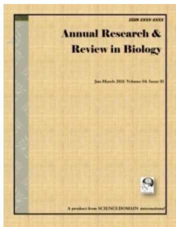

Annual Research & Review in Biology
4(23): 3492-3503, 2014

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GIS study on Chemical Properties of Salt Affected Soils of Coastal Kachchh, Gujarat, India

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Authors' contributions

This work was carried out in collaboration between both authors. Author JPS designed and performed the study, statistical analysis, wrote the protocol and wrote first draft of the manuscript with literature. Author AT corrected and prepared a final draft of manuscript. Both the author read and approved the final manuscript.

Original Research Article

Received 14th March 2014
Accepted 2nd May 2014
Published 19th June 2014

ABSTRACT

The aim of this study is to understand the soil profile of coastal and near coastal region of Kachchh and their surrounding vegetation giving the green coverage as well as useful for many purposes. In Gujarat and Kachchh, distribution of salt tolerant vegetation (halophytes) is considerable. Nevertheless. There is a total lack of study on Kachchh halophytes. The study was conducted at 40 sites and 185 locations; spread over a six talukas, each sampled at 10 cm depth along a 300km long stretch of coastal and near coastal region of Kachchh district, Gujarat. The study determines salt characterization of coastal soils of Kachchh and highlights the halophytes growing in the region to sustainable use of these saline soils. The study period was between July 2011 and september 2012. The laboratory test of composite soil samples was done for each parameter in triplicate. The ph, ec, major minerals such as na^{+}, k^{+}, ca^{2+}, mg^{2+},cl^{-}, li^{-} and so_4^{-} were analyzed by standard methods and from that results sodium absorption ratio (sar), percent sodium (na%), potential salinity (ps) and exchangeable sodium ratio (esr) were calculated. Spatial variations of various soil quality parameters were studied using the geographical information system (gis). The distribution map of soil salinity in all coastal talukas was created based on analyzed soil classification using gis tools. The findings of this study clearly indicate that the soil of coastal kachchh is dominated by sodium and in most of the area it is sodic. Variation in soil properties from the study area such as non saline, slightly saline, high ph, saline, saline- sodic and sodic soil was reported.

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Keywords: Saline soil; sodic soil; sodium absorption ratio; coastal and near coastal area; kachchh.

1. INTRODUCTION

Soil is a major component of the environmental system. Soils are composed of solid, liquid, and gas; soluble and insoluble; and organic as well as inorganic substances. There are ions and compounds, salts, acids, bases, minerals and rock fragments. It is a major resource of the earth with a lot of potential. In fact, soil has been described as the basis of human civilization. This is because soil supports plants, which provide nutrition for man and his livestock [1,2]. Different types of soils occur in various regions under different geological and soil forming processes. For instance, coastal plain soils are formed from sedentary rocks deposited mostly in a Marine environment, which are uplifted and tilt seaward with part of it being submerged by Continental Shelf [3].

If the soil with high salt content is termed saline and if it is with higher sodium then soil is considered as sodic. Soil is likely to show great variability in their physical, chemical, biological properties because the soil is a heterogeneous unit. Knowledge of variability of soil properties is very indispensable as this can affect crop yield. Salt-affected soils are characterized by excess levels of soluble salts (salinity) and/or Na+ in the solution phase as well as on cation exchange complex (sodicity). These salts and Na^+ originate either by the weathering of parent minerals causing primary salinity/sodicity or from anthropogenic activities, involving the inappropriate management of land and water resources causing secondary salinity [4]. Soil electrical conductivity is a measure of the soil's acidity or basicity. Two factors namely salinity and Sodium Absorbance Ratio (SAR) provide information on soil salinity and sodicity. If SAR is <10, the sodium hazard is low and SAR >13, the soil could be categorized as saline and hazardous to plant growth.

