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Physico-chemical characteristics of mangrove soil in Gulf of Kachchh, Gujarat, India

Patel Rajal*[1], Christian Lamb[1], Bhagat Roshan[1], Kamboj R.D.[1] and Salvi Harshad[2]

[1]Gujarat Ecological Education and Research (GEER) Foundation Indroda Nature Park, P.O. Sector 7, Gandhinagar-382007, India
[2]Government Science College, Songadh, Tapi, India

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Abstract. This paper presents comprehensive scientific details about mangrove soil in Gulf of Kachchh, Gujarat. A total of ten sites were studied during November, 2011 to December, 2014 in order to know the physico-chemical characteristics of mangrove soil. The results indicated that the soil in GoK had silty loam texture. Other physico-chemical parameters ranged as; pH: 7.39–7.61, Bulk Density: 0.30 g/cm^3-0.54 g/cm^3, Particle Density: 1.26 g/cm^3–1.76 g/cm^3, Organic Carbon: 0.70%-1.13%, Organic Matter: 1.01%-1.74% and Moisture Content: 33.45%-56.38%. The paper would be useful to the stakeholders, coastal managers and scientific communities to know the mangrove soil conditions of Gulf of Kachchh for management and planning for conservation of mangrove ecosystem.

Keywords: Gulf of Kachchh; Mangrove soil; physico-chemical parameters; spatial variation

1. Introduction

Mangroves are among the most productive and biologically important ecosystems in the world, playing crucial role in conservation of marine life as mangrove swamps are considered nursery and shelter grounds for prawns, fishes, birds and host of other marine life (Gomes *et al.* 2016). They are distributed in the inter-tidal regions at sea and land interface in the tropical and subtropical regions of the world (Kaseng 2018). The mangroves are adapted to loose and wet soils and periodic submergence in the saline water. They survive in difficult conditions of high salinity, low oxygen and nutrient availability in the soil, wind and wave action and substrate instability. The sedimentation process in mangrove areas is influenced by hydro-geomorphic settings that represent the tidal range and coastal geological formation (Murdiyarso 2018).The mangrove ecosystem as a whole is autotrophic, but the water column and the sediment are largely heterotrophic, due to high turbidity which limits primary production, and low oxygen content (Jennerjahn and Ittekkot 2002). Soil, being an important constituent of lithosphere comprises of organic and inorganic matter and water (Osman 2012). The type and origin of mangrove sediments may play an important role in mangrove ecosystem to enhance its ability to recover from various

*Corresponding author, Ph.D., E-mail: rajal.solanki01@gmail.com

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pollution stresses. A number of authors have studied the physical and chemical characteristics of soil and water with reference to mangroves (Saha and Choudhury 1995, Joshi and Ghose 2003, Marchand *et al.* 2006, Rao and Rao 2014, Kiranmai *et al.* 2015, Ataullah *et al.* 2017). Similarly, the present study had been carried out in order to assess the physico-chemical characteristics of mangrove soil of Gulf of Kachchh, Gujarat, India.

2. Materials and methods

2.1 Study area

The Gulf of Kachchh (GoK) is a wedge like extension of the Arabian Sea which penetrates into the land mass. Geographically, it is located between 20° 15' to 23° 40' North latitude and 68° 20' to 70° 40' East longitude on the west coast of India. This funnel shaped east-west oriented, seismically active zone provides habitat to a variety of marine flora and fauna. The coastal configuration of the entire Gulf is more or less irregular with a number of islands, creeks and bays. Except for an extensive area from the mouth of the Gulf to the centre, which consists of rocks (sand stone), the remainder consists of silt and clay with patches of the fine sand (Naik *et al.*, 1991). The area covered by mangroves along the Gujarat coast is the second largest in India, next to the Sundarbans area and major mangroves covered area of the state is confined to the Gulf (Singh, 2006). To achieve the objective of present study, ten sites were selected from the Gulf of Kachchh having mangrove cover viz; Poshitra (PO), Kalubhar (KA), Narara (NA), Sikka (SI),

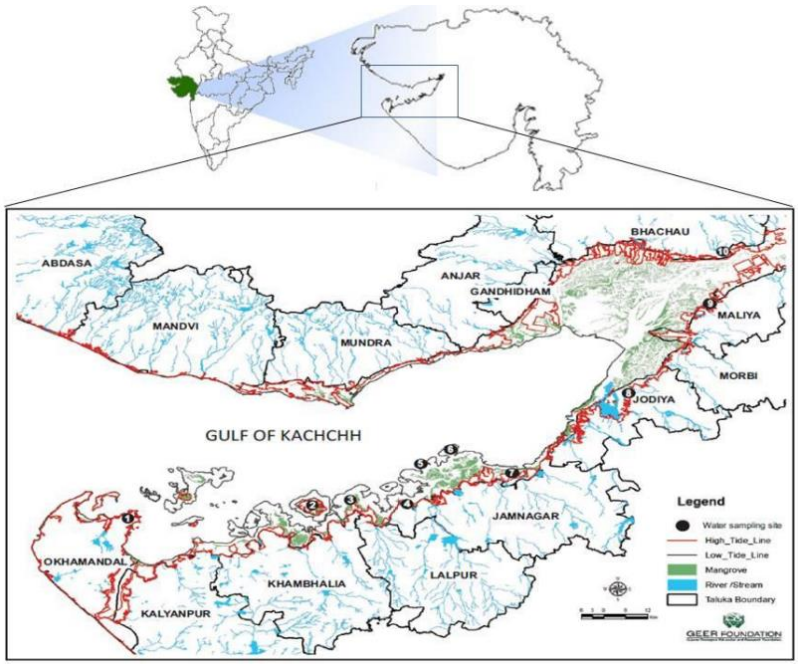


Fig. 1 Map showing study area and selected sites for the collection of Mangrove soil in GoK [1. Poshitra (PO), 2. Kalubhar (KA), 3. Narara (NA), 4. Sikka (SI), 5.Dedeka Mundeka (DM), 6. Pirotan (PI), 7. Khijadiya (KH), 8. Jodiya (JO), 9. Vavaniya(VA), 10. Surajbari (SU).]

