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Research Paper

Water and Soil Quality Analysis of Selected Areas of Sunderban and Mapping Using GIS Technique

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Abstract: *Mangrove ecosystem of Sunderbans is dynamic, fragile and comprised of a complex network of estuaries, tidal inlets, tidal creeks and large number of islands. Due to temporal and spatial variations in water and soil qualities, monitoring programs help to understand quality of natural ecosystems. The present investigation was undertaken to assess seasonal and spatial variations in pH, electrical conductivity, total dissolved solids, hardness, turbidity, sodium and potassium of water. Similarly, soil samples were also checked for pH, electrical conductivity, total dissolved solids, water holding capacity, organic carbon, organic matter and calcium carbonate. The results of the various parameters significantly fluctuated over different seasons. The surface water of the study area was brackish to brine. All parameters except turbidity have shown highest concentration in monsoon. Overall, the concentration of water quality parameters were governed by flushing of rainfall, river water flow, seawater intrusion, runoff from agricultural fields and oil from spill. The high percentage of organic matter and calcium carbonate content might beattributedto decomposition of plant-animal residues in mangrove area. Mud content in the study area was higher because of high organic matter in the soil while the high water holding capacity directs that soil was clayey in texture. It is advisable that continuous baseline, monitoring studies for water and soil quality analysis is carried out with scientific approach to conserve the mangrove ecosystem. Monitoring programs using remote sensing and GIS can be used to tackle the threats at all levels efficiently.*

Keywords: Sunderban, Mangroves, Water Analysis, Soil Quality, GIS Mapping

Introduction

Estuarine and coastal areas are complex and dynamic aquatic environment[1]. Coastal waters has become a major concern because of its value for socioeconomic development and human health. With the growth of human population and commercial industries, estuarine water has received large amounts of pollution from a variety of sources such as recreation, fish culture and the assimilation and transport of pollution effluents through river [2]. These situations have generated great pressure on estuarine ecosystem, resulting in degradation of water quality, soil quality and biodiversity. Overall, these reasons have caused loss of critical natural habitats[3]. Other drivers of mangrove destruction are wood extraction, climate change and industrial development, such as harbours and tourism. Oil contamination of mangrove habitat has significant hydrocarbon levels after a spill event [4,5].These impacts are likely to continue and worsen as human population and other activities expand further. Recognition of these impacts on mangrove ecosystem is likely to develop sustainable approaches. Mangroves represent only 1% (100,000 sq.km) of the area of tropical forests with tree species number showing decline from equatorial region to sub tropical region with increase of latitude. Mangroves grow throughout the tropics and are limited in their subtropical distribution due to lack of temperature resistance [6] and are available along almost 75% of the coastline [7] between 25º N and 25 ºS latitudes. Mangroves vary both in their salinity tolerance and in the degree to which salinity maybe necessary to maintain their growth and competitive dominance[8].

Mangrove ecosystem of Sunderbans is dynamic, fragile with vegetation and environmental factors interconnecting the process of energy fixation, accumulation of biomass, decomposition of dead organic matter and nutrient cycling. Belonging to the class of a tide-dominated wetland [9] the Sunderban wetland is comprised of a complex network of estuaries, tidal inlets, tidal creeks and a large number of islands which are frequently inundated with salt water. Most of the creeks act as a s pathway for to-and-fro movement of tidal water and downstream flow of river systems. The region is covered solely by quaternary sediments carried and deposited by the rivers Ganges, Matla and Bidyadhari. It is the largest remaining tract of mangrove forest in the world which is an independent biome and has rich biodiversity[10]. Sunderban's highly productive ecosystem acts as a natural fish nursery. Over 1186 numbers of known living species (flora and fauna) are found in the biome [11]. Sunderban mangrove reduces the fury of cyclonic storm and prevents erosion due to tidal action. Millions of people depend on Sunderban ecosystem for their livelihood through fishing,fuelwood, timber collection and other materials of importance. Over one million people directly or indirectly depend on the forest for their livelihood and the forest contributes a great amount of Gross Domestic Product (GDP) [12,13]. The main concern at present is that, this area is under pressure of urbanization, industrialization and oil from spills, transport and refineries [14]. Due to temporal and spatial variations in water and soil qualities, monitoring programs help to understand water and soil quality [15]. Quality of water and soil is identified in terms of its physical, chemical and biological parameters [16].

Geographical Information system (GIS) is a computer- based technology for handling geographical data in digital form. It is designed to capture, store, manipulate, analyze, and display diverse sets of spatial or geo-referenced data [17]. GIS hence, is a powerful and essential tool for mapping, water and soil quality [18]. It is very useful and easy to feed data into a GIS environment for integration with other types of data and perform analysis [19]. This application is used to obtain informative and user-friendly maps [20]. The present investigation was undertaken to assess basic physico-chemical parameters of water and soil of selected areas of Sunderban, West Bengal. The purpose of the study was to examine seasonal and spatial variations in pH, electrical conductivity, total dissolved solids, total hardness, calcium hardness, magnesium hardness, turbidity, sodium and potassium of water. Soil samples were also checked to find out pH, EC, total dissolved solids, water holding capacity, organic carbon, organic matter and calcium carbonate. We hypothesized that the water and soil quality changes over seasons under the influence of rain, river and seawater.

Study Area

The Sunderban mangrove forest is located between $21^0 31'$N and $22^0 30'$N and longitude $88^0 10'$E and $89^0 51'$E along the North East coast of Bay of Bengal, India. The climate in the region is characterized by the south-west monsoon (June-September), northeast monsoon or post-monsoon (October-January), and pre-monsoon (February-May), 70% - 80% of annual rainfall occur during the summer monsoon (southwest monsoon). The deltaic soil of Sundarban Biosphere Reserve comprises mainly saline alluvial soil consisting of clay, silt, fine sand and coarse sand particles[21]. The study area of the investigation extends from 22^0 00' N to 22^0 25' N latitude and from 88^0 75' E to 89^0 00' E longitude. Samples were collected from a stretch of 15 km along the Vidyadhari River (distributary of Ganga). Sampling area covers eight stations, namely Bally (Site1), Mocumberia (Site 2), Birajmoni (Site3), Amlamethi (Site 4), Bijoynagar (Site 5), Gosaba (Site 6), Chandipur (Site7), Godhkhali (Site 8).

Materials and Methods

Sample Collection: Surface water and soil samples were collected thrice over a period of six months in the monsoon (September 2014), post-monsoon (December 2014) and winter (February 2015). Water samples were collected in pre-cleaned polythene bottles during high tide in forenoon hours. The bottles were kept in black polythene bags to avoid direct interference with sunlight. They were transported to the laboratory and preserved for 24 hours in refrigerator after which they were analyzed. Soil samples were collected from adjacent areas in white plastic bottles and kept in black polythene bags to avoid sunlight. They were transported to the lab where the samples were analyzed within 48 hours.

Water Quality Analysis

The methods of water quality analysis were in consistent with the standard methods mentioned in 'Handbook of Water Analysis' [22] and 'Practical Methods in Ecology and Environmental Science' [23].

pH

pH of the water samples was determined digitally by using Digital pH meter of Hanna Instruments.

Electrical Conductivity and Total Dissolved Solids

Electrical conductivity (EC) and Total dissolved solids (TDS) of the water sample was determined by using Cyberscan Con 11 Conductivity/TDS meter of Eutech Instruments where the electrode was directly dipped into water samples to get a direct digital display of the result.