Soil salinisation is a common phenomenon in semi-arid and arid regions, where the amount of rainfall is insufficient for substantial leaching [5]. Persistent soil salinity leads to the degradation of productive land to wasteland. Salinity affects 7% of the world’s land area, which amounts to 930 million ha [6; based on FAO 1989 data]. In India, nearly 9.38 million ha area is occupied by salt-affected soils out of which 5.5 million ha are saline soils (including coastal) and 3.88 million ha alkali soils [7]. Most of the salt affected areas are in arid and semi-arid regions of Rajasthan, Gujarat, Western Haryana and Uttar Pradesh, where rainfall is scanty and the evapo-transpiration is very high. Being an arid zone, rainfall in Kachchh ranges between 100 to 350 mm/yr with most of the rainfall confined to 10 to 13 days. Likewise, evapo-transpiration is very high with 2.25m. The spread of salinity from these affected areas are negatively influencing fertile and pasture lands. A study of the variability trends of soil is essential in order to highlight the soil potentials and for improved management and productivity [8,9]. Satellite Remote Sensing and Geographical Information System have provided very useful methods of surveying, identifying, classifying and monitoring several forms of earth resources, especially soil categories [10].

Therefore, there is need to devise a method of identifying the crucial soil properties influencing crop production, pasture development and for green vegetation as a forest land, wasteland and for fertile land. Many halophytes have potential agricultural value and can be grown in the degraded saline areas. This will not only utilize the unproductive land for economic growth but also will help in improving the ecological and social environment and biodiversity [11]. In order to develop a more reliable model to establish the relationship between yield of crops and basic properties of soil it is imperative to understand chemical properties of soils of Kachchh region. This work narrates crucial soil properties of the coastal and near coastal area of Kachchh, Gujarat. In addition, it demonstrates how saline land could be useful to promote halophytes as dominant vegetation in coastal regions of arid Kachchh. Establishing this link could be useful to explore the possibility that how some halophytes can be converted into crops and with a view to use them for forage, fodder, fuel and medicinal purposes. This study was prompted since such records are lacking in Kachchh landscape.

2. MATERIALS AND METHODS

2.1 Study Area

Kachchh is the second largest district in the country, covering a total area of 45,652 km^2 and located on the western-most tip of India. Rann of Kachchh is a seasonal marshy region surrounding Kachchh. It is salty lowland, rich in natural gas and a resting site for migratory Siberian birds. Administratively, this district encompasses 10 talukas and 950 villages. Kachchh district covering the coastal area is 6749.77km^2 and Six talukas are coastal i.e. Lakhpat, Abdasa, Mandvi, Anjar, Gandhidham, Mundra and some part of Bhachau. For this study all these talukas are selected. Kachchh coast is one of the rare ecological zones in the world having rich biodiversity. It comprises mangroves, halophytes, mudflats, seaweeds, commercial fishes, and several rare marine species. The mangroves of Kachchh are the largest entity in the west coast of mainland India. A prominent feature of the Coast is the vast intertidal zone comprising network of creeks, estuaries and mudflats. The Kachchh coast provides conducive environment for several sea based traditional occupations like fishing, salt making, apart from land based occupations like agriculture, horticulture and animal husbandry. The role of mangroves and halophytes in coastal ecosystem is significant. Mangroves are critical to marine coastal soil conservation, breeding and nursery ground for fish, crustaceans and other sea life, as well as vital habitat for birds and other wildlife. The large tracts of mudflats are providing space for developing saltpans, Jetties and for industrial purposes.

Soil studies specific to coastal and near coastal region of Gujarat are limited. Looking to the lack of information on halophytes soil for Kachchh region, an attempt was made to understand the baseline status of soil across coastal talukas of Kachchh. The methodology adapted for the presented study is schematically represented below (Fig. 1).

2.1.1 Sample collection from coastal and near coastal region

Soil samples were collected from 20 km inland to coastline at 10 cm depth from 185 sampling areas falling under different habitats such as saltpan area, sand dunes and samples from Intertidal area dominated by mangroves. From near coast reserved forest, open scrub patch, agricultural hedge and *Prosopis juliflora* dominated area. GPS (Global Positioning System) coordinates were noted at the point of collection and GIS (Geographic Information System) map was prepared (Fig. 2). The soil samples collected between 1 to 5th sub plots from the transects of plant species on the same date of the material sampling were transported to the laboratory for further analysis.

