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Evaluation of Soil Chemical Properties and Organic Carbon along the Distance Gradient from Sea Coast in Coastal Soils of Northern Saurashtra Region of Gujarat

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Authors' contributions

This work was carried out in collaboration among all authors. Author KY did the writing-preparation, editing and reviewing of the original draft. Author KBP did conceptualized of the study. Authors KY and BN did the sample collection and data analysis. All authors read and approved the final manuscript.

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ABSTRACT

Aims: In present time, salinity and alkalinity of the soils are serious problems in India as well as in Gujarat. These soils are usually supposed to be originated as a result of high water table, arid and semi-arid weather, ingress the sea, water, saline nature of barren materials, poor drainage and salt deposition through wind-blown particles. The current study aimed to study the soil chemical properties and organic carbon in soils of Northern Saurashtra coastal region (Jamnagar, Devbhumi Dwarka and Porbandar district) of Gujarat.
Study Design: Field survey and laboratory analysis
Place and Duration of Study: The twenty surface soil samples were collected from each taluka *viz*. Jodiya, Jamnagar and Lalpur talukas of Jamnagar district, Khambhalia, Dwarka and Kalyanpur talukas of Devbhumi Dwarka district and Porbandar taluka of Porbandar district of Northern Saurashtra Coastal region of Gujarat during May, 2019 and analysed in laboratory of Department of

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Soil Science & Agricultural Chemistry, JAU, Junagadh (Gujarat) during 2019-2021.
Methodology: In this field-laboratory investigation, 141 grid-based surface (0-15 cm) soil samples were collected from farmer's field, through the use of GPS at the distance of 0-5, 5-10, 10-15 and 15-20 km from coastal line and analysed for different chemical properties. Sampling sites were selected based on geographical situation, climate and local data of taluka. In laboratory, the collected samples were analysed for SOC, $EC_{2.5}$, $CaCO_3$, CEC and water-soluble ions.
Results: On the basis of analyzed data, it can be concluded that soil $EC_{2.5}$ was found beyond to its critical or marginal limit up to 0 to 5 km distance from sea coast. The soil organic carbon status of Northern Saurashtra coastal region was found in medium (5.14 g kg^{-1}) category. The soils are calcareous in nature ($CaCO_3$ 121.20 g kg^{-1}) with alkaline in reaction ($pH_{2.5}$ 7.58).
Conclusion: The $EC_{2.5}$, $CaCO_3$, CEC and water-soluble ions except K^+ were decreased, while $pH_{2.5}$ and SOC were slightly increased with increasing the distance from sea coast. The content of organic carbon in soil was noted below to its critical limit up to 10 km distance from sea coast in Northern Saurashtra which might be due to salinity hazard and shallow light texture.

Keywords: Northern; CEC; $CaCO_3$; saurashtra; coastal.

1. INTRODUCTION

Soil survey provides useful information for planning proper soil management practices, with play an important part in augmenting crop production. Poor performance of crops in salts affected soil may be due to excessive quantities of soluble salts, which consequently resulted in nutritional disorders in plants. In present time, salinity and alkalinity of the soils are serious problems in India as well as in Gujarat. These soils are usually supposed to be originated as a result of high water table, arid and semi-arid weather, ingress the sea, water, saline nature of barren materials, poor drainage and salt deposition through wind-blown particles.

Around 6.72 million ha area in India is salt-affected, of which 2.95 million ha is saline and the rest 3.77 million ha is sodic [1]. Nearly 75% of salt-affected soils in the country exist in the states of Gujarat (2.23 million ha), Uttar Pradesh (1.37 million ha), Maharashtra (0.61 million ha), West Bengal (0.44 million ha) and Rajasthan (0.38 million ha) [2]. Salt build-up in soils and water are major constraints for human habitat, sustainable development, soil health and crop productivity [3] due to severe problem of water and soil salinity in the coastal regions [4]. Since soils in general are degrading due to poor management and faulty land use at a rate faster than their natural degeneration, it becomes imperative to protect them from further degradation; as there is a concomitant decline in the quality of soil to produce healthy crops. Soil pH reaction, electrical conductivity (EC) and other properties of soil have marked effects on plant growth. The most important constituent in soil is organic matter, an appreciable amount of it in the soil tremendously increase soil fertility. Decay of organic matter releases nitrogen, phosphorus and mineral nutrient in available form to plants. Organic carbon is also positively correlated with total and available nitrogen in all soil groups [5]. Better crop production in salt affected soils can be attained by if the nature and extent of salinity problems are correctly diagnosed and appropriate reclamation and management practices are adopted.

