

**“CHARACTERIZATION OF SOILS AND UNDER GROUND
WATER QUALITY OF MAHISAGAR DISTRICT OF GUJARAT”**

**BY
PARAGI NILESHKUMAR SHANTILAL
B. Sc. (Hons.) Agriculture
(Registration No: 04 - 3104 - 2017)**



**B. A. COLLEGE OF AGRICULTURE
ANAND AGRICULTURAL UNIVERSITY
ANAND – 388 110
2019**

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WATER QUALITY OF MAHISAGAR DISTRICT OF GUJARAT”**

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IN
SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**

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Characterization of Soils and Under Ground Water Quality of Mahisagar District of Gujarat

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ABSTRACT

An attempt has been made in the present study to evaluate the physical and chemical properties and fertility status of soils and quality of underground (well/tube well) water by collecting 180 underground irrigation water samples and 180 surface soil samples from cultivated fields of Mahisagar district.

The mean bulk density value of the soils of Mahisagar district was 1.32 Mg m^{-3} and it was ranged from 1.23 to 1.45 Mg m^{-3} . The mean particle density value of the soils of Mahisagar district was 2.53 Mg m^{-3} and it was ranged widely from 2.32 to 2.78 Mg m^{-3} . The porosity of soils ranged from 37.07 to 51.50 per cent with a mean value of 47.97 per cent. The overall range of MWHC was 29.25 to 64.23 per cent with a mean value of 45.97 per cent.

The soils of Mahisagar district were high in organic carbon content. It was ranging from 0.12 to 1.77 per cent with a mean value of 0.81 per cent. The soils are non-calcareous in nature (4.28 % CaCO_3) with alkaline in reaction (pH value ranging from 6.29 to 8.76 with a mean value of 7.60) in reaction. The mean $\text{EC}_{2.5}$ value in the soils of Mahisagar district was (0.38 dSm^{-1}) and ranged from 0.11 to 2.1 dSm^{-1} . The mean CEC value was ($24.47 \text{ cmol (p}^+) \text{ kg}^{-1}$).

The results further indicated that dominance of Ca^{++} ($5.87 \text{ cmol (p}^+) \text{ kg}^{-1}$ and Mg^{++} ($9.51 \text{ cmol (p}^+) \text{ kg}^{-1}$) among the exchangeable cations in soil, while among the water soluble ions Cl^- (4.41 me L^{-1}) and Mg^{++} (1.56 me L^{-1}) were found in higher proportion. About 3, 1, 20 and 76 percent soil samples were found saline, saline-sodic, sodic and normal, respectively.

Overall the soils of Mahisagar district were low with respect to available N (232 kg ha^{-1}), Medium in P_2O_5 (30.5 kg ha^{-1}), S (16.69 mg kg^{-1}) and available K_2O (228 kg ha^{-1}) status. The soils of Mahisagar district were high in available Fe, Zn, Mn, and Cu with their corresponding mean values of 15.14, 11.59, 1.64 and 1.53 mg kg^{-1} , respectively.

The result of quality of underground wells/tube wells water revealed that the EC values ranged 0.26 to 8.80 with a mean value of 1.10 dSm^{-1} . The water are alkaline in reaction (pH 7.49). The overall RSC value ranged from 0.0 to 1.30 with mean value of 0.007 me L^{-1} and overall 99.5 and 0.5 per cent samples fall under safe and marginal classes of RSC, respectively. The overall mean value of SSP was found 13.07, which varied from 0.11 to 65.95 and overall 99 and 1 per cent samples fall under safe and unsafe classes of SSP, respectively. The SAR values ranged from 0.00 to 11.03 with a mean value of 0.76 and overall 99.5 and 0.5 per cent samples fall under S_1 and S_2 classes of SAR, respectively.