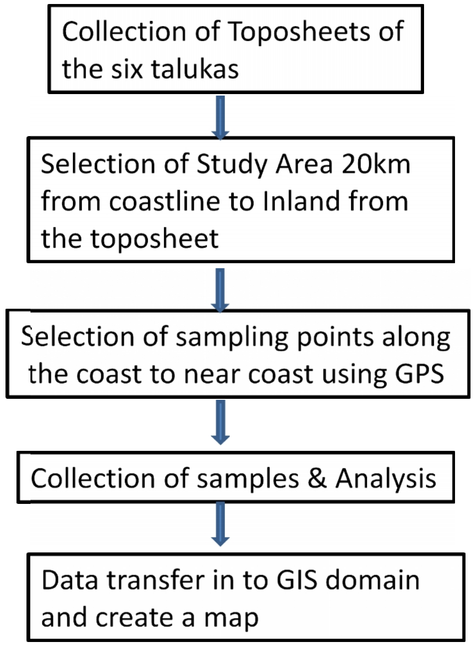

Fig. 1. Methodology of the study

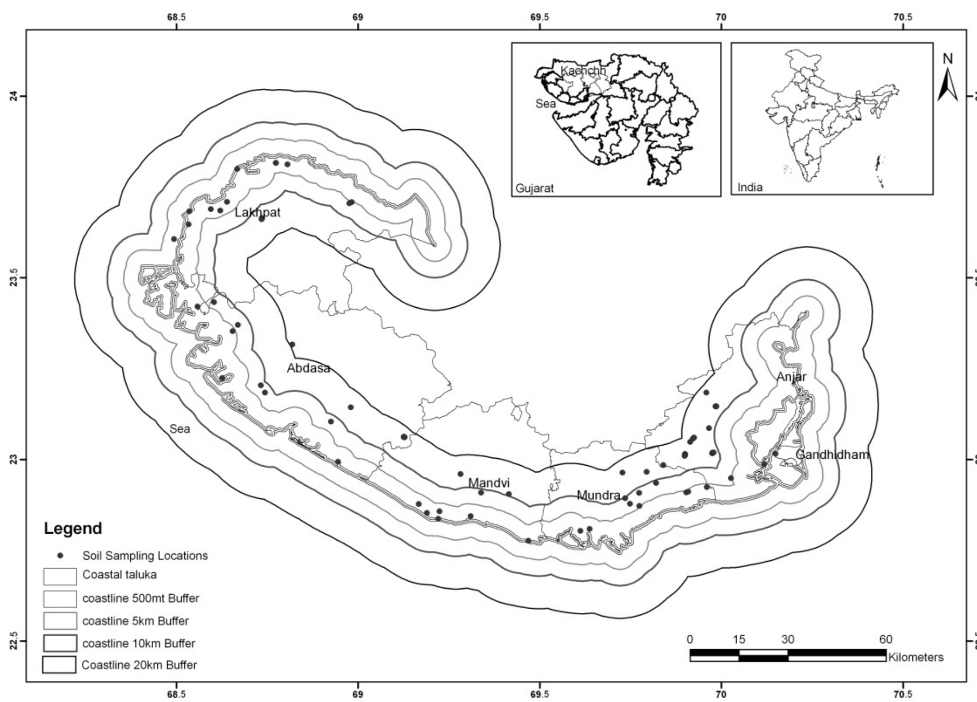

Fig. 2. Image showing the soil surveyed locations across study area from coastline to various distances