The soils of Saurashtra region have possess the longest coastal area in India which contains variety of soil constraints like shallow to medium depth land, calcareous in nature, soil erosion, undulating topography, soil salinity/alkalinity and poor quality irrigation water. The quality of well and tube well water become saline and sodic day by day. This poor quality of water decrease the productivity of soil and finally reduce the crop yield. Due to these soils and water related constraints, the sustainable crops yield is not obtained even though use of heavy amount of fertilizer by farmers. The yield of different crops are also varies with variation in soil fertility. Soil survey provides useful information for planning of proper soil, water and nutrient management. It is highly imperative to have the knowledge of the soil fertility levels and quality of underground water and their effect on soil properties in coastal districts of Jamnagar, Devbhumi Dwarka and Porbandar, as identified Northern coastal region of Saurashtra which will help the cultivators in sight and guidance for adoption of suitable soil and crop management practices.

Gujarat has wide variety of soils for growing of multiple crops in different seasons but each soil has been posing some problems for normal

cultivation of crops. These soils of Saurashtra region are medium black and calcareous having several productivity problems like low to medium fertility status, $CaCO_3$, soil salinity *etc*. Due to these constraints, the sustainable crops yield is not obtained even though use of heavy amount of fertilizer by farmers. The yield of different crops are also varies with variation in soil fertility. Soil salinity issue through secondary salinization and saline water due to ingress of sea water in aquifer are major constraints for cultivation of crops in coastal districts of Jamnagar, Devbhumi Dwarka and Porbandar.

Looking to the importance of above views, an investigation was carried out with the objective of evaluation of the fertility and salinity/sodicity status of the soils.

2. MATERIALS AND METHODS

2.1 Collection and Preparation of Soil Samples

Study had been performed by collecting the 141 surface soil samples from each taluka *viz*. Jodiya, Jamnagar and Lalpur talukas of Jamnagar district, Khambhalia, Dwarka and Kalyanpur talukas of Devbhumi Dwarka district and Porbandar taluka of Porbandar district of Northern Saurashtra Coastal region of Gujarat through use of GPS during May, 2019 (Fig. 1).

Two kilograms of surface soil sample from the study area were collected in plastic bag and transfer to cotton bag and it was label properly. Collected samples were air dried and gently crushed (ground) with a wooden mortar with pestle and passed through 2 mm sieve and chemically analyzed.

2.2 Methods for Analysis

Soil samples were analyzed for chemical properties *viz*; $EC_{2.5}$, $pH_{2.5}$, free lime, organic carbon, CEC and water-soluble ions by using standard methods. The $EC_{2.5}$, $pH_{2.5}$ and water-soluble ions of soil samples were determined by use of 1:2.5 soil-water ratio, free lime (equivalent) content was estimated by the rapid acid neutralization method, SOC was determined by 1 N $K_2Cr_2O_7$ method as described by Walkley and Black [6] and CEC was worked out by Ammonium acetate extractable method as described by Chapman [7].