Table 1 Global Positioning System (GPS) locations of sampling sites in Gulf of Kachchh

No.	Name of location	Site code	Latitude (N)	Longitude (E)
1.	Poshitra coast	PO	22° 23' 58.6"	69° 12' 31.1"
2.	Kalubhar island	KA	22º 26' 22.7"	69º 38' 48.3"
3.	Narara island	NA	22° 29’ 07.1’’	69° 42’ 56.3’’
4.	Sikka coast	SI	22°26′43.4″	69°52′08.5″
5.	Dedeka Mundeka island	DM	22º 32' 39.6"	69º 52' 18.9"
6.	Pirotan island	PI	22º 35' 44.03"	69º 57' 22.04"
7.	Khijadiya coast	KH	22°31’20.7”	70° 07’ 54.1”
8.	Jodiya coast	JO	22º 43' 22.1"	70º 16' 46.0"
9.	Vavania coast	VA	23° 1' 38.2"	70º 33' 37.6"
10.	Surajbari coast	SU	23°13' 07.3"	70º 42' 48.5"

Dedeka Mundeka (DM), Pirotan (PI), Khijadiya (KH), Jodiya (JO), Vavaniya(VA), and Surajbari (SU) (Fig. 1). All the selected sites are represented by mangrove ecosystem; from these sites the soil samples were collected and analyzed.

2.2 Sample collection and analysis

Soil samples from ten intertidal locations of GoK were collected from the surface during pre-monsoon (March-June), Monsoon (July-October), and post-monsoon (November–February) season on monthly basis for three years (November 2011-December 2014. The soil samples were collected in zip-lock polythene bags from selected sites. The collected soil samples were first air dried at room temperature, then crushed using a porcelain mortar and pestle and then sieved for further analysis (Saha *et al.* 2001, Dalai *et al.* 2004). The pH of the sediment was measured *in-situ* by using a pH sphere whereas the organic carbon and organic matter content was determined by following Walkley and Black’s method, the moisture content, bulk density and particle density was determined by using the gravimetric method (Maiti 2003), the soil texture was also determined by using USDA soil triangle.

For preparation of GIS based maps, the precise locations of sampling points were determined in field using GARMIN 12-Channel GPS and the exact longitudes and latitudes of sampling points were imported in GIS platform (Table 1). The results of the physicochemical analysis (three year’s seasonal average value for each site) were then used as input data in Arc GIS 10.3 software. The sampling locations were integrated with the soil quality data for the generation of spatial distribution maps (thematic maps) to easily identify the variation in concentration by different color gradients.

3. Results and discussion

The average values with standard deviation of three years’ data were calculated for the physicochemical parameters of soil and showed spatial and temporal variation in sediment quality seasonally for soil pH (Fig. 2(a) & 2(b)), Bulk density (Fig. 3(a) & 3(b)), Particle density (Fig. 4(a) & 4(b)), Organic carbon (Fig. 5(a) & 5(b)), Organic matter (Fig. 6(a) & 6(b)), Moisture content (Fig. 7(a) & 7(b)) and soil texture (Fig. 8(a) & 8(b)).

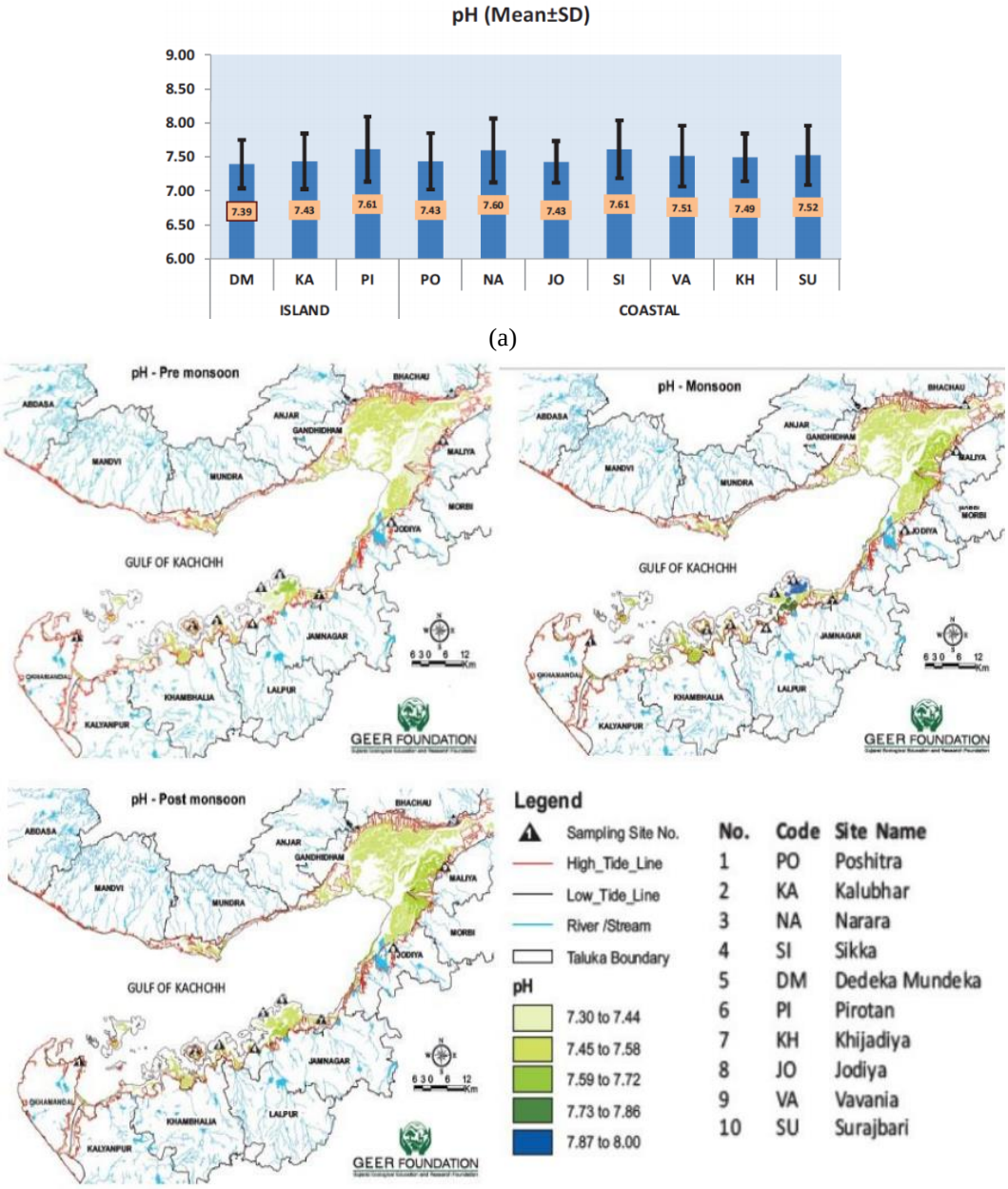
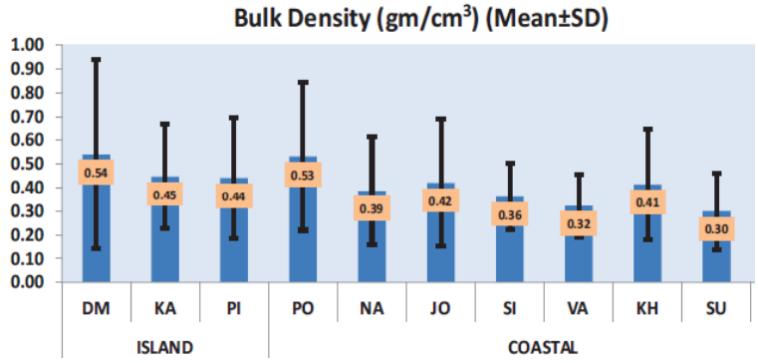


