EVALUATION OF SOIL FERTILITY, SALINITY STATUS AND PRE & POST MONSOON UNDERGROUND WATER QUALITY OF NORTHERN SAURASHTRA COASTAL REGION OF GUJARAT

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IN

SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

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|| कृषिमूलम् जगत् सर्वम् ||

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KIRAN YADAV	**Dr. K. B. PARMAR**

"EVALUATION OF SOIL FERTILITY, SALINITY STATUS AND PRE & POST MONSOON UNDERGROUND WATER QUALITY OF NORTHERN SAURASHTRA COASTAL REGION OF GUJARAT"

ABSTRACT

Key words: *Organic carbon, Nitrogen, Phosphorus, Potassium, Saurashtra, Coastal, Salinity, Irrigation water*

An attempt has been made in the present investigation to study the quality of underground wells/tube wells water and their effect on soil properties of Northern Saurashtra coastal region (Jamnagar, Devbhumi Dwarka and Porbandar district) of Gujarat by collecting 141 surface soil samples from the farmer's cultivated field during May, 2019. In order, to study the fluctuation in quality of water, only water samples were collected twice i.e. before monsoon (May, 2019) and after monsoon (December, 2019).

On the basis of analyzed data of soil samples, collected from different districts of Northern Saurashtra coastal region of Gujarat, it can be concluded that all the soil fertility parameters viz., SOC, available N, P_2O_5, K_2O, S, Fe, Mn, Cu and Zn content were increased with increasing the sampling distance (0-5, 5-10, 10-15, 15-20 km) from coastal line except B. In salinity parameters, EC, ESP, SSP and SAR were decreased, while pH was slightly increased with increasing the distance from sea coast.

The soils were low with respect to available N (204.70 kg ha^{-1}), but medium in available P_2O_5 (28.95 kg ha^{-1}) and S (20.00 mg kg^{-1}), whereas high in K_2O (401.82 kg ha^{-1}) status. The overall available (DTPA extractable) Fe, Mn, Cu and Zn varied between 2.92 to 8.92, 1.32 to 18.80, 0.13 to 7.31 and 0.06 to 3.58 with their

corresponding mean values of 5.44, 7.45, 1.01 and 0.46 mg kg^{-1}, respectively. The available B was found high and it was ranged from 0.78 to 6.61 with the mean value of 3.49 mg kg^{-1}.

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). The overall mean value of CEC of the soils was 36.99 cmol (p^+) kg^{-1}.

The result of quality of underground wells/tube wells water in pre & post monsoon of Northern Saurashtra coastal region indicated that values of EC, SSP, SAR & RSC were decreased with increasing the sampling distance (0-5, 5-10, 10-15, 15-20 km) from coastal line but reverse trend was noted in case of pH. The quality of underground wells/tube wells water before monsoon (May, 2019) revealed that almost all the samples of irrigation water were found saline (EC 0.75 dS m^{-1} and above). The EC values were ranged from 0.25 to 7.35 with a mean value of 2.22 dS m^{-1}. The water was slightly alkaline in reaction (pH 7.21) with value ranged from 6.45 to 8.47. The SAR values were ranged from 0.95 to 15.91 with a mean value of 5.08 and overall 92.98, 7.02, 0.00 and 0.00 per cent sample falls under S_1, S_2, S_3 and S_4 classes of SAR, respectively. The overall RSC values were ranged from 0.00 to 9.40 with mean value of 0.33 me L^{-1} and overall 89.82, 5.26 and 4.91 per cent sample falls under safe, marginal and unsafe classes of RSC, respectively. The overall mean value of SSP was found 50.63, which were varied from 20.27 to 82.56 and overall 74.74 and 25.26 per cent sample falls under safe and unsafe classes of SSP, respectively. After monsoon (December, 2019), almost all the samples of irrigation water were found saline (EC 0.75 dS m^{-1} and above). The EC values were ranged between 0.18 to 6.83 with mean value of 2.01 dS m^{-1}. The water was alkaline in reaction (pH 7.73) with range of 7.00 to 8.90. The SAR values were ranged from 0.47 to 13.05 with a mean value of 4.06 and overall 96.14, 3.86, 0.00 and 0.00 per cent sample falls under S_1, S_2, S_3 and S_4 classes of SAR, respectively. The overall RSC values ranged from 0.00 to 4.80 with a mean value of 0.19 me L^{-1} and overall 92.28, 5.26 and 2.46 per cent sample falls under safe, marginal and unsafe classes of RSC, respectively. The overall mean value of SSP was 44.72, which varied between 14.08 to 78.00 and overall 85.61 and 14.39 per cent sample falls under safe and unsafe class, respectively. All the soil samples were analyzed for EC and pH from saturated and dilute (1:2.5) extract and found that the overall highly significant correlation of EC_e with $EC_{2.5}$ (r = 0.8012**) and pH_s with $pH_{2.5}$ (r = 0.4004**) were observed. The highly significant correlation coefficient between SOC and N (r = 0.7798^{**}), ESP and EC_e (r = 0.6531^{**}), ESP and $EC_{2.5}$ (r = 0.6050^{**}) were observed in soil samples.

The correlation among fertility parameters (SOC, available N, P_2O_5, K_2O and S) and salinity/sodicity parameters ($EC_{2.5}$, EC_e, $pH_{2.5}$, pH_s and $CaCO_3$) in soils of 0 to 20 km distance from sea coast indicates that $EC_{2.5}$ was significant and positively correlated with EC_e, SSP, SAR, ESP and $CaCO_3$ and $pH_{2.5}$ was significant and positively correlated with $pH_{s,}$ SOC, available N, K_2O and S.

The correlation between different properties of pre-monsoon irrigation water (EC_{iw}, pH_{iw}, RSC_{iw}, SSP_{iw} and SAR_{iw}) and properties of irrigated soils ($EC_{2.5}$, EC_e, $pH_{2.5}$, pH_s, SAR_s, SSP_s, and ESP_s) of 0 to 20 km distance from sea coast indicates that EC_{iw} was observed significant and positively correlated with SAR_{iw}, EC_e, $EC_{2.5}$, ESP_s, SSP_s and SAR_s and pH_{iw} was significant and positively correlated with RSC_{iw}, pH_s and $pH_{2.5}$. The correlation between different properties of post-monsoon irrigation water (EC_{iw}, pH_{iw}, RSC_{iw}, SSP_{iw} and SAR_{iw}) and properties of irrigated soils ($EC_{2.5}$, EC_e, $pH_{2.5}$, pH_s, SAR_s, SSP_s, and ESP_s) of 0 to 20 km distance from sea coast indicates that EC_{iw} was observed significant and positively correlated with SAR_{iw}, EC_e, $EC_{2.5}$, ESP_s, SSP_s and SAR_s and pH_{iw} was significant and positively correlated with RSC_{iw}, pH_s and $pH_{2.5}$.

Thus, major constraints related to soil fertility (SOC, N, P_2O_5, S & Zn), soil salinity (EC, ESP & SSP) of Northern Saurashtra coastal region are associated with poor quality of wells/tube wells water and soil fertility/salinity parameters were found critical upto the 5 km distance away from sea coast. Overall, soils of Northern Saurashtra coastal region were low in N & Zn, medium in SOC, P_2O_5, S, Fe, Mn and high in K_2O & Cu. In case of water quality, almost all well/ tube well water samples (Pre & Post monsoon) of Northern Saurashtra coastal region having higher amount of soluble salts (2.22 & 2.01 dS m^{-1}) mainly due to dominance of Na and Cl ions, however, all the quality parameters *viz.*, EC, pH, SSP, RSC and ESP of collected well/tube well water samples after monsoon were improved as compared to the samples collected before monsoon.

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C E R T I F I C A T E – I

This is to certify that the thesis entitled **"EVALUATION OF SOIL FERTILITY, SALINITY STATUS AND PRE & POST MONSOON UNDERGROUND WATER QUALITY OF NORTHERN SAURASHTRA COASTAL REGION OF GUJARAT''** submitted by **Miss. KIRAN YADAV** inpartial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy (Agriculture)** in the subject of **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** to the Junagadh Agricultural University is a record of bonafide research work carried out by her under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree or other similar title. The candidate had fulfilled all prescribe requirements. The assistance and help received during the course of investigation have been fully acknowledged. She has successfully completed the comprehensive/preliminary examination held on **MARCH 20th, 2021** as required under the regulation for post-graduate studies. She has submitted *kachcha* bound thesis on **AUGUST 17th, 2021.**

Place: Junagadh
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Date: 07/10/2021

This is to certify that the thesis entitled **"EVALUATION OF SOIL FERTILITY, SALINITY STATUS AND PRE & POST MONSOON UNDERGROUND WATER QUALITY OF NORTHERN SAURASHTRA COASTAL REGION OF GUJARAT"** submitted by **Miss. KIRAN YADAV (Registration No. 1010118017)** to Junagadh Agricultural University, Junagadh in partial fulfillment of the requirements for award of the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in the subject of **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** after recommendation by the external examiners were defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination was satisfactory. We, therefore, forward with recommendation.

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To,
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Sub: Submission of *Kaccha* Bound Thesis
Through: Professor and Head, Department of Agril. Chemistry and Soil Science, CoA, JAU, Junagadh

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I am submitting two copies of my *Kaccha* bound thesis entitled **"Evaluation of Soil Fertility, Salinity Status and Pre & Post Monsoon Underground Water Quality of Northern Saurashtra Coastal Region of Gujarat"** to my Major Guide **Dr. K. B. Parmar,** Associate research scientist (Directorate of research), JAU, Junagadh, on the date: **/08/2021** after completion of all the course work, preliminary examination and research work.

Signature of Student:
(Kiran Yadav)

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No. JAU/ Soil/Tech-3/PG/Thesis/ / /21
Date: /08/2021

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(1) The Rector, College of Agriculture, JAU, Junagadh for information and necessary action.

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"We are what our thoughts have made us. So take care about what you think.

Words are secondary. Thoughts live, they travel far."

- Swami Vivekananda

Yes! Words are the only available means of expressing emotions in such a formal acknowledgment as the breathless words cannot carry the fragrance of emotions with them.

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Place: *Junagadh*

Date: *17/08/2021* *(Kiran Yadav)*

CONTENTS

LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviations	**Meanings**
%	Per cent
^0C	Degree Celsius
^0E	Degree East
^0N	Degree North
>	Greater than
<	Lower than
AAS	Atomic Absorption Spectrophotometer
Anon	Anonymous
B	Boron
Ca	Calcium
CEC	Cation exchange capacity
cm	Centimeter
cmol (p^+) kg^{-1}	Centimol positive ion per kilogram
Cu	Copper
DAP	Di-ammonium phosphate
dS m^{-1}	DeciSeimens per meter
DTPA	Diethylene Triamine Penta Acetic Acid
EC	Electrical conductivity
EC_e	Electrical conductivity of saturation extract
$EC_{2.5}$	Electrical conductivity of 1:2.5 soil:water extract
Ex.	Exchangeable
et al.	Et allii, and others
etc.	*et cetera*
FAO	Food and Agriculture Oraganization
Fe	Iron
g	Gram
Ha	Hectare
i.e	That is
K_2O	Potassium oxide
kg	Kilogram
Km	Kilometer(s)

Max.	Maximum
Mg	Magnesium
mg kg^{-1}	Milligram per kilogram
Min.	Minimum
Mn	Manganese
N	Nitrogen
No.	Number
NS	Non-significant
OC	Organic Carbon
P	Phosphorus
pH_s	pH of saturation extract
$pH_{2.5}$	pH of 1:2.5 soil:water extract
P_2O_5	Phosphorus oxide
ppm	parts per million
R	Regression Coefficient
R.H.	Relative humidity
RSC	Residual Sodium Carbonate
SAR	Sodium Adsorption Ratio
SSP	Soluble Sodium Percentage
S	Sulphur
S. Em.	Standard Error of means
Sig.	Significant
Viz.	Namely
Zn	Zinc

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CHAPTER – II

REVIEW OF LITERATURE

Monitoring of the natural resources is a prime responsibility of every society. Least attention has been paid to this aspect in the developing countries. Particularly the interior regions are least attended. Our target is also one of them. Sporadic efforts have been made to study the soil and water resources of the Northern Saurashtra coastal region of Gujarat. The present study includes different aspects of monitoring soil and water resources. An attempt has been made to review the available literature on the related aspects and presented in this chapter under the following headings:

2.1 CHEMICAL PROPERTIES AND SALINITY/SODICITY STATUS OF THE SOILS

2.2 FERTILITY STATUS OF THE SURFACE SOIL

2.2.1 AVAILABLE MACRONUTRIENT

2.2.2 AVAILABLE MICRONUTRIENT

2.2.3 NUTRIENT INDEX

2.3 QUALITY OF UNDERGROUND IRRIGATION WATER

2.4 PERIODICAL CHANGES IN WATER QUALITY

2.5 INTER-RELATIONSHIP AMONG AND BETWEEN SALINITY/SODICITY INDICES AND FERTILITY STATUS OF IRRIGATED SOILS

2.6 INTER-RELATIONSHIP BETWEEN PROPERTIES OF IRRIGATION WATER AND IRRIGATED SOILS

2.1 CHEMICAL PROPERTIES AND SALINITY/SODICITY STATUS OF THE SOILS

Saline-sodic soils are characterized by the accumulation of salts in the soil solution and adsorption of sodium on exchange complex beyond an arbitrary limit adversely affecting plant growth. Saline soils may be developed due to (I) Continues use of saline irrigation water (II) High salt content in the profile (III) Saline ground water and high water table condition (IV) Occurrence of salt layer in the soil crust and rise in water table (V) Weathering of rock minerals (VI) Seepage from canal and adjacent irrigated areas (VII) Restricted surface and sub-surface drainage and (VIII) Ingress of seawater (Bhumbla and Abrol, 1979).

Kabaria and Polara (2006) collected twenty surface (0-15 cm) soil samples from each of the eleven talukas of coastal Amreli district from the cultivated soils and were analyzed for different chemical properties. The results revealed that Na^{+} and Cl^{-} were dominant among the water soluble ions, whereas Ca^{++} and Mg^{++} were dominant among the exchangeable cations. More than half (61.4 %) of the cultivated soils of coastal Amreli district were normal in nature, followed by saline (13.6 %), saline-sodic (12.7 %) and sodic (12.3 %).

Guruprasad *et al.* (2007) an extensive survey was carried out to characterize some of the salt affected soils under Kabini tract of Cauvery command area, southern dry zone of Karnataka. The pHs of soils were ranged from 7.41 to 8.94, ECe from 0.48 to 1.31 dS m^{-1} , SAR from 4.25 to 18.40, CEC from 14.7 to 39.12 cmol (p+) kg^{-1} and ESP from 11.11 to 39.58 per cent.

Marsonia *et al.* (2008) revealed the seventy three surfaces (0-15 cm) soil samples from the three taluka viz., Kutiyana, Ranavav and Porbandar of Porbandar district were collected from cultivated field and were analyzed for different chemical properties. The results revealed that Na^{+} and Cl^{-} were dominant among the water soluble ions, whereas, Ca^{++} and Mg^{++} were dominant among the exchangeable cations. Nearly half (48.0%) of the cultivated coastal soils of Porbandar district were found normal in nature, followed by sodic (20.5%), saline (16.4%) and saline-sodic (15.1%).

Ashok kumar and Jagdish (2010) characterized the sugarcane growing soils of Ahmadnagar district of Maharashtra. They revealed that the soils were moderately to strongly alkaline in reaction and CEC varied from 21.6 to 67.7 cmol (p+) kg^{-1}. Calcium and magnasium were found to be dominant cations on the exchange complex.

Pujar *et al.* (2010) studied surface soils (0-20 cm) of sugarcane growing area of five talukas from Bijapur district and reported that soil pH varied from 5.2 to 8.8 and the electrical conductivity (EC) varied from 0.08 to 2.38 mmhos cm^{-1}. They also reported that organic carbon content of soils ranged from 0.29 to 1.24 per cent.

Sojitra (2010) collected 280 soil samples from the Junagadh district and observed that the pHs, ECe, organic carbon, $CaCO_3$ and CEC of soils varied from 7.20 to 9.01, 0.21 to 2.61 dS m^{-1} , 1.50 to 10.67 g kg^{-1} , 8.06 to 104.6 g kg^{-1} and 18.06 to 57.94 cmol (p+) kg^{-1} with a mean values of 8.11, 1.01 dS m^{-1}, 5.32 g kg^{-1}, 42.94 g kg^{-1} and 41.75 cmol (p+) kg^{-1}, respectively.

Bhanwaria *et al.* (2011) determine physico-chemical properties in Mokala soil Series of Rajasthan and revealed that soil pH, EC and OC ranged from pH 7.9 to 8.9, 0.09 to 1.76 dS m^{-1} and 0.7 to 2.4 g kg^{-1} with mean values of 8.42, 0.78 dS m^{-1} and 1.4 g kg^{-1}, respectively.

Kumar and Babel (2011) collected seventy surface soil samples (0-30 cm depth) from Jhunjhunu district of Rajasthan and they reported that the soils pH, EC and OC varied from 8.10 to 9.20, 0.20 to 2.14 dS m^{-1} and 0.06 to 0.43 per cent with the mean values of 8.52, 1.05 dS m^{-1} and 0.21 per cent, respectively.

The survey work was carried out by Srinivas *et al.* (2011) to know the physico-chemical properties of soils of krishna western delta of Andhra Pradesh. The majority of the soils have neutral in pH (pH ranged from 7.02 to 7.75) and normal electrical conductivity. The SAR value ranged from 3.96 to 45.26 with an average of 12.70. The ESP varied from 10.00 to 14.24. CEC of soils ranged from 1.65 to 47.4 with an average of 34.5 cmol (p+) kg^{-1}.

Rajput and Polara (2012) collected 220 surface soil sample (0-20cm) from eleven talukas of Bhavnagar district during 2009 for monitoring the chemical properties of the soils and reported that the ECe of these soils ranged from 1.09 to 17.8 dS m^{-1} with an average value of 6.89 dS m^{-1} . The pHs of these soils ranged from 7.3 to 8.9 with an average value of 7.86 and the $CaCO_3$ content in these soils varied from 8.06 to 199.9 g kg^{-1} with an average value of 49.2 g kg^{-1}, respectively.

Shirgire (2012) reported that the pH, EC, organic carbon, $CaCO_3$ and CEC of soils varied from 7.66 to 9.01, 0.26 to 3.06 dS m^{-1}, 0.30 to 10.20 g kg^{-1}, 4.18 to 115.6 g kg^{-1} and 15.8 to 56.8 cmol (p+) kg^{-1} with a mean values of 8.18, 0.86 dS m^{-1}, 4.97 g kg^{-1}, 54.9 g kg^{-1} and 36.5 cmol (p+) kg^{-1}, respectively.

Singh and Kumar (2012) collected 110 surface soil samples from vegetable growing area of Varanasi district and found that the EC of these soils varied from 0.50 to 0.90 dS m^{-1}, pH were ranged from 7.8 to 8.4 and organic carbon varied from 3.12 to 9.3 g kg^{-1} with the mean value of 0.6 dS m^{-1}, 7.9 and 7.3 g kg^{-1}, respectively.

Athokpam *et al.* (2013) collected 200 soil samples (0-30 cm) from Senapati district of Manipur and reported that pH of the soils ranged from 5.08 to 6.97 (slightly acidic to neutral) with mean of 5.93, EC ranged from 0.02 to 0.22 dS m^{-1} with mean of 0.07 dS m^{-1} and organic carbon ranged from 6.0 to 25.2 g kg^{-1} with average of 14.74 g kg^{-1}.

Devdas and Srivastava (2013) determine the status of physico-chemical properties in black soil of Navagarh block under Janjgir district of Chhattisgarh and reported that pH, EC and OC ranged from 5.8 to 8.0, 0.04 to 0.98 dS m^{-1} and 0.29 to 0.88 per cent with a mean values 6.24, 0.25 dS m^{-1} and 0.58 per cent, respectively.

Doneriya *et al.* (2013) collected 50 soil samples (0-15 cm) from Marihan block of Mirzapur district in Uttar Pradesh and they observed that the pH, EC and OC of soils varied from 5.5 to 7.6, 0.022 to 0.093 dS m^{-1} and 0.22 to 0.66 per cent with the mean value of 6.53, 0.065 dS m^{-1} and 0.46 per cent, respectively.

Gajare *et al.* (2013) collected 140 soil samples from the Latur district during 2009-10 for monitoring the chemical properties of the soils and observed the EC of soils varied from 0.12 to 1.96 dS m^{-1} with an average value of 0.31 dS m^{-1}. The soils were neutral to alkaline in reaction and pH varied from 6.39 to 8.89 with an average value of 7.98. The organic carbon varied from 0.15 to 1.03 per cent with an average value of 0.56 per cent and $CaCO_3$ varied from 0.66 to 14.26 per cent with an average value of 4.25 per cent.

Gandhi (2013) revealed that the pH, EC, organic carbon and $CaCO_3$ ranged from 7.13 to 8.15, 0.28 to 4.69 dS m^{-1}, 0.46 to 1.01 per cent and 2.30 to 78.78 per cent with the overall mean value of 7.70, 1.91 dS m^{-1}, 0.50 per cent and 27.67 per cent, respectively which indicate the soils of Girnar toposequence were slightly alkaline in reaction, low in organic carbon content and highly calcareous in nature. The CEC, BSP and ESP ranged from 18.11 to 68.44 cmol (p+) kg^{-1}, 90.06 to 97.14 and 0.33 to 31.40 with overall mean value of 34.89 cmol (p+) kg^{-1}, 93.38 and 8.27, respectively which were increased with increasing of elevation. The order of dominance of exchangeable base was Ca^{++}> Mg^{++} > Na^{+}> K^{+}.

Nandy *et al.* (2013) studied the chemical properties of coastal soils (sandy and inland black soils) in the Pedapuluguvaripalem village of Guntur district, Andhra Pradesh. Results revealed that the soil was neutral to strongly alkaline in nature, overall pH ranged from 7.0 to 9.8, low in organic carbon ranged from 1.5 to 4.2 g kg^{-}

^{1}, overall CEC ranged from 3.86 to 38.64 cmol (p+) kg^{-1} and ESP ranged from 5.90 to 24.99, respectively.

Sudharani *et al.* (2013) collected 69 soil samples (0-15 cm) from rice growing soils of Visakhapatnam district in Andhra Pradesh and revealed that the pH, EC and OC of soils were ranged from 5.0 to 8.7, 0.03 to 0.9 dS m^{-1} and 1.0 to 8.9 per cent with mean value of 6.8, 0.26 dS m^{-1} and 4.27 per cent, respectively.

Srinivasan and Poongothai (2013) collected 30 soil samples (0-20 cm) from 30 revenue villages of Tittakudi taluka of Tamil Nadu and reported that the soils pH and EC ranged from 6.9 to 8.3 and 0.12 to 2.3 dS m^{-1} with a mean value of 7.6 and 1.21 dS m^{-1}, respectively.

Verma *et al.* (2013) observed that characterized the Inceptisols of 110 villages of Malkharauda block, Janjgir Champa district of Chhattisgarh during 2011-12. The results revealed that the soils having $EC_{2.5}$ varied from 0.05 to 0.75 dS m^{-1} with a mean value of 0.20 dS m^{-1}, the soils were acidic to alkaline in reaction and pH ranged from 4.7 to 7.1 with an average value of 6.0 and organic carbon ranged from 1.1 to 7.8 g kg^{-1} with a mean value of 4.9 g kg^{-1}.

Singh *et al.* (2014) studied the physico-chemical properties in medium black soils of Chambal region of Madhya Pradesh and reported that the soils pH, EC and OC ranged from 7.0 to 8.4, 0.31 to 1.19 dS m^{-1} and 0.26 to 0.92 per cent with a mean value of 7.83, 0.58 dS m^{-1} and 0.46 per cent, respectively.

Sixty surface soil samples were collected from saffron growing soils of Kishtwar district of Jammu and Kashmir for determining the chemical properties of the soils by Tundup and Akbar (2014). They observed that the EC of soils were ranged from 0.15 to 0.23 dS m^{-1} with a mean value of 0.18 dS m^{-1}, the pH of these soils ranged from 6.65 to 7.64 with a mean value of 7.37 and organic carbon ranged from 0.58 to 0.81 with a mean value of 0.68 per cent.

Tsanglao *et al.* (2014) studied the fertility status and soil acidity under different land use systems in Wokha district of Nagaland. The pH of soils under cultivated and forest land use systems varied from 4.46 to 4.85 and 4.53 to 5.10 with an average of 4.65 and 4.77, respectively, indicating that soils are acidic in reaction. OC of the soils under cultivated and forest land use systems ranged from 9.7 to 19.4 and 15.6 to 23.7 g kg^{-1} with an average of 15.4 and 20.0 g kg^{-1}, respectively.

Arunkumar and Paramasivan (2015) studied the fertility status of the soils of Orathur village of Veeranam command area of Cuddalore district in Tamilnadu and revealed that the pH, EC and OC of soils varied from 6.70 to 8.30, 0.20 to 1.20 dS m^{-1} and 0.49 to 0.88 per cent with the mean value of 7.86, 0.50 dS m^{-1} and 0.68 per cent, respectively.

Chauhan and Polara (2015a) collected thirty surface (0-15 cm) soil samples from each of the eleven talukas of Gir Somnath district. The ECe, pHs and ESP values were ranged from 1.80 to 9.60, 7.0 to 8.98 and 6.53 to 23.56 with mean value of 4.08, 8.17 and 12.80, respectively and near to half (46.1 %) of the cultivated soils of Gir Somnath district were normal in nature, followed by saline (25.0 %), saline-sodic (13.9 %) and sodic (15.0 %).

Rajput *et al.* (2015) collected 150 composite surface soil samples (0-15 cm) from irrigated and non-irrigated mustard growing fields covering 30 villages of northern Madhya Pradesh. They reported that overall soil pH, EC and OC varied from 7.0 to 8.2, 0.10 to 0.97 dS m^{-1} and 1.12 to 8.1 g kg^{-1} with mean values of 7.57, 0.23 dS m^{-1} and 4.08 g kg^{-1}, respectively.

Hadiyal *et al.* (2016) studied 250 soil samples (0-15 cm) from Girgadhda and Una talukas of Gir Somanth district in Gujarat and revealed that the OC of soils varied from 0.12 to 1.11 per cent with the mean value of 0.61 per cent. Soils were medium in organic carbon.

Karajanagi *et al.* (2016) collected 75 soil samples from Dundur village under Malaprabha command area in Karnataka and reported that soil pH, EC and OC varied from 7.9 to 9.1, 0.13 to 0.41 dS m^{-1} and 4.02 to 7.43 g kg^{-1} with mean values of 8.4, 0.24 dS m^{-1} and 5.02 g kg^{-1}, respectively.

Mustafa *et al.* (2016) reported that six pedons of the Kheragarah tehsil of Agra district were slightly to strongly alkaline pH (7.98 - 9.43), slightly to highly saline EC (1.81- 7.23 dS m^{-1}), low in organic carbon (1.1–2.7 g kg^{-1}), CEC medium to high [19.7 - 24.4 cmol (p+) kg^{-1}]. The calcium carbonate content ranged from nil to 14.3%.

Nagaral *et al.* (2016) collected 57 soil samples (0-15 cm) from chilli growing area of northern transitional zone of Haveri, Gadag and Dharwad districts of Karnataka and observed that the pH varied from 6.12 to 9.52 (average 8.15), having 8 per cent samples were acidic, 22 per cent neutral and 70per cent samples alkaline, while EC of soils varied from 0.09 to 1.43 dS m^{-1} (average 0.37 dS m^{-1}) and OC content of soils varied from 3.20 to 9.0 g kg^{-1} (average 4.78 g kg^{-1}) having 61 per cent samples were low, 31 per cent medium and 8 per cent high.

Patel *et al.* (2016) analyzed soil of Patan district of Gujarat and reported that the pH, EC and OC of soils varied from 7.10 to 9.30, 0.10 to 9.23 dS m^{-1} and 0.039 to 2.388 per cent with mean values of 7.96, 1.139 dS m^{-1} and 0.36 per cent, respectively. Reddy and Naidu (2016) studied physico-chemical properties in semi-arid region of Chennurmandal of Kapada district in Andhra Pradesh and reported that pH, EC and OC varied from 7.4 to 8.5, 0.13 to 0.77 dS m^{-1} and 1.6 to 8.8 g kg^{-1}, respectively.

Shinde *et al.* (2016) conducted a study during the year 2015-2016 at Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dhule with an aim to know the fertility status of soils of Agriculture College Farm, Nandurbar. The soils were collected and analyzed as per standard procedure for assessing chemical properties and available nutrient status. The pH of soil varied from 6.80 to 7.90, while, EC varied from 0.08 to 0.89 dS m^{-1}, the organic carbon content in soil were varied from 3.7 to 9.9 g kg^{-1}.

Wagh *et al.* (2016) carried out an investigation in sunflower growing soils of Nagpur district of Maharashtra and they reported that soil pH, EC and OC ranged from 7.93 to 8.64, 0.19 to 0.67 dS m^{-1} and 0.24 to 0.79 per cent with mean values of 8.39, 0.28 dS m^{-1} and 0.51 per cent, respectively.

Hadiya and Polara (2017) collected 120 surface soil samples from cultivated farmer’s fields of the Devbhumi Dwarka district and found that the soils were medium (5.1 g kg^{-1}) in organic carbon and calcareous in nature ($CaCO_3$ 167 g kg^{-1}) with alkaline in reaction (pH 7.98). The CEC value of the soils was 30.58 cmol (p+) kg^{-1}. The results further indicated the dominance of Ca^{++} (17.04 cmol (p+) kg^{-1} and Mg^{++} 11.88 cmol (p+) kg^{-1}) among the exchangeable cations. About 18.3, 2.5, 2.5 and 76.7 per cent soil samples were found saline, saline-sodic, sodic and normal, respectively.

Bhaskar *et al.* (2017) studied on electromagnetic induction methods of salinity assessment in the soils of Rohtak, Haryana. Soil samples were collected from 8 sampling location points in field at 15 cm depth increment up to 90 cm depth for calibrating EM-38 observations. Sodium (Na^+) and chloride (Cl^-) ions were strongly correlated with apparent conductivity (EMV and EMH) measured by EM-38 as well as soil salinity (ECe). Therefore, Na^+ and Cl ions were mainly responsible for observed salinity in the field. Quantitative evaluation of soil salinity for 0-90 cm profile indicated that more than 91% area of the field had salinity levels (ECe) above 4 dS m^{-1}.

Parhad *et al.* (2018) reported the pH of the soils of Sindkheda ranged from 6.62 to 8.84 and the mean was 7.79. Among the soil samples tested, 04 (1.99%) were slightly acidic, 127 (66.19%) were slightly alkaline and 70 (34.82%) soil samples were moderately alkaline. The highest soil pH (8.84) was observed in soil sample taken at Sukavad (21017.064|N – 074048.839|E) and lowest soil pH (6.62) was observed at Sonshelu village (21011.524|N– 074039.012|E). The similar natures of observation for soil pH were also recorded by Jibhakate *et al.* (2009) in soils of Katol tehsil of Nagpur District. Soils are in general, alkaline in nature, it might be due to medium deep black soils brought under irrigation since long have shifted to alkaline condition and soil had pH less than 8.0 might be due to soil having well drained condition and light in colour. The data indicate that soils were slightly to moderately alkaline in respect of soil reaction.

Parhad *et al.* (2018) observed that electrical conductivity (EC) of various soil samples were ranged from 0.12 to 0.86 dS m^{-1}, the lowest (0.12 dS m^{-1}) was recorded at Mhalsar village (21013.710|N074055.392|E) and highest (0.86 dS m^{-1}) at Betawad village (21010.395|N-074054.319|E). The mean of EC for all soil samples was 0.37 dS m^{-1}. It is observed that all 201 soils (100 per cent) were non saline in nature. The similar results were reported by Waikar *et al*. (2004) for the soils of Maharashtra. The EC indicated that all 201 the soils were normal in respect of salt content and hence suitable for healthy plant growth.

Kondvilkar and Thakare (2018) reported that the pH of the Sakri Tehsil ranges from 5.70 to 8.37. The mean of pH was 7.79, were slightly acidic to moderately alkaline in reaction. The similar results were reported by Golhar and Chaudhari (2013) at Chalisgaon Tehsil of Jalgaon District, Maharashtra. The normal values of EC are recorded for upstream and topographically higher areas can be attributed to the rolling topography relatively higher gradient, seasonal irrigation and alternating cropping pattern.

Hammam and Mohamed (2018) focused on evaluation of soil salinization at East of Nile Delta using geographical information system (GIS). Ninety-two surface soil samples were collected at depth 0–30 cm. Inverse distance weighting (IDW) was used for spatial distribution mapping of soil salinity and salinization degree. Normalized Difference Vegetation Index (NDVI) was used to identify the correlation between vegetation density cover and soil salinity levels. The obtained data and salinity maps of the studied area presented that salinity levels according to agronomic classification occupied areas of 60% non-saline, 15% slightly saline, 13% moderately saline, 2% strongly saline and 10% for extremely saline level. Soil salinization degrees according to Russian classification located 71% – non-saline, 10.5% – slight saline, 9% – moderate saline, 3.8% – strongly saline and 5.7% – for very strongly saline of the investigated area.

Paz *et al*. (2020) collected soil samples at five layers to a depth of 1.35 m, at sampling sites along the EMI transects, and used for laboratory determination of the soil physico-chemical properties – electrical conductivity of the soil saturation paste extract (EC_e), sodium adsorption ratio (SAR), pH, cation exchange capacity (CEC), exchangeable sodium percentage (ESP), volumetric water content (θ), and particle size distribution and predict EC_e (RMSEP = 2.03 dS m^{-1}), SAR (RMSEP = 4.68 (mmolcL −10.5), and ESP (RMSEP = 3.83%) from σ and to classify the soil according to salinity and sodicity.

2.2 FERTILITY STATUS OF THE SURFACE SOIL

There exists a wide variation among the soils under different Agro Climatic Zones of Gujarat. The use of high analysis fertilizers coupled with varying management practices of the farmers necessitates regular monitoring of soil fertility. While changes in physical parameters occur over a longer period, but the change in soil available nutrients may happen in a shorter span. To characterize the soils, it is imperative to take into consideration its important soil properties such as pH, EC, texture, organic carbon and status of available nutrients. Moreover, knowledge about the cropping history of the fields along with soil characteristics may help in the formulation of a sound fertilizer recommendation for crops under different Agro Climatic Zone.

2.2.1 Available macronutrient

Meena *et al.* (2006) collected 120 surface soil samples (0–20 cm) from Tonk district of Rajasthan and reported that the available N, P_2O_5 and K_2O values were ranged between 125 to 555, 9.2 to 65.2 and 105 to 1059 kg ha^{-1} with mean values of 309, 25.2 and 377 kg ha^{-1}, respectively. Similarly, Polara *et al*. (2006a) collected 440 soil samples from salt affected soils of North West agro climatic zone of Gujarat and found organic carbon, P_2O_5 and K_2O ranged from 0.53 to 9.55 g kg^{-1}, 5.12 to 122.9 and 104.8 to 1048.4 kg ha^{-1} with mean value of 3.2 g kg-1, 40.0 and 464.4 kg ha^{-1}, respectively.

Singh *et al.* (2006) collected thirty-seven surface soils (0-15 cm) representing both valley and hill soils of Manipur and revealed that available S (0.15 per cent $CaCl_2$ extractable S) in soils were ranged from 10.0 to 70.0 mg kg^{-1} with mean value of 26.6 mg kg^{-1}.

Patel and Patel (2008) studied the sulphur fraction in different soil series of South Gujarat and found that on an average, the heat soluble-S varied between 20.3 to 137.7 mg kg^{-1}.

Singh *et al.* (2009) reported that available sulphur ranged from 4.6 to 118.4 mg kg^{-1} with a mean value of 24.6 mg kg^{-1} in soils (500 surface soil samples) of Udham Singh Nagar district of Uttarakhand.

Talukdar *et al.* (2009) reported that the available nitrogen, phosphorus and potassium content of the soils of Golaghat district of Assam (in two agro-ecosystems) varied from 205 to 479, 9.50 to 28.5 and 60 to 347 kg ha^{-1}, respectively. The rice ecosystem showed the highest values of available N, P_2O_5 and K_2O as compared to the sugarcane one. The reason might be the high content of organic carbon which on mineralization released higher amounts of NPK as compared to those in sugarcane system.

Patel (2010) observed that the available potassium content ranged from 133.5 to 450.24 kg ha^{-1} with an overall mean of 251.97 kg ha^{-1} in the in different landforms of Meghal Irrigation Command area of Southern Saurashtra in the Gujarat.

Kumar *et al.* (2011) studied the available major nutrients in arid soils of Churu district of Western Rajasthan and reported that available phosphorus and potassium content in soils varied from 7 to 80 and 108 to 837 kg ha^{-1} with mean value of 18.6 and 258 kg ha^{-1}, respectively. They found that organic carbon content in these soils ranged from 0.05 to 0.40 % with an average 0.13 %. All the samples rated low in organic carbon content. This also reflects on the poor in available nitrogen status of soil. The available phosphorus and potassium content varies from 7 to 80 and 108 to 837 kg ha^{-1}, respectively.

Srinivas *et al.* (2011) collected 72 soil samples (0-15 cm) from Krishna western delta in Andhra Pradesh and reported that the soil organic carbon, available N, P_2O_5 and K_2O were ranged from 0.27 to 0.62 per cent, 244 to 406, 30.6 to 69.4 and 233 to 590 with mean value of 0.49 per cent, 318, 48.2 and 398 kg ha^{-1}, respectively.

Bhaskaran *et al.* (2012) surveyed eight sugarcane growing districts of Tamil Nadu and reported that the sulphur content of soils (0-30 cm) varied widely from 2.45

to 96.07 ppm with an average of 25.37 ppm. About 17 per cent of the soils were found to be deficit (low) in available S content (20 ppm) category.

Patel *et al.* (2012) reported that available sulphur ranged from 5.24 to 60.17 mg kg^{-1} with a mean value of 19.01 mg kg^{-1} in soils (240 surface soil samples) of Banaskantha district of Gujarat. They further reported that, 30.0, 32.1 and 37.9 per cent soil samples were found low, medium and high in available sulphur, respectively

Punithraj *et al.* (2012) analyzed 80 soil samples (0-15 cm) from tomato growing area of Hassan district of Karnataka and observed that available N content varied from 205 to 376.3 kg ha^{-1} (mean 265.7 kg ha^{-1}), having 71.3 per cent samples were low (< 250 N kg ha^{-1}) and 28.7 per cent medium (250 to 500 N kg ha^{-1}) in status. Available P_2O_5 content varied from 43.6 to 238.7 kg ha^{-1} (mean 117.9 kg ha^{-1}) with 1.3 per cent medium (28 to 56 P_2O_5 kg ha^{-1}) and 98.7 per cent high (>56 P_2O_5 kg ha^{-1}) in status. Available K_2O content varied from 315 to 692 kg ha^{-1} (mean 505.4 kg ha^{-1}) with only 10 per cent medium (140 to 280 K_2O kg ha^{-1}) and 90 per cent high (> 280 K_2O kg ha^{-1}) in status. Available S content varied from 2.7 to 28.4 mg kg^{-1} (mean 8.8 mg kg^{-1}) with 67.5 per cent samples were low (< 10 S mg kg^{-1}), 23.8 per cent medium (10 to 20 S mg kg^{-1}) and 8.7 per cent high (> 20 S mg kg^{-1}) in status.

Rajput and Polara (2012) studied that the fertility status in eleven talukas of Bhavnagar district and found that the available N, P_2O_5 and K_2O were varied from 72.1 to 516.2, 2.21 to 85.7 and 38.0 to 990.0 kg ha^{-1} with an average value of 312.1, 28.6 and 451.2 kg ha^{-1}, respectively.

Singh and Kumar (2012) collected 110 surface soil samples from vegetable growing area of Varanasi district and found that the available N, P_2O_5, K_2O and S were varied from 249.0 to 685.0, 8.4 to 14.2, 101.0 to 262.0 kg ha^{-1} and 4.37 to 23.75 mg kg^{-1} with a mean value of 295.0, 10.8, 162.0 kg ha^{-1} and 14.9 mg kg^{-1}, respectively.

Athokpam *et al.* (2013) collected 200 soil samples (0-30 cm) from Senapati district in Manipur and reported that available N, P_2O_5 and K_2O were ranged from 290.20 to 893.17, 24.62 to 64.37, 55.60 to 359.11 with mean values of 382.04, 38.31 and 208.86 kg ha^{-1}, respectively.

Devdas and Srivastava (2013) collected 112 surface soil samples from the Navagarh block under Janjgir district of Chhattisgarh and found that available N, P_2O_5 and K_2O were varied from 88.0 to 399.0, 1.52 to 29.33 and 101.0 to 504.0 with mean value of 265.0, 7.34 and 268.0 kg ha^{-1}, respectively.

Gajare *et al.* (2013) collected 140 soil samples from the Latur district during 2009-10 and found that available P_2O_5 and S were ranged from 0.2 to 21.15 kg ha^{-1} and 3.62 to 53.52 mg kg^{-1} with an average value of 7.42 kg ha^{-1} and 21.47 mg kg^{-1}, respectively.

Singh and Munth (2013) studied fertility status of soil under forest and cultivated land use system of Nagaland. The available N, P_2O_5 and K_2O in forest area ranged from 251 to 426.4, 20 to 52.2 and 134.4 to 221.5 with mean values of 318.9, 30.8, 165.1 and 44.6 kg ha^{-1}, respectively. The available N, P_2O_5 and K_2O in cultivated area ranged from 230.2 to 413.9, 21.5 to 59.7 and 120.9 to 209.8 13.7 to 59.5 kg ha^{-1} with mean values of 286, 31.5 and 154.5 kg ha^{-1}, respectively.

Srinivasan and Poongothai (2013) collected 30 soil samples (0-20 cm) from 30 revenue villages of Tittakudi taluka of Tamil Nadu and found that available N, P_2O_5 and K_2O ranged from 21 to 140, 7.5 to 25 and 62.5 to 90 kg ha^{-1} with mean values of 80.5, 16.25 and 76.25 kg ha^{-1}, respectively.

Sudharani *et al.* (2013) collected 69 soil samples (0-15 cm) from rice growing soils of Visakhapatnam district of Andhra Pradesh and revealed that the available N, P_2O_5 and K_2O in soils varied from 125 to 392, 9 to 39 and 98 to 420 kg ha^{-1} and with mean values of 226, 20.8 and 230 kg ha^{-1}, respectively.

Malavath and Mani (2014) carried out study for assessment of the nutrient status of soils of Dryland Agricultural Research Station at Chettinad in Sivaganga district of Tamilnadu and found that the available N, P_2O_5 and K_2O ranged from 123.0 to 209.0, 14.0 to 28.1 and 126.0 to 319 kg ha^{-1} , respectively, while S ranged from 9.1 to 18.9 mg kg^{-1}.

Singh *et al*. (2014) carried out analysis on macronutrients fertility status in medium black soils of Chambal region of Madhya Pradesh. They found that the available N, P_2O_5, K_2O and S varied from 178 to 408, 7.9 to 28.8, 122 to 386 and 8.5 to 34.4 kg ha^{-1}, respectively with corresponding mean values of 227, 16.1, 295 and 17.4 kg ha^{-1}, respectively.

Padmavathi *et al.* (2014) reported that available N in soils of Coimbatore district ranged from 102 to 394 kg ha^{-1}, while the available P_2O_5 and K_2O varied from 5.30 to 75.10 and 102 to 789 kg ha^{-1}, respectively. They clearly indicated that the available N was found to be low in 86.41 percent of soil samples, phosphorus was medium, while nearly 56.55 percent soil samples were high in available K.

Singh *et al.* (2014) determined fertility status of alluvial, medium black soil and ravinous land and their correlations were carried out for Chambal region of Madhya Pradesh. The range of available P_2O_5 were 7.0 to 29.5 kg ha^{-1} in alluvial soil, 7.9 to 28.8 kg ha^{-1} in medium black soil and 6.2 to 25.3 kg ha^{-1} in ravinous land, respectively. Of alluvial soil samples, 14% low, 68% medium and 18% high in P. Of medium black soil samples, 21% low, 69% medium and 10% high in P of ravinous land soil samples, 68% low and 32% medium in P.

Arunkumar and Paramasivan (2015) studied the fertility status of the soils of Orathur village of veeranam command area of Cuddalore district in Tamil Nadu and revealed that the available N, P_2O_5, K_2O and S in soils were ranged from 173.60 to 235.20, 4.90 to 17.10, 180.0 to 330.0 kg ha^{-1} and 3.10 to 21.30 mg kg^{-1} with mean values of 203.30, 11.77, 237.32 kg ha^{-1} and 13.21 mg kg^{-1}, respectively.

Polara and Chauhan (2015) analyzed various soil parameters from 180 surface soil (0-15 cm) samples covering different taluka of Gir Somnath district. They reported that available N, P_2O_5, K_2O and S status ranged from 114 to 406 kg ha^{-1} (mean 207 kg ha^{-1}), 3 to 78.1 kg ha^{-1} (mean 21.2 kg ha^{-1}), 137 to 778 kg ha^{-1} (mean 358 kg ha^{-1}) and 1.2 to 54.4 mg kg^{-1} (mean 14.0 mg kg^{-1}), respectively. They observed that overall samples were deficient with respect to available N and P_2O_5, high in available K_2O and medium in available S status in soils.

Ramana *et al.* (2015) reported that soil fertility evaluation of an area is an important aspect in context of sustainable agriculture production. The macronutrients govern the fertility of soils and control the growth and yields of crops. In the present investigation Raisingh Nagar block was selected in the district Sri Ganganagar of Rajasthan and studied the available macronutrient status and their relationship with physico-chemical properties. Sri Ganganagar district have different cropping systems and irrigated by Ganga canal and Bhakhra canal tributaries. Twenty seven representative villages were chosen and four surface soil (0-15 cm) samples collected from each village and analysed for physico-chemical properties and available N, P, K, S, exchangeable Ca and Mg status using standard laboratory procedures. Results of the study indicated that soils of Raisingh Nagar block were low to medium in organic carbon. Out of 108 collected soil samples, 97% were medium in available nitrogen and medium to high in available phosphorus, potassium and sulphur.

Tundup *et al*. (2015) reported that the pH, EC and OC of the soils of Kishtwar district varied from 6.65-7.47, 0.15-0.23 dS m^{-1} and 5.8-8.1 g kg^{-1} with mean values of 7.26, 0.19 dS m^{-1} and 6.8 g kg^{-1}, respectively. They also reported the available N and P was varied from 280 to 385 and 12 to 20 kg ha^{-1} with mean values of 331 and 15.3 kg ha^{-1}, respectively.

Hadiyal *et al.* (2016) collected 250 soil samples (0-15 cm) from Girgadhda and Una talukas of Gir Somanth district in Gujarat and revealed that the available P_2O_5, K_2O and S in soils varied from 6 to 285, 22 to 760 kg ha^{-1} and 9.50 to 22.70 mg kg^{-1} and with mean values of 56, 220 kg ha^{-1} and 14.32 mg kg^{-1}, respectively.

Nagaral *et al.* (2016) collected 57 soil samples (0-15 cm) from chilli growing area of Northern Transitional Zone of Karnataka and observed that available N content varied from 112 to 672 kg ha^{-1} (mean 221 kg ha^{-1}), having 48 per cent samples were low (< 250 N kg ha^{-1}), 47 per cent medium (250 to 500 N kg ha^{-1}) and only 4 per cent sample high (>500 N kg ha^{-1}). Available P_2O_5 content varied from 15.6 to 68.0 kg ha^{-1} (mean 32.6 kg ha^{-1}) with 8 per cent samples being low (56 P_2O_5 kg ha^{-1}). Available K_2O content varied from 168 to 576 kg ha^{-1} (mean 332 kg ha^{-1}) with 40 per cent medium (140 to 280 K_2O kg ha^{-1}) and 60 per cent high (> 280 K_2O kg ha^{-1}).

Patel *et al.* (2016) studied the fertility status of soil of Patan district of Gujarat and reported that the available phosphorus, potassium and sulphur of soils varied from 9.99 to 138.82, 105.91 to 940.80 kg ha^{-1} and 2.22 to 170.32 mg kg^{-1} with a mean values of 52.42, 402.21 kg ha^{-1} and 29.03 mg kg^{-1}, respectively.

Shinde *et al.* (2016) conducted a study during the year 2015- 2016 at Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dhule with aim to know the fertility status of soils of Agriculture College Farm, Nandurbar. The soils were collected and analyzed as per standard procedure for assessing chemical properties and available nutrient status. The available nitrogen, phosphorus and potassium ranged from 125 to 238, 7.49 to 32.42 and 336 to 459 kg ha^{-1}, respectively. Soils of Agriculture College farm, Nandurbar were very low to low in available nitrogen, low to high in available phosphorus and very high in available potassium.

Bodar *et al.* (2018) collected the twenty surface (0-15 cm) soil samples from cultivated farmer's field of each taluka of Rajkot district viz. Paddhari, Rajkot, Lodhika, Kotda Sangani, Jetpur, Dhoraji, Upleta, Gondal and Jasdan. The chemical analysis of 200 surface samples indicates that soils were medium in available N and P_2O_5, whereas high in available S and in available K_2O status.

Kondvilkar and Thakare (2018) observed that the available nitrogen values in soils varied from 87.81 to 279.06 kg ha^{-1} with an average of 174.92 kg ha^{-1}, available phosphorus in soils were ranged from 4.57 to 22.96 kg ha^{-1} with an mean value of 14.76 kg ha^{-1} and available potassium in soils was ranged from 154.8 to 560 kg ha^{-1} with an average of 346.73 kg ha^{-1}. The soils were categorized as very low to low in available nitrogen, very low to moderately high in available phosphorus and moderate to very high in available potassium. The similar trends of results were recorded by Shinde and Phalke (2013) at soil from Godavari basin of Beed, Maharashtra and Ratnakumari *et al.* (2006) in soils Guntur District of Andhra Pradesh. The low available nitrogen in most of the soils might be due to the higher temperature in semi arid climate of Sakri Tehsil, which might have increased the rate of denitrification resulted in low status of available nitrogen. Low status of available P in soils of studied area might be due to alkaline soil reaction and high content of $CaCO_3$ in the soil. At the higher pH, calcium can precipitate with P as Ca-phosphate and reduce phosphorus availability. At low pH, due to low CEC and low clay content reduction in P availability was observed. The available potassium content in major portion of the study area was in high category. Black soils were higher in available K status than red soils which may due to predominance of K rich micaceous and feldspars minerals in parent material.

Parhad *et al.* (2018) observed that the organic carbon content ranged from 1.1 g kg^{-1} to 9.9 g kg^{-1} with the mean of 6.8 g kg^{-1}. The highest content of organic carbon was (9.9 g kg^{-1}) was observed for soil at Darkhede village (21012.714|N-074042.959|E) and the lowest (1.1 g kg^{-1}) organic carbon was observed at Dalwade village (21010.389|N074041.498|E). Out of the total soil samples analyzed and categorized for organic carbon, 5 soil samples (2.49 %) were in very low organic carbon content, 02 soil samples (0.99%) in low category, 50 soil samples (24.87%) in moderately, 111 soil samples (55.23%) in moderately high category and 33 soil samples (16.42%) in high. The similar observations were recorded for organic carbon by Chaudhari and Kadu (2007) in soils of Dhule tehsil of Dhule district.

2.2.2 Available micronutrient

Hundal *et al.* (2008) studied the nutrient status of rice crops cultivated in low land areas in the vicinity of Satlaj River in district of Ludhiana and reported that the range for Fe, Mn, Zn and Cu were 64-217, 72-187, 15-24 and 3-6 mg kg^{-1}, respectively.

Nagendran and Angayarkanni (2010) collected 56 soil samples from 16 pedons in two transects representing various physiographic positions along a double toposequence of Cumbum valley of Tamil Nadu and reported that DTPA extractable Fe, Mn, Zn and Cu in pedons of soils varied from 1.0 to 16.8, 0.88 to 13.2, 0.13 to 0.90 and 0.14 to 1.32 mg kg^{-1}, respectively.

Patel (2010) studied that the available iron, manganese, zinc and copper content ranged from 0.77 to 6.88 ppm, 0.63 to 4.49 ppm, 0.02 to 0.68 ppm and 0.03 to 1.37 ppm with an overall mean of 3.08 ppm, 2.11 ppm, 0.40 ppm and 0.81 ppm, respectively in the different landforms of Meghal Irrigation Command area of Southern Saurashtra region of Gujarat.

Bhanwaria *et al.* (2011) determined available micronutrient status in Mokala soil Series of Rajasthan and revealed that available micronutrients Fe, Mn, Zn and Cu ranged from 1.40 to 5.43, 2.50 to 7.90, 0.24 to 0.79 and 0.21 to 0.45 mg kg^{-1} with average values of 3.43, 4.75, 0.53 and 0.31 mg kg^{-1}, respectively.

Rajendra *et al.* (2011) reported the available micronutrient status of soils of Mokala soil series of Rajasthan. They found that the content of Fe, Zn, Mn and Cu varied from 1.40 to 5.43, 0.24 to 0.79, 2.50 to 7.90 and 0.21 to 0.45 mg kg^{-1} with mean value of 3.43, 0.53, 4.75 and 0.65 mg kg^{-1}, respectively. A soil survey was conducted to study fertility status of Banaskantha district of Gujarat with 494 surface soil samples and it was found that DTPA extractable Fe, Mn, Zn and Cu values were ranged between 2.66 to 20.38, 4.10 to 24.38, 0.18 to 2.76 and 0.16 to 2.84 mg kg^{-1} with mean values of 6.61, 10.97, 0.71 and 0.68 mg kg^{-1}, respectively.

Chouhan *et al.* (2012) studied micronutrient status from medium black soils of Dewas district of Madhya Pradesh. They observed that DTPA-Fe, Mn, Zn and Cu in soils varied from 4.50 to 22.5 mg kg^{-1} (mean 6.80 mg kg^{-1}), 1.70 to 25.70 mg kg^{-1} (mean 5.4 mg kg^{-1}), 0.04 to 4.9 mg kg^{-1} (mean 0.49 mg kg^{-1}) and 0.24 to 5.90 mg kg^{-1} (mean 1.80 mg kg^{-1}), respectively.

Patel *et al.* (2012) collected 2531 samples from different eighteen sites of Mandvi tahsil near Coastal Region of Kutch district and revealed that available Fe, Mn, Zn and Cu ranged from 1 to 5.2, 2 to 8, 0.2 to 8 and 0.2 to 0.8 ppm with mean values of 2.81, 4.65, 4.56 and 0.39 ppm, respectively.

Shirgire (2012) studied the fertility status of the soils of different talukas of Jamnagar district and revealed that the available Fe (10.41 mg ha^{-1}), Mn (18.04 mg ha^{-1}) and Cu (1.32 mg ha^{-1}) were found sufficient, whereas the soils were medium in available Zn (0.87 mg ha^{-1}) among the DTPA extracted micronutrients.

Rajput and Polara (2012) collected 220 surface (0-20 cm depth) soil samples from cultivated field of eleven talukas of Bhavnagar district and analyzed for the DTPA extractable Fe, Mn, Zn, and Cu which varied from 2.1 to 20, 2.18 to 33.3, 0.07 to 2.12 and 0.04 to 3.12 mg kg^{-1}, respectively.

Singh and Rathore (2013) studied available nutrient status in different topographic profile of Aravalli mountain ranges and Malwa plateau in Pratapgarh district of Rajasthan. The DTPA extractable Fe, Mn, Zn and Cu ranged from 4.56 to 10.04, 1.10 to 12.24, 0.04 to 0.66 and 0.14 to 0.89 mg kg^{-1} with mean values of 6.40, 6.13, 0.23 and 0.52 mg kg^{-1}, respectively in soils of Aravalli mountain ranges. In soils of Malwa plateau, the content of available Fe, Mn, Zn and Cu ranged from 5.86 to 14.20, 0.55 to 36.84, 0.04 to 2.19 and 0.48 to 1.15 mg kg^{-1} with mean values 10.09, 15.58, 0.92 and 0.87 mg kg^{-1}, respectively. The DTPA extractable micronutrients like iron, manganese and copper were found sufficient and zinc was deficient in soils of both transect.

Srinivasan and Poongothai (2013) collected 30 soil samples (0-20 cm) from 30 revenue villages of Tittakudi taluka of Tamil Nadu and reported that available Fe, Mn, Zn and Cu ranged from 2.52 to 34.66, 4.05 to 21.44, 0.79 to 3.12 and 0.64 to 9.26 mg kg^{-1} with mean value of 18.59, 12.75, 1.96 and 9.9 mg kg^{-1}, respectively.

Verma *et al.* (2013) collected 1800 soil samples of Malkharauda block of Janjgir Champa district and found that DTPA extractable Fe, Zn, Cu and Mn were varied from 3.2 to 60.1, 0.1 to 5.8, 0.2 to 11.1 and 3.9 to 66.0 mg kg^{-1} with mean value of 21.0, 1.1, 4.1 and 26.0 mg kg^{-1}, respectively. Overall 86.63, 99.22 and 96.62 per cent soil sample were found high in Fe, Cu and Mn, respectively.

Malavath and Mani (2014) reported that the DTPA extractable Fe, Zn, Mn and Cu varied range from 8.9 to 22.4, 0.10 to 3.52, 24.0 to 49.2, and 0.85 to 3.63 mg kg^{-1}, respectively for the soils of Dryland Agricultural Research Station at Chettinad in Sivaganga district of Tamil Nadu.

Tundup and Akbar (2014) collected 60 surface soil samples from the Kishtwar district of Jammu and Kashmir and found that DTPA extractable Zn, Cu, Mn and Fe ranged from 1.24 to 5.55, 1.20 to 2.97, 13.26 to 47.56 and 7.17 to 17.18 mg kg^{-1} with mean value of 2.34, 2.10, 22.35 and 10.65 mg kg^{-1}, respectively.

Singh *et al.* (2014) analyzed available nutrient status from medium black soils of Chambal region of Madhya Pradesh. They found that DTPA-Zn, Fe, Cu and Mn content varied from 0.37 to 1.30, 0.93 to 8.79, 0.23 to 0.52 and 1.34 to 7.36 mg kg^{-1}, respectively with corresponding mean values of 0.75, 5.10, 0.46 and 3.91 mg kg^{-1}, respectively.

Kumar (2015) studied the fertility status of the soils of different block of Saharsa district of Bihar and revealed that the available Fe, Mn, Cu and Zn in soils were ranged from 11 to 104, 45 to 150, 0.65 to 2.60 and 1.30 to 4.90 mg kg^{-1} with mean values of 776.03, 113.93, 1.52 and 2.36 mg kg^{-1}, respectively.

Polara and Chauhan (2015) analyzed various soil parameters from 180 surface soil (0-15 cm) samples covering different taluka of Gir Somnath district. They reported that available Fe, Mn, Cu and Zn status ranged from 3.48 to 19.00 mg kg^{-1} (average 9.01 mg kg^{-1}), 4.04 to 59.81 mg kg^{-1} (average 16.58 mg kg^{-1}), 1.09 to 6.72 mg kg^{-1} (average 2.27 mg kg^{-1}) and 0.08 to 5.88 mg kg^{-1} (average 1.02 mg kg^{-1}), respectively. They observed that soils were sufficient with respect to available Mn and Cu, whereas the soils were medium in Fe and Zn.

Prabhavati *et al.* (2015) studied 69 surface samples from deep black soils of Belgaum district (Yadawadwaterhed) of Karnataka. They found that 100 per cent Yadvad soils were deficient for DTPA-Zn content (mean 0.18 mg kg^{-1}) by considering the critical value of 0.6 mg kg^{-1}. The DTPA extractable Fe content of entire microwaterhed soils was low. DTPA-Mn and Cu content was sufficient against the critical level 1.0 mg kg^{-1} (Lindsay and Norvell 1978) and > 0.2 mg kg^{-1}, respectively in soils.

Rajput *et al.* (2015) collected 150 composite surface soil samples (0-15 cm) from irrigated and non-irrigated mustard growing fields covering 30 villages of northern Madhya Pradesh and reported that DTPA extractable Fe, Mn, Zn and Cu in soil ranged from 1.25 to 18.65, 0.36 to 16.65, 0.18 to 2.56 and 0.12 to 4.62 mg kg^{-1} with mean values of 5.55, 4.36, 0.69 and 1.14 mg kg^{-1}, respectively. Available Fe, Mn, Zn and Cu were deficient to the extent of 35, 7, 46 and 7 per cent, respectively.

Hadiyal *et al.* (2016) collected 250 soil samples (0-15 cm) from Girgadhda and Una talukas of Gir Somanth district in Gujarat and revealed that available Fe, Zn, Mn and Cu in soils varied from 0.72 to 14.06, 0.20 to 4.98, 0.96 to 27.0 and 0.46 to 3.16 mg kg^{-1} and with mean values of 5.33, 0.57, 10.8 and 1.29 mg kg^{-1}, respectively.

Karajanagi *et al.* (2016) analyzed micronutrients of 75 soil samples from Dundur village under Malaprabha command area in Karnataka and reported that available Fe, Mn, Zn and Cu in soils were ranged from 0.47 to 4.67, 2.40 to 9.50, 0.43 to 0.65 and 0.02 to 1.03 mg kg^{-1} with mean values of 1.79, 4.80, 0.55 and 0.43 mg kg^{-1}, respectively. Major portion of the area was deficient in zinc and iron, whereas copper and manganese were sufficient in these soils.

Nagaral *et al.* (2016) collected 57 soil samples (0-15 cm) from chilli growing area of Northern Transitional Zone of Karnataka and observed that available Zn content varied from 0.19 to 0.80 mg kg^{-1} (mean 0.44 mg kg^{-1}), with 70 per cent per cent samples being sufficient and 30 per cent deficient. Available Cu content varied from 0.10 to 0.98 mg kg^{-1} (mean 0.51 mg kg^{-1}) with 97 per cent samples being sufficient and 3 per cent deficient. Available Fe content varied from 1.01 to 7.59 mg kg^{-1} (mean 3.48 mg kg^{-1}) with 15 per cent samples being sufficient and 84 per cent deficient. Available Mn content varied from 4.86 to 17.38 mg kg^{-1} (mean 7.35 mg kg^{-1}) with 100 per cent samples being sufficient.

Patel *et al.* (2016) studied the fertility status of Patan district of Gujarat and reported that 316 surface soil samples having DTPA extractable Fe, Mn, Zn, and Cu values were ranged between 3.48 to 23.92, 3.60 to 38.08, 0.14 to 2.10 and 0.10 to 2.76 mg kg^{-1} with mean values of 6.77, 12.51, 0.71 and 0.86 mg kg^{-1}, respectively.

Wagh *et al.* (2016) studied status of available micronutrients in sunflower growing soils of Nagpur district of Maharashtra and found that available Fe, Mn, Zn and Cu ranged from 10.02 to 22.52, 9.21 to 29.41, 0.18 to 0.54 and 0.76 to 3.32 mg mg kg^{-1} with mean values of 16.10, 18.45, 0.33 and 1.13 mg kg^{-1}, respectively. The soil samples were deficient in available Zn and sufficient in available Fe, Mn and Cu.

Sharma *et al.* (2017) conducted an experiment during 2014-2015 under All India coordinated research Project for Dry land Agriculture at College of Agriculture, Indore (Madhya Pradesh) to study the major nutrient and other chemical properties of sampled vertisoils and associated soils of Ralyawan village of Jhabua district of western Madhya Pradesh. Results showed that the soils of Ralyawan village in Jhabua district of Madhya Pradesh were varied from 2.36 to 10.9 mg kg^{-1} in available iron with a mean value of 5.9 mg kg^{-1}. The status of available manganese and Copper varied from 1.34 to 4.02 mg kg^{-1} and 0.08 to 0.89 mg kg^{-1} with a mean value of 2.7

and 0.37 mg kg^{-1}, respectively. Similarly, the status of available zinc varied from 0.2 to 1.94 mg kg^{-1} with a mean value of 0.645 mg kg^{-1}.

2.2.3 Nutrient index

Polara and Kabaria (2006) revealed that 220 surface soil samples were collected from Amreli district and reported that the nutrient index values were low for available N (1.02) and S (1.27), medium for available P_2O_5 (1.83), K_2O (2.11), DTPA extractable Fe (2.04) and Zn (1.65) and high for Mn (2.68) and Cu (3.0) in the soils of Amreli District.

Polara *et al.* (2006) collected 440 surface soil samples from cultivated farmer's field of north west agroclimatic zone of Gujarat and reported that the nutrient index values were low for organic carbon (1.18) and Zn (1.45), medium for P_2O_5 (1.85) and high for K_2O (2.60), DTPA extractable Fe (2.60), Mn (2.68) and Cu (2.93).

Prakash *et al.* (2008) soil survey was done during the year 2004-05, Bajaj sugar mill Bhasana, Muzaffarnagar district, Uttar Pradesh, India, were collected six hundred soil samples from 22 circles of sugar factory zone and analyzed for the current status of the available macronutrients and other parameters. It was found the nutrient index value of the zone for organic carbon (N), available phosphorus and available potash were found 1.41, 1.20 and 1.97, respectively showing the deficiency of all these three nutrients and they required judicious supplementation of the nutrients for sustained productivity.

Sojitra (2010) collected 280 surface soil samples from fourteen talukas of Junagadh district and reported that the nutrient index values were low for P_2O_5 (1.60) and S (1.59), medium for N (2.06), Zn (1.70) and high for K_2O (2.69), Fe (2.53), Mn (2.45) and Cu (2.43).

Rajput and Polara (2012) collected 220 surface soil sample from eleven talukas of Bhavnagar district and reported that the nutrient index values were medium for N (1.59), S (1.62) and P (1.68), high for K (2.67), medium for DTPA-Zn (1.59) and high for Fe (2.35), Mn (2.36) and Cu (2.48) in the soils of Bhavnagar district of Gujarat.

Shirgire (2012) collected 200 surface soil samples from ten talukas of Jamnagar district and reported that the nutrient index values were low for N (1.15) and P_2O_5 (1.55), medium for S (1.69), DTPA Zn (2.11) and high for K_2O (2.68), Fe (2.48), Mn (2.74) and Cu (3.00).

Malavath and Mani (2014) reported that based on nutrient index value and fertility ratings the soils of Dryland Agriculture Research Station at Chettinand in Sivganga district of Tamil Nadu were found very low in N (1.00), P (1.40), high in S (2.47) and very high in Cu (2.91), Mn (3.00) and Fe (3.00). Similarly, Singh (2014) reported low nutrient indices for organic carbon (1.0), medium for available P_2O_5 (1.80) and potassium (1.97).

Bodar *et al.* (2018) collected the twenty surface (0-15 cm) soil samples from cultivated farmer's field of each taluka of Rajkot district viz. Paddhari, Rajkot, Lodhika, Kotda Sangani, Jetpur, Dhoraji, Upleta, Gondal and Jasdan. The nutrient index value was low for DTPA available Zn (1.48), medium for available N (1.55), available P_2O_5 (2.01), available S (2.44) and DTPA available Fe (1.57) and high for K_2O (2.94), DTPA available Mn (2.84) and DTPA available Cu (2.94) in the soils of Rajkot district.

2.3 QUALITY OF UNDERGROUND IRRIGATION WATER

2.3.1 Classification of irrigation water

Attempts have been made from time to time to classify the irrigation waters on the basis of one or more criteria for their suitability for irrigation purposes. Undoubtedly, salinity is the most important single criterion, which has been included in several classifications with various limits for judging the quality of irrigation water (Thorne and Thorne, 1951; Christiansen and Lyerly, 1952). Using total salt concentration and soluble percentage as a criterion, different limits have been proposed (Schofield, 1936 and Wilcox, 1948). Among the prevailing criteria are;

2.3.1.1. Total salt concentration.

2.3.1.2 Relative proportion of sodium to other cations.

2.3.1.3 Carbonate and bicarbonate concentration.

2.3.1.1 Total salt concentration

The total salt concentration in water is expressed as,

- Part per million of water (ppm)
- Milligram per liter of water (mg L^{-1})
- Electrical conductivity of the water (EC)

Table 2.1: Quality ratings of irrigation water according to the amount and nature of salt present

Salts (parts per 10^5 parts)	Quality rating for free draining soils			Quality rating with impeded drainage		
	Good	Fair	Bad	Good	Fair	Bad
Total soluble salt	100	100-150	150	75	75-100	100
Sodium carbonate	8	8-10	10	5	5-8	8
Sodium bicarbonate	12	12-15	15	8	8-12	12
Sodium sulphate	20	20-30	30	10	10-15	15
Sodium chloride	30	30-50	50	15	15-20	20
Ca:Na ratio (Equivalent)	1	1	1	1	1	1

(ICAR, 1961)

ICAR (1961) presented suitability of irrigation water based on parts of salts per 1,00,000 parts of water is given in table 2.1. It depends on the quality and nature of salt present and drainage condition of soil. Water with higher salt present can be used in well-drained soil than in soil with impeded drainage. As the osmotic pressure of salt solution varies with different types of salt, evaluation of salt concentration on weight basis is less reliable.

Table 2.2: Quality ratings of ground water (Gupta *et al*., 1994)

Water quality	Class	EC_{iw} (dS m^{-1})	SAR_{iw} (mmol $L^{-1})^{1/2}$	RSC (me L^{-1})
Good	A	<2	<10	<2.5
Saline				
Marginally saline	B	2-4	<10	<2.5
Saline	C	4	<10	<2.5
High- SAR saline	D	4	>10	<2.5
Alkaline water				
Marginal alkali	E	<4	<10	2.5-4.0
Alkali	F	<4	<10	4.0
Highly alkali	G	variable	>10	4.0

Gupta *et al*. (1994) presented a quality rating of ground water which is being used in India by the different co-operating centers of AICRP for mapping saline water quality.

However, for mapping of ground water quality for irrigation on a large scale, four rating have been used as follows:

1. Good water, EC_{iw} < 2 dS m^{-1} and SAR < 10
2. Saline water, EC_{iw} 2 dS m^{-1} and SAR < 10
3. High SAR saline water, EC_{iw} 4.0 dS m^{-1} and SAR > 10
4. Alkaline water, EC_{iw} (dS m^{-1}) variable and RSC value >2.5 me L^{-1}.

2.3.1.2 Relative proportion of sodium to other cations

The presence of sodium salts and their concentration in water decide largely the quality of water for irrigation purpose. The sodium adsorption ratio (SAR), exchangeable sodium percentage (ESP) and sodium percentage (SP) are considered for evaluating sodium problems in water. Water may contain carbonate and bicarbonate that aggravate the sodium hazards by precipitating the calcium and magnesium ions (Eaton, 1950).

Table 2.3: Classification of irrigation water according to salinity and sodium hazards (Kanwar, 1961)

Salinity hazard	Class	EC (micromhos/cm) at 25˚C
Low	C_1	0.0-250
Medium	C_2	250-750
Medium to high	C_3	750-2250
High	C_4	2250-5000
Very high	C_5	5000-20000

Sodium hazard	Class	SAR	EC (micromhos/cm) at 25^{o}C
Low	S_1	0-10	0.0-1000
Moderate	S_2	10-18	1000-1800
High	S_3	18-26	1800-2600
Very high	S_4	>26	>2600

Kanwar (1961) has classified the salinity hazards of irrigation waters into low, medium, medium to high, high and high to very high based on EC (micromhos cm^{-1}) denoting the classes as C_1, C_2, C_3, C_4 and C_5, respectively and sodium hazards of irrigation water into four classes namely low, moderate, high and very high based on the SAR denoting the classes as S_1, S_2, S_3 and S_4, respectively.

The sodium adsorption ratio (SAR) measure the sodium cations in relation to the calcium and magnesium ions present in a solution and is expressed as,

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{++} + Mg^{++})/2}}$$

(Concentration of all cations are in me L^{-1})

Where the ionic concentrations are in me L^{-1}, the SAR is expressed in (mmol $L^{-1})^{1/2}$.

The soluble sodium percentage (SP) is calculated as follows,

$$SSP = \frac{Na^{+}}{Na^{+} + Ca^{++} + Mg^{++} + K^{+}} \times 100$$

Where the ionic concentrations are in me L^{-1}.

The exchangeable cations on soil colloids are in equilibrium with sodium ions in soil solution. As the sodium percentage in irrigation water increase, there is a tendency to greater adsorption of sodium ions on the clay complex leading to alkalization of the soil. This may be represented by,

$$2\ Na^{+} + Ca\ (clay) \rightarrow Na^{+}\ (clay)\ Na^{+} + Ca^{++}$$

Bhumbla (1969) represented that if SSP is more then 60, the use of water for irrigation is questionable.

2.3.1.3 Carbonate and Bicarbonate content

Eaton (1950) suggested the term, residual sodium carbonate (RSC) to indicate the residual carbonate in excess of the lime elements. The RSC is expressed as,

$$RSC = (CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$$

(Where, the ionic concentrations are in me L^{-1}).

Bhumbla (1969) has classified the RSC as good, fair and bad, when the RSC is below 1.25, 1.25 to 2.5 and above 2.5 me L^{-1}, respectively. Where appreciable RSC occurs (perhaps above 2.5 me L^{-1}), special precautions are needed in irrigation to prevent lime accumulation and possible soil alkalization. More frequent irrigation is therefore necessary to prevent soil during and to do leaching at frequent intervals under this situation.

2.3.2 Quality of wells/tube wells water

In arid and semi-arid areas, irrigation is very essential for successful agriculture. Irrigation water through source of well/tube well which have dissolved salt in terms of sodium, calcium, magnesium and sometimes potassium as cations and chloride, sulphate, bicarbonate and little amount of carbonate and sometimes nitrate as anions. The suitability of irrigation waters should be evaluated on the basis of criteria indicative to their potential to create hazardous soil condition for crop growth;

Verma *et al.* (2003) collected 556 water samples from seven tehsils of Churu district (Rajasthan) during October to February, 1995-2000. They found that EC of the water samples were ranged from 0.4-19.7 dS m^{-1}. About 32 per cent of water samples had EC < 2.0 dS m^{-1}, while 36 per cent water samples showed EC between 2-4 dS m^{-1}. The pH of water samples was ranged from 7.2 to 9.3. The Cl^- was dominant anion and it was ranged from 1.2-200.4 me l^{-1}, while Na^+ was the dominant cation ranging from 1.7-118.0 me l^{-1}. The SAR of water samples ranged from 2.2 to 33.5 and RSC of water varied from nil to 13.1 me l^{-1}. About 75 per cent water samples were recorded RSC < 2.5 me l^{-1}, whereas 8.8 per cent samples had RSC between 2.5 to 5.0 me l^{-1} and 16.0 per cent samples had RSC > 5.0 me l^{-1}.

Kabaria (2004) collected 220 well/tube well water samples from the Amreli district and reported that almost three forth of the samples of irrigation waters were found saline (EC 0.75 dS m^{-1} and above). The EC value ranged between 0.4 and 12.5 with a mean value of 2.32 dS m^{-1}. The waters were alkaline in reaction (pH 8.06). The overall RSC values ranged from 0.0 to 7.05 with mean value of 1.07 me l^{-1} and overall 74.5, 6.8 and 18.7 per cent samples fell under safe, marginal and unsafe classes of RSC, respectively. The overall mean value of SSP was found 56.21, which varied from 4.49 to 89.54 and overall 51.8 and 48.2 per cent samples fell under safe and unsafe classes, respectively. The SAR values ranged from 0.19 to 34.18 with a mean value of 7.18 and overall 75.0, 21.0, 2.3 and 1.2 per cent samples fell under S_1, S_2, S_3 and S_4 classes of SAR, respectively.

The collected 164 under irrigation water samples from Surendranagar district and found that almost half of the samples of water from cultivate fields were saline (EC> 2.25 dS m^{-1}). The EC value was ranged between 0.4 and 12.0 with a mean value of 3.51dS m^{-1}. The waters were alkaline in reaction (mean pH value 7.82). The SAR values were ranged from 1.47 to 140.7 with a mean value of 14.5 (Patel, 2004).

Hadiyal (2005) collected 53 underground irrigation water samples from Porbandar district and found that 50 per cent samples of water from cultivated fields of the Porbandar district were saline (EC > 2.25 dS m^{-1}). The EC values were ranged between 1.20 to 18.60 dS m^{-1} with mean value of 6.14 dS m^{-1}. The waters were alkaline in reaction (mean pH value 7.97). The SAR values were ranged from 3.06 to 33.84 with a mean value of 10.14.

Bhatt *et al.* (2006) carried out a preliminary survey of the coastal city Bhavnagar to assess salinity ingress probed through groundwater quality. Water samples from the wells and bores located in the study area were collected and analyzed. Bhavnagar city is found significantly affected by the seawater intrusion. The ground water showed very high values of SO_4^{-2}, Cl^- , Na^+ and K^+ compared to the permissible limits for drinking purposes. The quality of ground water in some of the areas was found highly saline and can not be used even for irrigation purpose. The results also indicated a gradual encroachment of seawater into the native ground water.

Savalia *et al.* (2006) concluded that underground water of open wells/tube wells situated at higher elevations have low pH, EC, water soluble Mg^{++}, Na^+, CO_3^{-2}, HCO_3^-, $C1^-$, SSP and SAR that of lower elevations in different land slopes of Southern Saurashtra.

Ram *et al.* (2006) survey and analysis of water samples collected from 70 tube wells distributed in different villages of Rajgarh tehsil of Churu district, Rajasthan, India, were performed in 2002-03. They revealed that the pH of irrigation water varied from 8.0 to 9.1, EC ranged between 1.70 to 14.10 dS m^{-1}. Cations, like Ca^{++}, Mg^{++}, Na^+ and K^+ of irrigation water of Rajgarh tehsil ranged from 0.70-8.6, 2.3-55.8, 10.6-84.2 and 0.2-0.5 me l^{-1}, respectively. Sodium adsorption ratio (SAR) and adj. SAR of irrigation water varied from 6.0 to 39.3 and 15.3 to 83.7, respectively. Residual sodium carbonate varied from nil to 6.1me l^{-1}. Majority of the water samples were of high SAR-saline category followed by marginally alkalinity problem. Approximately 4.3, 45.7 and 50.2% of the water samples had EC of < 2, 2-4 and >4 dS m^{-1}, respectively. On the basis of salinity (1.96) and alkalinity (2.77) indices, soils of the study area had slight salinity and moderate alkalinity problems.

The analyzed 1131 well/tube well water samples of Mahboob Nagar district of Andhra Pradesh (Prasad and Minhas, 2007) and found that the depth of water in the bore/open wells varied from 3 to 96 m. The EC and pH of water samples varied from

0.3 to 8.5 dS m^{-1} and 6.3 to 9.4, respectively. The soluble carbonate, bicarbonates, RSC and SAR of these waters varied from nil to 11.2, 0.2 to 17.0, nil to 16.1 me L^{-1} and 0.1 to 27.1 (mmol L^{-1})1/2, respectively. About 96.7 per cent of water samples recorded EC values less than 2.0 dS m^{-1}, 55 per cent of samples recorded pH ranging from 7.0 to 8.0, while remaining 45 per cent had pH ranged from 8.0 to 9.5. Similarly, 58 and 42 per cent of water samples recorded RSC less than and more than 2.5 me L^{-1}, respectively. Based on EC, SAR and RSC, 56 per cent water samples were characterized as good, 3 per cent marginally saline, 19 per cent marginally alkali and 22 per cent alkali in nature. The predominant cations were in the order of Na^{+} > Mg^{++} > Ca^{++}, whereas in few cases it was in the order of Mg^{++} > Na^{+} > Ca^{++} with dominance of bicarbonate followed by chlorides.

The study was conducted to determine the quality of the ground waters of Mohindergarh block of Mohindergarh district of Haryana, their effect on soil properties and to categorize them for their suitability for irrigation. According to Manchanda's classification, half of the waters (51.2 %) were sodic having EC<4 dS m^{-1}, SAR>10 (mmol $L^{-1})^{1/2}$ and RSC>2.50 me L^{-1} followed by saline-sodic (30.1 %) and good quality (17.0 %) waters. Whereas according to CSSRI classification, 16.87, 2.11, 1.00, 25.19, 7.44, 7.44 and 28.41 per cent samples were good, marginal saline, saline, high SAR saline, marginally alkali, alkali and highly alkali, respectively. The waters were mostly Na-Mg-Ca type with dominance of chlorides and sulphate followed by (Rajput *et al.*, 2008).

Rajput (2010) collected 220 underground well/tube well water samples from Bhavnagar district and found that almost half of the samples of irrigation water were found saline (EC 0.75 dS m^{-1} and above). The overall EC values ranged between 0.38 and 18.2 dS m^{-1} with a mean value of 2.77 dS m^{-1}. The overall mean value of SAR was found 9.80, which varied from 1.32 to 26.3 and overall 49.6, 34.1, 14.1 and 2.3 percent samples fell under S_1, S_2, S_3 and S_4 classes of SAR, respectively. The overall RSC values ranged from 0.00 to 4.17 with mean value of 0.39 me l^{-1} and overall 87.7, 5.5 and 6.8 me l^{-1} per cent samples fell under safe, marginal and unsafe classes of RSC, respectively. The overall value of SSP was found 68.7, which varied from 30.3 to 90.5 and 25.5 and 74.5 percent samples fell under safe and unsafe according to classes of SSP, respectively.

The collected and determined 280 underground irrigation water samples from Junagadh district (Sojitra, 2010) and reported that almost three fourth (3/4) of the samples of water from cultivated fields were found saline (EC 0.75 dS m^{-1} and above). The EC values were ranged between 0.38 and 16.2 dS m^{-1} with a mean value of 3.10 dS m^{-1}. The waters were alkaline in reaction (mean pH value 7.71). The SAR values were ranged from 1.23 to 28.9 with a mean value of 8.88 and overall 46.0, 30, 18.6 and 5.4 percent samples fell under S_1, S_2, S_3 and S_4 classes of SAR, respectively. The overall RSC value ranged from 0.0 to 8.80 with mean value of 0.54 me l^{-1} and overall 85, 6.8 and 8.2 per cent sample falls under safe, marginal and unsafe classes of RSC, respectively. The overall value of SSP was found 64.3, which varied from 33.3 to 87.1 and 24.6 and 75.4 per cent sample falls under safe and unsafe according to classes of SSP, respectively.

The underground water quality of different landforms of Meghal Irrigation Command area of Southern Saurashtra region of Gujarat. They observed low pH, EC, water soluble Mg^{++}, Na^{+}, CO_3^{--}, HCO_3^{-}, Cl^{-}, SSP and SAR at higher elevation than in lower elevation (Patel *et al.*, 2012b).

Gandhi (2013) studied that the underground water samples from different land slopes of Girnar toposequence were placed under C_4S_2 water quality class. As per the Semi-logarithmic USSL diagrams, out of 43 wells/tube well water sample, 74.4, 18.6 and 6.9 per cent were placed in C_3S_1, C_4S_1 and C_4S_2 water quality class, respectively indicating the majority of water samples fall in C_3S_1 class.

Rajput and Polara (2013) collected 220 irrigation ground water sample from eleven talukas of Bhavnagar district and analyzed. They reported that the overall EC values of irrigation water ranged from 0.38 to 18.2 dS m^{-1} with mean values of 2.77 dS m^{-1}. The pH values ranged from 6.79 to 8.78 with mean values of 7.72 and the overall mean SAR was 9.80 with values varying from 1.32 to 26.3, respectively. Among the cations, overall highest proportion of Na^{+} (20.93 me l^{-1}) was observed, which was followed by Ca^{++} (4.45 me l^{-1}), Mg^{++} (3.64 me l^{-1}) and K^{+} (0.11 me l^{-1}). The overall concentrations of Ca^{++}, Mg^{++}, Na^{+} and K^{+} varied from 0.83 to 31.10, 0.39 to 26.20, 1.46 to 139.5 and 0.00 to 1.37 me l^{-1}. In case of anion, overall highest proportion of Cl^{-} (20.47 me l^{-1}) was observed, which was followed by HCO_3^{-} (6.16 me l^{-1}), SO_4^{--} (3.95 me l^{-1}) and CO_3^{--} (0.27 me l^{-1}). The overall concentrations of CO_3^{--}, HCO_3^{-}, Cl^{-} and SO_4^{--} varied from 0.0 to 4.10, 1.90 to 38.4, 1.90 to 135.4 and 0.00 to 18.2 me l^{-1}, respectively.

