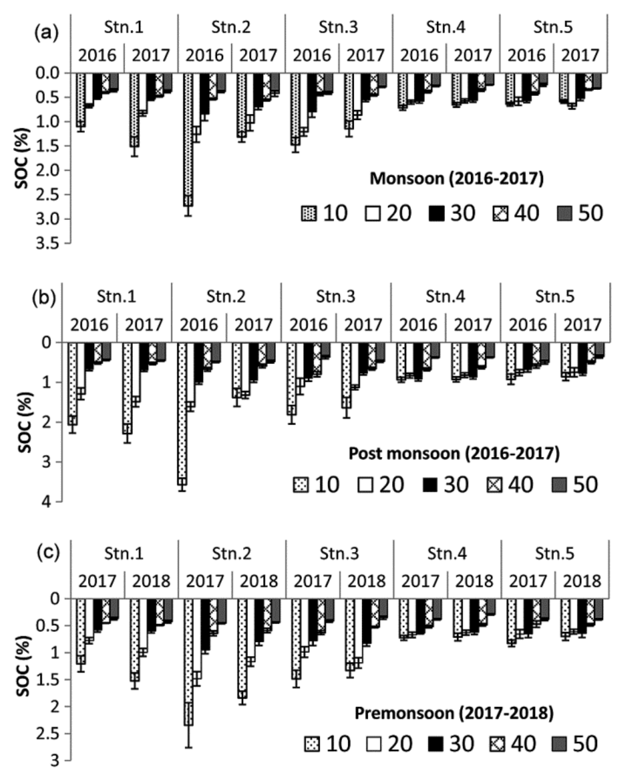

Fig. 6 — Seasonal depth-wise variations in soil organic carbon (%) of the selected stations: a) Monsoon (2016-17), b) Post-monsoon (2016-17), and c) Premonsoon (2017-18)

characterized by healthy and dense mangrove vegetation (Fig. 7). This has also been proved by significant variations of OC with depth, seasons and stations at 1 % and 5 % level of significance. Considering the values of SOC for 2 years (2016-17 and 2017-18), it has been observed that SOC values are comparatively higher at stns. 1, 2 and 3 as stns. 1 and 2 are areas with dense mangrove patches and stn. 3 is a comparatively more anthropogenically stressed area. Depth-wise variation of SOC also showed a decreasing trend down below from 0-50 cm depth (Fig. 8).

Comparing the BD and SOC, the SOC has shown an inverse relationship with BD. The high SOC values at 0-10 cm depth are because of the maximum deposition of soil organic matter takes place at the uppermost layers, and it is a feasible environment for bacteria and other organisms for degradation. Higher

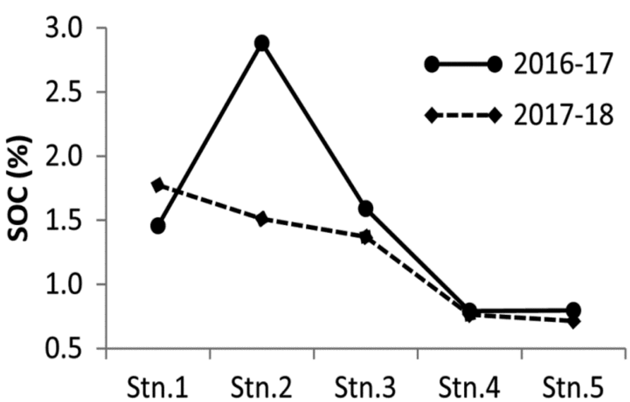

Fig. 7 — Station-wise variation of SOC among two years (2016-17 and 2017-18)