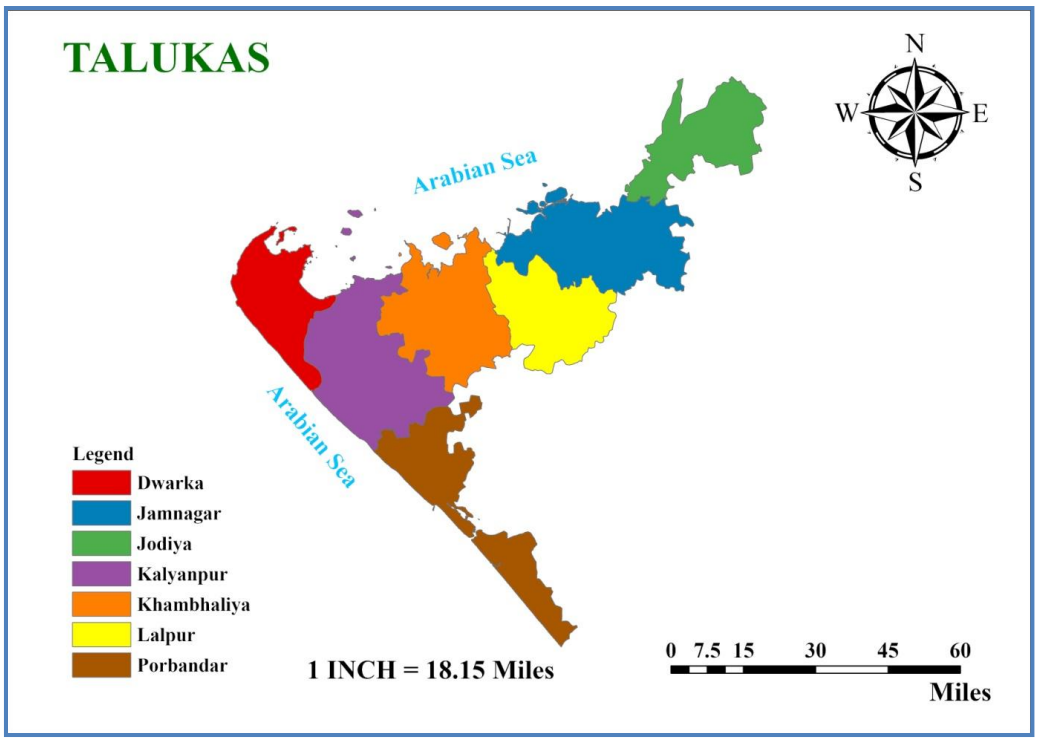

Fig. 1. Map of survey talukas of Jamnagar, Devbhumi Dwarka and Porbandar district

3. RESULTS AND DISCUSSION

3.1 $EC_{2.5}$

The $EC_{2.5}$ of soil samples were determined by use of 1:2.5 soil-water ratio. Overall, it was varied widely ranging from 0.23 to 5.97 dS m^{-1} with a mean value of 1.23 dS m^{-1} (Table 1). The lowest (0.23 dS m^{-1}) $EC_{2.5}$ value was recorded in the soil sample collected from Kalyanpur taluka at the distance of 15 to 20 km from the sea coast, whereas highest value of (5.97 dS m^{-1}) was recorded in the soil sample collected from Dwarka taluka at the distance of 0 to 5 km from the sea coast. The data further revealed that the lowest mean value of 0.86 dS m^{-1} was obtained in the soils of Lalpur taluka and the highest mean value of 1.39 dS m^{-1} was registered in the soils of Porbandar taluka. In Jamnagar district, overall mean value of $EC_{2.5}$ was 1.09 dS m^{-1}, maximum $EC_{2.5}$ (3.67 dS m^{-1}) was found at 0 to 5 km distance from the sea coast and minimum $EC_{2.5}$ (0.29 dS m^{-1}) was found at 15 to 20 km distance from the sea coast. In Devbhumi Dwarka district, maximum $EC_{2.5}$ (5.97 dS m^{-1}) was found at 0 to 5 km distance from the sea coast and minimum $EC_{2.5}$ (0.23 dS m^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of $EC_{2.5}$ was 1.32 dS m^{-1}. In Porbandar district, overall mean value of $EC_{2.5}$ was 1.39 dS m^{-1}, maximum $EC_{2.5}$ (4.80 dS m^{-1}) was found at 0 to 5 km distance from the sea coast and minimum $EC_{2.5}$ (0.30 dS m^{-1}) was found at 15 to 20 km distance from the sea coast.

The wide variation in $EC_{2.5}$ could be due to the accumulation of salts in underground water or influence of sea water or shallow water table or poor quality of ground water prevailing in a particular location. Similar results were also obtained for Girnar topo sequence [8], for Patan district [9], for Kapada district of Andhra Pradesh [10], for Nagpur district of Maharashtra [11], for Nagaur district of Rajasthan [12] and for Southern Saurashtra of Gujarat [13].