The collected 27 underground water samples from Rajkot district (Dhiman, 2014) and reported that majority of sites have SAR < 10 indicating water class to be of excellent quality and 81.48 per cent samples have RSC less than the permissible limit of 1.5. Furthermore, 70.37 per cent sites have (Ca^{++} + Mg^{++}) >HCO_3^- indicating as base exchanged-hardened waters, while remaining 29.63 per cent samples have HCO_3^- > (Ca^{++} + Mg^{++}), which may be referred as base exchanged-softened waters.

Polara and Chauhan (2015) collected 180 well/tube well water samples from the Gir Somnath district of Saurashtra region of Gujarat and reported that almost three fourth of the samples of irrigation waters were found saline (EC 0.75 dS m^{-1} and above). The EC values ranged from 1.15 and 12.39 with a mean value of 3.31 dS m^{-1}. The waters were alkaline in reaction (pH 7.71). The overall RSC values ranged from 0 to 2.60 with mean value of 2.22 me l^{-1} and overall 92.2, 7.2 and 7.2 percent samples fell under safe, marginal and unsafe classes of RSC, respectively. The overall mean value of SSP was found 64.06, which varied between 44.24 to 85.35 and overall 31.7 and 68.3 percent samples fell under safe and unsafe classes, respectively. The SAR values ranged from 4.02 to 19.43 with a mean value of 8.59 and overall 7.2, 42.8, 37.8 and 12.2 percent samples fell under S_1, S_2, S_3 and S_4 classes of SAR, respectively.

Hadiya and Polara (2017) collected water samples from cultivated farmer’s fields of the Devbhumi Dwarka district and found that the EC values were ranged between 0.34 to 7.45 with mean value of 1.79 dS m^{-1}. The waters were alkaline in reaction (pH 7.88) with range values of 7.07 to 8.73. The SAR values were ranged from 0.15 to 10.39 with a mean value of 4.23 and overall 62.5, 13.3, 24.2 and 0.0 per cent samples under S_1, S_2, S_3 and S_4 classes of SAR, respectively. The overall RSC values ranged from 0.00 to 4.90 with a mean value of 0.26 me L^{-1} and overall 92.5, 5.0 and 2.5 per cent samples fall under safe, marginal and unsafe according to classes of RSC, respectively. The overall mean value of SSP was 43.16, which varied between 5.19 to 75.22 and overall 67.5 and 32.5 per cent samples fell under safe and unsafe according to classes, respectively.

Parhad *et al.* (2018) reported that the calcium carbonate in soils of Sindkheda tehsil of Dhule district ranged from 7.75 to 16.0 per cent with an average of 10.77 per cent. Out of total soil samples, 75 (37.31%) soil samples were high in calcium carbonate content and 126 (62.69%) soil samples in very high category. The highest calcium carbonate was (16.0%) in soil collected at Mandal village (21018.246|N-074034.469|E) and the lowest (7.75%) in soil samples at Bramhane village (21020.572|N074037.220|E). The similar nature of observation for $CaCO_3$ in soils of Shevgaonn tehsil of Ahmednager District was reported by Dhage *et al.* (2000). Out of total soil samples, 126 (62.69%) soil samples were under very high category. The calcareousness of soils are common feature in soils of arid and semiarid climate particularly in Vertisols (black soils) due to precipitation of carbonates and bicarbonates under water stress.

2.4 PERIODICAL CHANGES IN WATER QUALITY

An investigation carried out by Gupta and Khosla (1982) on the seasonal variation in salt and water content profiles in shallow and saline ground water table and found a rapid rise in water table with onset of rainy season and it remain close to the soil surface during July and August. The EC of the underground water, owing to dilution effects decreased during rainy season.

The periodical observation on fluctuations of ground water table and quality of water in Jayakwadi command area during 1985 to 1990. Water table rise considerably in the command area indicating possibility of water logging in the area (Bhrambe *et al.*, 1992). The ground water in command area was rated as low saline water. The sodicity on the basis of sodium adsorption ratio showed an increasing trend in command area. The result showed the ground water table rise during rainy season (June-Aug.) remained almost constant during winter season and subsequently increased during summer season. Periodical analysis of water samples during 1989-90 showed that SAR of ground water decreased during rainy and winter season and increased considerably during summer season. The pH decreased during June to August and thereafter followed an increasing trend. Electrical Conductively (EC) remained more or less unchanged.

The collected 79 irrigation water sample from various sources of Canning I and II blocks, respectively, during 1991-1994 and were classified on the basis of EC and SAR. There was good rise in salinity and Na^+, Mg^{++}, Ca^{++} and Cl^- concentration of irrigation waters with change in the time of collection from December -January to April – May (Das, 1998). Water of each class strongly influenced the salinity of the irrigated soils except class I water having EC ≤ 1.0 dS m^{-1} and SAR <10 (mmol $L^{-1})^{1/2}$. Using the threshold salt concentration limit ≤ 1 to 1.3 mg L^{-1} (EC ≤ 1.5 to 2.3 dS m^{-1}) of water and its influence on corresponding soils, 77 and 47 per cent water in Canning I and II blocks, respectively, were found suitable for irrigation in December – January; and 35 and 25 per cent in April – May.

Das and Maji (2001) found that the ground water depth varied from 0 (at surface) to 1.58 m and salinity (EC_{iw}) and SAR decreased from June onwards, attaining minimum (0.65 – 4.26 dS m^{-1}) during July – August, increasing from November onwards and reaching maximum during March to May.

The collected and analyzed 20 irrigation water samples each from 11 talukas of Amreli district during pre-monsoon (May. 2003) and post-monsoon (Nov. 2003) by Kabaria, 2004. He found that all the water quality indices (EC, SAR, RSC, SSP) of well/tube well water samples collected post-monsoon improved in comparison to the samples collected before monsoon.

Basker *et al.* (2006) investigated the impact of tsunami incident on the ground water of Pondichery. The analytical results of 203 water samples collected before tsunami were compared with the samples analysed after the incident for studying its impact on ground water of Pondichery. The results shown that there were no marked variations in the pH, EC or on their ionic composition between pre-tsunami and post-tsunami samples. Similarly, the quality indices like soluble sodium percentage (SSP), residual sodium carbonate (RSC), sodium adsorption ratio (SAR), potential salinity (SI), Puri's salt index (PSI), and permeability index (PI) did not show marked variation between the two stages.

Patil *et al.* (2014) collected 300 underground water samples from 30 villages of Ahmedpur tehsil of Latur district, Maharashtra and observed that during summer season EC and pH values varied from 0.478 to 1.310 dS m^{-1} and 7.18 to 8.81 with an average value of 0.812 dS m^{-1} and 7.93, while during winter season it was ranged from 0.236 to 1.012 dS m^{-1} and 7.12 to 8.68 with an average of 0.575 dS m^{-1} and 7.58, respectively. The increase in pH value during summer season might be due to increase in concentration of sodium dominated with carbonates and bicarbonates in summer season as compared to water sample collected during the winter season.

2.5 INTER-RELATIONSHIP AMONG AND BETWEEN SALINITY/SODICITY INDICES AND FERTILITY STATUS OF IRRIGATED SOILS

If the main chemical characteristics of irrigation water, saturation extract and saline-sodic soils bear some relationship between themselves, these can be utilized for a quick appraisal of the saline-sodic condition of soil on the basis of few sample analysis. Attempt have been made by several works in this direction with differing conclusions and limited success. Results of the main relationship are reviewed here.

Pandey *et al.* (2000) reported that the available P concentration had significant and positive relationship with pH (r = 0.386**), EC (r = 0.397**), organic carbon (r = 0.592**) and CEC (r = 0.367**). The available S was significantly and positively influenced by soil properties like pH (r = 0.521**), EC (r = 0.679**), organic carbon (r = 0.684**) and CEC (r = 0.679**) in Inceptisols of central Uttar Pradesh.

Maliwal and Timbadia (2000) studied on soils of Amreli district and found that EC and pH of irrigation water had significant and positive correlation with EC_e (r = 0.745 **) and pH_s (r = 0.895 **) of soil. Similarly, pH of soil is also correlated positively and significantly with RSC (r = 0.671*) and CO_3^{--} + HCO_3^- (r = 0.676 **) of well water. Correlation between SAR_{iw} and SAR of soil was found positive (r = 0.439). ESP of soils was positively correlated with RSC, and SSP of irrigation water with low coefficient value (r = 0.294) with SAR_{iw}. Such relationships were also reported by Paliwal and Maliwal (1971) and Lal *et al.* (1998) in well water and soils of western Rajasthan.

Prasad and Prasad (2001) observed that EC and pH of irrigation water were highly significantly correlated with EC_e (r = 0.914**) and pH (r = 0.394**) of soils. Similarly, SAR_{iw} was also correlated positively and significantly with SAR of soil (r = 0.386**).

Patel (2004) found that the simple correlation among fertility parameters (O.C., available N, P_2O_5, K_2O and S) and salinity/sodicity, parameters ($EC_{2.5}$, $pH_{2.5}$, $CaCO_3$, ESP and SAR) were worked of the soils of Surendranagar district. The examination of correlation values indicates significant positive relations of $EC_{2.5}$ with $pH_{2.5}$ (r=0.1714*), ESP (r=0.2964**), SAR (r=0.8778**), OC (r=0.1589*) and P_2O_5 (r=0.1476*). The $pH_{2.5}$ was significantly and positively correlated with $CaCO_3$ content (r=0.422**), ESP (r=0.7308**) and P_2O_5 (r=0.1943*). A significant positive correlation (r=0.2390**) was observed between ESP and SAR of soils. Organic carbon was significantly and positively correlated with available N (r=0.6932**) and available K_2O was also significantly and positively correlated with available N (r=0.1764*) and available P_2O_5 (r=0.1981*).

Kabaria (2004) studies the correlation between the different properties (EC, pH, RSC, SSP and SAR) of well/tube well water of Amreli district. The data indicate that EC was negatively correlated with pH (r= -0.1827**) of irrigation water. Highly significant positive correlations between EC and SSP (r= 0.3951**) and SAR (r= 0.8201**) of irrigation water were observed. Which indicate the SSP and SAR of irrigation water increase with increasing the EC of irrigation water. The pH of irrigation water were highly significantly positively correlated with RSC (r= 0.7259**), SSP (r= 0.3957**) and SAR (r= 0.1345*). The RSC of irrigation water significantly correlated with SSP (r= 0.4535**) and SAR (r= 0.2272**) of water. A highly significant correlation (r= 7637**) was observed between SSP and SAR of irrigation water.

Babar *et al.* (2007) were observed in Vidarbha region of Maharashtra. The forms of potassium except exchangeable and available K, were decreased with increase in depth. The available K, exchangeable K, total K and lattice K, influenced by total N (r=0.3268*, r=0.3122*, r=0.2950, r=0.3079*) respectively. The available K and exchangeable K was also affected by available N (r=0.9784**, r=0.9773**) respectively, in Vidarbha region. In Central Vidarbha available and exchangeable K influenced by total and available N respectively. In eastern Vidarbha the available K and exchangeable K influenced by total S and available N.

Waghmare *et al.* (2009) collected 100 surface soil samples for studied available N, P, and K in relation to chemical properties in soils of Ausa tahsil of Latur district. The data shows that these soils were neutral to alkaline in reaction, safe in EC, low to medium in organic carbon and non-calcareous to calcareous in nature. Considering soil nutrient index values these soils were medium in available N and P while high in respect of available K. Availability of N, P and K shows relationship with chemical characteristics. Further data showed that available N and P showed significant relationship with organic carbon. Available P showed negative correlation with pH and EC, whereas available K was significantly related with pH, EC, and $CaCO_3$.

Shirgire (2012) studied the Correlation between soil fertility and salinity/sodicity indices of soils and results indicated that EC_e had highly significantly positive relationships with $EC_{2.5}$ (r = 0.988**), SAR (r = 0.672**) and ESP (r = 0.484**). Similarly, pHs had highly significant and positive relations with $pH_{2.5}$ (r = 0.977**), RSC (r= 0.222**) and SAR (r= 0.234**). There was a highly significantly close correlation between $SAR_{2.5}$ and ESP (r = 0.487**) and $SSP_{2.5}$ (r=0,289**) obviously, the O.C. was significantly correlated with available N (r =0.626**), K_2O (r =0.179*) and B.D. (r=0.191**).

Gajare *et al.* (2013) reported that the available P_2O_5 was significantly negative correlated with pH (r = -0.362**) and $CaCO_3$ (r = -0.253*), while positively significantly correlated with organic carbon (r = 0.362**), while available S had significantly negative relationship with $CaCO_3$ (r = -0.311**).

Rajeshwar and Mani (2014) reported that the pH had significant positive correlation with EC, organic carbon and sulphur (r = 0.239*, 0.293* and 0.241*, respectively) and negatively correlated with $CaCO_3$ (r = -0.302*). Though, the pH had also positive correlation with CEC, available P_2O_5, Zn and Mn but not significant and showed negative correlation with available N, K_2O, and Fe respectively.

Tundup and Akbar (2014) reported that the available Zn, Cu, Mn and Fe was significantly and negatively correlated with pH (r = -0.183*), (r = -0.281*), (r = -0.455**) and (r = -0.367**), while positively significantly correlated with organic carbon (r = 0.417**), (r = 0.256*), (r = 0.395**) and (r = 0.422**), respectively.

2.6 INTER-RELATIONSHIP BETWEEN PROPERTIES OF IRRIGATION WATER AND IRRIGATED SOILS

Lal and Lal (1977) collected 47 water samples and an equal number of corresponding soil samples were analyzed for different constituents. Significant positive coefficient of correlation was found between both EC and potential salinity of irrigation water and EC_e of the irrigated soils. Similarly, significant positive coefficients of correlation were obtained between SAR and RSC of the water and ESP of the irrigated soils in respective soils.

Timbadia (1988) found significant relationship between EC of irrigation water and EC of saturation extract. A highly significant correlation between RSC of irrigation water and ESP (r = 0.877**) was observed.

Khandenwal *et al*. (1990) found that the EC_e of soils increased with increase in levels of salinity in irrigation water. The EC_e of soil (irrigated with water having EC 2, 4 and 6 dS m^{-1}) was 1.12, 2.21 and 3.03 dS m^{-1}, respectively, which was 56, 55.25 and 50.5 per cent of the EC of respective water used for irrigation. The pH of saturation paste decrease significantly with an increase in EC of irrigation water. The pH of soil irrigated with water having EC level 0.8, 2, 4 and 6 dS m^{-1} was 8.3, 8.24, 8.17 and 8.08, respectively.

Padole and Bhalkar (1995) found that the application of saline water (EC 4.2 dS m^{-1}) or saline-sodic water (EC 1.5 dS m^{-1} and SAR 8.2 and EC 4 dS m^{-1} and SAR

8.6) increased the soil pH, EC_e, ESP and SAR. Exchangeable Na decreased with the use of saline-sodic water (EC 1.5 dS m^{-1} & SAR 8.2). The correlation studies showed positive relationship between EC_{iw} and EC_e, SAR_{iw} and ESP and SAR_e and pH, while working at Akola. Girdhar (1996) observed that soil pH and ESP increased significantly with an increase in RSC and its adverse effect became additive at high SAR and EC of water.

Maliwal and Timbadia (2000) studied soils of Amreli district and found that EC and pH of irrigation water had significant and positive correlation with EC_e (r = 0.745 **) and pH_s (r = 0.895 **) of soil. Similarly, pH of soil is also correlated positively and significantly with RSC (r = 0.671*) and CO_3^{--} + HCO_3^- (r = 0.676 **) of well waters. Correlation between SAR_{iw} and SAR of soil was found positive (r = 0.439). ESP of soils was positively correlated with RSC, and SSP of irrigation water with low coefficient value (r = 0.294) with SAR_{iw}. Such relationships were also reported by Paliwal and Maliwal (1971) and Lal *et al.* (1998) in well waters and soils of Western Rajasthan.

Prasad and Prasad (2001) observed that EC and pH of irrigation water were highly significantly correlated with EC_e (r = 0.914**) and pH (r = 0.394**) of soils. Similarly, SAR_{iw} was also correlated positively and significantly with SAR of soil (r = 0.386**).

Hadiyal (2005) studied soils of Porbandar district and found highly significant and positive relationship between EC_{iw} with $EC_{2.5}$ (r = 0.3983**) and SAR_{se} (r = 0.4176**), while SSP_{iw} with positive correlation between SAR_{se} (r = 0.3447**) and SSP_{se} (r = 0.3584**). The SAR of irrigation water was significantly correlated with $EC_{2.5}$ (r = 0.4578**), SAR_{se} (r = 0.6524**) and ESP (r = 0.3782**).

Kabaria (2004) observed that EC of irrigation water were highly significantly correlated with $EC_{2.5}$ (r = 0.6279**), $pH_{2.5}$ (r = 0.3445**), SAR_{se} (r = 6299**), SSP_{se} (r = 0.4512**) and ESP (r = 0.3736**). The highly significant and positive correlation between pH_{iw} with $pH_{2.5}$ (r = 0.2627**) and ESP (r = 0.2543**). Similarly, RSC_{iw} was also correlated positively and significantly with $pH_{2.5}$ (r = 0.4511**) and ESP (r = 0.4666**). The SAR_{iw} was highly significantly correlated with $EC_{2.5}$ (0.5678**), $pH_{2.5}$ (0.5467**), SAR_{se} (0.6096**), SSP_{se} (0.4985**) and ESP (0.5807**).

Rajput (2010) observed that EC of irrigation water were highly significantly correlated with EC_e (r = 0.384**), $EC_{2.5}$ (r = 0.2721**), EC_5 (0.4094**). The highly significant and positive correlation between pH_{iw} with $pH_{2.5}$ (r = 0.2878**), pH_5 (r =

0.3639**) and $RSC_{2.5}$ (r = 0.2121**). The highly significant and positive correlation between RSC_{iw} with $pH_{2.5}$ (r = 0.2369**), pH_s (r = 0.2495**). Similarly, SSP_{iw} was also correlated positively and significantly with $SSP_{2.5}$ (r = 0.2349**) and SAR_{se} (r = 0.2415**).

CHAPTER – III

MATERIALS AND METHODS

The general features of Jamnagar, Devbhumi Dwarka and Porbandar districts viz., geographic location, physiography, geology, climate, soil, water, vegetation and cropping pattern are described below.

3.1 GENERAL INFORMATION OF JAMNAGAR DISTRICT

3.1.1 Geographic location

Jamnagar district lies between 21º 47' and 22º 57′ North latitude and 68º 57′ and 70º 37′ West longitude in the peninsular region in the north west, in the state of Gujarat (fig. 3.1). This district is bounded on the North by the Rann and Gulf of Kutch, on the East by Rajkot district, on the South by Junagadh district and on the West by the Arabian Sea. The Jamnagar district consist of 6 talukas viz., Jam Jodhpur, Jodiya, Dhrol, Jamnagar, Lalpur and Kalavad.

3.1.2 Physiography

Jamnagar district forms a part of *Kathiawar* peninsula and is subdivided into three regions, namely, the Coastal Plain including the Island offshore, the Plains and the Hills on the basis of topography, climate, geology, soils and natural vegetation.

3.1.3 Geology

The geographical formation of Saurashtra is of volcanic origin; hence the soils of Jamnagar district with the exception of a few strips are derived from trap rock. Geology of Jamnagar district are generally falls under position of residual, residual with colluviums and alluviums soils which derived from basalt, limestone and alluvium material. The most of the soils are derived from deccan trap of basalt.

3.1.4 Climate

The climate of Jamnagar district is generally pleasant and characterized by semi-arid to sub-humid region. The summer season extends from March to June, with day time temperature reaching to 42ºC. The monsoons are from July to September. Winter season sets in during October and extends till February. The Jamnagar and Jodiya talukas are susceptible to cyclonic storms or depressions in the Arabian Sea in the post monsoon months. Thunder storms occur in June and July. In the cold season occasional fog occurs. The summer temperature ranges from 24ºC to 42ºC and winter temperature ranges from 10ºC to 24ºC.

3.1.5 Soils

The following are the main soil types generally found in Jamnagar district-

- Medium Black soils
- Shallow Black soils
- Shallow to Medium Black soils
- Coastal Shallow soils
- Deep black soils

3.1.6 Water

Dhandhar River is a river near Lalpur. Dhandhar River is a monsoon river that has water only in the Monsoon season. It has a very less quantity of water in winters while the volume of water increases in the summer season. It flows nearby from Jamnagar's city Lalpur.

3.1.7 Natural Vegetation

Sr. No.	**Common Name**	**Botanical Name**
Trees and shrubs		
1	Aval	*Cassia auricuata*
2	Asopalav	*Polyalthia longifolia*
3	Piludi	*Salvadora persica*
4	Baval	*Acacia arabica*
5	Khijdo	*Prosopis cineraria*
6	Neem	*Azadirechta indica*
7	Jamfal	*Psidium guajava*
8	Kantado thor	*Euphorbia nivadia*
9	Vad	*Ficus bengalem*
10	Mitho saragvo	*Moringa olefera*
11	Gorus ambali	*Pithecellobium duica*
12	Khakhro	*Butea momosperma*
13	Kerda	*Capparis decidua*
14	Samadi	*Euphorbia nerifollia*
15	Gandobaval	*Prosopis juliflora*

16	Bordi	*Ziziphus rotandifolia*
17	Jipto	*Triumfetta rotundifolia*
18	Desi Baval	*Acacia nilotica*
19	Ber (chania)	*Zizyphus nummularia*
20	Amaltas	*Cassia fistula*
21	Saru	*Casuarinas equisetifolia*
22	Gunda	*Cordial myxa*
23	Gulmohar	*Delonix regia*
24	Bamboo	*Dendrocalamus strictus*
25	Amla	*Emblica officinalis*
26	Sitaphal	*Anona squamosa*
27	Glyricidia	*Glyricidia maculate*
28	Su-babul	*Leucaena leucocephala*
29	Mahua	*Madhuka latifolia*
30	Mango	*Mangifera indica*
31	Sargvo	*Moringa oleifera*
32	Shatur	*Morus alba*
33	Karanj	*Pongamia pinnata*
34	Ambli	*Tamarindus indica*
35	Rain tree	*Samania saman*
36	Aritha	*Sepindus mukorossi*
37	Nariyali	*Cocos nucifera*
38	Citrus	*Citrus aurantifolia*
Grasses and weeds		
1	Gokhru	*Tridex procumbens*
2	Kala Bhangro	*Eciypta erecta*
3	Dhatura	*Datura stramonium*
4	Barru	*Sorghum halphense*
5	Pardesi Bhangaro	*Argemon maxicana*
6	Dharo	*Cynodon dectylon*
7	Agiya	*Striga lutera*
8	Phulni	*Vernonin cinaria*

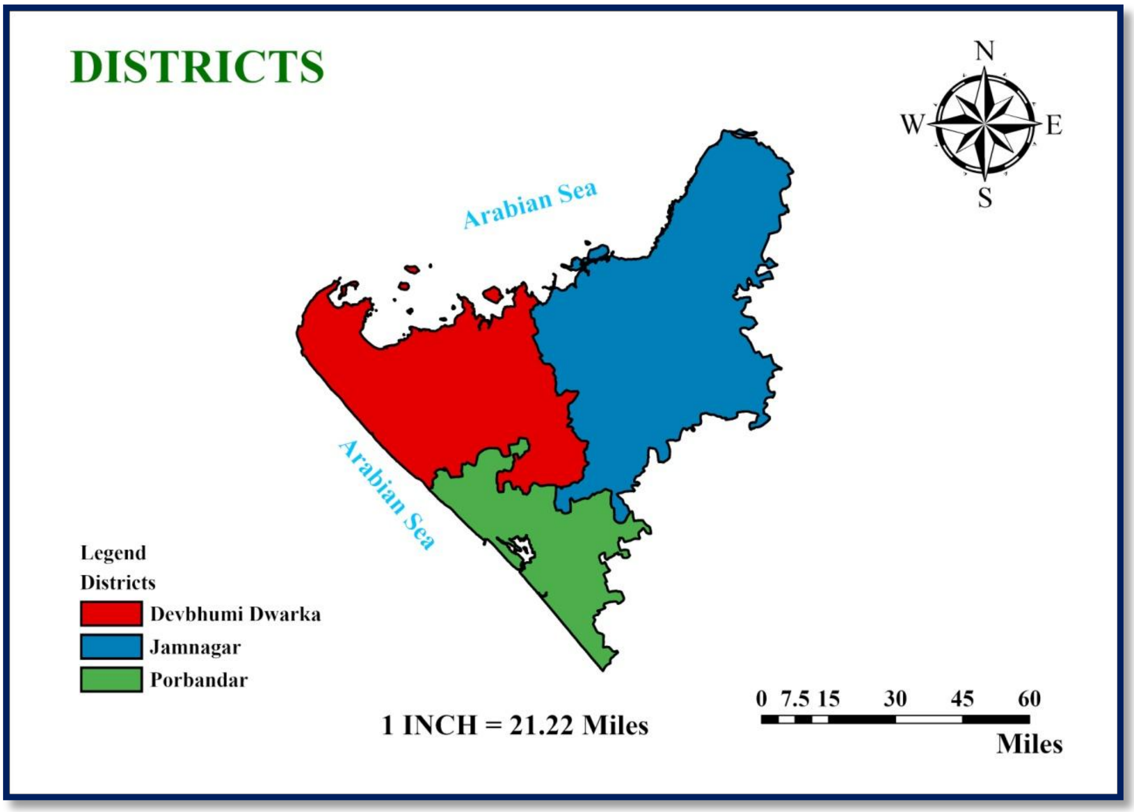
9	Gaderdi	*Xanthium strumarium*
10	Darudi	*Argemon annulatum*
11	Amar bel	*Cuscuta reflexa*
12	Zinzavo	*Dicanthium annulatum*
13	Chidho	*Cyprus rotandus*
14	Dudheli	*Euphorbia macrophylla*
15	Hazar dana	*Phyllanthus niruri*
16	Baghnakhi	*Martynia diandra*
17	Jangali joot	*Corcorus fascicularis*
18	Nagphani	*Opuntia dillenia*
19	Nori	*Ipomoea reptans*

3.1.8 Agriculture

Majority areas of the Jamnagar district are rainfed agriculture except villages of Jamnagar and Jodiya talukas receiving water from canal and groundwater source. The major *kharif* crops include groundnut, cotton, castor and bajra, sesame, moth bean, green gram and black gram. The jowar is cultivated for fodder purpose. The *rabi* crops include wheat, garlic, onion and cumin. The vegetable and horticulture crops are grown on 2 % agriculture land.

3.1.9 Cropping pattern

The *kharif* crops are sown in June-July and harvested in September-October and *rabi* crops are sown in September-October and harvested in February-March. The main *kharif* crops in the district are groundnut, jowar and cotton, while wheat and gram are important *rabi* crops. Jowar is grown both as *rabi* and *kharif* crop. The other crops taken in the monsoon are sesame, cotton, bajra and jowar etc. in the areas where irrigation water is not available. But, where irrigation water is available, double cropping follows and crops like- wheat, gram and cumin etc. are under cultivation.



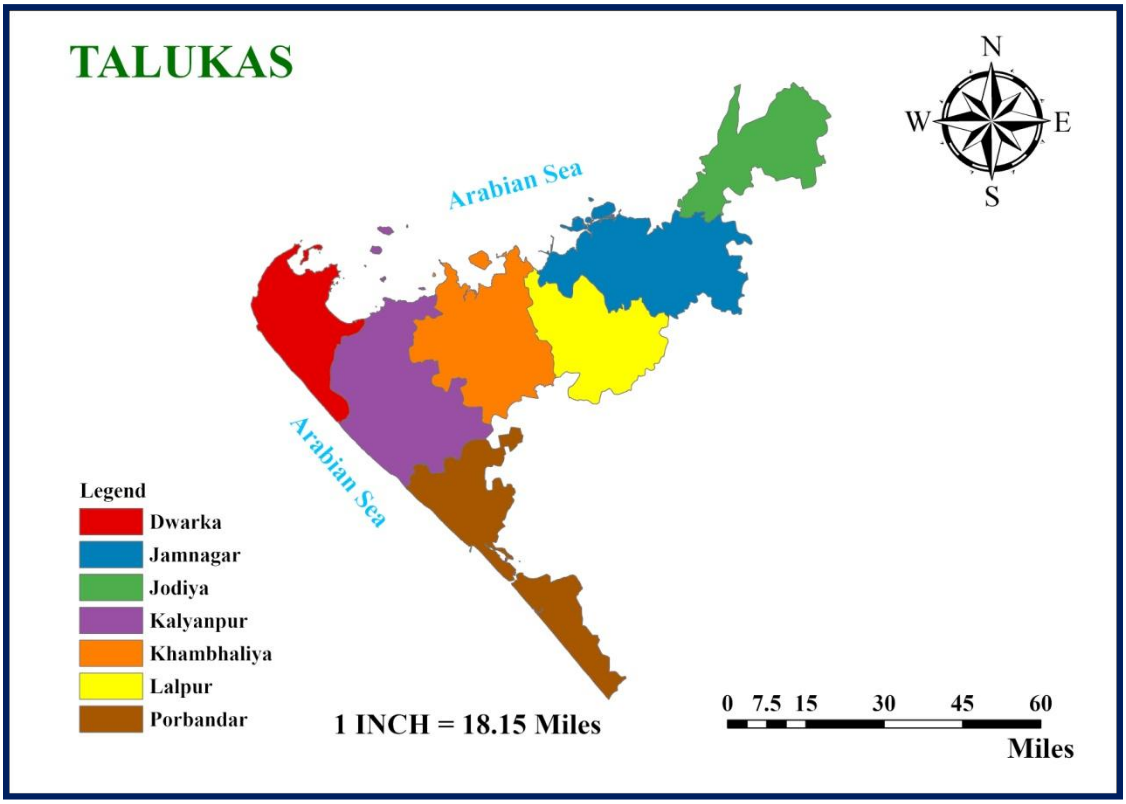


Fig 3.1: Map of survey talukas of Jamnagar, Devbhumi Dwarka and Porbandar district

3.2 GENERAL INFORMATION OF DEVBHUMI DWARKA DISTRICT

3.2.1 Geographic location

Devbhumi Dwarka district is situated in the Northern Saurashtra part of the state having four talukas *viz*., Dwarka, Bhanvad, Kalyanpur and Khambhalia. This district is bounded by the Porbandar, Jamnagar district and Arabian Sea (fig. 3.1).

3.2.2 Physiography

Devbhumi Dwarka district forms a part of *Kathiawar* peninsula and is subdivided into three regions, namely, the Coastal Plain including the Island offshore, the Plains and the Hills on the basis of topography, climate, geology, soils and natural vegetation.

3.2.3 Geology

Geology of Devbhumi Dwarka district are generally falls under position of residual, residual with colluviums and alluviums soils which derived from basalt, limestone and alluvium material. The most of the soils are mainly derived from deccan trap of basalt and Gujarat beds. South western parts of the district have alluvium soil and generally derived from milliolite. North side of district consists of basalt and basalt with lime stone.

3.2.4 Climate

The climate of this district is characterized by semi-arid to sub humid region. The climate of Dwarka, Kalyanpur and Khambhalia taluka of Devbhumi Dwarka district is susceptible to cyclone storm due to nearness of Arabian Sea. The year may be divided into three seasons. The cold season from December to February is followed by the hot season from March to May. June to September is south-west monsoon season. In past maximum temperature was observed 40 ^{o}C and minimum temperature was observed 9.2 ^{o}C. The summer season is slightly hot.

3.2.5 Soils

Devbhumi Dwarka district mainly have five types of soils.

- Shallow Black soils
- Medium Black soils
- Mix Red and Black soils
- Shallow to Medium Black soils
- Coastal Shallow soils

3.2.6 Water

"*Hiran*" river passes from Bhanvad taluka. "*Shindhni*" river passes Kalyanpur taluka. "*Ghee*" river passes from Khambhalia taluka. The rainfall is uneven and scanty in Devbhumi Dwarka district therefore irrigation practices followed by using wells/tube wells water. So, for intensive agriculture conserving the rain water by wells, dam, farm ponds are necessary.

3.2.7 Natural Vegetation

The area under study is occupied partly by arable land and partly by natural grass or weed lands and scattered shrubs. Alternating with these grass lands or weed lands, there are entirely barren stretches. The natural vegetation observed in surveyed area are as under.

Sr. No.	**Common Name**	**Botanical Name**
Trees and shrubs		
1	Aval	*Cassia auricuata*
2	Akado	*Calotropis procera*
3	Piludi	*Salvadora persica*
4	Baval	*Acacia arabica*
5	Khijdo	*Prosopis cineraria*
6	Neem	*Azadirechta indica*
7	Pipal	*Populous ciliate*
8	Kantado thor	*Euphorbia nivadia*
9	Vad	*Ficus bengalem*
10	Mitho saragvo	*Moringa olefera*
11	Gorus ambali	*Pithecellobium duica*
12	Khakhro	*Butea momosperma*
13	Kerda	*Capparis decidua*
14	Samadi	*Euphorbia nerifollia*
15	Gandobaval	*Prosopis juliflora*
16	Bordi	*Ziziphus rotandifolia*
17	Jipto	*Triumfetta rotundifolia*
18	Desi Baval	*Acacia nilotica*
19	Ber (chania)	*Zizyphus nummularia*

20	Amaltas	*Cassia fistula*
21	Saru	*Casuarinas equisetifolia*
22	Gunda	*Cordial myxa*
23	Gulmohar	*Delonix regia*
24	Bamboo	*Dendrocalamus strictus*
25	Amla	*Emblica officinalis*
26	Sitaphal	*Anona squamosa*
27	Glyricidia	*Glyricidia maculate*
28	Su-babul	*Leucaena leucocephala*
29	Mahua	*Madhuka latifolia*
30	Mango	*Mangifera indica*
31	Sargvo	*Moringa oleifera*
32	Shatur	*Morus alba*
33	Karanj	*Pongamia pinnata*
34	Ambli	*Tamarindus indica*
35	Rain tree	*Samania saman*
36	Aritha	*Sepindus mukorossi*
37	Citrus	*Citrus aurantifolia*
Grasses and weeds		
1	Gokhru	*Tridex procumbens*
2	Kala Bhangro	*Eciypta erecta*
3	Dhatura	*Datura stramonium*
4	Barru	*Sorghum halphense*
5	Pardesi Bhangaro	*Argemon maxicana*
6	Dharo	*Cynodon dectylon*
7	Agiya	*Striga lutera*
8	Phulni	*Vernonin cinaria*
9	Gaderdi	*Xanthium strumarium*
10	Darudi	*Argemon annulatum*
11	Amar bel	*Cuscuta reflexa*
12	Zinzavo	*Dicanthium annulatum*
13	Chidho	*Cyprus rotandus*

14	Dudheli	*Euphorbia macrophylla*
15	Hazar dana	*Phyllanthus niruri*
16	Baghnakhi	*Martynia diandra*
17	Jangali joot	*Corcorus fascicularis*
18	Nagphani	*Opuntia dillenia*
19	Nori	*Ipomoea reptans*

3.2.8 Agriculture

Majority areas of Devbhumi Dwarka district are rain-fed agriculture, except village of Dwarka, Bhanvad, Kalyanpur Talukas receiving water from canal and ground water source. The cropping pattern includes all varieties of food, cash and horticulture crops. The major *kharif* crops include groundnut, cotton, castor and bajara, sesame, green gram, moth bean and black gram crops. The jowar is cultivated for fodder purpose. The *rabi* crops include wheat, garlic, coriander, onion and cumin.

3.2.9 Cropping pattern

Groundnut is extensively grown throughout the district in rainy season. The other crops taken in monsoon are sesame, cotton, bajara, sorghum, castor and vegetable etc. Mostly the single or double cropping pattern is followed in the district. The double cropping system is followed in areas where irrigation facilities are available. In *rabi* season, where irrigation water is available, gram, wheat, coriander, cumin and onion crops are grown.

3.3 GENERAL INFORMATION OF PORBANDAR DISTRICT

3.3.1 Geographic location

The name Porbandar itself conjures a picture of massive port, a city connected with the two names- Sudama, the childhood friend of Lord Krishna and Mahatma Gandhi, the father of Nation. Porbandar district is situated in the Southern part of the state having three talukas *viz*., Porbandar, Ranavav and Kutiyana. This district was carved out of Junagadh District. This district is surrounded by Jamnagar district and Devbhumi Dwarka to the North, Junagadh district and Rajkot district to the East and the Arabian Sea to the West and South (fig. 3.1). The Porbandar district is situated between the parallels of latitude 21^o 20' and 22^o 10' and the meridians of longitude (69^o 40' and 70^o 10').

3.3.2 Physiography

Porbandar district lies on the Kathiawar peninsula and is subdivided into three regions, namely, the Coastal Plain including the Island offshore, the Plains and the Hills on the basis of topography, climate, geology, soils and natural vegetation.

3.3.3 Geology

The geology of Porbandar district is mainly composed of alluvium, brown sand etc, deccan traps, Inter-trappean beds. The alluvium soil found in the plain areas of the district is known as ‘Ghed’ and these are fertile soil however, the soils of Ghed area with typical characteristics like clay in texture and alkali in nature due to low leaching. In Ghed area, the crops like gram and jowar are cultivated in conserved moisture in rabi season. This soil is black soil, found more or less in all talukas of Porbandar district. The district has good deposits of limestone and chalk clay. Some patches of forests are found in the district.

3.3.4 Climate

Like most of Gujarat, Porbandar has a hot semi-arid climate with three distinct seasons: the “cool” from October to March, the “hot” in April, May and early June, and the monsoonal “wet” from mid-June to September. Almost no rain falls outside the monsoon season, except for a very few late-season tropical cyclones. Porbandar, owing to its coastal location, is the least hot of all major cities in Gujarat. Average high temperatures do not reach 35 °C or 95 °F in any month.

3.3.5 Soils

The soils of Porbandar district may be classified into two main categories:

- Shallow to Medium black soils
- Deep black soil (Ghed area)
- Coastal alluvial soils

Shallow to Medium black soils are very widespread and occurs in 75 % of the area and are found almost in all the talukas. They are more productive and are rich in lime, magnesia and alumina and poor in phosphorous, nitrogen and organic matters. They can retain considerable moisture and are much suitable for agricultural.

Coastal alluvial soils are found in coastal parts of Porbandar taluka where the soils are less productive as they are saline.

3.3.6 Water

The major river draining the district in the north and eastern part is Bhadar River. The other rivers draining the eastern part of the district are Bobadi river, Minsar river and Kalinder nadi. These rivers flow from north to south in direction except the Ojat river which meets Bhadar river flows from south west to north east in direction. The river draining the area in north of the district are Kaman river and Vartu river. The river flow from east to west in direction

3.3.7 Natural Vegetation

Sr. No.	**Common Name**	**Botanical Name**
Trees and shrubs		
1	Aval	*Cassia auricuata*
2	Akado	*Calotropis procera*
3	Piludi	*Salvadora persica*
4	Baval	*Acacia arabica*
5	Khijdo	*Prosopis cineraria*
6	Neem	*Azadirechta indica*
7	Pipal	*Populous ciliate*
8	Kantado thor	*Euphorbia nivadia*
9	Vad	*Ficus bengalem*
10	Mitho saragvo	*Moringa olefera*
11	Gorus ambali	*Pithecellobium duica*
12	Khakhro	*Butea momosperma*
13	Kerda	*Capparis decidua*
14	Samadi	*Euphorbia nerifollia*
15	Gandobaval	*Prosopis juliflora*
16	Bordi	*Ziziphus rotandifolia*
17	Jipto	*Triumfetta rotundifolia*
18	Desi Baval	*Acacia nilotica*
19	Ber (chania)	*Zizyphus nummularia*
20	Amaltas	*Cassia fistula*

21	Saru	*Casuarinas equisetifolia*
22	Gunda	*Cordial myxa*
23	Gulmohar	*Delonix regia*
24	Bamboo	*Dendrocalamus strictus*
25	Amla	*Emblica officinalis*
26	Sitaphal	*Anona squamosa*
27	Glyricidia	*Glyricidia maculate*
28	Su-babul	*Leucaena leucocephala*
29	Mangrove	*Rhizophora mangle*
30	Mango	*Mangifera indica*
31	Sargvo	*Moringa oleifera*
32	Shatur	*Morus alba*
33	Karanj	*Pongamia pinnata*
34	Ambli	*Tamarindus indica*
35	Rain tree	*Samania saman*
36	Aritha	*Sepindus mukorossi*
37	Citrus	*Citrus aurantifolia*
Grasses and weeds		
1	Gokhru	*Tridex procumbens*
2	Kala Bhangro	*Eciypta erecta*
3	Dhatura	*Datura stramonium*
4	Barru	*Sorghum halphense*
5	Pardesi Bhangaro	*Argemon maxicana*
6	Dharo	*Cynodon dectylon*
7	Phulni	*Vernonin cinaria*
8	Gaderdi	*Xanthium strumarium*
9	Darudi	*Argemon annulatum*
10	Amar bel	*Cuscuta reflexa*
11	Zinzavo	*Dicanthium annulatum*
12	Chidho	*Cyprus rotandus*
13	Dudheli	*Euphorbia macrophylla*
14	Hazar dana	*Phyllanthus niruri*

15	Baghnakhi	*Martynia diandra*
16	Jangali joot	*Corcorus fascicularis*
17	Nagphani	*Opuntia dillenia*
18	Nori	*Ipomoea reptans*

3.2.8 Agriculture

Porbandar is primarily an agricultural district with groundnut and cotton as the predominant crops. The other major crops cultivated are wheat, cumin and til etc. About 60% of land holdings are with small and marginal farmers and the average size of the holdings is 2.35 ha.

3.3.9 Cropping pattern

Major crops being grown in the district are groundnut, gram, cotton, wheat, bajra and jowar, pulses and sugarcane. Groundnut is the most important crop of the district with about 66% of total cultivated area under this crop. This has given rise to development of oil mills-producing and processing groundnut oil. Second most important crop in the district is gram grown on about 17% of the cultivated land.

3.4 COLLECTION OF WATER AND SOIL SAMPLES

Soil and water samples were collected from distance demarcation of 0-5, 5-10, 10-15 and 15-20 km from sea coast through use of GPS. The twenty surface soil samples and forty each pre-monsoon underground water samples of wells/tube wells were collected from 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 the summer season of year 2019.

In order, to study the fluctuation in quality of underground well/tube well water, only water samples were collected twice i.e. before (May, 2019) and after monsoon (December, 2019). Before collecting the water samples, the pump is let to run for half an hour and rinse the plastic bottles of capacity-500 ml with that water. The underground well/ tube well water samples were collected, filtered and stored in the plastic bottle by adding few drops of toluene.

Plate 3.1: Collection of samples by using hand held GPS and laboratory analysis of samples

The forty each post-monsoon water samples were also collected from same well/ tube well from where pre-monsoon samples were drawn from taluka viz. Jodiya, Jamnagar and Lalpur talukas of Jamnagar district, Khambhalia, Dwarka and Kalyanpur talukas of Devbhumi Dwarka districst and Porbandar taluka of Porbandar district of Northern Saurashtra Coastal region of Gujarat during the summer season.

Total 141 soil and 285 irrigation water samples were collected before monsoon (May, 2019) and only 285 irrigation water samples were collected after monsoon (December, 2019). List of village with the name of farmers for each taluka are given in Appendix-I. The methods employed for chemical analysis of soil and water samples and for statistical analysis are as under.

3.5 PREPARATION OF SOIL SAMPLES

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

3.6 METHODS OF IRRIGATION WATER SAMPLE ANALYSIS

The underground well/tube well water samples were collected, filtered and stored in the plastic bottle putting a layer of toluene. The methods used for analysis of different constituents of water are as under.

Table 3.1: Methods used for analysis of irrigation water samples

Characteristics	Methods used	Reference
pH	pH meter	Richards (1954)
EC	Conductivity meter	Richards (1954)
CO_3^{--} & HCO_3^-	Titration with sulphuric acid	Reitemeir (1943)
Cl^-	$AgNO_3$ precipitation method	Richards (1954)
SO_4^{--}	Turbidity method	Chesnin and Yien (1950)
Na^+	Flame photometrically	Richards (1954)
K^+	Flame photometrically	Richards (1954)
Ca^{++}	Versenate method	Cheng and Bray (1951)
Mg^{++}	Versenate method	Cheng and Bray (1951)

The following water quality indices were calculated by standard formulas for categorization purpose.

1) Soluble Sodium Percentage (SSP)

$$SSP = \frac{Na^{+}}{(Na^{+} + Ca^{++} + Mg^{++} + K^{+})} \times 100$$

(Concentration of all cations are in me L^{-1})

2) Sodium Adsorption Ratio (SAR)

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{++}+Mg^{++})/2}}$$

(Concentration of all cations are in me L^{-1})

3) Residual Sodium Carbonate (RSC)

$$RSC = (CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$$

(All ionic concentrations are in me L^{-1})

3.7 CHEMICAL ANALYSIS OF SOIL SAMPLES

For the analysis of water soluble cations and anions in surface soil samples, 1:2.5 soil-water ratios were used. The soil EC, pH, water soluble cations (Na^{+}, K^{+}, Ca^{++} and Mg^{++}) as well as anions (Cl^{-}, CO_3^{--}, HCO_3^{-} and SO_4^{--}) were determined as per the methods described by Richards (1954).

The exchangeable cations (Na^{+}, K^{+}, Ca^{++} and Mg^{++}) were determined by neutral normal ammonium acetate method as described by Richards (1954).

Saturation paste of soil was prepared as described by Richards (1954). The extract was obtained after transferring the paste on the Buchner funnel under vacuum. These extract were utilized for determination of EC_e and pH_s as per the methods described for irrigation water analysis.

Other soil properties were determined by methods given in table 3.2.

Table 3.2: Chemical methods used for analysis of soil samples

Chemical characteristics	Method	Reference
EC (1:2.5 and Saturation extract)	Conductivity meter	Richards (1954)
pH (1:2.5 and Saturation extract)	pH meter	Richards (1954)
Exchangeable cations		

Sodium	Flame photometrically	Richards (1954)
Potassium	Flame photometrically	Richards (1954)
Calcium	Versenate method	Cheng and Bray (1951)
Magnesium	Versenate method	Cheng and Bray (1951)
CEC (cmol(p^+) kg^{-1})	Ammonium acetate method	Chapman (1965)
Available nutrients		
Organic carbon	1 N $K_2Cr_2O_7$ method	Walkley and Black(1935)
Available N	Alkaline $KMnO_4$ method	Subbiah and Asija (1956)
Available P_2O_5	0.5 M $NaHCO_3$ (pH 8.5) method	Olsen *et al*. (1954)
Available K_2O	1 N NH_4OAc method	Jackson (1973)
Available S	Heat soluble	Williams and Stainbergs (1959)
Available micronutrient (Fe, Mn, Cu and Zn)	DTPA extractable	Lindsay and Norvell (1978)
Free $CaCO_3$ content	Acid neutralization method	Piper (1950)
Available Boron	Atomic Absorption Spectrophotometer	Tan (1996)

3.8 RATINGS USED FOR WATER QUALITY AND SOIL APPRAISAL

The results of water and soil analysis were appraised in view of the salinity/sodicity indices and fertility rating mentioned below,

3.8.1 Rating used for water quality appraisal

3.8.1.1 Electrical conductivity (Richards, 1954)

EC (dS m^{-1} at 25°C)	Symbol	Salinity class
0-0.25	C_1	Low
0.25-0.75	C_2	Medium
0.75-2.25	C_3	High
2.25-5.00	C_4	Very high

3.8.1.2 Sodium Adsorption Ratio (Richards, 1954)

SAR value	Symbol	Class
0-10	S_1	Low Na^+ water
10-18	S_2	Medium Na^+ water
18-26	S_3	High Na^+ water
>26	S_4	Very high Na^+ water

3.8.1.3 Residual Sodium Carbonate (Eaton, 1950)

RSC (me L^{-1}) value	Class
<1.25	Safe
1.25-2.50	Marginal
>2.50	Unsafe

3.8.1.4 Soluble Sodium Percentage (Richards, 1954)

Sr. No.	SSP	Class
1.	<60	Good
2.	>60	Fair

3.8.2 Rating used for categorizing the soil

3.8.2.1 Soil salinity / sodicity status

3.8.2.1.1 Electrical Conductivity of saturation extract (EC_e in dS m^{-1}).

Sr. No.	EC_e (dS m^{-1})	Salinity class	Effect on plant growth
1	0-2	Normal soil	Salinity effects mostly negligible
2	2-4	Low saline soil	Yield of very sensitive crops may be restricted
3	4-8	Moderate saline soil	Yield of many crops restricted
4	8-16	Saline soil	Only tolerant crops yield satisfactorily
5	>16	Highly saline soil	Only a few very tolerant crops yield satisfactorily

(Richards, 1954)

3.8.2.1.2 Exchangeable Sodium Percentage (ESP)

Sr. No.	ESP	Class
1.	<15	No alkalinity
2.	15-25	Slight alkalinity
3.	25-35	Moderate alkalinity
4.	35-50	Strong alkalinity
5.	>50	Very strong alkalinity

(Richards, 1954)

3.8.2.1.3 Sodium Adsorption Ratio (SAR)

Sr. No.	SAR	Class
1.	<10	I
2.	10-18	II
3.	18-26	III
4.	>26	IV

(Richards, 1954)

3.8.2.1.4 Soluble Sodium Percentage (SSP)

Sr. No.	SSP	Class
1.	<60	Good
2.	>60	Fair

3.8.2.2 Classification of salt affected soils

By making use of EC_e and exchangeable sodium percentage (ESP) of the soil, the criteria as initially suggested by Richards (1954), total 141 soil samples were collected from the different talukas of Devbhumi Dwarka, Porbandar and Jamnagar district and categorized into three classes viz., saline, saline-sodic and sodic as below.

Salt affected soils	EC_e (dS m^{-1})	pH_s	ESP
Saline	>4	<8.5	<15
Saline-sodic	>4	8.5-10.0	>15
Sodic	<4	>8.5	>15

3.8.2.3 Soil fertility status

Parameters	Low	Medium	High
Organic carbon (%)	< 0.5	0.5-0.75	> 0.75
Available N (kg ha^{-1})	< 250	250-500	> 500
Available P_2O_5 (kg ha^{-1})	< 28	28-56	> 56
Available K_2O (kg ha^{-1})	< 140	140-280	> 280
Available S (mg kg^{-1})	< 10	10-20	> 20
DTPA extractable Fe (mg kg^{-1})	< 5	5-10	> 10
DTPA extractable Mn (mg kg^{-1})	< 5	5-10	> 10
DTPA extractable Zn (mg kg^{-1})	< 0.5	0.5-1.0	> 1.0
DTPA extractable Cu (mg kg^{-1})	< 0.2	0.2-0.4	> 0.4

(Kanwar, 1976)

3.8.2.4 Nutrient index (NI): Nutrient index was calculated utilizing the following formula,

$$\frac{(Nl \times 1) + (Nm \times 2) + (Nh \times 3)}{Nt}$$

Where, Nl, Nm and Nh are the number of soil samples falling in low, medium and high categories for nutrient status and are given weightage of 1, 2 and 3, respectively. Nt is the total number of samples.

Parker *et al.* (1951) classified this index as low (< 1.5), medium (1.5 to 2.5) and high (> 2.5) giving undue weightage to medium category.

3.9 Statistical analysis

The data were generated by analysis of soil and water sample and these were statistically analyzed for correlation studies as per method given by Panse and Sukhatme (1985).

CHAPTER- IV

RESULTS AND DISCUSSION

The results of analysis of chemical characteristics and fertility status of soils, well/tube well water samples collected before and after monsoon, fluctuation in water quality, inter-relationship among and between salinity/sodicity indices and fertility status of soils and inter-relationship between the properties of wells/tube wells water and irrigated soils are presented and discussed in the succeeding pages. The details of the soil samples collected from farmer's cultivated field of different talukas of Jamnagar, Devbhumi Dwarka and Porbandar district are given in Appendix-I.

The findings of the present investigation have been described in the following sub-head:

4.1 CHEMICAL PROPERTIES AND SALINITY/SODICITY STATUS OF THE SOILS

4.2 FERTILITY STATUS AND NUTRIENT INDEX OF THE SURFACE SOIL

4.3 QUALITY OF UNDERGROUND IRRIGATION WATER

4.4 PERIODICAL CHANGES IN WATER QUALITY

4.5 INTER-RELATIONSHIP AMONG AND BETWEEN SALINITY/SODICITY INDICES AND FERTILITY STATUS OF IRRIGATED SOILS

4.6 INTER-RELATIONSHIP BETWEEN PROPERTIES OF IRRIGATION WATER AND IRRIGATED SOILS

4.1 CHEMICAL PROPERTIES AND SALINITY/SODICITY STATUS OF THE SOILS

4.1.1 Chemical properties

Soil samples were analyzed for chemical properties *viz*; $EC_{2.5}$, $pH_{2.5}$, free lime, organic carbon and CEC by using standard methods. Sample wise values for different chemical parameters for all the 141 soil samples of Northern Saurashtra coastal region are given in Appendix II, III and IV and talukawise range and mean values are given in tables 4.1.1 to 4.1.5.

4.1.1.1 $EC_{2.5}$

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 4.1.1). 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. Polara *et al*. (2006) while working at north west agro climatic zone of Gujarat State reported that about 27.0 per cent samples with $EC_{2.5}$<0.5 dS m^{-1}, while 22.7 per cent samples with $EC_{2.5}$ between 0.50 to 0.90 dS m^{-1} and rest of the samples have moderate to high salinity.

Similar results were also obtained for Girnar toposequence by Gandhi (2013), for Patan district by Patel *et al*. (2016), Reddy and Naidu (2016) for Kapada district of Andhra Pradesh and Wagh *et al.* (2016) for Nagpur district of Maharashtra.

Table 4.1.1: 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**

4.1.1.2 $pH_{2.5}$

In general, the soil samples of Northern Saurashtra coastal region were slightly alkaline in reaction. The overall $pH_{2.5}$ values of Northen Saurashtra's soil samples were ranged from 7.20 to 8.59 with mean value of 7.78. The data (Table 4.1.2) 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. The lowest value of $pH_{2.5}$ (7.20) was recorded in the samples collected from Jamnagar taluka in Jamnagar district, whereas the highest value of $pH_{2.5}$ (8.59) was found in Dwarka taluka of Devbhumi Dwarka district. Overall, soil $pH_{2.5}$ was below its critical limit in coastal region of North Saurashtra. Similar results were also obtained for Pedapuluguvaripalem village of Guntur district by Nandy *et al*. (2013), for Patan district by Patel *et al*. (2016), Reddy and Naidu (2016) for Kapada district of Andhra Pradesh, Wagh *et al*. (2016) for Nagpur district of Maharashtra and Vaghela (2017) for Kheda district of Gujarat.

4.1.1.3 Free Lime ($CaCO_3$)

Along with salinity parameters, free lime (equivalent) content in soils was also estimated by the rapid acid neutralization method and values are reported in table 4.1.3. 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} 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 Northen Saurashtra coastal region. The highest mean value of 205.67 g kg^{-1} was recorded in soils of Porbandar taluka and the lowest mean value of 60.93 g kg^{-1} was found in soils of Porbandar Lalpur. In Jamnagar

Table 4.1.2: Talukawise range and mean values of $pH_{2.5}$ in different districts of Northern Saurashtra coastal region

Talukas \ Distance (km)	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 4.1.3: 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
Dev Bhumi 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 a	**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**

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 Dwarka district, whereas the highest value of free lime 420.31 g kg^{-1} was found in Porbandar taluka of Porbandar district. High content of $CaCO_3$ in salt affected soils of coastal areas were also observed by Kabaria (2004) for the soils of Amreli district. Similarly, Polara *et al.* (2006) also observed similar results for the soils of north-west agro climatic zone of Gujarat, Sojitra (2010) for Junagadh district, Rajput and Polara (2012) for Bhavnagar district, Gajare *et al*. (2013) for Latur district and Vaghela (2017) for Kheda district.

4.1.1.4 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 4.1.4, Fig 4.1 and 4.2). 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

Table 4.1.4: Talukawise range and mean values of SOC (g kg^{-1}) in different districts of Northern Saurashtra coastal region

Talukas / Distance (km)	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**

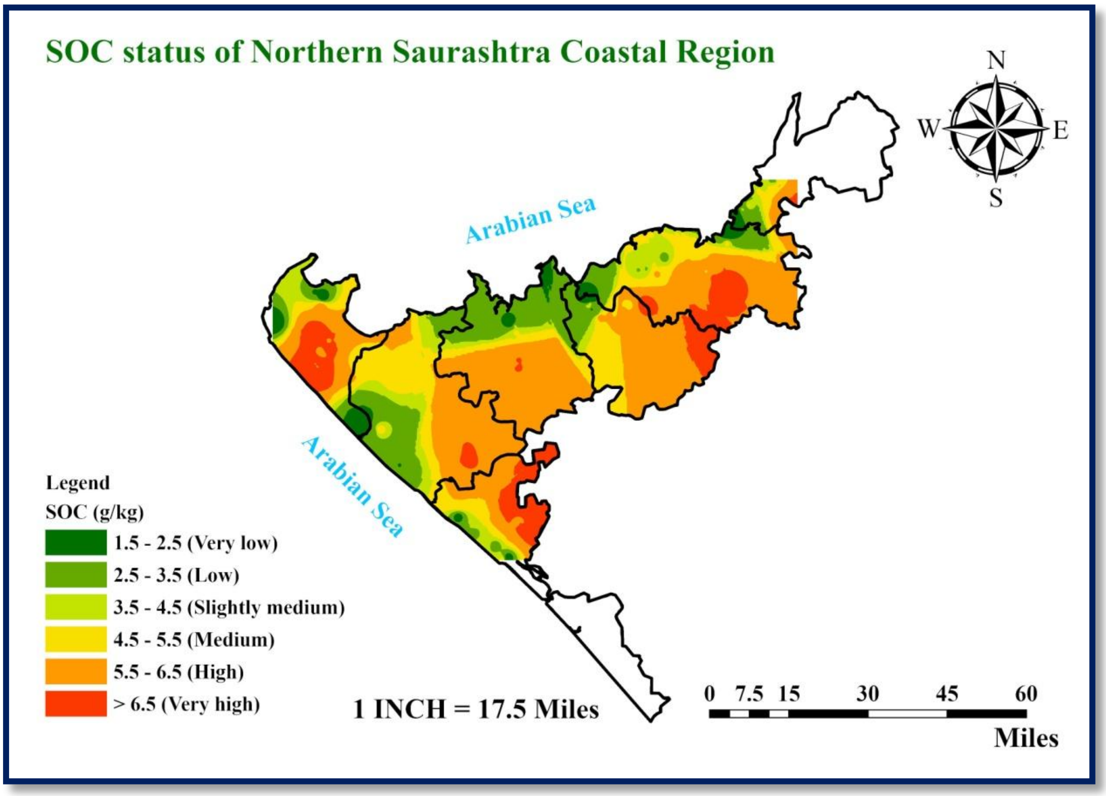


Fig. 4.1: Map of overall SOC status in coastal soils of Northern Saurashtra region

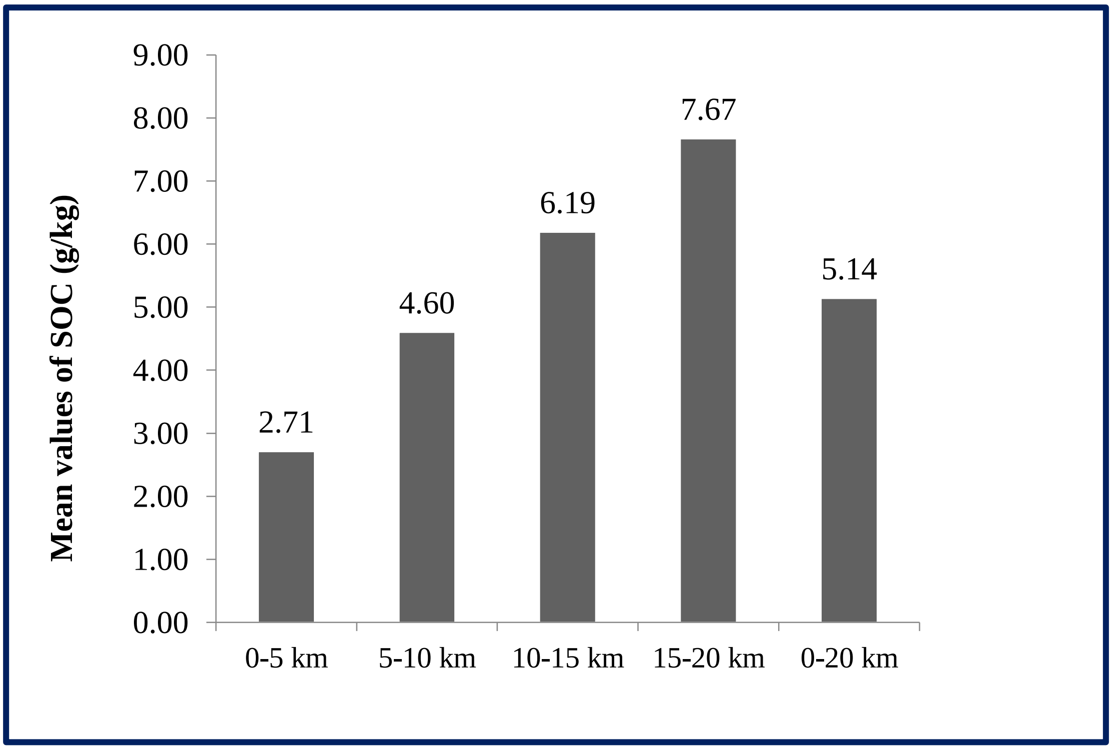


Fig. 4.2: Overall SOC status in coastal soils of Northern Saurashtra region

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 upto 10 km distance fron sea coast in North Saurashtra which might be due to salinity hazard and shallow light texture. Similar findings were made by Polara *et al*. (2006) for the north west agro climatic zone of Gujarat, by Punithraj *et al.* (2012) for Hassan district of Karnataka, by Singh (2014) for Degana tahsil, Nagaur district of Rajasthan, for Kishtwar district of Jammu and Kashmir by Tundup and Akbar (2014), for Veeranam command area of Cuddalore district of Tamil Nadu by Arunkumar and Paramasivan (2015), by Hadiyal *et al*. (2016) for Gir Somnath district and Nagaral *et al*. (2016) for Haveri, Gadag and Dharwad districts of Karnataka.

4.1.1.5 Cation Exchange Capacity (CEC)

The CEC was worked out from the values of exchangeable cations (Ammonium acetate extractable) and are given in table 4.1.5. The overall range of CEC in Nothern Saurashtra coastal region was 19.49 to 59.72 (cmol (p+) kg^{-1}) with the mean value of 36.99 (cmol (p+) kg^{-1}). The data revealed that the lowest mean value of CEC [29.24 (cmol (p+) kg^{-1})] was obtained from the samples of Dwarka taluka of Devbhumi Dwarka district and the highest mean value of CEC [40.10 (cmol (p+) kg^{-1})] was found in the samples of Jodiya taluka of Jamnagar district. 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. The lowest value of CEC [19.49 (cmol (p+) kg^{-1})] was recorded in the samples collected from Dwarka taluka in Devbhumi Dwarka district, whereas the highest value of CEC

Table 4.1.5: 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	**19.88-59.72**	**39.49**	**19.49-52.83**	**38.72**	**22.53-47.81**	**35.84**	**23.20-47.13**	**32.57**	**19.49-59.72**	**36.99**

[59.72 (cmol (p+) kg^{-1})] was found in Porbandar taluka of Porbandar district. Similar findings were also recorded by Kabaria (2004) for Amreli district, by Hadiyal (2005) for Porbandar district, by Rajput (2010) for Bhavnagar district, by Sojitra (2010) for Junagadh district, by Shirgire (2012) for Jamnagar district, by Singh and Sharma (2013) for Bhatinda district of Punjab by Malavath and Mani (2014) for Sivaganga district of Tamil Nadu, by Chauhan and Polara (2015a) for Gir Somnath district and by Hadiya and Polara (2017) for Devbhumi Dwarka district of Gujarat.

4.1.2 Salinity/Sodicity status of soils

Salinity/sodicity indices are very important criterion for classifying salt affected soils into saline, sodic, saline-sodic or normal soil. For characterization of the soils of Northern Saurashtra coastal region for salinity/sodicity status, all the 141 samples were analyzed for ECe, pHs, ESP, SSP, SAR, water soluble ions (1:2.5 soil: water extract) and exchangeable cations. The salinity/sodicity indices were also worked out from water soluble ions. Sample wise values of the ECe, pHs, ESP, SSP, SAR, water soluble ions and exchangeable cations are given in Appendix III and IV and and talukawise range and mean values are given in tables 4.1.6 to 4.1.10.

4.1.2.1 ECe

The ECe of soil samples were determined by saturation extract of soil. The overall mean value of ECe of soil samples was 3.21 dS m^{-1}, which was varied widely from 0.49 to 18.22 dS m^{-1}. So, as per classification given by Richards (1954), the soils of Northen Saurashtra coastal region were lied in low saline soil. In Jamnagar district, the overall mean value of ECe was 2.20 dS m^{-1}, maximum ECe (12.04 dS m^{-1}) was found at 0 to 5 km distance from the sea coast and the minimum ECe (0.49 dS m^{-1}) was found at 15 to 20 km distance from the sea coast. In Devbhumi Dwarka district, the maximum ECe (18.22 dS m^{-1}) was found at 0 to 5 km distance from the sea coast and minimum ECe (0.54 dS m^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of ECe was 3.98 dS m^{-1}. In Porbandar district, overall mean value of ECe was 3.90 dS m^{-1}, maximum ECe (12.20 dS m^{-1}) was found at 0 to 5 km distance from the sea coast and minimum ECe (0.66 dS m^{-1}) was found at 15 to 20 km distance from the sea coast (Table 4.1.6 and Fig 4.3). The lowest value of ECe (0.49 dS m^{-1}) was recorded in the soil samples collected from Jodiya taluka in Jamnagar district, whereas the highest value of ECe (18.22 dS m^{-1}) was found in

Table 4.1.6: Talukawise range and mean values of ECe (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	6.12-10.40	8.26	1.09-2.31	1.80	0.74-1.66	1.11	0.52-1.03	0.76	0.52-10.40	2.03
Jodiya	3.14-12.04	6.07	1.28-3.64	2.36	0.67-1.78	1.20	0.49-1.17	0.78	0.49-12.04	2.74
Lalpur	3.02-10.27	5.86	0.90-2.72	1.47	0.57-1.46	0.95	0.56-0.81	0.68	0.56-10.27	1.83
Jamnagar District	**3.02-12.04**	**6.44**	**0.90-3.64**	**1.88**	**0.57-1.78**	**1.07**	**0.49-1.17**	**0.74**	**0.49-12.04**	**2.20**
Kalyanpur	4.03-17.03	7.80	2.17-3.98	2.96	1.12-2.40	1.55	0.54-0.97	0.74	0.54-17.03	3.30
Khambhalia	2.84-15.17	8.46	1.65-4.12	2.45	1.25-1.58	1.37	0.67-1.30	1.05	0.67-15.17	3.09
Dwarka	4.06-18.22	8.26	3.12-6.87	5.20	0.93-3.83	2.26	0.78-0.96	0.87	0.78-18.22	5.56
Devbhumi Dwarka District	**2.84-18.22**	**8.18**	**1.65-6.87**	**3.41**	**0.93-3.83**	**1.70**	**0.54-1.30**	**0.90**	**0.54-18.22**	**3.98**
Porbandar	**4.10-12.20**	**7.49**	**3.05-6.27**	**4.02**	**0.91-4.09**	**2.47**	**0.66-1.28**	**0.92**	**0.66-12.20**	**3.90**
Overall	**2.84-18.22**	**7.55**	**0.90-6.87**	**2.71**	**0.57-4.09**	**1.51**	**0.49-1.30**	**0.84**	**0.49-18.22**	**3.21**

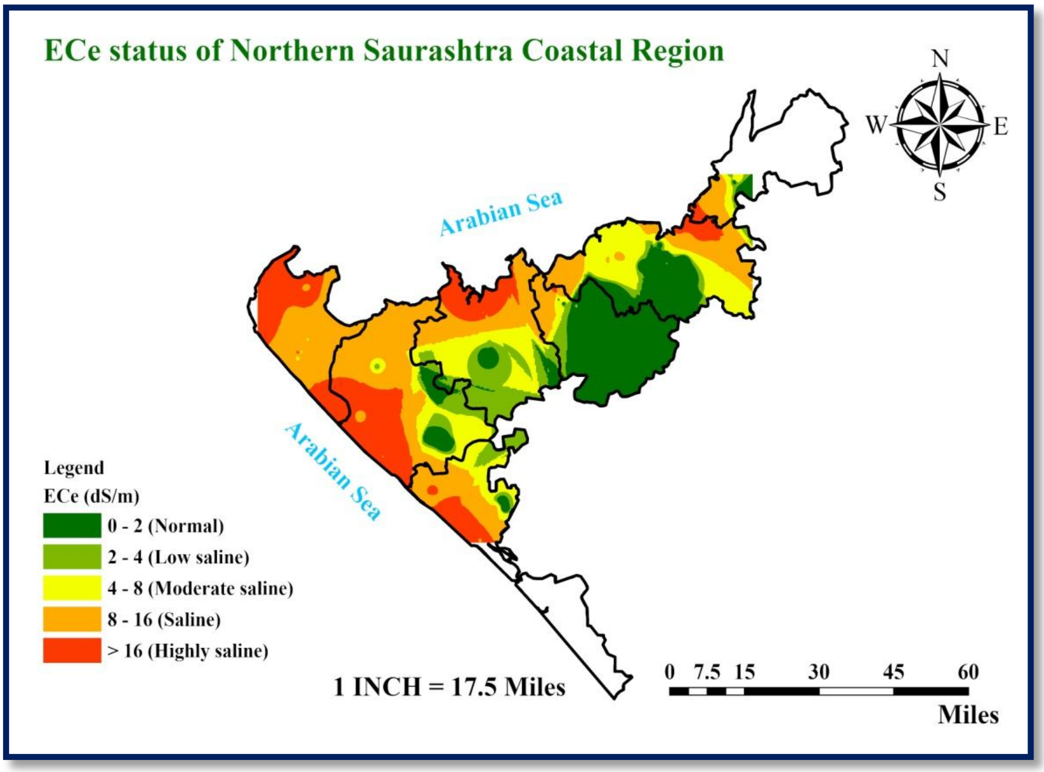


Fig. 4.3: Map of overall EC_e status in coastal soils of Northern Saurashtra region

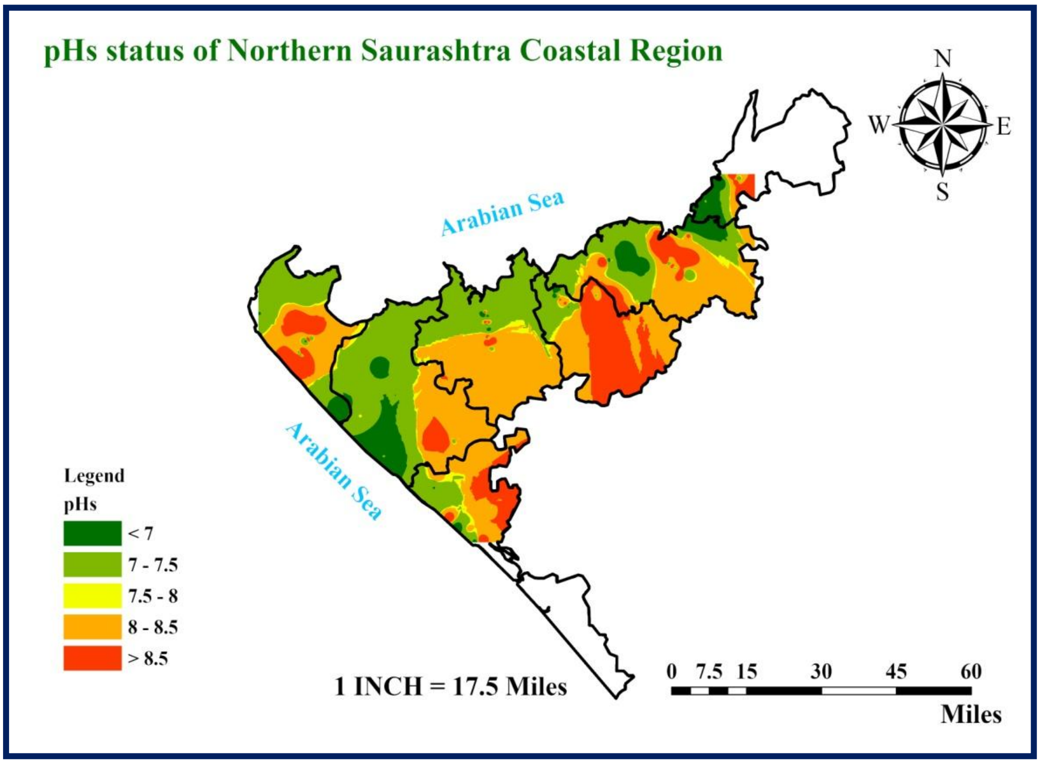


Fig. 4.4: Map of overall pH_s status in coastal soils of Northern Saurashtra region

Dwarka taluka of Devbhumi Dwarka district. The data further revealed that the lowest mean value of ECe (2.03 dS m^{-1}) was obtained from the samples of Jamnagar taluka of Jamnagar district and the highest mean value of ECe (5.56 dS m^{-1}) was registered in the samples of Dwarka taluka of Devbhumi Dwarka district. From this information we can say that the soils of Northen Saurashtra coastal region were normal to highly saline. This might be due to arid and semi-arid climate and less annual rainfall prevailed in the area. So, it is necessary to monitored soil frequently in respect to ECe. This finding is in conformity with the findings of earlier work done by Guruprasad *et al*. (2007) in Southern dry zone of Karnataka, by Sojitra (2010) for Junagadh district, for Bhavnagar district by Rajput and Polara (2012), by Wagh *et al*. (2016) for Nagpur district of Maharashtra and by Hadiya and Polara (2017) for Devbhumi Dwarka district of Gujarat. The higher mean value of ECe (2.60 dS m^{-1}) is an indicative of potential development of saline soils in Kalyanpur taluka of Devbhumi Dwarka district.

4.1.2.2 pH_s

The pH_s values of the soils for the entire Northen Saurashtra region were ranging from 6.82 to 8.36 with mean values of 7.58 (Table 4.1.7 and Fig 4.4). The values of pH_s do not differ much from the values of $pH_{2.5}$. Although, pH_s values are slightly lower than the $pH_{2.5}$ at all the times. In general, soils of Northen Saurashtra coastal region are slightly alkaline in reaction. The data revealed that the lowest mean value of pH_s (7.53) was obtained from the samples of Jodiya taluka of Jamnagar district and the highest mean value of pH_s (7.65) was found in the samples of Porbandar taluka of Porbandar district. In Jamnagar district, maximum pH_s (8.19) was found at 5 to 10 km distance from the sea coast and minimum pH_s (6.91) was found at 0 to 5 km distance from the sea coast, whereas overall mean value of pH_s was 7.57. In Devbhumi Dwarka district, maximum pH_s (8.36) was found at 15 to 20 km distance from the sea coast and minimum pH_s (6.82) was found at 0 to 5 km distance from the sea coast, while overall mean value of pH_s was 7.57. In Porbandar district, overall mean value of pH_s was 7.65, maximum pH_s (8.08) was found at 15 to 20 km distance from the sea coast and minimum pH_s (7.14) was found at 0 to 5 km distance from the sea coast. The lowest value of pH_s (6.82) was recorded in the samples collected from Khambhalia taluka in Devbhumi Dwarka district, whereas the highest value of pHs (8.36) was found in Dwarka taluka of Devbhumi Dwarka district. This finding is in

Table 4.1.7: Talukawise range and mean values of pHs in different districts of Northern Saurashtra coastal region

Talukas \ Distance (km)	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Jamnagar	6.91-7.32	7.12	7.15-8.19	7.58	7.24-8.12	7.64	7.38-8.15	7.63	6.91-8.19	7.56
Jodiya	7.01-7.31	7.20	7.04-7.84	7.45	7.46-8.05	7.74	7.53-8.11	7.86	7.01-8.11	7.53
Lalpur	7.14-7.42	7.31	7.20-7.90	7.63	7.32-7.97	7.66	7.80-7.94	7.87	7.14-7.94	7.63
Jamnagar District	**6.91-7.42**	**7.21**	**7.04-8.19**	**7.56**	**7.24-8.12**	**7.67**	**7.38-8.15**	**7.78**	**6.91-8.19**	**7.57**
Kalyanpur	6.97-7.51	7.22	7.46-7.80	7.61	7.33-7.72	7.61	7.47-7.88	7.74	6.97-7.88	7.54
Khambhalia	6.82-8.05	7.46	7.11-8.14	7.51	7.35-8.03	7.80	7.53-7.85	7.66	6.82-8.14	7.60
Dwarka	7.13-7.54	7.38	7.27-8.00	7.51	7.33-8.12	7.79	8.04-8.36	8.20	7.13-8.36	7.58
Devbhumi Dwarka District	**6.82-8.05**	**7.35**	**7.11-8.14**	**7.54**	**7.33-8.12**	**7.72**	**7.47-8.36**	**7.79**	**6.82-8.36**	**7.57**
Porbandar	**7.14-7.91**	**7.55**	**7.26-7.92**	**7.58**	**7.48-8.00**	**7.70**	**7.55-8.08**	**7.80**	**7.14-8.08**	**7.65**
Overall Northern Saurashtra	**6.82-8.05**	**7.35**	**7.04-8.19**	**7.55**	**7.24-8.12**	**7.69**	**7.38-8.36**	**7.78**	**6.82-8.36**	**7.58**

conformity with the findings of earlier work done by Guruprasad *et al*. (2007) in Southern dry zone of Karnataka, by Sojitra (2010) for Junagadh district and for Bhavnagar district by Rajput and Polara (2012), for Latur district of Maharashtra by Patil *et al*. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015), for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.1.2.3 Exchangeable Sodium Percentage (ESP)

The overall range of ESP in Nothern Saurashtra region was 4.74 to 32.14 with the mean value of 12.56. The data (Table 4.1.8) revealed that the lowest mean value of ESP (9.88) was obtained from the samples of Khambhalia taluka of Devbhumi Dwarka district and the highest mean value of ESP (14.61) was found in the samples of Porbandar taluka of Porbandar district. In Jamnagar district, maximum ESP (21.20) was found at 10 to 15 km distance from the sea coast and minimum ESP (5.41) was found at 0 to 5 km distance from the sea coast, whereas overall mean value of ESP was 12.89. In Devbhumi Dwarka district, maximum ESP (32.14) was found at 0 to 5 km distance from the sea coast and minimum ESP (4.74) was found at 15 to 20 km distance from the sea coast, while overall mean value of ESP was 12.03. In Porbandar district, overall mean value of ESP was 13.15, maximum ESP (18.81) was found at 0 to 5 km distance from the sea coast and minimum ESP (5.54) was found at 15 to 20 km distance from the sea coast. The highest value of ESP (32.14) and lowest value of ESP (4.74) were recorded in the samples collected from Dwarka taluka in Devbhumi Dwarka district. The values of ESP were beyond to its critical limit (>15) in all talukas of Northern Saurashtra coastal region except Jodiya Lalpur and taluka upto 5 km distance from sea coast. Similar findings were also recorded by Hadiyal (2005) for Porbandar district, by Rajput (2010) for Bhavnagar district, by Sojitra (2010) for Junagadh district, by Shirgire (2012) for Jamnagar district, by Singh and Sharma (2013) for Bhatinda district of Punjab by Malavath and Mani (2014) for Sivaganga district of Tamil Nadu, by Chauhan and Polara (2015a) for Gir Somnath district and by Hadiya and Polara (2017) for Devbhumi Dwarka district of Gujarat.