2.1.1.1 Preparation of Soil Sample and Analysis

In the laboratory, samples were air dried at 35ºC and then ground with pestle and mortar. Five samples (from one transect) were combined and thoroughly mixed by rolling procedure and passed through a 2mm sieve. The stored samples were analyzed as one sample. In total, 40 samples were analyzed for their physical and chemical characteristics. Soil texture was estimated by passing the soil samples through sieves with mesh size ranging from 0.05 to 2 mm and the sieved fractions such as sand, silt and clay were weighed using an electronic balance with four digit sensitivity. Estimation of chemical characteristics of soil, water soil extracts (1:5) were determined and analyzed for pH, and ECe (Sat. Ext. EC), using a conductivity meter (Cyber Scan PC 300). pH and ECe denote the degree of acidity and alkalinity and influences solubility of chemical substances, availability and uptake of nutrients, and growth and activity of soil microorganisms [12]. The concentrations of major mineral ions (Na^+, K+, Ca^{2+}, Mg^{2+},Cl^-, Li^- and So_4^-) in the water soil extracts were determined [13]. Sodium, potassium and Lithium in soil / sediment were estimated after filtering the water sediment suspension and the emission value was recorded in a Flame photometer. Calcium and Magnesium were determined by 0.05N EDTA method. Chloride in soil was estimated by filtering the soil water suspension and titrating it against a 0.05N silver nitrate solution. For sulphate, the sample was filtered and then adding Barium chloride and standard sulphate solution using gravimetric method [13].

Alkalinity was expressed in terms of Sodium Absorption Ratio (SAR) and Sodium percentage (Na%).

SAR [14, 15, 16]
$SAR= (Na^+) /\sqrt{1/2}\ (Ca^{2+}+Mg^{2+})$
Sodium percentage (Na%) [17,18]
$Na\% = (Na^+ + K^+)/(Ca^{2+}+Mg^{2+}+ Na^+ + K^+) x\ 100$

Potential salinity (PS) was defined as the chloride concentration plus half of the sulphate concentration.

$PS= Cl^- + So_4^{2-}/2$

Exchangeable sodium ratio (ESR) was used to characterize the sodicity of soils. ESR= (-0.0126+0.01475 SAR) [19].

Classification of salt affected soil adopted from Colorado State University analysis [20]. The laboratory obtained results for salinity were further brought under GIS domain of Arc GIS - 9.3 software. To minimize the time and labour, a stratified sampling approach of analyzed ground data could be incorporated.

The statistical analysis such as Mean, Standard deviation and Correlation coefficient (r) (two tails) was carried out using the SPSS software (ver. 17) to find out significant variations in parameters of coastal and near coastal areas soil.

3. RESULTS AND DISCUSSION

Survey of India (SoI) topomap was taken as a reference map of study area for identifying the locations. At all the sampling locations, the substratum was predominated by sand followed by silt and clay which were comparatively in smaller proportions. The results of soil texture at all the locations were Sandy Loam to Loamy Sand. The results indicate that the quality of soil significantly varies from location to location (Table 1).

Among all the sampling sites at twelve sites pH was slightly acidic in nature (6.29- 6.7) whereas at six location pH ranged between 6.7 to 7.3. At sixteen locations it was slightly alkaline (7.32 to 7.9) and at five locations it was moderately alkaline with a range of 7.90 - 8.5. Only at one location, it was strongly alkaline. The soil electrical conductivity ranged from 0.003 to 29 dS/m. The dominant soluble salts in saline soils mostly comprised of chlorides and sulphates of Na, Ca and K. At 24 locations >100mg/kg potassium ion were recorded. At 22 locations >250 mg/kg (0.5 ppt) chloride concentration were recorded. Comparatively, high chloride (up to 16310 mg/kg.) and potassium (up to 19960mg/kg.) were recorded from all the locations. Ion abundance followed the order Potassium >Chloride >Sodium > Sulphate > and Lithium at coastline. In near coastal areas ion abundance followed the order, Chloride >Sodium > Potassium >Lithium and > Sulphate. Soil pH has a direct effect on the availability of most of the nutrients and is important for proper nutrient management [21]. Soil pH has considerable impact in controlling the plant nutrients, particularly the availability of micronutrients such as Zn, Cu, Fe and Mn [22,23].In our study, at 22 locations soil pH was slightly to strongly alkaline (Table 1).

Sodium Absorption Ratio (SAR) was found higher (>13) at 17 locations and lower (<4) at only one location. High SAR values having the potential for deterioration in soil structure, low infiltration rate, specific-ion effect, and deficiencies of several nutrients such as K, Cu, Fe, Mn, and Zn [24]. In our study soil SAR considerably higher at seventeen locations (Table 1).