3.2 $pH_{2.5}$

In general, the soil samples of Northern Saurashtra coastal region were slightly alkaline in reaction. The overall $pH_{2.5}$ values of Northern Saurashtra's soil samples were ranged from 7.20 to 8.59 with mean value of 7.78. The data (Table 2) revealed that the lowest mean value of $pH_{2.5}$ 7.66 was obtained from the samples of Kalyanpur taluka of Devbhumi Dwarka district and the highest mean value of $pH_{2.5}$ 7.96 was found in the samples of Dwarka taluka of Devbhumi Dwarka district. In Jamnagar district, maximum $pH_{2.5}$ (8.21) was found at 5 to 10 km distance from the sea coast and minimum $pH_{2.5}$ (7.20) was found at 0 to 5 km distance from the sea coast, whereas overall mean value of $pH_{2.5}$ was 7.75.

In Devbhumi Dwarka district, maximum $pH_{2.5}$ (8.59) was found at 10 to 15 km distance from the sea coast and minimum $pH_{2.5}$ (7.21) was found at 0 to 5 km distance from the sea coast, while overall mean value of $pH_{2.5}$ was 7.80. In Porbandar district, overall mean value of $pH_{2.5}$ was 7.80, maximum $pH_{2.5}$ (8.19) was found at 15 to 20 km distance from the sea coast and minimum $pH_{2.5}$ (7.36) was found at 0 to 5 km distance from the sea coast. Overall, soil $pH_{2.5}$ was below its critical limit in coastal region of Northern Saurashtra. Similar results were also obtained for Pedapuluguvaripalem village of Guntur district [14], for Patan district [9], for Kapada district of Andhra Pradesh [10], for Nagpur district of Maharashtra [11], for Nagaur district of Rajasthan [12] and for Southern Saurashtra of Gujarat [13].

3.3 Free Lime ($CaCO_3$)

The overall free lime content was ranging from 12.34 to 420.31 g kg^{-1} with mean value of 121.20 g kg^{-1} (Table 3) indicating the calcareous nature of the soil. This might be due to impregnation of lime in the transported materials and accumulation of shells in the marine alluvial soils particularly in Northern Saurashtra coastal region.

In Jamnagar district, overall mean value of free lime was 81.19 g kg^{-1}, maximum free lime (231.04 g kg^{-1}) was found at 0 to 5 km distance from the sea coast and minimum free lime (13.02 g kg^{-1}) was found at 15 to 20 km distance from the sea coast. In Devbhumi Dwarka district, maximum free lime (400.28 g kg^{-1}) was found at 0 to 5 km distance from the sea coast and minimum free lime (12.34 g kg^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of free lime was 131.63 g kg^{-1}. In Porbandar district, overall mean value of free lime was 205.67 g kg^{-1}, maximum free lime (420.31 g kg^{-1}) was found at 0 to 5 km distance from the sea coast and minimum free lime (45.05 g kg^{-1}) was found at 15 to 20 km distance from the sea coast. The lowest value of free lime 12.34 g kg^{-1} was recorded in the samples collected from Kalyanpur taluka in Devbhumi

Table 1. Talukawise range and mean values of $EC_{2.5}$ (dS m^{-1}) in different districts of Northern Saurashtra coastal region

Distance (km) / Talukas	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Jamnagar	2.78-3.56	3.17	0.55-1.84	1.07	0.46-1.13	0.76	0.37-0.84	0.55	0.37-3.56	1.08
Jodiya	1.37-3.67	2.53	0.76-1.74	1.23	0.48-1.20	0.81	0.32-0.89	0.58	0.32-3.67	1.34
Lalpur	1.19-3.13	2.01	0.53-1.32	0.85	0.36-0.92	0.59	0.29-0.47	0.36	0.29-3.13	0.86
Jamnagar District	1.19-3.67	2.41	0.53-1.84	1.05	0.36-1.20	0.70	0.29-0.89	0.51	0.29-3.67	1.09
Kalyanpur	1.31-5.60	2.58	0.58-1.33	0.86	0.38-1.05	0.67	0.23-0.56	0.36	0.23-5.60	1.13
Khambhalia	1.17-4.33	2.59	0.54-1.64	0.90	0.45-0.97	0.65	0.24-0.46	0.36	0.24-4.33	1.05
Dwarka	1.44-5.97	2.67	0.80-2.31	1.45	0.57-1.13	0.82	0.36-0.69	0.53	0.36-5.97	1.78
Devbhumi Dwarka District	1.17-5.97	2.63	0.54-2.31	1.05	0.38-1.13	0.71	0.23-0.69	0.39	0.23-5.97	1.32
Porbandar	1.44-4.80	2.73	0.82-1.74	1.18	0.58-1.11	0.86	0.30-0.78	0.51	0.30-4.80	1.39
Overall	1.17-5.97	2.58	0.53-2.31	1.06	0.36-1.20	0.73	0.23-0.89	0.46	0.23-5.97	1.23