Highly significant positive correlation between EC_{iw} with $EC_{2.5}$ ($r = 0.238^{**}$), SSP ($r = 0.148^*$), SAR ($r = 0.269^{**}$) and RSC ($r = 0.165^*$) of soil. In case of ESP is negatively correlated with EC_{iw} ($r = -0.278^{**}$). This indicates the EC_{iw} increased $EC_{2.5}$, SSP , RSC & decreased ESP of soil. The pH_{iw} was significantly positive correlated with ESP ($r = 0.298^{**}$). This indicates the pH_{iw} increased with ESP of soil. Highly significant positive relations were observed between $EC_{2.5}$ with $pH_{2.5}$ ($r=0.156^*$), SSP ($r=0.311^*$) and $SAR(r=0.675^*)$ of the soil. The $pH_{2.5}$ was negatively significant correlated with $RSC(r = -0.182^*)$. RSC was positively significant correlated with $SAR(r =0.155^*)$ and negatively correlated with $ESP(r = -0.197^{**})$ and SAR was negatively correlated with ESP .

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C E R T I F I C A T E

This is to certify that the thesis entitled **“Characterization of Soils and Under Ground Water Quality of Mahisagar District of Gujarat”** submitted by **Paragi Nileshkumar S. (Reg. No. 04 -3104 –2017)** in partial fulfillment of the requirements for the award of the degree of **Master in Science (Agriculture)** in **Soil Science and Agricultural Chemistry** of the Anand Agricultural University is a record of bonafide research work carried out by him under my personal guidance and supervision. The thesis has not previously formed the basis for award of any degree, diploma or other similar title.

Place: Anand

Date: 30 /07/2019

(M. B. Viradiya)

Major Guide

DECLARATION

This is to declare that the whole of the research work reported here in the thesis entitled “**Characterization of Soils and Under Ground Water Quality of Mahisagar District of Gujarat**” for the partial fulfillment of the requirement for the degree of **Master in Science (Agriculture)** in **Soil Science and Agricultural Chemistry** by the undersigned is the results of investigation done by me under the direct guidance and supervision of **Dr. M. B. Viradiya**, Associate Professor, Department of Soil Science and Agricultural Chemistry, B.A.C.A, AAU, Anand-388 110 and no part of work has been submitted for any other degree so far.

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"Gratitude is the most exquisite form of memory"

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Place: Anand

CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
I	INTRODUCTION	1-4
II	REVIEW OF LITERATURE	5-37
	2.1 Physical properties of the soil	5
	2.2 Chemical properties and salinity/sodicity status of surface soils	7
	2.3 Fertility status of the surface soils	14
	2.4 Quality of underground well/tube well waters and their classifications	26
	2.5 Relations among and between soil fertility and salinity/sodicity parameters of soils	34
III	MATERIALS AND METHODS	38-50
	3.1 General information of Mahisagar district	38
	3.2 Collection of soils and water samples	44
	3.3 Preparation of soil samples	44
	3.4 Chemical analysis of soil samples	44
	3.5 Soil fertility status	45
	3.6 Methods of analysis of irrigation water samples	46
	3.7 Ratings used for water quality and soil appraisal	47
	3.8 Statistical analysis	50
IV	RESULTS AND DISCUSSION	51-84
	4.1 Physical properties of soils of Mahisagar district	51
	4.2 Chemical properties of soils of Mahisagar district	54
	4.3 Salinity/sodicity status of the soils of Mahisagar district	56
	4.4 Fertility status and nutrient index of the soils of Mahisagar district	65
	4.5 Inter-relationships among and between fertility and salinity/sodicity parameters of the soils	72
	4.6 Irrigation water quality appraisal of Mahisagar district	75
	4.7 Inter-relationships between properties of irrigation water and irrigated soils of Mahisagar district	83
VI	SUMMARY AND CONCLUSIONS	85-89
	5.1 Physical properties of soil of Mahisagar district	85
	5.2 Chemical properties status of surface soils of Mahisagar district	86

5.3	Salinity/Sodicity status of surface soils of Mahisagar district	86
5.4	Fertility status of the soils of Mahisagar district	87
5.5	Quality of underground well/tube well water and their classification	88
5.6	Relationship between different properties of well/tube well water and soil properties	89