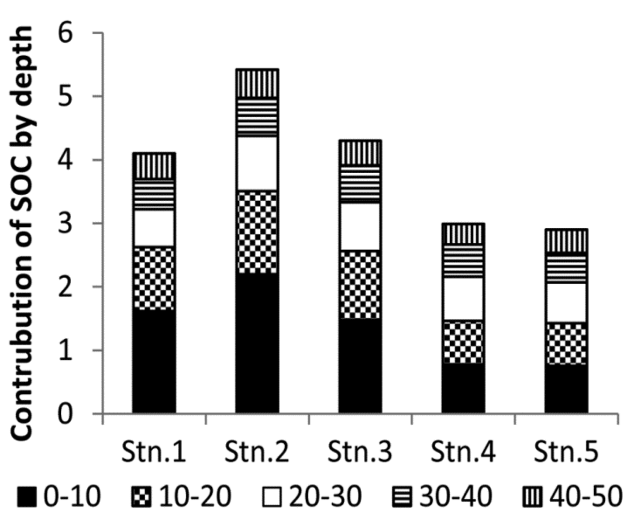

Fig. 8 — Contribution of total SOC by depth range

values of SOC in the sediments of stn. 3 is because of the landward activities of landing of capture fisheries, ecotourism impacts, mosaic development of communities and shrimp culture units which contributes a substantial quantity of OC to the sediment. The low SOC at stns. 4 and 5 may be because of its seafront position where the mangrove litter and detritus are washed off periodically by waves and tides. Since these two stations are located with one side sea and one side river, they represent a mixed composition of sediments with more sand percentage in the eastern side and more silt percentage on the western side. As the mangrove roots and pneumatophores trap the silt particles, their deposition is more in mangrove dominated areas and so also the OC. Similar reports are also cited by Bhomia *et al.*[30] and Biswas *et al.*[10].

To find out the significance of soil temperature, pH, EC and BD on sediment organic carbon, correlation coefficient was computed station-wise, depth-wise and season-wise, respectively. Significantly negative relationship ($p < 0.01$) of SOC was observed with reference to EC, pH and temperature station-wise, with EC and BD depth-wise and with temperature season-wise; whereas no relationship was observed depth-wise with temperature, station-wise for BD and pH as well as for EC and BD, season-wise. Concerning the depth, SOC and pH showed a significant positive relationship ($p < 0.01$) which has already been proved before. SOC has shown a significant negative relationship ($p < 0.01$) with BD and EC with depth which proved the inverse relationship between the two. However, SOC has shown a positive relationship ($p < 0.05$) with EC for seasons which proves that there is a significant variation in salinity profile in the study site. The atmospheric CO_2 equivalent calculated station wise at all depth has shown maximum absorption of CO_2 at depth of 0-10 cm (Table 1). The amount of CO_2e observed above is as per the order stn. 2 followed by stns. 1, 3, 4 and 5 (Table 1). This has proved stn. 2 to be the most effective carbon sink for sediment being located in Bhitarkanika National Park area and the densest mangrove forest. Our results on variations of SOC with depth were compared with four different mangrove forests of the tropical countries (Table 2). Results indicate that Bhitarkanika wetland has good carbon storage potential at par with India and Bangladesh Sundarbans and Selangor mangroves, Malaysia.

Table 1 — Mean depths wise BD, carbon (%) (min-max), carbon (t ha^{-1}) and atmospheric CO_2e at the selected stations

Stations	Depth (cm)	Bulk density (kg m^{-3})	C (%) (min-max)	C (%)	C (t ha^{-1})	CO_2e
Stn. 1	00-10	820±0.05	1.10-2.29	1.62±0.86	13.23±7.02	48.55±25.75
	10-20	860±0.07	0.67-1.49	1.01±0.42	8.62±3.61	31.65±13.24
	20-30	960±0.08	0.50-0.70	0.60±0.19	5.72±1.85	20.98±6.79
	30-40	1010±0.08	0.40-0.53	0.48±0.09	4.83±0.86	17.72±3.16
	40-50	1060±0.10	0.35-0.46	0.40±0.12	4.28±1.26	15.72±4.61
Stn. 2	00-10	790±0.05	1.31-3.57	2.20±1.31	17.30±10.31	63.51±37.84
	10-20	860±0.07	1.02-1.61	1.31±0.69	11.21±5.93	41.15±21.77
	20-30	890±0.08	0.69-1.0	0.87±0.47	7.72±4.17	28.34±15.31
	30-40	930±0.08	0.51-0.67	0.60±0.18	5.56±1.69	20.39±6.21
	40-50	1010±0.10	0.38-0.49	0.44±0.11	4.47±1.11	16.40±4.07
Stn. 3	00-10	930±0.05	1.10-1.81	1.48±0.92	13.75±8.50	50.46±31.19
	10-20	970±0.07	0.86-1.21	1.08±0.75	10.49±7.28	38.48±26.72
	20-30	1040±0.08	0.55-0.91	0.77±0.55	8.05±5.70	29.54±20.92
	30-40	1090±0.08	0.43-0.80	0.58±0.21	6.34±2.33	23.28±8.54
	40-50	1120±0.10	0.28-0.47	0.38±0.27	4.29±3.02	15.73±11.09
Stn. 4	00-10	910±0.05	0.65-0.94	0.78±0.26	7.07±2.36	25.95±8.68
	10-20	950±0.07	0.57-0.83	0.69±0.24	6.53±2.30	23.96±8.43
	20-30	1050±0.08	0.56-0.93	0.70±0.22	7.31±2.32	26.83±8.52
	30-40	1110±0.08	0.35-0.68	0.51±0.14	5.59±1.59	20.50±5.82
	40-50	1150±0.10	0.24-0.38	0.32±0.06	3.69±0.65	13.55±2.38
Stn. 5	00-10	810±0.05	0.58-92	0.76±0.38	6.12±3.06	22.45±11.24
	10-20	850±0.07	0.58-0.76	0.67±0.38	5.73±3.20	21.02±11.74
	20-30	850±0.08	0.52-0.79	0.64±0.34	5.48±2.86	20.10±10.48
	30-40	870±0.08	0.34-0.59	0.47±0.22	4.04±1.89	14.83±6.94
	40-50	920±0.10	0.24-0.50	0.36±0.15	3.34±1.40	12.25±5.13