Table 2. Talukawise range and mean values of $pH_{2.5}$ in different districts of Northern Saurashtra coastal region

Distance (km) / Talukas	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Jamnagar	7.20-7.64	7.42	7.51-8.21	7.84	7.41-8.20	7.78	7.51-8.18	7.77	7.20-8.21	7.76
Jodiya	7.22-7.66	7.43	7.37-7.95	7.62	7.68-8.16	7.91	7.74-8.20	7.97	7.22-8.20	7.70
Lalpur	7.51-7.83	7.70	7.37-8.02	7.79	7.42-7.90	7.71	7.91-8.07	7.97	7.37-8.07	7.78
Jamnagar District	7.20-7.83	7.51	7.37-8.21	7.75	7.42-8.20	7.78	7.51-8.20	7.90	7.20-8.21	7.75
Kalyanpur	7.28-7.74	7.48	7.60-8.14	7.77	7.64-7.84	7.71	7.51-7.87	7.70	7.28-8.14	7.66
Khambhalia	7.21-8.09	7.63	7.50-7.83	7.70	7.62-8.12	7.87	7.70-8.02	7.87	7.21-8.12	7.76
Dwarka	7.44-8.04	7.81	7.65-8.12	7.82	7.93-8.59	8.19	8.52-8.55	8.54	7.44-8.59	7.96
Devbhumi Dwarka District	7.21-8.09	7.68	7.50-8.14	7.76	7.62-8.59	7.89	7.51-8.55	7.93	7.21-8.59	7.80
Porbandar	7.36-8.10	7.74	7.50-8.12	7.75	7.55-8.15	7.83	7.71-8.19	7.90	7.36-8.19	7.80
Overall	7.20-8.10	7.64	7.37-8.21	7.75	7.42-8.59	7.83	7.51-8.55	7.91	7.20-8.59	7.78

Table 3. Talukawise range and mean values of $CaCO_3$ (g kg^{-1}) in different districts of Northern Saurashtra coastal region

Distance (km) / Talukas	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Jamnagar	103.24-132.54	117.89	63.12-90.00	74.05	42.58-60.23	50.01	19.99-40.67	28.95	19.99-132.54	62.20
Jodiya	174.07-231.04	194.78	114.20-170.00	136.64	60.12-95.37	72.16	42.58-52.02	47.45	42.58-231.04	120.44
Lalpur	122.08-152.47	138.52	50.00-102.03	67.90	23.21-50.00	36.65	13.02-34.06	23.73	13.02-152.47	60.93
Jamnagar District	103.24-231.04	162.53	50.00-90.00	92.01	23.21-95.37	49.72	13.02-52.02	34.25	13.02-231.04	81.19
Kalyanpur	224.10-360.12	269.42	56.24-163.28	116.66	12.34-80.00	50.43	12.34-41.03	25.85	12.34-360.12	116.82
Khambhalia	114.02-241.03	186.34	68.17-114.00	93.74	42.74-90.00	65.90	18.24-52.64	31.01	18.24-241.03	91.01
Dwarka	190.00-400.28	285.54	100.04-187.28	136.51	88.17-116.26	97.20	32.17-68.02	50.10	32.17-400.28	187.07
Devbhumi Dwarka District	114.02-400.28	259.02	56.24-187.28	113.06	12.34-116.26	68.21	12.34-41.03	32.60	12.34-400.28	131.63
Porbandar	241.25-420.31	348.32	192.03-292.57	232.92	91.47-190.36	138.63	45.05-92.14	74.29	45.05-420.31	205.67
Overall	103.24-420.31	246.40	50.00-292.57	116.15	12.34-190.36	69.26	12.34-92.14	41.00	12.34-420.31	121.20

Table 4. Talukawise range and mean values of SOC (g kg^{-1}) in different districts of Northern Saurashtra coastal region