Turbidity

Turbidity of the sample was measured by Nephalometric method using the Nephelo-turbidity Meter 132 model of Systronics. The sample was poured into the cell and turbidity was read directly from digital display of the instrument.

Total Hardness

The total hardness of the water samples was determined by **EDTA** titration method where50 ml of the sample was taken in a conical flask and pH of the solution was adjusted to 10 by adding Buffer solution. A pinch of Eriochrome black-T indicator was added and titrated with 0.01M EDTA till wine red solution changes to blue. The volume of EDTA consumed was noted and similarly a reagent blank with distilled water was run to calculate the hardness of water samples.

$$\text{Total Hardness} = \frac{CxDx1000}{mlofsample}$$

Where, C = ml of EDTA required, D = 1M

Calcium and Magnesium Hardness as $CaCO_3$

The Calcium hardness of the water sample was determined by EDTA titration method**.** 50 ml sample was taken in a conical flask and pH of the solution was adjusted to 10 by adding 1ml NaOH. A pinch of Murexide indicator was added and titrated with 0.01M EDTA till pink color solution changes to purple. The volume of EDTA consumed was noted and similarly a reagent blank with distilled water was run to calculate the hardness of water sample.

$$\text{Calcium Hardness} = \frac{Cx1000x1.05}{\text{ml. of sample}}$$

Where, C = volume of Titrant

The Magnesium hardness as $CaCO_3$ was determined by subtracting the Calcium hardness (as $CaCO_3$) from Total Hardness (as $CaCO_3$).

Sodium and Potassium

Sodium and potassium content in the water samples were estimated by using a Flame photometer (Systronics-128) where standard concentrations of sodium and potassium were prepared to obtain a standard graph. The air pressure was kept at 0.5 kg/cm² and the gas feeder knob was adjusted so as to obtain a sharp blue flame.

Soil quality Analysis

pH, Electrical Conductivity and Total Dissolved Solids

pH of the water sample was determined digitally by using pH meter (Hanna Instruments). Electrical conductivity (EC) and Total dissolved solids (TDS) of the water sample was determined after two days using Cyberscan Con 11 Conductivity/TDS meter of Eutech Instruments where the electrode was directly dipped into water samples to get direct digital display of the result. The soil suspension of 1:5 was prepared in distilled water to obtain these values.

The Organic carbon content of the soil sample was estimated by Walkley and Black (1934) rapid dichromate oxidation method where 0.5 g of oven-dried soil was taken in conical flask and 10 ml 1N potassium dichromate was added. 20 ml concentrated sulphuric acid was poured in a conical flask followed by 200 ml distilled water and 10 ml Ortho-phosphoric acid. 1 ml of Diphenylamine indicator was used to obtain blue-violet to green end point with ferrous ammonium sulphate (FAS) as titrant.

$$\text{Organic carbon (\%)} = \frac{10(B-T)\,X\,0.003\,X\,100}{B\,x\,S}$$

B= Vol. of FAS for blank, T= Vol. of FAS for soil sample, S= Wt. of soil in gm.

The value of organic carbon is multiplied by 1.724 to get the organic matter content of the soil sample.

Water Holding Capacity

Water holding capacity of the soil sample was estimated byWhatmann filter paper 41 in which 50 g of oven dried soil sample was taken. 50 ml distilled water was poured into it and the filtered water was collected in beaker to obtain volume of water which formed the basis to calculate water holding capacity of the soil.

Calcium Carbonate:

Calcium carbonate content of the soil was estimated by a rapid titration method. 5g soil was taken in 150 ml beaker and 100 ml 1N HCl was added in it. After vigorous stirring for 1 hour, it was allowed to settle and 20 ml of the supernatant was used for titration by using bromothymol blue indicator against 1N NaOH titrant.

$$\text{Calcium carbonate (\%)} = (B-T)\,x\,5$$

where, B= Volume of 1N NaOH for blank, T= Volume of 1N NaOH for soil

Data Analysis:

All the data sets have been compiled using Microsoft excel. Each parameter was estimated for two times and the average value was considered as the final result. The Standard deviation was also calculated and presented in tables.

Mapping:

Google Earth software was used to obtain a base map of the study area. WGS 1984 (Geographic Coordinate System) was selected for spatial reference of the map in ArcCatalogue of ArcGIS 10.1 software. Control points were added to the base map in ArcMap by using the Geo-referencing tool. The coordinates of the Google Earth map were considered as reference for creating the shape file. Lastly, Krigging was performed by using ArcGIS 10.1 software in which interpolation in spatial analyst tool from ArcTool Box was used.

Discussion of Water Quality Analysis:

pH:

The pH was recorded in the range of 6.18 to 8.24 over the study period. Highest pH in the month of September 2014 was 7.22 at Chandipur while it was highest for the month of December 2014 and February 2015 by 7.93 at Chandipur and 8.24 at Gosabarespectively. The lowest pH for the month of September 2014 was 6.18 at site Birajmoni while in December 2014 it was 7.82 at Amlamethiand in February 2015 it was 8.06 at Bally.pH in surface estuarine water mostly remained alkaline (pH>7) while it was slightly acidic (pH<7) at few sites during study period, especially in monsoon (Table 1, 2, 3). Generally fluctuations in pH values during different seasons of the year is attributed to factors like removal of CO_2 by photosynthesis through bicarbonate degradation, dilution of seawater by freshwater influx, reduction of salinity, temperature and decomposition of organic matter [24,35]. The recorded variations in pH value might be due to influence of seawater penetration and high biological activity [26], similar results were also reported by Velsamy*et al*.[27].