4.1.2.4 Soluble Sodium Percentage (SSP)

The SSP values of the soils for the entire Northen Saurashtra coastal region were ranging from 33.67 to 88.38 with mean value of 66.09 (Table 4.1.9). The data

Table 4.1.8: Talukawise range and mean values of ESP (Exchangeable Sodium Percentage) 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	15.39-18.58	16.98	6.61-14.67	10.55	9.50-21.20	13.67	15.35-18.91	17.52	6.61-21.20	13.52
Jodiya	5.41-18.53	10.41	12.30-17.94	14.08	8.95-16.98	13.34	8.92-13.73	10.88	5.41-18.53	12.38
Lalpur	8.34-14.80	11.24	12.21-18.80	13.80	9.84-15.98	12.70	9.72-13.97	12.05	8.34-18.80	12.77
Jamnagar District	**5.41-18.58**	**11.98**	**6.61-18.80**	**12.71**	**8.95-21.20**	**13.19**	**8.92-18.91**	**13.62**	**5.41-21.20**	**12.89**
Kalyanpur	15.51-30.24	20.09	6.01-15.31	11.40	6.32-8.22	7.29	7.30-8.58	7.69	6.01-30.24	11.60
Khambhalia	6.93-20.28	14.87	5.03-15.17	9.38	5.76-10.08	7.63	5.54-11.22	8.38	5.03-20.28	9.88
Dwarka	9.73-32.14	19.56	10.04-24.38	15.11	4.81-15.36	7.75	4.74-4.91	4.83	4.74-32.14	14.61
Dev Bhumi Dwarka District	**6.93-32.14**	**18.67**	**5.03-24.38**	**11.66**	**4.81-15.36**	**7.51**	**4.74-11.22**	**7.48**	**4.74-32.14**	**12.03**
Porbandar	**12.88-18.81**	**15.25**	**13.04-15.88**	**14.43**	**11.96-16.09**	**13.57**	**5.54-11.49**	**8.91**	**5.54-18.81**	**13.15**
Overall	**5.41-32.14**	**16.10**	**5.03-24.38**	**12.50**	**4.81-21.20**	**11.04**	**4.74-18.91**	**10.25**	**4.74-32.14**	**12.56**

Table 4.1.9: Talukawise range and mean values of SSP (Soluble Sodium Percentage) 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	64.94-74.07	69.50	63.30-86.92	72.67	60.93-74.83	67.17	58.90-68.40	62.11	58.90-86.92	68.59
Jodiya	64.29-76.31	70.81	60.15-77.12	68.87	61.52-73.86	66.35	54.64-70.34	62.74	54.64-77.12	67.62
Lalpur	58.73-82.71	73.73	53.86-74.27	66.32	53.10-71.14	60.96	44.06-59.50	53.16	44.06-82.71	63.58
Jamnagar District	58.73-82.71	71.42	53.86-86.92	69.44	53.10-74.83	64.42	44.06-70.34	59.90	54.64-86.92	66.60
Kalyanpur	68.26-72.02	70.17	57.47-77.05	65.85	63.67-78.54	71.17	33.67-65.91	48.07	33.67-78.54	64.97
Khambhalia	59.89-73.32	64.92	60.09-74.31	68.11	53.65-68.24	63.48	40.32-66.45	51.71	40.32-74.31	62.44
Dwarka	55.56-88.38	69.03	60.00-73.36	68.07	51.87-74.12	66.61	65.45-68.93	67.19	51.87-88.38	68.12
Dev Bhumi Dwarka District	55.56-88.38	68.43	57.47-77.05	67.43	51.87-78.54	67.67	33.67-68.93	53.20	33.67-88.38	65.18
Porbandar	65.45-80.28	75.93	55.43-71.48	62.34	60.56-82.17	72.64	45.95-65.00	56.37	45.95-82.17	67.25
Overall	55.56-88.38	70.63	53.86-86.92	67.86	51.87-82.17	66.83	33.67-70.34	56.52	33.67-88.38	66.09

revealed that the lowest mean value of SSP (62.44) was obtained from the samples of Khambhalia taluka of Devbhumi Dwarka district and the highest mean value of SSP (68.59) was found in the samples of Jamnagar taluka of Jamnagar district. In Jamnagar district, maximum SSP (86.92) was found at 5 to 10 km distance from the sea coast and minimum SSP (54.64) was found at 15 to 20 km distance from the sea coast, whereas overall mean value of SSP was 66.60. In Devbhumi Dwarka district, maximum SSP (88.38) was found at 0 to 5 km distance from the sea coast and minimum SSP (33.67) was found at 15 to 20 km distance from the sea coast, while overall mean value of SSP was 65.18. In Porbandar district, overall mean value of SSP was 67.25, maximum SSP (82.17) was found at 10 to 15 km distance from the sea coast and minimum SSP (45.95) was found at 15 to 20 km distance from the sea coast. The lowest value of SSP (33.67) was recorded in the samples collected from Kalyanpur taluka in Devbhumi Dwarka district, whereas the highest value of SSP (88.38) was found in Dwarka taluka of Devbhumi Dwarka district. Overall the value of SSP (66.09) in coastal soils of North Saurashtra region recorded slightly higher than its safe limit (60.00). This finding is in conformity with the findings of earlier work done by Guruprasad *et al*. (2007) in Southern dry zone of Karnataka, by Sojitra (2010) for Junagadh district and for Bhavnagar district by Rajput and Polara (2012), for Latur district of Maharashtra by Patil *et al*. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015), for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.1.2.5 Sodium Adsoption Ratio (SAR)

The overall range of SAR in Nothern Saurashtra coastal region was 1.15 to 21.57 with the mean value of 6.04. The data (Table 4.1.10) revealed that the lowest mean value of SAR (4.90) was obtained from the samples of Lalpur taluka of Jamnagar district and the highest mean value of SAR (7.66) was found in the samples of Dwarka taluka of Devbhumi Dwarka district. In Jamnagar district, maximum SAR (15.04) was found at 0 to 5 km distance from the sea coast and minimum SAR (1.53) was found at 15 to 20 km distance from the sea coast, whereas overall mean value of SAR was 5.76. In Devbhumi Dwarka district, maximum SAR (21.57) was found at 0 to 5 km distance from the sea coast and minimum SAR (1.15) was found at 15 to 20 km distance from the sea coast, while overall mean value of SAR was 6.02. In

Table 4.1.10: Talukawise range and mean values of SAR (Sodium Adsorption Ratio) 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	6.75-13.78	10.26	4.46-11.44	6.98	4.06-5.37	4.77	3.21-5.01	3.84	3.21-13.78	6.02
Jodiya	5.28-15.04	9.42	4.15-8.53	6.35	4.12-5.47	4.77	3.06-5.89	4.19	3.06-15.04	6.37
Lalpur	4.51-14.01	10.77	3.35-6.23	4.80	2.60-5.22	3.54	1.53-2.98	2.47	1.53-14.01	4.90
Jamnagar District	**4.51-15.04**	**10.00**	**3.35-11.44**	**6.08**	**2.60-5.47**	**4.26**	**1.53-5.89**	**3.59**	**1.53-15.04**	**5.76**
Kalyanpur	7.26-14.01	8.97	3.50-6.55	4.75	3.54-6.79	5.14	1.15-4.21	2.30	1.15-14.01	5.43
Khambhalia	5.27-10.85	7.97	4.06-7.11	5.32	2.92-5.41	4.15	1.86-4.24	2.67	1.86-10.85	4.96
Dwarka	4.66-21.57	10.04	4.30-8.33	6.65	3.10-6.53	5.14	4.26-4.86	4.56	3.10-21.57	7.66
Devbhumi Dwarka District	**4.66-21.57**	**9.28**	**3.50-8.33**	**5.55**	**2.92-6.79**	**4.86**	**1.15-4.86**	**2.88**	**1.15-21.57**	**6.02**
Porbandar	**5.87-16.35**	**11.71**	**3.93-7.45**	**5.15**	**3.95-9.10**	**6.47**	**2.14-3.99**	**3.28**	**2.14-16.35**	**6.89**
Overall	**4.51-21.57**	**9.92**	**3.35-11.44**	**5.77**	**2.60-9.10**	**4.80**	**1.15-5.89**	**3.24**	**1.15-21.57**	**6.04**

Porbandar district, overall mean value of SAR was 6.89, maximum SAR (16.35) was found at 0 to 5 km distance from the sea coast and minimum SAR (2.14) was found at 15 to 20 km distance from the sea coast. The lowest value of SAR (1.15) was recorded in the samples collected from Kalyanpur taluka in Devbhumi Dwarka district, whereas the highest value of SAR (21.57) was found in Dwarka taluka of Devbhumi Dwarka district. Similar findings were also recorded by Hadiyal (2005) for Porbandar district, by Rajput (2010) for Bhavnagar district, by Sojitra (2010) for Junagadh district, by Shirgire (2012) for Jamnagar district, by Singh and Sharma (2013) for Bhatinda district of Punjab by Malavath and Mani (2014) for Sivaganga district of Tamil Nadu, by Chauhan and Polara (2015a) for Gir Somnath district and by Hadiya and Polara (2017) for Devbhumi Dwarka district of Gujarat.

4.1.2.6 Soil Characterization

By making use of ECe and ESP criteria as initially suggested by Richards (1954), the 141 soil samples collected from the Northern Saurashtra coastal region were categorized into three classes, viz., saline, saline-sodic and sodic soils. The soils having ECe value > 4.0 dS m^{-1} and ESP value < 15 were classified as saline, those having ECe value > 4.0 dS m^{-1} and ESP value > 15 as saline-sodic and those having ECe value < 4 dS m-1 and ESP value > 15 as sodic soils. As the samples were collected from the cultivated fields, some of the samples did not fall into the said criteria, and hence samples were placed in the non-saline and non-sodic group which we called as normal soils.

Out of 141 samples, 17, 21, 14 and 89 samples were dropped as saline, saline-sodic, sodic and normal soils, respectively. About 12.06, 14.89, 9.93 and 63.12 percent soil samples were found in saline, saline-sodic, sodic and normal soil, respectively. Among the salt affected soil samples, higher number of sample falls under normal class followed by saline-sodic, saline and sodic (Table 4.1.11). After the exclusion of non-saline and non-sodic samples, the remaining 52 samples were then grouped into three different salt affected soil classes by adopting USDA norms. The distribution indicates that 32.69 per cent soil samples were falling in the saline group, 40.38 per cent into saline-sodic group and 26.92 per cent samples fall into sodic group. This amply suggests that soil salinity-sodicity is more dominant process, while soil salinity more or less equally distributed in the soils of Northern Saurashtra

Table 4.1.11: Talukawise percentage distribution of soil samples into different categories of salt affected soils of different district of Northern Saurastra coastal region

Name of taluka	Percent distribution			
	Saline	Saline-Sodic	Sodic	Normal
Jamnagar	0.00 (0)*	10.00 (2)	25.00 (5)	65.00 (13)
Jodiya	10.00 (2)	5.00 (1)	10.00 (2)	75.00 (15)
Lalpur	10.00 (2)	0.00 (0)	10.00 (2)	80.00 (16)
Jamnagar District	6.67 (4)	5.00 (3)	15.00 (9)	73.33 (44)
Kalyanpur	0.00 (0)	25.00 (5)	5.00 (1)	70.00 (14)
Khambhalia	10.00 (2)	10.00 (2)	5.00 (1)	75.00 (15)
Dwarka	35.00 (7)	30.00 (6)	10.00 (2)	25.00 (5)
Devbhumi Dwarka District	15.00 (9)	21.67 (13)	6.67 (4)	56.67 (34)
Porbandar	19.05 (4)	23.81 (5)	4.76 (1)	52.38 (11)
Overall	12.06 (17)	14.89 (21)	9.93 (14)	63.12 (89)
Classification of salt affected soils (52)	32.69 (17)	40.38 (21)	26.92 (14)	-

(*) - Values in parenthesis are number of samples coastal region. The highest percentage of saline soils (35.00 %) was recorded in Dwarka taluka followed by Porbandar (19.05 %). Soils of Jamnagar taluka had the highest proportion of sodic soils (25.00 %). The highest percentage of saline-sodic soils (30.00 %) was reported in Dwarka taluka followed by Kalyanpur taluka (25.00 %) and Porbandar taluka (23.81 %). These findings are supported by Kabaria and Polara (2006), Marsonia *et al*. (2008), Sojitra (2010), Rajput and Polara (2012) and Chauhan and Polara (2015a).

4.1.2.7 Exchangeable Cations

The talukawise range and mean values for exchangeable cations (ammonium acetate extractable – water soluble) estimated from the soils of Northern Saurashtra coastal region and are presented in table 4.1.12 to 4.1.15.

4.1.2.7.1 Exchangeable Na^+

Among the talukas, highest proportion of exchangeable Na^+ [12.86 (cmol (p+) kg^{-1})] was observed at the distance of 0 to 5 km from the sea coast in Kalyanpur taluka, which was followed by Dwarka [12.45 (cmol (p+) kg^{-1})] and Jodiya [10.42 (cmol (p+) kg^{-1})]. The presence of large proportion of exchangeable Na^+ in most of area under investigation is indicative of a potential danger for the alkalinity hazards. The highest mean value for exchangeable Na^+ [5.54 (cmol (p+) kg^{-1})] was found in Jamnagar taluka followed by Porbandar taluka [5.15 (cmol (p+) kg^{-1})] and the lowest mean value for exchangeable Na^+ [3.56 (cmol (p+) kg^{-1})] was reported in Khambhalia taluka (Table 4.1.12). The lowest value of exchangeable Na^+ [1.10 (cmol (p+) kg^{-1})] was recorded in the samples collected from Dwarka taluka in Devbhumi Dwarka district, whereas the highest value of exchangeable Na^+ [12.86 (cmol (p+) kg^{-1})] was found in Kalyanpur taluka of Devbhumi Dwarka district. On comparison between the water soluble and exchangeable cations, proportion of Na^+ was more in former, while Ca^{++} was dominant in the latter (Table 4.37 and 4.39). This variation could be explained on the basis of strength of their adsorption on clay complex. Our results are in direct line with work reported by Kabaria and Polara (2006) for Amreli district, by Marsonia *et al*. (2008) for Porbandar district, by Sojitra (2010) for Junagadh district, Rajput and Polara (2012) for Bhavnagar district and Chauhan and Polara (2015a) for Gir Somnath district of Gujarat.

Table 4.1.12: Talukawise range and mean values of exchangeable Na^+ (cmol (p+) 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	6.58-7.62	7.10	1.54-7.00	4.25	3.24-9.74	5.94	6.04-7.61	6.72	1.54-9.74	5.54
Jodiya	2.68-10.42	5.20	4.21-8.02	6.32	2.77-6.00	4.70	2.53-3.24	2.88	2.53-10.42	5.03
Lalpur	3.44-6.14	4.44	3.78-9.50	5.61	3.28-5.83	4.30	3.22-4.62	3.77	3.22-9.50	4.70
Jamnagar District	**2.68-10.42**	**5.35**	**3.78-9.50**	**5.34**	**2.77-9.74**	**4.97**	**2.53-7.61**	**4.52**	**1.54-10.42**	**5.09**
Kalyanpur	4.25-12.86	7.32	2.88-6.10	4.47	2.66-3.28	2.92	2.45-3.70	3.04	2.45-12.86	4.43
Khambhalia	3.09-8.38	5.94	2.24-4.34	3.37	1.75-3.50	2.44	2.40-4.04	2.82	1.75-8.38	3.56
Dwarka	2.64-12.45	5.78	2.58-6.37	4.46	1.14-6.50	2.67	1.10-1.18	1.14	1.10-12.45	4.36
Devbhumi Dwarka District	**2.64-12.86**	**6.24**	**2.24-6.37**	**4.01**	**1.14-6.50**	**2.71**	**1.10-4.04**	**2.60**	**1.10-12.86**	**4.12**
Porbandar	**5.92-10.39**	**7.51**	**4.93-5.97**	**5.40**	**3.60-5.87**	**4.61**	**1.54-3.69**	**2.63**	**1.54-10.39**	**5.15**
Overall	**2.64-12.86**	**6.20**	**2.24-9.50**	**4.83**	**1.14-9.74**	**4.04**	**1.10-7.61**	**3.39**	**1.10-12.86**	**4.68**

4.1.2.7.2 Exchangeable K^+

Among the talukas, highest proportion of exchangeable K^+ [1.16 (cmol (p+) kg^{-1})] was observed at the distance of 15 to 20 km from the sea coast (Table 4.1.13). The highest mean value for exchangeable K^+ [0.60 (cmol (p+) kg^{-1})] was found in Dwarka taluka followed by Porbandar taluka [0.55 (cmol (p+) kg^{-1})] and the lowest mean value for exchangeable K^+ [0.28 (cmol (p+) kg^{-1})] was reported in Lalpur taluka. The lowest value of exchangeable K^+ [0.14 (cmol (p+) kg^{-1})] was recorded in the samples collected from Lalpur taluka in Jamnagar district, whereas the highest value of exchangeable K^+ [1.16 (cmol (p+) kg^{-1})] was found in Porbandar taluka of Porbandar district. This finding is in concurrence with the findings of Kabaria and Polara (2006) for soils of Amreli district, Polara *et al*. (2006) for North-West Agroclimatic Zone of Gujarat and Marsonia *et al*. (2008) for Porbandar district.

4.1.2.7.3 Exchangeable Ca^{++}

The overall exchangeable Ca^{++} values of Northen Saurashtra's soil samples were ranged from 7.04 to 31.82 (cmol (p+) kg^{-1}) with the mean value of 16.96 (cmol (p+) kg^{-1}). The data (Table 4.1.14) revealed that lowest mean value of exchangeable Ca^{++} [14.74 (cmol (p+) kg^{-1})] was obtained from the samples of Dwarka taluka of Devbhumi Dwarka district and the highest mean value of exchangeable Ca^{++} [18.66 (cmol (p+) kg^{-1})] was found in the samples of Kalyanpur taluka of Devbhumi Dwarka district. In Jamnagar district, maximum exchangeable Ca^{++} [26.20 (cmol (p+) kg^{-1})] was found at 0 to 5 km distance from the sea coast and minimum exchangeable Ca^{++} [8.15 (cmol (p+) kg^{-1})] was found at 15 to 20 km distance from the sea coast, whereas overall mean value of exchangeable Ca^{++} was 17.14 (cmol (p+) kg^{-1}). In Devbhumi Dwarka district, maximum exchangeable Ca^{++} [31.82 (cmol (p+) kg^{-1})] was found at 5 to 10 km distance from the sea coast and minimum exchangeable Ca^{++} [7.04 (cmol (p+) kg^{-1})] was found at 0 to 5 km distance from the sea coast, while overall mean value of exchangeable Ca^{++} was 16.81 (cmol (p+) kg^{-1}). In Porbandar district, overall mean value of exchangeable Ca^{++} was 16.84 (cmol (p+) kg^{-1}), maximum exchangeable Ca^{++} [25.65 (cmol (p+) kg^{-1})] was found at 0 to 5 km distance from the sea coast and minimum exchangeable Ca^{++} [10.76 (cmol (p+) kg^{-1})] was found at 15 to 20 km distance from the sea coast. The lowest value of exchangeable Ca^{++}

Table 4.1.13: Talukawise range and mean values of exchangeable K^+ (cmol (p+) 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	0.19-0.25	0.22	0.21-0.37	0.29	0.33-0.47	0.40	0.54-0.60	0.57	0.19-0.60	0.37
Jodiya	0.19-0.39	0.27	0.24-0.48	0.37	0.31-0.56	0.45	0.55-0.65	0.59	0.19-0.65	0.40
Lalpur	0.14-0.22	0.19	0.17-0.28	0.22	0.23-0.42	0.30	0.43-0.46	0.45	0.14-0.46	0.28
Jamnagar District	**0.14-0.39**	**0.24**	**0.17-0.48**	**0.29**	**0.23-0.56**	**0.37**	**0.43-0.65**	**0.54**	**0.14-0.65**	**0.35**
Kalyanpur	0.15-0.34	0.23	0.30-0.50	0.39	0.48-0.62	0.57	0.66-1.07	0.93	0.15-1.07	0.51
Khambhalia	0.20-0.30	0.24	0.32-0.50	0.39	0.53-0.60	0.57	0.53-0.92	0.75	0.20-0.92	0.49
Dwarka	0.25-0.56	0.44	0.49-0.68	0.61	0.68-0.89	0.80	0.89-0.93	0.91	0.25-0.93	0.60
Devbhumi Dwarka District	**0.15-0.56**	**0.34**	**0.30-0.68**	**0.45**	**0.48-0.89**	**0.64**	**0.53-1.07**	**0.85**	**0.15-1.07**	**0.53**
Porbandar	**0.30-0.37**	**0.33**	**0.39-0.47**	**0.43**	**0.46-0.77**	**0.59**	**0.70-1.16**	**0.90**	**0.30-1.16**	**0.55**
Overall	**0.14-0.56**	**0.31**	**0.17-0.68**	**0.37**	**0.23-0.89**	**0.51**	**0.43-1.16**	**0.73**	**0.14-1.16**	**0.46**

Table 4.1.14: Talukawise range and mean values of exchangeable Ca^{++} (cmol (p+) 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	15.60-19.02	17.31	11.70-25.01	17.65	13.51-22.40	19.45	13.40-19.00	15.51	11.70-25.01	17.73
Jodiya	20.60-26.20	22.89	14.60-21.25	19.09	11.08-18.90	15.04	8.15-13.41	10.11	8.15-26.20	17.43
Lalpur	17.04-23.20	19.41	13.80-21.61	17.10	13.02-17.34	15.36	11.21-14.72	13.25	11.21-23.20	16.26
Jamnagar District	**15.60-26.20**	**20.73**	**11.70-25.01**	**17.93**	**11.08-22.40**	**16.73**	**8.15-19.00**	**12.93**	**8.15-26.20**	**17.14**
Kalyanpur	10.89-20.37	15.72	14.41-31.82	20.32	17.00-21.40	19.48	17.79-20.43	19.06	10.89-31.82	18.66
Khambhalia	13.75-20.81	17.48	14.64-24.40	18.59	11.23-17.20	14.53	13.20-21.88	16.50	11.23-24.40	17.03
Dwarka	7.04-19.83	14.44	7.11-19.78	14.95	12.58-16.40	14.69	15.60-15.79	15.70	7.04-19.83	14.74
Dev Bhumi Dwarka District	**7.04-20.81**	**15.47**	**7.11-31.82**	**18.03**	**11.23-21.40**	**16.70**	**13.20-21.88**	**17.28**	**7.04-31.82**	**16.81**
Porbandar	**18.08-25.65**	**21.50**	**15.54-20.35**	**17.78**	**13.15-16.90**	**14.76**	**10.76-16.05**	**12.39**	**10.76-25.65**	**16.84**
Overall	**7.04-26.20**	**18.08**	**7.11-31.82**	**17.95**	**11.08-22.40**	**16.44**	**8.15-21.88**	**14.60**	**7.04-31.82**	**16.96**

[7.04 (cmol (p+) kg^{-1})] was recorded in the samples collected from Dwarka taluka in Devbhumi Dwarka district, whereas the highest value of exchangeable Ca^{++} [31.82 (cmol (p+) kg^{-1})] was found in Kalyanpur taluka of Devbhumi Dwarka district. Similar findings were also recorded by Kabaria and Polara (2006) for Amreli district, by Marsonia *et al*. (2008) for Porbandar district, by Sojitra (2010) for Junagadh district, by Rajput and Polara (2012) for Bhavnagar district, by Chauhan and Polara (2015a) for Gir Somnath district of Gujarat and by Vaghela (2017) for Kheda district of Gujarat.

4.1.2.7.4 Exchangeable Mg^{++}

In Jamnagar district, overall mean value of exchangeable Mg^{++} was 13.18 (cmol (p+) kg^{-1}), maximum exchangeable Mg^{++} [20.02 (cmol (p+) kg^{-1})] was found at 0 to 5 km distance from the sea coast and minimum exchangeable Mg^{++} [5.31 (cmol (p+) kg^{-1})] was found at 5 to 10 km distance from the sea coast. In Devbhumi Dwarka district, maximum exchangeable Mg^{++} [18.62 (cmol (p+) kg^{-1})] was found at 5 to 10 km distance from the sea coast and minimum exchangeable Mg^{++} [2.20 (cmol (p+) kg^{-1})] was found at 5 to 10 km distance from the sea coast, while overall mean value of exchangeable Mg^{++} was 10.51 (cmol (p+) kg^{-1}). In Porbandar district, overall mean value of exchangeable Mg^{++} was 12.51 (cmol (p+) kg^{-1})], maximum exchangeable Mg^{++} [19.84 (cmol (p+) kg^{-1})] was found at 0 to 5 km distance from the sea coast and minimum exchangeable Mg^{++} [8.11 (cmol (p+) kg^{-1})] was found at 5 to 10 km distance from the sea coast (Table 4.1.15). The lowest value of exchangeable Mg^{++} [2.20 (cmol (p+) kg^{-1})] was recorded in the samples collected from Dwarka taluka in Devbhumi Dwarka district, whereas the highest value of exchangeable Mg^{++} [20.02 (cmol (p+) kg^{-1})] was found in Jodiya taluka of Jamnagar district. The data further revealed that the lowest mean value of exchangeable Mg^{++} [6.53 (cmol (p+) kg^{-1})] was obtained from the samples of Dwarka taluka of Devbhumi Dwarka district and the highest mean value of exchangeable Mg^{++} [13.21 (cmol (p+) kg^{-1})] was registered in the samples of Jamnagar taluka of Jamnagar district. Similar findings were also recorded for Junagadh district by Sojitra (2010), for Bhavnagar district by Rajput and Polara (2013), for Latur district of Maharashtra by Patil *et al*. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015), for Devbhumi Dwarka district of

Table 4.1.15: Talukawise range and mean values of exchangeable Mg^{++} (cmol (p+) 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	13.45-14.30	13.88	5.31-17.03	13.33	10.08-16.18	13.47	10.05-14.37	12.25	5.31-17.03	13.21
Jodiya	16.23-20.02	17.83	11.08-20.00	15.43	8.18-15.20	11.68	7.16-12.07	9.65	7.16-20.02	14.12
Lalpur	8.50-16.12	13.55	9.41-18.06	13.52	8.00-13.47	11.05	9.02-11.26	10.51	8.00-18.06	12.21
Jamnagar District	**8.50-20.02**	**15.76**	**5.31-20.00**	**14.06**	**8.00-16.18**	**12.05**	**7.16-14.37**	**10.83**	**5.31-20.02**	**13.18**
Kalyanpur	4.82-14.60	9.81	9.21-15.23	11.99	11.78-17.12	14.87	8.42-15.02	13.01	4.82-17.12	12.51
Khambhalia	10.32-17.22	13.62	5.38-18.62	13.45	10.16-13.80	11.45	6.42-17.59	10.99	5.38-18.62	12.47
Dwarka	2.21-11.67	5.52	2.20-15.34	7.63	2.46-15.37	9.43	2.40-2.70	2.55	2.20-15.37	6.53
Devbhumi Dwarka District	**2.21-17.22**	**8.51**	**2.20-18.62**	**11.31**	**2.46-17.12**	**12.34**	**2.40-17.59**	**10.19**	**2.20-18.62**	**10.51**
Porbandar	**12.15-19.84**	**16.33**	**8.11-14.11**	**11.84**	**8.26-16.57**	**11.27**	**8.12-12.60**	**9.85**	**8.11-19.84**	**12.51**
Overall	**2.21-20.02**	**12.02**	**2.20-20.00**	**12.75**	**2.46-17.12**	**12.05**	**2.40-17.59**	**10.39**	**2.20-20.02**	**11.94**

Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.1.2.8 Water soluble ions

Water soluble cations (Ca^{++}, Mg^{++}, Na^{+} and K^{+}) and anions ($CO3^{--}$, $HCO3^{-}$, Cl^{-} and $SO4^{--}$) were estimated from the soil:water (1:2.5) extract. Sample wise values for water soluble cations and anions for all the 141 samples are given in Appendix IV and range and mean values are presented in tables 4.1.16 to 4.1.23.

4.1.2.8.1 Water Soluble Cations

The values for water soluble cations estimated from the soils of Northern Saurashtra coastal region are given in tables 4.1.16 to 4.1.19.

4.1.2.8.1.1 Water Soluble Na^{+}

The highest mean value for water soluble Na^{+} (12.26 me L^{-1}) was found in Dwarka taluka followed by Porbandar (9.88 me L^{-1}) and Jodiya (9.44 me L^{-1}) taluka and the lowest mean value for water soluble Na^{+} (6.11 me L^{-1}) was reported in Lalpur taluka (Table 4.1.16). In Jamnagar district, overall mean value of water soluble Na^{+} was 7.16 me L^{-1}, maximum water soluble Na^{+} (34.96 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble Na^{+} (1.26 me L^{-1}) was found at 15 to 20 km distance from the sea coast. In Devbhumi Dwarka district, maximum water soluble Na^{+} (40.00 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble Na^{+} (1.00 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of water soluble Na^{+} was (9.00 me L^{-1}). In Porbandar district, overall mean value of water soluble Na^{+} was (9.88 me L^{-1}), maximum water soluble Na^{+} (32.70 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble Na^{+} (2.04 me L^{-1}) was found at 15 to 20 km distance from the sea coast. The lowest value of water soluble Na^{+} (1.00 me L^{-1}) was recorded in the samples collected from Kalyanpur taluka in Devbhumi Dwarka district, whereas the highest value of water soluble Na^{+} (40.00 me L^{-1}) was found in Kalyanpur taluka of Devbhumi Dwarka district. Similar findings were also recorded for Junagadh district by Sojitra (2010), for Bhavnagar district by Rajput and Polara (2013), for Latur district of Maharashtra by Patil *et al*. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015), for Devbhumi Dwarka district of

Table 4.1.16: Talukawise range and mean values of water soluble Na^{+} (me L^{-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	12.26-33.11	22.69	5.64-10.78	7.69	4.37-7.00	5.18	2.78-4.07	3.50	2.78-33.11	5.93
Jodiya	7.65-34.96	18.30	5.52-12.96	8.61	4.55-7.02	5.40	2.65-5.74	3.84	2.65-34.96	9.44
Lalpur	7.13-24.87	17.25	4.04-7.78	5.59	2.78-5.35	3.64	1.26-2.74	1.97	1.26-24.87	6.11
Jamnagar District	**7.13-34.96**	**15.54**	**4.04-12.96**	**7.31**	**2.78-7.02**	**4.60**	**1.26-5.74**	**3.20**	**1.26-34.96**	**7.16**
Kalyanpur	10.14-40.00	18.26	4.10-8.12	5.55	3.40-6.79	4.90	1.00-3.21	1.89	1.00-40.00	7.80
Khambhalia	9.12-30.01	17.04	5.21-8.56	6.25	3.29-5.80	4.19	1.50-3.09	1.98	1.50-30.01	6.93
Dwarka	7.10-35.48	18.67	6.00-13.82	9.84	4.16-6.53	5.34	2.86-3.75	3.31	2.86-35.48	12.26
Devbhumi Dwarka District	**7.10-40.00**	**18.19**	**4.10-13.82**	**7.10**	**3.29-6.79**	**4.82**	**1.00-3.75**	**2.19**	**1.00-40.00**	**9.00**
Porbandar	**9.00-32.70**	**20.91**	**5.54-10.80**	**7.53**	**4.14-7.88**	**6.07**	**2.04-3.43**	**2.79**	**2.04-32.70**	**9.88**
Overall	**7.10-40.00**	**17.89**	**4.04-13.82**	**7.26**	**2.78-7.88**	**4.89**	**1.00-5.74**	**2.71**	**1.00-40.00**	**8.35**

Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.1.2.8.1.2 Water Soluble K^+

Among the talukas, highest proportion of water soluble K^+ (0.95 me L^{-1}) was observed at the distance of 15 to 20 km from the sea coast in Porbandar taluka (Table 4.1.17). The highest mean value for water soluble K^+ (0.27 me L^{-1}) was found in Khambhalia taluka followed by Porbandar (0.26 me L^{-1}) and Dwarka (0.18 me L^{-1}) taluka and the lowest mean value for water soluble K^+ (0.11 me L^{-1}) was reported in Lalpur taluka. In Jamnagar district, maximum water soluble K^+ (0.70 me L^{-1}) was found at 15 to 20 km distance from the sea coast and minimum water soluble K^+ (0.01 me L^{-1}) was found at 0 to 5 km distance from the sea coast, whereas overall mean value of water soluble K^+ was 0.15 me L^{-1}. In Devbhumi Dwarka district, maximum water soluble K^+ (0.92 me L^{-1}) was found at 15 to 20 km distance from the sea coast and minimum water soluble K^+ (0.01 me L^{-1}) was found at 0 to 5 km distance from the sea coast, while overall mean value of water soluble K^+ was 0.19 me L^{-1}. In Porbandar district, overall mean value of water soluble K^+ was 0.26 me L^{-1}, maximum water soluble K^+ (0.95 me L^{-1}) was found at 15 to 20 km distance from the sea coast and minimum water soluble K^+ (0.03 me L^{-1}) was found at 0 to 5 km distance from the sea coast. Similar results were also found by Verma *et al.* (2003) for Churu district (Rajasthan), by Kabaria (2004) for Amreli district, by Hadiyal (2005) for Porbandar district, by Sojitra (2010) for Junagadh district, by Rajput and Polara (2013) for Bhavnagar district, by Patil *et al*. (2014) for Latur district of Maharashtra, by Polara and Chauhan (2015) for Gir Somnath district of Gujarat, for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.1.2.8.1.3 Water Soluble Ca^{++}

The overall water soluble Ca^{++} values of Northen Saurashtra's soil samples were ranged from 0.40 to 10.20 me L^{-1} with mean value of (2.05 me L^{-1}). The data (Table 4.1.18) revealed that lowest mean value of water soluble Ca^{++} (1.60 me L^{-1}) was obtained from the samples of Kalyanpur taluka of Devbhumi Dwarka district and the highest mean value of water soluble Ca^{++} (2.45 me L^{-1}) was found in the samples of Dwarka taluka of Devbhumi Dwarka district. In Jamnagar district, maximum water

Table 4.1.17: Talukawise range and mean values of water soluble K^+ (me L^{-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	0.02-0.04	0.03	0.04-0.10	0.06	0.09-0.26	0.16	0.25-0.56	0.41	0.02-0.56	0.16
Jodiya	0.02-0.06	0.04	0.05-0.11	0.07	0.09-0.24	0.16	0.33-0.70	0.50	0.02-0.70	0.17
Lalpur	0.01-0.03	0.02	0.04-0.07	0.05	0.06-0.20	0.11	0.24-0.48	0.36	0.01-0.48	0.11
Jamnagar District	**0.01-0.06**	**0.03**	**0.04-0.11**	**0.06**	**0.06-0.26**	**0.14**	**0.25-0.70**	**0.43**	**0.01-0.70**	**0.15**
Kalyanpur	0.01-0.04	0.02	0.03-0.06	0.04	0.06-0.10	0.09	0.21-0.54	0.43	0.01-0.54	0.13
Khambhalia	0.01-0.06	0.04	0.06-0.16	0.09	0.18-0.40	0.29	0.42-0.92	0.68	0.01-0.92	0.27
Dwarka	0.01-0.45	0.09	0.08-0.22	0.13	0.20-0.40	0.29	0.50-0.61	0.56	0.01-0.61	0.18
Devbhumi Dwarka District	**0.01-0.45**	**0.06**	**0.03-0.22**	**0.09**	**0.06-0.40**	**0.20**	**0.21-0.92**	**0.56**	**0.01-0.92**	**0.19**
Porbandar	**0.03-0.10**	**0.06**	**0.11-0.16**	**0.13**	**0.15-0.37**	**0.24**	**0.38-0.95**	**0.64**	**0.03-0.95**	**0.26**
Overall	**0.01-0.45**	**0.05**	**0.03-0.22**	**0.08**	**0.06-0.40**	**0.18**	**0.21-0.95**	**0.52**	**0.01-0.95**	**0.18**

Table 4.1.18: Talukawise range and mean values of water soluble Ca^{++} (me L^{-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	4.40-6.25	5.33	1.00-2.80	1.96	1.00-2.40	1.70	0.70-1.30	1.06	0.70-6.25	2.33
Jodiya	2.60-6.60	4.20	1.40-3.60	2.39	1.20-2.20	1.65	0.80-1.20	1.05	0.80-6.60	2.43
Lalpur	1.20-3.60	2.47	1.00-3.20	1.94	0.80-2.00	1.43	0.50-1.10	0.80	0.50-3.60	1.67
Jamnagar District	**1.20-6.60**	**4.48**	**1.00-3.60**	**2.09**	**0.80-2.40**	**1.58**	**0.50-1.30**	**0.98**	**0.50-6.60**	**2.14**
Kalyanpur	2.30-5.60	3.58	0.90-1.20	1.06	0.78-1.08	0.95	0.61-0.90	0.79	0.61-5.60	1.60
Khambhalia	3.40-7.50	4.93	1.00-1.50	1.33	0.80-1.80	1.15	0.40-0.90	0.59	0.40-7.50	1.83
Dwarka	1.20-10.20	3.66	1.40-3.10	2.08	0.80-1.70	1.15	0.50-0.66	0.58	0.50-10.20	2.45
Devbhumi Dwarka District	**1.20-10.20**	**3.92**	**0.90-3.10**	**1.47**	**0.78-1.80**	**1.06**	**0.40-0.90**	**0.66**	**0.40-10.20**	**1.96**
Porbandar	**1.80-5.20**	**3.30**	**1.90-3.40**	**2.58**	**0.90-1.70**	**1.27**	**0.67-1.10**	**0.88**	**0.67-5.20**	**2.07**
Overall	**1.20-10.20**	**3.97**	**0.90-3.40**	**1.91**	**0.78-2.40**	**1.33**	**0.40-1.30**	**0.83**	**0.40-10.20**	**2.05**

soluble Ca^{++} (6.60 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble Ca^{++} (0.50 me L^{-1}) was found at 15 to 20 km distance from the sea coast, whereas overall mean value of water soluble Ca^{++} was 2.14 me L^{-1}. In Devbhumi Dwarka district, maximum water soluble Ca^{++} (10.20 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble Ca^{++} (0.40 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of water soluble Ca^{++} was 1.96 me L^{-1}. In Porbandar district, overall mean value of water soluble Ca^{++} was 2.07 me L^{-1}, maximum water soluble Ca^{++} (5.20 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble Ca^{++} (0.67 me L^{-1}) was found at 15 to 20 km distance from the sea coast. The lowest value of water soluble Ca^{++} (0.40 me L^{-1}) was recorded in the samples collected from Khambhalia taluka in Devbhumi Dwarka district, whereas the highest value of water soluble Ca^{++} (10.20 me L^{-1}) was found in Dwarka taluka of Devbhumi Dwarka district. Similar findings were also recorded for Churu district (Rajasthan) by Verma et al. (2003), for Porbandar district by Hadiyal (2005), for Junagadh district by Sojitra (2010), for Bhavnagar district by Rajput and Polara (2013), for Latur district of Maharashtra by Patil *et al*. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015) for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.1.2.8.1.4 Water Soluble Mg^{++}

In Jamnagar district, overall mean value of water soluble Mg^{++} was 1.33 me L^{-1}, maximum water soluble Mg^{++} (5.30 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble Mg^{++} (0.30 me L^{-1}) was found at 15 to 20 km distance from the sea coast. In Devbhumi Dwarka district, maximum water soluble Mg^{++} (13.50 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble Mg^{++} (0.32 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of water soluble Mg^{++} was 2.09 me L^{-1}. In Porbandar district, overall mean value of water soluble Mg^{++} was 1.54 me L^{-1}, maximum water soluble Mg^{++} (4.00 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble Mg^{++} (0.34 me L^{-1}) was found at 15 to 20 km distance from the sea coast (Table 4.1.19). The lowest value of water soluble Mg^{++} (0.30 me L^{-1}) was recorded in the samples collected from Jamnagar and Jodiya

Table 4.1.19: Talukawise range and mean values of water soluble Mg^{++} (me L^{-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	2.20-5.30	3.75	0.40-1.50	0.81	0.36-1.20	0.73	0.30-1.00	0.65	0.30-5.30	1.50
Jodiya	1.60-4.20	2.78	0.40-2.40	1.31	0.32-1.30	0.98	0.30-0.90	0.60	0.30-4.20	1.47
Lalpur	1.50-3.80	2.67	0.50-1.20	0.86	0.40-1.10	0.71	0.32-0.70	0.53	0.32-3.80	1.03
Jamnagar District	**1.50-5.30**	**3.85**	**0.40-2.40**	**0.99**	**0.32-1.30**	**0.78**	**0.30-1.00**	**0.60**	**0.30-5.30**	**1.33**
Kalyanpur	1.60-10.70	4.10	0.80-4.40	1.88	0.40-1.10	0.88	0.32-0.90	0.63	0.32-10.70	1.89
Khambhalia	2.00-7.80	3.75	1.10-1.90	1.47	0.50-1.20	0.95	0.37-1.00	0.56	0.37-7.80	1.59
Dwarka	2.10-13.50	4.32	1.60-2.60	2.24	0.90-1.90	1.23	0.40-0.53	0.47	0.40-13.50	2.80
Devbhumi Dwarka District	**1.60-13.50**	**4.13**	**0.80-4.40**	**1.82**	**0.40-1.90**	**1.00**	**0.32-1.00**	**0.56**	**0.32-13.50**	**2.09**
Porbandar	**2.10-4.00**	**2.88**	**0.60-2.80**	**1.68**	**0.40-1.60**	**0.72**	**0.34-1.00**	**0.62**	**0.34-4.00**	**1.54**
Overall	**1.50-13.50**	**3.83**	**0.40-4.40**	**1.39**	**0.32-1.90**	**0.86**	**0.30-1.00**	**0.59**	**0.30-13.50**	**1.69**

talukas in Jamnagar district, whereas the highest value of water soluble Mg^{++} (13.50 me L^{-1}) was found in Dwarka taluka of Devbhumi Dwarka district. The data further revealed that the lowest mean value of water soluble Mg^{++} (1.03 me L^{-1}) was obtained from the samples of Lalpur taluka of Jamnagar district and the highest mean value of water soluble Mg^{++} (2.80 me L^{-1}) was registered in the samples of Dwarka taluka of Devbhumi Dwarka district. Similar findings were also recorded for Amreli district by Kabaria (2004), for Porbandar district by Hadiyal (2005), for Junagadh district by Sojitra (2010), for Bhavnagar district by Rajput and Polara (2013), for Latur district of Maharashtra by Patil *et al*. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015), for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.1.2.8.2 Water Soluble Anions

Talukawise range and mean values of different water soluble anions present in soils of Northern Saurashtra coastal region are given in tables 4.1.20 to 4.1.23.

4.1.2.8.2.1 Water Soluble CO_3^{--}

In case of water soluble CO_3^{--}, the highest overall mean value of (0.32 me L^{-1}) was recorded at the distance of 0 to 5 km from the sea coast. The highest mean value of water soluble CO_3^{--} (0.29 me L^{-1}) was observed in Jodiya taluka while the lowest mean value of water soluble CO_3^{--} (0.13 me L^{-1}) was observed in Khambhalia taluka (Table 4.1.20). In Jamnagar district, maximum water soluble CO_3^{--} (0.56 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble CO_3^{--} (0.00 me L^{-1}) was found at 15 to 20 km distance from the sea coast, whereas overall mean value of water soluble CO_3^{--} was 0.25 me L^{-1} . In Devbhumi Dwarka district, maximum water soluble CO_3^{--} (0.50 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble CO_3^{--} (0.00 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of water soluble CO_3^{--} was 0.18 me L^{-1}. In Porbandar district, overall mean value of water soluble CO_3^{--} was 0.24 me L^{-1}, maximum water soluble CO_3^{--} (0.50 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble CO_3^{--} (0.10 me L^{-1}) was found at 15 to 20 km distance from the sea coast. The highest value of water soluble CO_3^{--} (0.56 me L^{-1}) was found in Jodiya taluka of Jamnagar district. Similar results were also found by Verma *et al.* (2003) for Churu district (Rajasthan), by Kabaria (2004) for Amreli

Table 4.1.20: Talukawise range and mean values of water soluble CO_3^{--} (me L^{-1}) in different districts of Northern Saurashtra coastal region

Talukas \ Distance (km)	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Jamnagar	0.40-0.52	0.46	0.20-0.44	0.31	0.10-0.30	0.17	0.00-0.10	0.05	0.00-0.52	0.23
Jodiya	0.30-0.56	0.42	0.23-0.41	0.30	0.15-0.30	0.23	0.10-0.22	0.16	0.10-0.56	0.29
Lalpur	0.37-0.46	0.41	0.18-0.35	0.27	0.10-0.28	0.19	0.00-0.10	0.07	0.00-0.46	0.23
Jamnagar District	**0.30-0.56**	**0.43**	**0.18-0.44**	**0.29**	**0.10-0.30**	**0.19**	**0.00-0.22**	**0.09**	**0.00-0.56**	**0.25**
Kalyanpur	0.20-0.40	0.26	0.16-0.30	0.22	0.10-0.22	0.19	0.00-0.10	0.03	0.00-0.40	0.18
Khambhalia	0.20-0.40	0.28	0.00-0.30	0.16	0.00-0.20	0.08	0.00-0.08	0.02	0.00-0.40	0.13
Dwarka	0.19-0.50	0.27	0.20-0.36	0.27	0.10-0.22	0.16	0.00-0.00	0.00	0.00-0.50	0.22
Devbhumi Dwarka District	**0.19-0.50**	**0.27**	**0.00-0.36**	**0.21**	**0.00-0.22**	**0.15**	**0.00-0.10**	**0.02**	**0.00-0.50**	**0.18**
Porbandar	**0.20-0.50**	**0.30**	**0.20-0.37**	**0.27**	**0.17-0.29**	**0.22**	**0.10-0.20**	**0.17**	**0.10-0.50**	**0.24**
Overall	**0.19-0.56**	**0.32**	**0.00-0.44**	**0.26**	**0.00-0.30**	**0.18**	**0.00-0.22**	**0.08**	**0.00-0.56**	**0.22**

district, by Hadiyal (2005) for Porbandar district, by Rajput and Polara (2013) for Bhavnagar district, by Polara and Chauhan (2015) for Gir Somnath district, by Hadiya and Polara (2017) for Devbhumi Dwarka district of Gujarat and by Vaghela (2017) for Kheda district of Gujarat.

4.1.2.8.2.2 HCO_3^-

In Jamnagar district, overall mean value of water soluble HCO_3^- was 1.39 me L^{-1}, maximum water soluble HCO_3^- (5.24 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble HCO_3^- (0.40 me L^{-1}) was found at 15 to 20 km distance from the sea coast. In Devbhumi Dwarka district, maximum water soluble HCO_3^- (10.40 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble HCO_3^- (0.50 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of water soluble HCO_3^- was 2.03 me L^{-1}. In Porbandar district, overall mean value of water soluble HCO_3^- was 1.50 me L^{-1}, maximum water soluble HCO_3^- (3.30 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble $HCO3^-$ (0.52 me L^{-1}) was found at 15 to 20 km distance from the sea coast (Table 4.1.21). The lowest value of water soluble HCO_3^- (0.40 me L^{-1}) was recorded in the samples collected from Lalpur taluka in Jamnagar district, whereas the highest value of water soluble HCO_3^- (10.40 me L^{-1}) was found in Dwaka taluka of Devbhumi Dwarka district. The data further revealed that the lowest mean value of water soluble HCO_3^- (1.04 me L^{-1}) was obtained from the samples of Lalpur taluka of Jamnagar district and the highest mean value of water soluble HCO_3^- (2.55 me L^{-1}) was registered in the samples of Dwarka taluka of Devbhumi Dwarka district. Similar findings were also recorded for Churu district (Rajasthan) by Verma *et al*. (2003), for Amreli district by Kabaria (2004), for Bhavnagar district by Rajput and Polara (2013), for Latur district of Maharashtra by Patil *et al*. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015), for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.1.2.8.2.3 Cl^-

The overall water soluble Cl^- values of Northen Saurashtra's soil samples were ranged from 1.50 to 48.70 me L^{-1} with the mean value of 10.30 me L^{-1}. The data (Table 4.1.22) revealed that the lowest mean value of water soluble Cl^- (7.22 me L^{-1})

Table 4.1.21: Talukawise range and mean values of water soluble HCO_3^- (me L^{-1}) in different districts of Northern Saurashtra coastal region

Talukas \ Distance (km)	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Jamnagar	2.40-4.81	3.61	0.92-2.50	1.51	0.80-1.20	1.02	0.70-0.90	0.80	0.70-4.81	1.43
Jodiya	1.50-5.24	2.73	1.41-2.60	1.76	1.06-1.70	1.38	0.50-1.00	0.68	0.50-5.24	1.71
Lalpur	1.00-2.90	1.90	0.80-1.40	1.06	0.60-1.10	0.84	0.40-0.84	0.61	0.40-2.90	1.04
Jamnagar District	**1.00-5.24**	**2.66**	**0.80-2.60**	**1.45**	**0.60-1.70**	**1.03**	**0.40-1.00**	**0.70**	**0.40-5.24**	**1.39**
Kalyanpur	2.50-4.00	3.22	1.20-2.60	1.80	1.00-2.20	1.45	0.80-1.40	1.10	0.80-4.00	1.91
Khambhalia	1.80-3.80	2.70	1.10-2.80	1.63	1.00-1.80	1.48	0.50-1.10	0.92	0.50-3.80	1.64
Dwarka	1.60-10.40	3.71	1.40-2.70	2.30	0.70-1.40	1.13	0.70-0.80	0.75	0.70-10.40	2.55
Devbhumi Dwarka District	**1.60-10.40**	**3.35**	**1.10-2.80**	**1.88**	**0.70-2.20**	**1.36**	**0.50-1.40**	**0.95**	**0.50-10.40**	**2.03**
Porbandar	**1.60-3.30**	**2.30**	**1.60-2.20**	**1.78**	**0.80-1.70**	**0.12**	**0.52-0.70**	**0.63**	**0.52-3.30**	**1.50**
Overall	**1.00-10.40**	**2.96**	**0.80-2.80**	**1.65**	**0.60-2.20**	**1.17**	**0.40-1.40**	**0.79**	**0.40-10.40**	**1.68**

Table 4.1.22: Talukawise range and mean values of water soluble Cl^- (me L^{-1}) in different districts of Northern Saurashtra coastal region

Talukas \ Distance (km)	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Jamnagar	22.80-32.30	27.55	7.00-11.88	8.68	4.80-8.20	6.18	2.40-5.70	4.23	2.40-32.30	8.93
Jodiya	18.60-30.08	22.06	7.40-13.60	10.03	4.70-9.60	6.48	3.30-5.80	4.82	3.30-30.08	11.28
Lalpur	12.20-26.50	18.10	5.10-10.10	7.03	2.80-6.20	4.67	1.90-3.70	2.70	1.90-26.50	7.22
Jamnagar District	**12.20-32.30**	**21.97**	**5.10-13.60**	**8.58**	**2.80-9.60**	**5.63**	**1.90-5.80**	**4.02**	**1.90-32.30**	**9.14**
Kalyanpur	13.70-46.15	22.29	5.10-9.90	6.46	4.20-6.10	4.98	1.50-3.70	2.48	1.50-46.15	9.18
Khambhalia	13.20-40.20	22.98	2.80-8.50	7.16	3.60-6.20	4.95	1.80-3.60	2.68	1.80-40.20	8.76
Dwarka	12.30-48.70	22.33	8.87-14.40	11.58	5.40-8.70	6.70	2.84-5.03	3.94	2.84-48.70	14.68
Devbhumi Dwarka District	**12.30-48.70**	**22.47**	**2.80-14.40**	**8.25**	**3.60-8.70**	**5.46**	**1.50-5.03**	**2.83**	**1.50-48.70**	**10.87**
Porbandar	**9.40-48.40**	**24.43**	**6.40-13.80**	**9.92**	**4.80-8.00**	**6.90**	**2.50-5.78**	**4.10**	**2.50-48.40**	**11.96**
Overall	**9.40-48.70**	**22.67**	**2.80-14.40**	**8.61**	**2.80-9.60**	**5.74**	**1.50-5.80**	**3.55**	**1.50-48.70**	**10.30**

was obtained from the samples of Lalpur taluka of Jamnagar district and the highest mean value of water soluble Cl^- (14.68 me L^{-1}) was found in samples of Dwarka taluka of Devbhumi Dwarka district. In Jamnagar district, maximum water soluble Cl^- (32.30 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble Cl^- (1.90 me L^{-1}) was found at 15 to 20 km distance from the sea coast, whereas overall mean value of water soluble Cl^- was 9.14 me L^{-1}. In Devbhumi Dwarka district, maximum water soluble Cl^- (48.70 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble Cl^- (1.50 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of water soluble Cl^- was 10.87 me L^{-1}. In Porbandar district, overall mean value of water soluble Cl^- was 11.96 me L^{-1}, maximum water soluble Cl^- (48.40 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble Cl^- (2.50 me L^{-1}) was found at 15 to 20 km distance from the sea coast. The lowest value of water soluble Cl^- (1.50 me L^{-1}) was recorded in the samples collected from Kalyanpur taluka in Devbhumi Dwarka district, whereas highest value of water soluble Cl^- (48.70 me L^{-1}) was found in Dwarka taluka of Devbhumi Dwarka district. Similar findings were also recorded for Porbandar district by Hadiyal (2005), for Junagadh district by Sojitra (2010), for Latur district of Maharashtra by Patil *et al*. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015), for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.1.2.8.2.4 SO_4^{--}

In case of water soluble SO_4^{--}, the highest overall mean value of 0.18 me L^{-1} was recorded at the distance of 0 to 5 km from the sea coast. The highest mean value of water soluble SO_4^{--} (0.14 me L^{-1}) was observed in Dwarka taluka while the lowest mean value of water soluble SO_4^{--} (0.03 me L^{-1}) was observed in Lalpur taluka (Table 4.1.23). In Jamnagar district, maximum water soluble SO_4^{--} (0.82 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble SO_4^{--} (0.01 me L^{-1}) was found at 15 to 20 km distance from the sea coast, whereas overall mean value of water soluble SO_4^{--} was (0.07 me L^{-1}). In Devbhumi Dwarka district, maximum water soluble SO_4^{--} (0.95 me L^{-1}) was found at 0 to 5 km distance from sea coast and minimum water soluble SO_4^{--} (0.01 me L^{-1}) was found at 15 to 20 km distance from

Table 4.1.23: Talukawise range and mean values of water soluble SO_4^{--} (me L^{-1}) in different districts of Northern Saurashtra coastal region

Talukas \ Distance (km)	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Jamnagar	0.15-0.30	0.23	0.01-0.09	0.05	0.02-0.06	0.04	0.02-0.06	0.04	0.01-0.30	0.06
Jodiya	0.05-0.82	0.26	0.02-0.80	0.15	0.01-0.06	0.03	0.01-0.05	0.04	0.01-0.82	0.13
Lalpur	0.01-0.04	0.03	0.01-0.05	0.03	0.01-0.04	0.03	0.01-0.04	0.02	0.01-0.05	0.03
Jamnagar District	**0.01-0.82**	**0.18**	**0.01-0.80**	**0.07**	**0.01-0.06**	**0.03**	**0.01-0.06**	**0.03**	**0.01-0.82**	**0.07**
Kalyanpur	0.02-0.28	0.13	0.01-0.06	0.03	0.01-0.05	0.03	0.01-0.03	0.02	0.01-0.28	0.05
Khambhalia	0.03-0.09	0.07	0.03-0.09	0.05	0.01-0.06	0.04	0.01-0.05	0.03	0.01-0.09	0.04
Dwarka	0.01-0.95	0.24	0.02-0.15	0.07	0.02-0.08	0.06	0.02-0.07	0.05	0.01-0.95	0.14
Devbhumi Dwarka District	**0.01-0.95**	**0.17**	**0.01-0.15**	**0.05**	**0.01-0.08**	**0.04**	**0.01-0.07**	**0.03**	**0.01-0.95**	**0.08**
Porbandar	**0.04-0.60**	**0.22**	**0.02-0.17**	**0.07**	**0.01-0.08**	**0.04**	**0.01-0.05**	**0.03**	**0.01-0.60**	**0.10**
Overall	**0.01-0.95**	**0.18**	**0.01-0.80**	**0.06**	**0.01-0.08**	**0.04**	**0.01-0.07**	**0.03**	**0.01-0.95**	**0.08**

the sea coast, while overall mean value of water soluble SO_4^{--} was (0.08 me L^{-1}). In Porbandar district, overall mean value of water soluble SO_4^{--} was (0.10 me L^{-1}), maximum water soluble SO_4^{--} (0.60 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum water soluble SO_4^{--} (0.01 me L^{-1}) was found at 15 to 20 km distance from the sea coast. The highest value of water soluble SO_4^{--} (0.95 me L^{-1}) was found in Dwarka taluka of Devbhumi Dwarka district. Similar results were also found by Verma *et al.* (2003) for Churu district (Rajasthan), by Kabaria (2004) for Amreli district, by Hadiyal (2005) for Porbandar district, by Rajput and Polara (2013) for Bhavnagar district, by Polara and Chauhan (2015) for Gir Somnath district, by Hadiya and Polara (2017) for Devbhumi Dwarka district and by Vaghela (2017) for Kheda district of Gujarat.

4.2 FERTILITY STATUS AND NUTRIENT INDEX OF THE SURFACE SOIL

For studying the fertility status of soils of Northern Saurashtra coastal region, 141 soil samples were collected from the cultivated farmer's field and were analyzed for available N, P_2O_5, K_2O, S and DTPA extractable Fe, Mn, Cu and Zn. Sample wise values of fertility parameters (for all the 141 samples) are given in Appendix II and talukawise range and mean values for these parameters are presented in tables 4.2.1 to 4.2.9. The number of samples falling in low, medium and high fertility classes for macro and micronutrients are presented in table 4.2.10 and 4.2.11, respectively.

4.2.1 Available macronutrient status

4.2.1.1 Available N status

The values of available N estimated from the collected soil samples are given in table 4.2.1. The overall range of available N in Nothern Saurashtra coastal region was 80.41 to 431 kg ha^{-1} with the mean value of 204.70 kg ha^{-1}. The data revealed that the lowest mean value of available N (156.26 kg ha^{-1}) was obtained from the samples of Lalpur taluka of Jamnagar district and the highest mean value of available N (250.45 kg ha^{-1}) was found in the samples of Jamnagar taluka of Jamnagar district. In Jamnagar district, maximum available N (423.40 kg ha^{-1}) was found at 15 to 20 km

Table 4.2.1: Talukawise range and mean values of available N (kg ha^{-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	180.60-190.50	185.55	140.60-300.50	226.80	140.20-380.50	251.28	223.60-423.40	328.93	140.20-423.40	250.45
Jodiya	118.80-200.00	152.90	140.40-250.50	180.33	150.20-310.20	247.93	248.60-354.80	321.93	118.80-354.80	215.31
Lalpur	80.41-116.80	103.20	90.40-180.50	133.33	114.50-220.70	158.79	226.70-289.40	256.93	80.41-289.40	156.26
Jamnagar District	**80.41-200.00**	**144.52**	**90.40-300.50**	**182.27**	**114.50-380.50**	**212.41**	**223.60-423.40**	**306.75**	**80.41-423.40**	**207.34**
Kalyanpur	136.60-189.80	162.62	150.17-200.35	175.55	160.81-362.30	247.76	253.20-408.60	323.90	136.60-408.60	223.65
Khambhalia	124.60-147.09	134.39	130.63-180.50	146.79	168.99-240.76	215.25	153.16-251.62	210.56	124.60-251.62	173.94
Dwarka	122.30-162.72	139.61	134.20-184.10	158.28	158.20-252.40	204.65	403.10-431.59	417.35	122.30-431.59	185.06
Devbhumi Dwarka District	**122.30-189.80**	**144.84**	**130.63-200.35**	**158.63**	**158.20-362.30**	**226.15**	**153.16-431.59**	**289.37**	**122.30-431.59**	**194.22**
Porbandar	**126.80-136.10**	**130.80**	**131.20-291.00**	**193.40**	**170.20-329.10**	**232.64**	**328.60-428.61**	**370.87**	**126.80-428.61**	**227.11**
Overall	**80.41-200.00**	**142.27**	**90.40-300.50**	**174.40**	**114.50-380.50**	**220.56**	**153.16-431.59**	**311.54**	**80.41-431.59**	**204.70**

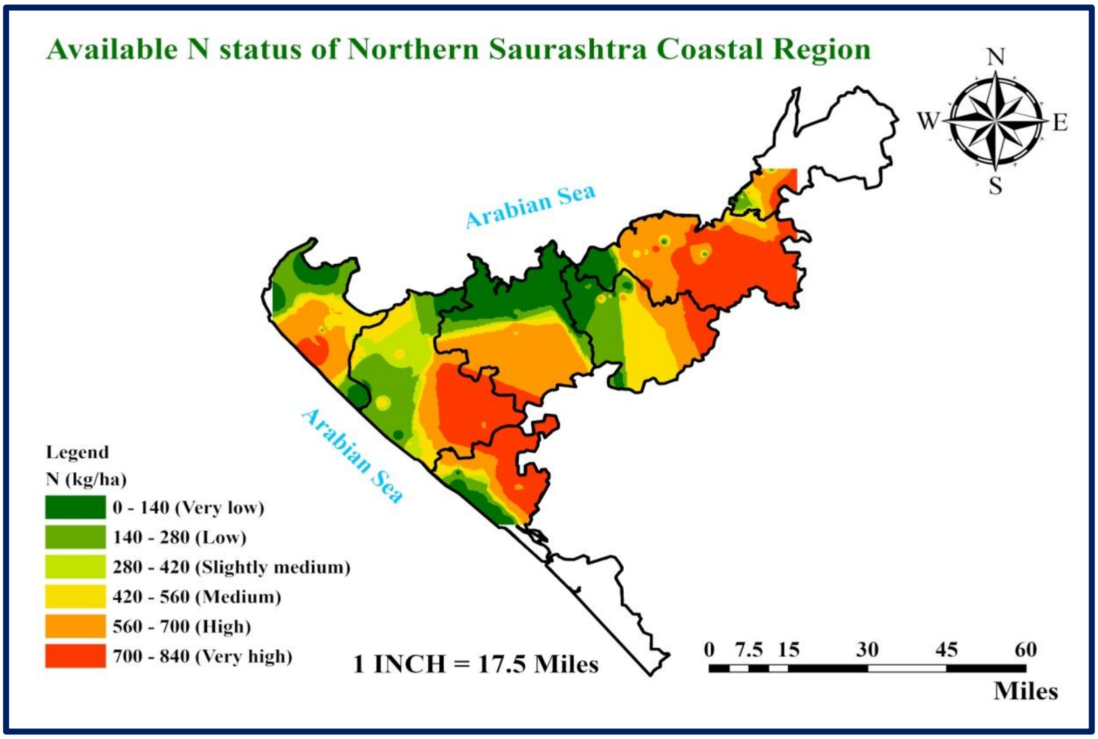


Fig. 4.5: Map of overall available N status in coastal soils of Northern Saurashtra region

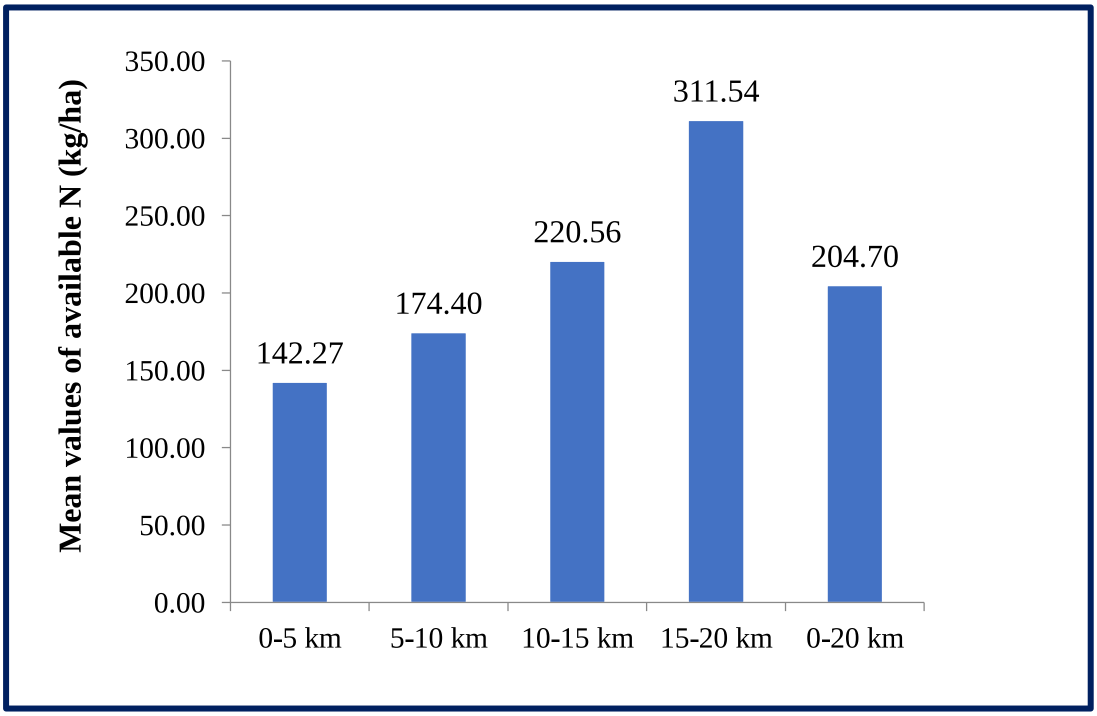


Fig. 4.6: Overall available N status in coastal soils of Northern Saurashtra region

distance from the sea coast and minimum available N (80.41 kg ha^{-1}) was found at 0 to 5 km distance from the sea coast, whereas overall mean value of available N was 207.34 kg ha^{-1} (Fig 4.5 and Fig 4.6). In Devbhumi Dwarka district, maximum available N (431.59 kg ha^{-1}) was found at 15 to 20 km distance from the sea coast and minimum available N (122.30 kg ha^{-1}) was found at 0 to 5 km distance from the sea coast, while overall mean value of available N was 194.22 kg ha^{-1}. In Porbandar district, overall mean value of available N was 227.11 kg ha^{-1}, maximum available N (428.61 kg ha^{-1}) was found at 15 to 20 km distance from the sea coast and minimum available N (126.80 kg ha^{-1}) was found at 0 to 5 km distance from the sea coast. The lowest value of available N (80.41 kg ha^{-1}) was recorded in the samples collected from Lalpur taluka in Jamnagar district, whereas the highest value of available N (431.59 kg ha^{-1}) was found in Dwarka taluka of Devbhumi Dwarka district.

Overall 73.05 per cent samples were tested as low class (< 250 kg N ha^{-1}), 26.95 per cent samples were under medium class for available N. None of the sample was found under high class of available N (Table 4.2.10). Such lower values for available N might be because of poor addition of organic matter as well as less use of organic manures in the semi arid tract. About 70.00, 80.00 and 61.90 per cent soil samples of Jamnagar, Devbhumi Dwarka and Porbandar districts, respectively were found under low class of available N. The soils of Northern Saurashtra coastal region were deficient (<250 kg ha^{-1}) in respect of available N upto 15 km from sea coast, while it was medium status i.e. 311.54 kg ha^{-1} between 15 to 20 km away from sea coast. Similar results were reported for Tonk district of Rajasthan by Meena *et al*. (2006), for Bhavnagar district by Rajput and Polara (2012), for Janjgir district by Devdas and Srivastava (2013), for Sivaganga district of Tamil Nadu by Malavath and Mani (2014), by Nagaral *et al*. (2016) for Northern Transitional Zone of Karnataka and for Kapada district of Tamil Nadu by Reddy and Naidu (2016).

4.2.1.2 Available P_2O_5 status

Taluka wise range and mean values of available P_2O_5 in soils of Northern Saurashtra coastal region are given in table 4.2.2, fig. 4.7 and 4.8. In Jamnagar district, overall mean value of available P_2O_5 was 28.58 kg ha^{-1}whereas, maximum available P_2O_5 (52.51 kg ha^{-1}) was found at 15 to 20 km distance from the sea coast and minimum available P_2O_5 (15.53 kg ha^{-1}) was found at 0 to 5 km distance from the

Table 4.2.2: Talukawise range and mean values of available P_2O_5 (kg ha^{-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	17.72-32.31	25.02	19.74-43.30	28.75	21.39-44.24	30.01	22.03-49.28	32.86	17.72-49.28	29.58
Jodiya	18.66-32.77	23.83	19.10-34.24	26.60	25.63-49.19	31.99	25.28-52.51	34.13	18.66-52.51	28.49
Lalpur	15.53-28.01	23.21	19.05-36.20	25.85	22.40-40.69	29.74	24.82-43.90	31.56	15.53-43.90	27.67
Jamnagar District	**15.53-32.77**	**23.88**	**19.05-43.30**	**27.14**	**21.39-49.19**	**30.37**	**22.03-52.51**	**32.97**	**15.53-52.51**	**28.58**
Kalyanpur	17.91-38.01	26.93	21.14-41.31	28.76	20.93-50.20	30.83	31.42-109.60	62.87	17.91-109.60	35.75
Khambhalia	21.69-27.80	24.32	22.56-34.03	27.59	22.12-41.54	28.50	23.43-44.59	31.90	21.69-44.59	28.20
Dwarka	14.82-35.98	23.97	25.72-41.82	31.60	25.97-45.34	32.97	27.87-45.66	36.77	14.82-45.66	28.96
Devbhumi Dwarka District	**14.82-38.01**	**24.87**	**21.14-41.82**	**29.11**	**20.93-50.20**	**30.78**	**23.43-109.60**	**44.05**	**14.82-109.60**	**30.97**
Porbandar	**13.21-25.30**	**16.81**	**12.34-26.95**	**18.43**	**17.22-32.91**	**24.23**	**30.32-54.07**	**39.03**	**12.34-54.07**	**24.25**
Overall	**13.21-38.01**	**23.16**	**12.34-43.30**	**26.91**	**17.22-50.20**	**29.67**	**22.03-109.60**	**38.60**	**12.34-109.60**	**28.95**

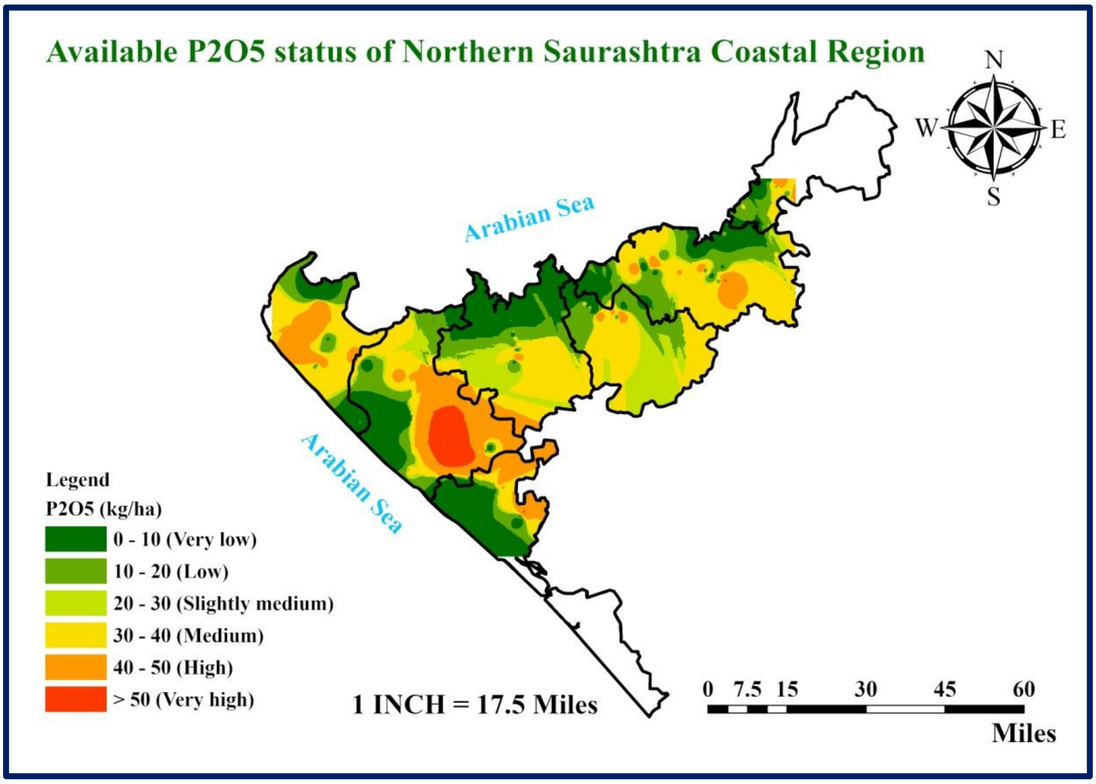


Fig. 4.7: Map of overall available P_2O_5 status in coastal soils of Northern Saurashtra region

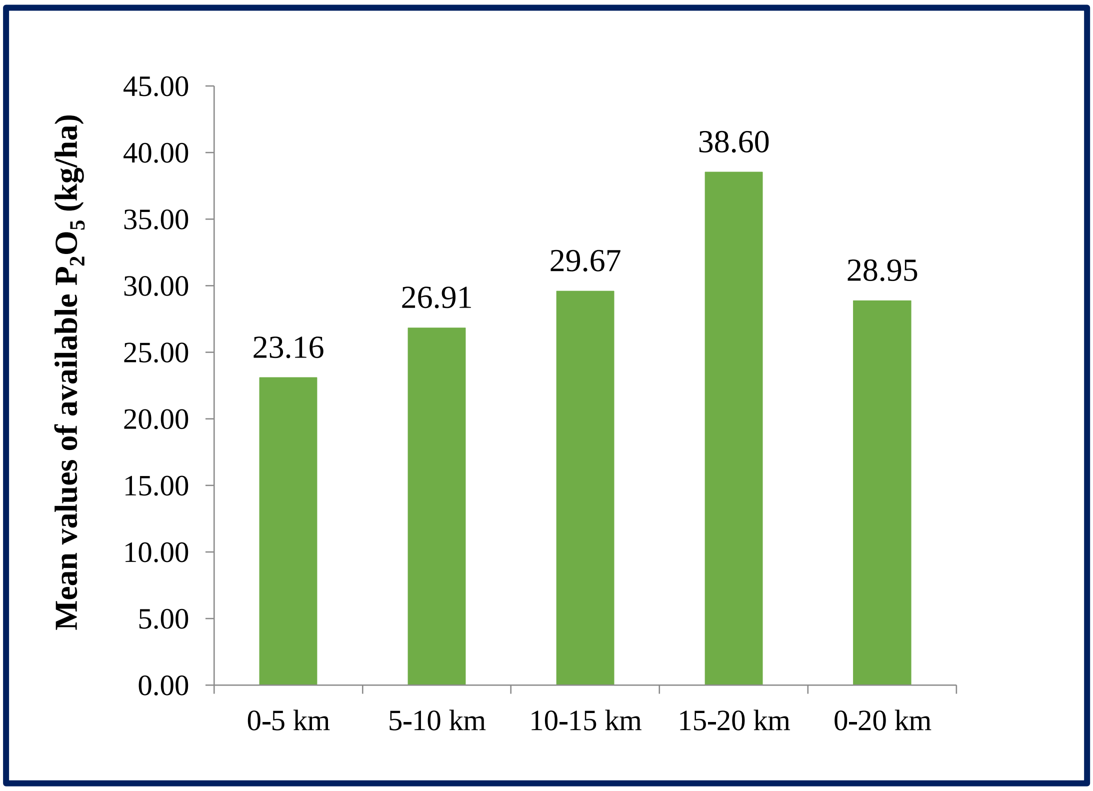


Fig. 4.8: Overall available P_2O_5 status in coastal soils of Northern Saurashtra region

sea coast. In Devbhumi Dwarka district, maximum P_2O_5 (109.60 kg ha^{-1}) was found at 15 to 20 km distance from the sea coast and minimum available P_2O_5 (14.82 kg ha^{-1}) was found at 0 to 5 km distance from the sea coast, while overall mean value of available P_2O_5 was 30.97 kg ha^{-1}. In Porbandar district, overall mean value of P_2O_5 was 24.25 kg ha^{-1}, maximum available P_2O_5 (54.07 kg ha^{-1}) was found at 15 to 20 km distance from the sea coast and minimum available P_2O_5 (12.34 kg ha^{-1}) was found at 5 to 10 km distance from the sea coast. The lowest value of available P_2O_5 (12.34 kg ha^{-1}) was recorded in the samples collected from Porbandar taluka in Porbandar district, whereas the highest value of available P_2O_5 (109.60 kg ha^{-1}) was found in Kalyanpur taluka of Devbhumi Dwarka district. The data further revealed that the lowest mean value of available P_2O_5 (24.25 kg ha^{-1}) was obtained from the samples of Porbandar taluka of Porbandar district and the highest mean value of available P_2O_5 (35.75 kg ha^{-1}) was registered in the samples of Kalyanpur taluka of Devbhumi Dwarka district.

About 58.16, 40.43 and 1.42 per cent soil samples were observed as low, medium and high in available P_2O_5, respectively (Table 4.2.10). About 61.67, 51.67 and 66.67 per cent soil samples of Jamnagar, Devbhumi Dwarka and Porbandar districts, respectively were found under low class of available P_2O_5. The status of available P_2O_5 was increased from 23.16 to 38.00 kg ha^{-1} in Northern Saurashtra coastal region with increased the distance from sea coast. It was deficient to marginal level. However, overall value of available P_2O_5 in the region was found medium status *i.e*. 28.95 kg ha^{-1}. Similar results were also reported by Punithraj *et al*. (2012) for Hassan district of Karnataka, Srinivasan and Poongothai (2013) for Tittakudi taluka of Tamil Nadu, Sudharani et al. (2013) for Visakhapatnam district of Andhra Pradesh, Polara and Chauhan (2015) for Gir Somnath district, Nagaral *et al*. (2016) for Northern Transitional Zone of Karnataka, for Kapada district of Tamil Nadu by Reddy and Naidu (2016).

4.2.1.3 Available K_2O status

The values of available K_2O estimated from the collected soil samples are given in table 4.2.3. The overall range of available K_2O in Nothern Saurashtra coastal region was 126.60 to 1014.20 kg ha^{-1} with the mean value of 401.82 kg ha^{-1}. The data revealed that the lowest mean value of available K_2O (243.94 kg ha^{-1}) was obtained

Table 4.2.3: Talukawise range and mean values of available K_2O (kg ha^{-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	170.60-220.30	195.45	187.20-321.20	257.65	287.40-415.20	352.53	472.40-524.20	496.88	170.60-524.20	327.74
Jodiya	164.50-340.90	233.12	207.80-423.30	319.87	274.40-492.90	397.45	478.10-572.60	519.65	164.50-572.60	353.66
Lalpur	126.60-190.10	167.03	145.30-246.40	194.61	201.90-370.60	263.04	372.40-405.60	391.37	126.60-405.60	243.94
Jamnagar District	**126.60-340.90**	**205.76**	**145.30-423.30**	**257.39**	**201.90-492.90**	**326.25**	**372.40-572.60**	**476.38**	**126.60-572.60**	**308.45**
Kalyanpur	135.00-294.10	203.28	264.70-439.80	338.96	423.90-541.20	494.52	578.60-935.60	817.43	135.00-935.60	447.40
Khambhalia	171.60-264.20	207.65	280.60-436.70	341.43	459.80-527.70	501.63	467.80-807.60	660.56	171.60-807.60	426.50
Dwarka	216.90-490.00	388.06	427.80-596.20	531.74	598.20-781.50	702.65	780.80-812.30	796.55	216.90-812.30	527.25
Devbhumi Dwarka District	**135.00-490.00**	**296.64**	**264.70-596.20**	**396.68**	**423.90-781.50**	**556.01**	**467.80-935.60**	**742.33**	**135.00-935.60**	**467.21**
Porbandar	**260.80-321.90**	**285.00**	**345.20-409.10**	**377.80**	**405.90-677.80**	**517.98**	**614.60-1014.20**	**785.76**	**260.80-1014.20**	**481.80**
Overall	**126.60-490.00**	**267.86**	**145.30-596.20**	**324.89**	**201.90-781.50**	**442.23**	**372.40-1014.20**	**642.02**	**126.60-1014.20**	**401.82**

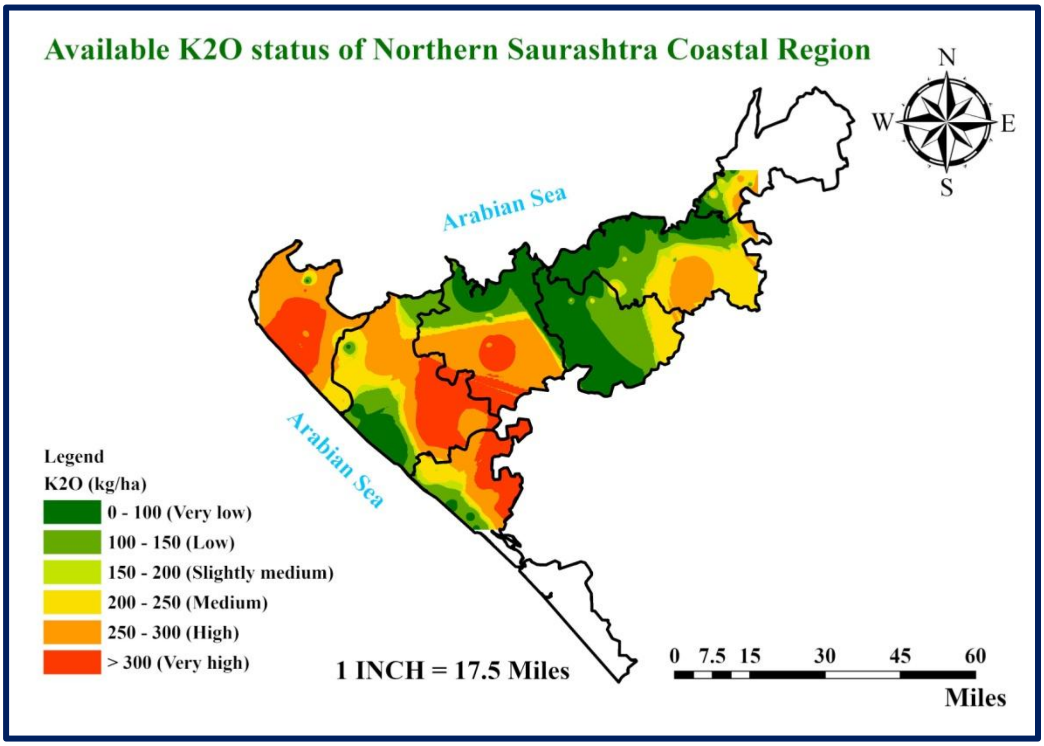


Fig. 4.9: Map of overall available K_2O status in coastal soils of Northern Saurashtra region

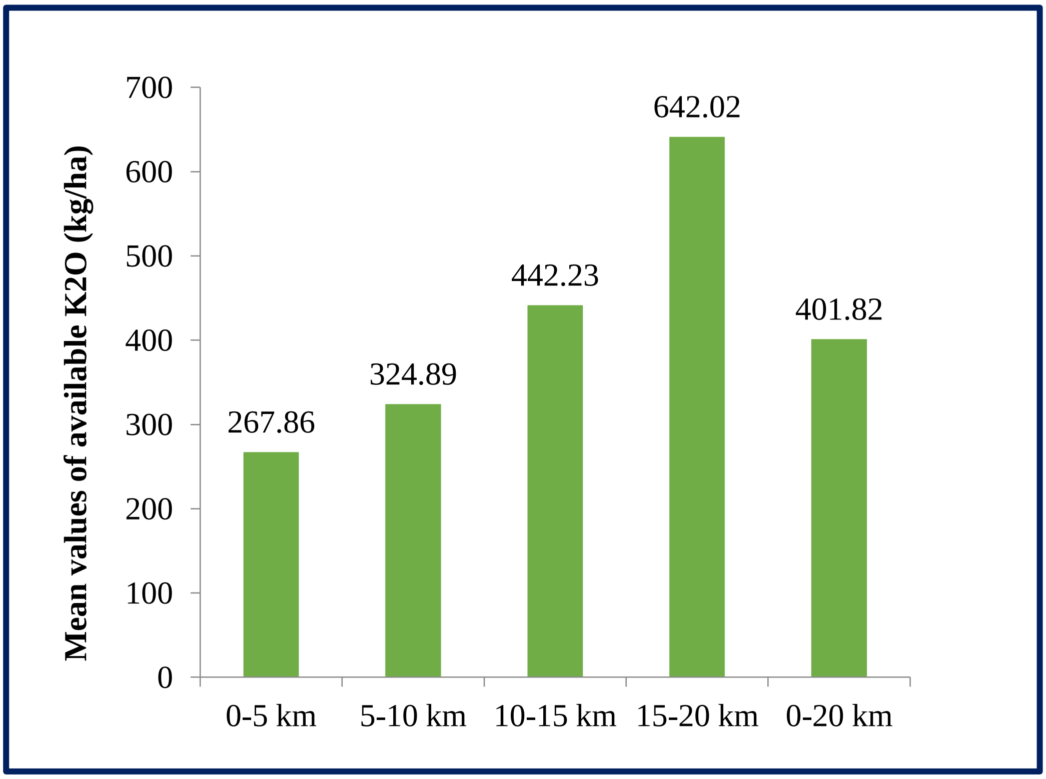


Fig. 4.10: Overall available K_2O status in coastal soils of Northern Saurashtra region

from the samples of Lalpur taluka of Jamnagar district and the highest mean value of available K_2O (527.25 kg ha^{-1}) was found in the samples of Dwarka taluka of Devbhumi Dwarka district. In Jamnagar district, maximum available K_2O (572.60 kg ha^{-1}) was found at 15 to 20 km distance from the sea coast and minimum available K_2O (126.60 kg ha^{-1}) was found at 0 to 5 km distance from the sea coast, whereas overall mean value of available K_2O was 308.45 kg ha^{-1} (Fig 4.9 and 4.10). In Devbhumi Dwarka district, maximum available K_2O (935.60 kg ha^{-1}) was found at 15 to 20 km distance from the sea coast and minimum available K_2O (135.00 kg ha^{-1}) was found at 0 to 5 km distance from the sea coast, while overall mean value of available K_2O was 467.21 kg ha^{-1}. In Porbandar district, overall mean value of available K_2O was 481.80 kg ha^{-1}, maximum available K_2O (1014.20 kg ha^{-1}) was found at 15 to 20 km distance from the sea coast and minimum available K_2O (260.80 kg ha^{-1}) was found at 0 to 5 km distance from the sea coast. The lowest value of available K_2O (126.60 kg ha^{-1}) was recorded in the samples collected from Lalpur taluka in Jamnagar district, whereas the highest value of available K_2O (1014.20 kg ha^{-1}) was found in Porbandar taluka of Porbandar district. Likewise to available N and P_2O_5, the status of available K_2O was increased with increased the distance from sea coast of Northern Saurashtra coastal region. However, it was found sufficient in terms of 401.82 kg ha^{-1} in all sampling distance of the study on the basis of overall mean value.

About 1.42, 31.21 and 67.38 per cent samples were found in low, medium and high categories of available K_2O, respectively (Table 4.2.10). Such high values of available K_2O might be due to the higher content of potash bearing minerals (feldspar, biotite and muscovite) which upon weathering slowly release potash. About 48.33, 80.00 and 85.71 per cent soil samples of Jamnagar, Devbhumi Dwarka and Porbandar districts, respectively were found under high class of available K_2O. Almost similar results were reported for Porbandar district by Hadiyal (2005), for Amreli district by Kabaria and Polara (2006), for Tonk district of Rajasthan by Meena *et al*. (2006), for Junagadh district by Sojitra (2010), for Bhavnagar district by Rajput and Polara (2012), for Janjgir district by Devdas and Srivastava (2013), for Sivaganga district of Tamil Nadu by Malavath and Mani (2014) and for Gir Somnath district of Gujarat by Polara and Chauhan (2015a).