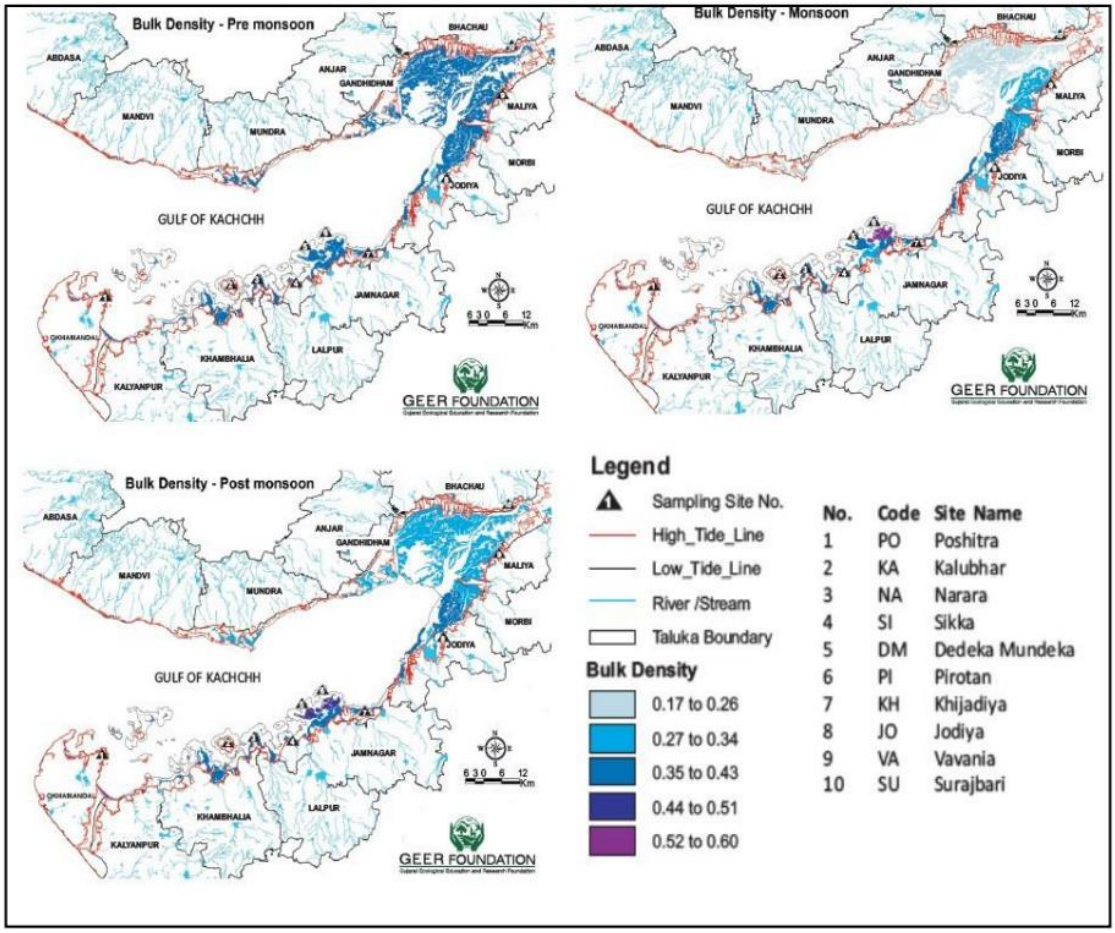
Fig. 2 (a) pH of soil at selected sites in GoK (Mean±SD), 2011-2014 and (b) Seasonal trend in pH of Mangroves soil at selected sites of GoK (2011-2014)

3.1 Soil pH

pH is an important parameter of the mangrove sediment. Acidity or Alkalinity of the sediment is always dependent on the presence of hydrogen ion concentration in the soil. Mangrove sediment



(a)



(b)

Fig. 3 (a) Bulk density of soil at selected sites of GoK (Mean±SD), 2011-2014 and (b) Seasonal trend in Bulk density of soil at selected sites of GoK (2011-2014)

is always alkaline as reported by various authors (Tam *et al.* 1995, Tam and Wong 1998). However, many other workers have recorded acidic pH which might be attributed to the oxidation