Figure 1: Overview of Sunderban Mangrove

Figure 2: Roots of Sunderban Mangrove Tree

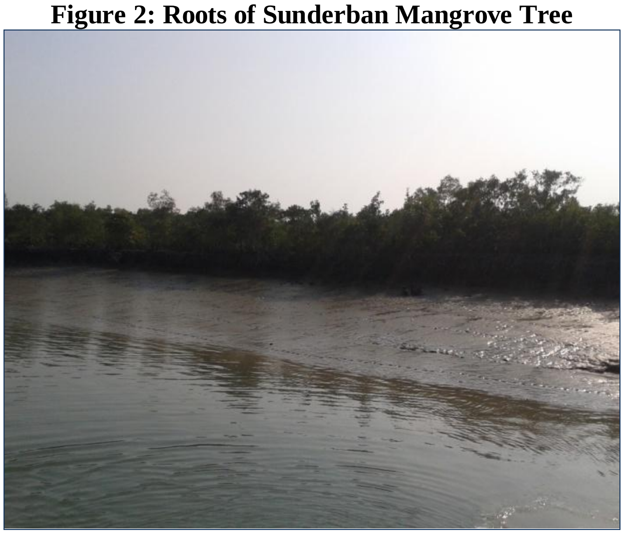

Figure 3: Bally

Figure 4: Mocumberia

Figure 5: Gosaba

Figure 6: Bijoynagar

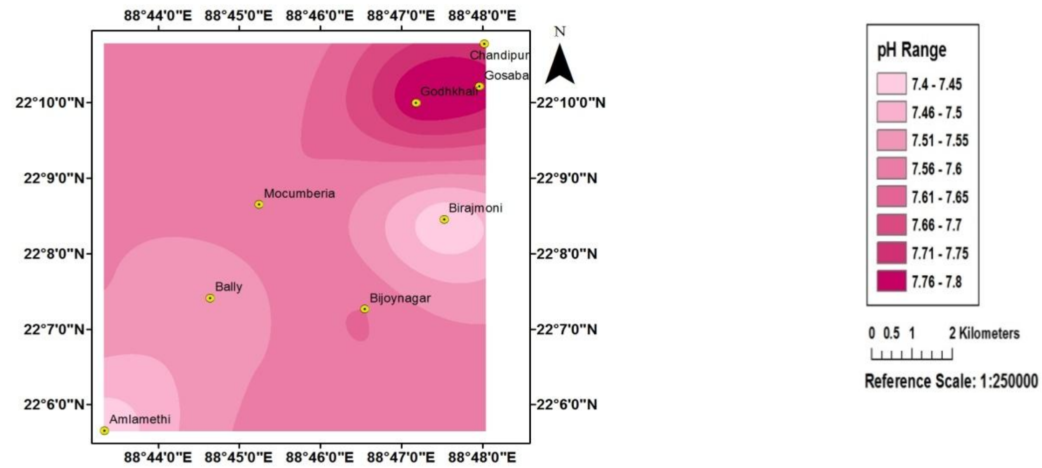

Figure 7: Variations in pH of Surface Water

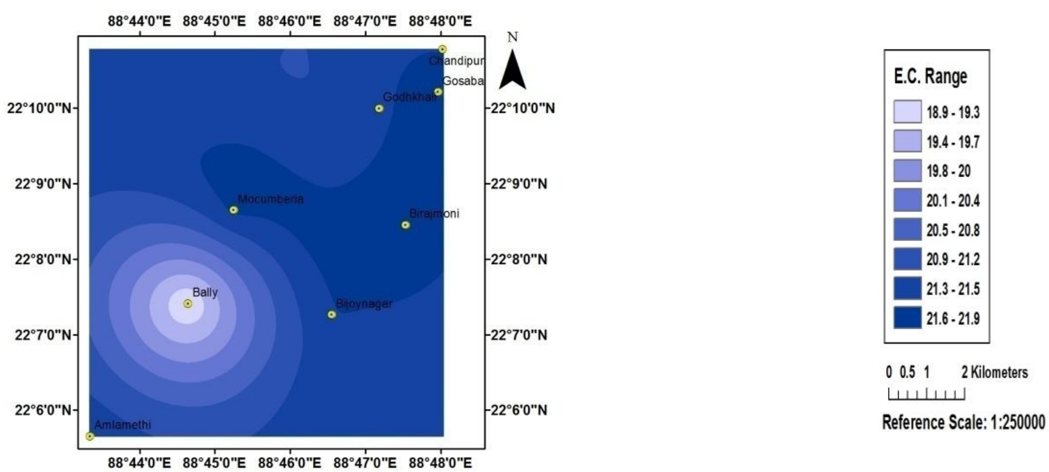

Figure 8: Variations in Electrical Conductivity (mS)of Surface Water

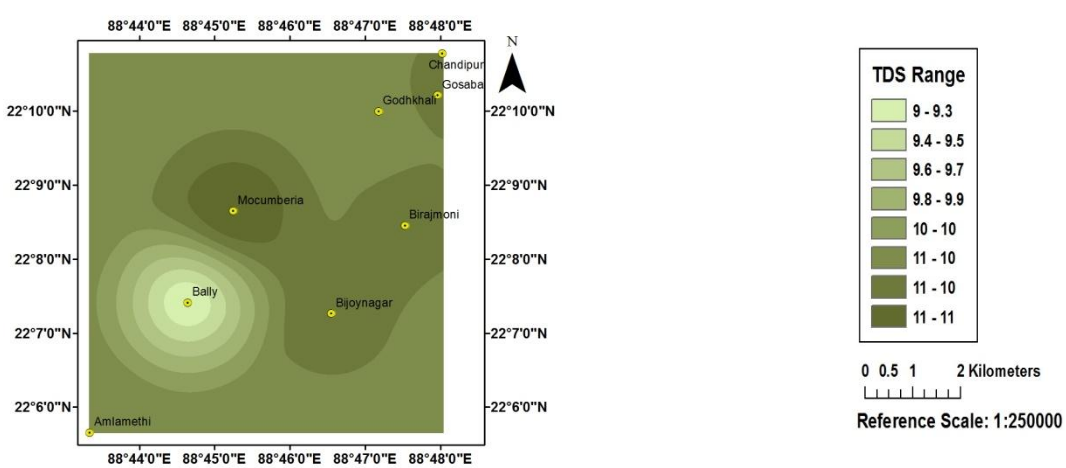

Figure 9: Variations in TDS(ppt)of Surface Water

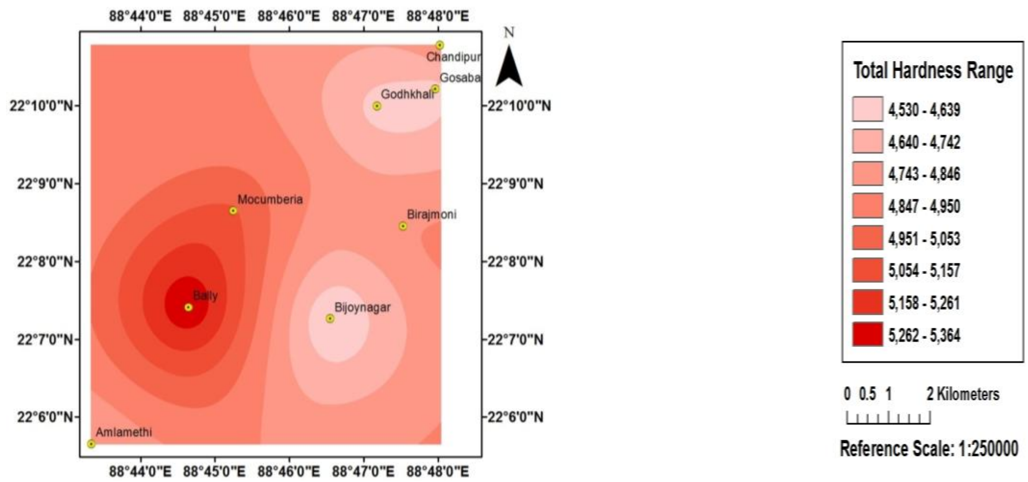