4.2.1.4 Available S status

The values of available S estimated from collected soil samples are given in table 4.2.4, fig 4.11 and 4.12. The overall range of available S in Nothern Saurashtra coastal region was 1.06 to 58.24 mg kg^{-1} with mean value of 20.00 mg kg^{-1}. The data revealed that lowest mean value of available S (13.72 mg kg^{-1}) was obtained from the samples of Lalpur taluka and highest mean value of available S (26.28 mg kg^{-1}) was found in samples of Khambhalia taluka. In Jamnagar district, maximum available S (48.69 mg kg^{-1}) was found at 15 to 20 km distance from the sea coast and minimum available S (1.37 mg kg^{-1}) was found at 0 to 5 km distance from the sea coast, whereas overall mean value of available S was 17.61 mg kg^{-1}. In Devbhumi Dwarka district, maximum available S (58.24 mg kg^{-1}) was found at 15 to 20 km distance from the sea coast and minimum available S (1.07 mg kg^{-1}) was found at 0 to 5 km distance from the sea coast, while overall mean value of available S was 21.27 mg kg^{-1}. In Porbandar district, overall mean value of available S was 23.23 mg kg^{-1}, maximum available S (52.90 mg kg^{-1}) was found at 15 to 20 km distance from the sea coast and minimum available S (1.06 mg kg^{-1}) was found at 0 to 5 km distance from the sea coast. The lowest value of available S (1.06 mg kg^{-1}) was recorded in the samples collected from Porbandar taluka in Porbandar district, whereas highest value of available S (58.24 mg kg^{-1}) was found in Khambhalia taluka of Devbhumi Dwarka district. Overall, value of available S (20.00 mg kg^{-1}) was noted which was higher than its critical limit (10-20 mg kg^{-1}) in soils of Northern Saurashtra coastal region but it was deficient (3.58 mg kg^{-1}) in soils belong under 5 km distance from sea coast.

About 35.46 per cent samples were tested as low class (< 10 mg kg^{-1}), 21.28 per cent samples were under medium class for available S and 43.26 per cent sample falls in high available S class (Table 4.2.10). Such lower status of sulphur in soils of Northern Saurashtra coastal region might be due to use of fertilizers such as urea and DAP by farmers and cultivation of S loving legume crops, resulting its deficiency. About 35.00, 38.33 and 28.57 per cent soil samples of Jamnagar, Devbhumi Dwarka and Porbandar districts, respectively were found under low class of available S. Such lower status of available sulphur was also recorded by Polara and Chauhan (2015) for Gir Somnath district, Patel *et al*. (2016) for Patan district, Hadiyal *et al*. (2016) for Girgadhda and Una talukas of Gir Somanth district, Reddy and Naidu (2016) for Kapada district of Tamil Nadu.

Table 4.2.4: Talukawise range and mean values of available S (mg 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	2.77-4.20	3.49	5.77-18.02	9.88	22.03-40.51	30.59	40.03-48.69	45.12	2.77-48.69	22.50
Jodiya	1.44-4.54	2.71	8.06-16.07	11.68	18.06-27.24	23.27	31.26-40.45	35.89	1.44-40.45	16.60
Lalpur	1.37-2.04	1.72	4.54-10.51	7.78	13.73-25.56	18.34	21.56-36.24	28.77	1.37-3624	13.72
Jamnagar District	**1.37-4.54**	**2.57**	**4.54-18.02**	**9.79**	**13.73-40.51**	**23.83**	**21.56-48.69**	**37.30**	**1.37-48.69**	**17.61**
Kalyanpur	1.87-5.10	3.47	5.41-9.54	8.27	10.47-31.70	21.09	38.90-56.80	46.25	1.87-56.80	18.51
Khambhalia	1.92-8.47	4.46	9.12-26.74	16.20	31.75-46.53	38.33	42.07-58.24	48.22	1.92-58.24	26.28
Dwarka	1.07-10.02	4.31	18.15-26.34	22.14	28.36-36.47	31.88	46.72-56.67	51.70	1.07-56.67	19.02
Devbhumi Dwarka District	**1.07-10.02**	**4.11**	**5.41-26.74**	**15.61**	**10.47-46.53**	**29.10**	**38.90-58.24**	**48.14**	**1.07-58.24**	**21.27**
Porbandar	**1.06-7.34**	**3.67**	**13.41-24.15**	**18.96**	**22.14-31.36**	**26.77**	**43.50-52.90**	**47.44**	**1.06-52.90**	**23.23**
Overall	**1.06-10.02**	**3.58**	**4.54-26.74**	**13.08**	**10.47-46.53**	**26.29**	**21.56-58.24**	**43.59**	**1.06-58.24**	**20.00**

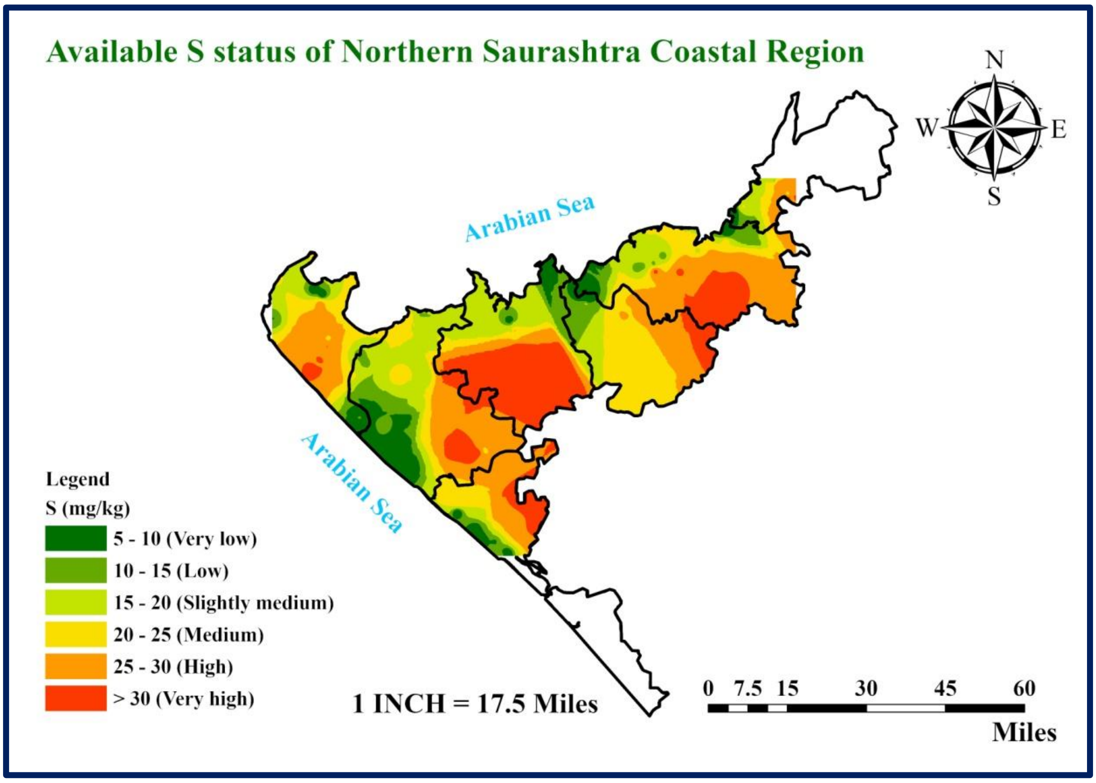


Fig. 4.11: Map of overall available S status in coastal soils of Northern Saurashtra region

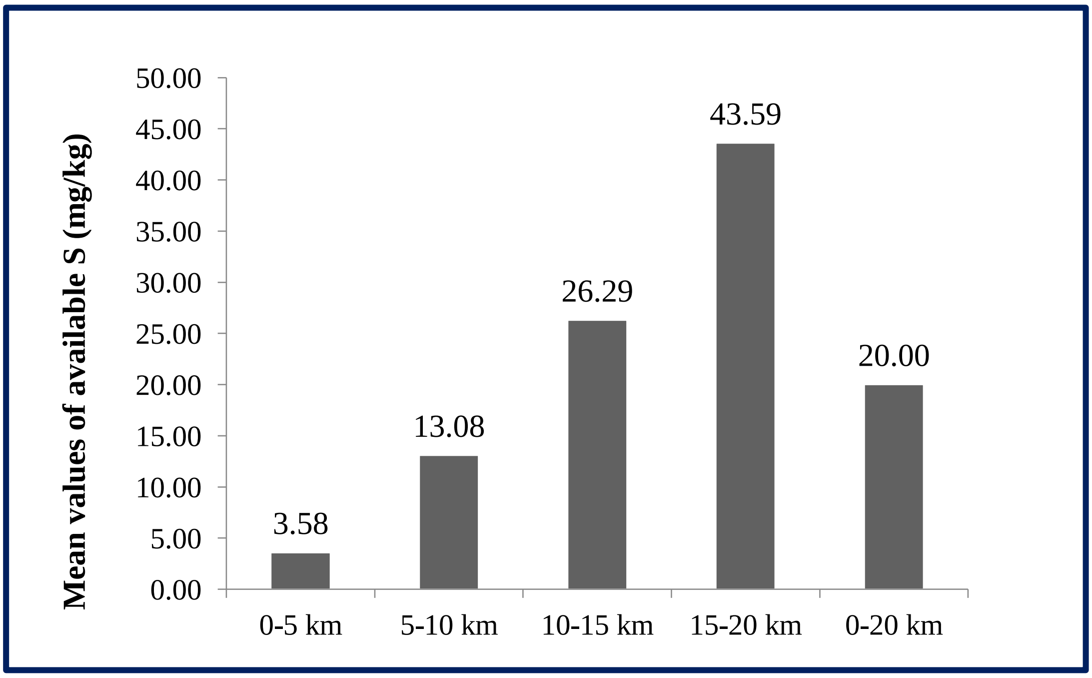


Fig. 4.12: Overall available S status in coastal soils of Northern Saurashtra region

4.2.2 Available micronutrients status

Taluka wise range and mean values for available micronutrients are given in tables 4.2.5 to 4.2.9.

4.2.2.1 DTPA Extractable Fe

The overall Fe status of the soils of Nothern Saurashtra coastal region was medium (Table 4.2.5, Fig 4.13 and 4.14). However, it was deficient (4.69 mg kg^{-1}) in soils of 0-5 km distance from sea coast. It was ranged from 2.92 to 8.92 mg kg^{-1} with mean value of 5.44 mg kg^{-1}. The data revealed that the lowest mean value of Fe (4.38 mg kg^{-1}) was obtained from the samples of Lalpur taluka of Jamnagar district and the highest mean value of Fe (6.01 mg kg^{-1}) was found in the samples of Khambhalia taluka of Devbhumi Dwarka district. In Jamnagar district, maximum Fe (8.43 mg kg^{-1}) was found at 15 to 20 km distance from the sea coast and minimum Fe (3.12 mg kg^{-1}) was found at 0 to 5 km distance from the sea coast, whereas overall mean value of Fe was 5.20 mg kg^{-1}. In Devbhumi Dwarka district, maximum Fe (8.92 mg kg^{-1}) was found at 15 to 20 km distance from the sea coast and minimum Fe (3.30 mg kg^{-1}) was found at 0 to 5 km distance from the sea coast, while overall mean value of Fe was 5.59 mg kg^{-1}. In Porbandar district, overall mean value of Fe was 5.72 mg kg^{-1}, maximum Fe (8.76 mg kg^{-1}) was found at 15 to 20 km distance from the sea coast and minimum Fe (2.92 mg kg^{-1}) was found at 0 to 5 km distance from the sea coast. The lowest value of Fe (2.92 mg kg^{-1}) was recorded in the samples collected from Porbandar taluka in Porbandar district, whereas the highest value of Fe (8.92 mg kg^{-1}) was found in Khambhalia taluka of Devbhumi Dwarka district.

Overall 38.30, 61.70 and 0.00 per cent samples rated as low, medium and high in DTPA-Fe status, respectively (Table 4.2.11). About 55.00, 68.33 and 61.90 per cent soil samples of Jamnagar, Devbhumi Dwarka and Porbandar districts, respectively were found under medium class of DTPA-Fe. Similar results were also reported for villages of northern Madhya Pradesh by Rajput et al. (2015), Hadiyal *et al*. (2016) for Girgadhda and Una talukas of Gir Somanth district, Karajanagi *et al*. (2016) for Malaprabha command area of Karnataka, for Patan district by Patel *et al*. (2016), Wagh et al. (2016) for Nagpur district of Maharashtra.

Table 4.2.5: Talukawise range and mean values of available Fe (mg 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	4.44-5.28	4.86	4.30-6.10	5.04	4.37-7.54	5.81	5.19-7.97	6.35	4.30-7.97	5.51
Jodiya	4.21-5.46	4.71	4.29-7.73	5.37	5.13-8.06	6.39	5.51-8.43	6.82	4.21-8.43	5.70
Lalpur	3.12-4.20	3.51	3.24-5.09	3.93	4.06-5.68	4.71	4.81-6.09	5.54	3.12-6.09	4.38
Jamnagar District	**3.12-5.46**	**4.38**	**3.24-7.73**	**4.79**	**4.06-8.06**	**5.49**	**4.81-8.43**	**6.30**	**3.12-8.43**	**5.20**
Kalyanpur	4.03-6.14	4.72	4.11-6.65	5.28	4.87-7.03	5.81	5.16-7.71	6.17	4.03-7.71	5.48
Khambhalia	4.37-6.57	5.38	4.61-7.14	5.84	5.12-7.74	6.15	5.53-8.92	6.65	4.37-8.92	6.01
Dwarka	3.30-6.43	4.78	4.23-6.74	5.16	4.52-7.54	5.95	5.56-7.57	6.57	3.30-7.57	5.29
Devbhumi Dwarka District	**3.30-6.57**	**4.90**	**4.11-7.14**	**5.48**	**4.52-7.74**	**5.94**	**5.16-8.92**	**6.46**	**3.30-8.92**	**5.59**
Porbandar	**2.92-5.36**	**4.60**	**4.18-7.64**	**5.29**	**4.74-8.09**	**6.38**	**5.18-8.76**	**6.82**	**2.92-8.76**	**5.72**
Overall	**2.92-6.57**	**4.69**	**3.24-7.73**	**5.11**	**4.06-8.09**	**5.79**	**4.81-8.92**	**6.46**	**2.92-8.92**	**5.44**

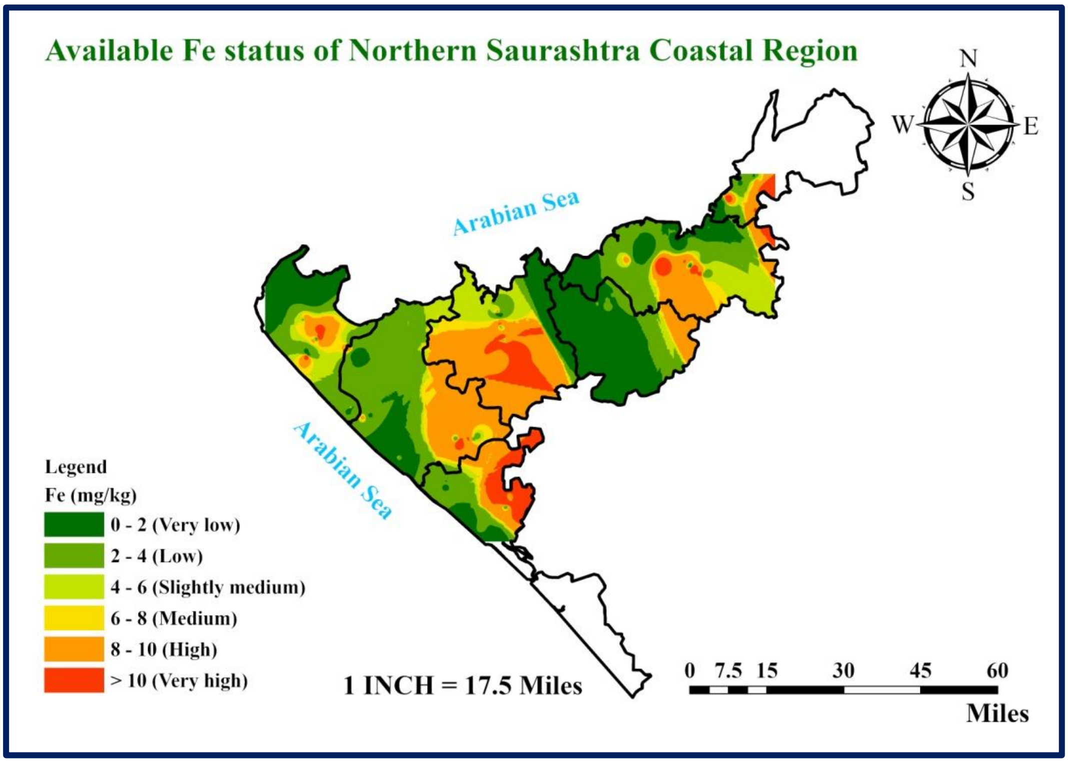


Fig. 4.13: Map of overall available Fe status in coastal soils of Northern Saurashtra region

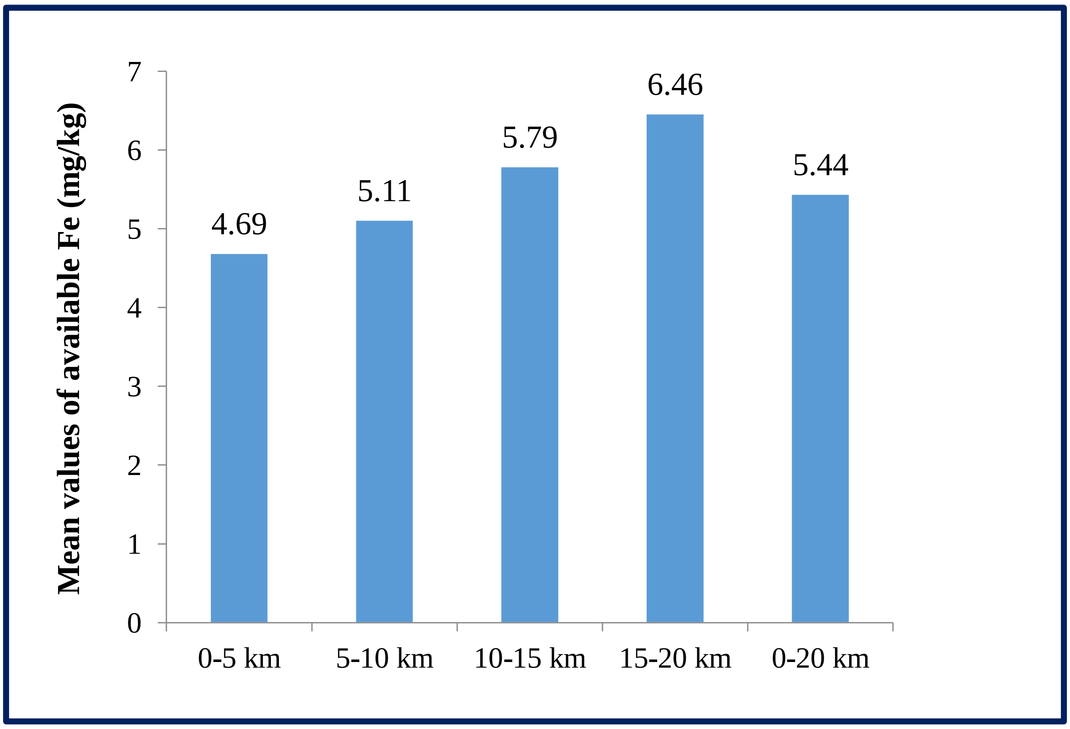


Fig. 4.14: Overall available Fe status in coastal soils of Northern Saurashtra region

4.2.2.2 DTPA Extractable Mn

The soils of Nothern Saurashtra coastal region were ranged from 1.32 to 18.80 mg kg^{-1} with the mean value of 7.45 mg kg^{-1} in case of DTPA-Mn (Table 4.2.6, Fig 4.15 and 4.16). In Jamnagar district, overall mean value of Mn was 7.31 mg kg^{-1}, maximum Mn (15.48 mg kg^{-1}) was found at 15 to 20 km distance from the sea coast and minimum Mn (1.32 mg kg^{-1}) was found at 0 to 5 km distance from the sea coast. In Devbhumi Dwarka district, maximum Mn (18.80 mg kg^{-1}) was found at 15 to 20 km distance from the sea coast and minimum Mn (1.88 mg kg^{-1}) was found at 0 to 5 km distance from the sea coast, while overall mean value of Mn was 7.04 mg kg^{-1}. In Porbandar district, overall mean value of Mn was 9.04 mg kg^{-1}, maximum Mn (15.27 mg kg^{-1}) was found at 15 to 20 km distance from the sea coast and minimum Mn (5.02 mg kg^{-1}) was found at 0 to 5 km distance from the sea coast. The lowest value of Mn (1.32 mg kg^{-1}) was recorded in the samples collected from Jodiya taluka in Jamnagar district, whereas the highest value of Mn (18.80 mg kg^{-1}) was found in Dwarka taluka of Devbhumi Dwarka district. The data further revealed that the lowest mean value of Mn (6.01 mg kg^{-1}) was obtained from the samples of Khambhalia taluka of Devbhumi Dwarka district and the highest mean value of Mn (9.04 mg kg^{-1}) was registered in the samples of Porbandar taluka of Porbandar district. Likewise to Fe, Mn content was also deficient (4.30 mg kg^{-1}) in soils nearest to sea coast (upto 5 km distance) of Northern Saurashtra coastal region.

Overall 22.70, 57.45 and 19.86 per cent samples rated as low, medium and high in DTPA-Mn status, respectively (Table 4.2.11). About 51.67, 58.33 and 71.43 per cent soil samples of Jamnagar, Devbhumi Dwarka and Porbandar districts, respectively were found under medium class of DTPA-Mn. Similar results were also reported for for villages of northern Madhya Pradesh by Rajput *et al*. (2015), Hadiyal *et al*. (2016) for Girgadhda and Una talukas of Gir Somanth district, Karajanagi *et al*. (2016) for Malaprabha command area of Karnataka, for Patan district by Patel *et al*. (2016), Wagh *et al*. (2016) for Nagpur district of Maharashtra.

4.2.2.3 DTPA Extractable Cu

In general, DTPA-Cu status of soils of Nothern Saurashtra coastal region was high (Table 4.2.7). The DTPA-Cu ranged from 0.13 to 7.31 mg kg^{-1} with the mean value of 1.01 mg kg^{-1}. In Jamnagar district, the lowest (0.23 mg kg^{-1}) Cu value was

Table 4.2.6: Talukawise range and mean values of available Mn (mg kg^{-1}) in different districts of Northern Saurashtra coastal region

Talukas \ Distance (km)	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Jamnagar	2.92-3.90	3.41	4.15-8.18	5.60	5.59-11.80	8.96	9.43-15.48	12.17	2.92-15.48	7.70
Jodiya	1.32-4.87	3.03	4.82-6.68	5.98	8.31-10.24	9.25	9.42-11.23	10.43	1.32-11.23	6.79
Lalpur	3.25-4.44	3.96	4.15-7.61	6.06	6.28-10.73	8.22	11.37-13.40	12.26	3.25-13.40	7.43
Jamnagar District	**1.32-4.87**	**3.38**	**4.15-8.18**	**5.87**	**5.59-11.80**	**8.73**	**9.42-15.48**	**11.56**	**1.32-15.48**	**7.31**
Kalyanpur	1.88-4.68	2.87	4.93-6.89	5.74	8.02-10.93	9.36	11.32-12.95	12.36	1.88-12.95	7.43
Khambhalia	3.68-4.37	4.05	4.30-5.58	4.91	5.30-7.92	6.43	7.25-10.91	8.77	3.68-10.91	6.01
Dwarka	2.62-6.94	5.40	6.27-8.32	7.44	8.38-9.06	8.69	14.11-18.80	16.46	2.62-18.80	7.67
Devbhumi Dwarka District	**1.88-6.94**	**4.40**	**4.30-8.32**	**5.90**	**5.30-10.93**	**8.33**	**7.25-18.80**	**11.47**	**1.88-18.80**	**7.04**
Porbandar	**5.02-6.59**	**5.54**	**7.28-9.50**	**8.38**	**9.05-10.60**	**9.55**	**11.67-15.27**	**13.40**	**5.02-15.27**	**9.04**
Overall	**1.32-6.94**	**4.30**	**4.15-9.50**	**6.16**	**5.30-11.80**	**8.69**	**7.25-18.80**	**11.87**	**1.32-18.80**	**7.45**

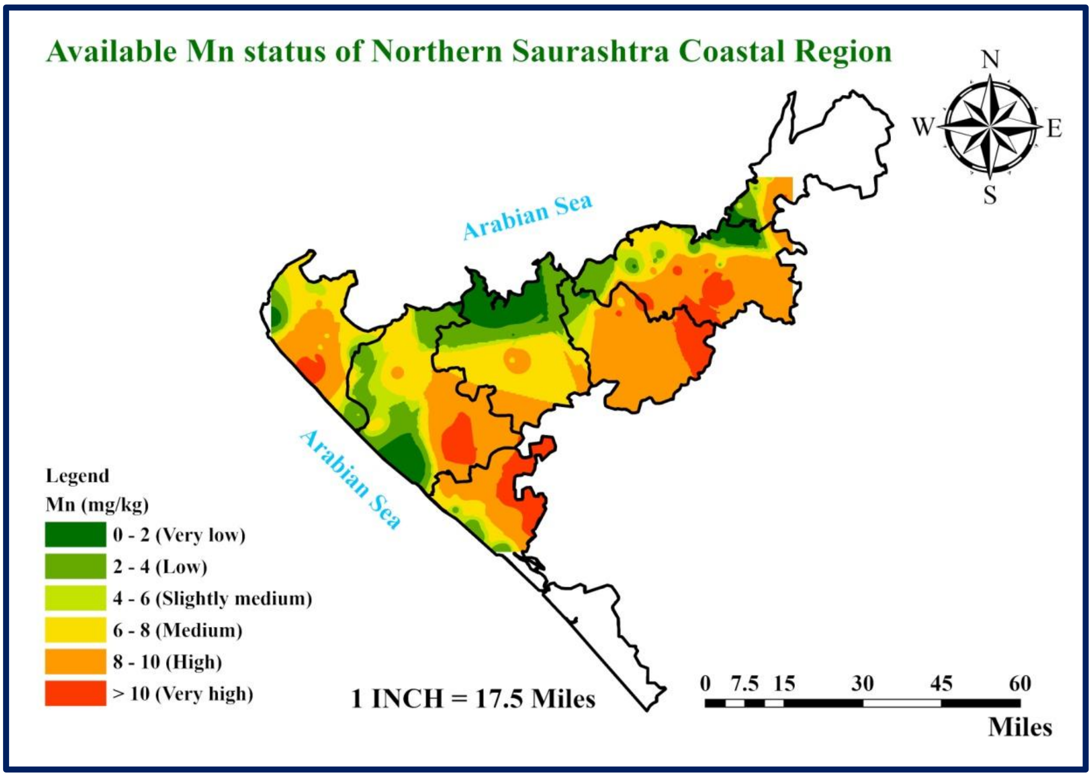


Fig. 4.15: Map of overall available Mn status in coastal soils of Northern Saurashtra region

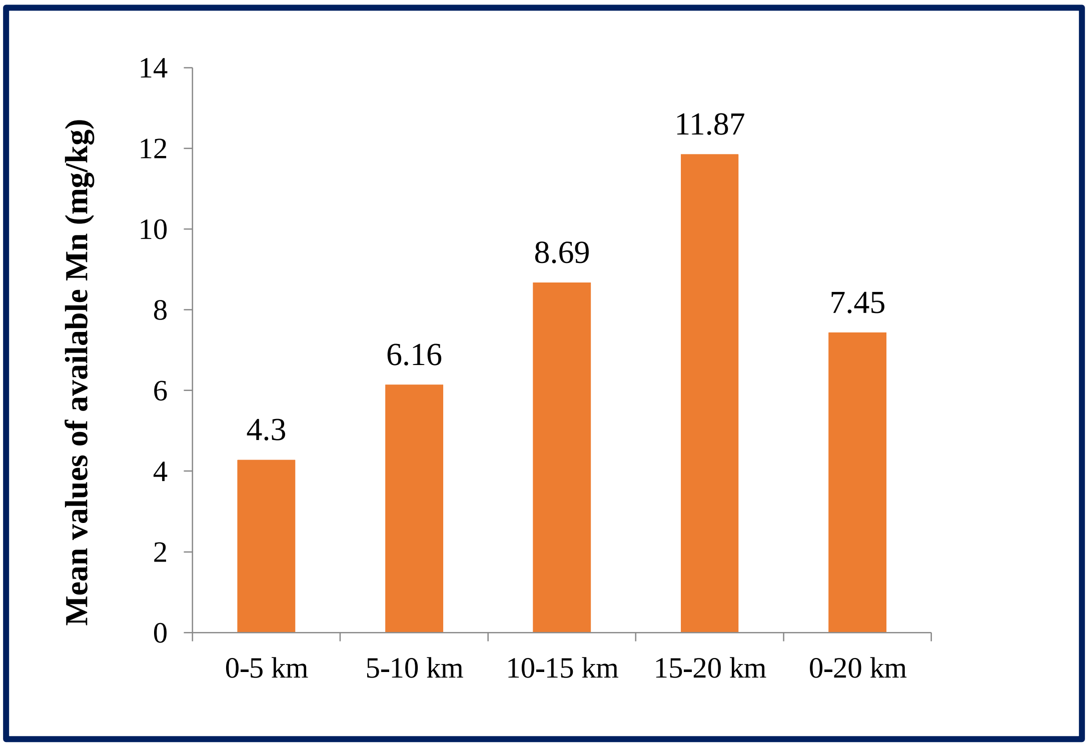


Fig. 4.16: Overall available Mn status in coastal soils of Northern Saurashtra region

recorded in soil samples collected from Jodiya taluka at the distance of 0 to 5 km from the sea coast and the highest (7.31 mg kg^{-1}) Cu value was recorded in soil samples collected from Jamnagar taluka at the distance of 15 to 20 km from the sea coast, while overall mean value of Cu was 1.38 mg kg^{-1} (Fig 4.17 and 4.18). In Devbhumi Dwarka district, maximum Cu (1.83 mg kg^{-1}) was found at 15 to 20 km distance from the sea coast and minimum Cu (0.13 mg kg^{-1}) was found at 0 to 5 km distance from the sea coast, while overall mean value of Cu was 0.74 mg kg^{-1}. In Porbandar district, overall mean value of Cu was 0.74 mg kg^{-1}, maximum Cu (1.30 mg kg^{-1}) was found at 15 to 20 km distance from the sea coast and minimum Cu (0.49 mg kg^{-1}) was found at 0 to 5 km distance from the sea coast. Data further revealed that the highest (2.47 mg kg^{-1}) and the lowest (0.57 mg kg^{-1}) mean Cu values were registered in Jamnagar and Dwarka talukas, respectively.

Overall 1.42, 3.55 and 95.04 per cent samples were found in low, medium and high categories of DTPA-Cu, respectively (Table 4.2.11). About 96.67, 91.67 and 100.00 per cent soil samples of Jamnagar, Devbhumi Dwarka and Porbandar districts, respectively were found under high class of DTPA-Cu. Results reported in present investigation find supports from the work reported elsewhere for villages of northern Madhya Pradesh by Rajput *et al*. (2015), Hadiyal *et al*. (2016) for Girgadhda and Una talukas of Gir Somanth district, Karajanagi *et al*. (2016) for Malaprabha command area of Karnataka, for Patan district by Patel *et al*. (2016) and Wagh *et al*. (2016) for Nagpur district of Maharashtra.

4.2.2.4 DTPA Extractable Zn

The DTPA-Zn status of the soils of Nothern Saurashtra coastal region was low (0.46 mg kg^{-1}). However, it was vary with distance away from soil sampling. The soil is deficient in Zn content upto 10 km distance and marginal in soils of 10 to 20 km distance. It was ranged from 0.06 to 3.58 mg kg^{-1} with the mean value of 0.46 mg kg^{-1}. The data (Table 4.2.8, Fig 4.19 and 4.20) revealed that the lowest mean value of Zn (0.21 mg kg^{-1}) was obtained from the samples of Kalyanpur taluka of Devbhumi Dwarka district and the highest mean value of Zn (1.10 mg kg^{-1}) was found in the samples of Jamnagar taluka of Jamnagar district. In Jamnagar district, the maximum Zn (3.58 mg kg^{-1}) was found at 15 to 20 km distance from the sea coast and the minimum Zn (0.13 mg kg^{-1}) was found at 0 to 5 km distance from the sea coast, whereas the overall mean value of Zn was 0.64 mg kg^{-1}.

Table 4.2.7: Talukawise range and mean values of available Cu (mg 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	0.62-0.83	0.73	0.71-1.66	1.21	1.96-4.29	2.72	4.27-7.31	5.49	0.62-7.31	2.47
Jodiya	0.23-0.57	0.45	0.48-0.72	0.60	0.75-0.85	0.81	0.86-2.35	1.29	0.23-2.35	0.74
Lalpur	0.39-0.75	0.59	0.76-0.87	0.81	0.91-1.22	1.03	1.24-1.46	1.34	0.39-1.46	0.93
Jamnagar District	**0.23-0.83**	**0.55**	**0.48-1.66**	**0.89**	**0.75-4.29**	**1.57**	**0.86-7.31**	**2.83**	**0.23-7.31**	**1.38**
Kalyanpur	0.25-0.55	0.45	0.46-0.62	0.55	0.79-1.13	0.90	1.20-1.39	1.30	0.25-1.39	0.78
Khambhalia	0.47-0.70	0.59	0.65-0.78	0.72	0.77-0.89	0.85	1.03-1.83	1.33	0.47-1.83	0.87
Dwarka	0.13-0.52	0.35	0.59-0.70	0.65	0.71-0.77	0.73	0.84-1.29	1.07	0.13-1.29	0.57
Devbhumi Dwarka District	**0.13-0.70**	**0.43**	**0.46-0.78**	**0.65**	**0.71-1.13**	**0.84**	**0.84-1.83**	**1.27**	**0.13-1.83**	**0.74**
Porbandar	**0.49-0.64**	**0.56**	**0.60-0.76**	**0.65**	**0.72-0.87**	**0.80**	**0.81-1.30**	**0.97**	**0.49-1.30**	**0.74**
Overall	**0.13-0.83**	**0.49**	**0.46-1.66**	**0.77**	**0.71-4.29**	**1.18**	**0.81-7.31**	**1.85**	**0.13-7.31**	**1.01**

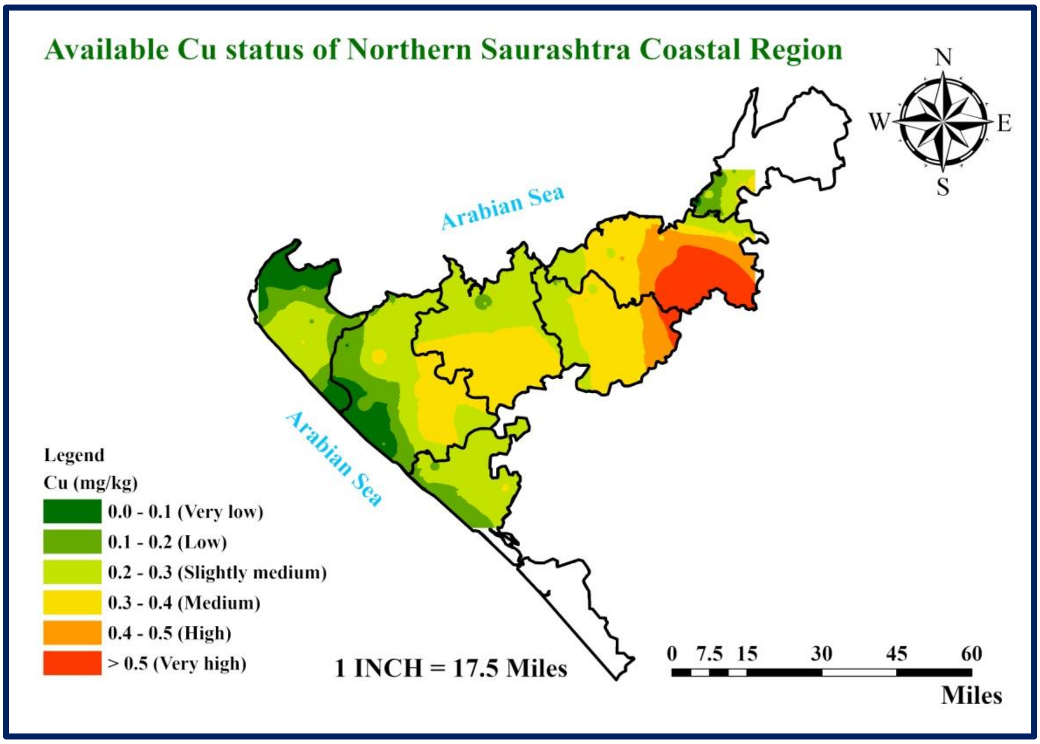


Fig. 4.17: Map of overall available Cu status in coastal soils of Northern Saurashtra region

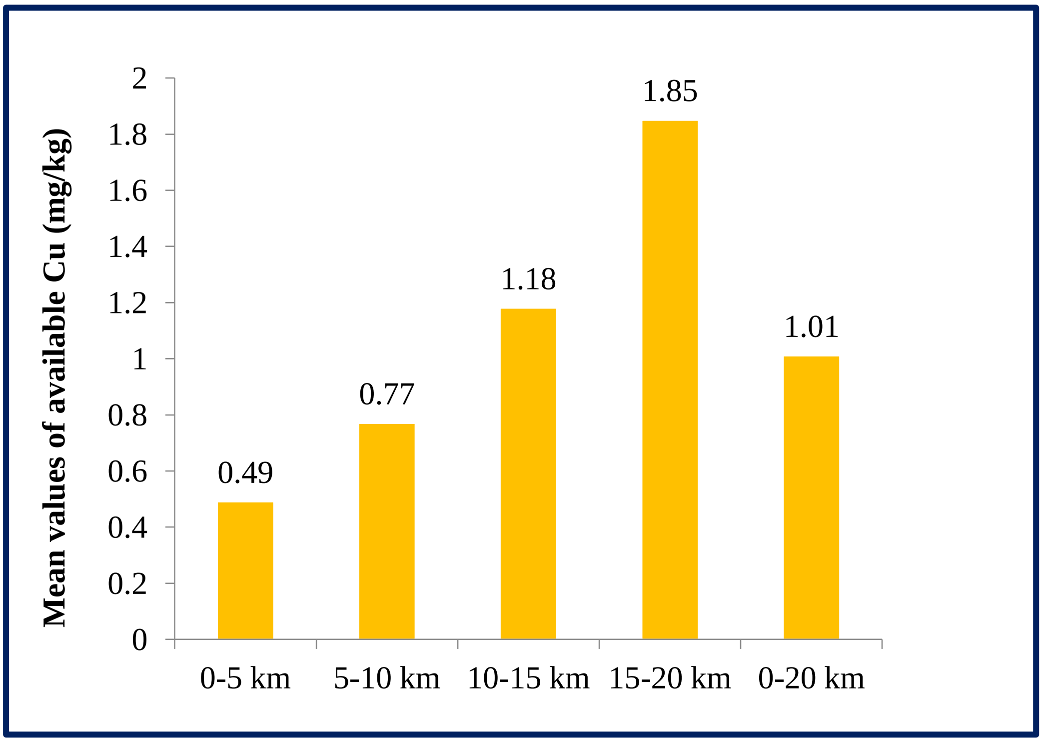


Fig. 4.18: Overall available Cu status in coastal soils of Northern Saurashtra region

Table 4.2.8: Talukawise range and mean values of available Zn (mg 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	0.23-0.30	0.27	0.25-0.69	0.49	1.17-1.64	1.41	1.64-3.58	2.29	0.23-3.58	1.10
Jodiya	0.13-0.21	0.18	0.17-0.32	0.26	0.41-0.58	0.48	0.63-1.12	0.82	0.13-1.12	0.39
Lalpur	0.18-0.31	0.24	0.28-0.41	0.36	0.38-0.63	0.48	0.53-0.66	0.60	0.18-0.66	0.42
Jamnagar District	**0.13-0.30**	**0.21**	**0.17-0.69**	**0.37**	**0.38-1.64**	**0.81**	**0.53-3.58**	**1.29**	**0.13-3.58**	**0.64**
Kalyanpur	0.08-0.19	0.12	0.12-0.21	0.16	0.20-0.30	0.25	0.26-0.45	0.33	0.08-0.45	0.21
Khambhalia	0.13-0.19	0.16	0.15-0.29	0.22	0.27-0.34	0.30	0.35-1.11	0.67	0.13-1.11	0.33
Dwarka	0.06-0.36	0.20	0.29-0.40	0.35	0.41-0.66	0.49	0.79-2.41	1.60	0.06-2.41	0.43
Devbhumi Dwarka District	**0.06-0.36**	**0.17**	**0.12-0.40**	**0.24**	**0.20-0.66**	**0.33**	**0.26-2.41**	**0.71**	**0.06-2.41**	**0.33**
Porbandar	**0.14-0.23**	**0.18**	**0.16-0.25**	**0.20**	**0.22-0.46**	**0.30**	**0.48-1.02**	**0.63**	**0.14-1.02**	**0.32**
Overall	**0.06-0.36**	**0.18**	**0.12-0.69**	**0.30**	**0.20-1.64**	**0.55**	**0.26-3.58**	**0.93**	**0.06-3.58**	**0.46**

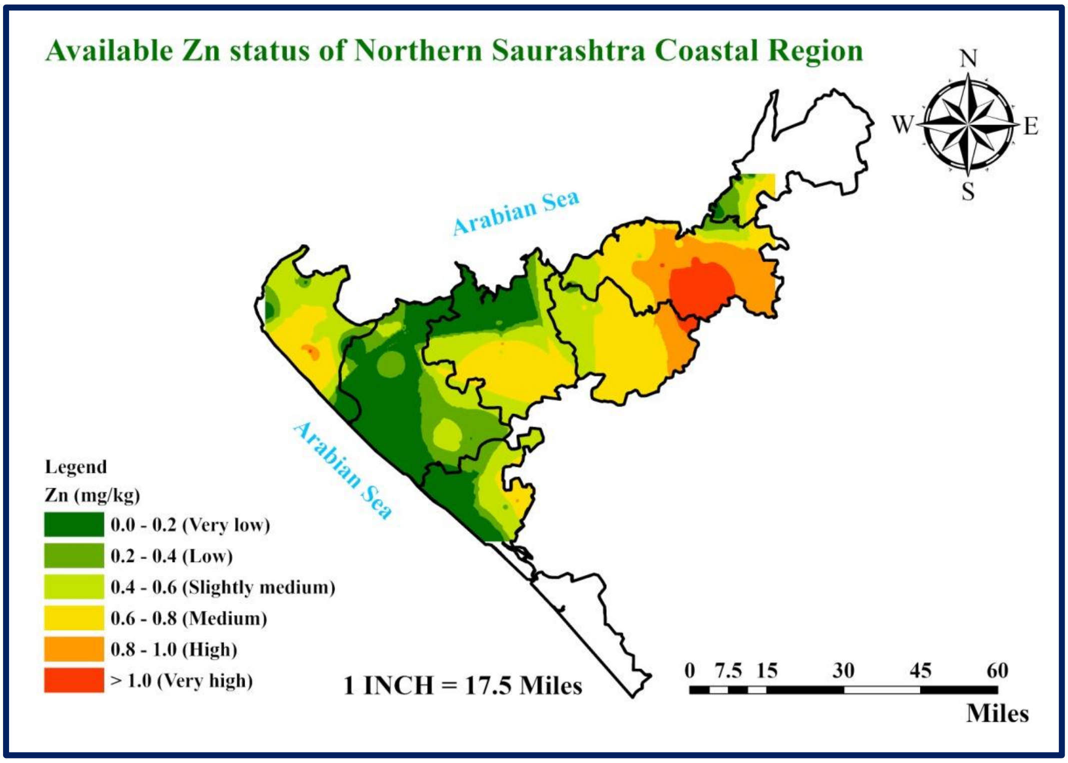


Fig. 4.19: Map of overall available Zn status in coastal soils of Northern Saurashtra region

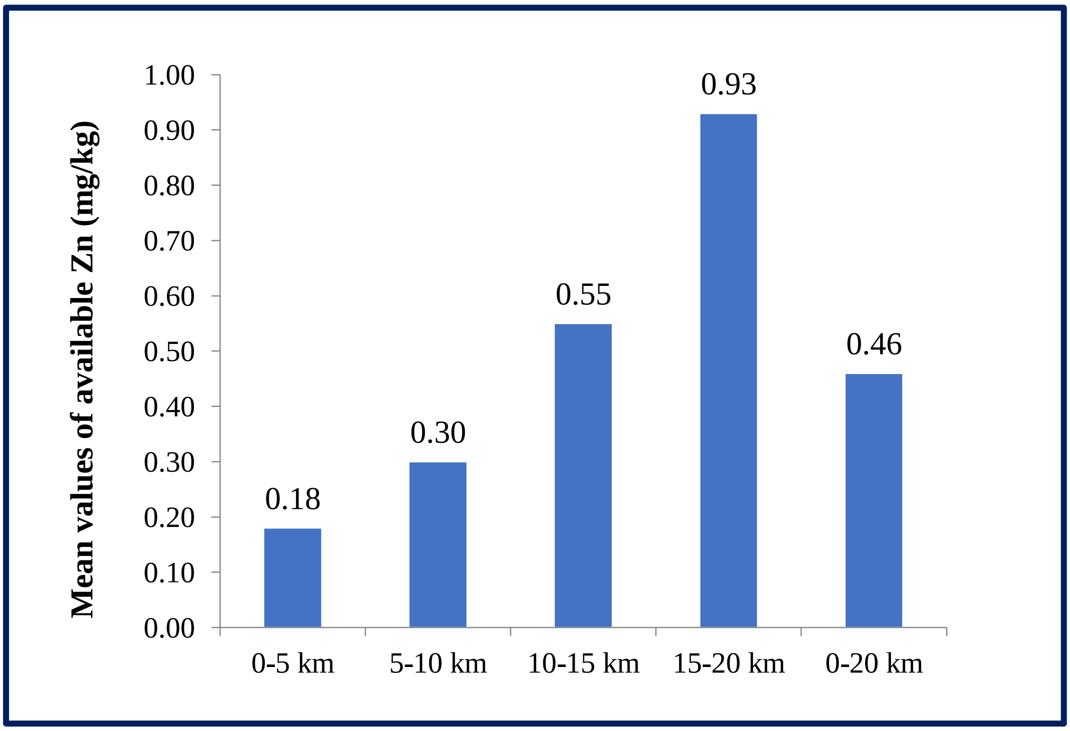


Fig. 4.20: Overall available Zn status in coastal soils of Northern Saurashtra region

In Devbhumi Dwarka district, maximum Zn (2.41 mg kg^{-1}) was found at 15 to 20 km distance from the sea coast and minimum Zn (0.06 mg kg^{-1}) was found at 0 to 5 km distance from the sea coast, while overall mean value of Zn was 0.33 mg kg^{-1}. In Porbandar district, overall mean value of Zn was 0.32 mg kg^{-1}, maximum Zn (1.02 mg kg^{-1}) was found at 15 to 20 km distance from the sea coast and minimum Zn (0.14 mg kg^{-1}) was found at 0 to 5 km distance from the sea coast. The lowest value of Zn (0.06 mg kg^{-1}) was recorded in the samples collected from Dwarka taluka in Devbhumi Dwarka district, whereas the highest value of Zn (3.58 mg kg^{-1}) was found in Jamnagar taluka of Jamnagar district.

About 78.01, 12.06 and 9.93 per cent soil samples were categorized as low, medium and high in DTPA-Zn status, respectively (Table 4.2.11). About 63.33, 90.00 and 85.71 per cent soil samples of Jamnagar, Devbhumi Dwarka and Porbandar districts, respectively were found under low class of DTPA-Zn. Similar results were also reported for Coastal Region of Kutch district by Patel *et al*. (2012), by Srinivasan and Poongothai (2013) for villages of Tittakudi taluka of Tamil Nadu, by Verma *et al*. (2013) for Malkharauda block of Janjgir Champa district, Singh *et al*. (2014) for Chambal region of Madhya Pradesh, by Kumar (2015) for Saharsa district of Bihar.

4.2.2.5 Available B status

The values of available B estimated from the collected soil samples are given in table 4.2.9. The overall range of available B in Nothern Saurashtra coastal region was 0.78 to 6.61 mg kg^{-1} with the mean value of 3.49 mg kg^{-1}. The data revealed that the lowest mean value of available B (2.75 mg kg^{-1}) was obtained from the samples of Lalpur taluka of Jamnagar district and the highest mean value of available B (3.95 mg kg^{-1}) was found in the samples of Porbandar taluka of Porbandar district. In Jamnagar district, maximum available B (5.95 mg kg^{-1}) was found at 0 to 5 km distance from the sea coast and minimum available B (0.78 mg kg^{-1}) was found at 15 to 20 km distance from the sea coast, whereas overall mean value of available B was 3.26 mg kg^{-1}. In Devbhumi Dwarka district, maximum available B (6.27 mg kg^{-1}) was found at 0 to 5 km distance from the sea coast and minimum available B (0.78 mg kg^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of available B was (3.56 mg kg^{-1}). In Porbandar district, overall mean value of available B was (3.95 mg kg^{-1}), maximum available B (6.61 mg kg^{-1}) was found at 0 to 5 km

Table 4.2.9: Talukawise range and mean values of available B (mg 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	5.17-5.34	5.26	2.09-5.26	4.36	2.36-3.80	2.94	1.77-2.64	2.31	1.77-5.34	3.61
Jodiya	3.80-5.95	4.96	2.77-4.41	3.49	2.38-3.21	2.82	1.02-2.73	1.92	1.02-5.95	3.41
Lalpur	3.87-4.77	4.44	2.62-4.08	3.28	1.08-3.18	2.14	0.78-1.97	1.24	0.78-4.77	2.75
Jamnagar District	**3.80-5.95**	**4.86**	**2.09-5.26**	**3.74**	**1.08-3.80**	**2.58**	**0.78-2.73**	**1.88**	**0.78-5.95**	**3.26**
Kalyanpur	4.69-6.27	5.41	3.71-4.81	4.22	2.22-3.86	3.26	1.43-2.87	2.24	1.43-6.27	3.83
Khambhalia	4.07-5.14	4.65	3.19-4.62	3.93	2.24-3.81	3.07	0.78-2.55	1.69	0.78-5.14	3.34
Dwarka	3.39-6.07	4.71	2.17-3.87	3.17	1.74-2.75	2.25	0.93-1.89	1.41	0.93-6.07	3.50
Dev Bhumi Dwarka District	**3.39-6.27**	**4.89**	**2.17-4.81**	**3.79**	**1.74-3.86**	**2.92**	**0.78-2.87**	**1.84**	**0.78-6.27**	**3.56**
Porbandar	**4.08-6.61**	**5.33**	**3.77-4.85**	**4.23**	**2.36-3.88**	**3.49**	**1.99-2.77**	**2.46**	**1.99-6.61**	**3.95**
Overall Northern Saurashtra	**3.39-6.61**	**4.96**	**2.09-5.26**	**3.82**	**1.08-3.88**	**2.84**	**0.78-2.87**	**1.97**	**0.78-6.61**	**3.49**

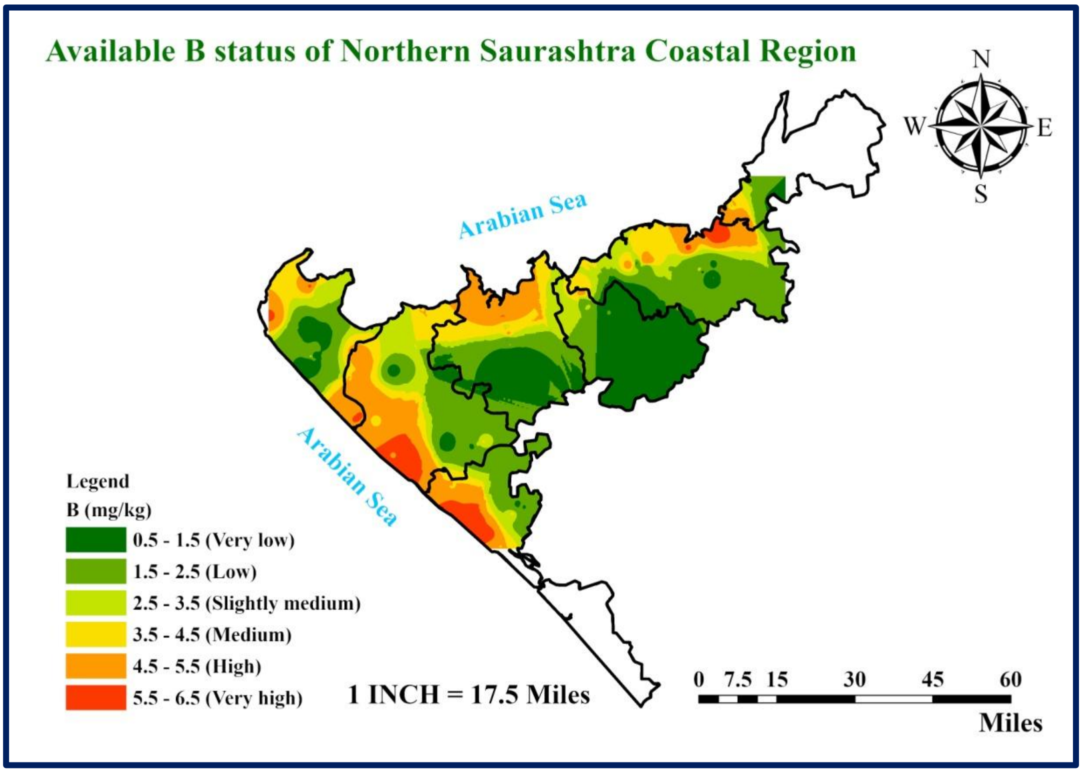


Fig. 4.21: Map of overall available B status in coastal soils of Northern Saurashtra region

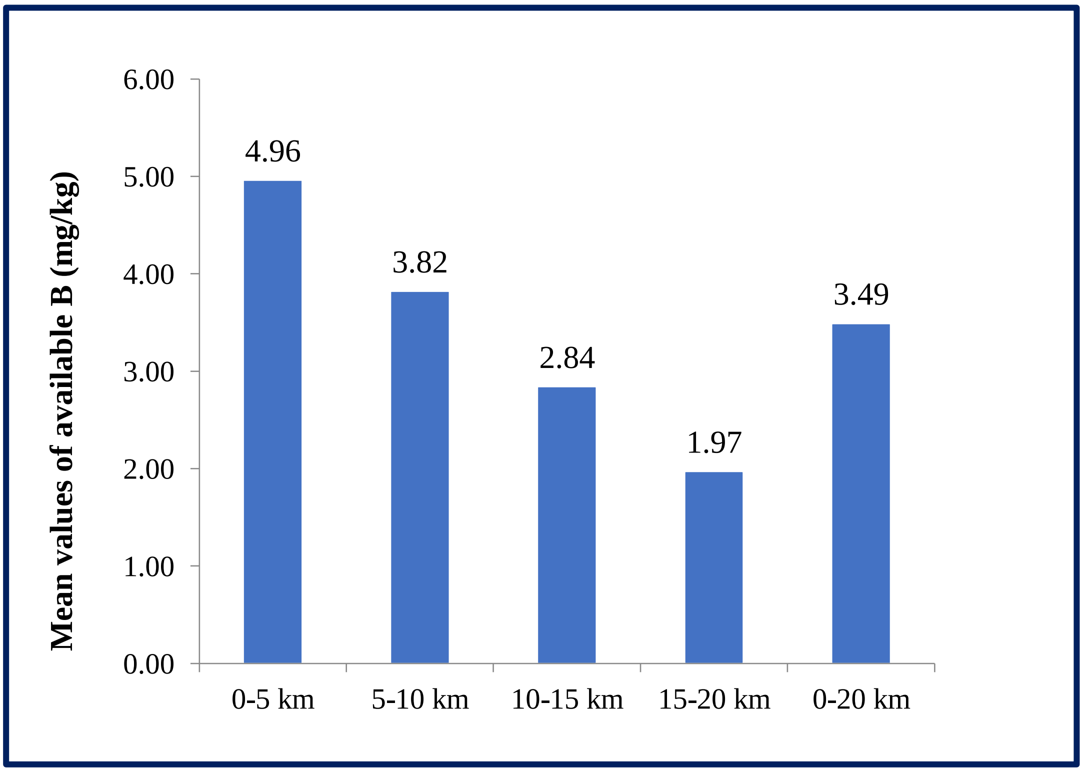


Fig. 4.22: Overall available B status in coastal soils of Northern Saurashtra region

distance from the sea coast and minimum available B (1.99 mg kg^{-1}) was found at 15 to 20 km distance from the sea coast. The lowest value of available B (0.78 mg kg^{-1}) was recorded in the samples collected from Lalpur and Khambhalia talukas, whereas the highest value of available B (6.61 mg kg^{-1}) was found in Porbandar taluka of Porbandar district. Similar results were also reported by Rajput and Polara (2012) for soils of Bhavnagar district and Rajendra *et al*. (2011) for Mokala soil series of Rajasthan.

In general, all the soil fertility parameters *viz.*, SOC, available N, P_2O_5, K_2O, Fe, Mn, Cu and Zn content were increased with increasing the sampling distance (0-5, 5-10, 10-15, 15-20 km) from coastal line except B.

4.2.3 Nutrient index values of available nutrients in soils

4.2.3.1 Nutrient index values of available macronutrients

The nutrient index values for available macronutrient are presented in table 4.2.12. Overall, the soils of Northern Saurashtra coastal region had nutrient index values of 1.27, 1.43, 2.66 and 2.08 for available N, P_2O_5, K_2O and S, respectively. The highest nutrient index values of 1.50, 1.70, 2.90 and 2.86 for available N, P_2O_5, K_2O and S were reported in soils of the Jamnagar, Kalyanpur, Dwarka and Porbandar talukas, respectively. The lowest nutrient index values of 1.05 was recorded for available N in the soils of Khambhalia taluka, while it was for P_2O_5, K_2O and S as 1.33, 2.20 and 1.85 for soils of Porbandar, Lalpur and Lalpur-Kalyanpur talukas, respectively. In districts, highest nutrient index values of 1.38, 2.86 and 2.86 for available N, K_2O and S, respectively were found in Porbandar district while 1.52 for P_2O_5 was reported in Devbhumi Dwarka district. Based on nutrient index values of soils and the criteria suggested by Parker *et al*. (1951) the soils of Northern Saurashtra coastal region were found deficient with respect to available N and P_2O_5, medium fertility class for available S, while high fertility class for available K_2O status. Similar results were also reported by Polara and Kabaria (2006) for soils of Amreli district, by Polara *et al*. (2006a) for soils of north-west agro climatic zone of Gujarat, by Sojitra (2010) for Junagadh district, by Rajput and Polara (2012) for Bhavnagar district, by Malavath and Mani (2014) for Sivaganga district of Tamil Nadu and by Polara and Chauhan (2015a) for Gir Somnath district of Gujarat.

Table 4.2.10: Talukawise percentage and number of soil samples falling in low, medium and high fertility classes for macronutrients

Name of taluka	Available N			Available P_2O_5			Available K_2O			Available S		
	L	**M**	**H**	**L**	**M**	**H**	**L**	**M**	**H**	**L**	**M**	**H**
Jamnagar	50.00 (10)*	50.00 (10)	0.00 (0)	55.00 (11)	45.00 (9)	0.00 (0)	0.00 (0)	40.00 (8)	60.00 (12)	35.00 (7)	15.00 (3)	50.00 (10)
Jodiya	70.00 (14)	30.00 (6)	0.00 (0)	65.00 (13)	35.00 (7)	0.00 (0)	0.00 (0)	40.00 (8)	60.00 (12)	30.00 (6)	35.00 (7)	35.00 (7)
Lalpur	90.00 (18)	10.00 (2)	0.00 (0)	65.00 (13)	35.00 (7)	0.00 (0)	5.00 (1)	70.00 (14)	25.00 (5)	40.00 (8)	35.00 (7)	25.00 (5)
Jamnagar district	**70.0 (42)**	**30.00 (18)**	**0.00 (0)**	**61.67 (37)**	**38.33 (23)**	**0.00 (0)**	**1.67 (1)**	**50.00 (30)**	**48.33 (29)**	**35.00 (21)**	**28.33 (17)**	**36.67 (22)**
Kalyanpur	60.00 (12)	40.00 (8)	0.00 (0)	40.00 (8)	50.00 (10)	10.00 (2)	5.00 (1)	25.00 (5)	70.00 (14)	50.00 (10)	15.00 (3)	35.00 (7)
Khambhalia	95.00 (19)	5.00 (1)	0.00 (0)	65.00 (13)	35.00 (7)	0.00 (0)	0.00 (0)	20.00 (4)	80.00 (16)	25.00 (5)	20.00 (4)	55.00 (11)
Dwarka	85.00 (17)	15.00 (3)	0.00 (0)	50.00 (10)	50.00 (10)	0.00 (0)	0.00 (0)	10.00 (2)	90.00 (18)	40.00 (8)	15.00 (3)	45.00 (9)
Dev Bhumi Dwarka district	**80.00 (48)**	**20.00 (12)**	**0.00 (0)**	**51.67 (31)**	**45.00 (27)**	**3.33 (2)**	**1.67 (1)**	**18.33 (11)**	**80.00 (48)**	**38.33 (23)**	**16.67 (10)**	**45.00 (27)**
Porbandar	**61.90 (13)**	**38.10 (8)**	**0.00 (0)**	**66.67 (14)**	**33.33 (7)**	**0.00 (0)**	**0.00 (0)**	**14.29 (3)**	**85.71 (18)**	**28.57 (6)**	**14.29 (3)**	**57.14 (12)**
Overall	**73.05 (103)**	**26.95 (38)**	**0.00 (0)**	**58.16 (82)**	**40.43 (57)**	**1.42 (2)**	**1.42 (2)**	**31.21 (44)**	**67.38 (95)**	**35.46 (50)**	**21.28 (30)**	**43.26 (61)**

(*)- Values in parenthesis are number of samples

Table 4.2.11: Talukawise percentage and number of soil samples falling in low, medium and high fertility classes for DTPA extractable micronutrients

Name of taluka	Fe^{++}			Mn^{++}			Cu^{++}			Zn^{++}		
	L	**M**	**H**	**L**	**M**	**H**	**L**	**M**	**H**	**L**	**M**	**H**
Jamnagar	35.00 (7)*	65.00 (13)	0.00 (0)	30.00 (6)	45.00 (9)	25.00 (5)	0.00 (0)	0.00 (0)	10.00 (20)	35.00 (7)	15.00 (3)	50.00 (10)
Jodiya	30.00 (6)	70.00 (14)	0.00 (0)	30.00 (6)	50.00 (10)	20.00 (4)	0.00 (0)	5.00 (1)	95.00 (19)	75.00 (15)	20.00 (4)	5.00 (1)
Lalpur	70.00 (14)	30.00 (6)	0.00 (0)	20.00 (4)	60.00 (12)	20.00 (4)	0.00 (0)	5.00 (1)	95.00 (19)	80.00 (16)	20.00 (4)	0.00 (0)
Jamnagar district	**45.00 (27)**	**55.00 (33)**	**0.00 (0)**	**26.67 (16)**	**51.67 (31)**	**21.67 (13)**	**0.00 (0)**	**3.33 (2)**	**96.67 (58)**	**63.33 (38)**	**18.33 (11)**	**18.33 (11)**
Kalyanpur	30.00 (6)	70.00 (14)	0.00 (0)	30.00 (6)	40.00 (8)	30.00 (6)	0.00 (0)	5.00 (1)	95.00 (19)	100.00 (20)	0.00 (0)	0.00 (0)
Khambhalia	15.00 (3)	85.00 (17)	0.00 (0)	35.00 (7)	65.00 (12)	5.00 (1)	0.00 (0)	0.00 (0)	100.00 (20)	85.00 (17)	10.00 (2)	5.00 (1)
Dwarka	50.00 (10)	50.00 (10)	0.00 (0)	15.00 (3)	75.00 (15)	10.00 (2)	10.00 (2)	10.00 (2)	80.00 (16)	85.00 (17)	10.00 (2)	5.00 (1)
Devbhumi Dwarka district	**31.67 (19)**	**68.33 (41)**	**0.00 (0)**	**26.67 (16)**	**58.33 (35)**	**15.00 (9)**	**3.33 (2)**	**5.00 (3)**	**91.67 (55)**	**90.00 (54)**	**6.67 (4)**	**3.33 (2)**
Porbandar	**38.10 (8)**	**61.90 (13)**	**0.00 (0)**	**0.00 (0)**	**71.43 (15)**	**28.57 (6)**	**0.00 (0)**	**0.00 (0)**	**100.00 (21)**	**85.71 (18)**	**9.52 (2)**	**4.76 (1)**
Overall	**38.30 (54)**	**61.70 (87)**	**0.00 (0)**	**22.70 (32)**	**57.45 (81)**	**19.86 (28)**	**1.42 (2)**	**3.55 (5)**	**95.04 (134)**	**78.01 (110)**	**12.06 (17)**	**9.93 (14)**

(*)- Values in parenthesis are number of samples

Table 4.2.12: Taluka wise nutrient index values of macro and micronutrients in soils of different districts of Northern Saurashtra coastal region

Name of Taluka	Macronutrients				Micronutrients			
	N	P_2O_5	K_2O	S	Fe^{++}	Mn^{++}	Cu^{++}	Zn^{++}
Jamnagar	1.50	1.45	2.60	2.15	1.65	1.95	3.00	2.15
Jodiya	1.30	1.35	2.60	2.05	1.70	1.90	2.95	1.30
Lalpur	1.10	1.35	2.20	1.85	1.30	2.00	2.95	1.20
Jamnagar District	**1.30**	**1.38**	**2.47**	**2.02**	**1.55**	**1.95**	**2.97**	**1.55**
Kalyanpur	1.40	1.70	2.65	1.85	1.70	2.00	2.95	1.00
Khambhalia	1.05	1.35	2.80	2.30	1.85	1.70	3.00	1.20
Dwarka	1.15	1.50	2.90	2.05	1.50	1.95	2.70	1.20
Devbhumi Dwarka District	**1.20**	**1.52**	**2.78**	**2.07**	**1.68**	**1.88**	**2.88**	**1.13**
Porbandar	**1.38**	**1.33**	**2.86**	**2.86**	**1.62**	**2.29**	**3.00**	**1.19**
Overall	**1.27**	**1.43**	**2.66**	**2.08**	**1.62**	**1.97**	**2.94**	**1.32**

4.2.3.2 Nutrient index values of available micronutrients

Overall, the soils of Northern Saurashtra coastal region had nutrient index values of 1.62, 1.97, 2.94 and 1.32 for DTPA extractable Fe, Mn, Cu and Zn, respectively. The highest nutrient index values of 1.85, 2.29, 3.00 and 2.15 for DTPA extractable Fe, Mn, Cu and Zn were reported in the soils of Khambhalia, Porbandar, Jamnagar-Khambhalia-Porbandar and Jamnagar talukas, respectively (Table 4.2.12). The lowest nutrient index value of 1.30, 1.70, 2.70 and 1.19 for Fe, Mn, Cu and Zn were found in Lalpur, Khambhalia, Dwarka and Porbandar talukas, respectively. Based on nutrient index values of soils and the criteria suggested by Parker *et al*. (1951), the soils of Northern Saurashtra coastal region were found in high category for DTPA extractable Cu, medium category for Fe and Mn and low category for Zn. Similar results were also reported by Polara and Kabaria (2006) for soils of Amreli district, by Polara *et al*. (2006a) for soils of north west agro climatic zone of Gujarat, by Sojitra (2010) for Junagadh district and by Rajput and Polara (2012) for Bhavnagar district, by Malavath and Mani (2014) for Sivaganga district of Tamil Nadu and by Polara and Chauhan (2015a) for Gir Somnath district of Gujarat.

4.3 QUALITY OF UNDERGROUND IRRIGATION WATER

Soil and water samples were collected from distance demarcation of 0-5, 5-10, 10-15 and 15-20 km from sea coast through the use of GPS. The twenty surface soil samples and forty each pre- monsoon underground water samples of well/tube well were collected from talukas 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 the summer season of year 2019.

In order, to study the fluctuation in quality of underground wells/tube wells water, only water samples were collected twice i.e. before (May, 2019) and after monsoon (December, 2019). Before collecting the water samples, the pump is let to run for half an hour and rinse the plastic bottles of capacity-500 ml with that water. The underground well/ tube well water samples were collected, filtered and stored in the plastic bottle by adding few drops of toluene. The forty each post-monsoon water samples were also collected from same well/ tube well from where pre-monsoon samples were drawn from taluka viz. Jodiya, Jamnagar and Lalpur talukas of

Jamnagar district, khambhaliya, Dwarka and Kalyanpur talukas of Devbhumi Dwarka district and Porbandar taluka of Porbandar district of Northern Saurashtra Coastal region of Gujarat during the summer season.

Total 141 soil and 285 irrigation water samples were collected before monsoon (May, 2019) and only 285 irrigation water samples were collected after monsoon (December, 2019). List of the name of farmers, from where water samples were collected, are given in Appendix V.

4.3.1 Irrigation water quality appraisal before monsoon (May, 2019)

Irrigation water samples were analyzed for EC, pH, cations (Ca^{++}, Mg^{++}, Na^{+} and K^{+}) and anions (CO_3^{--}, HCO_3^{-}, Cl^{-} and SO_4^{--}). Various indices viz., SAR, RSC and SSP were then worked out from the estimated cations and anions expressed in me L^{-1}. Sample wise values for EC, pH, cations, anions and different water indices of all the 285 samples are given in Appendix VI, Talukawise range and mean values for EC and pH in tables 4.3.1 and 4.3.2, cations and anions in tables 4.3.3 to 4.3.10 and their percent distribution in table 4.3.14.

4.3.1.1 Electrical conductivity (EC)

The overall mean value of EC of Northen Saurashtra's water samples was found 2.22 dS m^{-1}, which was varied widely from 0.25 to 7.35 dS m^{-1}. In Jamnagar district, overall mean value of EC was 2.15 dS m^{-1}, maximum EC (6.05 dS m^{-1}) was found in the samples collected from Jodiya taluka at 0 to 5 km distance from the sea coast and minimum EC (0.37 dS m^{-1}) was found in the samples collected from Lalpur taluka at 15 to 20 km distance from the sea coast. In Devbhumi Dwarka district, maximum EC (7.35 dS m^{-1}) was found in the samples collected from Kalyanpur taluka at 0 to 5 km distance from the sea coast and minimum EC (0.25 dS m^{-1}) was found in the samples collected from Khambhalia taluka at 15 to 20 km distance from the sea coast, while overall mean value of EC was 2.24 dS m^{-1}. In Porbandar district, overall mean value of EC was 2.37 dS m^{-1}, maximum EC (6.03 dS m^{-1}) was found at 0 to 5 km distance from the sea coast and minimum EC (0.44 dS m^{-1}) was found at 15 to 20 km distance from the sea coast (Table 4.3.1 and Fig 4.23). The lowest value of EC (0.25 dS m^{-1}) was recorded in the samples collected from Khambhalia taluka in Devbhumi Dwarka district, whereas the highest value of EC (7.35 dS m^{-1}) was found in Kalyanpur taluka of Devbhumi Dwarka district. The data further revealed that

Table 4.3.1: Talukawise range and mean values of EC (dS m^{-1}) of pre-monsoon wells/tube wells water samples in different districts of Northern Saurashtra coastal region

Distance (km)	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
Talukas	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Jamnagar	2.35-5.59	3.28	1.27-4.14	2.46	0.77-2.98	1.88	0.57-1.86	1.40	0.57-5.59	2.26
Jodiya	1.23-6.05	3.33	1.64-4.29	2.73	0.82-2.75	1.93	0.64-1.94	1.38	0.64-6.05	2.59
Lalpur	NA	NA	0.79-2.89	1.78	0.63-2.82	1.28	0.37-1.51	1.04	0.37-2.89	1.41
Jamnagar District	**1.23-6.05**	**3.31**	**0.79-4.29**	**2.40**	**0.63-2.98**	**1.62**	**0.37-1.94**	**1.31**	**0.37-6.05**	**2.15**
Kalyanpur	1.33-7.35	3.45	1.03-5.98	2.44	0.74-4.70	1.96	0.49-3.04	1.31	0.49-7.35	2.19
Khambhalia	3.85-4.87	4.24	0.36-3.51	1.80	0.47-3.05	1.61	0.25-1.74	1.00	0.25-4.87	1.68
Dwarka	1.36-5.94	3.31	1.04-4.27	2.36	1.03-2.13	1.58	NA	NA	1.03-5.94	2.98
Devbhumi Dwarka District	**1.33-7.35**	**3.44**	**0.36-5.98**	**2.12**	**0.47-4.70**	**1.77**	**0.25-3.04**	**1.13**	**0.25-7.35**	**2.24**
Porbandar	**2.03-6.03**	**3.37**	**1.07-4.13**	**2.42**	**0.83-2.66**	**1.72**	**0.44-1.87**	**1.19**	**0.44-6.03**	**2.37**
Overall	**1.23-7.35**	**3.39**	**0.36-5.98**	**2.30**	**0.47-4.70**	**1.68**	**0.25-3.04**	**1.20**	**0.25-7.35**	**2.22**

(NA) – Not available

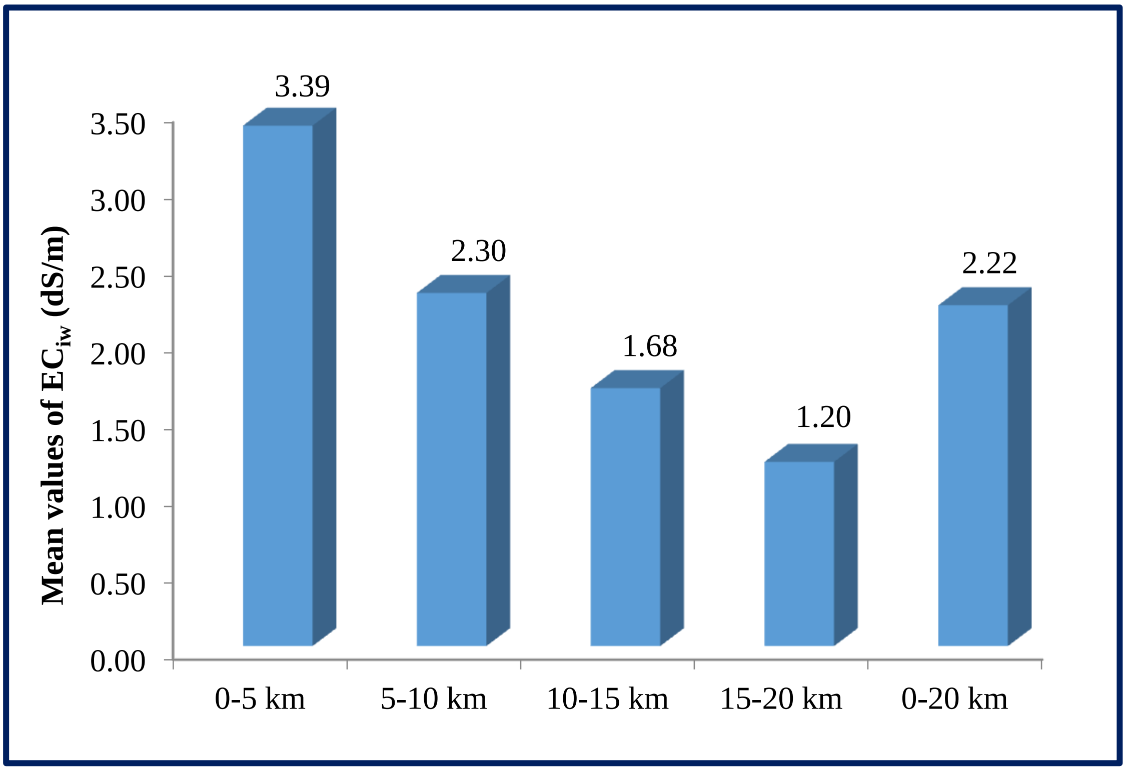


Fig. 4.23: Overall status of pre-monsoon EC_{iw} in samples of Northern Saurashtra coastal region

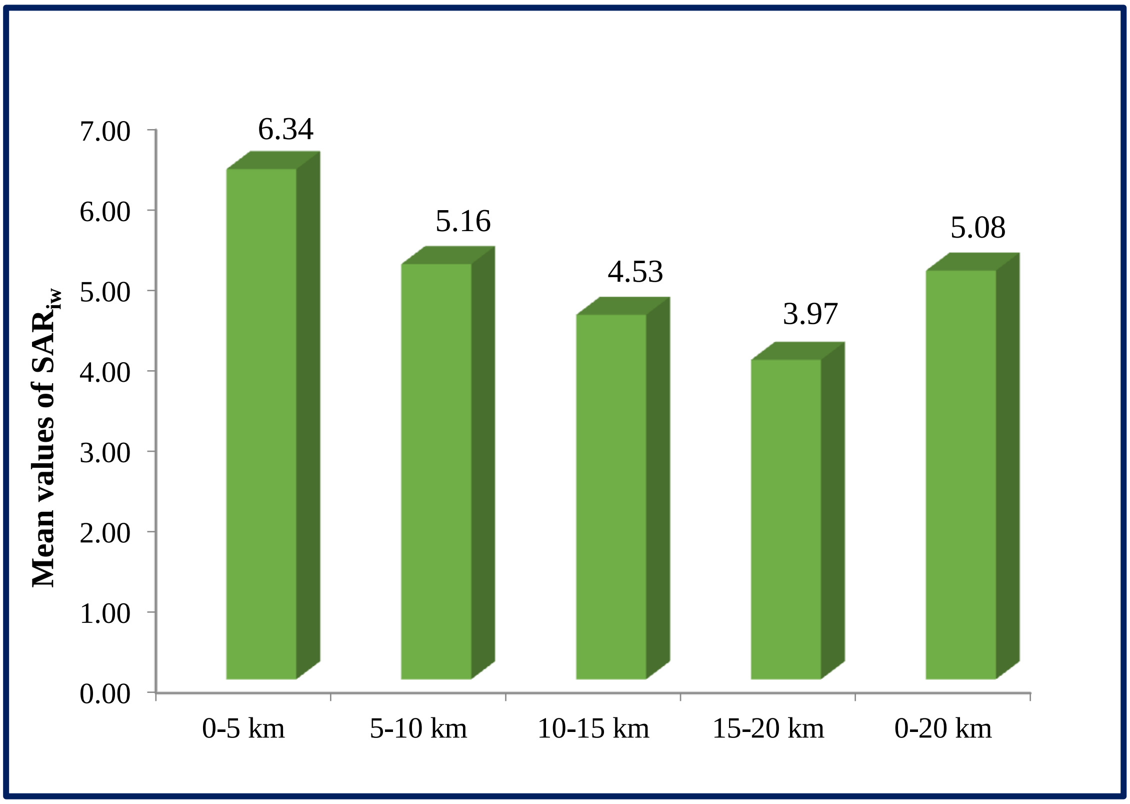


Fig. 4.24: Overall status of pre-monsoon SAR_{iw} in samples of Northern Saurashtra coastal region

lowest mean value of EC (1.41 dS m^{-1}) was obtained from the samples of Lalpur taluka of Jamnagar district and the highest mean value of EC (2.98 dS m^{-1}) was registered in the samples of Dwarka taluka of Devbhumi Dwarka district. The higher mean value of EC (2.98 dS m^{-1}) is an indicative of potential development of saline soils in Devbhumi Dwarka district.

Overall 0.35, 5.96, 52.28 and 41.40 per cent samples were falling under C_1, C_2, C_3 and C_4 classes of EC, respectively (Table 4.3.14, Fig. 4.27). More than half (52.28 per cent) of the water samples had EC value in the range of 0.75 to 2.25 dS m^{-1} (C_3 class). About 55.28, 49.59 and 51.22 per cent water samples of Jamnagar, Devbhumi Dwarka and Porbandar districts, respectively were found under C_3 class of EC. So, salinity hazard of irrigation water is the cause of the development of secondary salinization in the soils of Northern Saurashtra coastal region. Similar findings were also reported for Porbandar district by Hadiyal (2005), for Junagadh district by Sojitra (2010), for Bhavnagar district by Rajput and Polara (2013), for Latur district of Maharashtra by Patil *et al*., (2014), for Gir Somnath district by Polara and Chauhan (2015), for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.3.1.2 pH

In general, well/tube well water samples of Northern Saurashtra coastal region were neutral to slightly alkaline in reaction. The overall pH values of Northern Saurashtra's water samples were ranged from 6.45-8.47 with the mean value of 7.21. The data (Table 4.3.2) revealed that the lowest mean value of pH (7.06) was obtained from the samples of Kalyanpur taluka of Devbhumi Dwarka district and the highest mean value of pH (7.33) was found in the samples of Lalpur taluka of Jamnagar district. In Jamnagar district, maximum pH (8.47) was found at 10 to 15 km distance from the sea coast and minimum pH (6.45) was found at 5 to 10 km distance from the sea coast, whereas overall mean value of pH was 7.23. In Devbhumi Dwarka district, maximum pH (8.18) was found at 5 to 10 km distance from the sea coast and minimum pH (6.58) was found at 5 to 10 km distance from the sea coast, while overall mean value of pH was 7.17. In Porbandar district, overall mean value of pH was 7.24, maximum pH (8.18) was found at 15 to 20 km distance from the sea coast and minimum pH (6.76) was found at 5 to 10 km distance from the sea coast. The

Table 4.3.2: Talukawise range and mean values of pH of pre-monsoon wells/tube wells water samples in different districts of Northern Saurashtra coastal region

Talukas \ Distance (km)	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Jamnagar	6.76-7.69	7.35	6.45-7.40	7.10	6.59-7.80	7.16	7.10-7.60	7.37	6.45-7.80	7.21
Jodiya	6.62-7.50	7.00	6.59-7.69	7.11	7.03-7.90	7.30	7.20-7.93	7.61	6.62-7.93	7.18
Lalpur	NA	NA	6.84-7.61	7.20	7.10-8.47	7.39	7.10-8.00	7.42	6.84-8.47	7.33
Jamnagar District	**6.62-7.69**	**7.15**	**6.45-7.69**	**7.12**	**6.59-8.47**	**7.29**	**7.10-8.00**	**7.45**	**6.45-8.47**	**7.23**
Kalyanpur	6.90-7.31	7.14	6.70-7.38	7.09	6.59-7.31	6.87	6.70-7.60	7.11	6.59-7.60	7.06
Khambhalia	6.80-7.12	7.01	6.58-8.18	7.20	6.70-7.67	7.33	6.90-7.81	7.49	6.58-8.18	7.31
Dwarka	6.70-7.48	7.07	6.90-7.42	7.12	7.40-7.86	7.63	NA	NA	6.70-7.86	7.11
Devbhumi Dwarka District	**6.70-7.48**	**7.08**	**6.58-8.18**	**7.15**	**6.59-7.86**	**7.14**	**6.70-7.81**	**7.32**	**6.58-8.18**	**7.17**
Porbandar	**6.82-7.62**	**7.16**	**6.76-7.56**	**7.06**	**6.99-7.63**	**7.42**	**6.88-8.18**	**7.45**	**6.76-8.18**	**7.24**
Overall	**6.62-7.69**	**7.12**	**6.45-8.18**	**7.13**	**6.59-8.47**	**7.26**	**6.70-8.18**	**7.39**	**6.45-8.47**	**7.21**

(NA) – Not available

lowest value of pH (6.45) was recorded in the samples collected from Jamnagar taluka in Jamnagar district, whereas the highest value of pH (8.47) was found in Lalpur taluka of Jamnagar district. Similar findings were also recorded for Churu district (Rajasthan) by Verma et al. (2003), for Amreli district by Kabaria (2004), for Porbandar district by Hadiyal (2005), for Junagadh district by Sojitra (2010), for Bhavnagar district by Rajput and Polara (2013), for Latur district of Maharashtra by Patil et al. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015), for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.3.1.3 Cation concentration in well/tube well water samples

Talukawise range and mean values of different cations present in wells/tube wells water sample are given in tables 4.3.3 to 4.3.6.