Distance (km) / Talukas	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Jamnagar	1.90-2.80	2.35	3.50-4.80	4.19	5.10-6.90	6.07	7.20-9.00	7.80	1.90-9.00	5.29
Jodiya	1.80-3.00	2.46	3.10-4.90	4.06	5.00-6.10	5.55	6.40-8.10	7.33	1.80-8.10	4.61
Lalpur	1.50-1.90	1.70	2.40-4.80	3.73	4.50-6.60	5.60	6.20-8.70	7.47	1.50-8.70	4.64
Jamnagar District	1.50-3.00	2.21	2.40-4.90	4.00	4.50-6.90	5.75	6.20-9.00	7.54	1.50-9.00	4.85
Kalyanpur	3.00-4.10	3.56	4.20-5.40	4.84	5.30-6.70	6.15	6.50-8.30	7.28	3.00-8.30	5.40
Khambhalia	1.50-3.10	2.35	3.70-5.50	4.57	5.30-6.70	5.98	6.20-7.60	6.90	1.50-7.60	4.99
Dwarka	1.40-3.60	2.44	5.20-6.80	6.16	7.20-8.40	7.75	9.10-9.70	9.40	1.40-9.70	5.13
Devbhumi Dwarka District	1.40-4.10	2.73	3.70-6.80	5.12	5.30-8.40	6.56	6.20-8.30	7.49	1.40-9.70	5.17
Porbandar	2.00-4.70	3.48	4.90-6.00	5.44	6.10-7.20	6.66	7.10-9.40	8.34	2.00-9.40	5.86
Overall	1.40-4.70	2.71	2.40-6.80	4.60	4.50-8.40	6.19	6.20-9.40	7.67	1.40-9.40	5.14

Dwarka district, whereas the highest value of free lime 420.31 g kg^{-1} was found in Porbandar taluka of Porbandar district.

Similar results were also observed for the soils of north-west agro climatic zone of Gujarat [15], for Bhavnagar district [16], for Latur district [17] and for Southern Saurashtra of Gujarat [13].

3.4 Soil Organic Carbon

Organic carbon content in the soils is important parameter from the fertility and physical properties points of view. Hence, the samples were analyzed for soil organic carbon content in Northern Saurashtra coastal region (Table 4, Fig. 2). In general, the soils of Northern Saurashtra coastal region are medium in O.C. status. The overall organic carbon content in the soils of Northern Saurashtra coastal region were ranged from 1.40 to 9.40 g kg^{-1} having mean value of 5.14 g kg^{-1}. In Jamnagar district, maximum soil organic carbon (9.00 g kg^{-1}) was found at 15 to 20 km distance from the sea coast and minimum organic carbon (1.50 g kg^{-1}) was found at 0 to 5 km distance from the sea coast, whereas overall mean value of soil organic carbon was 4.85 g kg^{-1}. In Devbhumi Dwarka district, maximum soil organic carbon (9.70 g kg^{-1}) was found at 15 to 20 km distance from the sea coast and minimum soil organic carbon (1.40 g kg^{-1}) was found at 0 to 5 km distance from the sea coast, while overall mean value of soil organic carbon was 5.17 g kg^{-1}. In Porbandar district, overall mean value of organic carbon was 5.86 g kg^{-1}, maximum soil organic carbon (9.40 g kg^{-1}) was found at 15 to 20 km distance from the sea coast and minimum organic carbon (2.00 g kg^{-1}) was found at 0 to 5 km distance from the sea coast. The lowest value of organic carbon (1.40 g kg^{-1}) was recorded in the samples collected from Dwarka taluka in Devbhumi Dwarka district, whereas the highest value of organic carbon (9.40 g kg^{-1}) was found in Porbandar taluka of Porbandar district. The content of organic carbon in soil was noted below to its critical limit up to 10 km distance from sea coast in Northern Saurashtra which might be due to salinity hazard and shallow light texture.

Similar findings were made for the north-west agro climatic zone of Gujarat [15], for Hassan district of Karnataka [18], for Degana tahsil, Nagaur district of Rajasthan [19], for Kishtwar district of Jammu and Kashmir [20], for Veeranam command area of Cuddalore district of Tamil Nadu [21], for Gir Somnath district [22], for Haveri, Gadag and Dharwad districts of Karnataka [23] and for Southern Saurashtra of Gujarat [13].