Figure 10: Variations in Total Hardness(mg/l)of Surface Water

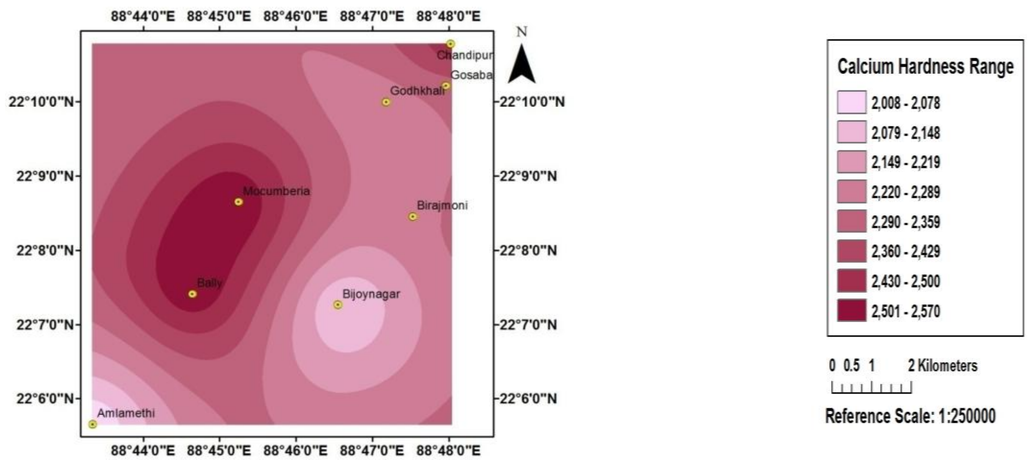

Figure 11: Variations in Calcium Hardness(mg/l) of Surface Water

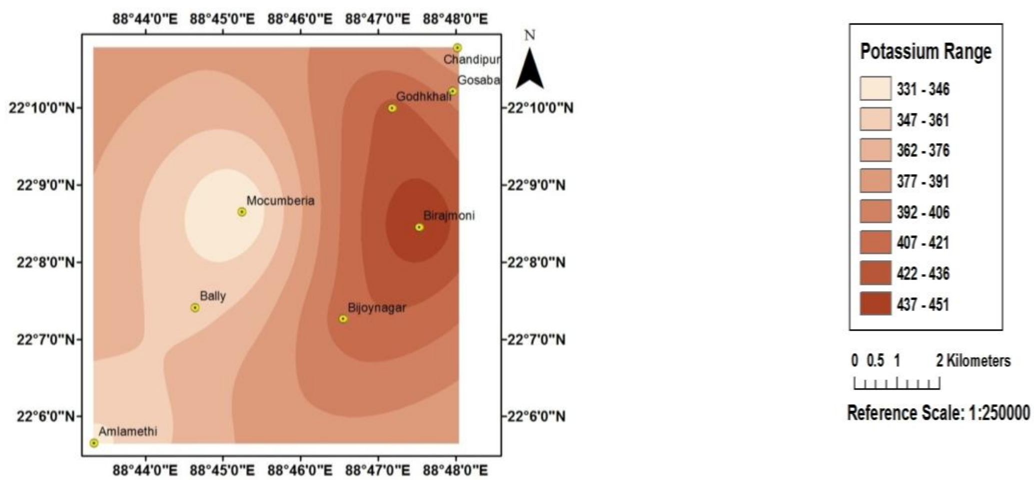

Figure 12: Variations in Potassium(mg/l)of Surface Water

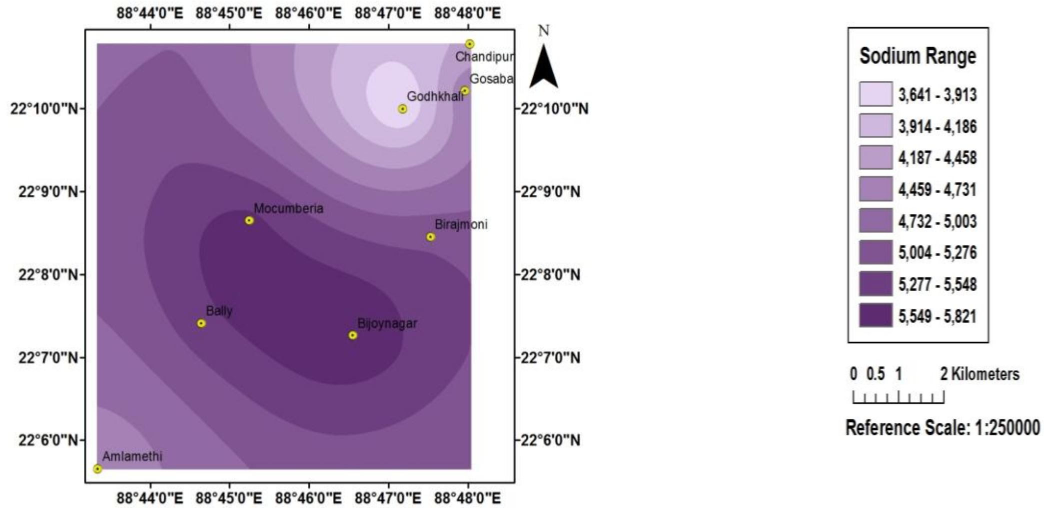

Figure 13: Variations in Sodium(mg/l)of Surface Water

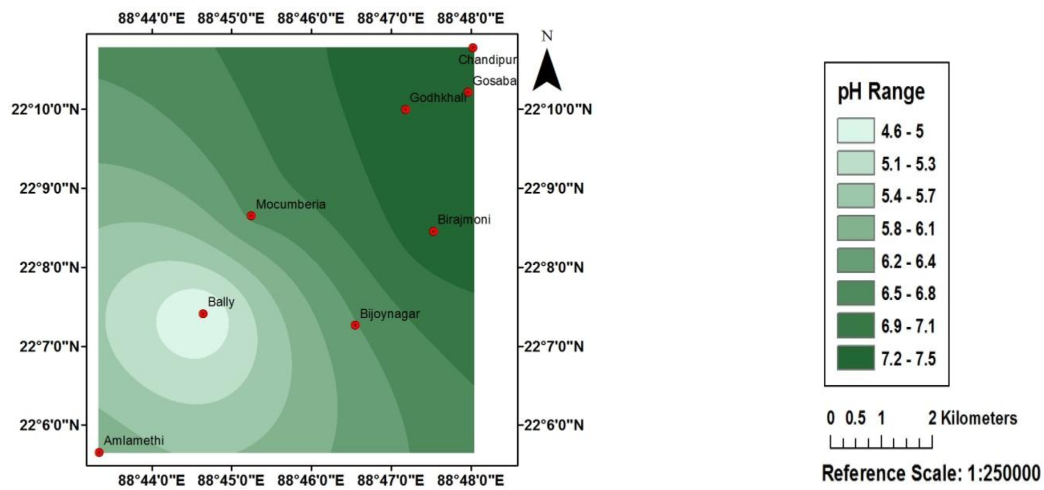

Figure 14: Variations in pH of Soil

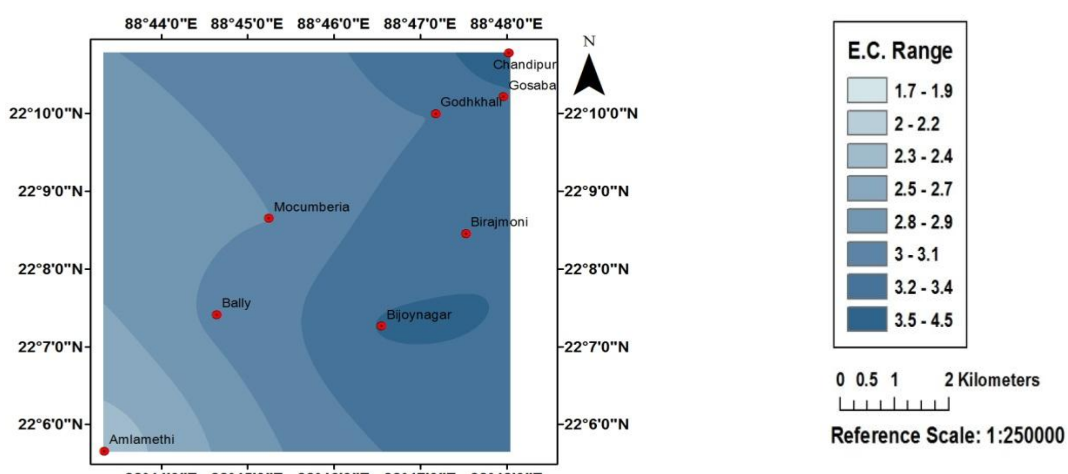

Figure 15: Variations in Electrical Conductivity (mS)of Soil