BIBLIOGRAPHY

I-XVIII

APPENDICES

I-LI

LIST OF TABLES

Table No.	Title	Page No.
3.1	Methods used for analysis of soil samples	44
3.2	Methods used for analysis of irrigation water	46
4.1	Talukawise range and mean values for bulk density, particle density, porosity and MWHC of soils	53
4.2	Talukawise range and mean values of chemical properties of soils	56
4.3	Talukawise range and mean values of exchangeable cations	58
4.4	Talukawise range and mean values of water soluble cations	59
4.5	Talukawise range and mean values of water soluble anions	60
4.6	Talukawise range and mean values of salinity/ sodicity indices of soil	63
4.7	Talukawise percentage distribution of soil samples into different categories of salt affected soils	65
4.8	Talukawise range and mean values of available N, P ₂ O ₅ , K ₂ O and S	68
4.9	Talukawise range and mean values of DTPA extractable micronutrients	70
4.10	Talukawise Value of nutrient index of macro and micro nutrient	72
4.11	Correlation coefficient among and between fertility and salinity/sodicity indices of soil	74
4.12	Taluka wise range and mean values EC, pH and indices of irrigation water	78
4.13	Talukawise range and mean values cations (Ca ⁺⁺ , Mg ⁺⁺ , Na ⁺ and K ⁺) of irrigation water	80
4.14	Talukawise range and mean values cations (CO ₃ ⁻ , HCO ₃ ⁻ , Cl ⁻ and SO ₄ ⁻) of irrigation water	81
4.15	Percentage distribution of well/tube well water samples into different EC and SAR, RSC and SSP classes	82
4.16	Correlation coefficients among different properties of irrigation water and irrigated soils	84

LIST OF APPENDICES

Sr. No.	Title	Page No.
I	Name of farmers, talukas and villages from where soil and water samples were taken	I
II	Sample wise values of B.D, P.D, Porosity and MWHC	XI
III	Sample wise values of EC _{2.5} , pH _{2.5} , O.C., fertility status and CaCO ₃ content of the soil	XIX
IV	Sample wise values of EC _{2.5} , pH _{2.5} , exchangeable cations, different indices and salinity-sodicity classes of soil	XXVII
V	Sample wise values of EC _{2.5} , pH _{2.5} water soluble ions (me L ⁻¹), indices of soil	XXXV
VI	Sample wise values of cations, anions and different water quality indices and water quality classes	XLIII
VII	Taluka wise nutrient index of the available macro and micro nutrients	LI

LIST OF ABBREVIATIONS

Anon.	:	Anonymous
$^{\circ}\text{C}$	:	Degree Celsius
cm	:	Centimeter(s)
EC	:	Electrical conductivity
ESP	:	Exchangeable Sodium Percentage
<i>et al.</i>	:	et alibi (and others)
Fig.	:	Figure
g.	:	gram(s)
ha	:	Hectare
K_2O	:	Potassium
kg	:	Kilogram(s)
M	:	Meter
Mg	:	Mega gram
N	:	Nitrogen
No.	:	Number
P_2O_5	:	Phosphorus
RSC	:	Residual Sodium Carbonate
SAR	:	Sodium Absorption Ratio
SSP	:	Soluble Sodium Percentage
viz.	:	Videlicet (namely)
CEC	:	Cation Exchange Capacity
dS m^{-1}	:	Deci Siemens per meter
EC_e	:	Electrical Conductivity of saturation Extract
$\text{EC}_{2.5}$	:	Electrical Conductivity of 1:2.5 soil:water Extract
EC_5	:	Electrical Conductivity of 1:5 soil:water Extract
me L^{-1}	:	Milliequivalent per litre
$\text{cmol(p}^+) \text{ kg}^{-1}$	:	Centimol positive ion per Kilogram

m ha m	:	Million hectare meter
pH _s	:	pH of saturation extract
pH _{2.5}	:	pH of 1:2.5 soil:water extract
pH ₅	:	pH of 1:5 soil:water extract
kg ha ⁻¹	:	Kilogram per hectare
Ex.	:	Exchangeable
R	:	Correlation coefficient
R ²	:	Percentage of variance
S _{yx}	:	Standard error of estimate
<	:	Lower than
>	:	Greater than
mg kg ⁻¹	:	Milligram per kilogram
mg l ⁻¹	:	Milligram per litre
mg	:	Milligram

I. INTRODUCTION

The concept of soil quality has evolved since the last decade of the 20th century to answer the growing concern about sustainable soil management. Over exploitation and mismanagement of soil resources in quest for immediate gains without any regards to long term sustainability of its health have led to adverse alteration in soil properties, environment quality, agricultural productivity and sustainability.