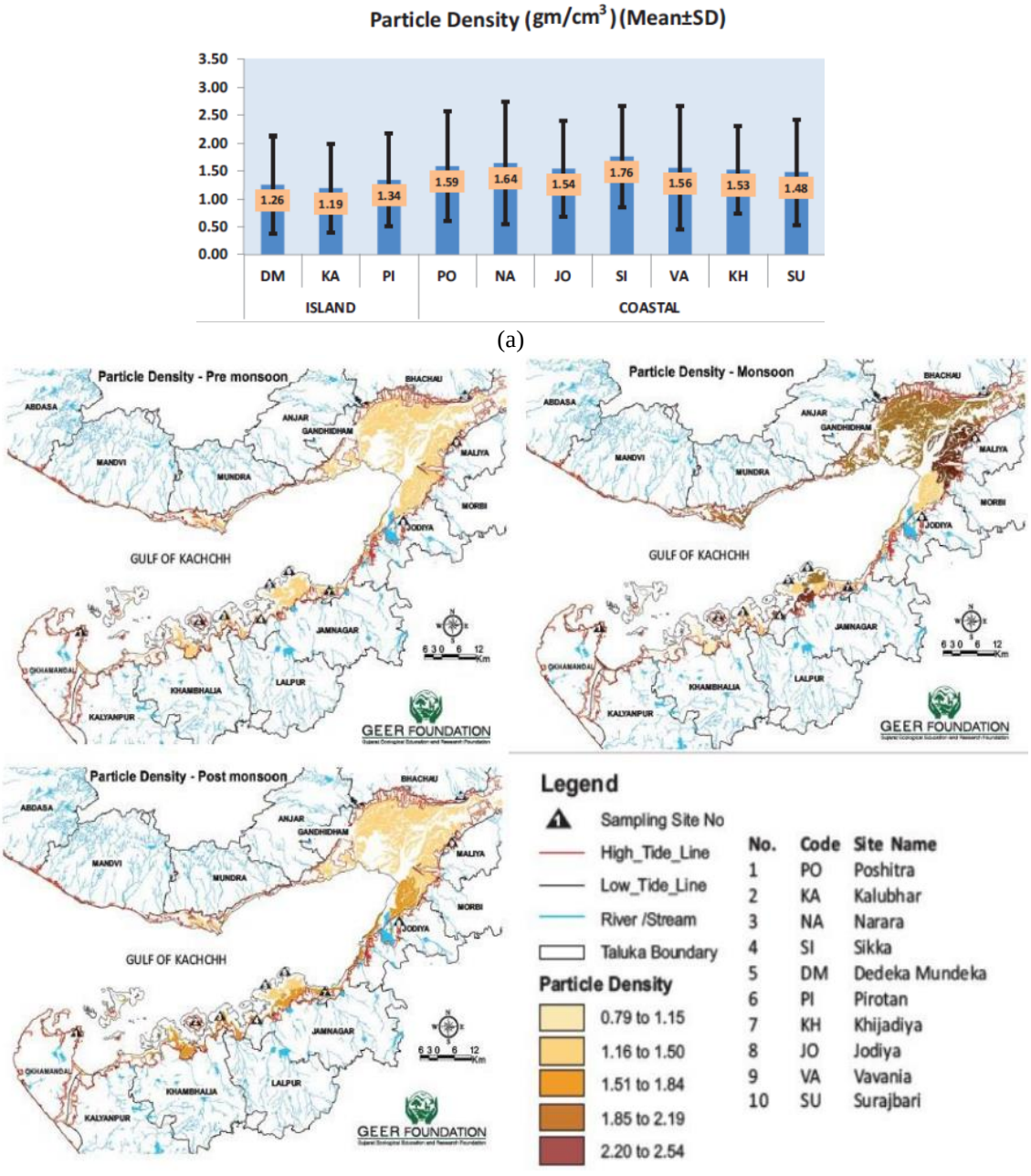


Fig. 4 (a) Particle density of soil at selected sites of GoK (Mean±SD), 2011-2014 and (b) Seasonal trend in particle density of soil at selected sites of GoK (2011-2014)

of $FeSO_4$ and FeS to H_2SO_4 (Holmer *et al.* 1994). Sediment acidity may also have resulted from decomposition of mangrove litter (Lacerda *et al.* 1995). In the present study, pH value ranged between 6.39 and 8.60 during the assessment period of November 2011 to December 2014 for all

the GoK sites, which coincide with the research carried out by Saravanakumar, 2008 wherein pH of the soil ranged between 6.25 and 8.45 in GoK. In tropical countries like India, July to October is dominated by rainy season. Rain water plays an important role in the pH of the Coastal soil. According to the Ramnathan (1997), the sediment pH was high in summer and low in monsoon possibly due to redox changes in the sediments and water column apart from the influence of freshwater. pH fluctuation is mainly the function of seasonal variation. In rainy season, it represents high (Basic) pH, could be the result of dilution by influx of rainwater (Fig 2(b)). Fig. 2(a) shows the mean values with the standard deviation of pH for the individual sites. For Island sites, the mean pH value recorded was 7.39 ± 0.48 and for coastal sites the value was 7.61 ± 0.36 for study period. Similar kind of trend was noted by Joshi and Kumar (1986) during the study of chemical characteristics of mangrove soil of Gujarat coast with pH range of 7.6 to 8.5.

3.2 Bulk density

Soils containing higher Organic Matter have lower Bulk Density, whereas compaction increases the Bulk Density (Maiti 2003) and depends greatly on the mineral make up of soil and the degree of compaction. Bulk density greater than 1.8 gm/cm^3 are considered as extremely bad for plant growth. For better plant growth bulk density should range around 1.4 gm/cm^3 for clayey soil and 1.6 gm/cm for sandy soil (Schoeneberger *et al.* 2002). In present study, the bulk density results ranged from 0.06 g/cm^3 to 2.12 g/ cm^3. The maximum value was recorded as 2.12 gm/cm^3 during Pre monsoon and the minimum value 0.06 gm/cm^3 during Post monsoon season at Jodiya and Pirotan, respectively. Figure 3b shows the seasonal change in bulk density for each location. The Bulk density did not showed considerable difference among the sites of GoK. Higher bulk density obtained due to sand deposition (Holmes*et al.* 2012). Figure 3a shows the average and standard deviation values of bulk density for the individual sites for the entire study period. Higher bulk density at the Dedeka Mundeka (0.54 gm/cm^3) indicates low pore space in the soil; compacted soil. Low bulk density of soils of Surajbari (0.30 gm/cm^3) indicates soil having more pore spaces; loosely bind soil. As compared to other studies, the average bulk density of the soils in Gulf of Kachchh is quite low showing less water content within the soil stratum.

3.3 Particle density

The weight per unit volume of the solid portion of soil is called Particle Density. With increase in Organic Matter of the soil the Particle Density decreases. Particle Density is higher if large amount of heavy minerals such as magnetite, limonite and hematite are present in the soil. During whole study period, the Particle Density results varied from 0.02 gm/cm^3 to 5.26 gm/cm^3. Fig. 4(a) depicts Mean± SD values of particle density for the whole study period for the selected sites in GoK. The values for Island and coastal sites were ranged from 1.19 ± 0.83% to 1.76 ± 0.97gm/cm^3, respectively. Island site i.e., Kalubhar showed low Particle Density, i.e.,, 1.19 gm/cm^3, while coastal sites having sandy nature of soil showed high Particle Density (Fig. 4(b)) i.e.,1.76gm/cm^3 at Sikka.