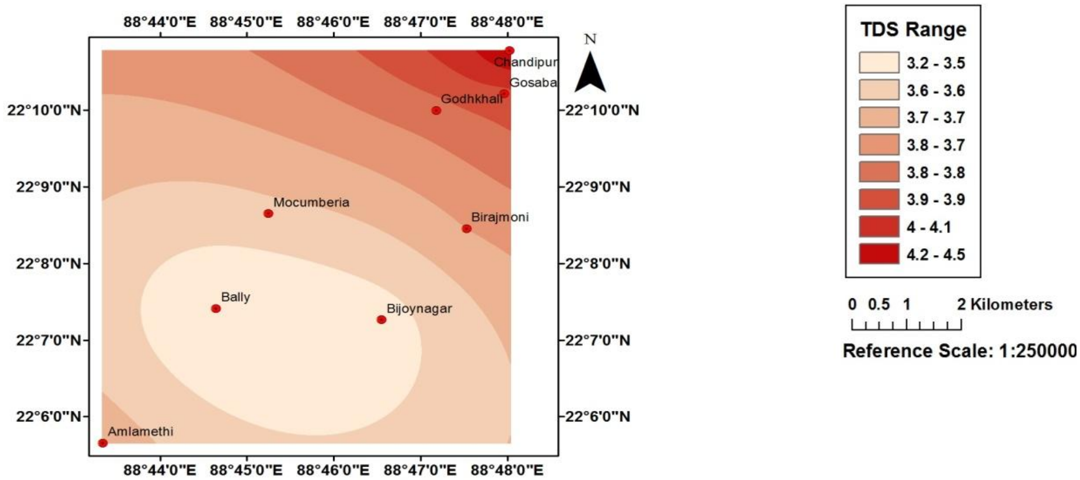

Figure 16: Variations in TDS (ppt)of Soil

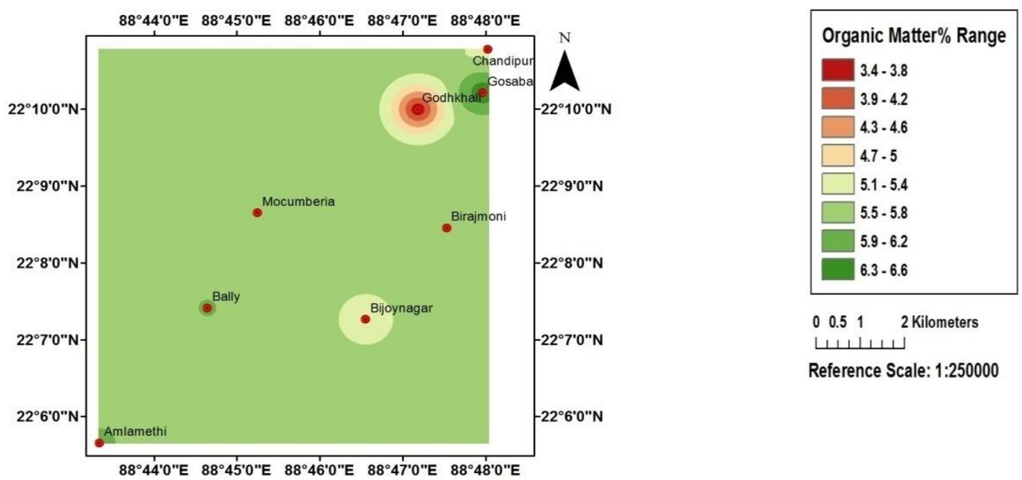

Figure 17: Variations in Organic Matter (%) of Soil

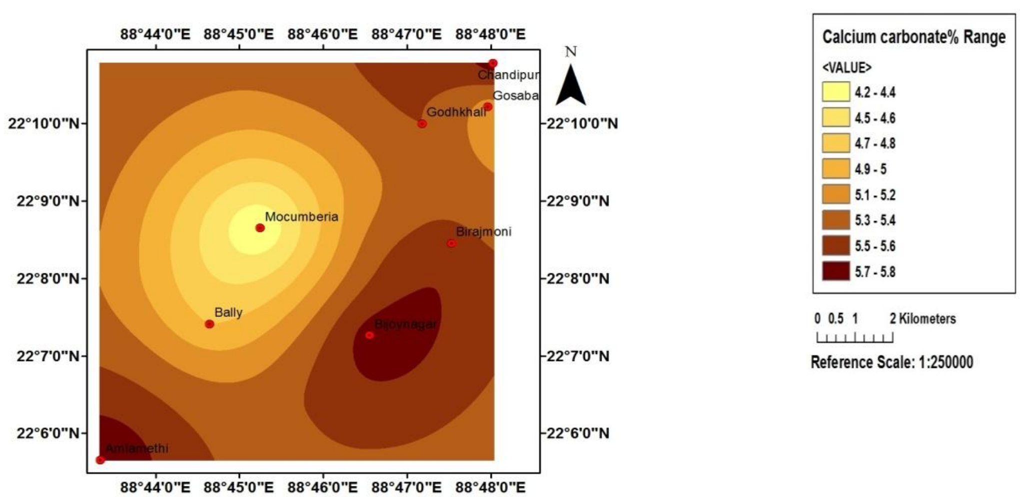

Figure 18: Variations in Calcium Carbonate (%) of Soil

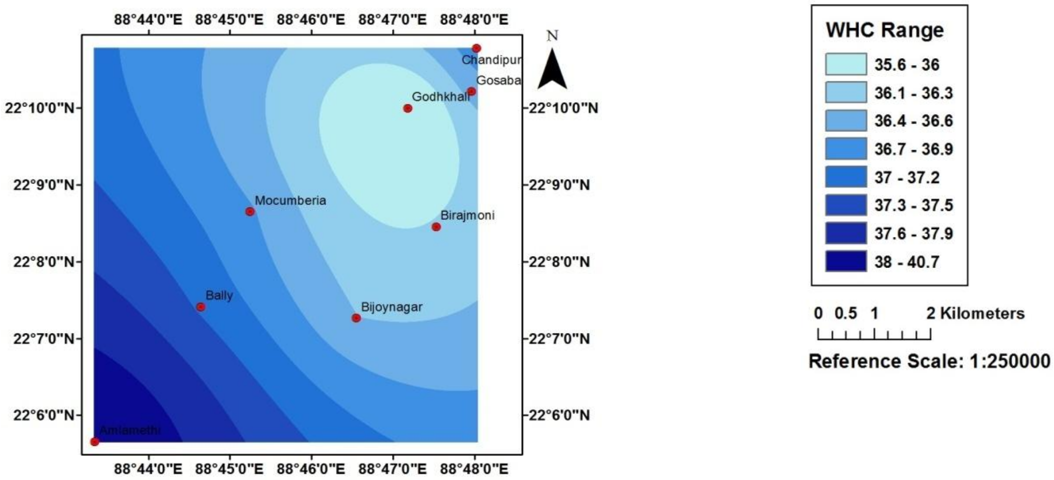

Figure 19: Variations in Water Holding Capacity(%) of Soil

Results and Discussion

Table 1: Water Quality Analysis of the Samples Collected from Selected Areas of Sunderban in September, 2014