4.3.1.3.1 Na^+

Among the talukas of Northern Saurashtra coastal region, highest proportion of Na^+ (37.52 me L^{-1}) was observed from the Jodiya taluka at the distance of 0 to 5 km from the sea coast, which was followed by Porbandar taluka (37.45 me L^{-1}) and Jamnagar taluka (34.66 me L^{-1}). The presence of large proportion of Na^+ in most of area under investigation is indicative of a potential danger for the alkalinity hazards. The highest mean value for Na^+ (16.54 me L^{-1}) was found in Dwarka taluka followed by Jodiya (12.78 me L^{-1}) and Porbandar (11.86 me L^{-1}) taluka and the lowest mean value for Na^+ (6.33 me L^{-1}) was reported in Lalpur taluka (Table 4.3.3). The overall mean value of Na^+ in Northern Saurashtra coastal region 11.46 me L^{-1} was found. Similar results were also found by Verma *et al.* (2003) for Churu district (Rajasthan), by Kabaria (2004) for Amreli district, by Hadiyal (2005) for Porbandar district, by Sojitra (2010) for Junagadh district, by Rajput and Polara (2013) for Bhavnagar district, by Patil *et al*. (2014) for Latur district of Maharashtra, by Polara and Chauhan (2015) for Gir Somnath district of Gujarat and for Kheda district of Gujarat by Vaghela (2017).

4.3.1.3.2 K^+

The overall mean value of K^+ in Northern Saurashtra coastal region 0.06 me L^{-1} was found which was varied from 0.00 to 1.56 me L^{-1}. Among the talukas, highest

Table 4.3.3: Talukawise range and mean values of Na^+ (me L^{-1}) of pre-monsoon well/tube well water samples 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	6.53-34.66	14.92	4.60-31.34	11.96	3.77-24.55	10.00	3.70-18.33	8.33	3.70-34.66	11.31
Jodiya	8.24-37.52	15.92	7.97-32.16	13.03	5.24-20.87	10.64	4.59-13.67	7.97	4.59-37.52	12.78
Lalpur	NA	NA	4.92-12.87	8.67	2.47-11.48	5.50	1.34-5.67	4.15	1.34-12.87	6.33
Jamnagar District	**6.53-37.52**	**15.49**	**4.60-32.16**	**11.60**	**2.47-24.55**	**8.13**	**1.34-18.33**	**7.23**	**1.34-37.52**	**10.56**
Kalyanpur	6.36-30.21	18.01	7.64-26.95	12.73	3.74-21.67	10.55	3.01-12.62	6.38	3.01-30.21	11.37
Khambhalia	15.86-33.75	26.21	2.58-26.63	9.68	2.61-21.29	9.32	1.29-10.28	5.72	1.29-33.75	9.59
Dwarka	9.74-34.46	17.99	8.31-20.54	14.47	4.32-11.26	7.79	NA	NA	4.32-34.46	16.54
Devbhumi Dwarka District	**6.36-34.46**	**18.86**	**2.58-26.95**	**11.76**	**2.61-21.67**	**9.74**	**1.29-12.62**	**6.01**	**1.29-34.46**	**12.24**
Porbandar	**7.25-37.45**	**16.69**	**4.72-26.07**	**11.69**	**4.15-20.03**	**9.47**	**2.16-12.14**	**6.01**	**2.16-37.45**	**11.86**
Overall	**6.36-37.52**	**17.48**	**2.58-32.16**	**11.67**	**2.47-24.55**	**8.81**	**1.29-18.33**	**6.44**	**1.29-37.52**	**11.46**

(NA) – Not available

Table 4.3.4: Talukawise range and mean values of K^+ (me L^{-1}) of pre-monsoon well/tube well water samples 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	0.00-0.17	0.05	0.00-0.03	0.01	0.00-0.04	0.01	0.00-0.04	0.02	0.00-0.17	0.02
Jodiya	0.02-0.28	0.07	0.01-0.14	0.05	0.01-0.05	0.03	0.01-0.04	0.02	0.01-0.28	0.05
Lalpur	NA	NA	0.00-0.00	0.00	0.00-0.02	0.00	0.00-0.05	0.01	0.00-0.05	0.00
Jamnagar District	**0.00-0.28**	**0.06**	**0.00-0.14**	**0.02**	**0.00-0.05**	**0.01**	**0.00-0.05**	**0.02**	**0.00-0.28**	**0.02**
Kalyanpur	0.01-0.06	0.03	0.02-0.69	0.13	0.01-0.06	0.03	0.00-0.02	0.01	0.00-0.69	0.04
Khambhalia	0.00-0.07	0.04	0.00-0.20	0.04	0.00-0.06	0.02	0.00-0.05	0.02	0.00-0.20	0.03
Dwarka	0.06-0.48	0.21	0.05-0.18	0.09	0.05-0.08	0.07	NA	NA	0.05-0.48	0.17
Devbhumi Dwarka District	**0.00-0.48**	**0.15**	**0.00-0.69**	**0.08**	**0.00-0.08**	**0.03**	**0.00-0.05**	**0.01**	**0.00-0.69**	**0.08**
Porbandar	**0.03-1.56**	**0.29**	**0.00-0.07**	**0.04**	**0.01-0.05**	**0.03**	**0.01-0.04**	**0.02**	**0.00-1.56**	**0.12**
Overall	**0.00-1.56**	**0.15**	**0.00-0.69**	**0.04**	**0.00-0.08**	**0.02**	**0.00-0.05**	**0.02**	**0.00-1.56**	**0.06**

(NA) – Not available

proportion of K^+ (1.56 me L^{-1}) was observed from Porbandar taluka at the distance of 0 to 5 km from the sea coast (Table 4.3.4). The highest mean value for K^+ (0.17 me L^{-1}) was found in Dwarka taluka followed by Porbandar taluka (0.12 me L^{-1}) and the lowest mean value for K^+ (0.00 me L^{-1}) was reported in Lalpur taluka. Similar results were also found by Verma *et al.* (2003) for Churu district (Rajasthan), by Kabaria (2004) for Amreli district, by Hadiyal (2005) for Porbandar district, by Sojitra (2010) for Junagadh district, by Rajput and Polara (2013) for Bhavnagar district, by Patil *et al*. (2014) for Latur district of Maharashtra, by Polara and Chauhan (2015) for Gir Somnath district of Gujarat, for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.3.1.3.3 Ca^{++}

The overall Ca^{++} values of Northen Saurashtra's water samples were ranged from 0.90 to 24.60 me L^{-1} with the mean value of 5.11 me L^{-1}. The data (Table 4.3.5) revealed that the lowest mean value of Ca^{++} (3.62 me L^{-1}) was obtained from the samples of Lalpur taluka of Jamnagar district and the highest mean value of Ca^{++} (6.44 me L^{-1}) was found in the samples of Jodiya taluka of Jamnagar district. In Jamnagar district, maximum Ca^{++} (20.05 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Ca^{++} (1.08 me L^{-1}) was found at 15 to 20 km distance from the sea coast, whereas overall mean value of Ca^{++} was 5.38 me L^{-1}. In Devbhumi Dwarka district, maximum Ca^{++} (24.60 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Ca^{++} (0.90 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of Ca^{++} was 4.82 me L^{-1}. In Porbandar district, overall mean value of Ca^{++} was 5.13 me L^{-1}, maximum Ca^{++} (15.64 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Ca^{++} (1.10 me L^{-1}) was found at 15 to 20 km distance from the sea coast. The lowest value of Ca^{++} (0.90 me L^{-1}) was recorded in the samples collected from Khambhalia taluka in Devbhumi Dwarka district, whereas the highest value of Ca^{++} (24.60 me L^{-1}) was found in Kalyanpur taluka of Devbhumi Dwarka district. Similar findings were also recorded for Churu district (Rajasthan) by Verma et al. (2003), for Porbandar district by Hadiyal (2005), for Junagadh district by Sojitra (2010), for Bhavnagar district by Rajput and Polara (2013), for Latur district of Maharashtra by Patil et al. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015) for Devbhumi Dwarka

Table 4.3.5: Talukawise range and mean values of Ca^{++} (me L^{-1}) of pre-monsoon well/tube well water samples in different districts of Northern Saurashtra coastal region

Talukas \ Distance (km)	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Jamnagar	4.12-18.30	9.58	2.00-13.52	6.00	1.64-10.60	4.30	1.54-4.50	2.83	1.54-18.30	5.60
Jodiya	5.25-20.05	8.44	4.89-16.40	7.23	1.62-7.76	4.11	1.08-4.94	2.77	1.08-20.05	6.44
Lalpur	NA	NA	2.15-10.10	4.13	1.84-7.54	3.53	1.60-5.64	2.88	1.60-10.10	3.62
Jamnagar District	**4.12-20.05**	**8.93**	**2.00-16.40**	**5.99**	**1.62-10.60**	**3.93**	**1.08-5.64**	**2.82**	**1.08-20.05**	**5.38**
Kalyanpur	2.50-24.60	8.84	2.00-22.60	6.56	2.03-13.20	4.58	1.30-6.05	2.86	1.30-24.60	5.43
Khambhalia	7.20-11.10	9.60	1.50-8.50	3.96	1.70-6.42	3.56	0.90-3.50	2.22	0.90-11.10	3.73
Dwarka	3.50-9.54	6.61	2.00-5.00	3.01	1.36-4.47	2.92	NA	NA	1.36-9.54	5.50
Devbhumi Dwarka District	**2.50-24.60**	**7.45**	**1.50-22.60**	**4.40**	**1.36-13.20**	**3.97**	**0.90-6.05**	**2.50**	**0.90-24.60**	**4.82**
Porbandar	**2.50-15.64**	**7.23**	**2.10-11.50**	**5.52**	**1.90-8.15**	**3.26**	**1.10-4.50**	**2.77**	**1.10-15.64**	**5.13**
Overall	**2.50-24.60**	**7.84**	**1.50-22.60**	**5.35**	**1.36-13.20**	**3.85**	**0.90-6.05**	**2.65**	**0.90-24.60**	**5.11**

(NA) – Not available

district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.3.1.3.4 Mg^{++}

In Jamnagar district, overall mean value of Mg^{++} was 5.56 me L^{-1}, maximum Mg^{++} (17.50 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Mg^{++} (1.20 me L^{-1}) was found at 15 to 20 km distance from the sea coast. In Devbhumi Dwarka district, maximum Mg^{++} (12.57 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Mg^{++} (0.90 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of Mg^{++} was 5.19 me L^{-1}. In Porbandar district, overall mean value of Mg^{++} was 6.55 me L^{-1}, maximum Mg^{++} (15.64 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Mg^{++} (1.17 me L^{-1}) was found at 15 to 20 km distance from the sea coast (Table 4.3.6). The lowest value of Mg^{++} (0.90 me L^{-1}) was recorded in the samples collected from Khambhalia taluka in Devbhumi Dwarka district, whereas the highest value of Mg^{++} (17.50 me L^{-1}) was found in Jodiya taluka of Jamnagar district. The data further revealed that the lowest mean value of Mg^{++} (3.43 me L^{-1}) was obtained from the samples of Khambhalia taluka in Devbhumi Dwarka district and the highest mean value of Mg^{++} (7.51 me L^{-1}) was registered in the samples of Dwarka taluka in Devbhumi Dwarka district. Similar findings were also recorded for Amreli district by Kabaria (2004), for Porbandar district by Hadiyal (2005), for Junagadh district by Sojitra (2010), for Bhavnagar district by Rajput and Polara (2013), for Latur district of Maharashtra by Patil *et al*. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015), for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.3.1.4 Anion concentration in well/tube well water samples

Talukawise range and mean values of different anions present in wells/tube wells water sample are given in tables 4.3.7 to 4.3.10.

4.3.1.4.1 CO_3^{--}

The overall CO_3^{--} values of Northen Saurashtra’s water samples were ranged from 0.00 to 2.80 me L^{-1} with the mean value of 0.51 me L^{-1}. The highest mean value of CO_3^{--} (1.89 me L^{-1}) was observed in Kalyanpur taluka at the distance of 0 to 5 km

Table 4.3.6: Talukawise range and mean values of Mg^{++} (me L^{-1}) of pre-monsoon well/tube well water samples 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	2.88-16.70	8.20	2.56-11.86	6.61	2.34-9.10	4.47	1.50-4.80	2.70	1.50-16.70	5.63
Jodiya	4.50-17.50	8.86	4.13-12.20	7.07	3.02-7.71	4.45	1.38-4.85	2.93	1.38-17.50	6.58
Lalpur	NA	NA	2.40-6.85	5.04	1.20-6.50	3.83	1.20-4.69	2.98	1.20-6.85	4.09
Jamnagar District	**2.88-17.50**	**8.58**	**2.40-12.20**	**6.42**	**1.20-9.10**	**4.18**	**1.20-4.85**	**2.83**	**1.20-17.50**	**5.56**
Kalyanpur	2.00-12.50	7.60	2.40-8.84	5.18	2.80-5.87	4.36	2.20-4.80	3.75	2.00-12.50	5.08
Khambhalia	6.12-6.90	6.43	2.10-6.20	4.35	1.40-5.62	3.15	0.90-4.50	1.98	0.90-6.90	3.43
Dwarka	3.00-12.57	8.25	4.00-11.67	6.07	2.44-7.03	4.74	NA	NA	2.44-12.57	7.51
Devbhumi Dwarka District	**2.00-12.57**	**7.91**	**2.10-11.67**	**5.03**	**1.40-7.03**	**3.89**	**0.90-4.80**	**2.75**	**0.90-12.57**	**5.19**
Porbandar	**2.57-15.64**	**9.50**	**2.15-11.67**	**6.95**	**2.36-8.50**	**4.40**	**1.17-5.80**	**2.98**	**1.17-15.64**	**6.55**
Overall	**2.00-17.50**	**8.41**	**2.10-12.20**	**5.97**	**1.20-9.10**	**4.12**	**0.90-5.80**	**2.81**	**0.90-17.50**	**5.54**

(NA) – Not available

Table 4.3.7: Talukawise range and mean values of CO_3^{--} (me L^{-1}) of pre-monsoon well/tube well water samples in different districts of Northern Saurashtra coastal region

Talukas \ Distance (km)	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Jamnagar	0.00-2.40	1.04	0.00-1.40	0.49	0.00-1.00	0.29	0.00-0.26	0.05	0.00-2.40	0.45
Jodiya	0.00-2.60	1.05	0.00-1.70	0.50	0.00-0.84	0.36	0.00-0.54	0.23	0.00-2.60	0.61
Lalpur	NA	NA	0.00-1.70	1.00	0.00-1.20	0.38	0.00-0.60	0.12	0.00-1.70	0.54
Jamnagar District	**0.00-2.60**	**1.05**	**0.00-1.70**	**0.60**	**0.00-1.20**	**0.34**	**0.00-0.60**	**0.12**	**0.00-2.60**	**0.52**
Kalyanpur	1.20-2.80	1.89	0.60-2.67	1.40	0.00-2.40	0.76	0.00-2.00	0.45	0.00-2.80	1.06
Khambhalia	0.00-0.80	0.45	0.00-2.00	0.23	0.00-0.86	0.20	0.00-0.74	0.18	0.00-2.00	0.22
Dwarka	0.00-0.77	0.24	0.00-0.41	0.12	0.00-0.18	0.09	NA	NA	0.00-0.77	0.20
Devbhumi Dwarka District	**0.00-2.80**	**0.65**	**0.00-2.67**	**0.51**	**0.00-2.40**	**0.45**	**0.00-2.00**	**0.30**	**0.00-2.80**	**0.49**
Porbandar	**0.60-1.60**	**0.94**	**0.00-1.21**	**0.50**	**0.00-1.10**	**0.43**	**0.00-0.27**	**0.06**	**0.00-1.60**	**0.55**
Overall	**0.00-2.80**	**0.82**	**0.00-2.67**	**0.56**	**0.00-2.40**	**0.39**	**0.00-2.00**	**0.20**	**0.00-2.80**	**0.51**

(NA) – Not available

from the sea coast while the lowest mean value of CO_3^{--} (0.05 me L^{-1}) was observed in Jamnagar taluka at the distance of 15 to 20 km from the sea coast (Table 4.3.7). In Jamnagar district, maximum CO_3^{--} (2.60 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum CO_3^{--} (0.00 me L^{-1}) was found at 15 to 20 km distance from the sea coast, whereas overall mean value of CO_3^{--} was 0.52 me L^{-1}. In Devbhumi Dwarka district, maximum CO_3^{--} (2.80 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum CO_3^{--} (0.00 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of CO_3^{--} was 0.49 me L^{-1}. In Porbandar district, overall mean value of CO_3^{--} was 0.55 me L^{-1}, maximum CO_3^{--} (1.60 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum CO_3^{--} (0.00 me L^{-1}) was found at 15 to 20 km distance from the sea coast. The highest value of CO_3^{--} (2.80 me L^{-1}) was found in Kalyanpur taluka of Devbhumi Dwarka district. Similar results were also found by Verma *et al.* (2003) for Churu district (Rajasthan), by Kabaria (2004) for Amreli district, by Hadiyal (2005) for Porbandar district, by Rajput and Polara (2013) for Bhavnagar district, by Polara and Chauhan (2015) for Gir Somnath district, by Hadiya and Polara (2017) for Devbhumi Dwarka district of Gujarat and by Vaghela (2017) for Kheda district of Gujarat.

4.3.1.4.2 HCO_3^-

In Jamnagar district, overall mean value of HCO_3^- was 3.56 me L^{-1}, maximum HCO_3^- (8.40 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum HCO_3^- (0.67 me L^{-1}) was found at 15 to 20 km distance from the sea coast. In Devbhumi Dwarka district, maximum HCO_3^- (17.00 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum HCO_3^- (1.16 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of HCO_3^- was 6.13 me L^{-1}. In Porbandar district, overall mean value of HCO_3^- was 5.62 me L^{-1}, maximum HCO_3^- (11.14 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum $HCO3^-$ (2.81 me L^{-1}) was found at 5 to 10 km distance from the sea coast (Table 4.3.8). The lowest value of HCO_3^- (0.67 me L^{-1}) was recorded in the samples collected from Jamnagar taluka in Jamnagar district, whereas the highest value of HCO_3^- (17.00 me L^{-1}) was found in Kalyanpur taluka of Devbhumi Dwarka district. The data further revealed that the lowest mean value of HCO_3^- (2.74 me L^{-1}) was obtained from the samples of Jamnagar taluka of Jamnagar district and the high

Table 4.3.8: Talukawise range and mean values of HCO_3^- (me L^{-1}) of pre-monsoon well/tube well water samples in different districts of Northern Saurashtra coastal region

Talukas \ Distance (km)	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Jamnagar	1.40-7.43	3.47	1.20-5.78	3.02	0.92-4.50	2.23	0.67-3.64	2.16	0.67-7.43	2.74
Jodiya	3.00-8.40	4.70	2.40-6.04	3.91	1.60-4.80	3.77	1.40-2.90	2.20	1.40-8.40	3.87
Lalpur	NA	NA	3.40-7.80	4.94	2.71-6.80	4.48	2.40-6.70	4.36	2.40-7.80	4.61
Jamnagar District	**1.40-8.40**	**4.17**	**1.20-7.80**	**3.71**	**0.92-6.80**	**3.49**	**0.67-6.70**	**2.69**	**0.67-8.40**	**3.56**
Kalyanpur	4.00-17.00	7.52	3.80-11.20	6.76	3.20-7.04	5.28	2.40-9.20	5.22	2.40-17.00	6.10
Khambhalia	7.62-11.04	9.08	3.08-9.40	4.96	2.21-7.77	4.66	1.16-7.07	4.79	1.16-11.04	5.21
Dwarka	3.20-12.37	7.51	4.28-12.63	7.69	1.69-4.77	3.23	NA	NA	1.69-12.37	7.32
Devbhumi Dwarka District	**3.20-17.00**	**7.68**	**3.08-12.63**	**6.16**	**1.69-7.77**	**4.80**	**1.16-9.20**	**4.98**	**1.16-17.00**	**6.13**
Porbandar	**3.82-11.14**	**6.47**	**2.81-8.13**	**5.54**	**3.74-6.71**	**5.18**	**3.14-6.10**	**4.67**	**2.81-11.14**	**5.62**
Overall	**1.40-17.00**	**6.44**	**1.20-12.63**	**4.83**	**0.92-7.77**	**4.12**	**0.67-9.20**	**4.12**	**0.67-17.00**	**4.95**

(NA) – Not available

Table 4.3.9: Talukawise range and mean values of Cl^- (me L^{-1}) of pre-monsoon well/tube well water samples 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	17.68-61.02	28.15	14.17-43.34	21.02	9.16-28.20	16.59	6.55-19.54	11.60	6.55-61.02	19.40
Jodiya	15.10-55.20	27.52	12.80-46.30	22.91	9.17-23.16	15.07	6.03-15.26	11.28	6.03-55.20	21.33
Lalpur	NA	NA	4.60-21.68	11.91	2.75-17.20	7.86	0.94-10.67	5.70	0.94-21.68	8.85
Jamnagar District	**15.10-61.02**	**27.79**	**4.60-46.30**	**19.68**	**2.75-28.20**	**12.47**	**0.94-19.54**	**10.11**	**0.94-61.02**	**17.44**
Kalyanpur	11.30-54.60	24.87	7.50-39.40	16.17	4.60-32.80	13.41	1.10-26.60	7.33	1.10-54.60	14.63
Khambhalia	19.68-42.57	32.43	4.70-34.70	12.89	3.71-20.64	11.13	0.90-11.37	4.92	0.90-42.57	11.30
Dwarka	10.21-49.28	25.28	8.03-34.51	15.72	6.50-17.82	12.16	NA	NA	6.50-49.28	22.16
Devbhumi Dwarka District	**10.21-54.60**	**25.94**	**4.70-39.40**	**14.51**	**3.71-32.80**	**12.32**	**0.90-26.60**	**5.96**	**0.90-54.60**	**15.63**
Porbandar	**10.22-44.18**	**26.25**	**6.15-35.31**	**18.12**	**4.80-26.80**	**11.49**	**1.10-16.30**	**7.03**	**1.10-44.18**	**17.44**
Overall Northern Saurashtra	**10.21-61.02**	**26.53**	**4.60-46.30**	**17.58**	**2.75-32.80**	**12.29**	**0.90-26.60**	**7.58**	**0.90-61.02**	**16.67**

(NA) – Not available

mean value of HCO_3^- (7.32 me L^{-1}) was registered in the samples of Dwarka taluka of Devbhumi Dwarka district. Similar findings were also recorded for Churu district (Rajasthan) by Verma *et al*. (2003), for Amreli district by Kabaria (2004), for Bhavnagar district by Rajput and Polara (2013), for Latur district of Maharashtra by Patil *et al*. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015), for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.3.1.4.3 Cl^-

The overall Cl^- values of Northen Saurashtra's water samples were ranged from 0.90 to 61.02 me L^{-1} with mean value of 16.67 me L^{-1}. The data (Table 4.3.9) revealed that the lowest mean value of Cl^- (8.85 me L^{-1}) was obtained from the samples of Lalpur taluka of Jamnagar district and the highest mean value of Cl^- (22.16 me L^{-1}) was found in the samples of Dwarka taluka of Devbhumi Dwarka district. In Jamnagar district, maximum Cl^- (61.02 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Cl^- (0.94 me L^{-1}) was found at 15 to 20 km distance from the sea coast, whereas overall mean value of Cl^- was 17.44 me L^{-1}. In Devbhumi Dwarka district, maximum Cl^- (54.60 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Cl^- (0.90 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of Cl^- was 15.63 me L^{-1}. In Porbandar district, overall mean value of Cl^- was 17.44 me L^{-1}, maximum Cl^- (44.18 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Cl^- (1.10 me L^{-1}) was found at 15 to 20 km distance from the sea coast. The lowest value of Cl^- (0.90 me L^{-1}) was recorded in the samples collected from Khambhalia taluka in Devbhumi Dwarka district, whereas the highest value of Cl^- (61.02 me L^{-1}) was found in Jamnagar taluka of Jamnagar district. Similar findings were also recorded for Churu district (Rajasthan) by Verma *et al*. (2003), for Porbandar district by Hadiyal (2005), for Junagadh district by Sojitra (2010), for Latur district of Maharashtra by Patil et al. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015), for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.3.1.4.4 SO_4^{--}

In case of SO_4^{--}, the highest mean value of SO_4^{--} (0.09 me L^{-1}) was observed in Jamnagar taluka at the distance of 0 to 5 km from the sea coast (Table 4.3.10). In Jamnagar district, maximum SO_4^{--} (0.24 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum SO_4^{--} (0.01 me L^{-1}) was found at 15 to 20 km distance from the sea coast, whereas overall mean value of SO_4^{--} was (0.04 me L^{-1}). In Devbhumi Dwarka district, maximum SO_4^{--} (0.09 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum SO_4^{--} (0.00 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of SO_4^{--} was (0.03 me L^{-1}). In Porbandar district, overall mean value of SO_4^{--} was (0.04 me L^{-1}), maximum $SO4^{--}$ (0.10 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum SO_4^{--} (0.01 me L^{-1}) was found at 15 to 20 km distance from the sea coast. The lowest value of SO_4^{--} (0.00 me L^{-1}) was recorded in the samples collected from Khambhalia taluka in Devbhumi Dwarka district, whereas the highest value of SO_4^{--} (0.24 me L^{-1}) was found in Jamnagar taluka of Jamnagar district. Similar results were also found by Verma *et al.* (2003) for Churu district (Rajasthan), by Kabaria (2004) for Amreli district, by Hadiyal (2005) for Porbandar district, by Rajput and Polara (2013) for Bhavnagar district, by Polara and Chauhan (2015) for Gir Somnath district, by Hadiya and Polara (2017) for Devbhumi Dwarka district and by Vaghela (2017) for Kheda district of Gujarat.

4.3.1.5 Sodium Adsorption Ratio (SAR)

The SAR value is an important criterion for studying the alkali hazards in irrigation water. Therefore, the talukawise range and mean values of SAR are given in table 4.3.11 and fig 4.24 and per cent distribution of water samples for different SAR classes (as suggested by USDA) are presented in table 4.3.14.

The overall mean value of SAR in Northen Saurashtra coastal region's water sample was 5.08 and it was varied from 0.95 to 15.91. In Jamnagar district, the lowest (1.13) SAR value was recorded in water samples collected from Lalpur taluka at the distance of 15 to 20 km from the sea coast and the highest (15.20) SAR value was recorded in water samples collected from Jamnagar taluka at the distance of 5 to 10

Table 4.3.10: Talukawise range and mean values of SO_4^{--} (me L^{-1}) of pre-monsoon well/tube well water samples in different districts of Northern Saurashtra coastal region

Talukas \ Distance (km)	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Jamnagar	0.01-0.24	0.09	0.01-0.13	0.05	0.01-0.08	0.03	0.01-0.04	0.02	0.01-0.24	0.05
Jodiya	0.02-0.12	0.07	0.01-0.10	0.06	0.02-0.08	0.04	0.01-0.05	0.03	0.01-0.12	0.05
Lalpur	NA	NA	0.01-0.06	0.03	0.01-0.06	0.02	0.01-0.03	0.02	0.01-0.06	0.03
Jamnagar District	**0.01-0.24**	**0.08**	**0.01-0.13**	**0.05**	**0.01-0.08**	**0.03**	**0.01-0.05**	**0.02**	**0.01-0.24**	**0.04**
Kalyanpur	0.01-0.08	0.04	0.01-0.06	0.03	0.01-0.09	0.04	0.01-0.05	0.02	0.01-0.09	0.03
Khambhalia	0.04-0.07	0.06	0.01-0.07	0.03	0.01-0.05	0.02	0.00-0.04	0.02	0.00-0.07	0.03
Dwarka	0.02-0.09	0.05	0.01-0.06	0.03	0.02-0.03	0.03	NA	NA	0.01-0.09	0.04
Devbhumi Dwarka District	**0.01-0.09**	**0.05**	**0.01-0.07**	**0.03**	**0.01-0.09**	**0.03**	**0.00-0.05**	**0.02**	**0.00-0.09**	**0.03**
Porbandar	**0.03-0.10**	**0.06**	**0.01-0.07**	**0.05**	**0.02-0.06**	**0.04**	**0.01-0.04**	**0.02**	**0.01-0.10**	**0.04**
Overall	**0.01-0.24**	**0.06**	**0.01-0.13**	**0.04**	**0.01-0.09**	**0.03**	**0.00-0.05**	**0.02**	**0.00-0.24**	**0.04**

(NA) – Not available

Table 4.3.11: Talukawise range and mean values of SAR (Sodium Adsorption Ratio) of pre-monsoon wells/tube wells water samples 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	2.69-8.90	4.86	1.95-15.20	5.10	2.15-10.32	4.85	2.18-10.65	5.22	1.95-15.20	5.02
Jodiya	2.34-12.77	5.56	2.11-14.23	5.11	2.09-12.32	5.65	3.12-8.27	4.70	2.09-14.23	5.27
Lalpur	NA	NA	2.47-7.83	4.23	1.43-5.60	3.00	1.13-3.65	2.43	1.13-7.83	3.31
Jamnagar District	**2.34-12.77**	**5.26**	**1.95-15.20**	**4.92**	**1.43-12.32**	**4.17**	**1.13-10.65**	**4.41**	**1.13-15.20**	**4.68**
Kalyanpur	1.80-13.51	7.13	3.23-12.37	5.74	1.84-8.20	4.96	2.05-7.12	3.60	1.80-13.51	5.18
Khambhalia	5.50-12.90	9.37	1.38-15.91	4.84	1.74-10.91	5.30	0.95-6.61	3.91	0.95-15.91	5.97
Dwarka	3.25-13.96	6.71	4.02-10.39	7.04	3.13-4.70	3.91	NA	NA	3.13-13.96	6.64
Devbhumi Dwarka District	**1.80-13.96**	**7.09**	**1.38-15.91**	**5.66**	**1.74-10.91**	**4.99**	**0.95-7.12**	**3.78**	**0.95-15.91**	**5.54**
Porbandar	**2.69-12.85**	**5.93**	**2.74-9.90**	**4.61**	**1.96-8.54**	**4.97**	**1.92-5.85**	**3.52**	**1.92-12.85**	**4.92**
Overall	**1.80-13.96**	**6.34**	**1.38-15.91**	**5.16**	**1.43-12.32**	**4.53**	**0.95-10.65**	**3.97**	**0.95-15.91**	**5.08**

(NA) – Not available

km from the sea coast. In Devbhumi Dwarka district, maximum SAR (15.91) was found at 5 to 10 km distance from the sea coast and minimum SAR (0.95) was found at 15 to 20 km distance from the sea coast, while overall mean value of SAR was 5.54. In Porbandar district, overall mean value of SAR was 4.92, maximum SAR (12.85) was found at 0 to 5 km distance from the sea coast and minimum SAR (1.92) was found at 15 to 20 km distance from the sea coast. Data further revealed that the highest (6.64) and the lowest (3.31) mean SAR values were registered in Dwarka and Lalpur talukas, respectively. All the talukas of Northern Saurashtra coastal region at different distances (0 to 5, 5 to 10, 10 to 15 and 15 to 20 km) had mean SAR values less than 10. These findings are in conformity with those of Nilsood *et al.* (1998), Kabaria (2004), Hadiyal (2005), Savalia *et al.* (2006), Sojitra (2010), Rajput and Polara (2013), Polara and Chauhan (2015), Hadiya and Polara (2017) and Vaghela (2017).

Overall 92.98, 7.02, 0.00 and 0.00 per cent samples were fall under S_1, S_2, S_3 and S_4 classes of SAR, respectively (Table 4.3.14 and Fig 4.27). Almost all of the water samples (92.98 per cent) had SAR value < 10 (S_1 class). None of sample falls under S_3 and S_4 classes of SAR. About 94.31, 90.08 and 97.56 per cent water samples of Jamnagar, Devbhumi Dwarka and Porbandar districts, respectively were found under S_1 class of SAR. These findings are in concurrence with the findings of Nilsood *et al.* (1998), Kabaria (2004), Savalia *et al.* (2006), Sojitra (2010), Rajput and Polara (2013), Polara and Chauhan (2015), Hadiya and Polara (2017) and Vaghela (2017).

4.3.1.6 Residual Sodium Carbonate (RSC)

Talukawise range and mean values of RSC are given in table 4.3.12 and fig 4.25 and percentage distribution of water sample in different RSC classes (as suggested by USDA) are presented in table 4.3.14. The overall RSC values were ranged from 0.00 to 9.40 me L^{-1} with mean value of 0.33 me L^{-1}, which is less than 1.25 me L^{-1}. The highest value of RSC (9.40 me L^{-1}) was recorded in Kalyanpur taluka at the distance of 0 to 5 km from the sea coast. In Jamnagar district, the maximum value of RSC (2.92 me L^{-1}) was found at 5 to 10 km distance from the sea coast, whereas the overall mean value of RSC was (0.07 me L^{-1}). In Devbhumi Dwarka district, the maximum value of RSC (9.40 me L^{-1}) was found at 0 to 5 km distance from the sea coast, while overall mean value of RSC was (0.59 me L^{-1}).

Table 4.3.12: Talukawise range and mean values of RSC (Residual Sodium Carbonate) of pre-monsoon wells/tube wells water samples 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	0.00-0.00	0.00	0.00-0.00	0.00	0.00-0.00	0.00	0.00-0.00	0.00	0.00-0.00	0.00
Jodiya	0.00-0.00	0.00	0.00-0.00	0.00	0.00-0.00	0.00	0.00-0.00	0.00	0.00-0.00	0.00
Lalpur	NA	NA	0.00-2.92	0.29	0.00-1.86	0.24	0.00-1.40	0.32	0.00-2.92	0.27
Jamnagar District	**0.00-0.00**	**0.00**	**0.00-2.92**	**0.06**	**0.00-1.86**	**0.10**	**0.00-1.40**	**0.08**	**0.00-2.92**	**0.07**
Kalyanpur	0.00-9.40	1.22	0.00-4.54	1.12	0.00-1.28	0.14	0.00-6.90	0.97	0.00-9.40	0.87
Khambhalia	0.00-0.00	0.00	0.00-2.40	0.17	0.15-2.64	0.68	0.00-3.80	1.42	0.00-3.80	0.72
Dwarka	0.00-0.00	0.00	0.00-2.26	0.52	0.00-0.00	0.00	NA	NA	0.00-2.26	0.13
Devbhumi Dwarka District	**0.00-9.40**	**0.29**	**0.00-4.54**	**0.51**	**0.00-2.64**	**0.35**	**0.00-6.90**	**1.23**	**0.00-9.40**	**0.59**
Porbandar	**0.00-4.21**	**0.58**	**0.00-0.81**	**0.07**	**0.00-1.57**	**0.33**	**0.00-1.08**	**0.35**	**0.00-4.21**	**0.35**
Overall	**0.00-9.40**	**0.26**	**0.00-4.54**	**0.23**	**0.0-2.64**	**0.21**	**0.00-6.90**	**0.70**	**0.00-9.40**	**0.33**

(NA) – Not available

In Porbandar district, overall mean value of RSC was (0.35 me L^{-1}) and maximum RSC (4.21 me L^{-1}) was found at 0 to 5 km distance from the sea coast. For all the talukas, the overall RSC mean values were lower than permissible limit of 2.5 me L^{-1}. The present investigations find supports from the works reported earlier (Nilsood *et al.*, 1998, Anon., 2004a, Kabaria, 2004, Hadiyal, 2005 and Rajput, 2010), for Gir Somnath district of Gujarat (Polara and Chauhan, 2015) and for Kheda district of Gujarat (Vaghela, 2017).

Overall 89.82, 5.26 and 4.91 per cent samples fall under safe, marginal and unsafe classes of RSC, respectively (Table 4.3.14 and Fig. 4.27). Most of (89.82 %) wells/tube wells water sample had RSC value less than 1.25 and only 4.91 percent sample had RSC value greater than 2.50. This finding is in concurrence with the findings of Nilsood *et al.* (1998) for Bhatinda district, Patel (2004) for Surendranagar district, Kabaria (2004) for Amreli district, Sojitra (2010) for Junagadh district, Rajput and Polara (2013) for Bhavnagar district and Polara and Chauhan (2015) for Gir Somnath district of Gujarat.

4.3.1.7 Soluble Sodium Percentage (SSP)

Talukawise range and mean values of SSP are given in table 4.3.13 and fig 4.26 and percentage distribution of water samples in different SSP classes (as suggested by USDA) are presented in table 4.3.14.

The overall mean value of SSP in Northen Saurashtra coastal region's water sample was 50.63 and it was varied from 20.27 to 82.56. In Jamnagar district, the lowest SSP value (21.63) was recorded in water samples collected from Jamnagar taluka at the distance of 5 to 10 km from the sea coast and the highest SSP value (78.61) was recorded in water samples collected from Jamnagar taluka at the distance of 5 to 10 km from the sea coast. In Devbhumi Dwarka district, maximum SSP (82.56) was found at 5 to 10 km distance from the sea coast and minimum SSP (20.27) was found at 0 to 5 km distance from the sea coast, while overall mean value of SSP was 53.33. In Porbandar district, overall mean value of SSP was 49.37, maximum SSP (70.41) was found at 10 to 15 km distance from the sea coast and minimum SSP (29.01) was found at 0 to 5 km distance from the sea coast (Table 4.3.13). Data further revealed that the highest mean SSP value (55.05) and the lowest mean SSP value (44.41) were registered in Dwarka and Lalpur talukas, respectively.

Table 4.3.13: Talukawise range and mean values of SSP ((Soluble Sodium Percentage) of pre-monsoon wells/tube wells water samples 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	30.62-57.96	44.10	21.63-78.61	47.22	31.25-74.07	51.44	37.85-75.59	57.79	21.63-78.61	49.67
Jodiya	24.95-68.29	47.40	21.71-75.68	47.38	29.36-78.28	53.19	47.94-71.39	56.59	21.71-78.28	49.70
Lalpur	NA	NA	33.00-71.51	49.01	21.95-68.37	42.56	32.37-54.91	40.76	21.95-71.51	44.41
Jamnagar District	**24.95-68.29**	**45.98**	**21.63-78.61**	**47.65**	**21.95-78.28**	**47.83**	**32.37-75.59**	**53.39**	**21.63-78.61**	**48.40**
Kalyanpur	20.27-75.02	53.24	29.48-73.65	54.07	31.05-71.36	52.02	32.57-71.07	48.15	20.27-75.02	51.50
Khambhalia	48.73-71.11	60.93	26.79-82.56	49.34	34.89-77.97	54.45	25.61-71.70	55.47	25.61-82.56	53.60
Dwarka	33.52-73.55	53.33	40.90-73.02	60.72	49.30-52.85	51.07	NA	NA	33.52-73.55	55.05
Devbhumi Dwarka District	**20.27-75.02**	**54.11**	**26.79-82.56**	**53.60**	**31.05-77.97**	**52.95**	**25.61-71.70**	**52.30**	**20.27-82.56**	**53.33**
Porbandar	**29.01-67.76**	**48.64**	**35.35-67.59**	**46.24**	**29.96-70.41**	**53.94**	**32.32-58.45**	**50.39**	**29.01-70.41**	**49.37**
Overall	**20.27-75.02**	**50.72**	**21.63-82.56**	**49.68**	**21.95-78.28**	**50.23**	**25.61-75.59**	**52.43**	**20.27-82.56**	**50.63**

(NA) – Not available

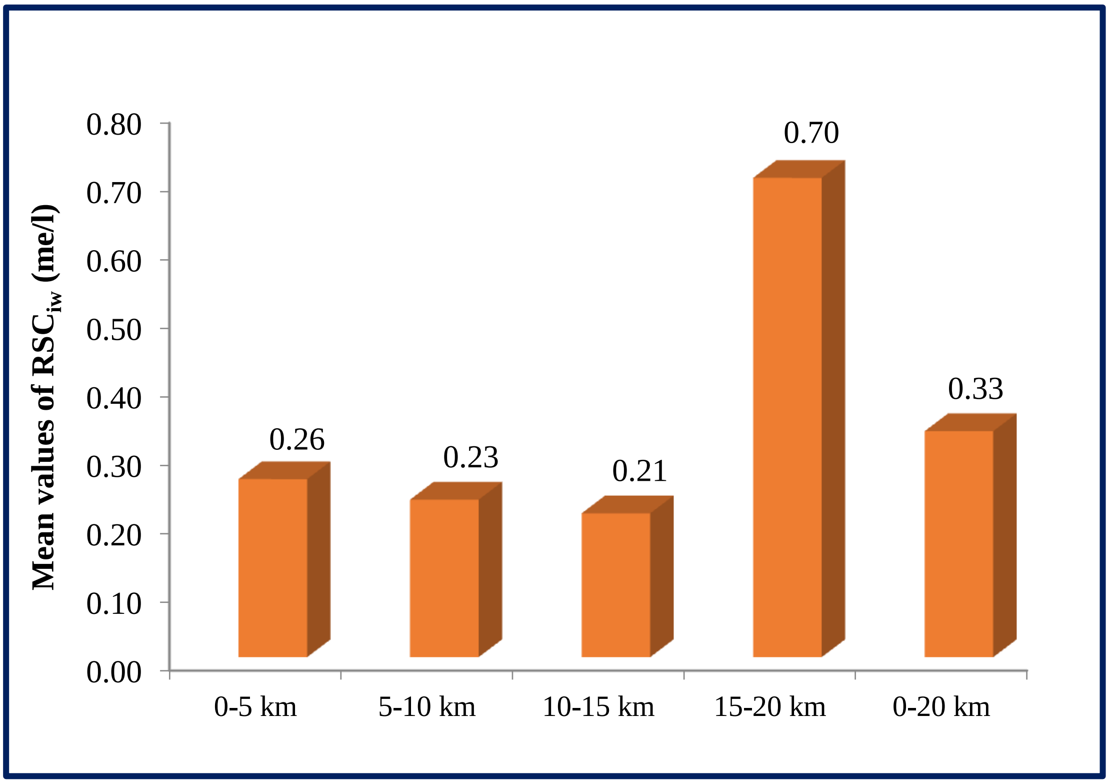


Fig. 4.25: Overall status of pre-monsoon RSC_{iw} in samples of Northern Saurashtra coastal region

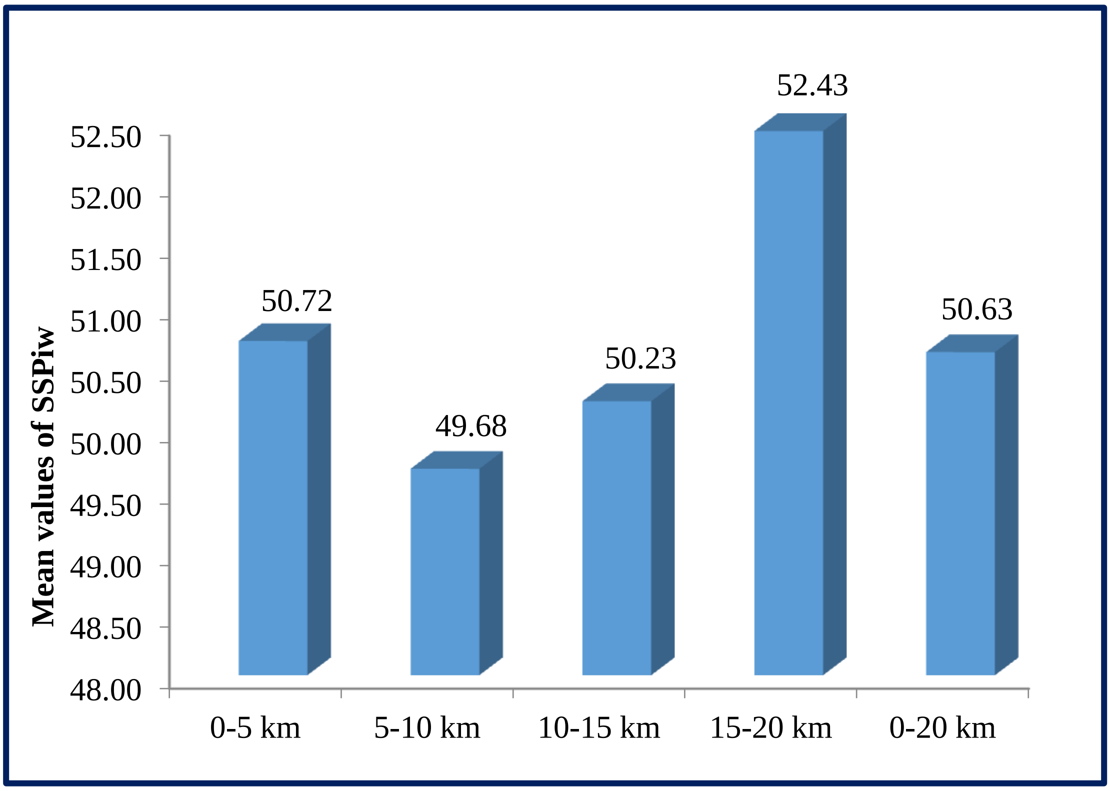


Fig. 4.26: Overall status of pre-monsoon SSP_{iw} in samples of Northern Saurashtra coastal region

Table 4.3.14: Percentage distribution of pre-monsoon well/tube well water samples into different EC, SAR, RSC and SSP classes

Name of Taluka	EC				SAR classes				RSC classes			SSP classes	
	C_1	C_2	C_3	C_4	S_1	S_2	S_3	S_4	Safe	Marginal	Unsafe	Safe	Unsafe
Jamnagar	0.00 (0)*	1.85 (1)	50.00 (27)	48.15 (26)	92.59 (50)	7.41 (4)	0.00 (0)	0.00 (0)	100.00 (54)	0.00 (0)	0.00 (0)	72.22 (39)	27.78 (15)
Jodiya	0.00 (0)	2.56 (1)	46.15 (18)	51.28 (20)	92.31 (36)	7.69 (3)	0.00 (0)	0.00 (0)	100.00 (39)	0.00 (0)	0.00 (0)	84.61 (33)	15.38 (6)
Lalpur	0.00 (0)	6.67 (2)	76.67 (23)	16.67 (5)	100.00 (30)	0.00 (0)	0.00 (0)	0.00 (0)	86.67 (26)	10.00 (3)	3.33 (1)	90.00 (27)	10.00 (3)
Jamnagar District	**0.00 (0)**	**3.25 (4)**	**55.28 (68)**	**41.46 (51)**	**94.31 (116)**	**5.69 (7)**	**0.00 (0)**	**0.00 (0)**	**96.75 (119)**	**2.44 (3)**	**0.81 (1)**	**80.49 (99)**	**19.51 (24)**
Kalyanpur	0.00 (0)	12.50 (5)	50.00 (20)	37.50 (15)	92.50 (37)	7.50 (3)	0.00 (0)	0.00 (0)	77.50 (31)	12.50 (5)	10.00 (4)	67.50 (27)	32.50 (13)
Khambhalia	2.22 (1)	13.33 (6)	62.22 (28)	22.22 (10)	88.89 (40)	11.11 (5)	0.00 (0)	0.00 (0)	75.55 (34)	8.89 (4)	15.55 (7)	66.67 (30)	33.33 (15)
Dwarka	0.00 (0)	0.00 (0)	33.33 (12)	66.67 (24)	88.89 (32)	11.11 (4)	0.00 (0)	0.00 (0)	94.44 (34)	5.55 (2)	0.00 (0)	66.67 (24)	33.33 (12)
Devbhumi Dwarka District	**0.83 (1)**	**9.09 (11)**	**49.59 (60)**	**40.50 (49)**	**90.08 (109)**	**9.92 (12)**	**0.00 (0)**	**0.00 (0)**	**81.82 (99)**	**9.09 (11)**	**9.09 (11)**	**66.94 (81)**	**33.06 (40)**
Porbandar	**0.00 (0)**	**4.88 (2)**	**51.22 (21)**	**43.90 (18)**	**97.56 (40)**	**2.44 (1)**	**0.00 (0)**	**0.00 (0)**	**92.68 (38)**	**2.44 (1)**	**4.88 (2)**	**80.49 (33)**	**19.51 (8)**
Overall	**0.35 (1)**	**5.96 (17)**	**52.28 (149)**	**41.40 (118)**	**92.98 (265)**	**7.02 (20)**	**0.00 (0)**	**0.00 (0)**	**89.82 (256)**	**5.26 (15)**	**4.91 (14)**	**74.74 (213)**	**25.26 (72)**

(*) – Values in parenthesis are number of samples

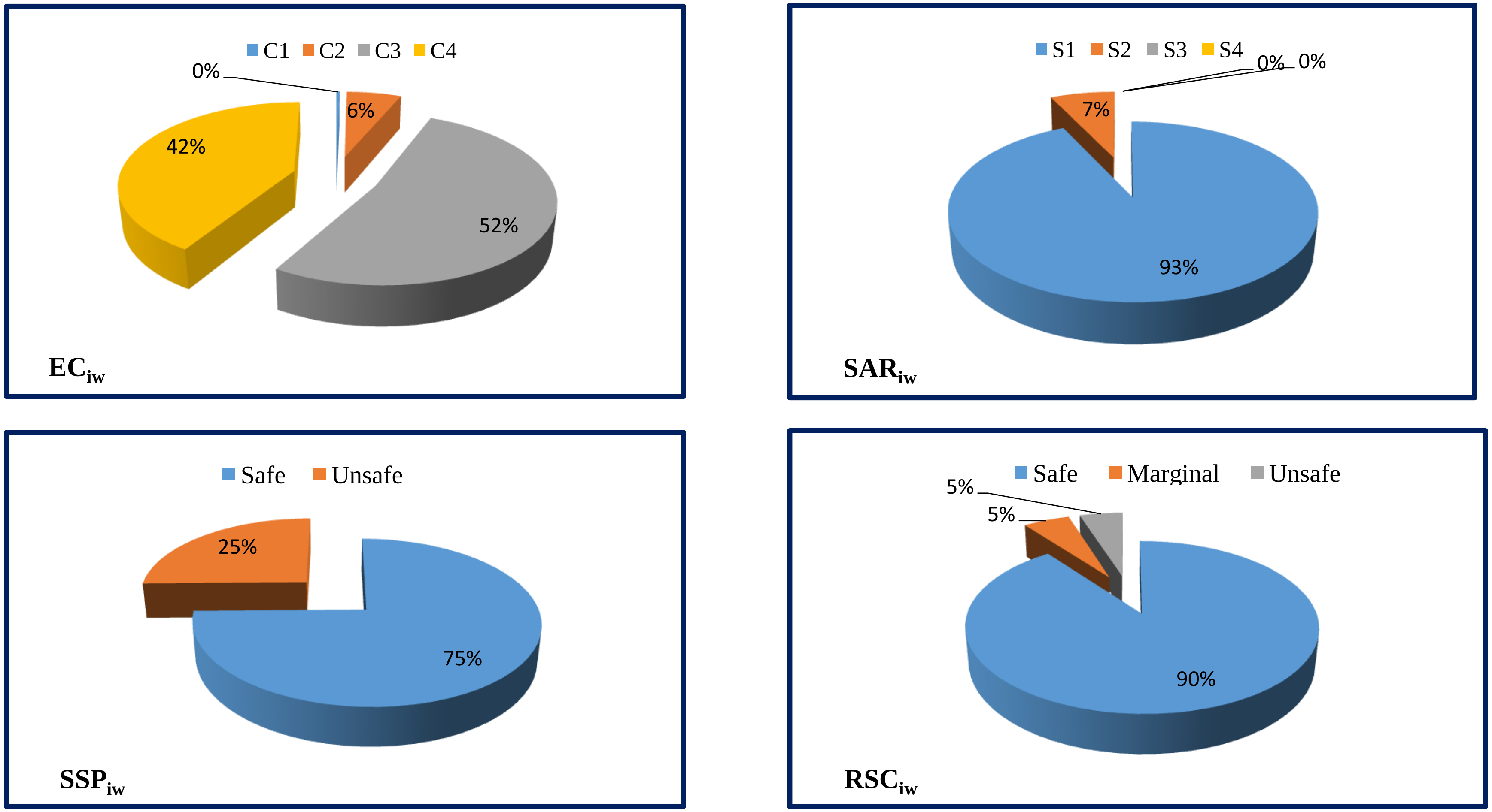


Fig. 4.27: Overall percentage of pre-monsoon EC_{iw}, SAR_{iw}, SSP_{iw} and RSC_{iw} in samples of Northern Saurashtra coastal region

The water samples of most of talukas of Northern Saurashtra coastal region having mean value of SSP less than 60, which is indicative of safe for alkali hazard in these waters. These findings are in conformity with those of Nilsood *et al.* (1998), Verma *et al.* (2003), Kabaria (2004), Hadiyal (2005), Sojitra (2010), Rajput and Polara (2013), Polara and Chauhan (2015) and Hadiya and Polara (2017).

Overall 74.74 and 25.26 per cent samples falls under safe and unsafe classes of SSP, respectively (Table 4.3.14 and Fig. 4.27). More than half of the water samples (74.74 per cent) had SSP value < 60 (safe class). About 80.49, 66.94 and 80.49 per cent water samples of Jamnagar, Devbhumi Dwarka and Porbandar districts, respectively were found under safe class of SSP. These findings are in concurrence with the findings of Nilsood *et al*. (1998), Kabaria (2004), Savalia *et al.* (2006), Rajput and Polara (2013), Polara and Chauhan (2015) and Vaghela (2017).

4.3.2 Irrigation water quality appraisal after monsoon (December, 2019)

Irrigation water samples were analyzed for EC, pH, cations (Ca^{++}, Mg^{++}, Na^{+} and K^{+}) and anions (CO_3^{--}, HCO_3^{-}, Cl^{-} and SO_4^{--}). Various indices *viz*., SAR, RSC and SSP were then worked out from the estimated cations and anions expressed in me L^{-1}. Sample wise values for EC, pH, cations, anions and different water indices of all the 285 samples are given in Appendix VII, talukawise range and mean values for EC and pH in tables 4.3.15 and 4.3.16, cations and anions in table 4.3.17 to 4.3.24, and their per cent distribution in table 4.3.28.

4.3.2.1 Electrical conductivity (EC)

The overall mean value of EC of Northen Saurashtra's water sample was found 2.01 dS m^{-1}, which was varied widely from 0.18 to 6.83 dS m^{-1}. In Jamnagar district, overall mean value of EC was 1.99 dS m^{-1}, maximum EC (5.46 dS m^{-1}) was found at 0 to 5 km distance from the sea coast and minimum EC (0.28 dS m^{-1}) was found at 15 to 20 km distance from the sea coast. In Devbhumi Dwarka district, maximum EC (6.83 dS m^{-1}) was found at 0 to 5 km distance from the sea coast and minimum EC (0.18 dS m^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of EC was 1.97 dS m^{-1}. In Porbandar district, overall mean value of EC was 2.16 dS m^{-1}, maximum EC (5.64 dS m^{-1}) was found at 0 to 5 km distance from the sea coast and minimum EC (0.26 dS m^{-1}) was found at 15 to 20 km

Table 4.3.15: Talukawise range and mean values of EC (dS m^{-1}) of post-monsoon wells/tube wells water samples 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	1.83-4.66	2.90	1.10-3.81	2.34	0.58-2.61	1.69	0.48-1.64	1.18	0.48-4.66	2.06
Jodiya	1.07-5.46	3.17	1.49-4.04	2.60	0.67-2.57	1.75	0.52-1.86	1.22	0.52-5.46	2.43
Lalpur	NA	NA	0.64-2.92	1.56	0.54-2.63	1.24	0.28-1.18	0.82	0.28-2.92	1.28
Jamnagar District	**1.07-5.46**	**3.06**	**0.64-4.04**	**2.26**	**0.54-2.63**	**1.50**	**0.28-1.86**	**1.11**	**0.28-5.46**	**1.99**
Kalyanpur	0.40-6.83	2.74	0.57-4.53	2.20	0.32-3.53	1.65	0.27-2.44	1.09	0.27-6.83	1.83
Khambhalia	3.59-4.46	3.98	0.21-4.06	1.59	0.27-2.76	1.25	0.18-1.42	0.83	0.18-4.46	1.45
Dwarka	1.27-5.46	3.10	0.93-3.93	2.24	0.64-1.71	1.18	NA	NA	0.64-5.46	2.78
Devbhumi Dwarka District	**0.40-6.83**	**3.10**	**0.21-4.53**	**1.92**	**0.27-3.53**	**1.43**	**0.18-2.44**	**0.94**	**0.18-6.83**	**1.97**
Porbandar	**1.68-5.64**	**3.09**	**0.88-3.89**	**2.24**	**0.72-2.42**	**1.55**	**0.26-1.70**	**1.05**	**0.26-5.64**	**2.16**
Overall	**0.40-6.83**	**3.09**	**0.21-4.53**	**2.13**	**0.27-3.53**	**1.49**	**0.18-2.44**	**1.01**	**0.18-6.83**	**2.01**

(NA) – Not available

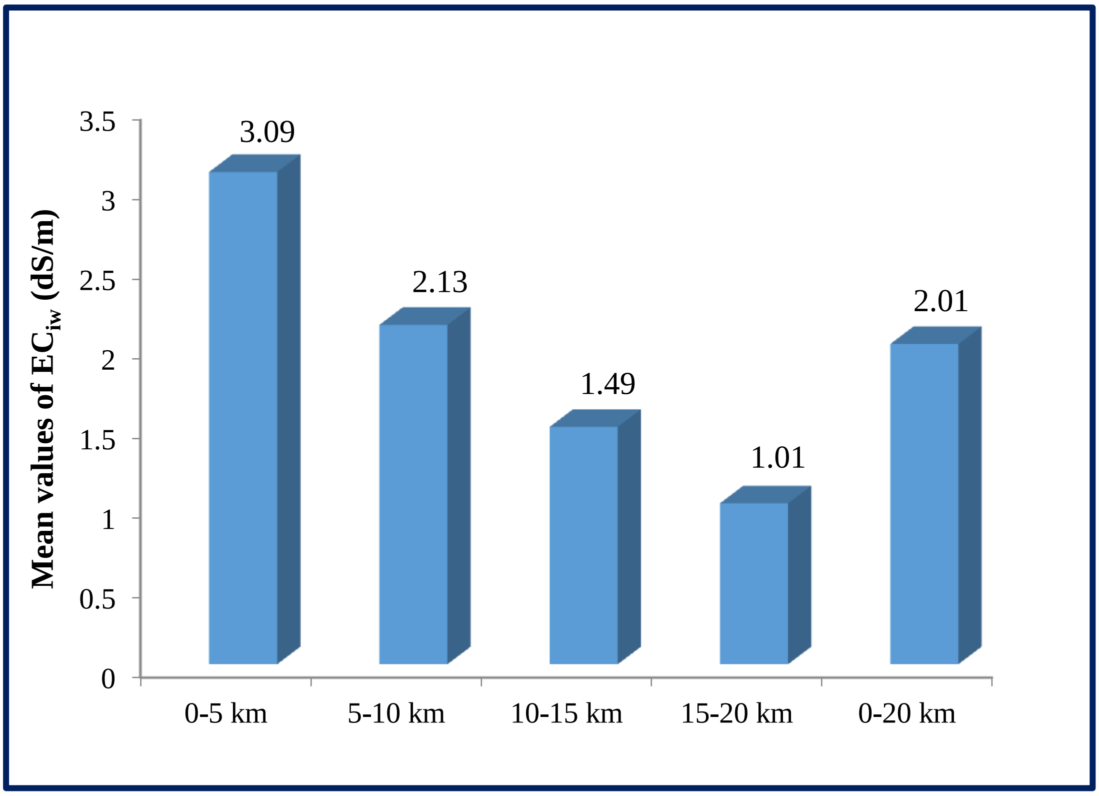


Fig. 4.28: Overall status of post-monsoon EC_{iw} in samples of Northern Saurashtra coastal region

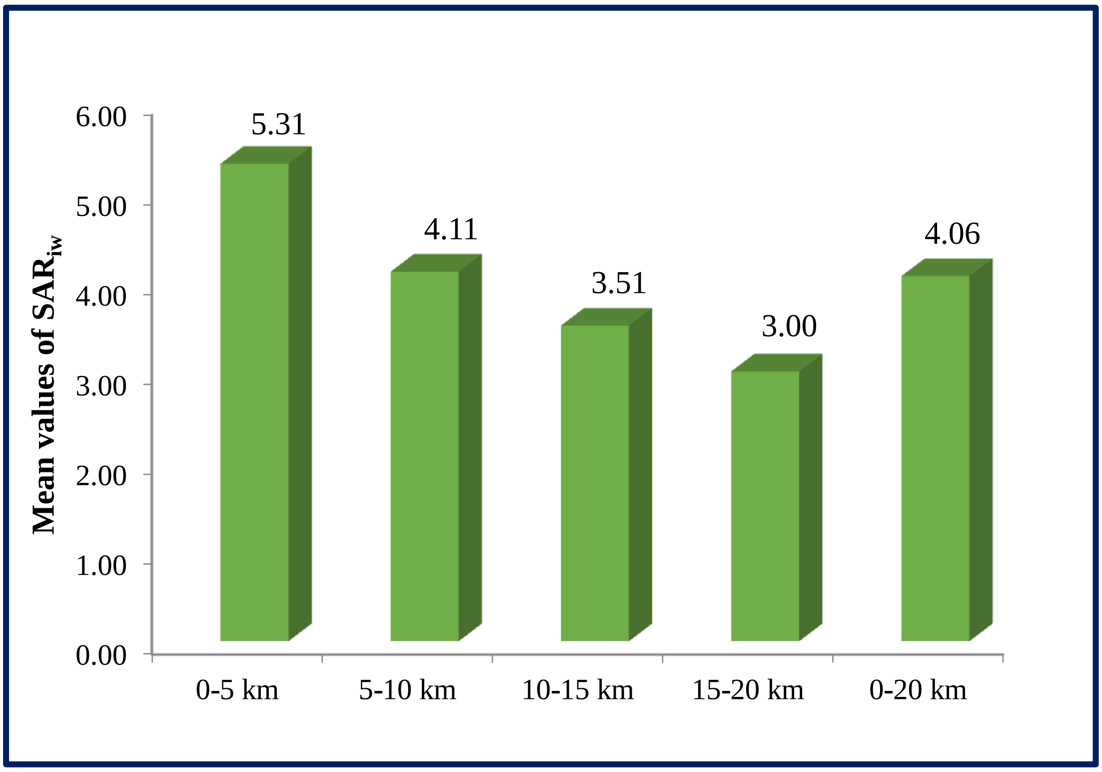


Fig. 4.29: Overall status of post-monsoon SAR_{iw} in samples of Northern Saurashtra coastal region

distance from the sea coast (Table 4.3.15 and Fig 4.28). The lowest value of EC (0.18 dS m^{-1}) was recorded in the samples collected from Khambhalia taluka in Devbhumi Dwarka district, whereas the highest value of EC (6.83 dS m^{-1}) was found in Kalyanpur taluka of Devbhumi Dwarka district. The data further revealed that the lowest mean value of EC (1.28 dS m^{-1}) was obtained from the samples of Lalpur taluka of Jamnagar district and the highest mean value of EC (2.78 dS m^{-1}) was registered in the samples of Dwarka taluka of Devbhumi Dwarka district.

The value of EC was decreased with increased the distance from sea coast in irrigation water samples of Northern Saurashtra coastal region after withdrawal of monsoon. Overall 0.70, 12.28, 51.23 and 35.79 per cent samples were falling under C_1, C_2, C_3 and C_4 classes of EC, respectively (Table 4.3.28, Fig. 4.32). More than half (51.23 per cent) of the water samples had EC value in the range of 0.75 to 2.25 dS m^{-1} (C_3 class). About 54.47, 46.28 and 56.10 per cent water samples of Jamnagar, Devbhumi Dwarka and Porbandar districts, respectively were found under C_3 class of EC. Similar findings were also reported for Porbandar district by Hadiyal (2005), for Junagadh district by Sojitra (2010), for Bhavnagar district by Rajput and Polara (2013), for Latur district of Maharashtra by Patil *et al*., (2014), for Gir Somnath district by Polara and Chauhan (2015), for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.3.2.2 pH

In general, well/tube well water samples of Northern Saurashtra coastal region were neutral to slightly alkaline in reaction. The overall pH values of Northen Saurashtra's water samples were ranged from 7.00 to 8.90 with mean value of 7.73. The data (Table 4.3.16) revealed that lowest mean value of pH (7.66) was obtained from the samples of Porbandar taluka of Porbandar district and the highest mean value of pH 7.88 was found in the samples of Lalpur taluka of Jamnagar district. In Jamnagar district, maximum pH (8.60) was found at 10 to 15 km distance from the sea coast and minimum pH (7.20) was found at 0 to 5 km distance from the sea coast, whereas overall mean value of pH was 7.74. In Devbhumi Dwarka district, maximum pH (8.90) was found at 10 to 15 km distance from the sea coast and minimum pH (7.00) was found at 0 to 5 km distance from the sea coast, while overall mean value

Table 4.3.16: Talukawise range and mean values of pH of post-monsoon wells/tube wells water samples 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	7.20-7.90	7.67	7.30-7.90	7.59	7.50-8.03	7.70	7.20-8.40	7.87	7.20-8.40	7.68
Jodiya	7.40-7.90	7.58	7.20-8.10	7.62	7.60-8.10	7.85	7.70-8.30	8.03	7.20-8.30	7.71
Lalpur	NA	NA	7.40-8.00	7.72	7.40-8.60	7.93	7.60-8.40	8.02	7.40-8.60	7.88
Jamnagar District	**7.20-7.90**	**7.61**	**7.20-8.10**	**7.63**	**7.40-8.60**	**7.83**	**7.20-8.40**	**7.95**	**7.20-8.60**	**7.74**
Kalyanpur	7.00-8.80	7.70	7.10-8.10	7.53	7.20-8.40	8.09	7.30-8.50	7.70	7.00-8.80	7.75
Khambhalia	7.30-7.70	7.48	7.40-8.00	7.72	7.50-8.10	7.75	7.56-8.13	7.80	7.30-8.13	7.73
Dwarka	7.20-8.90	7.71	7.30-8.87	7.81	7.60-8.90	8.25	NA	NA	7.20-8.90	7.76
Devbhumi Dwarka District	**7.00-8.90**	**7.68**	**7.10-8.87**	**7.69**	**7.20-8.90**	**7.96**	**7.30-8.50**	**7.76**	**7.00-8.90**	**7.75**
Porbandar	**7.30-7.80**	**7.56**	**7.40-7.80**	**7.60**	**7.30-8.17**	**7.80**	**7.30-8.30**	**7.76**	**7.30-8.30**	**7.66**
Overall	**7.00-8.90**	**7.64**	**7.10-8.87**	**7.65**	**7.20-8.90**	**7.87**	**7.20-8.50**	**7.83**	**7.00-8.90**	**7.73**

(NA) – Not available

of pH was 7.75. In Porbandar district, overall mean value of pH was 7.66, maximum pH (8.30) was found at 15 to 20 km distance from the sea coast and minimum pH (7.30) was found at 0 to 5 km distance from the sea coast. The lowest value of pH (7.00) was recorded in the samples collected from Kalyanpur taluka in Devbhumi Dwarka district, whereas the highest value of pH (8.90) was found in Dwarka taluka of Devbhumi Dwarka district. Almost, pH value of post-monsoon water sample had minimum changes among the different distance of sampling from sea coast of Northern Saurashtra. Similar findings were also recorded for Churu district (Rajasthan) by Verma *et al.* (2003), for Amreli district by Kabaria (2004), for Porbandar district by Hadiyal (2005), for Junagadh district by Sojitra (2010), for Bhavnagar district by Rajput and Polara (2013), for Latur district of Maharashtra by Patil et al. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015), for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.3.3.3 Cation concentration in well/tube well water samples

Talukawise range and mean values of different cations present in wells/tube wells water sample are given in tables 4.3.17 to 4.3.20.

4.3.3.3.1 Na^+

The overall Na^+ values of Northen Saurashtra's water sample were ranged from 0.48 to 35.61 me L^{-1} with mean value of 9.36 me L^{-1}. Among the different talukas of survey area, highest proportion of Na^+ (35.61 me L^{-1}) was observed at the distance of 0 to 5 km from the sea coast in Jodiya taluka, which was followed by Porbandar (35.21 me L^{-1}) and Dwarka taluka (33.94 me L^{-1}). The presence of large proportion of Na^+ in most of area under investigation is indicative of a potential danger for the alkalinity hazards. The highest mean value for Na^+ (14.94 me L^{-1}) was found in Dwarka taluka followed by Jodiya (10.44 me L^{-1}) and Porbandar (10.28 me L^{-1}) taluka and the lowest mean value for Na^+ (5.34 me L^{-1}) was reported in Lalpur taluka (Table 4.3.17). Overall data basis of Na^+ in water samples of Northern Saurashtra coastal region, Na^+ decreased with increased the distance fron sea coast. Similar results were also found by Verma *et al.* (2003) for Churu district (Rajasthan), by Kabaria (2004) for Amreli district, by Hadiyal (2005) for Porbandar district, by Sojitra (2010) for Junagadh district, by Rajput and Polara (2013) for Bhavnagar

Table 4.3.17: Talukawise range and mean values of Na^+ (me L^{-1}) of post-monsoon well/tube well water samples 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	5.27-31.14	10.71	4.06-28.74	9.84	3.45-22.16	7.17	2.30-16.24	5.70	2.30-31.14	8.57
Jodiya	7.11-35.61	12.95	6.55-30.75	10.92	4.12-18.15	8.39	3.28-11.32	6.27	3.28-35.61	10.44
Lalpur	NA	NA	3.68-11.74	6.97	2.24-10.24	4.97	1.23-5.41	3.20	1.23-11.74	5.34
Jamnagar District	**5.27-35.61**	**11.99**	**3.68-30.75**	**9.57**	**2.24-22.16**	**6.42**	**1.23-16.24**	**5.26**	**1.23-35.61**	**8.38**
Kalyanpur	7.06-27.57	12.72	6.48-22.15	10.28	1.06-15.91	7.64	1.48-11.37	4.96	1.06-27.57	8.50
Khambhalia	13.3-31.64	21.01	1.67-24.51	7.72	1.26-18.62	7.13	0.48-8.35	4.25	0.48-31.64	7.48
Dwarka	8.12-33.94	16.66	6.48-24.35	12.16	3.42-8.25	5.84	NA	NA	3.42-33.94	14.94
Devbhumi Dwarka District	**7.06-33.94**	**16.18**	**1.67-24.51**	**9.57**	**1.06-18.62**	**7.23**	**0.48-11.37**	**4.55**	**0.48-33.94**	**10.04**
Porbandar	**6.27-35.21**	**14.87**	**4.02-24.35**	**10.21**	**3.18-18.46**	**7.74**	**1.91-11.03**	**4.88**	**1.91-35.21**	**10.28**
Overall	**5.27-35.61**	**14.72**	**1.67-30.75**	**9.65**	**1.06-22.16**	**6.84**	**0.48-16.24**	**4.85**	**0.48-35.61**	**9.36**

(NA) – Not available

district, by Patil *et al*. (2014) for Latur district of Maharashtra, by Polara and Chauhan (2015) for Gir Somnath district of Gujarat and for Kheda district of Gujarat by Vaghela (2017).

4.3.3.3.2 K^+

Among the different talukas of survey area, highest proportion of K^+ (0.84 me L^{-1}) was observed at the distance of 0 to 5 km from the sea coast (Table 4.3.18). The highest mean value for K^+ (0.27 me L^{-1}) was found in Dwarka taluka followed by Porbandar (0.12 me L^{-1}) taluka and the lowest mean value for K^+ (0.01 me L^{-1}) was reported in Lalpur taluka. The overall K^+ values of Northen Saurashtra's water sample were ranged from 0.00 to 0.84 me L^{-1} with the mean value of 0.07 me L^{-1}. Overall, negligible amount of K^+ (0.07 me L^{-1}) was noted in post-monsoon waster samples of Northern Saurashtra coastal region. Similar results were also found by Verma *et al.* (2003) for Churu district (Rajasthan), by Kabaria (2004) for Amreli district, by Hadiyal (2005) for Porbandar district, by Sojitra (2010) for Junagadh district, by Rajput and Polara (2013) for Bhavnagar district, by Patil *et al*. (2014) for Latur district of Maharashtra and by Polara, Chauhan (2015) for Gir Somnath district of Gujarat, for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.3.3.3.3 Ca^{++}

The overall Ca^{++} values of Northen Saurashtra's water samples were ranged from 1.03 to 24.50 me L^{-1} with mean value of 5.54 me L^{-1}. The data (Table 4.3.19) revealed that the lowest mean value of Ca^{++} (3.90 me L^{-1}) was obtained from the samples of Lalpur taluka of Jamnagar district and the highest mean value of Ca^{++} (7.15 me L^{-1}) was found in the samples of Jodiya taluka of Jamnagar district. In Jamnagar district, maximum Ca^{++} (22.34 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Ca^{++} (1.20 me L^{-1}) was found at 15 to 20 km distance from the sea coast, whereas overall mean value of Ca^{++} was 5.86 me L^{-1}. In Devbhumi Dwarka district, maximum Ca^{++} (24.50 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Ca^{++} (1.03 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of Ca^{++} was 5.24 me L^{-1}. In Porbandar district, overall mean value of Ca^{++} was 5.47 me L^{-1}, maximum Ca^{++} (17.40 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Ca^{++} (1.70

Table 4.3.18: Talukawise range and mean values of K^+ (me L^{-1}) of post-monsoon well/tube well water samples 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	0.00-0.06	0.02	0.00-0.05	0.02	0.00-0.05	0.02	0.00-0.03	0.01	0.00-0.06	0.02
Jodiya	0.00-0.06	0.03	0.00-0.05	0.02	0.00-0.04	0.02	0.00-0.03	0.01	0.00-0.06	0.02
Lalpur	NA	NA	0.00-0.04	0.01	0.00-0.02	0.01	0.00-0.05	0.02	0.00-0.05	0.01
Jamnagar District	**0.00-0.06**	**0.02**	**0.00-0.05**	**0.02**	**0.00-0.05**	**0.01**	**0.00-0.05**	**0.01**	**0.00-0.06**	**0.02**
Kalyanpur	0.10-0.33	0.19	0.02-0.16	0.06	0.02-0.14	0.06	0.00-0.07	0.02	0.00-0.33	0.07
Khambhalia	0.01-0.05	0.04	0.00-0.29	0.04	0.00-0.06	0.01	0.00-0.05	0.01	0.00-0.29	0.02
Dwarka	0.00-0.84	0.32	0.07-0.26	0.18	0.05-0.14	0.01	NA	NA	0.00-0.84	0.27
Devbhumi Dwarka District	**0.00-0.84**	**0.26**	**0.00-0.29**	**0.08**	**0.00-0.14**	**0.04**	**0.00-0.07**	**0.02**	**0.00-0.84**	**0.11**
Porbandar	**0.04-0.80**	**0.26**	**0.02-0.18**	**0.08**	**0.02-0.11**	**0.05**	**0.01-0.05**	**0.03**	**0.01-0.80**	**0.12**
Overall	**0.00-0.84**	**0.19**	**0.00-0.29**	**0.05**	**0.00-0.14**	**0.03**	**0.00-0.07**	**0.02**	**0.00-0.84**	**0.07**

(NA) – Not available

Table 4.3.19: Talukawise range and mean values of Ca^{++} (me L^{-1}) of post-monsoon well/tube well water samples in different districts of Northern Saurashtra coastal region

Talukas \ Distance (km)	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Jamnagar	5.40-20.06	9.47	2.40-17.70	6.61	2.12-13.30	4.88	1.80-5.10	3.15	1.80-20.06	6.03
Jodiya	6.03-22.34	9.78	5.08-18.30	7.72	1.80-8.20	4.58	1.20-5.40	2.99	1.20-22.34	7.15
Lalpur	NA	NA	2.20-10.37	4.39	2.12-8.20	3.89	1.72-5.20	2.92	1.72-10.37	3.90
Jamnagar District	**5.40-22.34**	**9.65**	**2.20-18.30**	**6.49**	**1.80-13.30**	**4.39**	**1.20-5.40**	**3.05**	**1.20-22.34**	**5.86**
Kalyanpur	3.70-24.50	8.37	1.60-17.40	7.06	2.03-12.07	4.97	1.03-7.03	3.03	1.03-24.50	5.57
Khambhalia	9.58-13.66	11.46	2.08-9.60	5.00	1.80-7.10	3.66	1.20-4.20	2.49	1.20-13.66	4.39
Dwarka	4.20-11.70	6.78	3.05-6.80	4.17	1.40-4.61	3.01	NA	NA	1.40-11.70	5.92
Devbhumi Dwarka District	**3.70-24.50**	**7.65**	**1.60-17.40**	**5.33**	**1.40-12.07**	**4.21**	**1.03-7.03**	**2.72**	**1.03-24.50**	**5.24**
Porbandar	**2.50-17.40**	**7.32**	**2.17-14.30**	**6.10**	**2.11-9.20**	**3.92**	**1.70-5.30**	**2.92**	**1.70-17.40**	**5.47**
Overall	**2.50-24.50**	**8.16**	**1.60-18.30**	**6.02**	**1.40-13.30**	**4.27**	**1.03-7.03**	**2.87**	**1.03-24.50**	**5.54**

(NA) – Not available

me L^{-1}) was found at 15 to 20 km distance from the sea coast. The lowest value of Ca^{++} (1.03 me L^{-1}) was recorded in the samples collected from Kalyanpur taluka in Devbhumi Dwarka district, whereas the highest value of Ca^{++} (24.50 me L^{-1}) was found in Kalyanpur taluka of Devbhumi Dwarka district. Likewise to Na^{+}, Ca^{++} was also decreased with increasing the distance fron sea coast. However, the rate of reduction of Ca^{++} was higher than Na^{+}, hence the SSP was increased with increased the distance fron sea coast. Similar findings were also recorded for Churu district (Rajasthan) by Verma et al. (2003), for Porbandar district by Hadiyal (2005), for Junagadh district by Sojitra (2010), for Bhavnagar district by Rajput and Polara (2013), for Latur district of Maharashtra by Patil et al. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015) for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.3.3.3.4 Mg^{++}

In Jamnagar district, overall mean value of Mg^{++} was 5.68 me L^{-1}, maximum Mg^{++} (19.60 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Mg^{++} (1.40 me L^{-1}) was found at 15 to 20 km distance from the sea coast. In Devbhumi Dwarka district, maximum Mg^{++} (11.80 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Mg^{++} (0.50 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of Mg^{++} was 4.42 me L^{-1}. In Porbandar district, overall mean value of Mg^{++} was 5.74 me L^{-1}, maximum Mg^{++} (14.20 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Mg^{++} (0.90 me L^{-1}) was found at 15 to 20 km distance from the sea coast (Table 4.3.20). The lowest value of Mg^{++} (0.50 me L^{-1}) was recorded in the samples collected from Khambhalia taluka in Devbhumi Dwarka district, whereas the highest value of Mg^{++} (19.60 me L^{-1}) was found in Jodiya taluka of Jamnagar district. The data further revealed that the lowest mean value of Mg^{++} (2.66 me L^{-1}) was obtained from the samples of Khambhalia taluka of Devbhumi Dwarka district and the highest mean value of Mg^{++} (6.76 me L^{-1}) was registered in the samples of Jodiya taluka of Jamnagar district. Similar findings were also recorded for Amreli district by Kabaria (2004), for Porbandar district by Hadiyal (2005), for Junagadh district by Sojitra (2010), for Bhavnagar district by Rajput and Polara (2013), for Latur district of

Table 4.3.20: Talukawise range and mean values of Mg^{++} (me L^{-1}) of post-monsoon well/tube well water samples in different districts of Northern Saurashtra coastal region

Talukas \ Distance (km)	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Jamnagar	3.70-18.52	8.86	3.14-14.80	6.93	2.30-11.20	4.92	1.70-5.46	3.08	1.70-18.52	6.06
Jodiya	5.02-19.60	8.96	4.30-14.70	7.29	3.12-8.04	4.66	1.56-5.04	3.13	1.56-19.60	6.76
Lalpur	NA	NA	2.28-7.50	4.31	2.06-6.20	3.58	1.40-4.20	2.19	1.40-7.50	3.59
Jamnagar District	**3.70-19.60**	**8.92**	**2.28-14.80**	**6.49**	**2.06-11.20**	**4.28**	**1.40-5.46**	**2.88**	**1.40-19.60**	**5.68**
Kalyanpur	2.03-11.80	6.23	2.40-8.34	4.72	2.60-5.40	4.07	1.60-4.28	3.00	1.60-11.80	4.35
Khambhalia	5.86-7.77	7.02	1.28-5.36	3.23	0.90-3.20	1.91	0.50-2.70	1.45	0.50-7.77	2.66
Dwarka	4.07-11.70	7.21	3.80-10.91	6.01	1.68-5.06	3.37	NA	NA	1.68-11.70	6.70
Devbhumi Dwarka District	**2.03-11.80**	**6.96**	**1.28-10.91**	**4.36**	**0.90-5.40**	**3.09**	**0.50-4.28**	**2.12**	**0.50-11.80**	**4.42**
Porbandar	**3.40-14.20**	**8.37**	**2.60-12.10**	**6.03**	**2.18-8.03**	**3.82**	**0.90-5.15**	**2.64**	**0.90-14.20**	**5.74**
Overall	**2.03-19.60**	**7.79**	**1.28-14.80**	**5.65**	**0.90-11.20**	**3.85**	**0.50-5.46**	**2.46**	**0.50-19.60**	**5.15**

(NA) – Not available

Maharashtra by Patil et al. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015), for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.3.3.4 Anion concentration in well/tube well water samples

Talukawise range and mean values of different anions present in wells/tube wells water sample are given in tables 4.3.21 to 4.3.24.

4.3.3.4.1 CO_3^{--}

In case of CO_3^{--}, the highest overall mean value of 0.25 me L^{-1} was recorded at the distance of 0 to 5 km from the sea coast. The highest mean value of CO_3^{--} (0.24 me L^{-1}) was observed in Dwarka taluka of Devbhumi Dwarka district while the lowest mean value of CO_3^{--} (0.02 me L^{-1}) was observed in Khambhalia taluka of Devbhumi Dwarka district (Table 4.3.21). In Jamnagar district, maximum CO_3^{--} (1.60 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum CO_3^{--} (0.00 me L^{-1}) was found at 15 to 20 km distance from the sea coast, whereas overall mean value of CO_3^{--} was (0.15 me L^{-1}). In Devbhumi Dwarka district, maximum CO_3^{--} (1.60 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum CO_3^{--} (0.00 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of CO_3^{--} was (0.13 me L^{-1}). In Porbandar district, overall mean value of CO_3^{--} was (0.12 me L^{-1}), maximum CO_3^{--} (1.60 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum CO_3^{--} (0.00 me L^{-1}) was found at 15 to 20 km distance from the sea coast. The content of CO_3^{--} in post-monsoon water was negligible amount in coastal area of North Saurashtra. Similar results were also found by Verma *et al.* (2003) for Churu district (Rajasthan), by Kabaria (2004) for Amreli district, by Hadiyal (2005) for Porbandar district, by Rajput and Polara (2013) for Bhavnagar district, by Polara and Chauhan (2015) for Gir Somnath district, by Hadiya and Polara (2017) for Devbhumi Dwarka district of Gujarat and by Vaghela (2017) for Kheda district of Gujarat.

4.3.3.4.2 HCO_3^{-}

In Jamnagar district, overall mean value of HCO_3^{-} was 2.95 me L^{-1}, maximum HCO_3^{-} (7.60 me L^{-1}) was found at 5 to 10 km distance from the sea coast and minimum HCO_3^{-} (0.42 me L^{-1}) was found at 15 to 20 km distance from the sea coast.