3.4 Organic carbon

The determination of Organic Carbon (OC) is an essential part of any site characterization or ecological assessment since its presence or absence can markedly influence as to how chemicals

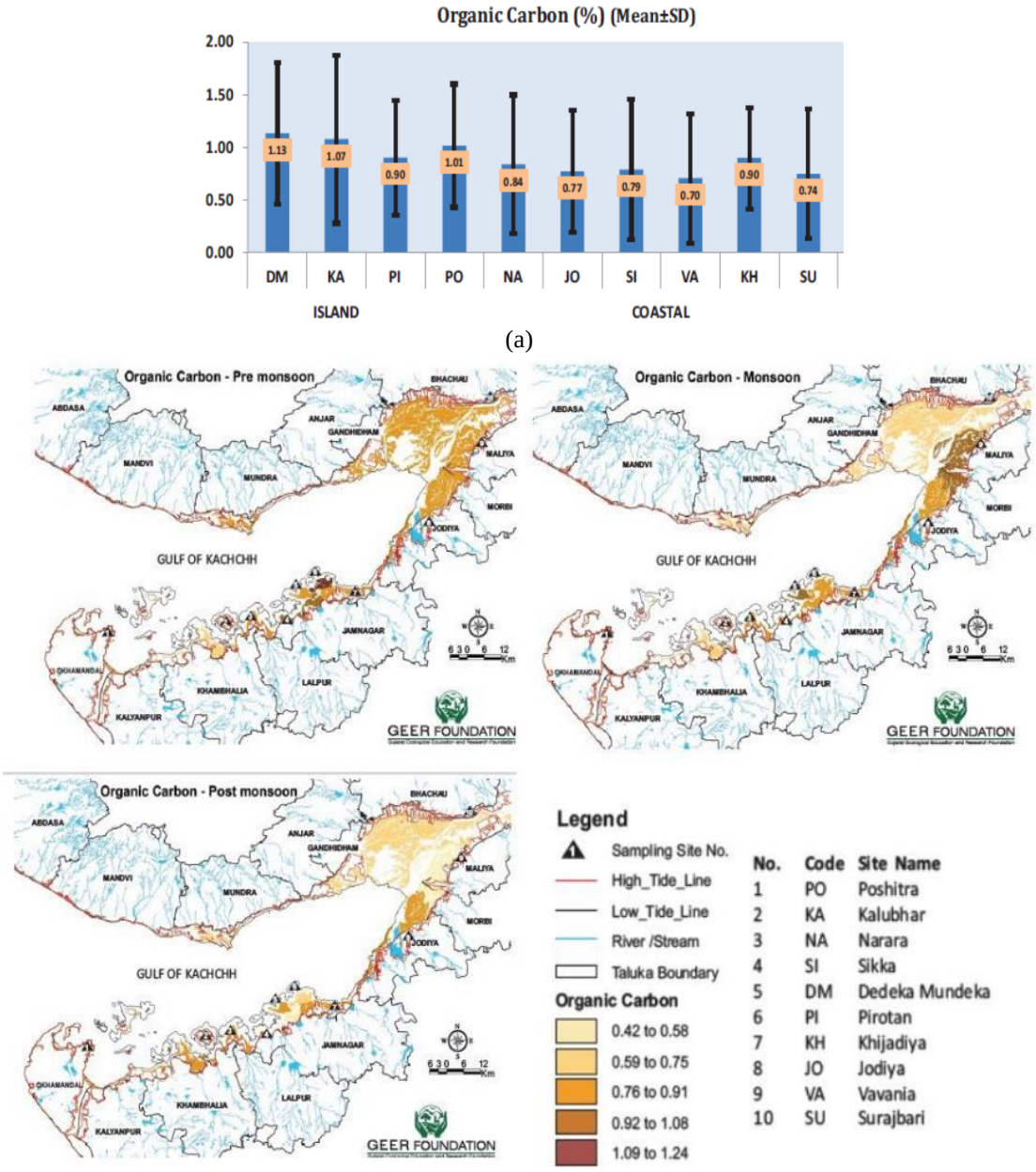
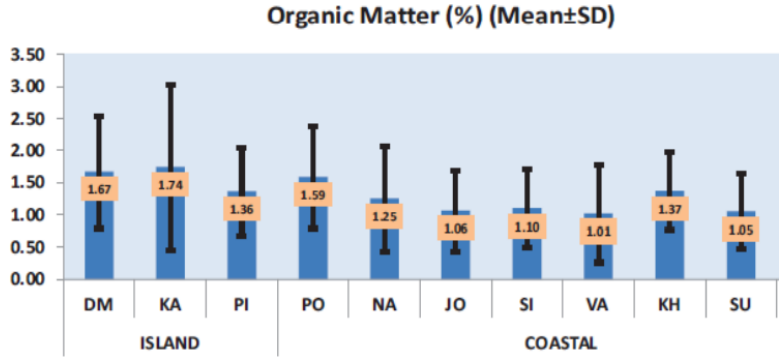
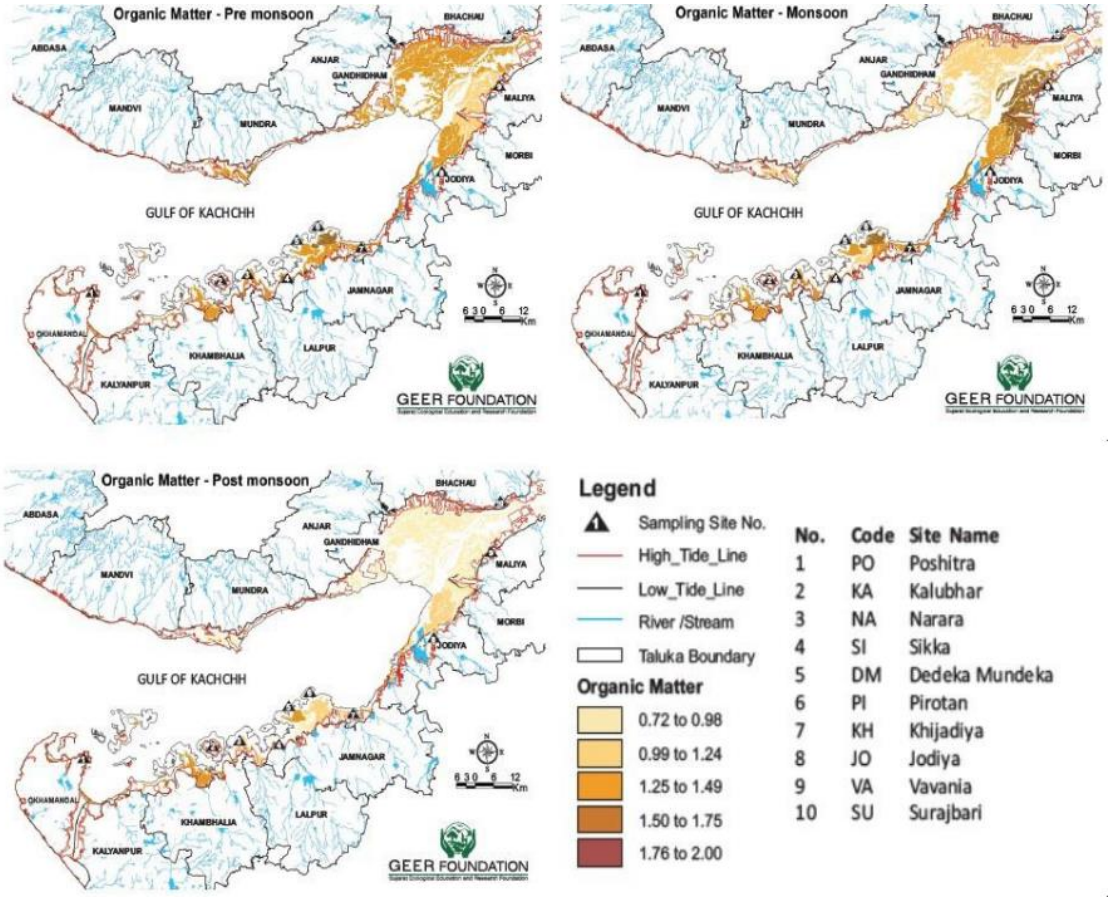