S. No.	Parameters	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
1.	pH	6.82 (±0.03)	6.84 (±0.02)	6.82 (±0.04)	6.24 (±0.03)	6.18 (±0.07)	7.15 (±0.04)	7.22 (±0.06)	7.20 (±0.02)
2.	EC (mS)	18.3 (±1.2)	25.5 (±0.8)	24.8 (±0.9)	24.4 (±1.3)	25.9 (±0.9)	25.7 (±0.7)	25.9 (±0.8)	25.5 (±0.7)
3.	TDS(ppt)	9.1 (±0.8)	12.5 (±0.5)	12.6 (±0.7)	12.3 (±0.9)	12.8 (±0.8)	12.7 (±1.1)	12.9 (±0.9)	12.8 (±0.9)
4.	Total Hardness (mg/l)	9200 (±200)	8600 (±200)	8400 (±200)	8800 (±100)	9000 (±100)	7400 (±200)	8200 (±100)	7800 (±200)
5.	Calcium Hardness (mg/l)	3700 (±105)	3200 (±105)	3600 (±210)	3400 (±210)	4200 (±105)	3100 (±210)	3600 (±105)	3000 (±105)
6.	Magnesium Hardness(mg/l)	5500	5400	4800	4400	4800	3300	4600	4800
7.	Turbidity (NTU)	1.1 (±0.2)	1.0 (±0.1)	1.2 (±0.1)	0.7 (±0.1)	1.3 (±0.2)	0.9 (±0.1)	1.3 (±0.2)	1.9 (±0.1)
8.	Sodium (mg/l)	6750 (±150)	6900 (±100)	7500 (±150)	6450 (±150)	7600 (±100)	6900 (±100)	5900 (±150)	5700 (±150)
9.	Potassium (mg/l)	375 (±54)	344 (±64)	437 (±62)	356 (±76)	487 (±68)	406 (±64)	392 (±52)	434 (±56)

Electrical Conductivity (EC)

The electrical conductivity of the samples collected from different sites over study period ranged from 18.1 to 25.9 mS (milli-Siemens).EC was highest at Birajmoni (25.9mS) and lowest at Bally (18.3mS) in September 2014. In the month of December 2014, EC was observed to be highest atBijoynagar andChandipur (18.8mS)and lowest atGosaba(18.1mS). In Ferbuary 2015, EC was found to be highest at Birajmoni (21.6mS) and lowest at Chandipur (19.9mS). Themaximum EC was found in monsoon which might be due to increase in sediment load and influence of high concentration of anions, cations and organic matter. In general, high temperature also favours the conductivity in water bodies.

The TDS of the samples collected ranged from 7.2 to 12.9 ppt (parts per thousand). The Highest value of TDS was observed to be 12.9 ppt at Chandipur in the month of September while in the months of December 2014 and February 2015, highest TDS was found to be 8.8 and 10.6 ppt in Mocumberia and Gosaba areas respectively. The lowest TDS in the month of September was reported to be 9.1 ppt at site Bally while lowest TDS in December 2014 was 7.24 ppt at Gosaba and in February 2015 was 9.2ppt at Godhkhali (Table 1,2,3). Dissolved solids are an important part of water mass which influence the ecology and quality of water [28].TDS had a direct correlation with EC in all the sites. TDS is generally associated with inorganic salt and there is a close parallelism between TDS and conductivity. Though there is no generally valid exact quantitative relationship between TDS and conductivity but high conductivity indicates high TDS [29].

Table 2: Water Quality Analysis of the Samples Collected from Selected Areas of Sunderban in December,2014

S. No.	Parameters	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
1.	**pH**	7.86 (±0.05)	7.84 (±0.04)	7.83 (±0.04)	7.82 (±0.06)	7.84 (±0.05)	7.90 (±0.03)	7.93 (±0.05)	7.88 (±0.04)
2.	**EC (mS)**	18.3 (±0.9)	18.6 (±0.8)	18.8 (±0.6)	18.6 (±0.8)	18.2 (±0.7)	18.1 (±0.6)	18.8 (±0.9)	18.6 (±0.8)
3.	**TDS(ppt)**	7.97 (±0.7)	8.80 (±0.6)	8.08 (±0.6)	7.93 (±0.9)	7.73 (±0.8)	7.24 (±0.7)	7.38 (±0.9)	8.04 (±0.6)
4.	**Total Hardness (mg/l)**	2100 (±100)	2500 (±200)	2200 (±100)	2500 (±100)	2300 (±100)	1800 (±200)	2300 (±200)	2600 (±100)
5.	**Calcium Hardness (mg/l)**	945 (±105)	2100 (±105)	735 (±210)	630 (±105)	630 (±105)	1040 (±105)	840 (±210)	1740 (±105)
6.	**Magnesium Hardness (mg/l)**	1155	500	1465	1870	1670	760	1460	860
7.	**Turbidity (NTU)**	1.0 (±0.1)	0.9 (±0.1)	3.2 (±0.2)	0.9 (±0.1)	1.1 (±0.1)	3.0 (±0.2)	2.2 (±0.2)	3.4 (±0.2)
8.	**Sodium (mg/l)**	4000 (±150)	4000 (±100)	4400 (±150)	2400 (±100)	3600 (±100)	3600 (±100)	3200 (±100)	2400 (±150)
9.	**Potassium (mg/l)**	335 (±58)	312 (±52)	395 (±74)	322 (±64)	426 (±66)	388 (±74)	354 (±54)	408 (±72)

Table 3: Water Quality Analysis of the Samples Collected from Selected Areas of Sunderban in February, 2015

S. No.	Parameters	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
1.	**pH**	8.06 (±0.06)	8.14 (±0.12)	8.20 (±0.14)	8.19 (±0.08)	8.19 (±0.16)	8.24 (±0.09)	8.20 (±0.12)	8.23 (±0.07)
2.	**EC (mS)**	20.0 (±0.9)	20.7 (±0.8)	20.9 (±0.7)	21.0 (±0.7)	21.6 (±0.8)	21.5 (±0.9)	19.9 (±0.8)	20.1 (±0.9)
3.	**TDS(ppt)**	10.0 (±0.9)	10.4 (±0.6)	10.1 (±0.9)	10.1 (±0.8)	10.2 (±0.5)	10.6 (±0.8)	10.1 (±0.9)	9.2 (±0.7)
4.	**Total Hardness (mg/l)**	4800 (±100)	4100 (±100)	3000 (±100)	3000 (±200)	3200 (±100)	4600 (±200)	4000 (±200)	3400 (±100)
5.	**Calcium Hardness (mg/l)**	3045 (±210)	2415 (±105)	1890 (±210)	1995 (±105)	1995 (±105)	2835 (±210)	3045 (±105)	1995 (±105)
6.	**Magnesium Hardness (mg/l)**	1755	1685	1110	1005	1205	1765	955	1405
7.	**Turbidity (NTU)**	3.6 (±0.2)	0.9 (±0.1)	1.0 (±0.1)	2.0 (±0.2)	0.8 (±0.1)	0.8 (±0.1)	1.8 (±0.2)	4.2 (±0.3)
8.	**Sodium (mg/l)**	5600 (±150)	6000 (±100)	5600 (±150)	4800 (±150)	4400 (±100)	3600 (±150)	3600 (±150)	2800 (±100)
9.	**Potassium (mg/l)**	354 (±56)	338 (±52)	412 (±64)	346 (±46)	442 (±58)	406 (±62)	392 (±58)	438 (±66)

Table 4: Average Values of the Water Quality Parameters over Study Period (Used for Mapping)