Table 2 — Comparison of average depth wise SOC of different mangrove forest of the world and Bhitarkanika Wildlife Sanctuary

Sl. No	Country wise mangrove forest	Type of forest	SOC at 0-10 cm	SOC at 10-20 cm	SOC at 20-30 cm	SOC at 30-40 cm	SOC at 40-50 cm	References
1	Xuan Thuy National Park, North Viet Nam	Planted age 18 years	14.13±2 mg cm^{-3}	19±2 mg cm^{-3}	19.30±2 mg cm^{-3}	19.30±2 mg cm^{-3}	18±2 mg cm^{-3}	Hien *et al.*[37]
2	Guaratuba Bay, Brazil	Natural mangrove	82.41±51.01 g/dm^{-3}	80.92±51.66 g/dm^{-3}	72.65±35.33 g/dm^{-3}	61.06±29.47 g/dm^{-3}	50.28±22.66 g/dm^{-3}	Madi *et al.*[38]
3	Antonina Bay, Brazil	Natural mangrove	84.26±8.02 g/dm^{-3}	89.98±17.58 g/dm^{-3}	83.73±9.36 g/dm^{-3}	78.49±13.04 g/dm^{-3}	72.14±5.09 g/dm^{-3}	Madi *et al.*[38]
4	Selangor, Malaysia	Natural mangrove	1.49±0.34 %	1.49±0.34 %	1.65±0.63 %	1.65±0.63 %	1.79±1.07 %	Sofawi *et al.*[39]
5	Kelantan, Malaysia	Natural mangrove	4.28±3.58 %	4.28±3.58 %	4.07±2.73 %	4.07±2.75 %	3.79±2.09 %	Sofawi *et al.*[39]
6	Johor, Malaysia	Natural mangrove	5.01±2.75 %	5.01±2.75 %	5.01±2.75 %	5.01±2.75 %	6.97±4.10 %	Sofawi *et al.*[39]
7	Sundarban, India	Natural mangrove	1.1±0.30 %	0.79±0.25 %	1.42±0.55 %	1.03±0.10 %	1.0±0.10 %	Prasad *et al.*[40]
8	Sundarban, Bangladesh	Natural mangrove	1.36±0.16 %	1.25±0.10 %	1.29±0.13 %	1.22±0.13 %	1.12±0.10 %	Prasad *et al.*[40]
9	Bhitarkanika Wildlife Sanctuary, India	Natural mangrove	1.36±0.75 %	0.95±0.50 %	0.72±0.35 %	0.53±0.17 %	0.38±0.14 %	Present Study

Conclusion

Mangroves are known for their significant contribution in carbon cycling because of the continuous cycle of litterfall and decomposition of mangrove litter into inorganic carbon to the atmosphere. In this study, a proper understanding of the effect of temperature, pH, EC, and BD on soil organic carbon has been discussed and the amount of CO_2 that can be sequestered by the soil has been estimated, which is a marked research need of the present time. The present study is very important in terms of carbon cycling in mangroves and for effective management of soil salinity which will lead to greater growth of mangroves leading to more organic carbon deposit as well as act as a sink for carbon dioxide emissions at the local level.

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Conflict of Interest

Authors declare that there is no competing or conflict of interest.

Author Contributions

KB involved in conceptualization, funding acquisition, investigation and supervision and writing of original draft; GB and KM is responsible for formal analysis and field work; RP for software and editing.

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