Fig. 5 (a) Organic carbon content of soil at selected sites of GoK (Mean±SD), 2011-2014 and (b) Seasonal trend in organic carbon content of soil at selected sites of GoK (2011-2014)

will react in the soil or sediment. Kumary *et al.* (2001) reported that the organic carbon content in sediments is a reliable index of nutrient regeneration and the productivity of a water body. In the present study, the organic carbon ranged between 0.05 % to 3.37 %, being highest in the month of April at Dedeka Mundeka and lowest in February at Narara among important mangrove sites. Fig.



(a)



(b)

Fig. 6 (a) Organic matter content of soil at selected sites of GoK (Mean±SD), 2011-2014 and (b) Seasonal trend in organic matter content of soil at selected sites of GoK (2011-2014)

5(b) shows the individual season wise Organic Carbon content for each site. No marked seasonal variation was observed among the sites of GoK during present research work. The average values of Organic Carbon at the selected sites varied between 0.70% and 1.13% at Vavaniya and Dedeka

Table 2 Organic carbon and Organic matter content in the soils of mangrove forests worldwide

Names of forest	Regions	Organic carbon (%)	Organic matter (%)
Avicennia forest in Apar nature reserve*	East Kalimantan, Indonesia	3.96	6.81
Ceriops forest in Apar nature reserve*	East Kalimantan, Indonesia	11.40	19.61
Calabar mangrove swamp*	Nigeria	6.43	11.06
Hooker Bay mangrove*	SanAndres Island, Colombia	13.31	22.89
Prentice Island mangrove*	Sunderbans, India	0.55	0.95
Lotihan Island mangrove *	Sunderbans, India	0.62	1.07
Sagar Island mangrove*	Sunderbans, India	0.65	1.12
Harinbari Island mangrove*	Sunderbans, India	0.75	1.29
Cheringa mangrove*	Bangladesh	2.92	5.02
Wildlife Sanctuary Sibuti mangrove*	Miri, Sarawak, Malaysia	12.18	20.96
Awat-Awat Lawas mangrove*	Limbang,Sarawak, Malaysia	9.38	16.20
Sundarban mangrove*	NE coast of Bay of Bengal, India		
Sundarban mangrove*	Bangladesh	0.38	0.65
Crumahu river mangrove*	Sao Paulo, Brazil		-
Sundarban Mangrove#	Bangladesh	0.83	-
Tamilnadu Mangrove@	Muthupet, Tamilnadu, India	0.29	0.59
Pondhichery mangrove##	Pondichery coast, India	-	2.79
Gulf of Kachchh Mangrove (Present study)	Southern Gulf	0.92	1.38

Ref: * Hossain and Nuruddin (2016); #Md. Ataulla *et al.* (2017); @ Vaijayanthi and Vijaykumar (2014); ##Satheeshkumar and Khan (2011)

mundeka, respectively. The investigation of physicochemical properties of soils of Sundarban carried out by Sengupta and Chaudhuri (1991) revealed that the organic carbon status of the soils also differed with the eco-successional stages. The formative mangrove swamp soil had a very low organic carbon status while soils from old formation mangrove soil had a higher value. Main source of soil organic carbon and matter is litter. Soil organic carbon gives nature of the soil composition. Sandy soil holds very less organic matter as compared to the clay soil. Sites which are coasts have invariably sandy beaches and thus soil of such sites is less in organic carbon and organic matter content (Fig. 5(b)). The lower values of OC and OM were reported from mangrove soils of Indian region which indicates the poor nutritional conditions of the mangrove forest (Hossain and Nuruddin 2015).