Sr. No.	Parameters	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
1.	pH	7.5	7.6	7.6	7.4	7.4	7.8	7.7	7.8
2.	EC (mS)	18.9	21.6	21.5	21.3	21.9	21.9	21.5	21.4
3.	TDS(ppt)	9.02	10.56	10.26	10.11	10.24	10.18	10.13	10.01
4.	Total Hardness (mg/l)	5367	5066	4533	4766	4833	4600	4833	4600
5.	Calcium Hardness (mg/l)	2563	2571	2075	2008	2275	2325	2495	2245
6.	Magnesium Hardness (mg/l)	2803	2528	2453	2425	2558	1941	2338	2355
7.	Turbidity (NTU)	1.9	0.7	1.8	1.2	1.1	1.5	1.8	3.1
8.	Sodium (mg/l)	5450	5633	5833	4550	5200	4700	4233	3633
9.	Potassium (mg/l)	355	331	415	341	451	400	379	426

Total Hardness, Calcium Hardness & Magnesium Hardness

The noted value of total hardness ranged from 1800 to 9200 mg/l. The maximum total hardness of water was observed in monsoon and minimum in post-monsoon phase. In September 2014, highest total hardness value was 9200 mg/l at Bally and lowest was 7400 mg/l at Gosaba. Highest total hardness in December 2014 and February 2015 were 2600 mg/l and 4800 mg/l at Godhkhali and Bally respectively, while lowest total hardness in December 2014 and February 2015 were 1800 mg/l and 3000 mg/l atGosaba and Bijoynagar, Amlamethirespectively.Calcium hardness ranged across 630 mg/l in December 2014 atAmlamethi and Birajmoni to4200 mg/l at Birajmoni while Mg ranged from 955 mg/l in December 2014 at Mocumberia to 5500 mg/l in September 2014 at Bijoynagar, Birajmoni and Godhkhali. Both calcium and magnesium hardness were maximum in monsoon and minimum in post-monsoon phase (Table 1, 2, 3).Hardness of water is not a specific constituent but it is a variable and complex mixture of cations and anions. It is caused by dissolved polyvalent-metallic ions [30]. Hardness in water is mostly due to accumulation of salts/compoundswhich come in contact with soil and various geological formations [31] which may enter from direct pollution,anthropogenic activities and agricultural runoff as well. Seasonal variations in Ca and Mg may be attributed due to seawater/freshwater influx [32] and fertilizer application on nearby land. High level of hardness may be due to the influx and decay of debris in the area as well as imbalanced level of H^+ ions from surface run-offs during the monsoon [33].

Turbidity

The recorded values of turbidity range from 0.7 NTU to 3.6 NTU. It was recorded to be highest in February 2015 at Bally and lowest in September 2014 at Amlamethi. Turbidity is a condition resulting from presence of suspended solids in the water, including silts, clays, domestic and industrial sewage and plankton. Turbidity is known to lower oxygen level [34].

Sodium and Potassium

The range of recorded values forsodium and potassium were 2400 to 7600 mg/l and 322 to 487 mg/l respectively. Highest sodium and potassium concentration in September 2014 were observed to be 7600mg/l and 487mg/l respectively at Birajmoni while the lowest sodium and potassium at concentration in the same month were 5700mg/l and 344mg/l at Godhkhali and Mocumberia respectively. In December 2014, highest sodium and potassium concentrations were noted to be 4400mg/l and 426mg/l at Amlamethi-Godhkhali and Birajmoni respectively whereas lowest sodium and potassium concentration were found to be 2400mg/l and 312mg/lat Bijoynagar and Mocumberia respectively. Highest sodium and potassium concentration in February 2015 were observed to be 6000mg/l and 442mg/l at Mocumberia and Bijoynagar respectively while the lowest sodium and potassium at concentration were reported to be 2800mg/l and 338mg/l at Godhkhali and Mocumberia respectively (Table 1,2,3). High concentration of Na^+ and K^+ions were mostly due to seawater intrusion in this area.According to surface water standard, the K^+ in fresh water should be 2.3 mg/l [35]. Bergman[36] found potassium content of seawateras 392 mg/l.

Discussion of Soil Quality Analysis

pH

The pH in soil remained maximum in monsoon and post-monsoon phases.Bally showed acidic condition while soil samples collected from Mocumberia, Bijoynagar and Amlamethiwere weakly acidic. On the other hand,Birajmoni, Gosaba and Chandipur showed neutral to mildly alkaline pH values. Similar findings were recorded by Janakiraman et al.[37] in Adyar estuary where it ranged from 7.06 to 7.86. The factors like photosynthesis, respiratory activity, temperature, airconditon, disposal of industrial wastes, bring out changes in pH [37].Hassan and Razzaque[38] found that pH value of soil is neutral to slightly alkaline in Sunderban area under field conditions but in some localities, the pH value of dried up subsoil samples drop to 6.5. Mahmood and Saikat[39] reported the acidic pH values in the soil of ChakariaSunderban area and mentioned that this area has a rich reserve of pyrite in its soil.

Electrical Conductivity (EC)

The electrical conductivity ranged from 0.09 to 8.7mS. The EC value was maximum in the post-monsoon season and minimum in monsoon, highest being 8.7mS in December 2014 at Chandipur and lowest being 0.2mS in September 2014 at Amlamethi and Godkhali (Table 5, 6, 7). Higher electrical conductivity in the soil suspension of the samples was due to presence of high percentage of soluble salts.

Total Dissolved Solids (TDS)

The TDS ranged from 1.3 to 8.2 pptin the soil suspension (1:5). Lowest TDS was observed to be 1.3ppt in February 2015 at Birajmoni while the highest TDS was noted to be 8.2ppt at Mocumberia in September 2014. It is clear from the results that maximum TDSoccurred in monsoon and minimum in winter. EC, TDS and soluble salts are interrelated.Generally, salinity acts as a limiting factor in the distribution of living organisms and its variation coursed by dilution and evaporation is most likely to influence the final distribution [40].

Water Holding Capacity (WHC)

The WHC of soil had been recorded in the range of 28% in September 2014 at Bijoynagar to 44%in December 2014 and February 2015 at Birajmoni and Chandipur respectively (Table 5,6,7). The results of the present investigation indicate that the soil of the study area contains a huge amount of clay.

Table 5: Soil Quality Analysis of the Samples Collected from Selected Areas of Sunderban in September, 2014

S. No.	Parameters	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
1.	**pH**	7.2 (±0.09)	7.1 (±0.08)	7.3 (±0.04)	7.4 (±0.12)	7.2 (±0.09)	7.4 (±0.06)	7.4 (±0.08)	7.2 (±0.05)
2.	**EC (mS)**	0.9 (±0.17)	1.7 (±0.15)	0.9 (±0.22)	0.2 (±0.19)	1.3 (±0.16)	0.4 (±0.17)	1.3 (±0.25)	0.2 (±0.19)
3.	**TDS(ppt)**	4.7 (±0.42)	8.2 (±0.54)	4.5 (±0.36)	7.6 (±0.24)	6.5 (±0.28)	6.7 (±0.32)	7.1 (±0.34)	7.2 (±0.26)
4.	**Organic Carbon (%)**	2.4 (±0.24)	2.8 (±0.36)	2.2 (±0.42)	4.0 (±0.38)	2.2 (±0.32)	4.1 (±0.46)	3.2 (±0.26)	4.2 (±0.34)
5.	**Organic Matter (%)**	4.1	4.8	3.8	6.9	2.2	7.1	5.5	7.2
6.	**Calcium carbonate content (%)**	7.1 (±0.5)	7.0 (±1.5)	7.0 (±1)	7.0 (±2)	7.0 (±1.5)	7.0 (±0.5)	7.0 (±0.5)	7.0 (±1)
7.	**WHC (%)**	32.0 (±4)	32.0 (±4)	32.0 (±2)	36.0 (±4)	28.0 (±2)	36.0 (±2)	28.0 (±4)	28.0 (±2)