Percent sodium (Na%) ranged between 89.6 to 99.9%. Potential salinity (PS) was found higher (<15) at 11 locations but other areas PS ranged from 3.12 to 14.4 (Table 1). The results of SAR, Na% and PS clearly indicate that the soil of coastal Kachchh is dominated by sodium in proportion to calcium (Ca^{++}) and magnesium (Mg^{++}) and most of coastal belt are Sodic in nature within 5km from coastline except some part of Mandvi and Mundra taluka. In near coastal areas the soil is dominated by Sodium as well as chloride toxicity. However, there is no detailed study carried out till now to establish the presence of species and the range of salinity values governing their distribution [25]. Based on this findings, it could be concluded that in surface soil electric conductivity was higher up to 16 dS/m and SAR level was lower (<10) indicating the tolerance level for halophytes and their growth in coastal regions of arid Kachchh. Halophytic plants reaches up to the 1mt to 20mt depths [25]. However, there no detailed investigation was carried out at different depth of soils for halophytic plants especially in Gujarat.

3.1 Statistical Analysis

Two Tailed Pearson correlation results shows that SAR was significant among Sodium percentage (Na%) and Exchangeable Sodium Ratio (ESR) at 0.01 level and Percent Salinity (PS) at 0.05 levels. Sodium percentage (Na%) was correlate with SAR and ESR at 0.01 level. Percent Salinity (PS) was correlate SAR and ESR at 0.05 levels. ESR was correlate SAR and Na% at 0.01 levels and PS at 0.05 levels. No significant correlation was found in pH and EC values.

Table 1. Soil salinity parameters and their value of the various soil samples in the study area

Latitude	Longitude	Sampling Locations	pH	EC dS/m	SAR	Na%	PS(meq/l)	ESR	Soil class
23.015850	70.148850	Intertidal	7.33	6.070	792.464	99.958	127.267	11.676	Saline - sodic
22.986900	70.118516	Intertidal	7.23	4.350	4.463	93.205	89.568	0.053	Saline - sodic
22.871944	69.774444	Intertidal	6.39	2.810	28.935	98.922	8.075	0.414	Sodic
23.224083	68.625733	Intertidal	8.02	0.021	299.464	99.547	170.009	4.405	High pH and Sodic
22.852500	69.189350	Sand dune/Dhuvo	7.57	0.008	13.169	96.811	11.740	0.182	Sodic
22.775800	69.469000	Sand dune/Dhuvo	7.38	0.004	5.273	96.714	3.115	0.065	Non saline
23.606266	68.493616	Sand dune/Dhuvo	7.33	0.023	461.298	99.892	58.007	6.792	Sodic
23.683183	68.535116	Sand dune/Dhuvo	7.89	0.871	9.116	95.203	4.011	0.122	Non saline
22.836733	69.220866	Sand dune/Dhuvo	7.34	0.164	10.674	95.268	4.200	0.145	Non saline
22.803216	69.611833	Reserved Forest	6.69	0.007	25.407	98.980	4.009	0.362	Sodic
23.704950	68.976283	Reserved Forest	8.33	6.710	9.422	95.551	4.048	0.126	Saline - sodic
22.877633	69.748283	Reserved Forest	6.36	0.286	3.937	89.627	6.293	0.045	Non saline
22.877550	69.166666	Open scrub	7.11	2.600	2077.513	99.976	39.404	30.631	Sodic
22.843816	69.310233	Open scrub	7.55	0.005	6.266	97.783	6.146	0.080	Non saline
22.948533	70.026583	Open scrub	7.36	0.003	18.663	98.249	8.189	0.263	Sodic
23.816450	68.773916	Open scrub	6.6	0.022	6.455	93.114	6.002	0.083	Non saline
23.816450	68.773916	Open Scrub	6.58	0.239	124.128	97.939	459.993	1.818	Sodic
23.432850	68.603283	Open scrub	7.51	0.216	7.137	93.864	5.986	0.093	Non saline
22.908150	69.773800	Open scrub	6.27	0.230	4.041	92.414	5.199	0.047	Non saline
22.893350	69.735150	Open scrub	6.32	0.275	4.408	93.590	5.951	0.052	Non saline
22.935100	69.820216	Wasteland	6.52	0.273	8.144	95.564	7.941	0.108	Non saline
22.923888	69.960000	Wasteland	6.85	0.011	7.350	85.962	14.416	0.096	Non saline
23.104444	68.925277	Wasteland	8.35	0.012	20.674	98.273	5.182	0.292	High pH
68.944979	22.993398	Waterbody	7.27	0.013	30.055	98.959	6.962	0.431	Sodic
68.669310	23.370628	Waterbody	7.38	8.540	11.900	92.763	73.737	0.163	Saline
23.203816	68.732350	Waterbody	8.5	0.020	322.524	99.783	18.013	4.745	Sodic
23.684800	68.620733	Waterbody	7.39	14.270	16.359	94.953	8.009	0.229	Saline
23.709083	68.639333	Riverine	7.25	5.410	134.520	99.198	47.026	1.972	Saline
22.808433	69.637600	Riverine	7.39	2.420	12.106	97.689	28.957	0.166	Slightly saline