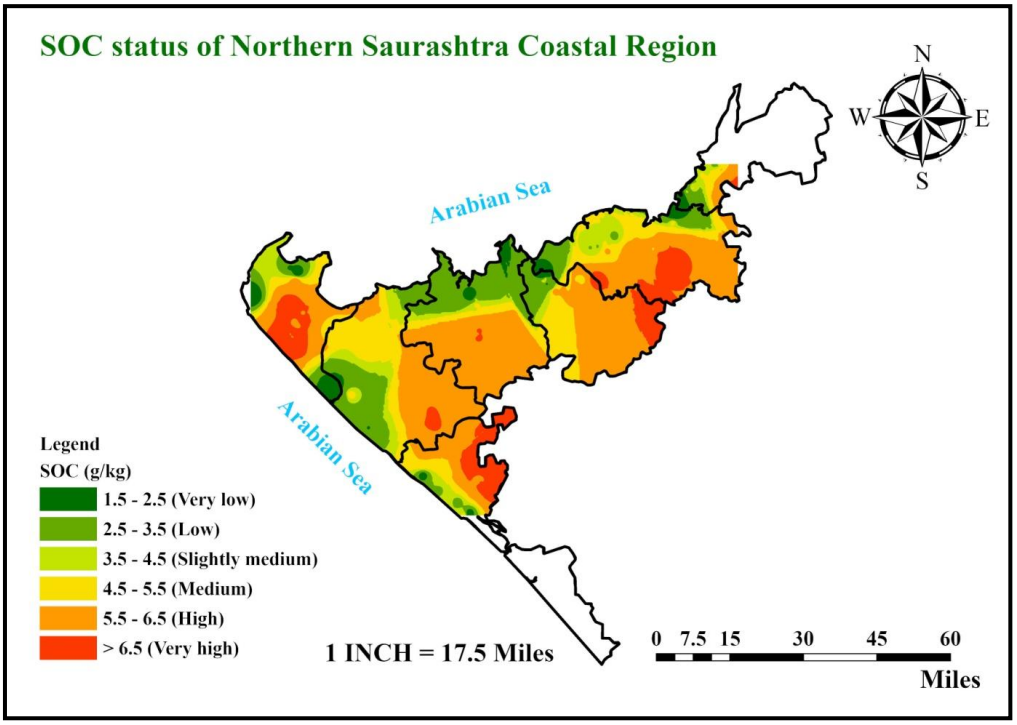

Fig. 2. Map of overall SOC status in coastal soils of Northern Saurashtra region

Table 5. Talukawise range and mean values of CEC (cmol (p+) kg^{-1}) in different districts of Northern Saurashtra region

Distance (km) / Talukas	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Jamnagar	41.02-42.74	41.88	23.29-52.83	38.42	30.14-47.81	42.52	34.63-42.86	38.50	23.29-52.83	40.01
Jodiya	44.33-56.25	48.49	32.59-49.96	44.70	30.93-39.36	34.88	23.59-28.49	26.77	23.59-56.25	40.10
Lalpur	32.50-44.87	39.62	30.97-50.54	39.87	29.27-37.51	33.60	27.92-33.14	31.38	27.92-50.54	36.36
Jamnagar District	32.50-56.25	44.51	23.29-52.83	40.88	29.27-47.81	37.05	23.59-42.86	32.29	23.29-56.25	38.82
Kalyanpur	23.70-45.79	35.95	35.66-47.91	40.04	34.67-44.02	40.19	33.27-43.14	39.35	23.70-47.91	38.92
Khambhalia	32.45-44.58	40.21	28.47-45.42	37.82	27.16-35.03	31.82	26.38-47.13	34.54	26.38-47.13	36.28
Dwarka	19.88-40.73	29.37	19.49-42.04	30.27	22.53-42.31	30.48	23.20-24.01	23.61	19.49-42.31	29.24
Devbhumi Dwarka District	19.88-45.79	33.61	19.49-47.91	36.25	22.53-44.02	35.02	23.20-47.13	34.30	19.49-47.91	34.81
Porbandar	39.64-59.72	48.78	31.04-42.32	37.58	29.23-39.72	34.04	27.06-32.11	29.39	27.06-59.72	37.99
Overall	1.40-4.70	2.71	2.40-6.80	4.60	4.50-8.40	6.19	6.20-9.40	7.67	1.40-9.40	5.14