3.5 Organic matter

The knowledge of the sources of organic matter in estuarine and mangrove sediments and factors controlling their distribution are important in understanding the global biogeochemical cycles. In these transitional systems, primary production generates large amounts of organic matter

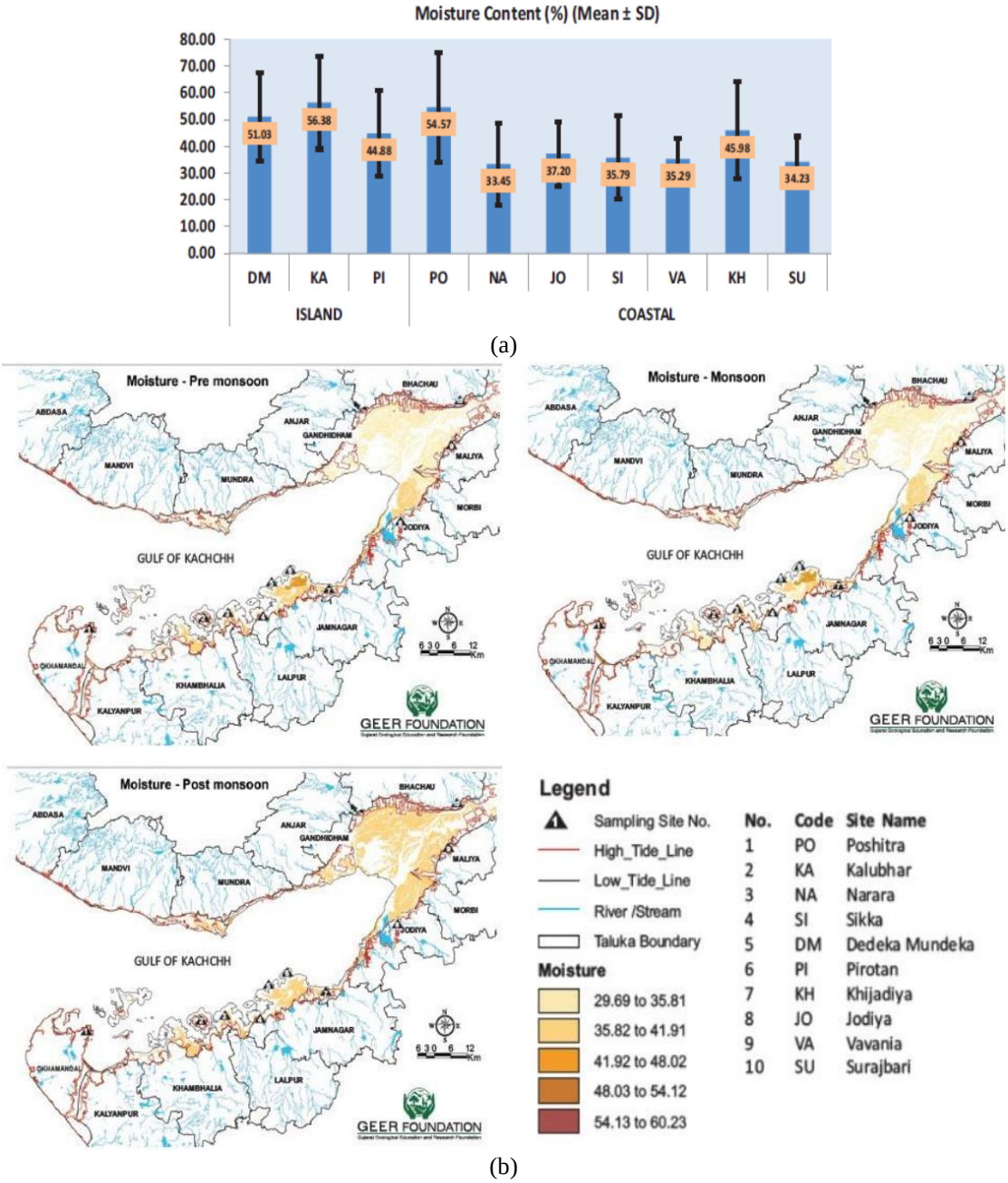


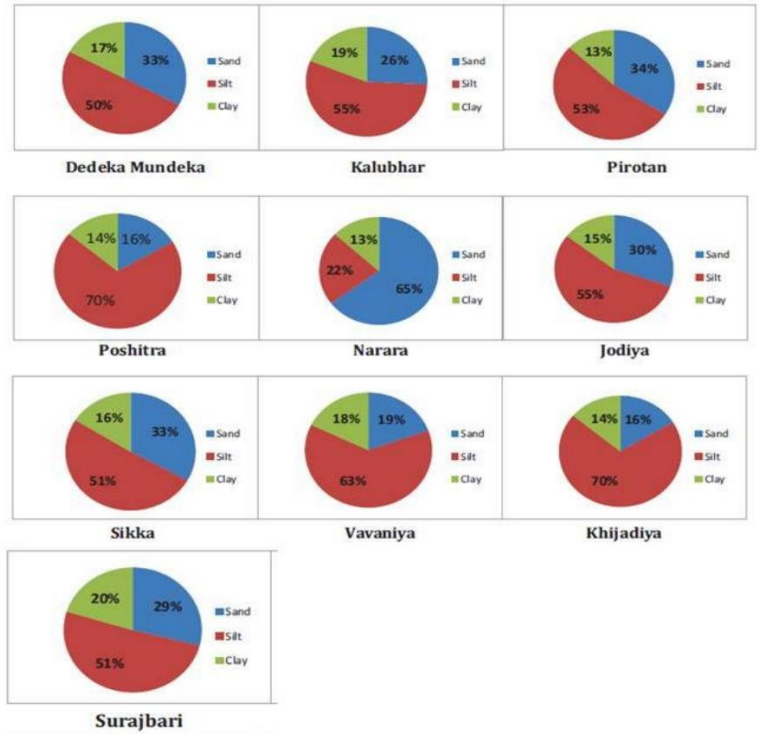
Fig. 7 (a) Moisture content in sediments at selected sites of GoK (Mean±SD), 2011-2014 and (b) Seasonal trend in Moisture content of soil at selected sites of GoK (2011-2014)

of which a significant portion sinks and ultimately gets preserved in sediments (Hu *et al.* 2006). Ramanathan *et al.* (1997) found that organic matter content remains higher in the mangrove sediments in comparison to adjacent estuaries. In the present study, the amount of organic matter ranged from 0.08% to 4.62%. The highest value i.e., 4.62% was recorded during Pre-monsoon

season at Kalubhar whereas the lowest i.e., 0.08% of organic matter was noted at Surajbari during monsoon season. The seasonal variation in organic matter content is illustrated in the form of Maps (Fig. 6(b)); like organic carbon content the percentage organic matter did not showed considerable seasonal fluctuations at selected sites of GoK. Moreover, the average values of Organic matter varied between 1.01% and 1.74% with the lowest and the highest values at Vavaniya and Kalubhar, respectively. All the island sites i.e Dedeka Mundeka (DM), Kalubhar, Pirotan and some of the coastal sites like Poshitra and Khijadiya are black to dark colored soil and their organic matter content is relatively higher, so have high water holding capacity (Turner and Gardner , 2001). Further, the OC and OM content in the mangrove soils of GoK were found to be low as compared to the other mangrove forests of the world. As stated by Hossain and Nuruddin, 2016, less than one percent of Organic carbon indicates the poort nutritional conditions of the mangrove soils.