The basic objective of the soil-testing programme is to give farmers a service leading to better and more economic use of fertilizers and better soil management practices for increasing agricultural production. High crop yields cannot be obtained without applying sufficient fertilizers to overcome existing deficiencies. Soil survey is the process of classifying soil types and other soil properties in given area and geo-encoding such information. The information in a soil survey can be used by farmers and ranchers to help determine whether a particular soil type is suited for crops or livestock and what type of soil management might be required.

Soil fertility is one of the important factors which determines the productivity and profitability of crops and cropping systems in agriculture. In simple terms soil fertility is the ability of the soil to provide all essential nutrients required for plant growth in a proper proportion. In order to achieve higher productivity and profitability, every farmer should realize that fertility levels must be measured as these measurements can be used to manage soil fertility.

Soil survey provides useful information for planning proper soil and water management practices, which play important part in augmenting crop production. Among the natural resources, soil is available finite, non-elastic and non-renewable asset. In India the dwindling per capita availability of land that decreased from 0.5 to 0.15 ha in 1999-2000 because of population escalation, is likely to reduce further to 0.08 ha in 2020 AD (Yadav and Singh, 2000). Approximately 80 per cent of total farm holdings fall in the category of small and marginal with an average holding of less than 1 ha. Research findings have amply shown 3 to 4 times productivity potential of land even with the currently available technologies. Thus, land if properly managed shall not be a serious constraint to feed the population.

Soil surveying and mapping provide information regarding nutrient availability in soils which forms the basis for the fertilizer recommendations for

maximizing crop yields. Soil fertility maps are meant for highlighting the nutrient needs, based on fertility status of soils (and adverse soil conditions which need improvement) to realize good crop yields. Obviously, a soil fertility map for a particular area can prove high benefit in guiding the farmers, manufacturers and planners in ascertaining the requirement of various fertilizers in a season/year and making projections for increased requirement based on cropping pattern and intensity.

It is estimated that about 8.087 million hectares of land in India are affected by the problem of salinity and sodicity (Abrol and Bhumbla, 1971; Yadav *et al.* 1983). In Gujarat, about 2.22 million hectares of land is lost to agriculture because of salinity and sodicity and extensively distributed both on the coastal and inland areas (Anon., 2012). Agriculture major part of *Bhal* tract adjoining the Gulf of Cambay in Saurashtra is salt affected. Areas under Ukai-Kankarapar command are also salt affected. Coastal saline soils are spread over the districts of Surat, Valsad, Bharuch, Kaira, Amdavad, Bhavnagar, Surendranagar, Amreli, Rajkot, Jamnagar, Junagadh and Kutch including newly formed Gir Somnath and Dev Bhumi Dwarka district of Gujarat.

The water used for irrigation purpose always contain soluble salts in respective of their source, but the total concentrations and the kind of salt present in any irrigation water are important in deciding whether it will suitable for irrigation or not. Moreover, due to implementation of new irrigation project, coupled with important use of canal water, more and more areas are being affected by the problem of water logging as well as soil salinity and alkalinity in India. Quality of irrigation water is one of the main factors to be understood in irrigated agriculture. “Injudicious irrigations” even with good quality waters, turn many agriculturally good soils into saline or alkali conditions, specific ion toxicity in plants and restricted water infiltration into soils with consequent adverse effects on crop production. Irrigation with saline waters further complicates the problem where the interactions of several factors are to be understood.

A good crop yield is the result of integrated effect of the prevailing weather conditions of a particular area, genetic potentiality of plant, soil and crop management practices and availability as well as reserve of the plant nutrients. Under normal conditions, moisture availability, nutrient availability and physical condition of the soil are the main three important soil factors, which determine crop production. In

addition to these, the accumulation of excessive quantities of salts in the soils of semi-arid and arid areas affects the crop production adversely.