3.5 Cation Exchange Capacity (CEC)

The CEC was worked out from the values of exchangeable cations (Ammonium acetate extractable) and are given in Table 5. The overall range of CEC in Northern Saurashtra coastal region was 19.49 to 59.72 (cmol (p+) kg^{-1}) with the mean value of 36.99 (cmol (p+) kg^{-1}). In Jamnagar district, maximum CEC [56.25 (cmol (p+) kg^{-1})] was found at 0 to 5 km distance from the sea coast and minimum CEC [23.29 (cmol (p+) kg^{-1})] was found at 5 to 10 km distance from the sea coast, whereas overall mean value of CEC was 38.82 (cmol (p+) kg^{-1}). In Devbhumi Dwarka district, maximum CEC [47.91 (cmol (p+) kg^{-1})] was found at 5 to 10 km distance from the sea coast and minimum CEC [19.49 (cmol (p+) kg^{-1})] was found at 5 to 10 km distance from the sea coast, while overall mean value of CEC was 34.81 (cmol (p+) kg^{-1}).

In Porbandar district, overall mean value of CEC was 37.99 (cmol (p+) kg^{-1}), maximum CEC [59.72 (cmol (p+) kg^{-1})] was found at 0 to 5 km distance from the sea coast and minimum CEC [27.06 (cmol (p+) kg^{-1})] was found at 15 to 20 km distance from the sea coast.

Similar findings were also recorded for Bhatinda district of Punjab [24], for Sivaganga district of Tamil Nadu [25], for Gir Somnath district [26], for Nagaur district of Rajasthan [12] and for Southern Saurashtra of Gujarat [13].

3.6 Water Soluble Ions

Water soluble cations (Ca^{++}, Mg^{++}, Na^{+} and K^{+}) and anions (CO_3^{--}, HCO_3^{-} , Cl^{-} and SO_4^{--}) were estimated from the soil: water (1:2.5) extract. Sample wise values of water-soluble cations and anions for all the 141 samples are given in Tables 6 and 7.

Among the water-soluble cations, Na^{+} was predominant one followed by Ca^{++}, Mg^{++} and K^{+}. The mean values of water-soluble Ca^{++}, Mg^{++}, Na^{+} and K^{+} were 2.05, 1.69, 8.35 and 0.18 me L^{-1}, respectively. Among the water-soluble anions, Cl^{-} was predominant one followed by HCO_3^{-} , CO_3^{--} and SO_4^{--}. The mean values of water-soluble CO_3^{--}, HCO_3^{-} , Cl^{-} and SO_4^{--} were 0.22, 1.68, 10.30 and 0.08 me L^{-1}, respectively. The results of water-soluble ions revealed that Na^{+} and Cl^{-} were predominant cation and anion in soil solution, respectively. Similar findings were also recorded for Sivaganga district of Tamil Nadu [25], for Gir Somnath district [26] and for Southern Saurashtra of Gujarat [13].

Table 6. Mean values of water-soluble cations (me L^{-1}) in soils of Northern Saurashtra coastal region

Distance (km)	Water soluble cations (me L^{-1})			
	Ca^{++}	Mg^{++}	Na^{+}	K^{+}
0 to 5	3.97	3.83	17.89	0.05
5 to 10	1.91	1.39	7.26	0.08
10 to 15	1.33	0.86	4.89	0.18
15 to 20	0.83	0.59	2.71	0.52
Overall	2.05	1.69	8.35	0.18

Table 7. Mean values of water-soluble anions (me L^{-1}) in soils of Northern Saurashtra coastal region

Distance (km)	Water soluble anions (me L^{-1})			
	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}
0 to 5	0.32	2.96	22.67	0.18
5 to 10	0.26	1.65	8.61	0.06
10 to 15	0.18	1.17	5.74	0.04
15 to 20	0.08	0.79	3.55	0.03
Overall	0.22	1.68	10.30	0.08

4. CONCLUSION

The analyzed data of collected soil samples revealed that $EC_{2.5}$, $CaCO_3$, CEC and water-soluble ions except K^+ were decreased, while $pH_{2.5}$ and SOC was slightly increased with increasing the distance from sea coast. Soil $EC_{2.5}$ was found beyond to its critical or marginal limit up to 0 to 5 km distance from sea coast. The content of organic carbon in soil was noted below to its critical limit up to 10 km distance from sea coast in Northern Saurashtra which might be due to salinity hazard and shallow light texture.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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