Table 4.3.21: Talukawise range and mean values of CO_3^{--} (me L^{-1}) of post-monsoon well/tube well water samples in different districts of Northern Saurashtra coastal region

Talukas \ Distance (km)	0 to 5		5 to 10		10 to 15		15 to 20		Overall	
	Range	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Jamnagar	0.00-1.20	0.27	0.00-1.12	0.19	0.00-0.80	0.06	0.00-0.16	0.03	0.00-1.20	0.14
Jodiya	0.00-1.60	0.33	0.00-1.20	0.22	0.00-0.41	0.15	0.00-0.36	0.09	0.00-1.60	0.22
Lalpur	NA	NA	0.00-0.80	0.08	0.00-0.34	0.07	0.00-0.08	0.02	0.00-0.80	0.06
Jamnagar District	**0.00-1.60**	**0.30**	**0.00-1.20**	**0.18**	**0.00-0.80**	**0.08**	**0.00-0.36**	**0.04**	**0.00-1.60**	**0.15**
Kalyanpur	0.00-1.60	0.32	0.00-1.24	0.14	0.00-1.20	0.13	0.00-0.80	0.08	0.00-1.60	0.16
Khambhalia	0.00-0.00	0.00	0.00-1.02	0.06	0.00-0.00	0.00	0.00-0.00	0.00	0.00-1.02	0.02
Dwarka	0.00-0.81	0.26	0.00-0.64	0.21	0.00-0.37	0.19	NA	NA	0.00-0.81	0.24
Devbhumi Dwarka District	**0.00-1.60**	**0.24**	**0.00-1.24**	**0.12**	**0.00-1.20**	**0.08**	**0.00-0.80**	**0.03**	**0.00-1.60**	**0.13**
Porbandar	**0.00-1.60**	**0.17**	**0.00-1.17**	**0.14**	**0.00-0.45**	**0.11**	**0.00-0.00**	**0.00**	**0.00-1.60**	**0.12**
Overall	**0.00-1.60**	**0.25**	**0.00-1.24**	**0.15**	**0.00-1.20**	**0.08**	**0.00-0.80**	**0.03**	**0.00-1.60**	**0.14**

(NA) – Not available

Table 4.3.22: Talukawise range and mean values of HCO_3^- (me L^{-1}) of post-monsoon well/tube well water samples 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	1.17-6.60	2.81	1.03-5.40	2.66	0.71-3.40	2.01	0.42-2.60	1.85	0.42-6.60	2.38
Jodiya	1.20-6.75	3.27	1.10-5.28	2.98	1.06-3.80	2.60	0.98-2.46	1.91	0.98-6.75	2.84
Lalpur	NA	NA	2.10-7.60	4.23	1.84-6.42	4.10	1.28-5.42	3.89	1.28-7.60	4.11
Jamnagar District	**1.20-6.75**	**3.07**	**1.03-7.60**	**3.10**	**0.71-6.42**	**3.04**	**0.42-5.42**	**2.35**	**0.42-7.60**	**2.95**
Kalyanpur	3.20-13.60	6.31	2.90-8.00	5.20	2.40-7.80	4.55	2.06-6.60	4.42	2.06-13.60	5.05
Khambhalia	6.68-9.84	8.17	2.00-8.20	4.87	1.62-7.20	4.42	0.60-6.70	4.23	0.60-9.84	4.84
Dwarka	4.00-11.60	7.11	3.60-10.28	6.93	1.27-3.01	2.14	NA	NA	1.27-11.60	6.79
Devbhumi Dwarka District	**3.20-13.60**	**7.03**	**2.00-10.28**	**5.50**	**1.27-7.80**	**4.24**	**0.60-6.70**	**4.32**	**0.60-13.60**	**5.49**
Porbandar	**3.60-9.48**	**6.03**	**2.29-7.00**	**4.84**	**2.04-6.06**	**4.57**	**2.00-5.72**	**4.31**	**2.00-9.48**	**5.09**
Overall	**1.20-13.60**	**5.70**	**1.03-10.28**	**4.19**	**0.71-7.80**	**3.61**	**0.42-6.70**	**3.62**	**0.42-13.60**	**4.34**

(NA) – Not available

In Devbhumi Dwarka district, maximum HCO_3^- (13.60 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum HCO_3^- (0.60 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of HCO_3^- was 5.49 me L^{-1}. In Porbandar district, overall mean value of HCO_3^- was 5.09 me L^{-1}, maximum HCO_3^- (9.48 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum HCO_3^- (2.00 me L^{-1}) was found at 15 to 20 km distance from the sea coast (Table 4.3.22). The lowest value of HCO_3^- (0.42 me L^{-1}) was recorded in samples collected from Jamnagar taluka in Jamnagar district, whereas highest value of HCO_3^- (13.60 me L^{-1}) was found in Kalyanpur taluka of Devbhumi Dwarka district. The data further revealed that the lowest mean value of HCO_3^- (2.38 me L^{-1}) was obtained from the samples of Jamnagar taluka of Jamnagar district and the highest mean value of HCO_3^- (6.79 me L^{-1}) was registered in the samples of Dwarka taluka of Devbhumi Dwarka district. The content of HCO_3^- in water samples was relatively higher as compared to CO_3^{--}. However, the concentration of HCO_3^- was decreased with increased the distance of sampling from sea coast of Northern Saurashta region. Similar findings were also recorded for Churu district (Rajasthan) by Verma *et al*. (2003), for Amreli district by Kabaria (2004), for Bhavnagar district by Rajput and Polara (2013), for Latur district of Maharashtra by Patil *et al*. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015), for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.3.3.4.3 Cl^-

The overall Cl^- values of Northen Saurashtra’s water samples were ranged from 0.60 to 58.41 me L^{-1} with mean value of 15.06 me L^{-1}. The data (Table 4.3.23) revealed that the lowest mean value of Cl^- (8.20 me L^{-1}) was obtained from the samples of Lalpur taluka of Jamnagar district and the highest mean value of Cl^- (20.62 me L^{-1}) was found in the samples of Jodiya taluka of Jamnagar district. In Jamnagar district, maximum Cl^- (58.41 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Cl^- (0.80 me L^{-1}) was found at 15 to 20 km distance from the sea coast, whereas overall mean value of Cl^- was 16.26 me L^{-1}. In Devbhumi Dwarka district, maximum Cl^- (53.00 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Cl^- (0.60 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of Cl^- was 13.60 me L^{-1}. In Porbandar district, overall

Table 4.3.23: Talukawise range and mean values of Cl^- (me L^{-1}) of post-monsoon well/tube well water samples 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	14.46-58.41	25.17	11.23-41.04	19.94	8.30-26.68	14.37	5.62-17.76	9.74	5.62-58.41	17.58
Jodiya	14.30-53.00	27.21	11.80-44.32	22.16	8.90-22.04	14.22	5.80-13.80	9.96	5.80-53.00	20.62
Lalpur	NA	NA	3.13-20.71	10.80	2.62-17.34	7.82	0.80-9.24	4.16	0.80-20.71	8.20
Jamnagar District	**14.30-58.41**	**26.34**	**3.13-44.32**	**18.70**	**2.62-26.68**	**11.45**	**0.80-17.76**	**8.47**	**0.80-58.41**	**16.26**
Kalyanpur	8.90-53.00	19.82	7.40-31.03	15.95	4.20-24.05	11.43	0.90-15.80	6.18	0.90-53.00	12.63
Khambhalia	19.52-40.86	30.57	2.89-28.60	10.40	2.41-17.50	7.56	0.60-10.72	3.84	0.60-40.86	9.21
Dwarka	9.96-47.83	22.83	5.30-32.61	15.17	3.04-15.77	9.41	NA	NA	3.04-47.83	20.17
Devbhumi Dwarka District	**8.90-53.00**	**22.93**	**2.89-32.61**	**13.13**	**2.41-24.05**	**9.59**	**0.60-15.80**	**4.86**	**0.60-53.00**	**13.60**
Porbandar	**7.50-42.57**	**23.89**	**5.57-34.65**	**16.81**	**3.76-25.12**	**10.30**	**0.60-14.27**	**5.80**	**0.60-42.57**	**15.81**
Overall	**7.50-58.41**	**24.09**	**2.89-44.32**	**16.42**	**2.41-26.68**	**10.72**	**0.60-17.76**	**6.27**	**0.60-58.41**	**15.06**

(NA) – Not available

mean value of Cl^- was 15.81 me L^{-1}, maximum Cl^- (42.57 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum Cl^- (0.60 me L^{-1}) was found at 15 to 20 km distance from the sea coast. The lowest value of Cl^- (0.60 me L^{-1}) was recorded in the samples collected from Khambhalia and Porbandar taluka, whereas the highest value of Cl^- (58.41 me L^{-1}) was found in Jamnagar taluka of Jamnagar district. Among the different dissolved anions, Cl^- is dominant in status. Therefore, it may contribute soil salinity and sometimes toxic ion effect in crops. Similar findings were also recorded for Churu district (Rajasthan) by Verma *et al*. (2003), for Porbandar district by Hadiyal (2005), for Junagadh district by Sojitra (2010), for Latur district of Maharashtra by Patil *et al*. (2014), for Gir Somnath district of Gujarat by Polara and Chauhan (2015), for Devbhumi Dwarka district of Gujarat by Hadiya and Polara (2017) and for Kheda district of Gujarat by Vaghela (2017).

4.1.3.4.4 SO_4^{--}

In case of SO_4^{--}, the highest overall mean value of (0.77 me L^{-1}) was recorded at the distance of 0 to 5 km from the sea coast. The highest mean value of SO_4^{--} (0.55 me L^{-1}) was observed in Jamnagar and Porbandar talukas while the lowest mean value of SO_4^{--} (0.39 me L^{-1}) was observed in Lalpur and Kalyanpur talukas (Table 4.3.24). In Jamnagar district, maximum SO_4^{--} (1.04 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum SO_4^{--} (0.04 me L^{-1}) was found at 10 to 15 km distance from the sea coast, whereas overall mean value of SO_4^{--} was 0.50 me L^{-1}. In Devbhumi Dwarka district, maximum SO_4^{--} (1.01 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum SO_4^{--} (0.02 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of SO_4^{--} was 0.44 me L^{-1}. In Porbandar district, overall mean value of SO_4^{--} was 0.55 me L^{-1}, maximum SO_4^{--} (1.08 me L^{-1}) was found at 0 to 5 km distance from the sea coast and minimum SO_4^{--} (0.11 me L^{-1}) was found at 15 to 20 km distance from the sea coast. The lowest value of SO_4^{--} (0.02 me L^{-1}) was recorded in the samples collected from Kalyanpur taluka in Devbhumi Dwarka district, whereas the highest value of SO_4^{--} (1.08 me L^{-1}) was found in Porbandar taluka of Porbandar district. Similar results were also found by Verma *et al.* (2003) for Churu district (Rajasthan), by Kabaria (2004) for Amreli district, by Hadiyal (2005) for Porbandar district, by Rajput and Polara (2013) for Bhavnagar district, by Polara and Chauhan (2015) for Gir Somnath district, by

Table 4.3.24: Talukawise range and mean values of SO_4^{--} (me L^{-1}) of post-monsoon well/tube well water samples 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	0.69-1.04	0.84	0.31-1.00	0.61	0.26-0.72	0.44	0.09-0.31	0.19	0.09-1.04	0.53
Jodiya	0.53-0.98	0.79	0.35-0.80	0.56	0.30-0.51	0.40	0.10-0.24	0.17	0.10-0.98	0.55
Lalpur	NA	NA	0.30-0.87	0.58	0.04-0.55	0.34	0.08-0.21	0.13	0.04-0.87	0.39
Jamnagar District	**0.53-1.04**	**0.81**	**0.30-1.00**	**0.59**	**0.04-0.72**	**0.39**	**0.08-0.31**	**0.17**	**0.04-1.04**	**0.50**
Kalyanpur	0.70-0.97	0.81	0.40-0.66	0.54	0.14-0.38	0.24	0.02-0.18	0.10	0.02-0.97	0.39
Khambhalia	0.81-0.94	0.89	0.34-0.78	0.54	0.12-0.64	0.42	0.10-0.27	0.15	0.10-0.94	0.40
Dwarka	0.34-1.01	0.70	0.10-0.31	0.20	0.10-0.24	0.17	NA	NA	0.10-1.01	0.54
Devbhumi Dwarka District	**0.34-1.01**	**0.74**	**0.10-0.78**	**0.45**	**0.10-0.64**	**0.30**	**0.02-0.27**	**0.13**	**0.02-1.01**	**0.44**
Porbandar	**0.42-1.08**	**0.78**	**0.34-0.86**	**0.58**	**0.27-0.62**	**0.41**	**0.11-0.41**	**0.22**	**0.11-1.08**	**0.55**
Overall Northern Saurashtra	**0.34-1.08**	**0.77**	**0.10-1.00**	**0.54**	**0.04-0.72**	**0.37**	**0.02-0.41**	**0.16**	**0.02-1.08**	**0.48**

(NA) – Not available

Hadiya and Polara (2017) for Devbhumi Dwarka district and by Vaghela (2017) for Kheda district of Gujarat.

4.3.3.5 Sodium Adsorption Ratio (SAR)

The SAR value is an important criterion for studying the alkali hazards in irrigation water. Therefore, the talukawise range and mean values of SAR are given in table 4.3.25 and fig 4.29 and per cent distribution of water samples for different SAR classes (as suggested by USDA) are presented in table 4.3.28.

The overall mean value of SAR in Northen Saurashtra coastal region's water samples was 4.06 and it was varied from 0.47 to 13.05. In Jamnagar district, the lowest SAR value (0.98) was recorded in water samples collected from Lalpur taluka at the distance of 15 to 20 km from the sea coast and the highest SAR value (13.05) was recorded in water samples collected from Jodiya taluka at the distance of 5 to 10 km from the sea coast. In Devbhumi Dwarka district, maximum SAR (12.17) was found at 0 to 5 km distance from the sea coast and minimum SAR (0.47) was found at 15 to 20 km distance from the sea coast, while overall mean value of SAR was 4.49. In Porbandar district, overall mean value of SAR was 4.26, maximum SAR (10.92) was found at 0 to 5 km distance from the sea coast and minimum SAR (1.14) was found at 15 to 20 km distance from the sea coast. Data further revealed that the highest (5.89) and the lowest (2.87) mean SAR values were registered in Dwarka and Lalpur talukas, respectively. However, there was no wide variation among the different distance of collecting water sample from sea coast of North Saurashtra region. All the talukas of Northern Saurashtra coastal region had mean SAR values less than 10. These findings are in conformity with those of Nilsood *et al.* (1998), Kabaria (2004), Hadiyal (2005), Savalia *et al.* (2006), Sojitra (2010), Rajput and Polara (2013), Polara and Chauhan (2015), Hadiya and Polara (2017) and Vaghela (2017).

Overall 96.14, 3.86, 0.00 and 0.00 per cent sample falls under S_1, S_2, S_3 and S_4 classes of SAR, respectively (Table 4.3.28 and Fig 4.32). Almost all of the water samples (96.14 per cent) had SAR value < 10 (S_1 class). None of sample falls under S_3 and S_4 classes of SAR. About 97.56, 95.04 and 95.12 per cent water samples of Jamnagar, Devbhumi Dwarka and Porbandar districts, respectively were found under

Table 4.3.25: Talukawise range and mean values of SAR (Sodium Adsorption Ratio) of post-monsoon wells/tube wells water samples 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	2.06-7.64	3.41	1.33-9.86	3.86	1.25-7.56	3.26	1.21-9.55	3.39	1.21-7.64	3.55
Jodiya	2.42-11.32	4.27	1.70-13.05	4.19	1.60-10.39	4.33	2.15-6.61	3.57	1.60-13.05	4.14
Lalpur	NA	NA	2.06-7.52	3.52	1.19-4.89	2.70	0.98-3.82	2.05	0.98-7.52	2.87
Jamnagar District	**2.06-11.32**	**3.90**	**1.33-13.05**	**3.89**	**1.19-10.39**	**3.20**	**0.98-9.55**	**3.12**	**0.98-13.05**	**3.57**
Kalyanpur	1.82-11.60	5.15	2.33-7.09	4.37	0.60-5.74	3.49	1.06-6.94	2.87	0.60-11.60	3.86
Khambhalia	4.18-10.80	7.01	0.96-11.75	3.89	1.01-9.81	4.41	0.47-6.31	3.00	0.47-11.75	3.93
Dwarka	3.40-12.17	6.25	2.94-12.10	5.48	2.76-3.75	3.25	NA	NA	2.76-12.17	5.89
Devbhumi Dwarka District	**1.82-12.17**	**6.07**	**0.96-12.10**	**4.44**	**0.60-9.81**	**3.85**	**0.47-6.94**	**2.95**	**0.47-12.17**	**4.49**
Porbandar	**2.31-10.92**	**5.36**	**2.25-8.26**	**4.05**	**1.64-7.83**	**3.99**	**1.14-5.23**	**2.88**	**1.14-10.92**	**4.26**
Overall	**1.82-12.17**	**5.31**	**0.96-13.05**	**4.11**	**0.60-10.39**	**3.51**	**0.47-9.55**	**3.00**	**0.47-13.05**	**4.06**

(NA) – Not available

S_1 class of SAR. These findings are in concurrence with the findings of Nilsood *et al.* (1998), Kabaria (2004), Savalia *et al.* (2006), Sojitra (2010), Rajput and Polara (2013), Polara and Chauhan (2015), Hadiya and Polara (2017) and Vaghela (2017).

4.3.3.6 Residual Sodium Carbonate (RSC)

Talukawise range and mean values of RSC are given in table 4.3.26 and fig 4.30 and percentage distribution of water sample in different RSC classes (as suggested by USDA) are presented in table 4.3.28. The overall RSC values were ranged from 0.00 to 4.80 with mean value of 0.19 me L^{-1}, which is less than 1.25 me L^{-1}. The highest value of RSC (4.80 me L^{-1}) was recorded in Khambhalia taluka at the distance of 15 to 20 km from the sea coast. In Jamnagar district, maximum value of RSC (1.56 me L^{-1}) was found at 15 to 20 km distance from the sea coast, whereas overall mean value of RSC was (0.03 me L^{-1}). In Devbhumi Dwarka district, maximum value of RSC (4.80 me L^{-1}) was found at 15 to 20 km distance from the sea coast, while overall mean value of RSC was (0.37 me L^{-1}). In Porbandar district, overall mean value of RSC was (0.13 me L^{-1}) and maximum RSC (2.67 me L^{-1}) was found at 15 to 20 km distance from the sea coast. For all the talukas, the overall RSC mean value were lower than permissible limit of 2.5 me L^{-1}. The present investigations find supports from the works reported earlier (Nilsood *et al.*, 1998, Anon. 2001, Anon., 2004a, Kabaria, 2004, Hadiyal, 2005 and Rajput, 2010), for Gir Somnath district of Gujarat (Polara and Chauhan, 2015) and for Kheda district of Gujarat (Vaghela, 2017).

Overall 92.28, 5.26 and 2.46 per cent samples fall under safe, marginal and unsafe classes of RSC, respectively (Table 4.3.28 and Fig. 4.32). Most of (92.28 %) wells/tube wells water sample had RSC value less than 1.25 and only 2.46 percent sample had RSC value greater than 2.50, which suggest that the wells/tube wells water of the Northern Saurashtra coastal region found free from RSC hazards. This finding is in concurrence with the findings of Nilsood *et al.* (1998) for Bhatinda district, Patel (2004) for Surendranagar district, Kabaria (2004) for Amreli district, Sojitra (2010) for Junagadh district, Rajput and Polara (2013) for Bhavnagar district and Polara and Chauhan (2015) for Gir Somnath district of Gujarat.

Table 4.3.26: Talukawise range and mean values of RSC (Residual Sodium Carbonate) of post-monsoon wells/tube wells water samples 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	0.00-0.00	0.00	0.00-0.00	0.00	0.00-0.00	0.00	0.00-0.00	0.00	0.00-0.00	0.00
Jodiya	0.00-0.00	0.00	0.00-0.00	0.00	0.00-0.00	0.00	0.00-0.00	0.00	0.00-0.00	0.00
Lalpur	NA	NA	0.00-0.83	0.08	0.00-0.00	0.00	0.00-1.56	0.59	0.00-1.56	0.13
Jamnagar District	**0.00-0.00**	**0.00**	**0.00-0.83**	**0.02**	**0.00-0.00**	**0.00**	**0.00-1.56**	**0.14**	**0.00-1.56**	**0.03**
Kalyanpur	0.00-3.90	0.43	0.00-0.00	0.00	0.00-2.67	0.30	0.00-2.40	0.43	0.00-3.90	0.30
Khambhalia	0.00-0.00	0.00	0.00-1.81	0.24	0.00-2.85	0.61	0.00-4.80	1.25	0.00-4.80	0.66
Dwarka	0.00-3.34	0.13	0.00-0.00	0.00	0.00-0.00	0.00	NA	NA	0.00-3.34	0.09
Devbhumi Dwarka District	**0.00-3.90**	**0.19**	**0.00-1.81**	**0.11**	**0.00-2.85**	**0.40**	**0.00-4.80**	**0.89**	**0.00-4.80**	**0.37**
Porbandar	**0.00-0.38**	**0.04**	**0.00-0.00**	**0.00**	**0.00-0.00**	**0.00**	**0.00-2.67**	**0.60**	**0.00-2.67**	**0.13**
Overall	**0.00-3.90**	**0.11**	**0.00-1.81**	**0.05**	**0.00-2.85**	**0.12**	**0.00-4.80**	**0.59**	**0.00-4.80**	**0.19**

(NA) – Not available

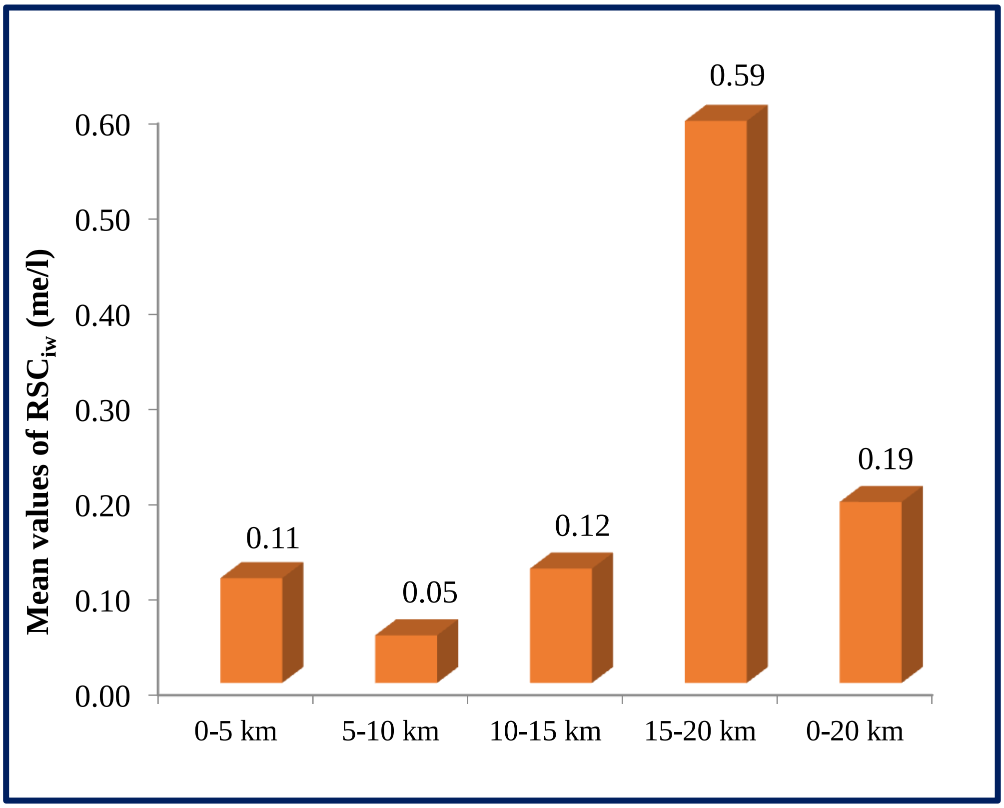


Fig. 4.30: Overall status of post-monsoon RSC_{iw} in samples of Northern Saurashtra coastal region

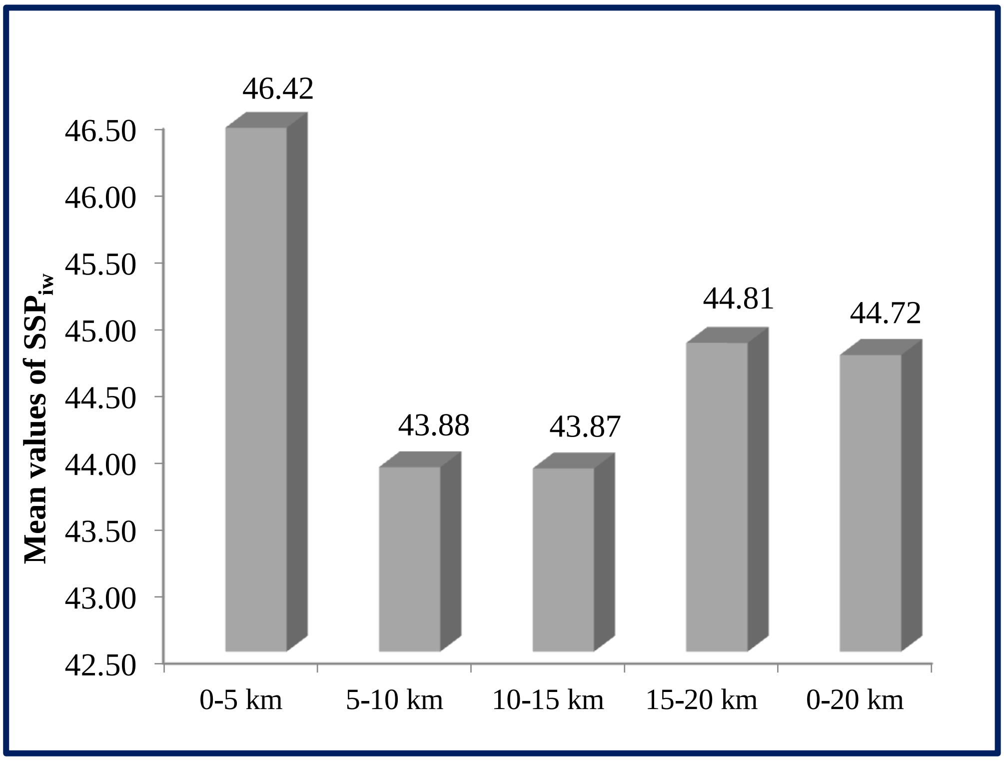


Fig. 4.31: Overall status of post-monsoon SSP_{iw} in samples of Northern Saurashtra coastal region

4.3.3.7 Soluble Sodium Percentage (SSP)

Talukawise range and mean values of SSP are given in table 4.3.27 and fig 4.31 and percentage distribution of water samples in different SSP classes (as suggested by USDA) are presented in table 4.3.28.

The overall mean value of SSP in Northen Saurashtra coastal region's water samples was 44.72 and it was varied from 14.08 to 78.00. In Jamnagar district, the lowest SSP value (14.94) was recorded in water samples collected from Jamnagar taluka at the distance of 5 to 10 km from the sea coast and the highest SSP value (74.81) was recorded in water samples collected from Jodiya taluka at the distance of 10 to 15 km from the sea coast. In Devbhumi Dwarka district, maximum SSP (78.00) was found at 10 to 15 km distance from the sea coast and minimum SSP (14.08) was found at 10 to 15 km distance from the sea coast, while overall mean value of SSP was 47.84. In Porbandar district, overall mean value of SSP was 46.13, maximum SSP (66.32) was found at 0 to 5 km distance from the sea coast and minimum SSP (22.80) was found at 15 to 20 km distance from the sea coast. Data further revealed that the highest (51.87) and the lowest (40.14) mean SSP values were registered in Dwarka and Jamnagar talukas, respectively. The water samples of all talukas of Northern Saurashtra coastal region having mean value of SSP less than 60, which is indicative of safe for alkali hazard in these waters. These findings are in conformity with those of Nilsood *et al.* (1998), Verma *et al.* (2003), Kabaria (2004), Hadiyal (2005), Sojitra (2010), Rajput and Polara (2013), Polara and Chauhan (2015) and Hadiya and Polara (2017).

Overall 85.61 and 14.39 per cent samples falls under safe and unsafe classes of SSP, respectively (Table 4.3.28 and Fig. 4.32). More than half of the water samples (85.61 per cent) had SSP value < 60 (safe class). About 89.43, 80.99 and 87.80 per cent water samples of Jamnagar, Devbhumi Dwarka and Porbandar districts, respectively were found under safe class of SSP. These findings are in concurrence with the findings of Nilsood *et al*. (1998), Kabaria (2004), Savalia *et al.* (2006), Rajput and Polara (2013), Polara and Chauhan (2015) and Vaghela (2017).

Table 4.3.27: Talukawise range and mean values of SSP ((Soluble Sodium Percentage) of post-monsoon wells/tube wells water samples 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	25.49-48.36	35.41	14.94-66.80	39.83	18.35-68.64	40.92	24.01-73.75	44.07	14.94-73.75	40.14
Jodiya	27.01-64.23	39.77	17.25-73.42	41.76	23.65-74.81	45.60	37.58-65.85	48.74	17.25-74.81	42.81
Lalpur	NA	NA	28.35-70.64	44.62	18.44-60.65	39.74	24.97-57.07	37.13	18.44-70.64	40.93
Jamnagar District	**25.49-64.23**	**37.91**	**14.94-73.42**	**41.46**	**18.35-74.81**	**41.23**	**24.01-73.75**	**43.75**	**14.94-74.81**	**41.18**
Kalyanpur	18.83-70.57	47.02	25.14-60.21	47.86	14.08-60.52	42.37	25.57-70.26	41.97	14.08-70.57	44.52
Khambhalia	39.42-64.80	51.90	21.72-77.27	44.00	26.63-78.00	51.44	15.01-70.17	48.06	15.01-78.00	47.56
Dwarka	38.65-68.57	52.11	39.71-74.49	51.85	45.68-52.21	48.95	NA	NA	38.65-74.49	51.87
Devbhumi Dwarka District	**18.83-70.57**	**50.88**	**21.72-77.27**	**47.10**	**14.08-78.00**	**46.88**	**15.01-70.26**	**45.42**	**14.08-78.00**	**47.84**
Porbandar	**27.15-66.32**	**47.06**	**28.83-62.27**	**44.21**	**27.22-62.34**	**47.96**	**22.80-56.36**	**45.31**	**22.80-66.32**	**46.13**
Overall	**18.83-70.57**	**46.42**	**14.94-77.27**	**43.88**	**14.08-78.00**	**43.87**	**15.01-73.75**	**44.81**	**14.08-78.00**	**44.72**

(NA) – Not available

Table 4.3.28: Percentage distribution of post-monsoon well/tube well water samples into different EC, SAR, RSC and SSP classes

Name of Taluka	EC				SAR classes				RSC classes			SSP classes	
	C_1	C_2	C_3	C_4	S_1	S_2	S_3	S_4	Safe	Marginal	Unsafe	Safe	Unsafe
Jamnagar	0.00 (0)*	3.70 (2)	53.70 (29)	42.59 (23)	100.00 (54)	0.00 (0)	0.00 (0)	0.00 (0)	100.00 (54)	0.00 (0)	0.00 (0)	88.89 (48)	11.11 (6)
Jodiya	0.00 (0)	7.69 (3)	46.15 (18)	46.15 (18)	92.31 (36)	7.69 (3)	0.00 (0)	0.00 (0)	100.00 (39)	0.00 (0)	0.00 (0)	87.17 (34)	12.82 (5)
Lalpur	0.00 (0)	23.33 (7)	66.67 (20)	10.00 (3)	100.00 (30)	0.00 (0)	0.00 (0)	0.00 (0)	93.33 (28)	6.67 (2)	0.00 (0)	93.33 (28)	6.67 (2)
Jamnagar District	**0.00 (0)**	**9.76 (12)**	**54.47 (67)**	**35.77 (44)**	**97.56 (120)**	**2.44 (3)**	**0.00 (0)**	**0.00 (0)**	**98.37 (121)**	**1.63 (2)**	**0.00 (0)**	**89.43 (110)**	**10.57 (13)**
Kalyanpur	0.00 (0)	22.50 (9)	52.50 (21)	25.00 (10)	97.50 (39)	2.50 (1)	0.00 (0)	0.00 (0)	90.00 (36)	5.00 (2)	5.00 (2)	85.00 (34)	15.00 (6)
Khambhalia	4.44 (2)	22.22 (10)	53.33 (24)	20.00 (9)	93.33 (42)	6.67 (3)	0.00 (0)	0.00 (0)	71.11 (32)	22.22 (10)	6.67 (3)	80.00 (36)	20.00 (9)
Dwarka	0.00 (0)	2.78 (1)	30.56 (11)	66.67 (24)	94.44 (34)	5.56 (2)	0.00 (0)	0.00 (0)	97.22 (35)	0.00 (0)	2.78 (1)	77.78 (28)	22.22 (8)
Dev Bhumi Dwarka District	**1.65 (2)**	**16.53 (20)**	**46.28 (56)**	**35.54 (43)**	**95.04 (115)**	**4.96 (6)**	**0.00 (0)**	**0.00 (0)**	**85.12 (103)**	**9.92 (12)**	**4.96 (6)**	**80.99 (98)**	**19.01 (23)**
Porbandar	**0.00 (0)**	**7.32 (3)**	**56.10 (23)**	**35.59 (15)**	**95.12 (39)**	**4.88 (2)**	**0.00 (0)**	**0.00 (0)**	**95.12 (39)**	**2.44 (1)**	**2.44 (1)**	**87.80 (36)**	**12.20 (5)**
Overall	**0.70 (2)**	**12.28 (35)**	**51.23 (146)**	**35.79 (102)**	**96.14 (274)**	**3.86 (11)**	**0.00 (0)**	**0.00 (0)**	**92.28 (263)**	**5.26 (15)**	**2.46 (7)**	**85.61 (244)**	**14.39 (41)**

(*) – Values in parenthesis are number of samples

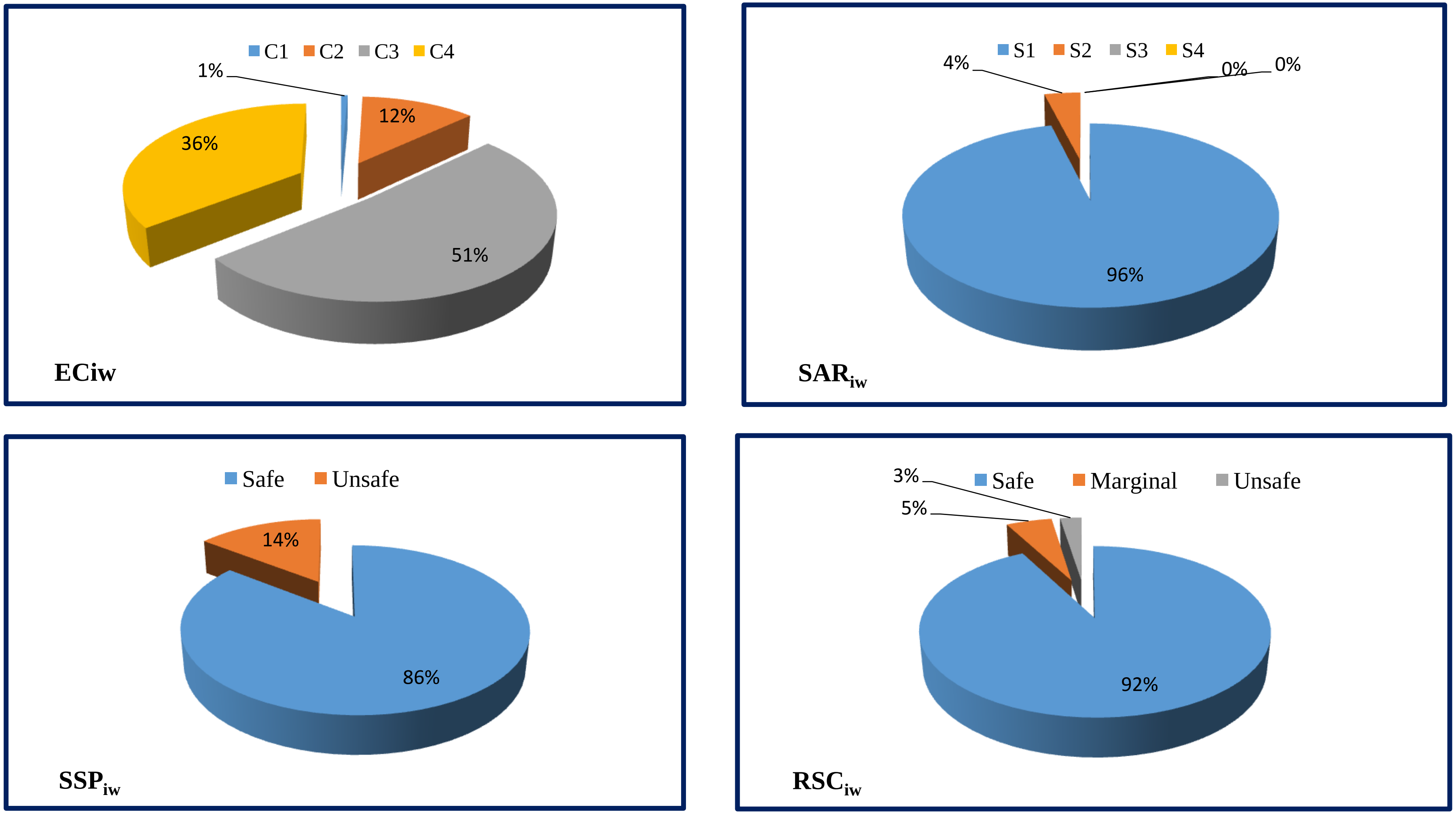


Fig. 4.32: Overall percentage of post-monsoon EC_{iw}, SAR_{iw}, SSP_{iw} and RSC_{iw} in samples of Northern Saurashtra coastal region

4.4 PERIODICAL CHANGES IN WATER QUALITY

Fluctuation in quality of underground wells/tube wells water with time were calculated from the mean data of various water quality indices of before (May, 2019) and after monsoon (December, 2019) and are present in table 4.4.1.

4.4.1 Fluctuation in EC value

The overall EC values of wells/tube wells water after monsoon was improved to the tune of 9.46 per cent and such improvement were observed in almost all the taluka of Northern Saurashtra coastal region. The maximum improvement was observed in EC values of irrigation waters of Kalyanpur (16.44 %) followed by Khambhalia (13.69 %) and Lalpur (9.22 %) talukas. In post-monsoon, the overall per cent samples were decreased from 41.40 to 35.79 per cent under the C_4 class of EC. The observed lower values of EC after monsoon (December, 2019) can be expected because of sufficient rainfallhaving higher rainy days with even distribution and increase in water table of wells/tube wells water of the regions. Similar findings were also reported by Sahu *et al.* (1982), More *et al*. (1988), Bharmbe *et al.* (1992), Kadam *et al*. (1995), Kabaria (2004), Patil *et al*. (2014) and Polara and Chauhan (2016).

4.4.2 Fluctuation in pH value

The overall pH value of wells/tube wells water sample increased to the tune of 7.21 per cent because of dilution effect. Almost similar findings were also reported by More *et al*. (1988), Bharmbe *et al*. (1992), Kadam *et al*. (1995), Kabaria (2004), Patil *et al*. (2014) and Polara and Chauhan (2016).

4.4.3 Fluctuation in SAR value

The overall SAR values of wells/tube wells water sample after monsoon decrease by 20.08 per cent and such improvement were observed in almost of the talukas of Northern Saurashtra coastal region ranging from 11.30 to 29.28 per cent (Table 4.4.1). In post-monsoon, the overall per cent of samples were decreased from 7.2 to 3.86 per cent under S_2 class of SAR. These indicated that the proportion of Na^+ ions were decrease in comparison to other cations in well/tube well water samples collected after monsoon. Almost similar findings were also reported by More *et al*.

Table 4.4.1: Fluctuation in quality indices of well/tube well water with time

Name of Taluka	EC (dS m^{-1})			pH			SSP			SAR			RSC (me L^{-1})		
	BM	**AM**	**% Change**	**BM**	**AM**	**% Change**	**BM**	**AM**	**% Change**	**BM**	**AM**	**% Change**	**BM**	**AM**	**% Change**
Jamnagar	2.26	2.06	8.85	7.21	7.68	-6.52	49.67	40.14	19.19	5.02	3.55	29.28	0.00	0.00	0.00
Jodiya	2.59	2.43	6.18	7.18	7.71	-7.38	49.70	42.81	13.86	5.27	4.14	21.44	0.00	0.00	0.00
Lalpur	1.41	1.28	9.22	7.33	7.88	-7.50	44.41	40.93	7.84	3.31	2.87	13.29	0.27	0.13	51.85
Jamnagar District	**2.15**	**1.99**	**7.44**	**7.23**	**7.74**	**-7.05**	**48.40**	**41.18**	**14.92**	**4.68**	**3.57**	**23.72**	**0.07**	**0.03**	**57.14**
Kalyanpur	2.19	1.83	16.44	7.06	7.75	-9.77	51.50	44.52	13.55	5.18	3.86	25.48	0.87	0.30	65.52
Khambhalia	1.68	1.45	13.69	7.31	7.73	-5.75	53.60	47.56	11.27	4.97	3.93	20.93	0.72	0.66	8.33
Dwarka	2.98	2.78	6.71	7.11	7.76	-9.14	55.05	51.87	5.78	6.64	5.89	11.30	0.13	0.09	30.77
Devbhumi Dwarka District	**2.24**	**1.97**	**12.05**	**7.27**	**7.75**	**-6.60**	**53.33**	**47.84**	**10.29**	**5.54**	**4.49**	**18.95**	**0.59**	**0.37**	**27.29**
Porbandar	**2.37**	**2.16**	**8.86**	**7.24**	**7.66**	**-5.80**	**49.37**	**46.13**	**6.56**	**4.92**	**4.26**	**13.41**	**0.35**	**0.13**	**62.86**
Overall	**2.22**	**2.01**	**9.46**	**7.21**	**7.73**	**-7.21**	**50.63**	**44.72**	**11.67**	**5.08**	**4.06**	**20.08**	**0.33**	**0.19**	**42.42**

Where, BM= Before monsoon (May, 2019), AM=After monsoon (December, 2019)

(1988), Bharmbe *et al*. (1992), Kadam *et al*. (1995), Kabaria (2004), Patil *et al*. (2014) and Polara and Chauhan (2016).

4.4.4 Fluctuation in RSC value

In general, RSC values decreased to the tune of 0.00 to 65.52 per cent in almost of the talukas of Northern Saurashtra coastal region after monsoon with overall reduction of 42.42 per cent. Almost similar findings were also reported by More *et al*. (1988), Bharmbe *et al*. (1992), Kadam *et al*. (1995), Kabaria (2004), Patil *et al*. (2014) and Polara and Chauhan (2016).

4.4.5 Fluctuation in SSP value

The overall SSP values of wells/tube wells water after monsoon decrease by 11.67 per cent and such improvement were observed in all the talukas of Northern Saurashtra coastal region ranging from 5.78 to 19.19 per cent. In post-monsoon, the overall per cent of samples were decreased from 25.26 to 14.39 per cent under unsafe class of SSP.Almost similar findings were also reported by More *et al*. (1988), Bharmbe *et al*. (1992), Kadam *et al*. (1995), Bharmbe *et al*. (2001), Kabaria (2004), Patil *et al*. (2014) and Polara and Chauhan (2016).

In general, all the indices of well/tube well water samples collected after monsoon (December, 2019) improved in comparisons to the samples collected before monsoon (May, 2019). Thus, the quality of water improved after monsoon might be due to the high rainfall with uniform distribution throughout the season resulting into rise in wells/tube wells water table in region during the year 2019.

4.5 INTER-RELATIONSHIP AMONG AND BETWEEN SALINITY/SODICITY INDICES AND FERTILITY STATUS OF IRRIGATED SOILS

4.5.1 Correlation study

- **0 to 5 km distance from sea coast**

The correlation among fertility parameters (SOC, available N, P_2O_5, K_2O and S) and salinity/sodicity parameters ($EC_{2.5}$, EC_e, $pH_{2.5}$, pH_s and $CaCO_3$) of soil from 0 to 5 km distance were worked out and presented in table 4.5.1. In 0 to 5 km distance, examination of correlation values were indicates that the highly significant positive relation of EC_e with $EC_{2.5}$ (r = 0.935**), ESP (r = 0.736**) and S (r = 0.417*) was found. Whereas, pH_s was significantly correlated with $pH_{2.5}$ (r = 0.704**) and $CaCO_3$

Table 4.5.1: Correlation co-efficient among and between fertility and salinity/sodicity indices of soils of Northern Saurashtra coastal region

0 to 5 km	$EC_{2.5}$	EC_e	$pH_{2.5}$	pH_s	SSP	SAR	ESP	SOC	N	P_2O_5	K_2O	S	$CaCO_3$
$EC_{2.5}$	1.000												
EC_e	0.935**	1.000											
$pH_{2.5}$	-0.545**	-0.510**	1.000										
pH_s	-0.533**	-0.548**	0.704**	1.000									
SSP	-0.024	0.079	-0.039	-0.035	1.000								
SAR	0.316	0.431*	-0.224	-0.198	0.864**	1.000							
ESP	0.641**	0.736**	-0.209	-0.331	-0.090	0.175	1.000						
SOC	0.075	0.062	-0.106	0.034	0.327	0.201	0.053	1.000					
N	0.009	-0.067	-0.167	-0.243	-0.009	-0.093	0.002	0.449**	1.000				
P_2O_5	0.114	0.115	-0.034	-0.187	-0.196	-0.177	0.191	-0.071	0.298	1.000			
K_2O	0.220	0.232	0.285	0.101	-0.043	-0.020	0.327	-0.088	-0.082	0.019	1.000		
S	0.380*	0.417*	-0.117	-0.008	0.124	0.180	0.388*	0.340*	0.175	0.039	0.263	1.000	
$CaCO_3$	-0.208	-0.162	0.430*	0.464**	0.196	0.017	0.035	0.433*	0.003	-0.324	0.421*	0.137	1.000

*,** Significant at 5% & 1 % level, respectively

(r = 0.464**). In case of SSP, the positive correlation was found with SAR (r = 0.864**). Obviously, the SOC was significantly correlated with available N (r = 0.449**), S (r = 0.340*) and $CaCO_3$ (r = 0.433*). $CaCO_3$ was also significantly correlated with available K_2O (r = 0.421*). Similar results were also reported by Maliwal and Timbadia (2000), Prasad and Prasad (2001) and Rajeshwar and Mani (2014).

- **5 to 10 km distance from sea coast**

The data on correlation studies between available major nutrients and salinity/sodicity parameters are presented in table 4.5.2. In 5 to 10 km distance, examination of correlation values were indicates that the highly significant positive relation of EC_e with $EC_{2.5}$ (r = 0.697**), ESP (r = 0.361*), available K_2O (r = 0.679**), S (r = 0.639**) and $CaCO_3$ (r = 0.500**). Whereas, pH_s was significantly correlated with $pH_{2.5}$ (r = 0.767**). SSP was found positively correlated with SAR (r = 0.869**). In case of major nutrients, positive correlation of SOC was found with available N (r = 0.368*), K_2O (r = 0.787**) and $CaCO_3$ (r = 0.499**). $CaCO_3$ was found highly significantly correlated with available K_2O (r = 0.464**) and S (r = 0.448**). Similar relationship were also observed by Maliwal and Timbadia (2000), Prasad and Prasad (2001) and Rajeshwar and Mani (2014).

- **10 to 15 km distance from sea coast**

The correlation data among fertility parameters (SOC, available N, P_2O_5, K_2O and S) and salinity/sodicity parameters ($EC_{2.5}$, EC_e, $pH_{2.5}$, pH_s and $CaCO_3$) of soil from 10 to 15 km distance are presented in table 4.5.3. Correlation data indicates that the highly significant positive relation of EC_e with $EC_{2.5}$ (r = 0.689**), SAR (r = 0.354*), SOC (r = 0.546**), available K_2O (r = 0.455**) and $CaCO_3$ (r = 0.642**) was found. The pH_s was significantly correlated with $pH_{2.5}$ (r = 0.696**). In case of SSP, the positive correlation was found with SAR (r = 0.924**). The SOC was significantly correlated with available N (r = 0.528**) and K_2O (r = 0.588**). $CaCO_3$ was also significantly correlated with available K_2O (r = 0.494**) and S (r = 0.332*). Similar relationship were also reported by Maliwal and Timbadia (2000), Prasad and Prasad (2001) and Rajeshwar and Mani (2014).

Table 4.5.2: Correlation co-efficient among and between fertility and salinity/sodicity indices of soils of Northern Saurashtra coastal region

5 to 10 km	$EC_{2.5}$	EC_e	$pH_{2.5}$	pH_s	SSP	SAR	ESP	SOC	N	P_2O_5	K_2O	S	$CaCO_3$
$EC_{2.5}$	1.000												
EC_e	0.697**	1.000											
$pH_{2.5}$	-0.427**	-0.247	1.000										
pH_s	-0.413**	-0.328*	0.767**	1.000									
SSP	0.117	-0.078	-0.203	-0.187	1.000								
SAR	0.380*	0.184	-0.273	-0.316*	0.869**	1.000							
ESP	0.380*	0.361*	-0.020	-0.134	-0.041	0.096	1.000						
SOC	0.380*	0.687**	-0.021	-0.063	-0.255	-0.067	0.168	1.000					
N	0.235	0.021	0.024	0.047	-0.137	-0.076	-0.107	0.368*	1.000				
P_2O_5	-0.019	-0.001	-0.137	-0.093	0.103	0.026	0.066	-0.002	-0.014	1.000			
K_2O	0.325*	0.679**	-0.088	-0.034	-0.090	0.038	0.158	0.787**	0.099	0.202	1.000		
S	0.410**	0.639**	-0.011	-0.045	-0.167	0.048	0.084	0.638**	0.068	-0.045	0.617**	1.000	
$CaCO_3$	0.196	0.500**	-0.163	-0.093	-0.251	-0.055	0.188	0.499**	0.062	-0.167	0.464**	0.448**	1.000

*,** Significant at 5% & 1 % level, respectively

Table 4.5.3: Correlation co-efficient among and between fertility and salinity/sodicity indices of soils of Northern Saurashtra coastal region

10 to 15 km	$EC_{2.5}$	EC_e	$pH_{2.5}$	pH_s	SSP	SAR	ESP	SOC	N	P_2O_5	K_2O	S	$CaCO_3$
$EC_{2.5}$	1.000												
EC_e	0.689**	1.000											
$pH_{2.5}$	-0.202	0.052	1.000										
pH_s	-0.518**	-0.287	0.696**	1.000									
SSP	0.020	0.182	0.055	-0.002	1.000								
SAR	0.194	0.354*	0.037	-0.051	0.924**	1.000							
ESP	0.033	0.033	0.134	0.023	0.061	0.071	1.000						
SOC	0.284	0.546**	0.272	0.025	0.161	0.263	-0.149	1.000					
N	0.160	0.235	0.026	0.083	0.258	0.231	-0.023	0.528**	1.000				
P_2O_5	0.105	0.013	0.140	-0.157	0.098	0.014	0.018	-0.000	-0.095	1.000			
K_2O	0.230	0.455**	0.402*	0.053	0.209	0.316	-0.461**	0.588**	0.069	0.074	1.000		
S	0.333*	0.344*	0.030	-0.091	0.048	0.154	-0.146	0.276	0.162	-0.192	0.353*	1.000	
$CaCO_3$	0.367*	0.642**	0.225	0.125	0.199	0.375*	0.075	0.417*	0.156	-0.320	0.494**	0.332*	1.000

*,** Significant at 5% & 1 % level, respectively

Table 4.5.4: Correlation co-efficient among and between fertility and salinity/sodicity indices of soils of Northern Saurashtra coastal region

15 to 20 km	$EC_{2.5}$	EC_e	$pH_{2.5}$	pH_s	SSP	SAR	ESP	SOC	N	P_2O_5	K_2O	S	$CaCO_3$
$EC_{2.5}$	1.000												
EC_e	0.622**	1.000											
$pH_{2.5}$	-0.036	-0.049	1.000										
pH_s	-0.133	-0.249	0.869**	1.000									
SSP	0.582**	0.270	0.351	0.289	1.000								
SAR	0.648**	0.333	0.339	0.258	0.946**	1.000							
ESP	0.136	-0.196	-0.249	-0.207	0.236	0.136	1.000						
SOC	0.063	-0.236	0.380*	0.327	0.069	0.097	-0.275	1.000					
N	0.176	-0.294	0.332	0.386*	0.099	0.159	-0.184	0.842**	1.000				
P_2O_5	0.091	0.127	-0.053	0.065	-0.008	-0.006	-0.136	-0.074	0.100	1.000			
K_2O	-0.148	0.112	0.008	0.000	-0.293	-0.131	-0.643**	0.299	0.301	0.362	1.000		
S	-0.014	0.260	0.001	-0.128	-0.091	-0.045	-0.320	0.260	0.216	0.027	0.581**	1.000	
$CaCO_3$	0.147	0.106	0.238	0.164	0.116	0.189	-0.179	0.247	0.319	-0.028	0.410*	0.100	1.000

*,** Significant at 5% & 1 % level, respectively

Table 4.5.5: Correlation co-efficient among and between fertility and salinity/sodicity indices of soils of Northern Saurashtra coastal region

0 to 20 km	$EC_{2.5}$	EC_e	$pH_{2.5}$	pH_s	SSP	SAR	ESP	SOC	N	P_2O_5	K_2O	S	$CaCO_3$
$EC_{2.5}$	1.000												
EC_e	0.954**	1.000											
$pH_{2.5}$	-0.467**	-0.423**	1.000										
pH_s	-0.578**	-0.558**	0.776**	1.000									
SSP	0.312**	0.300**	-0.128	-0.217**	1.000								
SAR	0.689**	0.705**	-0.317**	-0.434**	0.760**	1.000							
ESP	0.595**	0.625**	-0.223**	-0.344**	0.184*	0.389**	1.000						
SOC	-0.596**	-0.557**	0.365**	0.458**	-0.380**	-0.560**	-0.374**	1.000					
N	-0.405**	-0.421**	0.295**	0.387**	-0.321**	-0.416**	-0.305**	0.780**	1.000				
P_2O_5	-0.259**	-0.254**	0.137	0.158	-0.231**	-0.305**	-0.153	0.369**	0.353**	1.000			
K_2O	-0.359**	-0.298**	0.338**	0.332**	-0.394**	-0.396**	-0.341**	0.736**	0.580**	0.459**	1.000		
S	-0.543**	-0.510**	0.311**	0.401**	-0.458**	-0.550**	-0.364**	0.857**	0.692**	0.391**	0.779**	1.000	
$CaCO_3$	0.589**	0.617**	-0.166*	-0.299**	0.332**	0.575**	0.378**	-0.559**	-0.439**	-0.390**	-0.303**	-0.575**	1.000

*,** Significant at 5% & 1 % level, respectively

- **15 to 20 km distance from sea coast**

The data on correlation between available major nutrients and salinity/sodicity parameters in soil from 15 to 20 km distance are presented in table 4.5.4. The examination of correlation values were indicates the highly significant positive relation of $EC_{2.5}$ with EC_e (r = 0.622**), SSP (r = 0.582**) and SAR (r = 0.648**). Whereas, pH_s was significantly correlated with $pH_{2.5}$ (r = 0.869**) and SSP was found positively correlated with SAR (r = 0.946**). Obviously, positive correlation of SOC was found with available N (r = 0.842**) and available K_2O with S (r = 0.581**). Similar results were also reported by Maliwal and Timbadia (2000), Prasad and Prasad (2001), and Rajeshwar and Mani (2014).

- **0 to 20 km distance from sea coast**

The correlation among fertility parameters (SOC, available N, P_2O_5, K_2O and S) and salinity/sodicity parameters ($EC_{2.5}$, EC_e, $pH_{2.5}$, pH_s and $CaCO_3$) in soil of 0 to 20 km distance from sea coast were worked out, presented in table 5.5 and data indicates that $EC_{2.5}$ was significant and positively correlated with EC_e, SSP, SAR, ESP and $CaCO_3$ and $pH_{2.5}$ was significant and positively correlated with $pH_{s,}$ SOC, available N, K_2O and S.

Similar relationship were also observed by Maliwal and Timbadia (2000), Prasad and Prasad (2001) and Rajeshwar and Mani (2014).

4.5.2 Regression study

Linear regression equation were worked out for predicting the EC_e and pH_s from the measured EC and pH values of 1:2.5 soil water extracts. The soil samples were further grouped in to different classes based on the distance from sea coast, *viz;* 0 to 5 km, 5 to 10 km, 10 to 15 km, 15 to 20 km and 0 to 20 km, group wise as well as overall regression equation were computed. Such equations are very useful in characterization of large number of samples.

Out of total 141 soil samples, only 115 samples were used for regression study because of the lack of irrigation water in Lalpur taluka up to 0 to 5 km and in Dwarka taluka up to 15 to 20 km distance fron sea coast. In that area, rainfall water is used of cultivation of field and grown of crops.

4.5.2.1 Prediction of EC_e from $EC_{2.5}$

The highly significant correlation coefficient (r) values were obtained between EC of 1:2.5 and EC of saturation extract in all the distance from sea coast (Table 4.5.6). Highly significant correlation coefficient between EC_e and $EC_{2.5}$ were observed in soil sample ($r = 0.8653^{**}$) of 15 to 20 km distance. The higher correlation values were observed in all the groups and value in different distance from where soil samples were collected.

Table 4.5.6: Regression equation for EC of salt affected soil samples of Northern Saurashtra coastal region

Sr. No	Distance (km)	No. of Sample	Regression equation (y = a + bx)	Per cent of variance (R^2)	Correlation coeffiecient (r)
Soil:water (1:2.5)					
1	0 to 5	27	$EC_e = 2.7668 + 0.5983\ EC_{2.5}$	0.4617	0.6795^{**}
2	5 to 10	32	$EC_e = -1.1359 + 1.1240\ EC_{2.5}$	0.6803	0.8248^{**}
3	10 to 15	31	$EC_e = 0.2312 + 0.9563\ EC_{2.5}$	0.6667	0.8166^{**}
4	15 to 20	25	$EC_e = 0.2089 + 0.9596\ EC_{2.5}$	0.7487	0.8653^{**}
5	0 to 20	115	$EC_e = 0.1556 + 0.9978\ EC_{2.5}$	0.6419	0.8012^{**}

*,** significant at 5% & 1% level, respectively

4.5.2.2 Prediction of pH_s from $pH_{2.5}$

In order to predict pH_s (saturation extract) from $pH_{2.5}$ for overall as well as group wise equation were computed. The highly significant correlation coefficient (r) values were obtained between pH of 1:2.5 and pH of saturation extract in all the distance from sea coast. The correlation was found to be significant for all the groups at 1:2.5 soil: water ratios (Table 4.5.7). Highly significant correlation coefficient between pH_s and $pH_{2.5}$ were observed in soil sample ($r = 0.9550^{**}$) of 0 to 20 km distance followed by 0 to 5 km distance ($r = 0.9271^{**}$). The higher correlation value was observed in all the groups and values in different distance from where soil samples were collected.

4.5.2.3 Prediction of SOC from N, ESP from EC_e and $EC_{2.5}$

In order to predict SOC from N, ESP from EC_e and $EC_{2.5}$ for overall equation were computed and obtained the highly significant correlation coefficient (r) values between them. The highly significant correlation coefficient between SOC and N (r =

0.7798**), ESP and EC_e (r = 0.6531**), ESP and $EC_{2.5}$ (r = 0.6050**) were observed in soil samples (Table 4.5.8).

Table 4.5.7: Regression equation for pH of salt affected soil samples of Northern Saurashtra coastal region

Sr. No	Distance (km)	No. of Sample	Regression equation (y = a + bx)	Per cent of variance (R^2)	Correlation coeffiecient (r)
Soil:water (1:2.5)					
1	0 to 5	27	pH_s = -0.4886 + 3.0209 $pH_{2.5}$	0.8594	0.9271**
2	5 to 10	32	pH_s = 0.1824 + 2.2312 $pH_{2.5}$	0.4332	0.6582**
3	10 to 15	31	pH_s = -0.0553 + 2.0947 $pH_{2.5}$	0.4493	0.6704**
4	15 to 20	25	pH_s = 0.4515 + 0.8511 $pH_{2.5}$	0.3830	0.6189**
5	0 to 20	115	pH_s = -0.5845 + 3.0041 $pH_{2.5}$	0.9120	0.9550**

*,** significant at 5% & 1% level, respectively

Table 4.5.8: Regression equation of SOC with N, ESP with EC_e and $EC_{2.5}$ of soil samples of Northern Saurashtra coastal region

Sr. No	No. of Sample	Regression equation (y = a + bx)	Per cent of variance (R^2)	Correlation coeffiecient (r)
Soil:water (1:2.5)				
1	115	SOC = 1.3164 + 0.0187 N	0.6080	0.7798**
2	115	ESP = 9.7714 + 1.0076 EC_e	0.4266	0.6531**
3	115	ESP = 9.2931 + 2.9357 $EC_{2.5}$	0.3659	0.6050**

*,** significant at 5% & 1% level, respectively

4.6 INTER-RELATIONSHIP BETWEEN PROPERTIES OF IRRIGATION WATER AND IRRIGATED SOILS

4.6.1 Correlation

- **Pre-monsoon**
  - **0 to 5 km distance from sea coast**

The correlation among properties of irrigation water and irrigated soil parameters were presented in table 4.6.1. The correlation between different properties of irrigation water (EC_{iw}, pH_{iw}, RSC_{iw}, SSP_{iw} and SAR_{iw}) and properties of irrigated

Table 4.6.1: Correlation co-efficient among and between salinity/sodicity indices of soil and pre-monsoon irrigation water of Northern Saurashtra coastal region

0 to 5 km	EC_{iw}	pH_{iw}	SSP_{iw}	SAR_{iw}	RSC_{iw}	EC_e	pH_s	$EC_{2.5}$	$pH_{2.5}$	ESP_s	SSP_s	SAR_s
EC_{iw}	1.000											
pH_{iw}	-0.414**	1.000										
SSP_{iw}	0.080	0.017	1.000									
SAR_{iw}	0.431**	-0.146	0.832**	1.000								
RSC_{iw}	-0.640**	0.340**	0.340**	-0.093	1.000							
EC_e	0.521**	-0.318**	0.160	0.422**	-0.417**	1.000						
pH_s	-0.427**	0.305**	-0.054	-0.301**	0.415**	-0.551**	1.000					
$EC_{2.5}$	0.538**	-0.327**	0.120	0.411**	-0.508**	0.955**	-0.598**	1.000				
$pH_{2.5}$	-0.343**	0.252**	0.071	-0.135	0.400**	-0.411**	0.801**	-0.462**	1.000			
ESP_s	0.334**	-0.098	0.074	0.213*	-0.230*	0.653**	-0.339**	0.605**	-0.168	1.000		
SSP_s	0.301**	-0.323**	-0.003	0.169	-0.316**	0.309**	-0.225*	0.326**	-0.147	0.237*	1.000	
SAR_s	0.527**	-0.363**	0.078	0.324**	-0.412**	0.711**	-0.437**	0.690**	-0.307**	0.429**	0.762**	1.000

*,** significant at 5% & 1% level, respectively

Table 4.6.2: Correlation co-efficient among and between salinity/sodicity indices of soil and pre-monsoon irrigation water of Northern Saurashtra coastal region

5 to 10 km	**EC_{iw}**	**pH_{iw}**	**SSP_{iw}**	**SAR_{iw}**	**RSC_{iw}**	**EC_e**	**pH_s**	**$EC_{2.5}$**	**$pH_{2.5}$**	**ESP_s**	**SSP_s**	**SAR_s**
EC_{iw}	1.000											
pH_{iw}	-0.079	1.000										
SSP_{iw}	0.270	0.109	1.000									
SAR_{iw}	0.429*	0.121	0.905**	1.000								
RSC_{iw}	-0.178	0.173	0.574**	0.264	1.000							
EC_e	0.339	0.053	0.313	0.311	0.006	1.000						
pH_s	-0.163	-0.099	-0.034	-0.087	0.191	-0.336	1.000					
$EC_{2.5}$	0.368*	0.028	0.070	0.131	-0.205	0.658**	-0.602**	1.000				
$pH_{2.5}$	-0.176	-0.051	-0.119	-0.119	0.186	-0.375*	0.825**	-0.559**	1.000			
ESP_s	0.195	0.285	-0.014	-0.059	0.025	0.466**	-0.253	0.394*	-0.086	1.000		
SSP_s	-0.309	-0.031	-0.209	-0.229	-0.108	-0.210	-0.142	0.086	-0.138	-0.028	1.000	
SAR_s	-0.079	-0.026	-0.096	-0.114	-0.074	0.043	-0.322	0.333	-0.236	0.106	0.880**	1.000

*,** significant at 5% & 1% level, respectively

Table 4.6.3: Correlation co-efficient among and between salinity/sodicity indices of soil and pre-monsoon irrigation water of Northern Saurashtra coastal region

10 to 15 km	EC_{iw}	pH_{iw}	SSP_{iw}	SAR_{iw}	RSC_{iw}	EC_e	pH_s	$EC_{2.5}$	$pH_{2.5}$	ESP_s	SSP_s	SAR_s
EC_{iw}	1.000											
pH_{iw}	-0.291	1.000										
SSP_{iw}	0.275	-0.179	1.000									
SAR_{iw}	0.440*	-0.275	0.901**	1.000								
RSC_{iw}	-0.396*	0.103	0.325	-0.007	1.000							
EC_e	0.211	-0.291	-0.014	0.146	-0.072	1.000						
pH_s	-0.094	0.259	0.123	-0.083	0.264	-0.309	1.000					
$EC_{2.5}$	0.198	-0.291	0.058	0.237	-0.188	0.670**	-0.527**	1.000				
$pH_{2.5}$	0.000	0.127	0.287	0.091	0.267	-0.228	0.817**	-0.434*	1.000			
ESP_s	0.368*	0.024	0.050	0.129	-0.195	-0.043	0.046	0.007	0.098	1.000		
SSP_s	0.049	-0.267	-0.009	-0.101	0.077	0.123	0.022	-0.012	0.021	0.082	1.000	
SAR_s	0.208	-0.199	0.010	-0.022	-0.026	0.319	-0.025	0.176	-0.025	0.082	0.923**	1.000

*,** significant at 5% & 1% level, respectively

Table 4.6.4: Correlation co-efficient among and between salinity/sodicity indices of soil and pre-monsoon irrigation water of Northern Saurashtra coastal region

15 to 20 km	**EC_{iw}**	**pH_{iw}**	**SSP_{iw}**	**SAR_{iw}**	**RSC_{iw}**	**EC_e**	**pH_s**	**$EC_{2.5}$**	**$pH_{2.5}$**	**ESP_s**	**SSP_s**	**SAR_s**
EC_{iw}	1.000											
pH_{iw}	-0.013	1.000										
SSP_{iw}	0.584**	0.070	1.000									
SAR_{iw}	0.666**	0.153	0.898**	1.000								
RSC_{iw}	-0.413*	-0.223	0.108	-0.186	1.000							
EC_e	0.234	-0.184	0.201	0.242	-0.174	1.000						
pH_s	-0.048	0.296	-0.073	-0.104	-0.115	-0.337	1.000					
$EC_{2.5}$	0.317	-0.064	-0.063	0.026	-0.611**	0.619**	-0.280	1.000				
$pH_{2.5}$	0.045	0.396	0.068	0.038	-0.183	-0.099	0.865**	-0.149	1.000			
ESP_s	0.158	0.180	-0.034	0.082	-0.447*	-0.200	-0.019	0.199	0.035	1.000		
SSP_s	0.292	0.005	0.228	0.280	-0.526**	0.270	0.157	0.589**	0.198	0.411*	1.000	
SAR_s	0.302	-0.022	0.222	0.197	-0.429*	0.335	0.108	0.658**	0.171	0.303	0.940**	1.000

*,** significant at 5% & 1% level, respectively

Table 4.6.5: Correlation co-efficient among and between salinity/sodicity indices of soil and pre-monsoon irrigation water of Northern Saurashtra coastal region

0 to 20 km	EC_{iw}	pH_{iw}	SSP_{iw}	SAR_{iw}	RSC_{iw}	EC_e	pH_s	$EC_{2.5}$	$pH_{2.5}$	ESP_s	SSP_s	SAR_s
EC_{iw}	1.000											
pH_{iw}	-0.414**	1.000										
SSP_{iw}	0.080	0.017	1.000									
SAR_{iw}	0.431**	-0.146	0.832**	1.000								
RSC_{iw}	-0.640**	0.340**	0.340**	-0.093	1.000							
EC_e	0.521**	-0.318**	0.160	0.422**	-0.417**	1.000						
pH_s	-0.427**	0.305**	-0.054	-0.301**	0.415**	-0.551**	1.000					
$EC_{2.5}$	0.538**	-0.327**	0.120	0.411**	-0.508**	0.955**	-0.598**	1.000				
$pH_{2.5}$	-0.343**	0.252**	0.071	-0.135	0.400**	-0.411**	0.801**	-0.462**	1.000			
ESP_s	0.334**	-0.098	0.074	0.213*	-0.230*	0.653**	-0.339**	0.605**	-0.168	1.000		
SSP_s	0.301**	-0.323**	-0.003	0.169	-0.316**	0.309**	-0.225*	0.326**	-0.147	0.237*	1.000	
SAR_s	0.527**	-0.363**	0.078	0.324**	-0.412**	0.711**	-0.437**	0.690**	-0.307**	0.429**	0.762**	1.000

*,** significant at 5% & 1% level, respectively

soils ($EC_{2.5}$, EC_e, $pH_{2.5}$, pH_s, SAR_s, SSP_s, and ESP_s) were worked out. In 0 to 5 km distance, pH_{iw} was found significant positively correlated with RSC_{iw} (r = 0.340^{**}), pH_s (r = 0.305^{**}) and $pH_{2.5}$ (r = 0.252^{**}). In case of SSP_{iw}, highly significant positive correlation was found with RSC_{iw} (r = 0.340^{**}) and SAR_{iw} (r = 0.832^{**}). The $pH_{2.5}$ was significantly correlated with pH_{iw} (r = 0.252^{**}), RSC_{iw} (r = 0.400^{**}) and pH_s (r = 0.801^{**}). The SSP_s was positively correlated with EC_{iw} (r = 0.301^{**}), EC_e (r = 0.309^{**}) and $EC_{2.5}$ (r = 0.326^{**}). Similar relationship was also observed by Prasad and Prasad (2001), Kabaria (2004), Shirgire (2012) and Rajput and Polara (2013).

- **5 to 10 km distance from sea coast**

In 5 to 10 km distance, EC_{iw} was found significantly correlated with SAR_{iw} (r = 0.429^{*}) and $EC_{2.5}$ (r = 0.368^{*}) (Table 4.6.2). In case of SSP_{iw}, highly significant positive correlation was found with RSC_{iw} (r = 0.574^{**}) and SAR_{iw} (r = 0.905^{**}). The EC_e was high significantly correlated with $EC_{2.5}$ (r = 0.658^{**}) and ESP_s (r = 0.466^{**}). The $pH_{2.5}$ was significantly correlated with pH_s (r = 0.825^{**}). The SSP_s was positively correlated with SAR_s (r = 0.880^{**}). Similar results were also reported by Prasad and Prasad (2001), Kabaria (2004), Shirgire (2012) and Rajput and Polara (2013).

- **10 to 15 km distance from sea coast**

In 10 to 15 km distance, EC_{iw} was found significantly correlated with SAR_{iw} (r = 0.440^{*}) and ESP_s (r = 0.368^{*}) (Table 4.6.3). In case of SSP_{iw}, highly significant positive correlation was found with SAR_{iw} (r = 0.901^{**}). The EC_e was high significantly correlated with $EC_{2.5}$ (r = 0.670^{**}). The $pH_{2.5}$ was significantly correlated with pH_s (r = 0.817^{**}). The SSP_s was positively correlated with SAR_s (r = 0.923^{**}). Similar relationship was also observed by Prasad and Prasad (2001), Kabaria (2004), Shirgire (2012) and Rajput and Polara (2013).

- **15 to 20 km distance from sea coast**

In 15 to 20 km distance, EC_{iw} was found significantly correlated with SAR_{iw} (r = 0.666^{**}) and SSP_{iw} (r = 0.584^{**}) (Table 4.6.4). In case of SSP_{iw}, highly significant positive correlation was found with SAR_{iw} (r = 0.898^{**}). The EC_e was high significantly correlated with $EC_{2.5}$ (r = 0.619^{**}). The $pH_{2.5}$ was significantly correlated with pH_s (r = 0.865^{**}). The $EC_{2.5}$ was significantly correlated with SSP_s (r = 0.589^{**}) and SAR_s (r = 0.658^{**}). The SSP_s was positively correlated with ESP_s (r = 0.411^{*}) and SAR_s (r = 0.940^{**}). Similar results was also observed by Prasad and Prasad (2001), Kabaria (2004), Shirgire (2012) and Rajput and Polara (2013).

- **0 to 20 km distance from sea coast**

The correlation between different properties of irrigation water (EC_{iw}, pH_{iw}, RSC_{iw}, SSP_{iw} and SAR_{iw}) and properties of irrigated soils ($EC_{2.5}$, EC_e, $pH_{2.5}$, pH_s, SAR_s, SSP_s, and ESP_s) of 0 to 20 km distance from sea coast were worked out, presented in table 4.6.5 and data indicates that EC_{iw} was observed significant and positively correlated with SAR_{iw}, EC_e, $EC_{2.5}$, ESP_s, SSP_s and SAR_s and pH_{iw} was significant and positively correlated with RSC_{iw}, pH_s and $pH_{2.5}$.

- **Post-monsoon**
- **0 to 5 km distance from sea coast**

The correlation among properties of irrigation water and irrigated soil parameters were presented in table 4.6.6. The correlation between different properties of irrigation water (EC_{iw}, pH_{iw}, RSC_{iw}, SSP_{iw} and SAR_{iw}) and properties of irrigated soils ($EC_{2.5}$, EC_e, $pH_{2.5}$, pH_s, SAR_s, SSP_s, and ESP_s) were worked out. In 0 to 5 km distance, SSP_{iw} was found highly significant positive correlation with RSC_{iw} ($r = 0.433^{*}$) and SAR_{iw} ($r = 0.906^{**}$). The EC_e was significantly correlated with $EC_{2.5}$ ($r = 0.927^{**}$), ESP_s ($r = 0.760^{**}$) and SAR_s ($r = 0.440^{*}$). The $pH_{2.5}$ was significantly correlated with pH_s ($r = 0.679^{**}$) and SSP_s with SAR_s ($r = 0.842^{**}$). Similar relationship was also observed by Prasad and Prasad (2001), Kabaria (2004), Shirgire (2012) and Rajput and Polara (2013).

- **5 to 10 km distance from sea coast**

In 5 to 10 km distance, EC_{iw} was found significantly correlated with SAR_{iw} ($r = 0.421^{*}$), $EC_{2.5}$ ($r = 0.421^{*}$) and EC_e ($r = 0.457^{**}$) (Table 4.6.7). In case of SSP_{iw}, highly significant positive correlation was found with RSC_{iw} ($r = 0.574^{**}$) and SAR_{iw} ($r = 0.905^{**}$). The EC_e was high significantly correlated with $EC_{2.5}$ ($r = 0.658^{**}$) and ESP_s ($r = 0.466^{**}$). The $pH_{2.5}$ was significantly correlated with pH_s ($r = 0.825^{**}$) and pH_{iw} with RSC_{iw} ($r = 0.448^{*}$) and ESP_s ($r = 0.494^{**}$). The SSP_s was positively correlated with SAR_s ($r = 0.880^{**}$). Similar results were also reported by Prasad and Prasad (2001), Kabaria (2004), Shirgire (2012) and Rajput and Polara (2013).

- **10 to 15 km distance from sea coast**

In 10 to 15 km distance, SSP_{iw} was found highly significant positive correlation with SAR_{iw} ($r = 0.864^{**}$) (Table 4.6.8). The EC_e was high significantly correlated with $EC_{2.5}$ ($r = 0.670^{**}$) and $pH_{2.5}$ with pH_s ($r = 0.817^{**}$). The SSP_s was positively correlated with SAR_s ($r = 0.923^{**}$). Similar relationship was also observed

Table 4.6.6: Correlation co-efficient among and between salinity/sodicity indices of soil and post-monsoon irrigation water of Northern Saurashtra coastal region

0 to 5 km	EC_{iw}	pH_{iw}	SSP_{iw}	SAR_{iw}	RSC_{iw}	EC_e	pH_s	$EC_{2.5}$	$pH_{2.5}$	ESP_s	SSP_s	SAR_s
EC_{iw}	1.000											
pH_{iw}	-0.477**	1.000										
SSP_{iw}	-0.332	0.130	1.000									
SAR_{iw}	-0.100	-0.022	0.906**	1.000								
RSC_{iw}	-0.498**	0.312	0.433*	0.113	1.000							
EC_e	-0.242	-0.204	0.293	0.182	0.133	1.000						
pH_s	-0.029	-0.036	-0.152	-0.115	0.241	-0.487**	1.000					
$EC_{2.5}$	-0.226	-0.274	0.271	0.203	-0.015	0.927**	-0.491**	1.000				
$pH_{2.5}$	-0.286	0.334	0.103	0.075	0.322	-0.386*	0.679**	-0.447*	1.000			
ESP_s	-0.260	0.004	0.218	0.056	0.326	0.760**	-0.271	0.617**	-0.094	1.000		
SSP_s	-0.019	-0.220	-0.083	-0.014	-0.054	0.056	0.047	-0.096	0.026	-0.103	1.000	
SAR_s	0.038	-0.355	0.069	0.077	-0.007	0.440*	-0.120	0.285	-0.162	0.194	0.842**	1.000

*,** significant at 5% & 1% level, respectively

Table 4.6.7: Correlation co-efficient among and between salinity/sodicity indices of soil and post-monsoon irrigation water of Northern Saurashtra coastal region

5 to 10 km	EC_{iw}	pH_{iw}	SSP_{iw}	SAR_{iw}	RSC_{iw}	EC_e	pH_s	$EC_{2.5}$	$pH_{2.5}$	ESP_s	SSP_s	SAR_s
EC_{iw}	1.000											
pH_{iw}	-0.191	1.000										
SSP_{iw}	0.163	0.315	1.000									
SAR_{iw}	0.421*	0.257	0.904**	1.000								
RSC_{iw}	-0.540**	0.448*	0.466**	0.160	1.000							
EC_e	0.457**	0.223	0.435*	0.532**	0.112	1.000						
pH_s	-0.183	0.084	-0.202	-0.218	-0.088	-0.336	1.000					
$EC_{2.5}$	0.409*	0.188	0.221	0.370*	-0.087	0.658**	-0.602**	1.000				
$pH_{2.5}$	-0.180	0.124	-0.238	-0.223	-0.065	-0.375*	0.825**	-0.559**	1.000			
ESP_s	0.178	0.494**	0.179	0.175	0.277	0.466**	-0.253	0.394*	-0.086	1.000		
SSP_s	-0.237	0.181	-0.179	-0.136	0.025	-0.210	-0.142	0.086	-0.138	-0.028	1.000	
SAR_s	-0.032	0.235	-0.055	0.017	-0.012	0.043	-0.322	0.333	-0.236	0.106	0.880**	1.000

*,** significant at 5% & 1% level, respectively

Table 4.6.8: Correlation co-efficient among and between salinity/sodicity indices of soil and post-monsoon irrigation water of Northern Saurashtra coastal region

10 to 15 km	**EC_{iw}**	**pH_{iw}**	**SSP_{iw}**	**SAR_{iw}**	**RSC_{iw}**	**EC_e**	**pH_s**	**$EC_{2.5}$**	**$pH_{2.5}$**	**ESP_s**	**SSP_s**	**SAR_s**
EC_{iw}	1.000											
pH_{iw}	-0.446**	1.000										
SSP_{iw}	-0.137	0.178	1.000									
SAR_{iw}	0.113	0.026	0.864**	1.000								
RSC_{iw}	-0.162	0.246	0.151	-0.186	1.000							
EC_e	0.083	-0.028	-0.043	0.160	-0.111	1.000						
pH_s	-0.160	0.188	0.195	-0.044	0.323	-0.309	1.000					
$EC_{2.5}$	0.101	-0.023	0.007	0.233	-0.330	0.670**	-0.527**	1.000				
$pH_{2.5}$	-0.111	0.155	0.267	0.074	0.214	-0.228	0.817**	-0.434*	1.000			
ESP_s	0.343	-0.323	0.062	0.190	-0.303	-0.043	0.046	0.007	0.098	1.000		
SSP_s	-0.034	0.120	-0.233	-0.250	-0.118	0.123	0.022	-0.012	0.021	0.082	1.000	
SAR_s	0.047	0.079	-0.167	-0.142	-0.173	0.319	-0.025	0.176	-0.025	0.082	0.923**	1.000

*,** significant at 5% & 1% level, respectively

Table 4.6.9: Correlation co-efficient among and between salinity/sodicity indices of soil and post-monsoon irrigation water of Northern Saurashtra coastal region

15 to 20 km	EC_{iw}	pH_{iw}	SSP_{iw}	SAR_{iw}	RSC_{iw}	EC_e	pH_s	$EC_{2.5}$	$pH_{2.5}$	ESP_s	SSP_s	SAR_s
EC_{iw}	1.000											
pH_{iw}	-0.653**	1.000										
SSP_{iw}	0.371	-0.441*	1.000									
SAR_{iw}	0.504*	-0.442*	0.928**	1.000								
RSC_{iw}	-0.441*	0.159	0.368	0.097	1.000							
EC_e	0.250	-0.167	0.276	0.367	-0.110	1.000						
pH_s	-0.065	-0.071	0.056	-0.007	-0.063	-0.337	1.000					
$EC_{2.5}$	0.366	0.052	-0.079	0.026	-0.513**	0.619**	-0.280	1.000				
$pH_{2.5}$	-0.012	-0.023	0.232	0.153	0.022	-0.099	0.865**	-0.149	1.000			
ESP_s	0.080	0.136	-0.176	-0.103	-0.379	-0.200	-0.019	0.199	0.035	1.000		
SSP_s	0.350	-0.138	0.199	0.235	-0.380	0.270	0.157	0.589**	0.198	0.411*	1.000	
SAR_s	0.329	-0.051	0.197	0.193	-0.287	0.335	0.108	0.658**	0.171	0.303	0.940**	1.000

*,** significant at 5% & 1% level, respectively

Table 4.6.10: Correlation co-efficient among and between salinity/sodicity indices of soil and post-monsoon irrigation water of Northern Saurashtra coastal region

0 to 20 km	EC_{iw}	pH_{iw}	SSP_{iw}	SAR_{iw}	RSC_{iw}	EC_e	pH_s	$EC_{2.5}$	$pH_{2.5}$	ESP_s	SSP_s	SAR_s
EC_{iw}	1.000											
pH_{iw}	-0.541**	1.000										
SSP_{iw}	0.048	0.019	1.000									
SAR_{iw}	0.414**	-0.178	0.829**	1.000								
RSC_{iw}	-0.671**	0.479**	0.213*	-0.211*	1.000							
EC_e	0.478**	-0.326**	0.249**	0.474**	-0.371**	1.000						
pH_s	-0.417**	0.262**	-0.101	-0.329**	0.374**	-0.551**	1.000					
$EC_{2.5}$	0.494**	-0.348**	0.211*	0.462**	-0.463**	0.955**	-0.598**	1.000				
$pH_{2.5}$	-0.353**	0.278**	0.027	-0.161	0.312**	-0.411**	0.801**	-0.462**	1.000			
ESP_s	0.294**	-0.137	0.154	0.280**	-0.164	0.653**	-0.339**	0.605**	-0.168	1.000		
SSP_s	0.310**	-0.203*	-0.023	0.160	-0.346**	0.309**	-0.225*	0.326**	-0.147	0.237*	1.000	
SAR_s	0.501**	-0.336**	0.104	0.345**	-0.432**	0.711**	-0.437**	0.690**	-0.307**	0.429**	0.762**	1.000

*,** significant at 5% & 1% level, respectively

by Prasad and Prasad (2001), Kabaria (2004), Shirgire (2012) and Rajput and Polara (2013).