The pressing demand of higher grain production for the increasing population of the country has urged the scientists and extension agencies to explore most suitable techniques for the best utilization of land and water resources of the country. Though, there has been a regular increase in the irrigated area of the country in the last decade leading to higher yield potential but due attention has not been given for use of poor quality irrigation waters. Irrigation facilities unfortunately have not smiled happy at Gujarat state. About 41.73 per cent of the total irrigated area is covered by ground water in Gujarat (Anon., 2004). As per one estimate even if the potential of all the rivers in Gujarat is harvested the total area that can be brought under irrigation will be only about one third of the total cultivated land. Thus, the remaining land has to depend upon underground water sources only. Thus, underground well/tube well water is major source of irrigation in Gujarat, where water quality is highly variable due to climatological and hydrological conditions.

In India the length of coastal strips traverse more than 8,129 km along the east to west coast. Most of the ground water aquifers situated along the shoreline has been deteriorated by sea water intrusion. The rapidly growing population in India has too necessarily depends largely on ground water resources for its requirement and altering application of heavy dependency of ground water resources are lowering of water-table and consequent drying has forced the farmer of deepening the wells. According to the present estimate, the coastal saline soils are spread in an area of about 1.4 M ha in the coastal tracts of our country (Dhunushkhodh and Kannathasan, 2009).

Poor performance of crops on salts affected soil may be due to excessive quantities of soluble salts and/or higher exchangeable sodium percentage, which consequently result in nutritional disorders in plants. Excess salt content in soil create high osmotic pressure of soil solution, which obstructs water and nutrient uptake by plant roots. High ESP level deteriorates the soil physical condition and there by limit irrigations” even with good quality waters, turn many agriculturally good soils into saline or alkali conditions, adequate supply of air, water and nutrient to the crop. In present time salinity and alkalinity of soil are serious problem in India as well as in Gujarat.

The water used for irrigation purpose always contain soluble salts in respective of their source, but the total concentrations and the kind of salt present in any irrigation

water are important in deciding whether it will be suitable for irrigation or not. Moreover, due to implementation of new irrigation project, coupled with important use of canal water, more and more areas are being affected by the problem of water logging as well as soil salinity and alkalinity in India. Quality of irrigation water is one of the main factors to be understood in irrigated agriculture. “Injudicious specific ion toxicity in plants and restricted water infiltration into soils with consequent adverse effects on crop production. Irrigation with saline waters further complicates the problem where the interactions of several factors are to be understood.

The use of saline water is indispensable in some area where no alternative facility for irrigation is available; such water are being used in Anand district, knowing the problems related to seawater intrusion have seen a significant rise over the last decades. Seawater intrusion related problems have been reported in various countries and are especially of great concern to Gujarat State in India, as it has the longest coastline of about 1600 km where the quality of ground water would be continuously decreases. It is important to know the extent of damage caused to land due to use of poor quality underground waters for irrigation in salt affected areas.

Soil fertility and water quality survey furnishes useful information for proper planning of soil and water management practices, which play an important role in augmenting crop production. The main objectives of the present study are:

- 1.1 To evaluate soil physical and chemical properties of Mahisagar district
- 1.2 To evaluate quality of underground water of Mahisagar district
- 1.3 To study relationship between different indices of soil and water quality

II. REVIEW OF LITERATURE

Monitoring of 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 Middle Gujarat. The present study includes four different aspects of monitoring soil and water resources. Therefore, the whole review has been divided in to the following points:

2.1 Physical properties of surface soils of Mahisagar district

2.2 Chemical properties and salinity/sodicity status of surface soils of Mahisagar district

2.3 Fertility status of the surface soils of Mahisagar district

2.4 Quality of underground well/tube well water

2.5 Relationship among and between soil fertility and salinity/ sodicity parameters of soils

2.1 PHYSICAL PROPERTIES OF THE SOILS

Soil physical properties namely bulk density, hydraulic conductivity, moisture retention characteristics and co-efficient of linear extensibility are the reflections of moisture content and genetic characteristics. These properties influence several other properties, such as leaching, deep drainage and inter flow and susceptibility to drought, interacting with climate and land use, and these properties produce aridic condition in shallow soils and humid condition in deep soils (Virmani *et al.*, 1982).

Datta *et al.* (1990) observed that the low land soils have more total pore space than those from the upland. Rao (1993) noticed that the water holding capacity of sandy soils in Chakicharla village of Prakasam district, Andhra Pradesh ranged from 16.45 to 21.42 per cent.