Table 1 Continued…..

23.812366	68.805516	Near Creek	7.47	0.018	9.292	92.083	13.014	0.124	Saline - sodic
23.647133	68.533600	Near Creek	8.79	2.200	1934.682	99.980	220.013	28.524	Sodic
23.689316	68.594550	Near Creek	6.83	0.025	97.638	96.759	104.025	1.428	Sodic
23.799616	68.667283	Near Creek	7.79	13.620	8.913	95.856	10.003	0.119	Saline
23.352766	68.654800	Near Creek	7.75	11.900	10.458	94.411	5.216	0.142	Saline
23.708250	68.982690	Agriculture hedge	7.53	0.015	20.443	97.790	3.614	0.289	Sodic
23.420700	68.558050	Agriculture hedge	7.12	29.000	6.180	92.741	5.776	0.079	Saline
22.857450	69.224383	Agriculture hedge	7.28	6.160	11.930	95.093	6.304	0.163	Saline
22.908816	69.338716	Agriculture hedge	6.29	0.245	5.892	92.625	5.017	0.074	Non saline
22.910900	69.908550	Agriculture hedge	6.60	0.401	33.180	98.592	8.810	0.477	Sodic
23.183933	68.743950	Grassland- Naliya	8.41	0.017	6.138	93.194	5.002	0.078	High pH

With the use of geographical information system (GIS), diagnostic procedures have been made easier, cheaper and for baseline identification. This technique is useful for large areas where it is not possible to carry out intensive field studies. The obtained results were further brought under GIS domain of Arc GIS - 9.3 software and a map was generated using Kriging technique (3D analyst). This procedure generated an estimated surface from a scattered set of points with Z values (Altitude of the obtained results).The distribution of salinity map was generated using Kriging technique based on analysed results of 185 soil samples of sand class. The distribution of salinity in all coastal talukas was created based on analyzed soil classification (Fig. 3). From the prediction map non saline area was observed in parts of Abdasa, Anjar, Mandvi and Mundra taluka (Fig. 3). The map shows that Lakhpat and Gandhidham talukas are fully dominated by high salinity and saline –sodic soil. Half of the Abdasa, Anjar and Mandvi talukas are covered by marginally saline to high pH class. It could be further gleaned that some parts of Mandvi and Mundra taluka at near coastal area are non saline to slightly saline because of the presence of sandy beaches and sand dunes.