- **15 to 20 km distance from sea coast**

In 15 to 20 km distance, EC_{iw} was found significantly correlated with SAR_{iw} (r = 0.504*) (Table 4.6.9). In case of SSP_{iw}, highly significant positive correlation was found with SAR_{iw} (r = 0.928**). The EC_{e} was high significantly correlated with $EC_{2.5}$ (r = 0.619**). The $pH_{2.5}$ was significantly correlated with pH_{s} (r = 0.865**). The $EC_{2.5}$ was significantly correlated with SSP_{s} (r = 0.589**) and SAR_{s} (r = 0.658**). The SSP_{s} was positively correlated with ESP_{s} (r = 0.411*) and SAR_{s} (r = 0.940**). Similar results was also observed by Prasad and Prasad (2001), Kabaria (2004), Shirgire (2012) and Rajput and Polara (2013).

- **0 to 20 km distance from sea coast**

The correlation between different properties of irrigation water (EC_{iw}, pH_{iw}, RSC_{iw}, SSP_{iw} and SAR_{iw}) and properties of irrigated soils ($EC_{2.5}$, EC_{e}, $pH_{2.5}$, pH_{s}, SAR_{s}, SSP_{s}, and ESP_{s}) of 0 to 20 km distance from sea coast were worked out, presented in table 4.6.10 and data indicates that EC_{iw} was observed significant and positively correlated with SAR_{iw}, EC_{e}, $EC_{2.5}$, ESP_{s}, SSP_{s} and SAR_{s} and pH_{iw} was significant and positively correlated with RSC_{iw}, pH_{s} and $pH_{2.5}$.

4.6.2 Regression

The highly significant correlation coefficient (r) values were obtained between EC of irrigation water and SAR of irrigation water in overall samples (Table 4.6.11). Highly significant correlation coefficient between EC_{iw} and SAR_{iw} (r = 0.4310**) and between SAR_{iw} and SSP_{iw} (r = 0.8325**) were observed. Positive correlation were obtained between pH_{iw} and RSC_{iw} (r = 0.0441).

The highly significant correlation coefficient (r) values were obtained between EC of irrigation water and SAR of irrigation water in overall samples (Table 4.6.12). Highly significant correlation coefficient between EC_{iw} and SAR_{iw} (r = 0.4144**) and between SAR_{iw} and SSP_{iw} (r = 0.8288**) were observed. Positive correlation were obtained between pH_{iw} and RSC_{iw} (r = 0.2133).

Table 4.6.11: Regression equation of EC_{iw} with SAR_{iw}, pH_{iw} with RSC_{iw} and SAR_{iw} with SSP_{iw} of pre-monosoon water samples of Northern Saurashtra coastal region

Sr. No	No. of Sample	Regression equation (y = a + bx)	Per cent of variance (R^2)	Correlation coeffiecient (r)
1	285	EC_{iw} = 1.2022 + 0.2139 SAR_{iw}	0.1857	0.4310**
2	285	pH_{iw} = 7.3370 + 0.0167 RSC_{iw}	0.3184	0.3405
3	285	SAR_{iw} = -4.7087 + 0.1968 SSP_{iw}	0.6930	0.8325**

*,** significant at 5% & 1% level, respectively

Table 4.6.12: Regression equation of EC_{iw} with SAR_{iw}, pH_{iw} with RSC_{iw} and SAR_{iw} with SSP_{iw} of post-monosoon water samples of Northern Saurashtra coastal region

Sr. No	No. of Sample	Regression equation (y = a + bx)	Per cent of variance (R^2)	Correlation coeffiecient (r)
1	285	EC_{iw} = 1.2006 + 0.2169 SAR_{iw}	0.1716	0.4144**
2	285	pH_{iw} = 7.9464 + 0.0255 RSC_{iw}	0.2295	0.4791*
3	285	SAR_{iw} = -3.1097 + 0.1650 SSP_{iw}	0.6869	0.8288**

*,** significant at 5% & 1% level, respectively

CHAPTER– V

SUMMARY AND CONCLUSION

Gujarat has a variety of soils, grown with multiple crops in different seasons but each soil has been posing some or other problems for normal cultivation of crops. The soils of Saurashtra region are medium black calcareous having several productivity constraints like low to medium fertility status, calcium carbonate, soil salinity *etc*. Salinity in coastal groundwater is a widespread problem in many parts of India and Gujarat. The coastal tract of Saurashtra is about 850 km in Gujarat. Soil salinity issue through secondary salinization and saline water due to ingress of sea water in aquifer are major constraints for cultivation of crops.

The present investigation deals with the quality of underground wells/tube wells water and their effect on soil properties, fluctuation in quality of underground wells/tube wells water with time, availability of macro and micronutrients in soil and inter-relationship within the properties of wells/tube wells water, soils and between different properties of wells/tube wells water and soils and between the available nutrients. For evaluating fertility, salinity/ sodicity status of soils and quality of underground well/tube well waters, about 141 surface soil samples (20 soil samples from each taluka) and each 285 underground irrigation water samples on pre and post monsoon were collected from the cultivated fields. The soil samples were analyzed for fertility parameters viz., available N, P_2O_5, K_2O, S, B, Fe, Mn, Cu and Zn, salinity/sodicity parameters viz., EC_e, pH_s, ESP, SAR and SSP. In addition to this, chemical properties like organic carbon, $EC_{2.5}$, $pH_{2.5}$, free lime content and CEC were also determined. For appraising quality of irrigation water, water quality parameters like EC, pH, SAR, RSC and SSP were determined. The observations on these aspects are summarized here under.

5.1 Chemical properties of soils of Northern Saurashtra coastal region

1. The overall mean $EC_{2.5}$ value of the soils of Northern Saurashtra coastal region was 1.25 dS m^{-1} and it was ranged widely from 0.23 to 5.97 dS m^{-1}.

2. In general, the soils of Northern Saurashtra coastal region were slightly alkaline in reaction and $pH_{2.5}$ value ranging from 7.20 to 8.59 with a mean value of 7.78.
3. The $CaCO_3$ content in the soils of Northern Saurashtra coastal region ranged from 12.34 to 420.31 g kg^{-1} with the mean value of 121.20 g kg^{-1} showing the occurrence of calcareous soils.
4. The soils of Northern Saurashtra coastal region were medium in organic carbon content. It was ranged from 1.40 to 9.40 g kg^{-1} with the mean value of 5.14 g kg^{-1}.
5. The overall range of cation exchange capacity was 19.49 to 59.72 cmol (p^+) kg^{-1} with the mean value of 36.99 cmol (p^+) kg^{-1}.

5.2 Salinity/sodicity status of soils of Northern Saurashtra coastal region

1. The Ca^{++} was the dominant exchangeable cation followed by Mg^{++}, Na^+ and K^+. The exchangeable Ca^{++}, Mg^{++}, Na^+ and K^+ ranged from 7.04 to 31.82, 2.20 to 20.02, 1.10 to 12.86 and 0.14 to 1.16 cmol (p^+) kg^{-1} with their corresponding mean values of 16.96, 11.94, 4.68 and 0.46 cmol (p^+) kg^{-1}, respectively.
2. Among the water soluble cations, Na^+ was predominant one followed by Ca^{++}, Mg^{++} and K^+. The water soluble Ca^{++}, Mg^{++}, Na^+ and K^+ ranged from 0.40 to 10.20, 0.30 to 13.50, 1.00 to 40.00 and 0.01 to 0.95 with their mean values of 2.05, 1.69, 8.35 and 0.18 me L^{-1}, respectively.
3. Among the water soluble anions, Cl^- was predominant one followed by HCO_3^-, CO_3^{--} and SO_4^{--}. The water soluble CO_3^{--}, HCO_3^-, Cl^- and SO_4^{--} varied from 0.00 to 0.56, 0.40 to 10.40, 1.50 to 48.70 and 0.01 to 0.95 with mean values of 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.
4. The soils of Northern Saurashtra coastal region were low saline in nature and EC_e values ranged from 0.49 to 18.22 dS m^{-1} with mean value of 3.21 dS m^{-1}.
5. The overall mean value of pH_s was 7.58 and it was ranged from 6.82 to 8.36.
6. The exchangeable sodium percentage ranged from 4.74 to 32.14 with an average value of 12.56, suggesting relatively lower hazard of alkalinity in soils of Northern Saurashtra coastal region.

7. The overall values of soluble sodium percentage were ranged from 33.67 to 88.38 with a mean value of 66.09.
8. The overall mean value of sodium adsorption ratio was 6.04 and it was ranged from 1.15 to 21.57.
9. About 12.06, 14.89, 9.93 and 63.12 per cent soil samples were found saline, saline-sodic, sodic and normal, respectively. The highest number of samples were found under normal class followed by saline-sodic, saline and sodic.

5.3 Fertility status of soils of Northern Saurashtra coastal region

1. In general, the soils of Northern Saurashtra coastal region were low in available nitrogen but medium in phosphorus. It was ranged from 80.41 to 431.59 kg ha^{-1} and 12.34 to 109.60 kg ha^{-1} with the mean value of 204.70 and 28.95 kg N and P_2O_5 ha^{-1}, respectively. The available K_2O status was found high and ranged from 126.60 to 1014.20 kg ha^{-1} with an average value of 401.82 kg K_2O ha^{-1}. The available S was found medium and it was ranged from 1.06 to 58.24 with the mean value of 20.00 mg kg^{-1}.
2. The soils of Northern Saurashtra coastal region were high in available Cu, while medium in Mn and Fe and low in Zn. The overall available (DTPA extractable) Fe, Mn, Cu and Zn varied between 2.92 to 8.92, 1.32 to 18.80, 0.13 to 7.31 and 0.06 to 3.58 with their corresponding mean values of 5.44, 7.45, 1.01 and 0.46 mg kg^{-1}, respectively. The overall range of available B in Nothern Saurashtra region was 0.78 to 6.61 mg kg^{-1} with the mean value of 3.49 mg kg^{-1}.
3. The nutrient index values were low for available N (1.27), P_2O_5 (1.43) and DTPA extractable Zn (1.32), medium for available S (2.08), Mn (1.97) and Fe (1.62) and high for K_2O (2.66) and Cu (2.94) in the soils of Northern Saurashtra coastal region.

5.4 Quality of underground wells/tube wells water before monsoon (May, 2019)

1. In general, underground well/tube well water was slightly neutral to alkaline in reaction. The overall pH value of water samples of Northern Saurashtra coastal region ranged from 6.45 to 8.47 with the mean value of 7.21. The

water was saline in nature and overall EC values ranged from 0.25 to 7.35 dS m^{-1} with the mean value of 2.22 dS m^{-1}.

2. The relative proportion of cations showed that overall the highest mean of Na^{+} (11.46 me L^{-1}) was observed, followed by Mg^{++} (5.54 me L^{-1}), Ca^{++} (5.11 me L^{-1}) and K^{+} (0.06 me L^{-1}). The overall concentration of Ca^{++}, Mg^{++}, Na^{+} and K^{+} were varied between 0.90 to 24.60, 0.90 to 17.50, 1.29 to 37.52 and 0.00 to 1.56 me L^{-1}, respectively.
3. The relative proportion of anions showed that the highest overall mean value of 16.67 me L^{-1} was recorded for Cl^{-} followed by HCO_3^{-} (4.95 me L^{-1}), CO_3^{--} (0.51 me L^{-1}) and SO_4^{--} (0.04 me L^{-1}). The concentration of CO_3^{--}, HCO_3^{-}, Cl^{-} and SO_4^{--} were in the range of 0.00 to 2.80, 0.67 to 17.00, 0.90 to 61.02 and 0.00 to 0.24 me L^{-1}, respectively.
4. The frequency distribution of underground well/tube well water samples in relation to EC showed that overall 0.00, 5.96, 52.28 and 37.89 per cent samples were falling under C_1, C_2, C_3 and C_4 classes of EC, respectively.
5. The overall mean value of sodium adsorption ratio (SAR) was 5.08 and it was varied from 0.95 to 15.91. The lowest (3.31) and the highest (6.64) mean value of SAR were reported in samples collected from Lalpur and Dwarka talukas, respectively. Overall 92.98, 7.02, 0.00 and 0.00 per cent samples fall under S_1, S_2, S_3 and S_4 classes of SAR, respectively.
6. The overall value of residual sodium carbonate (RSC) ranged from 0.00 to 9.40 with a mean value of 0.33 me L^{-1}. The highest mean value of RSC (0.87 me L^{-1}) was recorded in Kalyanpur taluka. Overall 89.82, 5.26 and 4.91 per cent samples were found under safe, marginal and unsafe classes of RSC, respectively.
7. The overall mean value of soluble sodium percentage (SSP) was 50.63, which varied from 20.27 to 82.56. The highest mean value (55.05) was recorded in Dwarka taluka, whereas the lowest (44.41) in Lalpur taluka. Overall 74.74 and 25.26 per cent samples were found safe and unsafe classes of SSP, respectively.

5.5 Quality of underground wells/tube wells water after monsoon (December, 2019)

1. The relative proportion of cations showed that overall the highest mean of Na^+ (9.36 me L^{-1}) was observed, which was followed by Ca^{++} (5.54 me L^{-1}), Mg^{++} (5.15 me L^{-1}) and K^+ (0.07 me L^{-1}). The overall concentration of Ca^{++}, Mg^{++}, Na^+ and K^+ were varied between 1.03 to 24.50, 0.50 to 19.60, 0.48 to 35.61 and 0.00 to 0.84 me L^{-1}, respectively.
2. The relative proportion of anions showed that the highest overall mean value of 15.06 me L^{-1} was recorded for Cl^- and it was followed by HCO_3^- (4.34 me L^{-1}), SO_4^{--} (0.48 me L^{-1}) and CO_3^{--} (0.14 me L^{-1}). The concentration of CO_3^{--}, HCO_3^-, Cl^- and SO_4^{--} were in the range of 0.00 to 1.60, 0.42 to 13.60, 0.60 to 58.41 and 0.02 to 1.08 me L^{-1}, respectively.
3. In general, underground wells/tube wells water was neutral to alkaline in reaction. The overall pH values were ranged from 7.00 to 8.90 with mean value of 7.73. The water was saline in nature and overall EC values were ranged from 0.18 to 6.83 dS m^{-1} with mean value of 2.01 dS m^{-1}.
4. The frequency distribution of underground well/tube well water samples in relation to EC showed that overall 0.70, 12.28, 51.23 and 33.33 per cent samples were falling under C_1, C_2, C_3 and C_4 classes of EC, respectively.
5. The overall mean value of sodium adsorption ratio (SAR) was 4.06 and it was varied between 0.47 to 13.05. The lowest (2.87) and the highest (5.89) mean SAR values were recorded in samples collected from Lalpur and Dwarka talukas, respectively. Overall 96.14, 3.86, 0.00 and 0.00 per cent samples fall under S_1, S_2, S_3 and S_4 classes of SAR, respectively.
6. The overall value of residual sodium carbonate (RSC) ranged from 0.00 to 4.80 with a mean value of 0.19 me L^{-1}. The highest mean value (RSC 0.66 me L^{-1}) was recorded in Khambhalia taluka. Overall 92.28, 5.26 and 2.46 per cent samples were found under safe, marginal and unsafe classes of RSC, respectively.
7. The overall mean value of soluble sodium percentage (SSP) was 44.72, which was varied from 14.08 to 78.00. The highest mean value (51.87) was recorded in Dwarka taluka, whereas the lowest (40.14) in Jamnagar taluka. Overall 85.61 and 14.39 per cent samples were found under safe and unsafe classes of SSP, respectively.

5.6 Fluctuation in quality of underground well/tube well water with time

The overall EC, pH, SAR, RSC and SSP values of wells/tube wells water samples of Northern Saurashtra coastal region were improved by 9.46, 7.21, 20.08, 42.42 and 11.67 per cent, respectively after monsoon (December, 2019) in comparison to that observed before monsoon (May, 2019).

5.7 Inter-relationship among and between fertility status and salinity/sodicity indices of irrigated soils

The correlation among fertility parameters (SOC, available N, P_2O_5, K_2O and S) and salinity/sodicity parameters ($EC_{2.5}$, EC_e, $pH_{2.5}$, pH_s and $CaCO_3$) in soils of 0 to 20 km distance from sea coast were worked out and data indicates that $EC_{2.5}$ was significant and positively correlated with EC_e, SSP, SAR, ESP and $CaCO_3$ and $pH_{2.5}$ was significant and positively correlated with $pH_{s,}$ O.C., available N, K_2O and S.

5.8 Inter-relationship between properties of irrigation water and irrigated soils

The correlation between different properties of pre-monsoon irrigation water (EC_{iw}, pH_{iw}, RSC_{iw}, SSP_{iw} and SAR_{iw}) and properties of irrigated soils ($EC_{2.5}$, EC_e, $pH_{2.5}$, pH_s, SAR_s, SSP_s, and ESP_s) of 0 to 20 km distance from sea coast were worked out and data indicates that EC_{iw} was observed significant and positively correlated with SAR_{iw}, EC_e, $EC_{2.5}$, ESP_s, SSP_s and SAR_s and pH_{iw} was significant and positively correlated with RSC_{iw}, pH_s and $pH_{2.5}$.

The correlation between different properties of post-monsoon irrigation water (EC_{iw}, pH_{iw}, RSC_{iw}, SSP_{iw} and SAR_{iw}) and properties of irrigated soils ($EC_{2.5}$, EC_e, $pH_{2.5}$, pH_s, SAR_s, SSP_s, and ESP_s) of 0 to 20 km distance from sea coast were worked out and data indicates that EC_{iw} was observed significant and positively correlated with SAR_{iw}, EC_e, $EC_{2.5}$, ESP_s, SSP_s and SAR_s and pH_{iw} was significant and positively correlated with RSC_{iw}, pH_s and $pH_{2.5}$.

5.9 CONCLUSION

On the basis of analyzed data of soil and water samples, collected from different districts (Jamnagar, Devbhumi Dwarka and Porbandar) of Northern Saurashtra coastal region of Gujarat, it can be concluded that all the soil fertility parameters viz., SOC, available N, P_2O_5, K_2O, Fe, Mn, Cu and Zn content were increased with increasing the sampling distance (0-5, 5-10, 10-15, 15-20 km) from coastal line except B. In salinity parameters, EC, ESP, SSP and SAR were decreased, while pH was slightly increased with increasing the distance from sea coast. Soil EC was found beyond to its critical or marginal limit up to 0 to 5 km distance from sea coast, while SSP was found beyond to its critical limit up to 20 km from sea coast.

The soils of Northern Saurashtra coastal region were calcareous in nature and alkaline in reaction with medium in organic carbon. Overall cation exchange capacity was 36.99 cmol (p^+) kg^{-1}. Calcium was the dominant-exchangeable cation, whereas sodium and chloride were the dominant water soluble ions in the soils. Overall 12.06, 14.89, 9.93 and 63.12 per cent soil samples were saline, saline-sodic, sodic and normal, respectively. The soils were low with respect to available N (204.70 kg ha^{-1}), but medium in P_2O_5 (28.95 kg ha^{-1}) and available S (20.00 mg kg^{-1}), whereas it was high in K_2O (401.82 kg ha^{-1}) status. Among the DTPA extractable micronutrients, available Mn (7.45 mg kg^{-1}) and Fe (5.44 mg kg^{-1}) were found medium, whereas the soils were low in Zn (0.46 mg kg^{-1}) and high in Cu (1.01 mg kg^{-1}) and available B (3.49 mg kg^{-1}).

In case of water quality, almost all well/ tube well water samples (Pre & Post monsoon) of Northern Saurashtra coastal region having higher amount of soluble salts (2.22 & 2.01 dS m^{-1}) mainly due to dominance of Na and Cl ions, however, all the quality parameters *viz.,* EC, pH, SSP, RSC and ESP of collected well/tube well water samples after monsoon were improved as compared to the samples collected before monsoon.

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NOTE: * Original not seen

Appendix II: Sample wise $EC_{2.5}$, $pH_{2.5}$, SOC and fertility status of irrigated soils of Northern Saurashtra coastal region

Lab. No.	$EC_{2.5}$ (dS m^{-1})	$pH_{2.5}$	SOC (g kg^{-1})	kg ha^{-1}			mg kg^{-1}					
				N	P_2O_5	K_2O	S	Fe	Mn	Cu	Zn	B
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	2.78	7.64	2.80	190.50	32.31	170.60	4.44	2.92	0.83	0.23	4.20	5.17
2	3.56	7.20	1.90	180.60	17.72	220.30	5.28	3.90	0.62	0.3	2.77	5.34
3	1.17	7.56	4.30	260.10	32.79	321.20	4.41	4.75	1.36	0.25	12.40	4.97
4	1.36	7.51	4.60	270.60	43.30	297.60	4.71	8.18	1.25	0.45	5.77	4.67
5	0.78	7.84	3.80	160.50	22.53	254.10	5.90	6.26	0.71	0.49	9.17	2.09
6	1.84	7.53	4.10	220.90	21.64	250.90	6.10	6.33	0.83	0.51	7.27	4.22
7	0.55	8.16	3.90	180.90	41.13	274.10	5.60	4.15	1.20	0.48	6.90	4.70
8	1.05	7.87	3.50	140.60	26.79	200.80	4.42	5.45	1.06	0.69	6.54	3.86
9	0.67	8.21	4.50	280.30	19.74	275.30	4.30	4.73	1.66	0.66	13.00	5.10
10	1.10	8.01	4.80	300.50	22.05	187.20	4.89	4.96	1.62	0.37	18.02	5.26
11	1.13	7.52	5.80	230.80	24.05	363.20	5.10	8.19	1.96	1.64	40.51	2.51
12	0.48	7.41	6.70	310.40	32.70	305.10	7.54	11.80	2.14	1.63	37.27	3.32
13	0.87	7.89	6.40	288.70	31.97	287.40	4.37	11.74	2.14	1.17	27.16	3.80
14	1.08	7.45	5.10	140.20	21.39	410.10	5.78	9.28	2.99	1.17	32.32	2.86
15	0.55	8.19	5.50	157.10	44.24	334.20	6.70	7.16	2.77	1.45	24.27	2.77
16	0.46	8.20	6.90	380.50	25.74	415.20	5.37	5.59	4.29	1.42	22.03	2.36
17	0.84	7.64	9.00	423.40	49.28	472.40	5.31	9.43	4.27	1.85	48.69	2.50
18	0.54	7.51	7.20	223.60	34.05	506.20	5.19	13.63	6.07	1.64	40.03	2.64
19	0.43	8.18	7.60	346.90	26.08	524.20	6.91	15.48	7.31	2.08	46.00	1.77
20	0.37	7.75	7.40	321.80	22.03	484.70	7.97	10.14	4.29	3.58	45.75	2.32
21	2.60	7.66	3.00	200.00	21.98	223.30	5.46	3.15	0.57	0.18	4.54	5.10
22	1.37	7.54	2.70	155.70	18.66	225.70	4.21	1.75	0.49	0.21	2.10	5.26
23	2.38	7.34	2.50	146.50	19.49	340.90	4.31	4.06	0.51	0.18	3.61	5.95
24	2.65	7.40	1.80	118.80	32.77	211.20	4.37	1.32	0.46	0.18	1.88	4.68
25	3.67	7.22	2.30	143.50	26.22	164.50	5.21	4.87	0.23	0.13	1.44	3.80

1	2	3	4	5	6	7	8	9	10	11	12	13
26	1.31	7.53	4.40	180.30	28.72	362.40	4.29	6.53	0.55	0.29	13.46	3.43
27	0.86	7.60	3.10	140.40	31.40	265.10	5.27	6.68	0.7	0.27	16.07	4.41
28	1.62	7.45	4.70	200.40	26.38	423.30	7.73	4.82	0.72	0.29	11.42	3.77
29	1.50	7.62	4.90	250.50	24.32	398.30	5.07	5.76	0.48	0.32	10.18	3.76
30	1.74	7.37	4.00	170.40	19.10	275.80	5.00	6.06	0.52	0.27	12.26	2.99
31	0.76	7.95	3.80	169.80	34.24	306.40	4.82	5.78	0.56	0.17	8.06	3.32
32	0.80	7.81	3.50	150.50	22.03	207.80	5.38	6.25	0.68	0.19	10.34	2.77
33	1.06	7.72	5.00	150.20	26.88	417.10	5.13	8.56	0.85	0.42	27.24	3.11
34	1.20	7.68	5.70	290.50	49.19	405.40	6.25	8.31	0.83	0.41	21.73	2.38
35	0.48	8.07	5.40	240.80	25.63	492.90	6.12	9.89	0.75	0.5	26.04	3.21
36	0.51	8.16	6.10	310.20	26.24	274.40	8.06	10.24	0.80	0.58	18.06	2.58
37	0.62	7.82	7.60	345.10	25.28	495.30	8.43	9.42	0.92	0.65	31.26	1.89
38	0.89	7.74	6.40	248.60	27.89	532.60	5.51	10.2	0.86	1.12	34.62	2.73
39	0.50	8.10	7.20	339.20	30.85	478.10	6.25	11.23	2.35	0.63	37.21	1.02
40	0.32	8.20	8.10	354.80	52.51	572.60	7.10	10.85	1.02	0.88	40.45	2.05
41	3.13	7.51	1.70	112.40	28.01	184.40	3.22	3.25	0.75	0.31	1.74	4.68
42	1.72	7.76	1.90	116.80	26.08	126.60	4.20	4.44	0.62	0.23	1.37	4.77
43	1.19	7.83	1.50	80.41	15.53	190.10	3.12	4.18	0.39	0.18	2.04	3.87
44	1.32	7.37	4.20	160.20	35.54	214.90	3.24	5.48	0.83	0.35	10.34	4.08
45	1.12	7.68	4.50	170.40	19.79	145.30	4.18	5.12	0.81	0.28	10.51	2.70
46	0.75	7.95	2.40	90.40	36.20	215.30	5.09	6.84	0.76	0.41	7.94	3.44
47	0.81	7.82	3.70	120.80	19.05	246.40	3.31	4.15	0.87	0.37	5.65	2.62
48	0.62	7.80	3.00	100.70	24.89	147.80	4.05	7.53	0.78	0.35	8.47	3.12
49	0.53	8.02	3.50	110.30	20.88	219.40	4.35	7.61	0.80	0.38	7.01	3.59
50	0.77	7.91	4.80	180.50	24.59	173.20	3.26	5.70	0.84	0.38	4.54	3.38
51	0.87	7.42	6.60	220.70	40.69	370.60	4.19	8.44	1.08	0.49	13.73	3.15

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
52	0.92	7.46	6.50	190.80	31.24	226.30	4.06	9.2	1.22	0.46	20.24	2.14
53	0.44	7.80	4.50	114.50	34.99	201.90	5.68	7.63	1.12	0.42	18.14	1.08
54	0.52	7.89	6.10	153.60	25.21	315.70	4.06	10.73	0.95	0.38	14.18	3.18
55	0.43	7.83	5.50	177.10	22.40	221.70	5.44	6.64	0.91	0.47	17.49	2.39
56	0.36	7.90	5.20	124.20	25.92	270.50	4.35	6.28	0.95	0.48	19.07	1.88
57	0.57	7.66	4.80	130.60	27.73	234.60	5.21	8.65	0.99	0.63	25.56	1.14
58	0.29	8.07	6.20	226.70	43.90	396.10	5.72	12.02	1.31	0.6	28.51	0.78
59	0.32	7.93	8.70	289.40	24.82	405.60	6.09	11.37	1.24	0.66	36.24	0.97
60	0.47	7.91	7.50	254.70	25.97	372.40	4.81	13.40	1.46	0.53	21.56	1.97
61	1.31	7.74	3.80	187.80	38.01	193.70	6.14	1.88	0.49	0.19	3.47	5.44
62	2.34	7.59	3.50	150.17	24.59	135.00	4.03	1.91	0.53	0.08	5.10	5.10
63	2.05	7.46	4.10	189.80	28.30	294.10	5.09	3.18	0.25	0.13	1.87	5.55
64	1.60	7.34	3.40	148.74	25.81	157.90	4.13	2.72	0.55	0.11	2.90	6.27
65	5.60	7.28	3.00	136.60	17.91	235.70	4.21	4.68	0.42	0.11	4.02	4.69
66	0.92	8.14	5.10	186.20	21.34	289.30	5.02	6.89	0.6	0.12	8.80	3.71
67	0.58	7.75	4.20	150.17	41.31	265.40	6.65	4.93	0.59	0.13	9.54	4.16
68	0.84	7.64	4.90	172.62	28.99	435.60	6.13	5.62	0.62	0.12	9.50	4.21
69	0.62	7.60	5.40	200.35	31.01	439.80	4.50	5.87	0.46	0.2	5.41	4.23
70	1.33	7.71	4.60	168.40	21.14	264.70	4.11	5.41	0.47	0.21	8.12	4.81
71	0.38	7.65	6.50	262.74	31.85	470.20	7.03	9.2	0.84	0.3	23.12	3.18
72	0.45	7.71	5.30	160.81	50.20	537.80	6.15	8.22	0.79	0.2	14.60	3.79
73	1.05	7.64	6.70	250.17	26.93	541.20	6.27	10.45	0.79	0.22	29.40	3.18
74	0.51	7.74	6.40	275.26	21.62	423.90	4.87	10.93	0.88	0.28	10.47	3.32
75	0.87	7.65	6.70	362.30	20.93	456.10	5.38	9.32	0.98	0.24	31.70	3.86
76	0.74	7.84	5.30	175.25	33.48	537.90	5.15	8.02	1.13	0.28	17.25	2.22
77	0.41	7.87	7.50	366.41	46.49	578.60	5.16	12.57	1.20	0.45	47.70	2.81

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
78	0.56	7.74	6.50	253.20	109.60	891.30	6.29	12.95	1.24	0.32	41.60	1.85
79	0.23	7.68	8.30	408.60	63.98	864.20	7.71	12.60	1.39	0.29	38.90	2.87
80	0.24	7.51	6.80	267.40	31.42	935.60	5.52	11.32	1.35	0.26	56.80	1.43
81	1.17	8.09	2.30	131.36	27.80	171.60	6.57	4.11	0.70	0.15	1.92	5.14
82	1.85	7.71	1.50	124.60	25.26	204.50	5.88	4.37	0.62	0.19	2.87	5.10
83	4.33	7.21	2.50	134.49	22.53	190.30	4.37	3.68	0.56	0.13	4.57	4.07
84	3.02	7.52	3.10	147.09	21.69	264.20	4.71	4.02	0.47	0.17	8.47	4.28
85	0.92	7.65	4.50	137.63	25.17	280.60	4.61	4.32	0.74	0.18	11.02	4.16
86	0.54	7.50	4.90	147.06	31.85	334.60	5.58	4.30	0.78	0.15	13.14	4.53
87	0.72	7.75	4.00	131.36	22.56	301.20	5.34	5.31	0.72	0.18	19.07	3.62
88	1.15	7.63	4.20	134.49	23.91	294.60	7.14	4.74	0.76	0.29	12.54	4.62
89	1.64	7.76	5.50	180.50	28.79	374.50	6.22	5.58	0.65	0.24	26.74	3.32
90	0.54	7.83	5.20	165.85	34.03	436.70	6.61	5.08	0.74	0.22	21.75	4.07
91	0.76	7.77	3.70	130.63	26.84	367.80	5.38	5.01	0.65	0.25	9.12	3.19
92	0.45	8.00	6.20	237.63	22.12	497.80	5.12	5.72	0.88	0.29	46.53	3.81
93	0.64	8.12	5.30	168.99	26.61	521.20	5.39	7.92	0.89	0.34	31.75	2.46
94	0.97	7.74	6.70	240.76	41.54	527.70	7.74	5.30	0.84	0.29	40.42	3.76
95	0.53	7.62	5.70	213.60	23.75	459.80	6.34	6.79	0.77	0.27	34.61	2.24
96	0.24	7.80	6.60	200.30	23.43	467.80	5.91	7.25	1.03	0.35	44.15	0.78
97	0.29	7.70	7.30	231.36	27.23	641.50	5.98	7.67	1.22	0.74	47.95	2.34
98	0.40	7.93	6.80	216.34	31.99	807.60	8.92	9.36	1.83	0.63	48.69	0.87
99	0.46	7.88	7.60	251.62	44.59	783.40	5.53	8.66	1.32	0.5	58.24	1.89
100	0.43	8.02	6.20	153.16	32.27	602.50	6.89	10.91	1.27	1.11	42.07	2.55
101	5.97	7.44	1.50	128.20	33.50	490.00	4.03	2.62	0.44	0.16	8.24	4.95
102	2.56	7.88	2.30	143.90	29.47	432.50	4.28	5.31	0.47	0.23	4.46	5.12
103	2.33	7.62	3.00	128.22	19.05	447.20	4.17	6.10	0.13	0.22	3.01	4.99

1	2	3	4	5	6	7	8	9	10	11	12	13
104	1.62	7.80	3.60	162.72	19.21	216.90	5.98	6.94	0.21	0.08	3.37	4.34
105	3.34	8.04	2.50	146.20	24.05	382.30	5.84	4.72	0.47	0.25	2.26	6.07
106	2.41	8.02	2.70	148.50	35.98	461.10	4.82	4.80	0.42	0.18	4.20	5.32
107	2.02	7.90	1.40	122.30	18.37	426.40	3.30	5.27	0.52	0.06	1.07	3.74
108	2.31	7.87	3.20	150.17	21.32	365.40	6.43	6.74	0.36	0.26	10.02	4.46
109	1.44	7.71	1.80	126.30	14.82	270.70	4.14	6.10	0.13	0.36	2.17	3.39
110	2.31	7.65	6.50	172.60	36.04	531.20	4.23	7.32	0.59	0.39	24.12	3.87
111	1.76	7.77	6.40	154.20	41.82	582.10	4.39	7.87	0.66	0.4	26.34	3.73
112	0.90	8.12	6.80	184.10	25.85	596.20	6.74	7.42	0.62	0.33	19.51	2.17
113	0.80	7.67	5.90	134.20	25.72	521.40	4.47	8.32	0.69	0.32	18.15	3.18
114	1.47	7.90	5.20	146.30	28.56	427.80	5.98	6.27	0.70	0.29	22.57	2.88
115	1.13	8.59	8.40	252.40	45.34	781.50	6.48	8.55	0.74	0.43	32.03	2.75
116	0.86	7.93	7.50	158.20	25.97	694.20	7.54	8.38	0.77	0.41	36.47	2.29
117	0.57	8.04	7.90	233.90	28.95	736.70	4.52	9.06	0.71	0.46	28.36	2.22
118	0.73	8.20	7.20	174.10	31.62	598.20	5.24	8.75	0.71	0.66	30.67	1.74
119	0.69	8.52	9.70	431.59	27.87	780.80	7.57	18.80	0.84	0.79	56.67	0.93
120	0.36	8.55	9.10	403.10	45.66	812.30	5.56	14.11	1.29	2.41	46.72	1.89
121	3.43	7.46	4.70	134.50	13.21	260.80	4.82	5.02	0.49	0.18	7.34	4.23
122	2.16	7.77	3.50	127.00	16.30	264.20	5.32	6.59	0.57	0.14	5.52	5.55
123	4.80	7.36	4.50	136.10	25.30	293.70	4.86	5.55	0.54	0.23	3.18	6.07
124	2.64	8.07	3.80	132.00	14.27	265.10	4.30	5.34	0.64	0.17	2.74	6.61
125	1.89	7.69	2.40	128.40	14.63	304.30	5.36	5.60	0.60	0.19	2.16	5.44
126	1.44	8.10	2.00	126.80	17.13	321.90	2.92	5.11	0.51	0.16	1.06	4.08
127	1.74	7.51	5.20	136.70	18.46	409.10	4.92	7.28	0.76	0.2	21.54	4.85
128	1.23	7.83	6.00	291.00	14.29	395.60	7.64	7.91	0.6	0.25	24.15	4.76
129	0.82	7.50	5.40	137.50	20.13	345.20	4.70	7.78	0.60	0.16	18.45	3.91

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
130	1.14	8.12	4.90	131.20	12.34	354.70	5.02	9.41	0.71	0.16	17.24	3.77
131	0.98	7.78	5.70	270.60	26.95	384.40	4.18	9.50	0.60	0.24	13.41	3.86
132	1.04	7.55	6.80	238.60	17.22	526.30	5.03	9.57	0.79	0.25	29.45	3.87
133	1.11	7.92	7.20	329.10	21.89	437.70	4.74	9.44	0.87	0.22	31.36	3.88
134	0.82	7.63	6.70	240.70	28.40	405.90	6.10	9.05	0.78	0.29	22.14	3.72
135	0.74	8.15	6.10	170.20	32.91	542.20	7.94	9.08	0.72	0.3	26.87	3.60
136	0.58	7.90	6.50	184.60	20.75	677.80	8.09	10.6	0.83	0.46	24.03	2.36
137	0.56	7.76	8.40	352.80	39.09	706.50	5.18	12.38	0.91	0.61	51.30	2.43
138	0.78	8.01	7.10	328.60	54.07	614.60	6.17	13.6	0.9	0.55	45.40	1.99
139	0.43	7.71	7.70	341.25	32.24	783.20	7.07	15.27	0.81	0.48	52.90	2.75
140	0.30	8.19	9.10	403.10	39.41	810.30	8.76	11.67	1.30	1.02	44.10	2.36
141	0.47	7.84	9.40	428.61	30.32	1014.20	6.94	14.10	0.95	0.48	43.50	2.77

Appendix III: Sample wise EC_e, pH_s, exchangeable cations and different indices of irrigated soils of Northern Saurashtra coastal region

Lab. No.	EC_e (dS m^{-1})	pH_s	Exchangeable cations (cmol(p^+)kg^{-1})				Soil indices			$CaCO_3$ (g kg^{-1})
			Na^+	K^+	Ca^{++}	Mg^{++}	SSP	SAR	RSC (me l^{-1})	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	6.12	7.32	6.58	0.19	19.02	13.45	64.94	6.75	-3.80	132.54
2	10.40	6.91	7.62	0.25	15.60	14.30	74.07	13.78	-6.22	103.24
3	2.31	7.24	3.02	0.37	18.01	14.21	66.36	5.44	-0.66	90.00
4	2.04	7.16	6.36	0.34	22.80	13.01	73.40	5.74	-0.10	71.14
5	1.89	7.70	2.18	0.29	11.70	14.41	69.53	6.39	-2.39	82.16
6	2.24	7.15	7.00	0.29	25.01	17.03	85.28	11.36	-0.03	70.24
7	1.38	8.07	5.61	0.31	15.30	13.51	63.30	4.46	-1.86	74.31
8	1.54	7.35	5.78	0.23	17.50	15.12	86.92	11.44	0.70	70.00
9	1.09	8.19	2.53	0.31	18.16	14.04	72.56	5.92	-0.44	71.42
10	1.90	7.81	1.54	0.21	12.73	5.31	63.96	5.07	-2.88	63.12
11	1.66	7.32	6.71	0.42	21.03	16.18	66.57	4.48	-0.90	50.02
12	0.97	7.24	6.14	0.35	22.40	14.06	74.83	5.30	-0.16	60.23
13	1.10	7.82	6.21	0.33	21.02	15.42	60.93	4.06	-1.80	42.58
14	1.32	7.31	3.24	0.47	13.51	10.08	65.98	5.37	-2.10	52.02
15	0.86	8.01	9.74	0.38	19.05	13.27	67.02	4.67	-1.50	50.00
16	0.74	8.12	3.62	0.47	19.70	11.83	67.71	4.74	-1.00	45.21
17	1.03	7.41	6.58	0.54	19.00	13.24	61.13	3.74	-1.50	23.01
18	0.78	7.38	6.64	0.58	13.40	11.35	58.90	3.21	-0.60	40.67
19	0.69	8.15	6.04	0.60	14.16	10.05	68.40	5.01	-0.42	19.99
20	0.52	7.56	7.61	0.55	15.46	14.37	60.00	3.38	-0.90	32.12
21	3.14	7.23	2.68	0.26	26.20	18.08	64.29	5.28	-2.20	190.56

22	3.67	7.31	2.96	0.26	23.04	16.81	70.79	7.82	-2.15	174.07
23	5.32	7.18	4.00	0.39	21.00	16.23	73.00	9.06	0.30	231.04
24	6.16	7.26	5.92	0.24	20.60	18.00	69.59	9.91	-6.20	200.00
25	12.04	7.01	10.42	0.19	23.61	20.02	76.37	15.04	-8.93	178.25
26	2.52	7.33	7.48	0.41	21.25	17.04	71.35	5.88	-0.67	140.00
27	1.78	7.42	5.30	0.30	19.37	15.16	76.05	8.52	-1.43	142.03
28	3.25	7.36	6.24	0.48	20.20	16.08	67.96	7.48	-4.27	120.25
29	2.77	7.40	8.02	0.46	19.80	12.07	60.15	4.15	-1.60	120.00
30	3.64	7.04	4.21	0.32	14.60	11.08	63.67	5.21	-1.29	150.00
31	1.28	7.84	6.53	0.35	18.71	20.00	65.79	4.67	-0.90	170.00
32	1.31	7.79	6.44	0.24	19.70	16.58	77.12	8.53	-1.30	114.20
33	1.56	7.51	4.70	0.48	14.17	12.04	66.92	5.47	-1.92	95.37
34	1.78	7.46	2.77	0.46	16.02	8.18	63.09	4.12	-1.39	60.12
35	0.80	7.92	5.34	0.56	18.90	11.28	61.52	4.29	-1.23	71.03
36	0.67	8.05	6.00	0.31	11.08	15.20	73.86	5.22	0.48	62.13
37	0.84	7.78	2.53	0.57	8.15	12.07	67.15	4.71	-0.50	42.58
38	1.17	7.53	2.54	0.61	13.41	8.16	70.34	5.89	-1.30	45.21
39	0.62	8.01	3.22	0.55	9.82	11.20	58.85	3.09	-0.88	50.00
40	0.49	8.11	3.24	0.65	9.04	7.16	54.64	3.06	-0.60	52.02
41	10.27	7.14	3.44	0.21	18.00	8.50	79.74	14.01	-4.13	141.02
42	4.30	7.36	6.14	0.14	17.04	16.12	58.73	4.51	-1.64	152.47
43	3.02	7.42	3.74	0.22	23.20	16.04	82.71	13.80	-2.70	122.08
44	2.72	7.20	3.78	0.25	14.03	9.41	65.21	5.43	-2.50	102.03
45	1.78	7.41	4.51	0.17	15.23	13.02	69.91	5.28	-0.85	94.26
46	0.90	7.90	5.80	0.25	17.31	16.04	65.16	3.94	-1.00	50.00
47	1.34	7.62	4.62	0.28	13.80	12.60	68.73	5.05	-1.28	51.26
48	1.50	7.68	6.36	0.17	21.61	15.24	74.27	6.23	-1.27	61.28

49	0.94	7.81	9.50	0.25	19.61	18.06	67.13	4.28	-0.73	50.00
50	1.14	7.79	4.69	0.20	18.08	10.29	53.86	3.35	-2.60	66.45
51	1.27	7.35	3.28	0.42	16.07	8.00	61.34	3.56	-0.95	30.00
52	1.46	7.32	5.48	0.26	16.41	13.47	53.10	2.60	-1.67	30.03
53	0.57	7.97	3.47	0.23	17.34	12.28	55.82	2.69	-1.04	41.28
54	0.71	7.86	3.79	0.36	14.26	9.27	54.84	2.80	-1.50	40.78
55	0.84	7.77	4.62	0.25	15.03	12.32	71.14	5.22	-1.10	50.00
56	0.77	7.83	5.83	0.31	15.40	11.45	61.35	3.27	-0.94	41.27
57	1.03	7.54	3.62	0.27	13.02	10.54	69.14	4.62	-0.58	23.21
58	0.67	7.94	4.62	0.45	13.81	11.26	55.92	2.89	-0.86	34.06
59	0.56	7.86	3.22	0.46	14.72	11.24	59.50	2.98	-0.12	24.12
60	0.81	7.80	3.48	0.43	11.21	9.02	44.06	1.53	-0.96	13.02
61	4.52	7.12	7.10	0.22	20.37	14.60	69.38	7.26	-2.20	260.27
62	7.04	7.28	5.69	0.15	15.56	4.82	70.20	8.44	-3.60	240.59
63	6.37	7.21	6.70	0.34	17.40	11.03	72.02	7.26	-0.40	360.12
64	4.03	7.51	4.25	0.18	10.89	7.02	68.26	7.89	-2.70	262.03
65	17.03	6.97	12.86	0.27	14.36	11.57	71.01	14.01	-12.09	224.10
66	3.18	7.62	5.47	0.33	14.41	13.02	63.66	3.82	-0.90	132.07
67	2.22	7.60	3.93	0.30	17.80	11.27	57.47	3.50	-1.94	160.27
68	3.25	7.56	3.97	0.50	19.03	11.24	77.05	6.55	0.34	71.45
69	2.17	7.80	2.88	0.50	31.82	9.21	71.13	4.96	0.40	163.28
70	3.98	7.46	6.10	0.30	18.52	15.23	59.93	4.94	-2.50	56.24
71	1.29	7.72	2.85	0.54	17.00	11.78	72.97	5.84	-0.08	50.00
72	1.55	7.55	2.96	0.61	18.87	15.80	78.54	6.26	1.10	24.13
73	2.40	7.68	2.78	0.62	21.02	17.12	67.08	4.06	-0.58	80.00
74	1.12	7.70	3.28	0.48	21.40	15.56	63.67	3.54	-0.54	12.34
75	1.75	7.69	2.96	0.52	18.40	13.94	76.72	6.79	-0.38	72.05

76	1.21	7.33	2.66	0.61	20.20	15.03	68.04	4.35	-0.70	64.06
77	0.84	7.88	3.12	0.66	20.43	13.84	52.96	2.33	-0.70	12.34
78	0.97	7.81	3.70	1.02	20.21	14.76	65.91	4.21	0.24	20.02
79	0.54	7.78	2.45	0.99	17.80	8.42	33.67	1.15	-0.31	30.00
80	0.62	7.47	2.88	1.07	17.79	15.02	39.74	1.50	-0.38	41.03
81	2.84	8.05	3.09	0.20	20.81	17.22	60.28	5.27	-3.60	220.31
82	6.50	7.29	4.67	0.23	13.75	10.32	59.89	5.38	-3.10	170.00
83	15.17	6.82	8.38	0.22	17.60	12.57	66.19	10.85	-11.30	114.02
84	9.34	7.67	7.60	0.30	17.76	14.37	73.32	10.37	-4.80	241.03
85	2.94	7.22	4.32	0.32	14.95	5.38	66.80	5.19	-0.40	114.00
86	2.14	7.11	2.62	0.38	20.91	16.78	72.15	5.89	-0.70	103.45
87	1.98	7.60	2.24	0.34	21.81	18.62	63.01	4.27	-1.70	91.46
88	4.12	7.13	4.09	0.34	18.42	12.62	74.31	7.11	-1.50	80.02
89	2.38	8.02	4.34	0.43	14.64	12.13	68.74	5.34	-1.00	89.09
90	1.65	7.35	2.64	0.50	15.02	13.04	60.09	4.06	-1.20	110.00
91	1.94	8.14	3.33	0.42	24.40	15.60	71.65	5.43	-0.60	68.17
92	1.31	8.03	3.50	0.57	17.20	10.80	65.02	4.20	-0.20	60.86
93	1.25	7.97	2.19	0.60	11.23	11.05	67.01	4.08	0.20	90.00
94	1.58	7.35	2.31	0.60	14.82	13.80	68.24	5.41	-0.50	42.74
95	1.34	7.84	1.75	0.53	14.86	10.16	53.65	2.92	-1.70	70.00
96	0.67	7.72	2.40	0.53	13.81	6.42	53.58	2.29	0.16	18.24
97	0.96	7.64	2.54	0.73	17.79	6.68	51.74	2.64	-0.27	20.00
98	1.10	7.57	2.53	0.92	13.20	12.23	40.32	1.86	-0.40	40.17
99	1.21	7.53	2.61	0.90	21.88	17.59	46.46	2.32	-0.46	24.01
100	1.30	7.85	4.04	0.69	15.82	12.03	66.45	4.24	-0.06	52.64
101	18.22	7.28	12.45	0.56	19.83	2.64	59.87	10.31	-13.11	203.28
102	6.35	7.52	5.49	0.49	19.58	11.67	61.80	5.74	-3.59	240.00

103	7.54	7.40	4.10	0.51	14.00	10.77	64.36	7.01	-3.60	380.23
104	5.21	7.54	2.64	0.25	17.20	3.84	88.38	21.57	-1.80	293.07
105	11.20	7.13	8.55	0.44	14.81	8.00	70.35	10.64	-5.00	360.28
106	8.72	7.39	5.81	0.53	10.67	2.28	82.13	13.79	-2.49	190.00
107	5.24	7.37	2.95	0.49	13.60	2.21	59.92	4.84	-0.50	260.47
108	7.84	7.38	5.30	0.42	13.20	3.84	78.90	11.77	-1.60	400.28
109	4.06	7.44	4.71	0.31	7.04	4.42	55.56	4.66	-4.30	242.27
110	6.76	7.43	5.96	0.61	19.78	12.34	71.16	8.33	-2.67	142.03
111	6.87	7.47	4.75	0.67	7.11	4.46	73.36	8.06	-1.60	133.20
112	4.17	8.00	2.58	0.68	14.42	2.20	68.83	6.59	-1.06	187.28
113	3.12	7.36	6.37	0.60	16.23	15.34	60.00	4.30	-0.84	120.00
114	5.08	7.27	2.64	0.49	17.20	3.81	66.98	5.99	-2.60	100.04
115	3.83	7.64	6.50	0.89	16.40	15.37	73.32	6.26	-0.20	92.26
116	2.72	7.33	1.80	0.79	14.01	12.11	51.87	3.10	-2.20	88.17
117	0.93	8.12	1.14	0.84	15.78	2.46	74.12	6.53	-1.20	92.12
118	1.57	8.07	1.24	0.68	12.58	7.77	67.12	4.67	-0.78	116.26
119	0.96	8.36	1.18	0.89	15.79	2.70	68.93	4.86	-0.39	32.17
120	0.78	8.04	1.10	0.93	15.60	2.40	65.45	4.26	-0.20	68.02
121	12.20	7.30	9.67	0.30	24.20	14.65	80.28	16.35	-6.00	280.17
122	6.93	7.65	6.93	0.30	20.80	17.55	78.13	11.63	-3.22	420.31
123	11.65	7.14	10.39	0.34	25.65	19.84	74.79	12.82	-6.00	241.25
124	5.53	7.86	6.09	0.30	18.08	12.15	65.45	5.87	-2.80	372.65
125	4.50	7.42	6.06	0.35	20.40	17.45	77.25	10.25	-0.80	370.17
126	4.10	7.91	5.92	0.37	19.85	16.34	79.66	13.34	-2.68	405.36
127	6.27	7.36	5.89	0.47	18.14	13.80	64.17	5.90	-2.93	292.57
128	4.39	7.74	4.93	0.45	16.05	8.11	55.43	3.93	-2.30	192.03
129	3.14	7.26	5.97	0.39	20.35	14.11	71.48	7.45	-2.28	250.00

130	3.25	7.92	5.07	0.41	18.82	12.17	58.86	4.16	-2.03	210.00
131	3.05	7.62	5.12	0.44	15.54	11.00	61.76	4.31	-1.50	220.00
132	3.31	7.49	3.97	0.60	14.20	10.61	82.17	9.10	0.49	150.00
133	4.09	7.83	5.87	0.50	16.90	11.75	60.56	4.17	-2.29	190.36
134	2.47	7.48	4.88	0.46	13.15	8.26	80.33	7.78	-0.05	121.34
135	1.56	8.00	4.75	0.62	15.89	16.57	78.42	7.37	-0.34	91.47
136	0.91	7.70	3.60	0.77	13.65	9.16	61.70	3.95	-1.03	140.00
137	1.07	7.55	2.94	0.81	11.25	8.35	65.00	3.99	-0.40	45.05
138	1.28	7.91	3.69	0.70	16.05	8.12	62.48	3.74	-0.88	92.02
139	0.87	7.67	2.68	0.90	10.76	11.54	45.95	2.14	-0.91	68.23
140	0.66	8.08	1.54	0.93	12.40	8.62	52.12	2.97	-1.00	74.01
141	0.71	7.78	2.29	1.16	11.51	12.60	56.29	3.56	-0.32	92.14

Appendix IV: Samplewise water soluble ions (me L^{-1}) and salinity/sodicity indices of irrigated soils of Northern Saurashtra coastal region

Lab. No.	Water soluble ions (1:2.5)								Indices	
	Cations (me L^{-1})				Anions (me L^{-1})					
	Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	CEC (cmol (p+) kg^{-1})	ESP
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	12.26	0.02	4.40	2.20	0.40	2.40	22.80	0.15	42.74	15.39
2	33.11	0.04	6.25	5.30	0.52	4.81	32.30	0.30	41.02	18.58
3	7.30	0.10	2.80	0.80	0.44	2.50	11.88	0.07	37.50	8.05
4	5.74	0.08	1.60	0.40	0.30	1.60	8.15	0.09	44.16	14.40
5	8.81	0.06	2.40	1.40	0.32	1.09	8.13	0.05	30.94	7.05
6	10.78	0.06	1.00	0.80	0.35	1.42	7.00	0.01	52.83	13.25
7	5.64	0.07	2.40	0.80	0.30	1.04	8.10	0.04	38.23	14.67
8	9.57	0.04	1.00	0.40	0.20	1.90	10.70	0.02	42.10	13.73
9	6.48	0.05	2.00	0.40	0.36	1.60	8.35	0.04	38.29	6.61
10	7.17	0.04	2.50	1.50	0.20	0.92	7.11	0.05	23.29	6.61
11	4.70	0.16	1.70	0.50	0.30	1.00	8.20	0.02	47.81	14.04
12	4.37	0.11	1.00	0.36	0.10	1.10	5.70	0.03	46.45	13.22
13	5.13	0.09	2.40	0.80	0.20	1.20	6.50	0.04	46.67	13.31
14	7.00	0.21	2.30	1.10	0.20	1.10	6.70	0.05	30.14	10.75
15	5.12	0.12	1.20	1.20	0.10	0.80	4.80	0.06	45.94	21.20
16	4.74	0.26	1.60	0.40	0.10	0.90	5.20	0.04	38.12	9.50
17	4.01	0.25	1.30	1.00	0.00	0.80	5.70	0.02	42.86	15.35
18	2.78	0.44	0.70	0.80	0.00	0.90	3.90	0.05	35.11	18.91
19	4.07	0.56	1.02	0.30	0.10	0.80	2.40	0.06	34.63	17.44
20	3.12	0.38	1.20	0.50	0.10	0.70	4.90	0.02	41.40	18.38
21	7.65	0.05	2.60	1.60	0.30	1.70	18.60	0.05	49.57	5.41
22	12.48	0.05	2.60	2.50	0.45	2.50	30.08	0.14	45.20	6.55
23	15.03	0.06	3.00	2.50	0.56	5.24	20.30	0.20	44.33	9.02
24	21.40	0.03	6.20	3.12	0.42	2.70	20.20	0.09	47.10	12.57
25	34.96	0.02	6.60	4.20	0.37	1.50	21.10	0.82	56.25	18.53

26	6.70	0.09	1.40	1.20	0.23	1.70	12.70	0.02	49.96	14.97
27	11.27	0.05	2.20	1.30	0.27	1.80	7.40	0.02	43.09	12.30
28	12.96	0.11	3.60	2.40	0.32	1.41	8.30	0.80	47.01	13.27
29	5.57	0.09	3.20	0.40	0.30	1.70	13.60	0.04	44.70	17.94
30	7.64	0.06	2.60	1.70	0.41	2.60	10.60	0.07	32.59	12.92
31	5.52	0.07	1.60	1.20	0.30	1.60	9.20	0.05	49.09	13.30
32	10.62	0.05	2.10	1.00	0.30	1.50	8.40	0.02	46.46	13.86
33	7.02	0.17	2.20	1.10	0.18	1.20	6.40	0.01	33.89	13.87
34	4.70	0.15	1.40	1.20	0.15	1.06	9.60	0.06	30.93	8.95
35	5.34	0.24	1.80	1.30	0.30	1.57	4.70	0.02	39.36	13.57
36	4.55	0.09	1.20	0.32	0.30	1.70	5.20	0.04	35.33	16.98
37	4.21	0.46	0.80	0.80	0.10	1.00	5.80	0.04	27.35	9.25
38	5.74	0.52	1.00	0.90	0.10	0.50	3.30	0.05	28.49	8.92
39	2.76	0.33	1.20	0.40	0.22	0.50	5.46	0.01	27.67	11.64
40	2.65	0.70	1.20	0.30	0.20	0.70	4.70	0.04	23.59	13.73
41	24.87	0.02	3.60	2.70	0.37	1.80	26.50	0.04	32.50	10.58
42	7.13	0.01	1.20	3.80	0.46	2.90	15.60	0.03	41.48	14.80
43	19.76	0.03	2.60	1.50	0.40	1.00	12.20	0.01	44.87	8.34
44	7.78	0.05	3.20	0.90	0.20	1.40	10.10	0.05	30.97	12.21
45	5.90	0.04	2.00	0.50	0.33	1.32	8.20	0.03	36.43	12.38
46	4.04	0.06	1.20	0.90	0.30	0.80	5.40	0.02	42.90	13.52
47	5.65	0.07	1.60	0.90	0.32	0.90	5.10	0.01	34.75	13.29
48	6.61	0.04	1.75	0.50	0.18	0.80	6.30	0.04	47.12	13.50
49	4.39	0.05	1.00	1.10	0.20	1.17	6.74	0.05	50.54	18.80
50	4.74	0.06	2.80	1.20	0.35	1.05	7.40	0.02	36.36	12.90
51	3.65	0.20	1.40	0.70	0.15	1.00	4.46	0.01	29.27	11.20
52	2.91	0.07	2.00	0.50	0.23	0.60	4.70	0.03	37.51	14.61
53	2.78	0.06	1.74	0.40	0.20	0.90	2.80	0.04	35.26	9.84
54	3.00	0.17	1.80	0.50	0.20	0.60	3.50	0.02	30.03	12.62
55	5.35	0.07	1.20	0.90	0.10	0.90	5.21	0.02	35.72	12.93
56	3.19	0.11	0.80	1.10	0.16	0.80	6.20	0.04	36.49	15.98

57	4.57	0.08	1.06	0.90	0.28	1.10	5.80	0.03	30.95	11.70
58	2.74	0.36	1.10	0.70	0.10	0.84	3.70	0.01	33.08	13.97
59	1.91	0.48	0.50	0.32	0.10	0.60	2.50	0.02	33.14	9.72
60	1.26	0.24	0.80	0.56	0.00	0.40	1.90	0.04	27.92	12.47
61	11.60	0.02	2.90	2.20	0.40	2.50	16.00	0.06	45.79	15.51
62	15.10	0.01	3.50	2.90	0.20	2.60	14.60	0.02	29.72	19.14
63	10.14	0.04	2.30	1.60	0.30	3.20	13.70	0.28	38.00	17.63
64	14.45	0.02	3.60	3.10	0.20	3.80	21.02	0.04	23.70	17.93
65	40.00	0.03	5.60	10.70	0.21	4.00	46.15	0.26	42.53	30.24
66	4.10	0.04	1.20	1.10	0.20	1.20	5.10	0.04	35.73	15.31
67	4.50	0.03	1.20	2.10	0.16	1.20	5.40	0.06	35.66	11.02
68	6.21	0.05	1.00	0.80	0.24	1.90	6.20	0.02	37.58	10.56
69	4.83	0.06	0.90	1.00	0.20	2.10	5.70	0.01	47.91	6.01
70	8.12	0.03	1.00	4.40	0.30	2.60	9.90	0.01	43.30	14.09
71	6.10	0.08	1.08	1.10	0.10	2.00	4.20	0.01	34.67	8.22
72	5.05	0.08	0.90	0.40	0.20	2.20	5.00	0.04	39.74	7.45
73	3.83	0.10	0.78	1.00	0.20	1.00	4.80	0.01	44.02	6.32
74	3.40	0.10	1.04	0.80	0.20	1.10	6.10	0.05	43.39	7.56
75	6.79	0.06	1.00	1.00	0.22	1.40	4.20	0.05	39.32	7.53
76	4.24	0.09	0.90	1.00	0.20	1.00	5.60	0.01	40.00	6.65
77	2.15	0.21	0.90	0.80	0.00	1.00	2.60	0.01	41.55	7.51
78	3.21	0.50	0.84	0.32	0.00	1.40	3.70	0.01	43.14	8.58
79	1.00	0.46	0.61	0.90	0.00	1.20	1.50	0.03	33.27	7.36
80	1.20	0.54	0.80	0.48	0.10	0.80	2.10	0.02	39.43	7.30
81	9.12	0.01	3.40	2.60	0.20	2.20	13.20	0.08	44.58	6.93
82	9.63	0.05	3.80	2.60	0.30	3.00	13.70	0.06	32.45	14.39
83	30.01	0.03	7.50	7.80	0.20	3.80	40.20	0.09	41.33	20.28
84	19.40	0.06	5.00	2.00	0.40	1.80	24.80	0.03	42.47	17.89
85	6.56	0.06	1.40	1.80	0.00	2.80	8.30	0.04	28.47	15.17
86	6.45	0.09	1.30	1.10	0.10	1.60	7.00	0.06	43.19	6.07
87	5.23	0.07	1.20	1.80	0.20	1.10	6.70	0.03	44.51	5.03

88	8.56	0.06	1.50	1.40	0.10	1.30	8.50	0.09	36.82	11.11
89	6.20	0.12	1.50	1.20	0.30	1.40	7.40	0.03	33.85	12.82
90	5.21	0.16	1.40	1.90	0.10	2.00	5.80	0.03	32.48	8.13
91	5.56	0.10	1.00	1.10	0.30	1.20	6.40	0.04	45.42	7.33
92	4.20	0.26	0.90	1.10	0.00	1.80	4.30	0.01	34.71	10.08
93	3.29	0.32	0.80	0.50	0.00	1.50	3.60	0.06	27.16	8.06
94	5.80	0.40	1.10	1.20	0.20	1.60	6.20	0.04	35.03	6.59
95	3.45	0.18	1.80	1.00	0.10	1.00	5.70	0.04	30.37	5.76
96	1.57	0.42	0.43	0.51	0.00	1.10	1.80	0.05	26.38	9.10
97	1.64	0.76	0.40	0.37	0.00	0.50	2.40	0.01	31.24	8.13
98	1.50	0.92	0.90	0.40	0.00	0.90	2.60	0.04	31.93	7.92
99	2.10	0.78	0.64	1.00	0.08	1.10	3.00	0.02	47.13	5.54
100	3.09	0.50	0.56	0.50	0.00	1.00	3.60	0.04	36.02	11.22
101	35.48	0.08	10.20	13.50	0.19	10.40	48.70	0.47	38.74	32.14
102	10.11	0.05	3.80	2.40	0.21	2.40	13.70	0.04	40.73	13.48
103	13.49	0.07	3.60	3.80	0.20	3.60	27.20	0.21	32.62	12.57
104	30.50	0.01	1.20	2.80	0.40	1.80	12.30	0.06	27.13	9.73
105	23.80	0.03	4.60	5.40	0.20	4.80	30.20	0.25	35.28	24.24
106	20.45	0.05	2.30	2.10	0.31	1.60	22.50	0.17	21.93	26.50
107	7.10	0.45	2.00	2.30	0.20	3.60	12.70	0.04	21.66	13.62
108	18.43	0.03	2.10	2.80	0.50	2.80	18.60	0.95	26.26	20.18
109	8.65	0.02	3.10	3.80	0.20	2.40	15.10	0.01	19.98	23.57
110	13.82	0.10	3.10	2.40	0.23	2.60	14.40	0.04	40.82	14.60
111	11.40	0.14	1.40	2.60	0.20	2.20	11.30	0.04	19.49	24.38
112	9.32	0.22	2.40	1.60	0.34	2.60	9.50	0.02	22.72	11.35
113	6.00	0.10	1.70	2.20	0.36	2.70	8.87	0.15	42.04	15.15
114	8.68	0.08	1.80	2.40	0.20	1.40	13.83	0.08	26.29	10.04
115	5.77	0.40	0.80	0.90	0.10	1.40	6.20	0.07	42.31	15.36
116	4.16	0.26	1.70	1.90	0.20	1.20	5.40	0.08	31.29	5.75
117	6.53	0.28	1.10	0.90	0.10	0.70	6.50	0.05	22.53	5.06
118	4.90	0.20	1.00	1.20	0.22	1.20	8.70	0.02	25.77	4.81

119	3.75	0.50	0.66	0.53	0.00	0.80	5.03	0.07	24.01	4.91
120	2.86	0.61	0.50	0.40	0.00	0.70	2.84	0.02	23.20	4.74
121	32.70	0.03	4.40	3.60	0.20	1.80	36.20	0.18	51.40	18.81
122	18.75	0.05	2.40	2.80	0.28	1.70	17.80	0.34	49.03	14.13
123	27.50	0.07	5.20	4.00	0.50	2.70	48.40	0.60	59.72	17.40
124	9.00	0.05	2.60	2.10	0.30	1.60	9.40	0.07	39.64	15.36
125	15.21	0.08	1.80	2.60	0.30	3.30	19.20	0.04	46.90	12.92
126	22.32	0.10	3.40	2.20	0.22	2.70	15.60	0.08	45.98	12.88
127	9.42	0.16	2.60	2.50	0.37	1.80	9.60	0.08	40.80	14.44
128	6.02	0.14	1.90	2.80	0.20	2.20	13.80	0.05	31.04	15.88
129	10.80	0.11	2.80	1.40	0.32	1.60	10.20	0.17	42.32	14.11
130	5.88	0.11	3.40	0.60	0.27	1.70	6.40	0.04	38.88	13.04
131	5.54	0.13	2.20	1.10	0.20	1.60	9.61	0.02	34.84	14.70
132	7.88	0.21	1.10	0.40	0.29	1.70	8.00	0.04	32.88	12.07
133	5.36	0.19	1.70	1.60	0.21	0.80	7.40	0.01	38.04	15.43
134	6.74	0.15	0.90	0.60	0.25	1.20	6.60	0.02	30.32	16.09
135	6.25	0.28	1.04	0.40	0.20	0.90	4.80	0.08	39.72	11.96
136	4.14	0.37	1.60	0.60	0.17	1.00	7.70	0.06	29.23	12.31
137	3.12	0.46	0.82	0.40	0.20	0.62	4.76	0.03	27.06	10.87
138	3.43	0.38	1.04	0.64	0.10	0.70	5.78	0.01	32.11	11.49
139	2.04	0.59	1.10	0.71	0.20	0.70	3.68	0.04	28.66	9.35
140	2.71	0.82	0.67	1.00	0.15	0.52	2.50	0.03	27.80	5.54
141	2.64	0.95	0.76	0.34	0.18	0.60	3.80	0.05	31.34	7.31

Appendix V: General description of collected water samples

No.	Name of Farmer	Village	Taluka	District
1	Hiteshbhai Chhaganbhai	Gordhanpar	Jamnagar	Jamnagar
2	Babubhai Keshubhai	Dhinchda	Jamnagar	Jamnagar
3	Ranmalbhai Bharatbhai	Vasai	Jamnagar	Jamnagar
4	Manjibhai	Jambuda	Jamnagar	Jamnagar
5	Manjibhai	Jambuda	Jamnagar	Jamnagar
6	Karmshibhai Jethabhai Kanani	Jambuda	Jamnagar	Jamnagar
7	Punjabhai Rambhai	Jambuda	Jamnagar	Jamnagar
8	Khimabhai Hamirbhai	Vasai	Jamnagar	Jamnagar
9	Maldevbhai	Sikka	Jamnagar	Jamnagar
10	Hamirbhai	Jamnagar	Jamnagar	Jamnagar
11	Kaiswala Nagabhai Bura	Naghedi	Jamnagar	Jamnagar
12	Devsibhai Nathubhai Makhwana	Naghedi	Jamnagar	Jamnagar
13	Chhaganbhai Ratnabhai Rabari	Rawalsar	Jamnagar	Jamnagar
14	Rambhai Lakhabhai	Lakha-Baval	Jamnagar	Jamnagar
15	Manohar Mohanbhai Dharabhai	Rawalsar	Jamnagar	Jamnagar
16	Masribhai Karabhai	Rawalsar	Jamnagar	Jamnagar
17	KVK	Jamnagar	Jamnagar	Jamnagar
18	KVK	Jamnagar	Jamnagar	Jamnagar
19	Premjibhai Jayrajbhai	Dhua	Jamnagar	Jamnagar
20	Narayanbhai Devsibhai Panara	Jambuda	Jamnagar	Jamnagar
21	Harishbhai Bharaiya	Jambuda	Jamnagar	Jamnagar
22	Mulubhai Virabhai	Jambuda	Jamnagar	Jamnagar
23	Mandabhai Gopalbhai	Naghedi	Jamnagar	Jamnagar
24	Nathubhai Jadeja	Vasai	Jamnagar	Jamnagar
25	Keshubhai Surabhai	Vasai	Jamnagar	Jamnagar
26	Lalitbhai	Jambuda	Jamnagar	Jamnagar
27	Devsibhai Nathubhai Makhwana	Naghedi	Jamnagar	Jamnagar
28	Jayrajbhai	Dhua	Jamnagar	Jamnagar
29	Kantibhai Chhaganbhai	Dhua	Jamnagar	Jamnagar
30	Dayabhai Ranmalbhai	Jambuda	Jamnagar	Jamnagar
31	Rajsibhai Gangabhai	Jambuda	Jamnagar	Jamnagar
32	Maisurbhai Ranabhai Lokhi	Thavariya	Jamnagar	Jamnagar
33	Kasanbhai Malkiya	Mota-thavariya	Jamnagar	Jamnagar
34	Krishanbhai Gheesabhai Solanki	Mota-thavariya	Jamnagar	Jamnagar
35	Champakbhai Ajmalbhai	Mota-thavariya	Jamnagar	Jamnagar
36	Dayabhai Pappubhai	Theba	Jamnagar	Jamnagar
37	Devabhai Vangabhai	Khimaliya	Jamnagar	Jamnagar
38	Girdharbhai Atara	Jamnagar	Jamnagar	Jamnagar
39	Ibrahambhai Khanchi	Jamnagar	Jamnagar	Jamnagar
40	Lilabhai Karshanbhai	Jamnagar	Jamnagar	Jamnagar
41	Ramabhai Jethabhai	Khimaliya	Jamnagar	Jamnagar
42	Hansrajbhai	Khimaliya	Jamnagar	Jamnagar

43	Ranchhorbhai Sojitra	Theba	Jamnagar	Jamnagar
44	Ratanbhai Bhurabhai	Mota-thavariya	Jamnagar	Jamnagar
45	Ratik Babu	Vijarkhi	Jamnagar	Jamnagar
46	Rambhai Vaishnavbhai	Vijarkhi	Jamnagar	Jamnagar
47	Prabatbhai Sagarbhai Changa	Jamnagar	Jamnagar	Jamnagar
48	Bharatbhai Narayanbhai Wak	Godavari	Jamnagar	Jamnagar
49	Maisurbhai Ranabhai Lokhi	Thavariya	Jamnagar	Jamnagar
50	Ranmalbhai Kunabhai Makvana	Vijarkhi	Jamnagar	Jamnagar
51	Nathabhai Parbatbhai	Sapda	Jamnagar	Jamnagar
52	Chandrasingh	Changa payita	Jamnagar	Jamnagar
53	Chakubhai Bhavanbhai	Changa payita	Jamnagar	Jamnagar
54	Laljibhai	Chela	Jamnagar	Jamnagar
55	Brijraj Singh Bahadurbhai	Balachadi	Jodiya	Jamnagar
56	Tulsibhai Rojibhai	Balachadi	Jodiya	Jamnagar
57	Dharmibhai	Hadiyana	Jodiya	Jamnagar
58	Keshubhai Ramjibhai	Hadiyana	Jodiya	Jamnagar
59	Sardarbhai	Balachadi	Jodiya	Jamnagar
60	Boghubhai Fateh Singh Vaghela	Balachadi	Jodiya	Jamnagar
61	Manishbhai Kailashbhai	Hadiyana	Jodiya	Jamnagar
62	Dhamabhai lalabhai	Hadiyana	Jodiya	Jamnagar
63	Pratapbhai	Ghoogas	Jodiya	Jamnagar
64	Dineshbhai	Ghoogas	Jodiya	Jamnagar
65	Bharatbhai	Baradi/khedi	Jodiya	Jamnagar
66	Vijaybhai	Baradi	Jodiya	Jamnagar
67	Munnabhai	Hadiyana	Jodiya	Jamnagar
68	Nakum Jaysukhbhai Pitambhai	Hadiyana	Jodiya	Jamnagar
69	Satishbhai Dharmsibhai Kanani	Hadiyana	Jodiya	Jamnagar
70	Rameshbhai	Kunnad	Jodiya	Jamnagar
71	Sundabhai Bachchubhai	Kunnad	Jodiya	Jamnagar
72	Bhagwanbhai Gangabhai	Moti Khavdi	Jodiya	Jamnagar
73	Jivabhai Laxmanbhai	Moti Khavdi	Jodiya	Jamnagar
74	Danabhai Rajabhai	Moti Khavdi	Jodiya	Jamnagar
75	Vikarambhai Govindbhai	Bhadra	Jodiya	Jamnagar
76	Laxmanbhai Motibhai Bhimani	Badalpur	Jodiya	Jamnagar
77	Haribhai Kanabhai	Kunnad	Jodiya	Jamnagar
78	Mandeepbhai	Kunnad	Jodiya	Jamnagar
79	Merubhai Somabhai	Hadiyana	Jodiya	Jamnagar
80	Hiralbhai	Hadiyana	Jodiya	Jamnagar
81	Ganeshbhai Danabhai	Hadiyana	Jodiya	Jamnagar
82	Kanabhai Jivabhai	Bhadra	Jodiya	Jamnagar
83	Adhavjibhai Bhanderi	Badalpur	Jodiya	Jamnagar
84	Jivanbhai Masribhai	Bhadra	Jodiya	Jamnagar
85	Premji bhai Veerjibhai	Bhadra	Jodiya	Jamnagar
86	Rajeshbhai Veerjibhai Bhanderi	Bhadra	Jodiya	Jamnagar

87	Tulsibhai Dhalshaniya	Lakhatar	Jodiya	Jamnagar
88	Karnabhai Virambhai	Majoth	Jodiya	Jamnagar
89	Pamabhai Madhabhai	Lakhatar	Jodiya	Jamnagar
90	Shantilal Chanyara	Lakhatar	Jodiya	Jamnagar
91	Nathubhai Nagjibhai	Lakhatar	Jodiya	Jamnagar
92	Danabhai Vajsibhai	Lakhatar	Jodiya	Jamnagar
93	Ashokbhai Devabhai	Lakhatar	Jodiya	Jamnagar
94	Bharatbhai Kalyan Singh Jhala	Padana	Lalpur	Jamnagar
95	Bharatbhai Kalyan Singh Jhala	Padana	Lalpur	Jamnagar
96	Prabhubhai Devabhai	Padana	Lalpur	Jamnagar
97	Nathabhai Ajmalbhai	Padana	Lalpur	Jamnagar
98	Nathubhai Bikubhai Jadeja	Padana	Lalpur	Jamnagar
99	Mangubhai Jhala	Padana	Lalpur	Jamnagar
100	Gumanjibhai Jhala	Padana	Lalpur	Jamnagar
101	Mishribhai Rambhai	Navaniya	Lalpur	Jamnagar
102	Rajeshbhai Dheerabhai	Navaniya	Lalpur	Jamnagar
103	Popatbhai Sojitra	Padana	Lalpur	Jamnagar
104	Vikashbhai Jivanbhai Parmar	Navaniya	Lalpur	Jamnagar
105	Lakhanjibhai Charan	Navaniya	Lalpur	Jamnagar
106	Lakhanjibhai Charan	Navaniya	Lalpur	Jamnagar
107	Amarsingh Devisingh Chauhan	Kanalur	Lalpur	Jamnagar
108	Gulab Singh Jadhav	Setalur	Lalpur	Jamnagar
109	Jayabhai Chhotubhai	Meghna	Lalpur	Jamnagar
110	Takubhai	Pipli station	Lalpur	Jamnagar
111	Takubhai	Pipli station	Lalpur	Jamnagar
112	Gaubhai Jadeja	Padana	Lalpur	Jamnagar
113	Narayanbhai Chavda	Navaniya	Lalpur	Jamnagar
114	Narayanbhai Chavda	Navaniya	Lalpur	Jamnagar
115	Judabhai Krishanbhai	Navaniya	Lalpur	Jamnagar
116	Arjunbhai Chavda	Navaniya	Lalpur	Jamnagar
117	Dhyansingh	Navaniya	Lalpur	Jamnagar
118	Ranmalbhai	Navaniya	Lalpur	Jamnagar
119	Manishbhai Bheekhabhai	Pipli	Lalpur	Jamnagar
120	Asif Punjani	Kanalus	Lalpur	Jamnagar
121	Sureshbhai	Changa patiya	Lalpur	Jamnagar
122	Ajmalbhai	Changa patiya	Lalpur	Jamnagar
123	Hembhai	Chandragadh	Lalpur	Jamnagar
124	Palanugha Ghoochai	Lamba	Kalyanpur	Dwarka
125	Devanang Kheevabbhai Jetliya	Lamba	Kalyanpur	Dwarka
126	Narayanbhai Arjunbhai Ghoochai	Lamba	Kalyanpur	Dwarka
127	Dalubhai Krishanbhai	Lamba	Kalyanpur	Dwarka
128	Arjunbhai Devsibhai	Lamba	Kalyanpur	Dwarka
129	Palabhai Ranabhai Chetriya	Lamba	Kalyanpur	Dwarka
130	Hamirbhai Ranabhai Chetriya	Lamba	Kalyanpur	Dwarka

131	Bheekhubhai Chetriya	Lamba	Kalyanpur	Dwarka
132	Ratnabhai Samthbhai	Navdra	Kalyanpur	Dwarka
133	Harshadbhai Rajsi Suwa	Gurgadh	Kalyanpur	Dwarka
134	Devsibhai Hadabhai Suwa	Gurgadh	Kalyanpur	Dwarka
135	Vechimera Pramod	Gurgadh	Kalyanpur	Dwarka
136	Maheshbhai Kheemabhai Suwa	Gurgadh	Kalyanpur	Dwarka
137	Kheemabhai Hamirbhai Suwa	Gurgadh	Kalyanpur	Dwarka
138	Kanabhai Hamirbhai Suwa	Gurgadh	Kalyanpur	Dwarka
139	Ramdevbhai Kanabhai Suwa	Gurgadh	Kalyanpur	Dwarka
140	Keshubhai Virabhai	Gurgadh	Kalyanpur	Dwarka
141	Nathabhai Bhimabhai	Gurgadh	Kalyanpur	Dwarka
142	Ashish Goraniya	Gorana	Kalyanpur	Dwarka
143	Manojbhai Kanabhai Goraniya	Gorana	Kalyanpur	Dwarka
144	Arbam Mothwadia	Nagdiya	Kalyanpur	Dwarka
145	Jethabhai Jeevabhai Goraniya	Nagdiya	Kalyanpur	Dwarka
146	Nathubhai Parbatbhai	Nagdiya	Kalyanpur	Dwarka
147	Balubhai Ranmalbhai	Nagdiya	Kalyanpur	Dwarka
148	Punjabhai Nagabhai Mothwadia	Nagdiya	Kalyanpur	Dwarka
149	Dilipbhai Ranmalbhai	Nagdiya	Kalyanpur	Dwarka
150	Merakh Desha	Nandana	Kalyanpur	Dwarka
151	Sukhabhai Rajabhai Goraniya	Gorana	Kalyanpur	Dwarka
152	Mukeshbhai Maganbhai	Gorana	Kalyanpur	Dwarka
153	Madhavbhai Jeenabhai Kanjaria	Kalyanpur	Kalyanpur	Dwarka
154	Nathubhai Arjunbhai	Kalyanpur	Kalyanpur	Dwarka
155	Marubhai Chavda	Tankariya	Kalyanpur	Dwarka
156	Babubhai Najabhai	Tankariya	Kalyanpur	Dwarka
157	Kalyanbhai Jethabhai	Tankariya	Kalyanpur	Dwarka
158	Narayanbhai Kagdiya	Tankariya	Kalyanpur	Dwarka
159	Mahadevbhai	Tankariya	Kalyanpur	Dwarka
160	Swadeshbhai Mothwadia	Rawal	Kalyanpur	Dwarka
161	Arjunbhai Goraniya	Gorana	Kalyanpur	Dwarka
162	Bhojabhai Bheeemabhai	Rawal	Kalyanpur	Dwarka
163	Ramdevbhai Bheemabhai	Rawal	Kalyanpur	Dwarka
164	Umarbhai Ganthara	Sodsala	Khambhalia	Dwarka
165	Samin Noor Moh. Bagada	Sodsala	Khambhalia	Dwarka
166	Ali Talab Kungda	Sodsala	Khambhalia	Dwarka
167	Vali Moh. Haaji	Sodsala	Khambhalia	Dwarka
168	Jadeja Narendra	Kuber-Visotri	Khambhalia	Dwarka
169	Jadeja Gopalji Jairajsingh	Visotri	Khambhalia	Dwarka
170	Devendra Singh Jadeja	Visotri	Khambhalia	Dwarka
171	Vejanandbhai Aambliya	Visotri	Khambhalia	Dwarka
172	Jadeja Bhupendra Singh Manubhai	Visotri	Khambhalia	Dwarka
173	Chintanbhai Jadeja	Visotri	Khambhalia	Dwarka
174	Vadotriya Ranmalbhai Nathabhai	Sodsala	Khambhalia	Dwarka

175	Harshibhai Chavda	Sodsala	Khambhalia	Dwarka
176	Salim talab Kungda	Sodsala	Khambhalia	Dwarka
177	Rayabhai Kachrabhai Ghatwi	Sodsala	Khambhalia	Dwarka
178	Naveenbhai Bharay	Sodsala	Khambhalia	Dwarka
179	Kishorbhai Maharaj	Sodsala	Khambhalia	Dwarka
180	Mahendra Singh Chudasma	Visotri	Khambhalia	Dwarka
181	Virendra Singh Guman Singh Jadeja	Visotri	Khambhalia	Dwarka
182	Lalubhai Naval Singh Jadeja	Kuber-Visotri	Khambhalia	Dwarka
183	Kishanbhai Harsadbhai	Sodsala	Khambhalia	Dwarka
184	Nanjibhai Dhanjibhai	Harshadpur	Khambhalia	Dwarka
185	Bharat D. Khandhar	Harshadpur	Khambhalia	Dwarka
186	Research center	Harshadpur	Khambhalia	Dwarka
187	Krishanbhai Rudabhai Chopra	Haripar	Khambhalia	Dwarka
188	Haratchand Hathabhai Jatariya	Haripar	Khambhalia	Dwarka
189	Gaghiya Shailesh Nagabhai	Haripar	Khambhalia	Dwarka
190	Kalubhai Rambhai Gadhvi	Visotri	Khambhalia	Dwarka
191	Sujubhai Abesi	Visotri	Khambhalia	Dwarka
192	Khelubhai Ghati	Gunmohara	Khambhalia	Dwarka
193	Ashokbhai Gadvi	Gunmohara	Khambhalia	Dwarka
194	Karnabhai Vadiya	Ramnagar	Khambhalia	Dwarka
195	Harishbhai Keshavbhai	Khambhalia	Khambhalia	Dwarka
196	Kishorbhai	Ramnagar	Khambhalia	Dwarka
197	Khetambhai Maganbhai	Ramnagar	Khambhalia	Dwarka
198	Dayabhai Govindbhai Kanjaria	Ramnagar	Khambhalia	Dwarka
199	Laxmanbhai Nagjibhai	Harshadpur	Khambhalia	Dwarka
200	Arvindbhai Lohana	Harshadpur	Khambhalia	Dwarka
201	Jadeja Bheekhubhai Gopalji bhai	Harshadpur	Khambhalia	Dwarka
202	Dr Ranmalbhai vadotriya	Harshadpur	Khambhalia	Dwarka
203	Jeshabbhai Lakhabhai	Harshadpur	Khambhalia	Dwarka
204	Kishorbhai Danjibhai Nakum	Harshadpur	Khambhalia	Dwarka
205	Dayabhai	Juvangadh	Khambhalia	Dwarka
206	Rupabhai Lakhabhai	Ramnagar	Khambhalia	Dwarka
207	Mishribhai	Vinjalpar	Khambhalia	Dwarka
208	Jayantibhai Jethabhai	Vinjalpar	Khambhalia	Dwarka
209	Dhaneshbhai	Bhogat	Dwarka	Dwarka
210	Parbatbhai Maldevbhai Gothiya	Bhogat	Dwarka	Dwarka
211	Ranbirbhai	Goji	Dwarka	Dwarka
212	Jigneshbhai	Goji	Dwarka	Dwarka
213	Nagabhai Vejabhai Aambliya	Goji	Dwarka	Dwarka
214	Krishanbhai Sajjanbhai Varu	Goji	Dwarka	Dwarka
215	Devanandbhai Varu	Goji	Dwarka	Dwarka
216	Bhikhabhai Narayanbhai Varu	Gojinesh	Dwarka	Dwarka
217	Bheekhabhai Acharyabhai Manak	Gorinja	Dwarka	Dwarka
218	Pradeepbhai	Gorinja	Dwarka	Dwarka
219	Lalabhai Karshanbhai	Varvala	Dwarka	Dwarka