Sharma (1994) observed that the maximum water holding capacity of the soil is generally related to the texture of the soil and increase with increase in clay content. Maji *et al.*, (1995) revealed that the water holding capacity in coastal soils of Sundarban, West Bengal ranged from 21.40 to 37.60 per cent.

Chitdeshwari *et al.* (2000) reported the spatial variability of bulk density in *Alfisol* and *vertisol* soils. They found that the bulk density of the surface soil of *vertisol* varied from 1.27 t m^{-3} and in *Alfisol* it ranged from 1.11 to 1.48 t m^{-3} .

Review of Literature

Savaliya *et al.* (2000) found that the water holding capacity of surface soils of Uben command area of Saurashtra region at 0, 33 and 1500 kPa ranged from 0.380 to 0.633, 0.214 to 0.379 and 0.111 to 0.176 cm³, respectively.

The water holding capacity in soils of Haldi ghati region of Rajasthan was low to medium in per cent range of 17.10 to 37.30 (Sharma *et al.*, 2001). Savalia and Gundalia (2004) reported the bulk density, total porosity and water holding capacity of the soils Uben irrigation command area of Saurashtra region in Gujarat ranged from 1.21 to 1.33 Mg m⁻³, 42.4 to 55.0 and 38.9 to 54.1 per cent, respectively.

Savalia and Gundalia (2004) reported the bulk density, total porosity and water holding capacity of the soils of Uben irrigation command area of Saurashtra region in Gujarat ranged from 1.21 to 1.33 mg m⁻³, 42.4 to 55.0 percent and 38.9 to 54.1 per cent, respectively.

Ogunwale and Isa (2004) observed that the bulk density values of coarse textured soils range from 1.01 to 1.65 g cm⁻³. Savaliya (2005) recorded the particle density and WHC values of the soils of Southern Saurashtra region of Gujarat ranged from 2.41 to 2.52 Mg m⁻³ (2.46 Mg m⁻³ weighted mean) and 32.77 to 53.15 per cent (43.62 % weighted mean), respectively.

Thangasamy *et al.* (2005) noticed that the water holding capacity in soils of Sivagiri micro watershed in Chittor district of Andhra Pradesh ranged from 13.05 to 58.99 per cent. These differences were due to the variation in the depth, clay, silt and organic carbon content in the soils. Sitanggang *et al.* (2006) found that the soils of micro watered having high percentage of sand or gravel have more bulk density than those having high clay content.

Balpande *et al.* (2007) found that the water retention in different soils of Nasik district varied from 19.56 to 50.22 at 33 kpa and 9.81 to 30.94 at 1500 kpa.

Rao *et al.* (2008) found that the bulk density and water holding capacity of soils of Ramachandrapuram Mandal of Chittor district in Andhra Pradesh varied from 1.45 to 1.66 Mg m⁻³ and 19.96 to 47.81 per cent, respectively. Almost similar results were also found by Sankar and Dhadhwal (2009) and Savalia *et al.* (2009).

Kadu *et al.* (2009) characterized soils from upper wardha command area for physical properties and stated that saturated hydraulic conductivity of soils ranged from 0.01 to 3.82 cm hr⁻¹. The continuation of canal irrigation induced the sodification process in soil and there by reduced hydraulic conductivity.

The bulk density of the soils of Inceptisols, Vertisols and Entisols of salvi watershed in Nagpur District ranged from 1.40 to 1.76 mg m^{-3} (Kashiwar *et al.*, 2009).

Savalia *et al.* (2009) reported the bulk density of different land from of Southern Saurashtra varied from 1.28 to 1.57 mg m^{-3} (1.41 mg m^{-3} weighted mean).

Ram *et al.* (2010) observed bulk density, particle density and total porosity in the flood-prone soils of eastern plains of Rajasthan ranged from 1.32 to 1.61, 2.36 to 2.64 Mg m^{-3} and 37.70 to 46.36 per cent respectively.

Vijay Kumar *et al.* (2010) found that the bulk density ranged from 1.58 to 1.76 g cm^{-3} . Similarly, Patel (2010) observed that the bulk density varied from 1.28 to 1.60 Mg m^{-3} with mean value of 1.41 Mg m^{-3} in soils of different landforms of Meghal Irrigation Command area of Southern Saurashtra.