Table 6: Soil Quality Analysis of the Samples Collected from Selected Areas of Sunderban in December, 2014

S. No.	Parameters	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
1.	**pH**	2.8 (±0.11)	7.7 (±0.08)	7.9 (±0.06)	7.5 (±0.08)	7.5 (±0.05)	7.4 (±0.06)	7.7 (±0.08)	7.2 (±0.06)
2.	**EC (mS)**	6.6 (±0.35)	3.2 (±0.25)	5.5 (±0.27)	3.4 (±0.22)	6.2 (±0.28)	4.6 (±0.19)	8.7 (±0.34)	4.0 (±0.28)
3.	**TDS(ppt)**	3.2 (±0.22)	1.2 (±0.18)	2.8 (±0.32)	1.7 (±0.28)	3.2 (±0.26)	2.2 (±0.24)	4.3 (±0.19)	2.0 (±0.25)
4.	**Organic Carbon (%)**	1.0 (±0.2)	1.5 (±0.2)	1.3 (±0.4)	1.4 (±0.4)	1.2 (±0.2)	1.7 (±0.3)	2.7 (±0.3)	0.8 (±0.2)
5.	**Organic Matter (%)**	1.7	2.6	2.2	2.4	2.1	2.9	4.7	1.3
6.	**Calcium carbonate content (%)**	4.2 (±0.5)	3.5 (±2)	5.2 (±1.5)	5.8 (±0.5)	5.5 (±1.5)	5.4 (±0.5)	5.0 (±1)	5.2 (±0.5)
7.	**WHC (%)**	40.0 (±2)	40.0 (±4)	40.0 (±4)	46.0 (±2)	36.0 (±4)	40.0 (±6)	44.0 (±2)	38.0 (±4)

Table 7: Soil Quality Analysis of the Samples Collected from Selected Areas of Sunderban in February, 2015

S. No.	Parameters	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
1.	pH	3.6 (±0.07)	4.7 (±0.06)	4.0 (±0.09)	3.1 (±0.05)	7.5 (±0.14)	7.5 (±0.06)	7.4 (±0.05)	7.4 (±0.12)
2.	EC (mS)	3.1 (±0.15)	3.0 (±0.2)	4.9 (±0.23)	1.6 (±0.14)	2.6 (±0.25)	3.5 (±0.18)	3.5 (±0.22)	4.2 (±0.19)
3.	TDS(ppt)	1.6 (±0.2)	1.5 (±0.28)	2.6 (±0.25)	1.7 (±0.2)	1.3 (±0.3)	1.8 (±0.28)	2.1 (±0.3)	1.8 (±0.29)
4.	Organic Carbon (%)	2.9 (±0.3)	2.5 (±0.2)	2.4 (±0.2)	2.2 (±0.3)	2.5 (±0.3)	2.7 (±0.5)	1.2 (±0.4)	0.7 (±0.5)
5.	Organic Matter (%)	5.0	4.3	4.1	3.8	4.3	4.6	2.1	1.2
6.	Calcium carbonate content (%)	3.0 (±1)	2.1 (±0.5)	5.0 (±0.5)	4.5 (±1.5)	4.0 (±0.5)	3.0 (±1.5)	5.0 (±0.5)	4.0 (±1.5)
7.	WHC (%)	38.0 (±4)	40.0 (±2)	34.0 (±4)	40.0 (±4)	44.0 (±2)	36.0 (±6)	44.0 (±4)	38.0 (±2)

Table 8: Average Values of the Soil Quality Parameters over Study Period (Used for Mapping)

S. No.	Parameters	Site1	Site2	Site3	Site4	Site5	Site6	Site7	Site8
1.	pH	4.6	6.5	6.4	6.0	7.4	7.4	7.5	7.3
2.	EC (mS)	3.3	2.6	3.8	1.7	3.4	2.9	4.5	2.8
3.	TDS(ppt)	3.2	3.6	3.3	3.7	3.7	3.6	4.5	3.7
4.	Organic Carbon (%)	2.1	2.3	2.0	2.5	2.0	2.8	2.4	1.9
5.	Organic Matter (%)	5.9	5.6	5.1	6.1	5.7	6.6	5.2	3.3
6.	Calcium carbonate content (%)	4.8	4.2	5.7	5.8	5.5	5.1	5.7	5.4
7.	WHC (%)	36.7	37.3	35.3	40.7	36.0	37.3	38.7	31.3

Organic Carbon, Organic Matter and Calcium Carbonate Content

Highest organic carbon was found to be 4.2% at Godhkhali in September 2014 and the lowest was noted to be 0.7% at Godhkhali in February 2015. Similarly the high organic matter content was found to be 7.2% in September 2014 at Godkhali whereas the lowest organic matter was found to be 1.2% in the month of February 2015 at the same site (Table 5, 6, 7).Zafar et al.[41] reported that organic matter varied between 0.86 to 1.9% in the intertidal muddy beach of Bankhali river estuary of Bangladesh. 5% organic matter is known to be ideal for the proper composition of soil. The organic matter in mangrove soil belongs over 5% [42]. The Calcium carbonate content was observed to be in the range of 2.1 to 7.1%. Calcium carbonate was recorded to be highest with 7.1% at Bally in September 2014 while it was lowest with 2.1% in February 2015 at Mocumberia. Organic carbon is related to the mud percentage in the soil [43-45]. Therefore, values of organic carbon present in the study reflect the higher mud percentage in the soil than sand. The percentage of organic matter and content of calcium carbonate is higher in Sunderban due to the more decomposition of plant and animal residues in mangrove area [46]. In terms of seasonal variations, organic carbon, organic matter and calcium carbonate show similar patterns in concentration levels with maximum in monsoon and minimum in winter.

Conclusion

The present investigation summarizes various water and soil quality parameters of the samples collected from eight estuarine sites of Sunderban, West Bengal. The results of the parameters significantly fluctuated over different seasons. The surface water of the study area was brackish to brine. All parameters except turbidity have shown highest concentration in monsoon. Sodium concentration remained higher than potassium, calcium and magnesium hardness throughout the study period. EC and TDS have been found to be interrelated. Overall, the concentration of water quality parameters were governed by flushing of rainfall, river water flow, seawater intrusion, runoff from agricultural fields and oil from the spill. The soil quality analysis showed presence of EC and TDS in high concentration. This indicates the influence of seawater in this region. The percentage of organic matter and calcium carbonate content were higher and might be attributed to decomposition of plant-animal residues in mangroves area. This also imparts blackish brown color to soils of Sunderban. Mud content in the study area was higher because of high organic matter in the soil while higher water holding capacity directs that the soil was clayey in texture.The deterioration of water quality in estuarine regions of Sunderbanmay take place due to insufficiency in water resource protection and lack of environmental planning and management. It is advisable that continuous baseline, monitoring studiesfor water and soil quality analysis are carried out along with scientific approach in order to conserve the pristine mangrove ecosystem of Sunderban.Remote sensing and GIS techniques are the effective, cheaper and valuable tools in monitoring water and soil quality parameter in estuarine areas and various water bodies. The maps can provide guidelines for decision makers and conservationists. Therefore, monitoring programs using remote sensing and GIS are needed to tackle the threats at all levels efficiently.

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