220	Madhavbhai Jayrambhai Manik	Somalsar	Dwarka	Dwarka
221	Meghabhai Rambhai	Bhimrana	Dwarka	Dwarka
222	Devdasbhai Bhojabhai	Bhimrana	Dwarka	Dwarka
223	Manojbhai Kanjibhai	Hamusar	Dwarka	Dwarka
224	Ramsinghbhai Samatbhai	Goji	Dwarka	Dwarka
225	Kachrabhai Devsibhai	Somalsar	Dwarka	Dwarka
226	Govindbhai Punjabhai	Somalsar	Dwarka	Dwarka
227	Ishagbhai Asanbhai Chavda	Somalsar	Dwarka	Dwarka
228	Hamirbhai Polabhai	Somalsar	Dwarka	Dwarka
229	Bhikabhai parbatbhai	Somalsar	Dwarka	Dwarka
230	Idris Mamdni	Varvala	Okha	Dwarka
231	Yusuf Salman Mamdni	Varvala	Okha	Dwarka
232	Mandalbhai Sidhubhai Manik	Samlasar	Okha	Dwarka
233	Arjunbhai Narayanbhai	Varvala	Okha	Dwarka
234	Hadaba Ketabhai Manik	Runidra	Dwarka	Dwarka
235	Rajbhai Manak	Runidra	Dwarka	Dwarka
236	Ninthabhai Ramabhai Bhegada	Lovrali	Dwarka	Dwarka
237	Nanubhai Vallabhbhai	Nagheswar	Dwarka	Dwarka
238	Keshubhai	Nagheswar	Dwarka	Dwarka
239	Babubhai Najabhai	Tupni	Dwarka	Dwarka
240	Jadhavbhai Masribhai	Tupni	Dwarka	Dwarka
241	Jivabhai Aatabhai	Lovrali	Dwarka	Dwarka
242	Dayabhai Vasabhai	Lovrali	Dwarka	Dwarka
243	Raghubhai Danabhai	Tupni	Dwarka	Dwarka
244	Dineshbhai Kalyanbhai	Tupni	Dwarka	Dwarka
245	Pratapbhai Kesubhai	Kuchhadi	Porbander	Porbander
246	Nagabhai Kanabhai Kuchhadiya	Kuchhadi	Porbander	Porbander
247	Prabatsar Das Kuchhadiya	Kuchhadi	Porbander	Porbander
248	Prabatsar Das Kuchhadiya	Kuchhadi	Porbander	Porbander
249	Dulabhai Devsibhai Keshwala	Ratdi	Porbander	Porbander
250	Arjunbhai Kerwala	Kantela	Porbander	Porbander
251	Bhayabhai Mashribhai	Ratdi	Porbander	Porbander
252	Keshwala Oghadbhai	Visavada	Porbander	Porbander
253	Sukabhai M. Odedra	Visavada	Porbander	Porbander
254	Rajabhai Bhutiya	Kantela	Porbander	Porbander
255	Arjunbhai Vedhabhai Keshwala	Kuchhadi	Porbander	Porbander
256	Nagabhai Vikrambhai Odedra	Kuchhadi	Porbander	Porbander
257	Chhagan bhai Odedra	Kuchhadi	Porbander	Porbander
258	Agri. Farm	Khapat	Porbander	Porbander
259	Kesubhai Bhurabhai Mothwadiya	Hathiyani	Porbander	Porbander
260	Bheemabhai Mothwadiya	Sukhpur	Porbander	Porbander
261	Devabhai Keshabhai Mothwadiya	Sukhpur	Porbander	Porbander
262	Bharatbhai Ramdevbhai	Sukhpur	Porbander	Porbander
263	Maldevbhai Mishribhai	Sukhpur	Porbander	Porbander
264	Jivabhai Mashribhai	Sukhpur	Porbander	Porbander

265	Balubhai Hawabhai Mothwadia	Ambarama	Porbander	Porbander
266	Ramalbhai	Ambarama	Porbander	Porbander
267	Chhaganbhai Mulabhai	Sukhpur	Porbander	Porbander
268	Jethabhai Devsibhai	Palkhada	Porbander	Porbander
269	Sarmanbhai kalabhai	Palkhada	Porbander	Porbander
270	Nathabhai Swadeshbhai Khooti	Bakhrla	Porbander	Porbander
271	Merkhiraja Khooti	Bakhrla	Porbander	Porbander
272	Keshubhai Nagabhai Khooti	Bakhrla	Porbander	Porbander
273	Samadbhai Jadhavbhai Kodidra	Bakhrla	Porbander	Porbander
274	Prabatbhai Maldevbhai	Bakhrla	Porbander	Porbander
275	Kheemabhai Popatbhai Mandera	Katwana	Porbander	Porbander
276	Bheemabhai Bhurabhai Khooti	Katwana	Porbander	Porbander
277	Kanabhai Ramsibhai	Boricha	Porbander	Porbander
278	Katara Punjabhai Amrabhai	Katwana	Porbander	Porbander
279	Katara Bharatbhai Amrabhai	Katwana	Porbander	Porbander
280	Devsibhai Ranmalbhai Khooti	Katwana	Porbander	Porbander
281	Kheemabhai Geegabhai Khooti	Boricha	Porbander	Porbander
282	Samadbhai Parbatbhai Kodidra	Bakhrla	Porbander	Porbander
283	Babubhai Ramabhai Bhariya	Boricha	Porbander	Porbander
284	Vejabhai Arsibhai Odedra	Boricha	Porbander	Porbander
285	Bhayabhai Laxmanbhai	Katwana	Porbander	Porbander

Appendix VI: Talukawise EC (dS m^{-1}), pH cations, anions and different water quality indices of pre-monsoon well/tube well water samples of Northern Saurashtra coastal region (May, 2019)

Lab. No.	EC (dS m^{-1})	pH	Cation in me L^{-1}				Anion in me L^{-1}				Indices		
			Na^{+}	K^{+}	Ca^{++}	Mg^{++}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}	SSP	SAR	RSC (me L^{-1})
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	2.35	7.63	8.21	0.00	11.10	7.50	2.20	7.43	28.86	0.02	30.62	2.69	0.00
2	3.72	6.76	18.90	0.00	14.50	7.10	0.00	2.40	20.38	0.19	46.67	5.75	0.00
3	2.85	7.69	8.71	0.00	7.20	5.60	2.40	5.20	19.30	0.02	40.49	3.44	0.00
4	4.06	7.50	15.23	0.01	8.20	10.02	0.00	1.40	33.10	0.17	45.52	5.05	0.00
5	2.67	7.40	22.67	0.17	7.50	16.70	1.80	3.70	24.00	0.05	48.19	6.52	0.00
6	5.59	6.87	34.66	0.16	18.30	12.02	0.00	2.10	61.02	0.24	53.21	8.90	0.00
7	2.56	7.29	6.53	0.05	4.12	5.70	1.30	2.60	17.68	0.01	39.82	2.95	0.00
8	3.30	7.40	8.87	0.00	10.60	6.27	0.00	2.70	30.40	0.06	34.46	3.05	0.00
9	2.42	7.60	10.52	0.05	4.70	2.88	1.70	3.70	18.62	0.01	57.96	5.40	0.00
10	1.27	6.72	10.37	0.00	4.80	5.50	0.00	2.60	16.30	0.06	50.17	4.57	0.00
11	2.47	6.45	23.84	0.00	6.35	6.00	0.00	3.10	21.70	0.10	65.87	9.59	0.00
12	4.14	7.33	6.90	0.00	13.50	11.50	0.00	1.20	18.70	0.03	21.63	1.95	0.00
13	2.89	6.72	7.11	0.00	4.60	2.56	0.00	4.20	23.82	0.03	49.82	3.76	0.00
14	1.34	7.36	4.60	0.00	4.85	4.50	0.40	2.08	20.12	0.06	32.97	2.13	0.00
15	2.13	7.09	6.24	0.00	3.50	5.50	0.60	1.71	17.30	0.04	40.94	2.94	0.00
16	2.01	7.08	6.91	0.00	4.67	4.50	0.50	5.10	14.17	0.01	42.97	3.23	0.00
17	2.01	7.18	5.06	0.00	3.50	6.14	0.70	3.40	15.10	0.13	34.42	2.30	0.00
18	1.53	7.32	6.89	0.00	4.50	3.54	1.20	4.80	28.20	0.01	46.15	3.44	0.00
19	2.61	7.24	31.34	0.03	2.50	6.00	0.40	3.10	24.10	0.05	78.61	15.20	0.00
20	2.09	7.09	7.05	0.02	10.87	9.00	0.90	4.04	37.00	0.02	26.17	2.24	0.00
21	3.54	6.86	19.23	0.02	6.50	7.50	0.60	1.90	43.34	0.09	57.83	7.27	0.00
22	2.91	7.20	16.26	0.03	4.00	7.50	0.00	3.50	27.51	0.03	58.51	6.78	0.00
23	2.31	7.30	6.45	0.00	6.78	10.05	0.00	4.70	28.60	0.04	27.71	2.22	0.00
24	2.97	7.30	22.06	0.00	5.50	7.00	0.00	2.90	15.04	0.02	63.83	8.82	0.00

25	3.82	6.90	7.14	0.02	13.52	11.17	0.00	1.38	15.70	0.05	22.42	2.03	0.00
26	2.72	7.20	5.32	0.03	3.00	6.50	0.00	2.40	16.10	0.04	35.83	2.44	0.00
27	2.81	6.80	15.64	0.01	13.00	8.57	0.60	2.00	17.30	0.08	42.02	4.76	0.00
28	1.44	7.40	18.16	0.02	3.00	3.00	1.30	2.41	14.80	0.01	75.12	10.48	0.00
29	1.43	7.40	7.24	0.02	2.00	4.00	1.30	2.45	15.05	0.07	54.61	4.18	0.00
30	2.46	7.10	10.12	0.03	2.50	3.50	1.40	1.60	16.40	0.01	62.66	5.84	0.00
31	3.16	7.10	19.23	0.02	8.50	11.86	0.90	5.78	16.06	0.03	48.55	6.03	0.00
32	2.58	6.69	11.97	0.00	5.00	5.50	0.00	2.60	24.80	0.04	53.27	5.22	0.00
33	0.77	7.80	5.64	0.04	2.92	3.50	0.31	3.06	13.62	0.01	46.60	3.15	0.00
34	2.98	7.14	24.55	0.02	8.40	6.20	0.00	2.10	28.20	0.06	62.67	9.09	0.00
35	2.66	6.77	13.47	0.01	10.60	3.40	0.00	1.70	9.16	0.08	49.02	5.09	0.00
36	1.77	7.41	5.92	0.00	5.60	4.50	0.52	1.04	19.40	0.03	36.95	2.63	0.00
37	1.85	6.59	18.60	0.01	1.70	4.80	0.70	1.60	12.60	0.02	74.07	10.32	0.00
38	1.04	7.58	5.91	0.00	3.90	9.10	0.26	1.78	15.40	0.01	31.25	2.32	0.00
39	2.32	7.18	9.07	0.01	3.12	3.40	0.00	4.50	13.62	0.04	58.14	5.02	0.00
40	1.59	7.29	9.93	0.02	3.02	2.60	1.00	2.08	20.15	0.01	63.80	5.92	0.00
41	2.02	7.40	6.85	0.02	4.50	2.34	0.24	3.00	18.29	0.01	49.95	3.70	0.00
42	1.87	6.80	6.28	0.00	3.50	6.04	0.30	2.28	15.30	0.03	39.70	2.88	0.00
43	0.90	7.60	8.03	0.03	1.64	2.60	0.40	0.92	12.40	0.01	65.28	5.52	0.00
44	2.10	6.80	3.77	0.02	2.00	4.14	0.00	2.31	12.70	0.07	37.97	2.15	0.00
45	0.57	7.54	3.88	0.03	1.54	4.80	0.26	2.37	6.55	0.01	37.85	2.18	0.00
46	1.14	7.56	3.70	0.00	2.90	1.50	0.00	2.56	12.90	0.02	45.68	2.49	0.00
47	1.23	7.34	8.18	0.04	2.70	2.60	0.00	3.64	9.90	0.03	60.50	5.02	0.00
48	1.86	7.10	18.33	0.00	3.82	2.10	0.00	0.67	19.54	0.04	75.59	10.65	0.00
49	1.77	7.30	8.64	0.03	2.00	1.60	0.00	2.80	8.65	0.01	70.44	6.44	0.00
50	1.58	7.10	5.05	0.00	3.84	3.74	0.00	1.69	9.63	0.02	39.98	2.59	0.00
51	1.03	7.30	6.37	0.02	4.50	4.00	0.00	2.30	10.87	0.01	42.78	3.09	0.00
52	1.76	7.40	9.62	0.00	2.00	1.75	0.00	1.70	8.40	0.03	71.95	7.03	0.00
53	1.54	7.50	10.26	0.02	2.13	1.86	0.21	1.30	11.75	0.02	71.90	7.26	0.00
54	1.47	7.60	9.30	0.03	2.87	3.00	0.00	2.54	17.85	0.04	61.18	5.43	0.00
55	3.88	6.95	24.35	0.28	20.05	17.50	0.80	4.40	47.17	0.12	39.16	5.62	0.00

56	6.05	7.15	37.52	0.15	7.02	10.25	0.60	3.00	55.20	0.09	68.29	12.77	0.00
57	4.43	6.62	13.09	0.04	5.46	6.54	0.70	4.00	38.40	0.10	52.09	5.34	0.00
58	3.02	6.99	12.85	0.04	6.26	6.14	0.00	4.00	28.45	0.07	50.81	5.16	0.00
59	3.90	6.70	8.75	0.06	7.58	6.70	0.90	5.40	35.17	0.07	37.90	3.27	0.00
60	4.57	6.80	12.32	0.04	10.50	11.70	1.30	5.80	15.10	0.09	35.65	3.70	0.00
61	2.22	7.00	14.92	0.02	5.25	9.00	1.40	5.00	15.20	0.04	51.11	5.59	0.00
62	1.28	6.90	8.24	0.05	13.33	11.40	0.70	8.40	23.48	0.04	24.95	2.34	0.00
63	1.23	7.20	12.74	0.02	5.41	9.60	2.10	3.20	18.00	0.03	45.88	4.65	0.00
64	1.65	7.50	9.82	0.06	5.30	4.50	2.60	4.00	16.90	0.02	49.90	4.44	0.00
65	2.76	7.10	18.72	0.04	8.00	4.86	0.70	4.60	19.03	0.08	59.20	7.38	0.00
66	5.01	7.10	17.77	0.03	7.12	8.11	0.80	4.60	18.12	0.07	53.80	6.44	0.00
67	2.74	7.20	13.40	0.02	14.20	9.28	0.00	5.20	12.80	0.02	36.32	3.91	0.00
68	2.31	7.07	15.61	0.02	6.51	7.96	0.00	4.06	23.60	0.10	51.86	5.80	0.00
69	4.03	7.10	18.06	0.03	10.50	7.41	0.00	4.12	18.40	0.09	50.17	6.04	0.00
70	4.07	7.06	13.56	0.01	5.00	11.50	0.60	4.20	13.00	0.06	45.09	4.72	0.00
71	4.29	7.50	32.16	0.13	6.01	4.20	0.80	3.11	46.30	0.05	75.68	14.23	0.00
72	1.70	7.69	7.97	0.14	16.40	12.20	1.70	6.04	22.60	0.01	21.71	2.11	0.00
73	1.80	6.82	11.19	0.06	5.02	4.83	0.50	3.15	24.30	0.09	53.03	5.04	0.00
74	3.01	6.91	10.13	0.12	5.74	9.50	0.40	3.16	32.01	0.08	39.74	3.67	0.00
75	3.02	6.59	8.33	0.07	4.89	5.96	0.80	4.08	16.40	0.08	43.26	3.58	0.00
76	2.77	7.18	14.37	0.02	6.09	4.50	1.30	4.20	15.10	0.07	57.54	6.24	0.00
77	2.24	6.90	9.26	0.02	5.12	6.97	0.00	2.60	28.30	0.05	43.34	3.77	0.00
78	2.18	6.80	11.13	0.02	6.20	5.28	0.40	4.10	33.19	0.06	49.18	4.65	0.00
79	2.47	7.30	12.34	0.04	6.68	8.00	0.30	3.13	23.17	0.03	45.60	4.55	0.00
80	2.74	7.07	8.40	0.03	4.92	4.33	0.20	2.40	19.30	0.07	47.50	3.91	0.00
81	1.64	7.50	9.58	0.04	5.14	4.13	0.50	5.04	15.17	0.02	50.71	4.45	0.00
82	1.44	7.09	6.92	0.03	2.78	7.71	0.00	3.40	12.40	0.08	39.67	3.02	0.00
83	2.66	7.36	14.33	0.05	3.71	3.02	0.42	4.20	21.89	0.06	67.88	7.81	0.00
84	2.04	7.25	7.58	0.02	6.25	3.98	0.35	4.50	23.16	0.02	42.51	3.35	0.00
85	0.82	7.90	5.24	0.01	7.76	4.84	0.84	1.60	9.17	0.03	29.36	2.09	0.00
86	2.75	7.17	20.87	0.05	1.62	4.12	0.32	4.10	14.20	0.03	78.28	12.32	0.00

87	1.88	7.03	8.89	0.02	2.53	3.03	0.24	4.80	9.60	0.04	61.43	5.33	0.00
88	1.09	7.30	5.11	0.01	1.08	3.50	0.54	1.40	8.71	0.01	52.68	3.38	0.00
89	1.86	7.90	10.76	0.03	3.15	4.85	0.47	1.56	11.31	0.04	57.26	5.38	0.00
90	1.88	7.75	7.76	0.04	4.00	1.38	0.00	2.80	13.44	0.05	58.88	4.73	0.00
91	0.64	7.93	4.59	0.01	1.86	2.47	0.21	2.04	6.03	0.03	51.39	3.12	0.00
92	0.89	7.60	5.94	0.01	4.94	1.50	0.18	2.50	12.90	0.01	47.94	3.31	0.00
93	1.94	7.20	13.67	0.02	1.60	3.86	0.00	2.90	15.26	0.02	71.39	8.27	0.00
94	2.78	6.90	6.97	0.00	3.50	3.40	0.00	4.50	21.68	0.05	50.25	3.75	0.00
95	2.06	7.27	9.15	0.00	3.60	4.60	0.89	4.70	12.10	0.06	52.74	4.52	0.00
96	1.44	6.84	8.35	0.00	3.50	6.50	0.60	3.70	18.26	0.04	45.50	3.73	0.00
97	1.71	7.19	9.69	0.00	10.10	5.78	1.40	4.20	5.40	0.02	37.90	3.44	0.00
98	2.89	7.16	12.87	0.00	4.68	5.50	1.10	4.70	10.50	0.06	55.84	5.70	0.00
99	1.71	7.32	8.66	0.00	3.42	6.57	1.70	5.10	15.37	0.02	46.43	3.87	0.00
100	1.11	7.61	4.92	0.00	2.15	4.39	1.00	3.40	4.60	0.03	42.93	2.72	0.00
101	0.87	7.26	6.17	0.00	5.67	6.85	1.60	7.10	5.08	0.01	33.00	2.47	0.00
102	0.79	7.19	7.72	0.00	2.21	4.37	1.70	7.80	7.90	0.01	53.99	4.26	2.92
103	2.46	7.30	12.20	0.00	2.46	2.40	0.00	4.20	18.23	0.02	71.51	7.83	0.00
104	0.63	7.18	6.54	0.02	3.06	5.70	1.20	4.72	11.21	0.01	42.68	3.12	0.00
105	0.97	7.25	4.59	0.00	2.81	6.20	0.90	3.41	17.20	0.01	33.75	2.16	0.00
106	0.95	7.34	4.68	0.00	5.60	5.60	0.80	6.80	3.20	0.02	29.47	1.98	0.00
107	1.55	7.60	5.59	0.00	2.15	6.50	0.40	4.35	12.40	0.03	39.26	2.69	0.00
108	1.14	8.47	11.48	0.00	5.10	4.60	0.30	5.10	15.67	0.02	54.20	5.21	0.00
109	1.37	7.67	9.30	0.00	2.42	3.10	0.00	2.71	7.30	0.05	62.75	5.60	0.00
110	2.82	7.25	6.74	0.00	3.15	3.10	0.50	3.90	12.08	0.06	51.89	3.81	0.00
111	2.34	7.53	5.56	0.00	2.21	2.60	0.00	3.10	3.74	0.04	53.62	3.59	0.00
112	0.92	7.50	5.66	0.00	4.03	4.20	0.70	3.48	3.52	0.01	40.75	2.79	0.00
113	1.03	7.20	3.59	0.00	4.57	2.60	0.50	4.61	2.75	0.02	33.36	1.90	0.00
114	1.12	7.10	2.47	0.00	3.28	1.60	0.40	4.50	4.86	0.01	33.61	1.58	0.02
115	0.87	7.20	3.64	0.00	7.54	5.40	0.00	3.80	4.89	0.01	21.95	1.43	0.00
116	1.52	7.10	7.01	0.00	2.04	1.20	0.00	4.60	5.51	0.03	68.37	5.51	1.36
117	1.07	7.30	3.06	0.00	3.10	2.30	0.00	5.70	7.04	0.01	36.17	1.86	0.30

118	0.88	7.20	2.62	0.01	1.84	2.70	0.00	6.40	6.57	0.01	36.57	1.74	1.86
119	0.37	7.19	4.63	0.05	5.64	3.40	0.00	6.70	6.26	0.01	33.74	2.18	0.00
120	1.24	7.40	5.48	0.00	1.80	2.70	0.00	4.70	0.94	0.02	54.91	3.65	0.20
121	1.51	7.10	5.67	0.00	3.16	2.90	0.60	3.80	10.67	0.03	48.34	3.26	0.00
122	0.90	8.00	3.62	0.02	2.18	4.69	0.00	2.40	3.87	0.01	34.46	1.95	0.00
123	1.16	7.40	1.34	0.00	1.60	1.20	0.00	4.20	6.78	0.02	32.37	1.13	1.40
124	2.32	7.15	16.17	0.03	4.00	5.50	2.00	4.00	12.00	0.01	62.92	7.42	0.00
125	6.98	7.10	6.36	0.02	12.50	12.50	2.47	5.80	21.50	0.07	20.27	1.80	0.00
126	3.31	7.24	12.92	0.01	13.00	11.00	1.60	8.20	29.70	0.06	34.99	3.73	0.00
127	2.64	7.20	15.98	0.01	5.00	8.00	2.80	9.32	17.90	0.02	55.12	6.27	0.00
128	7.35	6.90	16.89	0.03	24.60	10.40	1.64	4.60	54.60	0.08	32.53	4.04	0.00
129	2.37	7.31	26.79	0.03	5.00	7.00	1.20	5.74	18.50	0.01	69.01	10.94	0.00
130	3.17	7.03	13.73	0.03	4.00	4.50	1.68	8.40	11.30	0.04	61.68	6.66	1.58
131	1.33	7.16	23.08	0.04	9.00	2.00	1.20	4.60	34.10	0.02	67.64	9.84	0.00
132	1.55	7.19	30.21	0.06	2.50	7.50	2.40	17.00	24.20	0.01	75.02	13.51	9.40
133	5.98	6.90	26.95	0.14	2.00	7.50	2.67	8.20	39.40	0.04	73.65	12.37	1.37
134	4.16	7.20	17.89	0.03	13.50	8.84	1.20	6.20	26.50	0.06	44.44	5.35	0.00
135	1.04	6.70	12.44	0.06	22.60	7.10	0.80	7.60	15.90	0.05	29.48	3.23	0.00
136	1.11	7.30	9.16	0.03	2.00	3.26	2.40	6.00	13.51	0.01	63.37	5.65	3.14
137	2.28	7.04	7.64	0.03	4.56	4.50	2.40	11.20	8.10	0.02	45.66	3.59	4.54
138	1.03	7.38	9.09	0.10	5.45	4.57	0.80	3.80	7.50	0.02	47.31	4.06	0.00
139	2.54	7.21	12.29	0.69	2.50	5.91	0.80	7.20	12.60	0.01	57.45	5.99	0.00
140	2.21	7.00	8.62	0.02	3.60	2.50	0.90	6.20	11.30	0.01	58.47	4.94	1.00
141	1.65	7.10	10.48	0.02	2.80	2.40	0.60	4.40	10.71	0.01	66.77	6.50	0.00
142	1.56	6.91	4.96	0.05	2.03	2.80	0.80	5.31	15.30	0.01	50.39	3.19	1.28
143	0.74	6.79	8.12	0.02	3.10	5.87	1.20	4.80	4.60	0.08	47.46	3.83	0.00
144	1.37	7.31	3.74	0.05	3.05	5.20	0.00	4.78	12.10	0.04	31.05	1.84	0.00
145	4.70	6.77	21.67	0.02	13.20	2.80	2.40	7.04	32.80	0.09	57.50	7.66	0.00
146	2.21	7.12	8.51	0.06	3.06	4.60	1.60	5.86	9.04	0.03	52.44	4.35	0.00
147	1.64	6.59	6.87	0.01	4.56	4.80	0.80	3.20	14.58	0.05	42.29	3.18	0.00
148	2.65	7.02	14.87	0.04	4.40	5.26	0.00	6.59	15.62	0.04	60.52	6.77	0.00

149	1.89	6.72	12.72	0.03	5.70	4.60	0.00	5.50	10.97	0.02	55.19	5.61	0.00
150	0.89	6.60	13.48	0.01	2.10	3.30	0.00	4.48	5.68	0.01	71.36	8.20	0.00
151	0.49	7.24	3.01	0.00	2.10	2.20	2.00	9.20	1.10	0.01	41.18	2.05	6.90
152	0.77	7.00	3.75	0.02	1.47	2.80	0.00	6.60	2.80	0.02	46.66	2.57	2.33
153	1.74	7.30	7.68	0.00	1.48	3.00	0.80	5.40	7.56	0.02	63.16	5.13	1.72
154	0.84	7.10	5.02	0.02	3.50	4.50	0.00	6.20	5.60	0.02	38.51	2.51	0.00
155	1.52	7.60	4.61	0.00	5.00	4.10	0.60	4.80	3.40	0.01	33.63	2.16	0.00
156	3.04	7.00	6.51	0.00	3.00	3.50	0.00	3.70	26.60	0.04	50.04	3.61	0.00
157	2.61	6.70	5.25	0.02	6.05	4.80	0.70	3.20	19.70	0.05	32.57	2.25	0.00
158	1.72	6.90	9.74	0.00	4.50	4.50	0.60	2.40	7.74	0.04	51.97	4.59	0.00
159	0.61	7.10	10.32	0.00	1.50	2.70	0.00	5.30	2.86	0.01	71.07	7.12	1.10
160	1.53	7.00	12.62	0.00	3.50	4.60	0.00	5.70	8.93	0.02	60.91	6.27	0.00
161	0.74	7.10	5.34	0.02	2.27	3.50	0.00	4.60	4.20	0.03	47.97	3.14	0.00
162	0.93	7.30	3.92	0.00	1.30	4.50	0.00	6.10	2.30	0.01	40.33	2.30	0.30
163	0.51	7.10	5.21	0.01	1.56	4.10	1.20	4.70	2.48	0.01	47.91	3.10	0.24
164	4.07	7.01	15.86	0.07	10.50	6.12	0.80	9.20	30.05	0.07	48.73	5.50	0.00
165	4.16	7.12	33.75	0.03	7.20	6.48	0.00	11.04	37.40	0.04	71.11	12.90	0.00
166	3.85	7.10	25.87	0.00	11.10	6.90	0.60	7.62	19.68	0.06	58.97	8.62	0.00
167	4.87	6.80	29.37	0.05	9.60	6.23	0.40	8.46	42.57	0.07	64.91	10.44	0.00
168	0.95	7.29	7.32	0.01	3.50	5.40	0.00	6.54	10.02	0.02	45.10	3.47	0.00
169	2.00	6.88	6.96	0.04	3.10	4.50	0.00	3.08	7.23	0.04	47.66	3.57	0.00
170	0.86	6.99	4.02	0.03	4.20	3.60	0.40	5.26	4.70	0.01	33.93	2.04	0.00
171	1.54	7.21	13.54	0.07	8.50	2.10	0.00	3.40	27.01	0.01	55.94	5.88	0.00
172	0.81	7.24	7.71	0.00	3.00	3.00	0.00	6.27	4.72	0.01	56.22	4.45	0.27
173	2.76	7.20	26.63	0.03	1.50	4.10	0.00	3.67	30.05	0.04	82.56	15.91	0.00
174	1.51	7.31	3.48	0.20	4.00	4.60	0.00	4.82	5.30	0.01	28.34	1.68	0.00
175	3.03	6.79	21.49	0.05	5.00	4.80	0.00	6.32	16.20	0.05	68.58	9.71	0.00
176	3.51	6.58	11.77	0.02	4.20	3.40	0.00	6.64	11.20	0.07	60.72	6.04	0.00
177	1.76	7.05	8.23	0.03	2.60	5.80	0.00	4.57	7.10	0.04	49.39	4.02	0.00
178	2.23	6.99	8.40	0.12	5.00	4.70	1.20	3.60	9.71	0.07	46.10	3.81	0.00
179	0.36	8.18	2.58	0.05	3.00	4.00	0.00	9.40	4.93	0.01	26.79	1.38	2.40

180	1.55	7.52	10.16	0.00	2.80	6.00	0.00	4.46	34.70	0.02	53.58	4.84	0.00
181	1.62	7.24	5.29	0.00	3.50	6.20	0.00	3.90	6.50	0.03	35.29	2.40	0.00
182	2.01	7.30	11.30	0.01	4.50	5.10	2.00	4.20	21.16	0.03	54.04	5.16	0.00
183	2.34	7.40	6.03	0.00	5.00	2.30	0.00	3.24	5.70	0.01	45.23	3.16	0.00
184	1.53	7.47	6.77	0.02	5.20	4.78	0.00	4.87	3.71	0.04	40.38	3.03	0.00
185	3.05	6.93	21.29	0.05	4.02	3.60	0.00	7.77	11.89	0.02	73.52	10.91	0.15
186	1.76	7.67	8.65	0.00	4.30	5.62	0.86	2.30	9.90	0.05	46.58	3.88	0.00
187	2.83	6.70	4.92	0.06	6.42	2.70	0.00	3.10	20.64	0.01	34.89	2.30	0.00
188	1.14	7.12	16.36	0.02	2.50	2.10	0.00	7.24	16.48	0.03	77.97	10.79	2.64
189	0.47	7.53	4.56	0.01	1.70	1.40	0.54	4.03	5.87	0.01	59.43	3.66	1.47
190	1.29	7.67	9.38	0.01	2.50	2.30	0.21	5.74	7.78	0.02	66.10	6.05	1.15
191	0.84	7.52	2.61	0.01	1.80	2.68	0.00	2.21	12.73	0.01	36.77	1.74	0.00
192	0.76	7.81	9.56	0.01	2.52	3.57	0.46	4.40	6.71	0.02	61.06	5.48	0.00
193	0.25	7.77	3.78	0.00	0.90	1.50	0.00	5.01	2.40	0.00	61.17	3.45	2.61
194	0.95	7.39	6.72	0.02	2.31	1.50	0.00	6.89	6.00	0.01	63.68	4.87	3.08
195	1.22	7.80	10.28	0.00	2.47	4.50	0.43	5.67	1.70	0.01	59.58	5.51	0.00
196	1.41	6.90	4.12	0.04	2.50	1.40	0.00	4.42	5.00	0.02	51.11	2.95	0.52
197	0.92	7.50	9.42	0.03	3.50	2.50	0.74	4.88	7.21	0.04	60.96	5.44	0.00
198	1.07	7.19	5.37	0.03	2.80	3.00	0.00	3.24	6.10	0.03	47.95	3.15	0.00
199	1.64	7.27	8.49	0.05	1.70	1.60	0.20	5.80	2.26	0.01	71.70	6.61	2.70
200	1.74	7.55	5.21	0.02	2.60	1.20	0.00	1.16	5.30	0.02	57.69	3.78	0.00
201	0.88	7.24	1.29	0.05	2.30	1.40	0.00	1.28	11.37	0.02	25.61	0.95	0.00
202	0.26	7.35	3.27	0.04	2.23	1.70	0.52	6.20	6.00	0.03	45.19	2.33	2.79
203	1.68	7.50	8.38	0.00	3.46	2.78	0.41	7.07	7.50	0.01	57.30	4.74	1.24
204	1.17	7.72	5.59	0.02	1.70	2.30	0.34	2.80	7.10	0.02	58.19	3.95	0.00
205	0.71	7.20	4.60	0.00	1.80	1.50	0.00	5.40	3.34	0.01	58.23	3.58	2.10
206	0.57	7.80	1.57	0.00	2.00	0.90	0.00	6.70	1.40	0.01	35.12	1.30	3.80
207	0.68	7.70	5.54	0.00	1.37	1.30	0.00	6.20	0.90	0.01	67.48	4.79	3.53
208	1.04	7.60	3.98	0.05	1.50	1.00	0.00	4.30	3.28	0.02	60.99	3.56	1.80
209	5.94	6.97	26.71	0.18	7.54	7.26	0.00	7.74	39.30	0.06	64.07	9.82	0.00
210	2.79	6.99	24.35	0.19	8.26	10.34	0.63	4.00	49.28	0.04	56.44	7.98	0.00

211	4.27	6.75	19.19	0.15	6.50	8.59	0.41	7.00	23.70	0.07	55.74	6.99	0.00
212	2.78	7.23	26.52	0.34	8.47	6.25	0.42	9.65	27.80	0.04	63.78	9.78	0.00
213	3.18	6.86	18.42	0.36	6.74	9.87	0.00	10.82	22.34	0.07	52.05	6.39	0.00
214	3.95	7.48	34.46	0.21	4.68	7.50	0.77	5.60	16.84	0.05	73.55	13.96	0.00
215	2.47	7.26	22.54	0.16	4.50	5.50	0.00	6.60	23.95	0.06	68.93	10.08	0.00
216	3.38	7.36	19.71	0.14	5.57	10.50	0.21	12.37	31.24	0.05	54.87	6.95	0.00
217	2.51	7.25	13.68	0.30	8.77	12.57	0.26	10.06	40.12	0.05	38.73	4.19	0.00
218	2.18	6.80	12.03	0.48	4.50	4.00	0.00	5.62	17.70	0.03	57.26	5.84	0.00
219	2.15	7.10	10.32	0.27	9.17	11.03	0.00	7.69	29.13	0.05	33.52	3.25	0.00
220	3.05	6.70	10.48	0.12	4.69	9.50	0.20	6.40	15.65	0.07	42.28	3.93	0.00
221	5.47	6.90	20.52	0.21	7.00	12.00	0.50	8.12	30.47	0.06	51.65	6.66	0.00
222	2.77	6.90	18.26	0.18	8.35	11.17	0.00	7.30	31.24	0.07	48.10	5.84	0.00
223	3.74	6.80	9.74	0.09	4.66	4.50	0.52	8.20	10.21	0.08	51.29	4.55	0.00
224	4.65	7.00	10.24	0.06	8.85	5.47	0.00	11.46	30.38	0.04	41.59	3.83	0.00
225	1.74	7.40	10.47	0.12	5.00	3.00	0.00	6.10	13.82	0.02	56.32	5.24	0.00
226	2.83	7.10	11.35	0.16	7.59	8.50	0.20	9.36	15.40	0.03	41.12	4.00	0.00
227	4.41	7.10	11.02	0.07	8.00	4.28	0.00	3.40	23.71	0.04	47.15	4.45	0.00
228	1.94	7.40	12.69	0.20	4.50	10.00	0.48	10.57	14.10	0.02	46.33	4.71	0.00
229	4.02	7.30	18.31	0.17	7.48	9.50	0.74	8.30	23.94	0.03	51.64	6.28	0.00
230	3.88	6.91	26.41	0.38	9.54	11.54	0.00	3.20	34.65	0.09	55.17	8.13	0.00
231	4.83	6.85	14.50	0.47	6.50	7.50	0.23	4.80	16.24	0.08	50.05	5.48	0.00
232	2.48	7.42	21.70	0.16	3.50	9.00	0.41	6.40	32.10	0.02	63.15	8.68	0.00
233	1.36	6.90	26.06	0.12	4.88	7.00	0.10	7.10	18.72	0.03	68.47	10.69	0.00
234	2.49	7.20	16.22	0.08	2.00	8.50	0.13	12.63	8.03	0.04	60.51	7.08	2.26
235	1.04	7.42	19.43	0.18	2.00	5.00	0.06	6.28	12.27	0.04	73.02	10.39	0.00
236	1.60	7.13	20.54	0.06	3.00	5.50	0.41	9.21	18.24	0.01	70.59	9.96	1.12
237	1.84	7.00	8.31	0.11	2.50	5.50	0.00	4.28	9.62	0.02	50.62	4.16	0.00
238	3.16	7.10	15.21	0.09	2.50	4.00	0.15	7.67	34.51	0.05	69.76	8.44	1.32
239	4.27	6.90	11.62	0.12	5.00	11.67	0.00	7.05	8.41	0.06	40.90	4.02	0.00
240	3.06	7.00	9.26	0.09	3.00	6.00	0.36	8.31	14.63	0.04	50.46	4.37	0.00
241	1.94	7.20	13.59	0.05	3.10	4.20	0.00	5.52	21.47	0.01	64.89	7.11	0.00

242	1.84	7.10	16.02	0.06	4.00	4.30	0.00	8.24	14.27	0.02	65.71	7.86	0.00
243	2.13	7.40	11.26	0.08	4.47	7.03	0.18	4.77	17.82	0.03	49.30	4.70	0.00
244	1.03	7.86	4.32	0.05	1.36	2.44	0.00	1.69	6.50	0.02	52.85	3.13	0.00
245	6.03	6.82	22.67	0.09	11.50	12.87	0.60	5.41	29.90	0.05	48.10	6.49	0.00
246	2.68	6.85	8.84	0.03	9.60	12.00	0.80	3.82	18.41	0.07	29.01	2.69	0.00
247	3.85	7.48	37.45	0.82	7.00	10.00	0.70	4.62	44.18	0.08	67.76	12.85	0.00
248	4.03	7.04	10.24	0.14	7.50	8.50	0.70	6.83	10.22	0.07	38.82	3.62	0.00
249	2.02	6.92	22.73	0.41	4.50	7.50	0.80	9.10	32.50	0.10	64.68	9.28	0.00
250	2.54	7.45	19.25	0.09	15.64	12.50	1.60	4.20	29.71	0.04	40.54	5.13	0.00
251	2.07	7.61	10.02	1.56	2.50	7.50	0.70	8.12	31.40	0.08	46.43	4.48	0.00
252	2.95	6.85	31.37	0.19	7.00	14.62	0.90	4.30	38.12	0.08	58.99	9.54	0.00
253	2.03	7.62	15.36	0.04	5.00	5.50	1.10	7.14	27.41	0.04	59.31	6.70	0.00
254	4.57	7.30	11.91	0.08	8.52	9.86	0.90	4.60	14.20	0.03	39.22	3.93	0.00
255	5.41	6.90	12.82	0.07	3.50	4.50	0.80	11.14	15.32	0.06	61.37	6.41	3.94
256	2.86	7.10	9.84	0.11	4.50	2.57	1.00	10.28	10.71	0.04	57.81	5.23	4.21
257	3.74	7.20	13.95	0.39	10.00	15.64	1.10	6.41	36.09	0.05	34.89	3.90	0.00
258	2.43	7.10	7.25	0.08	4.50	9.50	1.40	4.62	29.34	0.03	33.99	2.74	0.00
259	3.21	7.56	23.34	0.07	5.12	6.00	0.00	4.10	10.30	0.07	67.59	9.90	0.00
260	4.13	7.06	11.36	0.05	8.50	7.50	1.14	5.60	14.51	0.02	41.45	4.02	0.00
261	3.65	7.12	26.07	0.04	11.50	10.50	0.00	6.98	35.31	0.05	54.19	7.86	0.00
262	3.72	6.76	16.93	0.03	3.50	8.30	0.00	5.71	6.15	0.06	58.87	6.97	0.00
263	2.05	7.01	8.31	0.03	4.50	9.60	1.21	8.13	26.30	0.07	37.03	3.13	0.00
264	2.34	6.80	8.65	0.00	6.54	6.91	0.00	5.91	12.50	0.05	39.14	3.34	0.00
265	1.24	7.26	4.72	0.04	2.10	3.84	1.10	5.65	20.04	0.02	44.09	2.74	0.81
266	1.73	7.11	6.27	0.03	2.50	5.50	1.05	6.64	12.57	0.01	43.86	3.14	0.00
267	1.07	6.90	9.67	0.02	6.00	11.67	0.00	5.28	26.71	0.05	35.35	3.25	0.00
268	1.94	7.00	6.02	0.07	3.00	4.50	0.57	4.13	21.28	0.06	44.31	3.11	0.00
269	1.53	7.10	7.25	0.07	7.50	2.15	0.46	2.81	13.70	0.04	42.72	3.30	0.00
270	2.66	6.99	8.24	0.03	8.15	5.10	0.00	4.85	26.80	0.06	38.29	3.20	0.00
271	2.01	7.14	20.03	0.04	2.50	8.50	0.46	6.71	7.82	0.05	64.47	8.54	0.00
272	1.98	7.63	4.50	0.01	4.00	6.51	0.54	6.20	21.00	0.05	29.96	1.96	0.00

273	0.83	7.52	4.15	0.05	1.90	2.36	1.10	4.73	5.51	0.02	49.06	2.84	1.57
274	2.38	7.30	13.29	0.04	3.00	2.54	0.34	4.12	14.70	0.06	70.41	7.99	0.00
275	1.44	7.62	9.06	0.03	2.25	3.57	0.62	3.74	4.80	0.04	60.78	5.31	0.00
276	1.47	7.52	10.38	0.01	2.00	3.90	0.00	5.37	6.15	0.04	63.72	6.04	0.00
277	1.03	7.60	6.11	0.03	2.30	2.70	0.38	5.68	5.17	0.02	54.86	3.86	1.06
278	1.87	7.56	12.14	0.03	4.00	4.60	0.00	3.90	16.30	0.04	58.45	5.85	0.00
279	1.20	7.48	7.46	0.04	3.01	5.80	0.00	4.70	9.10	0.03	45.74	3.55	0.00
280	1.02	8.18	3.83	0.02	4.50	3.50	0.16	6.10	3.50	0.01	32.32	1.92	0.00
281	1.60	7.11	6.35	0.01	2.30	2.70	0.00	5.40	8.70	0.02	55.90	4.02	0.40
282	0.62	7.80	3.67	0.03	1.89	2.00	0.27	4.70	2.70	0.01	48.38	2.63	1.08
283	0.44	7.52	2.16	0.02	1.10	1.17	0.08	3.14	1.10	0.01	48.54	2.03	0.95
284	1.48	6.88	6.33	0.01	2.67	1.86	0.00	4.10	9.20	0.03	58.23	4.21	0.00
285	1.32	7.10	6.16	0.02	2.70	2.21	0.00	5.30	5.60	0.02	55.55	3.93	0.39

Appendix VII: Samplewise cations, anions and different water quality indices of post-monsoon well/tube well water samples of Northern Saurashtra coastal region (December, 2019)

Lab. No.	EC (dS m^{-1})	pH	Cation in me L^{-1}				Anion in me L^{-1}				Indices		
			Na^{+}	K^{+}	Ca^{++}	Mg^{++}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}	SSP	SAR	RSC (me L^{-1})
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	2.41	7.80	6.21	0.00	6.05	12.10	1.20	2.10	24.17	0.76	25.49	2.06	0.00
2	3.28	7.60	8.29	0.01	14.28	7.23	0.00	1.20	17.30	0.91	27.81	2.53	0.00
3	2.17	7.60	7.36	0.00	8.00	5.12	0.80	2.30	17.32	0.71	35.94	2.87	0.00
4	3.81	7.80	12.24	0.00	7.12	10.40	0.00	2.80	31.74	0.97	41.13	4.14	0.00
5	2.44	7.60	11.40	0.03	7.80	18.52	0.40	1.90	20.50	0.69	30.20	3.14	0.00
6	4.66	7.20	31.14	0.04	20.06	13.15	0.00	1.17	58.41	1.04	48.36	7.64	0.00
7	1.83	7.90	5.27	0.01	5.41	4.50	0.00	6.60	14.46	0.70	34.69	2.37	0.00
8	3.24	7.70	7.02	0.00	11.08	5.03	0.00	3.20	27.10	0.98	30.35	2.47	0.00
9	2.27	7.80	7.42	0.06	5.40	3.70	0.00	4.00	15.52	0.84	44.75	3.48	0.00
10	1.24	7.50	6.44	0.02	5.20	4.70	0.00	2.61	12.08	0.53	39.36	2.89	0.00
11	2.31	7.30	19.62	0.04	6.70	5.41	0.00	1.80	17.28	0.41	61.76	7.97	0.00
12	3.81	7.60	5.26	0.01	15.60	3.14	0.00	2.08	16.20	0.92	21.91	1.72	0.00
13	2.75	7.40	6.95	0.05	3.70	8.60	0.00	2.40	21.00	0.48	36.01	2.80	0.00
14	1.10	7.40	4.07	0.02	5.20	6.20	0.00	1.03	24.26	0.51	26.28	1.70	0.00
15	1.98	7.60	5.23	0.03	3.10	8.03	0.00	2.63	15.30	0.52	31.91	2.22	0.00
16	1.76	7.70	5.12	0.03	5.60	10.70	0.00	4.20	13.10	0.63	23.87	1.79	0.00
17	1.72	7.70	4.95	0.01	4.06	5.23	1.12	3.12	16.07	0.73	34.74	2.30	0.00
18	1.91	7.90	6.13	0.03	5.30	6.11	0.62	3.42	18.03	0.71	34.89	2.57	0.00
19	2.43	7.60	28.74	0.04	2.90	14.80	0.23	2.37	22.01	0.38	61.83	9.66	0.00
20	2.86	7.50	5.05	0.00	17.70	11.05	0.52	3.16	35.08	0.87	14.94	1.33	0.00
21	3.14	7.40	20.84	0.00	10.50	7.11	0.00	3.25	41.04	0.74	54.20	7.02	0.00
22	2.79	7.60	12.97	0.01	6.40	8.50	0.00	3.20	24.27	0.77	46.52	4.75	0.00
23	2.11	7.70	5.04	0.01	8.10	10.60	0.00	2.14	15.25	0.61	21.22	1.65	0.00
24	2.71	7.70	24.16	0.01	5.10	6.90	0.00	4.02	13.02	0.68	66.80	9.86	0.00

25	3.52	7.50	6.47	0.03	8.14	9.20	0.00	1.30	17.71	0.57	27.14	2.20	0.00
26	2.58	7.50	4.06	0.00	2.90	4.12	0.53	1.28	11.23	0.62	36.64	2.17	0.00
27	2.54	7.60	14.06	0.03	11.04	3.71	0.00	2.19	17.60	1.00	48.75	5.18	0.00
28	1.35	7.40	5.26	0.04	3.80	6.40	0.00	3.06	28.17	0.47	33.94	2.33	0.00
29	1.26	7.80	6.11	0.01	2.40	3.28	0.74	2.08	13.50	0.36	51.78	3.63	0.00
30	2.62	7.60	9.03	0.01	2.80	3.59	0.00	1.87	13.26	0.31	58.52	5.05	0.00
31	3.03	7.90	10.91	0.00	9.20	5.10	0.48	5.40	33.12	0.67	43.28	4.08	0.00
32	2.37	7.60	7.32	0.00	5.20	6.12	0.00	2.20	21.81	0.56	39.27	3.08	0.00
33	0.58	8.03	3.45	0.03	3.40	3.20	0.00	2.70	10.64	0.31	34.23	1.90	0.00
34	2.61	7.50	22.16	0.03	10.80	6.40	0.00	2.40	26.68	0.57	56.26	7.56	0.00
35	2.48	7.64	11.19	0.02	13.30	4.90	0.00	1.44	8.30	0.72	38.05	3.71	0.00
36	1.44	7.60	5.24	0.01	4.10	5.20	0.00	0.90	17.56	0.51	36.01	2.43	0.00
37	1.68	7.50	10.07	0.05	2.25	2.30	0.00	2.14	9.45	0.30	68.64	6.68	0.00
38	0.76	7.80	3.46	0.00	4.20	11.20	0.00	1.50	13.27	0.34	18.35	1.25	0.00
39	2.07	7.50	7.05	0.01	4.03	5.10	0.00	3.40	11.90	0.41	43.55	3.30	0.00
40	1.74	8.00	5.37	0.05	3.17	3.14	0.00	1.84	18.77	0.33	45.78	3.02	0.00
41	1.93	7.60	6.30	0.00	5.31	2.70	0.00	2.56	16.23	0.27	44.03	3.15	0.00
42	1.65	7.57	4.19	0.02	3.20	6.20	0.00	2.10	12.74	0.46	30.79	1.93	0.00
43	0.89	7.90	3.84	0.05	2.12	3.20	0.00	0.71	10.57	0.26	41.69	2.35	0.00
44	1.80	7.80	3.62	0.03	2.30	4.30	0.80	2.20	8.86	0.67	35.32	1.99	0.00
45	0.48	8.30	2.30	0.02	1.80	5.46	0.14	2.08	5.62	0.09	24.01	1.21	0.00
46	0.90	7.90	2.91	0.01	3.40	2.08	0.00	2.09	11.77	0.15	34.64	1.76	0.00
47	1.05	7.50	6.26	0.02	2.20	3.20	0.00	2.40	6.62	0.17	53.60	3.81	0.00
48	1.64	7.20	16.24	0.00	4.08	1.70	0.00	0.42	17.76	0.20	73.75	9.55	0.00
49	1.52	7.50	5.23	0.03	1.92	2.02	0.00	2.60	6.80	0.10	56.85	3.73	0.00
50	1.29	7.60	4.45	0.00	4.27	4.30	0.00	1.80	7.30	0.20	34.18	2.15	0.00
51	0.90	8.20	3.16	0.01	5.10	4.32	0.00	2.60	8.55	0.13	25.10	1.46	0.00
52	1.54	8.40	10.19	0.00	2.80	2.08	0.00	1.20	7.84	0.24	67.62	6.52	0.00
53	1.31	8.40	3.48	0.01	2.35	2.27	0.16	1.32	9.60	0.29	42.91	2.29	0.00
54	1.22	7.70	2.73	0.01	3.60	3.41	0.00	2.00	15.52	0.31	28.00	1.46	0.00
55	3.79	7.50	21.17	0.04	22.34	19.60	0.00	1.60	46.04	0.91	33.52	4.62	0.00

56	5.46	7.40	35.61	0.03	7.50	12.30	0.00	1.20	53.00	0.97	64.23	11.32	0.00
57	4.28	7.40	11.04	0.02	6.05	7.13	0.00	2.40	37.48	0.98	45.54	4.30	0.00
58	2.91	7.60	10.60	0.02	8.10	7.20	0.00	3.50	28.12	0.86	40.90	3.83	0.00
59	3.79	7.40	7.11	0.03	8.50	7.40	0.00	2.80	34.30	0.84	30.86	2.52	0.00
60	4.49	7.40	10.36	0.02	12.10	12.70	0.00	3.40	14.30	0.77	29.45	2.94	0.00
61	2.10	7.90	12.02	0.00	6.40	5.23	1.20	3.90	17.25	0.69	50.82	4.98	0.00
62	1.14	7.90	7.89	0.06	15.06	6.20	1.60	6.75	20.01	0.61	27.01	2.42	0.00
63	1.07	7.80	8.08	0.01	7.20	10.30	0.00	3.70	25.53	0.58	31.57	2.73	0.00
64	1.80	7.70	8.97	0.05	6.03	5.80	0.00	4.10	15.60	0.53	43.02	3.69	0.00
65	2.61	7.50	7.33	0.03	10.02	5.02	0.80	2.80	18.50	0.88	32.72	2.67	0.00
66	4.66	7.40	15.21	0.02	8.10	8.60	0.40	3.10	16.40	0.81	47.64	5.26	0.00
67	2.57	7.40	10.23	0.02	14.70	10.10	0.00	4.00	11.80	0.35	29.19	2.91	0.00
68	2.18	7.60	9.05	0.00	6.70	8.30	0.00	3.28	21.00	0.77	37.63	3.30	0.00
69	3.84	7.60	17.60	0.00	11.06	7.70	0.00	4.40	19.08	0.69	48.40	5.75	0.00
70	3.92	7.60	12.36	0.02	5.08	12.10	0.34	1.12	12.32	0.47	41.81	4.22	0.00
71	4.04	7.50	30.75	0.03	6.20	4.90	0.00	5.28	44.32	0.80	73.42	13.05	0.00
72	1.75	8.00	6.89	0.05	18.30	14.70	0.00	2.50	20.60	0.46	17.25	1.70	0.00
73	1.70	7.20	7.25	0.04	7.04	5.31	1.20	1.40	22.56	0.55	36.91	2.92	0.00
74	2.80	7.30	9.62	0.00	6.04	10.70	0.00	4.60	31.10	0.42	36.49	3.33	0.00
75	1.84	7.40	6.55	0.03	5.10	6.20	0.00	3.70	17.30	0.46	36.63	2.76	0.00
76	2.64	8.10	12.47	0.00	6.40	4.61	0.36	2.41	14.65	0.36	53.11	5.31	0.00
77	2.16	7.50	8.21	0.05	5.28	5.20	0.00	1.60	27.05	0.70	43.81	3.59	0.00
78	2.03	7.60	7.15	0.03	6.30	4.50	0.00	4.00	35.60	0.37	39.77	3.08	0.00
79	3.52	7.80	10.14	0.05	7.10	6.10	0.72	3.20	22.14	0.79	43.35	3.95	0.00
80	2.51	7.60	7.32	0.02	5.14	4.57	0.00	1.10	18.90	0.58	42.93	3.32	0.00
81	1.49	8.10	8.15	0.01	5.40	4.30	0.62	2.06	14.02	0.67	45.63	3.70	0.00
82	1.29	7.60	5.28	0.04	3.10	8.04	0.24	3.80	10.32	0.44	32.08	2.24	0.00
83	2.41	7.80	11.16	0.00	3.90	3.12	0.00	2.58	20.47	0.51	61.39	5.96	0.00
84	1.93	8.10	5.14	0.02	7.60	4.20	0.00	2.31	22.04	0.32	30.31	2.12	0.00
85	0.67	8.00	4.12	0.02	8.20	5.08	0.24	1.06	8.90	0.50	23.65	1.60	0.00
86	2.57	7.80	18.15	0.01	1.80	4.30	0.41	3.24	12.32	0.35	74.81	10.39	0.00

87	1.64	7.80	6.48	0.00	2.90	3.23	0.00	2.60	11.28	0.30	51.39	3.70	0.00
88	0.86	8.20	4.29	0.01	1.20	3.80	0.00	0.98	5.92	0.10	46.13	2.71	0.00
89	1.64	7.70	8.20	0.00	3.40	5.04	0.36	1.44	10.30	0.19	49.28	3.99	0.00
90	1.71	7.80	6.24	0.03	4.10	1.56	0.20	2.40	11.84	0.20	52.31	3.71	0.00
91	0.52	8.30	3.28	0.02	2.04	2.60	0.00	1.86	5.80	0.16	41.31	2.15	0.00
92	0.73	8.16	4.28	0.01	5.40	1.70	0.00	2.31	12.11	0.10	37.58	2.27	0.00
93	1.86	8.04	11.32	0.00	1.80	4.07	0.00	2.46	13.80	0.24	65.85	6.61	0.00
94	1.50	7.90	4.49	0.00	4.10	3.10	0.00	3.21	20.71	0.77	38.41	2.37	0.00
95	1.33	7.90	8.57	0.00	3.80	2.51	0.80	4.20	12.64	0.73	57.59	4.82	0.00
96	0.80	7.80	6.35	0.00	4.17	3.21	0.00	3.08	17.12	0.51	46.25	3.31	0.00
97	1.62	8.00	7.24	0.00	10.37	4.23	0.00	4.07	4.90	0.43	33.15	2.68	0.00
98	2.24	7.60	10.26	0.00	5.10	5.34	0.00	3.50	9.18	0.66	49.57	4.49	0.00
99	1.89	7.70	7.36	0.00	3.23	7.30	0.00	4.81	13.42	0.64	41.14	3.21	0.00
100	1.14	7.70	3.68	0.04	2.20	3.13	0.00	2.87	3.13	0.57	40.66	2.25	0.00
101	0.64	7.40	5.37	0.01	6.06	7.50	0.00	6.90	3.87	0.34	28.35	2.06	0.00
102	1.53	7.60	4.59	0.00	2.31	4.46	0.00	7.60	6.52	0.30	40.40	2.49	0.83
103	2.92	7.60	11.74	0.00	2.60	2.28	0.00	2.10	16.47	0.87	70.64	7.52	0.00
104	0.72	7.50	5.34	0.01	3.11	4.12	0.00	4.26	10.25	0.26	42.45	2.81	0.00
105	0.54	8.40	3.81	0.00	2.23	5.06	0.03	3.28	17.34	0.20	34.32	2.00	0.00
106	1.62	8.10	4.36	0.00	6.06	3.21	0.00	6.04	2.87	0.24	31.99	2.03	0.00
107	1.36	7.80	5.06	0.00	2.40	2.45	0.34	4.21	11.68	0.46	51.06	3.25	0.00
108	0.99	8.60	10.24	0.00	5.21	3.57	0.00	5.20	14.02	0.33	53.84	4.89	0.00
109	1.08	7.80	8.02	0.00	3.06	3.20	0.00	2.04	6.21	0.49	56.16	4.53	0.00
110	2.63	7.80	6.35	0.00	3.34	2.06	0.00	4.60	13.40	0.52	54.04	3.86	0.00
111	2.37	7.40	5.29	0.01	2.52	2.40	0.00	2.67	2.78	0.55	51.76	3.37	0.00
112	1.86	7.80	4.62	0.00	4.26	5.30	0.26	3.83	3.41	0.27	32.58	2.11	0.00
113	0.89	7.80	3.25	0.01	5.10	4.80	0.04	6.42	2.62	0.29	24.70	1.46	0.00
114	0.90	7.80	2.24	0.00	4.01	3.10	0.10	5.00	4.47	0.43	23.96	1.19	0.00
115	0.71	8.40	3.26	0.02	8.20	6.20	0.04	2.60	4.61	0.36	18.44	1.21	0.00
116	1.31	8.00	7.60	0.02	2.41	2.50	0.19	1.84	5.37	0.41	60.65	4.85	0.00
117	0.87	8.00	2.64	0.01	4.30	2.62	0.00	5.21	9.71	0.32	27.59	1.42	0.00

118	0.74	7.80	2.51	0.02	2.12	3.05	0.00	4.37	8.59	0.04	32.60	1.56	0.00
119	1.04	7.80	3.01	0.01	5.20	1.60	0.00	3.12	4.56	0.21	30.65	1.63	0.00
120	0.28	8.40	5.41	0.05	1.85	2.17	0.00	5.42	0.80	0.10	57.07	3.82	1.40
121	1.18	7.90	4.18	0.00	3.60	1.57	0.00	5.04	9.24	0.18	44.71	2.60	0.00
122	0.59	8.40	2.16	0.05	2.24	4.20	0.00	1.28	3.52	0.08	24.97	1.20	0.00
123	1.03	7.60	1.23	0.00	1.72	1.40	0.08	4.60	2.67	0.09	28.28	0.98	1.56
124	1.82	8.80	11.62	0.13	6.20	6.90	0.00	3.60	8.90	0.74	46.76	4.54	0.00
125	5.54	7.70	7.41	0.15	7.20	11.80	0.00	4.80	18.10	0.95	27.90	2.40	0.00
126	2.34	7.40	10.08	0.14	5.80	4.30	0.00	7.40	16.80	0.87	49.61	4.49	0.00
127	1.41	7.50	12.07	0.10	8.30	7.20	1.24	8.00	15.40	0.78	43.62	4.34	0.00
128	6.83	7.00	7.06	0.33	24.50	5.60	0.00	5.40	53.00	0.97	18.83	1.82	0.00
129	1.22	7.60	15.09	0.25	9.90	6.50	0.00	4.80	12.21	0.72	47.54	5.27	0.00
130	2.84	7.70	11.14	0.22	3.70	4.90	0.00	6.00	9.50	0.83	55.81	5.37	0.00
131	0.40	7.60	12.41	0.19	5.20	2.03	0.00	3.20	32.40	0.76	62.58	6.53	0.00
132	2.24	8.00	27.57	0.20	4.50	6.80	1.60	13.60	12.10	0.70	70.57	11.60	3.90
133	4.53	7.40	22.15	0.16	11.17	8.34	1.24	4.20	31.03	0.57	52.97	7.09	0.00
134	3.28	7.40	13.62	0.06	9.70	6.50	0.00	5.40	23.27	0.66	45.58	4.79	0.00
135	3.48	7.10	8.04	0.04	17.40	6.50	0.00	7.40	18.40	0.62	25.14	2.33	0.00
136	0.97	7.50	7.15	0.06	4.90	2.40	0.00	5.60	12.00	0.51	49.28	3.74	0.00
137	1.55	7.30	6.48	0.07	6.60	3.60	0.00	8.00	11.01	0.56	38.69	2.87	0.00
138	1.74	7.30	7.05	0.03	1.60	3.84	0.00	4.00	7.40	0.60	56.31	4.27	0.00
139	1.84	7.90	10.49	0.02	4.30	5.54	0.00	5.00	15.02	0.48	51.55	4.73	0.00
140	0.57	7.80	7.23	0.03	4.20	2.70	0.00	4.30	10.80	0.42	51.06	3.89	0.00
141	1.82	8.10	10.35	0.04	3.70	3.10	0.00	2.90	14.60	0.40	60.21	5.61	0.00
142	1.28	8.40	3.15	0.09	2.40	2.60	0.00	4.40	11.56	0.25	38.23	1.99	0.00
143	0.32	8.30	6.78	0.03	4.20	5.30	0.00	2.40	4.20	0.22	41.57	3.11	0.00
144	3.53	7.80	1.06	0.14	2.03	4.30	1.20	7.80	24.05	0.32	14.08	0.60	2.67
145	2.06	7.20	15.91	0.05	12.07	3.30	0.00	5.74	16.40	0.38	50.78	5.74	0.00
146	2.17	8.00	6.34	0.04	3.40	4.02	0.00	3.70	11.30	0.28	45.94	3.29	0.00
147	1.49	8.10	5.62	0.03	5.12	5.40	0.00	4.60	10.80	0.16	34.76	2.45	0.00
148	2.10	8.30	12.73	0.07	5.90	5.10	0.00	5.20	10.04	0.14	53.49	5.43	0.00

149	1.47	8.30	6.92	0.06	6.02	3.50	0.00	4.10	9.94	0.24	41.94	3.17	0.00
150	0.41	8.40	10.24	0.02	3.56	3.10	0.00	3.04	4.60	0.14	60.52	5.61	0.00
151	0.27	8.50	1.48	0.00	2.30	1.60	0.00	6.30	3.88	0.02	27.51	1.06	2.40
152	0.60	7.30	2.51	0.02	1.40	2.70	0.00	5.70	0.90	0.10	37.86	1.75	1.60
153	1.37	8.00	6.27	0.01	2.01	3.10	0.00	5.81	5.60	0.14	55.05	3.92	0.70
154	0.76	7.80	2.06	0.03	2.70	2.02	0.00	4.28	7.67	0.12	30.25	1.34	0.00
155	1.17	7.70	3.15	0.00	2.06	3.40	0.00	5.03	3.87	0.10	36.59	1.91	0.00
156	2.36	7.50	5.46	0.01	4.10	2.16	0.00	6.60	5.26	0.15	46.55	3.09	0.34
157	2.44	7.40	4.23	0.03	7.03	3.02	0.00	4.80	15.80	0.18	29.56	1.89	0.00
158	1.57	7.60	11.37	0.01	6.23	3.70	0.80	2.20	12.20	0.12	53.36	5.10	0.00
159	0.52	7.60	10.18	0.01	1.80	2.50	0.24	3.12	10.40	0.08	70.26	6.94	0.00
160	1.38	7.30	8.14	0.07	1.03	4.28	0.00	5.80	1.94	0.11	60.21	5.00	0.49
161	0.46	7.70	4.06	0.02	3.18	3.03	0.00	3.64	8.84	0.09	39.46	2.30	0.00
162	0.81	8.00	2.13	0.00	2.00	4.20	0.00	2.06	2.49	0.04	25.57	1.21	0.00
163	0.40	7.70	3.39	0.03	3.50	3.24	0.00	2.18	1.50	0.10	33.37	1.85	0.00
164	3.86	7.50	13.38	0.05	13.66	6.85	0.00	8.77	27.60	0.88	39.42	4.18	0.00
165	4.02	7.70	31.64	0.01	9.58	7.60	0.00	9.84	34.28	0.81	64.80	10.80	0.00
166	3.59	7.40	17.26	0.03	11.74	7.77	0.00	6.68	19.52	0.92	46.90	5.53	0.00
167	4.46	7.30	21.76	0.05	10.85	5.86	0.00	7.40	40.86	0.94	56.49	7.53	0.00
168	1.10	7.70	6.74	0.04	5.10	3.00	0.00	5.60	8.12	0.56	45.30	3.35	0.00
169	0.99	7.80	5.61	0.02	9.60	1.28	0.00	2.00	5.80	0.47	33.98	2.41	0.00
170	0.61	8.00	3.62	0.01	5.40	3.30	0.00	3.40	2.89	0.43	29.36	1.74	0.00
171	4.06	7.40	16.05	0.02	2.70	2.00	0.00	2.60	25.86	0.74	77.27	10.47	0.00
172	0.21	7.80	4.19	0.04	3.50	2.23	1.02	5.40	3.20	0.34	42.07	2.48	0.69
173	2.12	7.80	24.51	0.00	4.90	3.80	0.00	5.20	28.60	0.37	73.80	11.75	0.00
174	1.05	7.60	2.12	0.10	2.08	2.11	0.00	6.00	4.20	0.71	33.07	1.46	1.81
175	2.44	7.70	11.28	0.01	6.50	4.50	0.00	6.00	13.06	0.53	50.61	4.81	0.00
176	2.84	7.40	8.65	0.01	3.40	3.50	0.00	8.20	9.62	0.67	55.59	4.66	1.30
177	1.06	7.60	3.95	0.02	4.27	5.36	0.00	5.10	5.10	0.61	29.04	1.80	0.00
178	1.52	7.40	7.24	0.29	6.60	2.03	0.00	2.00	7.63	0.51	44.80	3.49	0.00
179	0.48	7.70	1.67	0.02	2.50	3.50	0.00	5.60	3.41	0.38	21.72	0.96	0.00

180	1.47	7.90	8.64	0.00	5.20	4.70	0.00	4.30	17.85	0.46	46.60	3.88	0.00
181	0.68	7.80	4.32	0.00	7.50	4.90	0.00	3.10	3.92	0.42	25.84	1.73	0.00
182	3.19	8.00	9.51	0.00	6.48	3.01	0.00	6.80	19.34	0.78	50.05	4.37	0.00
183	1.65	7.90	5.39	0.00	4.20	2.40	0.00	6.60	7.87	0.64	44.95	2.97	0.00
184	1.07	7.60	5.31	0.00	5.40	2.70	0.00	4.80	2.80	0.23	39.60	2.64	0.00
185	2.76	7.70	18.62	0.00	4.60	2.60	0.00	7.20	7.52	0.37	72.11	9.81	0.00
186	1.17	7.80	7.53	0.00	3.80	3.20	0.00	4.02	3.20	0.39	51.82	4.02	0.00
187	2.19	7.50	3.23	0.00	7.10	1.80	0.00	2.60	17.50	0.64	26.63	1.53	0.00
188	0.75	7.90	11.56	0.06	1.80	1.40	0.00	6.05	13.92	0.52	78.00	9.14	2.85
189	0.27	8.10	4.31	0.00	2.30	0.90	0.00	3.50	2.41	0.61	57.39	3.41	0.30
190	0.91	7.70	5.18	0.00	2.40	1.50	0.00	5.60	4.87	0.44	57.05	3.71	1.70
191	0.91	7.70	1.26	0.00	1.90	1.20	0.00	1.62	8.26	0.12	28.90	1.01	0.00
192	0.52	7.68	7.26	0.00	2.70	2.60	0.00	4.00	5.76	0.17	57.80	4.46	0.00
193	0.71	7.56	1.61	0.01	2.00	1.30	0.00	4.80	1.70	0.17	32.72	1.25	1.50
194	0.84	7.57	5.34	0.00	2.40	1.80	0.00	6.60	5.47	0.14	55.97	3.68	2.40
195	1.01	8.00	8.35	0.05	2.90	0.60	0.00	5.20	1.00	0.10	70.17	6.31	1.70
196	1.19	7.64	3.48	0.02	3.10	2.10	0.00	3.60	0.60	0.19	40.00	2.16	0.00
197	0.80	7.83	8.19	0.03	4.20	2.20	0.00	3.60	6.79	0.27	56.02	4.58	0.00
198	0.86	7.70	4.61	0.04	3.80	2.70	0.00	2.80	5.38	0.25	41.35	2.56	0.00
199	1.42	7.62	6.29	0.03	2.10	1.50	0.00	5.00	1.90	0.10	63.41	4.69	1.40
200	1.07	7.70	2.37	0.01	2.20	1.40	0.00	0.80	4.42	0.18	39.63	1.77	0.00
201	0.76	7.81	0.83	0.00	3.10	1.60	0.00	0.60	10.72	0.13	15.01	0.54	0.00
202	0.18	7.70	2.19	0.02	2.40	1.50	0.00	4.30	2.70	0.15	35.84	1.57	0.40
203	1.36	7.80	7.90	0.03	3.20	1.90	0.00	6.70	3.27	0.18	60.63	4.95	1.60
204	0.98	7.90	4.27	0.01	2.00	0.90	0.00	3.10	7.48	0.10	59.47	3.55	0.20
205	0.56	8.00	2.46	0.00	1.80	0.70	0.00	4.20	1.77	0.11	49.60	2.20	1.70
206	0.38	8.13	0.48	0.00	1.60	0.50	0.00	5.20	0.80	0.10	18.60	0.47	3.10
207	0.51	8.10	4.08	0.00	1.70	0.70	0.00	4.86	0.70	0.10	62.96	3.72	2.46
208	0.89	7.90	2.46	0.00	1.20	0.60	0.00	6.60	4.86	0.12	57.75	2.59	4.80
209	5.46	7.20	22.35	0.74	7.16	8.30	0.00	6.82	33.65	1.00	57.98	8.04	0.00
210	2.90	7.40	20.51	0.63	7.02	5.47	0.80	4.58	47.83	1.01	60.99	8.21	0.00

211	3.28	7.40	15.48	0.22	6.20	10.02	0.49	5.53	17.58	0.78	48.50	5.44	0.00
212	2.85	7.70	28.26	0.84	10.30	11.70	0.51	8.27	26.54	0.86	55.30	8.52	0.00
213	2.64	7.90	18.27	0.14	9.07	7.35	0.00	11.45	13.57	0.71	52.45	6.38	0.00
214	3.42	7.90	33.94	0.00	4.50	11.06	0.81	4.80	14.89	0.67	68.57	12.17	0.00
215	2.14	7.80	20.06	0.12	6.81	9.12	0.00	6.40	21.36	0.56	55.55	7.11	0.00
216	3.11	7.90	17.83	0.33	6.40	8.60	0.23	4.80	29.75	0.79	53.77	6.51	0.00
217	2.27	7.70	10.48	0.47	9.40	4.12	0.40	9.87	38.26	0.77	42.83	4.03	0.00
218	3.19	7.60	11.46	0.37	5.60	4.80	0.00	4.60	17.42	0.42	51.55	5.03	0.00
219	1.49	7.40	12.03	0.35	8.30	5.42	0.00	6.47	24.71	0.63	46.09	4.59	0.00
220	2.79	7.70	9.52	0.27	4.20	9.80	0.24	5.40	13.67	0.57	40.02	3.60	0.00
221	5.15	7.50	24.16	0.35	7.30	6.62	0.00	7.89	26.78	0.88	62.87	9.16	0.00
222	2.74	7.40	16.24	0.39	10.10	5.57	0.00	6.40	30.74	0.96	50.28	5.80	0.00
223	3.61	8.60	8.35	0.24	4.80	4.07	0.61	11.60	9.96	0.58	47.82	3.96	3.34
224	4.47	7.20	9.11	0.14	8.09	6.23	0.00	9.54	28.37	0.62	38.65	3.40	0.00
225	2.53	7.90	8.12	0.07	5.20	5.80	0.00	5.20	12.34	0.34	42.31	3.46	0.00
226	2.08	7.50	9.64	0.18	4.70	7.90	0.28	8.80	14.67	0.67	43.00	3.84	0.00
227	4.46	7.80	13.95	0.16	8.10	4.28	0.00	6.40	22.47	0.77	52.66	5.61	0.00
228	1.67	8.00	11.38	0.15	5.60	7.60	0.54	10.40	12.26	0.36	46.02	4.43	0.00
229	3.80	8.90	16.34	0.28	4.20	8.27	0.74	9.82	23.57	0.55	56.17	6.54	0.00
230	3.41	7.20	23.51	0.57	7.19	6.64	0.00	4.00	31.58	0.94	62.02	8.94	0.00
231	4.29	7.40	11.62	0.38	5.16	9.11	0.00	5.46	15.58	0.78	44.23	4.35	0.00
232	2.36	7.80	18.20	0.27	7.46	5.14	0.32	4.00	28.57	0.52	58.58	7.25	0.00
233	1.27	7.90	25.71	0.27	6.68	7.20	0.46	9.20	14.61	0.69	64.50	9.76	0.00
234	2.42	7.30	7.32	0.21	3.50	7.00	0.21	10.28	9.61	0.27	40.60	3.19	0.00
235	0.93	7.50	8.24	0.07	4.10	5.04	0.00	5.80	11.28	0.11	47.22	3.85	0.00
236	1.79	8.00	21.06	0.20	3.70	8.40	0.64	8.40	24.31	0.18	63.13	8.56	0.00
237	1.71	7.80	7.13	0.13	3.05	4.20	0.00	3.60	8.42	0.10	49.14	3.74	0.00
238	2.94	8.87	24.35	0.24	4.30	3.80	0.58	7.18	32.61	0.29	74.49	12.10	0.00
239	3.93	7.60	13.32	0.26	6.80	10.91	0.00	6.20	5.30	0.31	42.57	4.48	0.00
240	2.08	7.80	9.29	0.19	4.12	5.06	0.46	8.00	14.28	0.26	49.79	4.34	0.00
241	2.77	7.80	12.28	0.17	3.40	4.60	0.00	5.12	17.02	0.13	60.05	6.14	0.00

242	1.63	7.60	6.48	0.14	4.60	5.10	0.00	7.80	13.74	0.14	39.71	2.94	0.00
243	1.71	7.60	8.25	0.14	4.61	5.06	0.37	3.01	15.77	0.24	45.68	3.75	0.00
244	0.64	8.90	3.42	0.05	1.40	1.68	0.00	1.27	3.04	0.10	52.21	2.76	0.00
245	5.64	7.40	21.61	0.32	13.70	11.07	0.00	4.80	28.34	1.08	46.27	6.14	0.00
246	2.40	7.60	7.28	0.27	11.00	8.26	0.00	4.46	16.28	0.79	27.15	2.35	0.00
247	3.51	7.30	35.21	0.80	8.40	12.40	0.00	4.00	42.57	0.57	61.98	10.92	0.00
248	3.74	7.60	8.26	0.13	5.40	4.10	0.00	6.00	8.51	0.92	46.17	3.79	0.00
249	1.68	7.80	20.31	0.07	2.50	12.10	0.00	8.62	30.64	0.75	58.06	7.52	0.00
250	2.34	7.60	17.36	0.23	17.40	11.80	0.00	3.60	27.85	1.04	37.10	4.54	0.00
251	1.97	7.60	9.84	0.46	3.40	4.61	0.80	7.20	29.13	0.72	53.74	4.92	0.00
252	2.47	7.40	29.12	0.19	7.40	7.20	0.00	4.80	35.21	0.81	66.32	10.78	0.00
253	1.92	7.70	13.59	0.04	5.80	5.20	0.00	6.60	25.17	0.72	55.18	5.79	0.00
254	4.25	7.60	8.26	0.13	3.05	7.40	1.60	5.00	7.50	1.03	43.84	3.61	0.00
255	5.21	7.50	10.74	0.09	4.20	4.80	0.00	9.20	12.65	0.52	54.16	5.06	0.20
256	2.67	7.74	8.05	0.19	5.70	3.40	0.00	9.48	10.57	0.85	46.42	3.77	0.38
257	3.42	7.64	12.24	0.62	10.40	14.20	0.00	6.00	32.45	0.74	32.67	3.49	0.00
258	2.05	7.40	6.27	0.06	4.16	10.60	0.00	4.60	27.52	0.42	29.73	2.31	0.00
259	3.76	7.53	20.14	0.15	4.00	7.90	0.00	3.60	10.20	0.86	62.57	8.26	0.00
260	3.89	7.60	8.26	0.10	7.26	5.12	0.00	4.80	12.50	0.74	39.83	3.32	0.00
261	3.34	7.42	24.35	0.06	12.10	12.10	0.00	6.80	34.65	0.61	50.09	7.00	0.00
262	3.31	7.40	14.02	0.02	9.06	10.07	0.00	5.00	5.57	0.39	42.27	4.53	0.00
263	1.84	7.58	7.45	0.08	14.30	4.01	0.00	7.00	23.60	0.71	28.83	2.46	0.00
264	2.16	7.50	10.26	0.02	5.14	6.70	0.00	5.40	13.47	0.43	46.38	4.22	0.00
265	0.98	7.70	4.02	0.05	3.20	3.20	0.00	3.50	18.14	0.34	38.40	2.25	0.00
266	1.63	7.80	6.21	0.03	2.17	5.40	0.00	6.54	11.48	0.62	44.97	3.19	0.00
267	0.88	7.70	7.14	0.03	2.61	4.15	0.00	4.80	28.34	0.41	51.26	3.88	0.00
268	1.61	7.62	5.26	0.11	3.08	5.10	0.41	3.46	17.85	0.77	38.82	2.60	0.00
269	1.20	7.72	5.24	0.18	4.18	2.60	1.17	2.29	9.10	0.47	42.95	2.85	0.00
270	2.42	7.60	5.15	0.05	9.20	4.11	0.00	4.60	25.12	0.44	27.82	2.00	0.00
271	1.61	8.10	18.46	0.02	3.10	8.03	0.45	6.06	6.32	0.28	62.34	7.83	0.00
272	1.84	7.60	3.56	0.06	4.06	5.40	0.00	5.41	19.47	0.42	27.22	1.64	0.00

273	0.72	8.17	3.18	0.06	2.40	2.20	0.00	4.20	3.76	0.33	40.56	2.10	0.00
274	2.10	7.70	11.06	0.08	5.14	2.18	0.21	3.81	12.51	0.62	59.91	5.78	0.00
275	1.26	8.00	7.14	0.03	2.30	3.21	0.18	2.04	4.54	0.54	56.31	4.30	0.00
276	1.58	7.30	8.36	0.11	2.11	3.03	0.00	5.00	5.92	0.36	61.43	5.21	0.00
277	0.84	7.90	5.03	0.02	3.01	2.40	0.00	5.40	4.75	0.27	48.09	3.06	0.00
278	1.70	7.90	11.03	0.04	4.20	4.70	0.00	4.60	14.27	0.27	55.23	5.23	0.00
279	1.23	7.80	6.31	0.01	3.12	5.15	0.00	4.32	9.23	0.19	43.25	3.10	0.00
280	0.87	7.70	2.18	0.03	5.30	2.05	0.00	5.72	5.67	0.41	22.80	1.14	0.00
281	1.41	7.30	5.13	0.02	2.30	2.90	0.00	2.86	2.30	0.28	49.57	3.18	0.00
282	0.45	8.10	3.03	0.02	1.70	1.60	0.00	5.41	0.60	0.16	47.72	2.36	2.11
283	0.26	8.30	1.91	0.04	1.80	0.90	0.00	5.37	4.71	0.11	41.08	1.64	2.67
284	1.36	7.60	5.45	0.05	2.17	2.00	0.00	2.00	2.80	0.16	56.36	3.77	0.00
285	1.08	7.40	4.01	0.02	2.80	1.80	0.00	4.16	6.78	0.20	46.47	2.64	0.00

Appendix VIII: Mean values of various parameters of soil and water samples which was used for preparation of graphs

Parameters	Range (km)	Mean Value
Available N (kg ha^{-1})	0-5	142.27
	5-10	174.40
	10-15	220.56
	15-20	311.54
	0-20	204.70
Available P_2O_5 (kg ha^{-1})	0-5	23.16
	5-10	26.91
	10-15	29.67
	15-20	38.60
	0-20	28.95
Available K_2O (kg ha^{-1})	0-5	267.86
	5-10	324.89
	10-15	442.23
	15-20	642.02
	0-20	401.82
Available S (mg kg^{-1})	0-5	3.58
	5-10	13.08
	10-15	26.29
	15-20	43.59
	0-20	20.00
Available Fe (mg kg^{-1})	0-5	4.69
	5-10	5.11
	10-15	5.79
	15-20	6.46
	0-20	5.44
Available Mn (mg kg^{-1})	0-5	4.30
	5-10	6.16
	10-15	8.69
	15-20	11.87
	0-20	7.45
Available Cu (mg kg^{-1})	0-5	0.49
	5-10	0.77
	10-15	1.18
	15-20	1.85
	0-20	1.01
Available Zn (mg kg^{-1})	0-5	0.18
	5-10	0.30
	10-15	0.55
	15-20	0.93
	0-20	0.46

Available B (mg kg^{-1})		0-5	4.96
		5-10	3.82
		10-15	2.84
		15-20	1.97
		0-20	3.49
EC_e		0-5	7.55
		5-10	2.71
		10-15	1.51
		15-20	0.84
		0-20	3.21
pH_s		0-5	7.35
		5-10	7.55
		10-15	7.69
		15-20	7.78
		0-20	7.58
SOC (g kg^{-1})		0-5	2.71
		5-10	4.60
		10-15	6.19
		15-20	7.67
		0-20	5.14
Parameters	**Range (km)**	**Pre Monsoon**	**Post Monsoon**
EC (dS m^{-1})	0-5	3.39	3.09
	5-10	2.30	2.13
	10-15	1.68	1.49
	15-20	1.20	1.01
	0-20	2.22	2.01
RSC (me l^{-1})	0-5	0.26	0.11
	5-10	0.23	0.05
	10-15	0.21	0.12
	15-20	0.70	0.59
	0-20	0.33	0.19
SSP	0-5	50.72	46.42
	5-10	49.68	43.88
	10-15	50.23	43.87
	15-20	52.43	44.81
	0-20	50.63	44.72
SAR	0-5	6.34	5.31
	5-10	5.16	4.11
	10-15	4.53	3.51
	15-20	3.97	3.00
	0-20	5.08	4.06