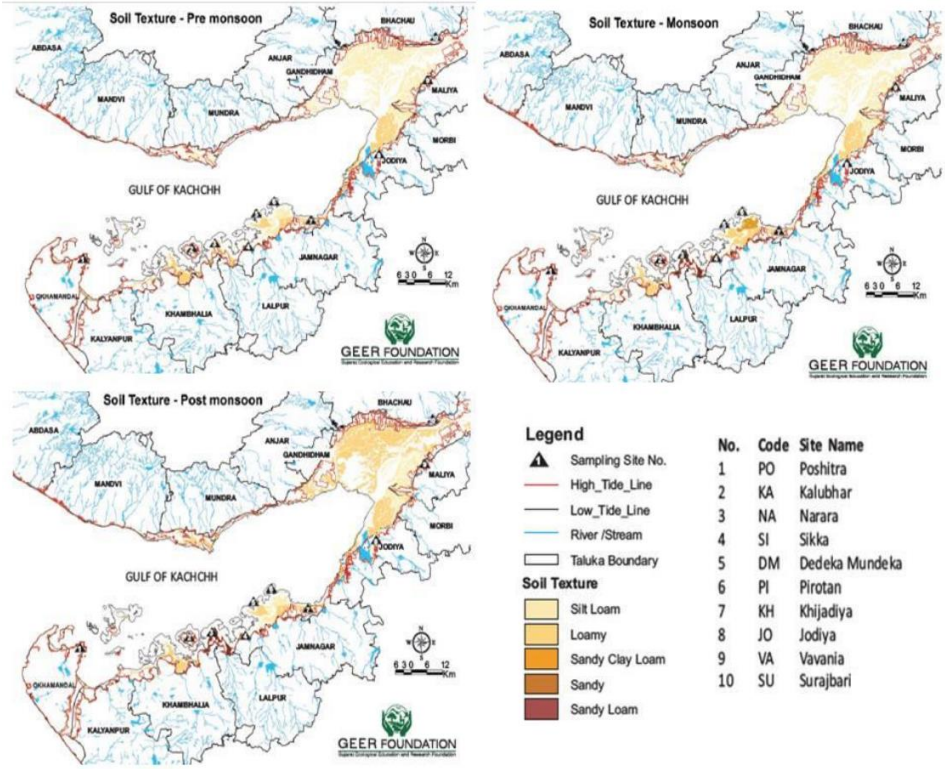
3.6 Moisture content

Soil moisture is a major controlling factor for many hydrological processes, especially runoff generation, soil evaporation and plant transpiration. It is the amount of natural water trapped within the soil. If organic matter is added to the soil, water holding capacity of the soil gets increased, while surface runoff, erosion etc. are reduced, as there is good infiltration (Baruti 2004). The results of present study showed that it varied from 4.89 % to 76.71 %. It was observed



(a)

Fig. 8 (a) Soil texture at selected sites of GoK (2011-2014) and (b) Seasonal trend in texture of soil at selected sites of GoK (2011-2014)



(b)

Fig. 8 Continued

highest during Pre monsoon at Dedeka Mundeka and lowest in same season at Mandvi (Fig. 7(b)). Fig. 7(a) shows the average values of Moisture Content (%) with the standard deviation values for each location sites. For Island locations, the Moisture Content values remained in between 44.88% and 56.38% and for Coastal sites it ranged between 33.45% and 54.57% during the entire study period (Nov. 2011 to Dec. 2014). The maximum value and the minimum values were found at Kalubhar (56.38 ± 17.41%) and at Pirotan (44.88 ± 15.93%) among the Island sites. It was observed the least at Narara (33.45 ± 6.98%) and the highest at Poshitra (54.57± 20.46%) among the coastal sites. Chowdhury *et al.* (2014) and Shaifullah *et al.*, (2008) studied the moisture content in mangrove environment and it was found to be higher in the mangroves plantation sites as compared to the other sites because of the presence of fully and partially decomposed litter covers over the soil and these areas get saturated twice a day due to tide cycle, which help to hold the moisture and also gradually decreased in general with the increase of the depth.

3.7 Soil texture

Soils can be classified based on the particle size distribution. Texture is used only to describe the distribution of inorganic fraction. Soil Texture refers to the relative proportion of sand, silt and clay size particles in a sample of soil. In current research, geographically, the sites Surajbari and Vavaniya creeks are at the head of the GoK, whereas the southern part of GoK represents the

coastal sites like Jodiya, Sikka, Khijadiya and Poshitra and island such as Dedeka Mundeka (DM), Kalubhar, Narara &Pirotan.The results obtained showed that, Poshitra, Sikka and Vavaniya had Silt loam textural class showing high content of silt; above 50% in most of the months. Narara showed high content of Sand; above 50% whereas it showed almost 20 - 40% silt in most of the months and low percent of clay. Kalubhar and Khijadiya showed high content of Silt; above 50% in most of the months while it showed almost up to 20% of clay. Dedeka mundeka and Surajbari showed more than 45% of sand and clay exceeded 30% in most of the months during whole study period. Narara showed high content of sand and almost up to 50% of silt and less percent of clay in most months showingvariation from Sandy Loam to Loamy Sand. It comes in the Sandy Loam textural class as it hasless percent of clay. Similar kind of trend was observed Saravanakumar *et al.* (2008) for the mangroves of Kachchh, sediment textures ranges in terms of % of sand, clay and silt were: 0.26-19.2; 7.6-47 and 47-87.4, respectively in all the stations. The nature of soil texture is characterized by the abundance of silty loam, silty clay and silty clay loam. For tropical mangrove ecosystem, high concentration of sand and silt shows the prevalence of a moderately high energy environment with very effective winnowing activity (Ramanathan *et al.* 1999).

4. Conclusions

The findings of present study provide baseline information on the physico-chemical characteristics of mangrove soil which would be useful for further ecological assessment and monitoring of this mangrove ecosystem of Gulf of Kachchh. Furthermore, the GIS map also indicated seasonal and spatial variation among the sites present in GoK. Additionally, in present study the values of organic carbon and organic matter were less as compared to other mangrove soils of world which shows reduced nutritional concentration in some mangrove soils of southern Gulf. The overall findings of the present research would also be useful in coastal plantation activities and management of mangrove ecosystem.

Acknowledgments

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