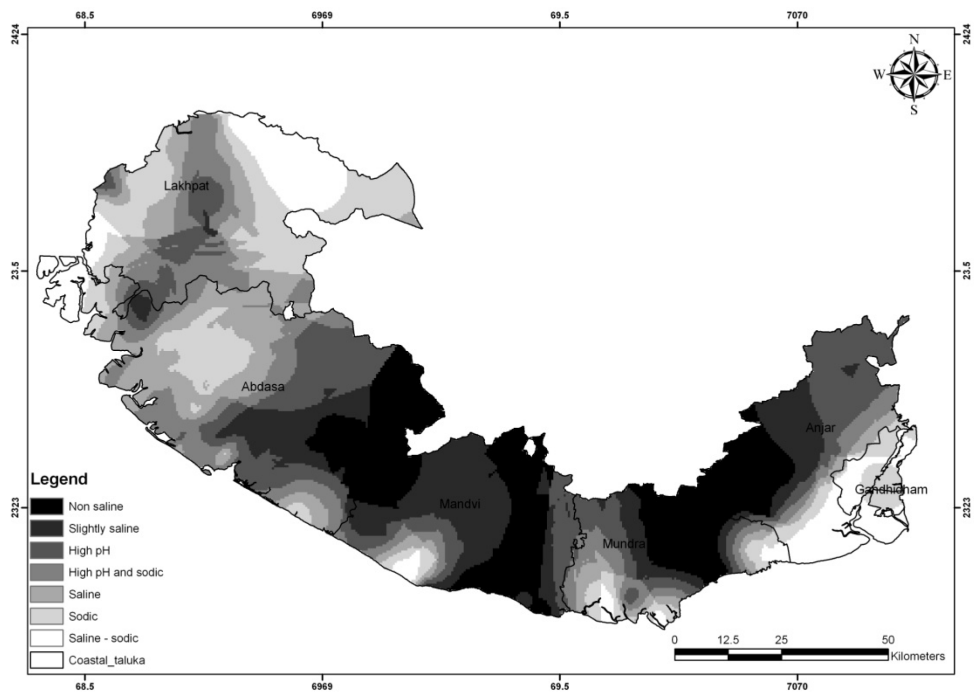

Fig. 3. Image showing the soil salinity classes in coastal Kachchh

Salinity always affects the society but the adverse effects could be better mitigated by proper knowledge and management. Sodium and chloride toxicity can be corrected by leaching excess of chloride, for Na^+ is the most toxic to agriculture crops. However, appropriate management could stop the deterioration in physical and chemical properties of soil and crop yield [24]. At first complete reclamation of soil before planting is recommended for crop and for better yield. Reclamation of saline-sodic soil could best be affected by leaching and reducing the level of exchangeable sodium by adding gypsum and removing the excess salts. The primary objective of this article is to gain an overview of sodic-saline nature of coastal soil. This knowledge along with the distribution of halophytes in these regions could be used to promote cultivation of varieties of wild halophytes such as *Prosopis juliflora*

(Gando baval), *Salvadora persica* (Piludi), *Acacia senegal* (Gorad), *Acacia nilotica* (Deshi Baval) and *Phoenix dactylifera* (Khajur), *Avicennia marina* (Cheriya) and *Commiphora wightii* (Gugal), halophytic shrub *Suaeda fruticosa* (Morad), *Calotropis procera* (Ankado), herb *Cressa cretica* (Lano), *Enicostemma axillare* (Mamejo),*Tribulus terrestris* (Gokhru) stands. These salt tolerant grasses and herbaceous crops such as Groundnut, Guar, Sorghum, Soybean, Sugarcane, Wheat, Maize and other halophytes could serve as a source of vegetable, fodder, oilseed crop, medicinal crop and so many purposes for the community needs.

4. CONCLUSION

This investigation attempts to gain a basic understanding of chemical composition of coastal and near coastal soil of Kachchh district. It also demonstrates how application of geographic information system in the surveyed locations could be used to predict the areas of highest and lowest salinity in a given the study area. The diagnosing results of coastal and near coastal Kachchh soil are available through this study such as high pH, saline, saline- sodic, sodic and non saline. Soil diagnosis with laboratory techniques has been a time consuming and laborious exercise. The attempt also demonstrates that these diagnostic techniques could be a better option for studying soil nature of large areas. With increasing awareness in the field of soil quality, it is expected that the approach described in this work will be an useful tool in evaluating the quality of soil to be utilized for various beneficial uses. The results of this study indicate that at surface of soil, the soluble salts NaCl and Na_2SO_4 are predominate. If the soil of coastal Kachchh can be used for growing varieties of salt tolerant plants than it is extremely productive and fulfills the demand of societies such as forage, fodder, fuel and medicinal purposes.

CONSENT

Not applicable.

ETHICAL APPROVAL

Not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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