Shirgire (2012) observed bulk density, particle density, porosity and MWHC in the soils of Jamnagar district varied from 1.15 to 1.52, 2.19 to 2.83 Mg m^{-3} , 22.89 to 56.80 and 36.47 to 73.02 per cent with mean value 1.30, 2.40 Mg m^{-3} , 45.57 and 52.16 per cent, respectively.

Singh and Sharma (2013) reported that soil bulk density varies from 1.40 to 1.61 Mg m^{-3} in sand dune, 1.42 to 1.66 Mg m^{-3} in interdunal and 1.49 to 1.72 Mg m^{-3} in alluvial terrace soils.

2.2 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).

The salt affected soils of Kuchchh (Anjar, Bhuj, Mundra and Lakhpat) and Surendranagar districts are saline, sodic and highly saline sodic in nature. The NaCl was dominant source of salinity. Free lime content decreased with depth. These soils were poorly supplied with organic carbon and nitrogen.

Review of Literature

The pH_s, EC_e and ESP ranged from 7.6 to 8.9, 1.2 to 60.0 dSm⁻¹ and 5.5 to 74.0 in Kuchchh district and 3.6 to 8.8, 23.3 to 64.2 dSm⁻¹ and 50.7 to 77.4 in Surendranagar district, respectively (Dubey *et al.* 1986b; Dubey and Sharma, 1987).

Sagare *et al.* (1991) characterized the saline-sodic and sodic soils of Vidarbha region of Maharashtra and noted that the pH_s, EC_e and ESP of saline-sodic soils ranged from 8.3 to 8.8, 2.25 to 3.90 dSm⁻¹ and 16 to 61, whereas those of sodic soils ranged from 8.4 to 8.9, 0.97 to 1.20 dSm⁻¹ and 15.3 to 51.1, respectively.

Singaravel *et al.* (1996) characterized the physico-chemical properties of coastal saline soils of Tamilnadu and revealed that the soils contain ESP as high as 42.75 with pH value ranged from 7.04 to 9.19.

Timbadia and Maliwal (2000) studied the physico-chemical properties of salt affected soils of coastal areas (Jafrabad, Kodinar and Rajula talukas) of Amreli district of Gujarat. The EC_e ranged from 1.0 to 10.0, 0.43 to 16.5 and 0.48 to 10.0 dSm⁻¹, while pH from 8.0 to 9.4, 7.6 to 8.7 and 8.1 to 9.2 in Jafrabad, Kodinar and Rajula talukas, respectively. The ESP value varied from 19.1 to 44.7, 11.7 to 63.4 and 12.0 to 66.7 in Jafrabad, Kodinar and Rajula talukas, respectively.

Polara *et al.* (2004) observed the dominance of Ca⁺⁺ and Mg⁺⁺ among the exchangeable cations, and among water soluble ions, dominance of Na⁺ and Cl⁻ in the soils of nine taluka of Kuchchh district. The soils of Kuchchh district were poor in organic carbon, alkaline in reaction and calcareous in nature. More than half (60.3%) of the cultivated soils of Kuchchh district were saline in nature, followed by saline-sodic (25.7 per cent) and sodic (14.0 per cent).

Twenty surface (0-15 cm) soil samples from each of the eleven talukas of Amreli district were composed 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 Amreli district were normal in nature, followed by saline (13.6 %), saline-sodic (12.7 %) and sodic (12.3 %) (Kabaria and Polara, 2006).

Polara *et al.* (2006) collected 440 surface soil samples from cultivated farmer's field of North-West Agro climatic Zone of Gujarat and reported that the dominance of Ca⁺⁺ 16.05 cmol(p⁺) kg⁻¹ and Mg⁺⁺ 8.12 cmol(p⁺) kg⁻¹ among the exchangeable cations, while the Na⁺ (11.8 me L⁻¹) and Cl⁻ (10.7 me L⁻¹) among the water soluble ions and poor in organic carbon (range 0.053 to 0.89, mean 0.312 per cent) and

alkaline in reaction (pH mean 8.03). The result further shows that half (49.7 per cent) of the cultivated soils of this zone are having salinity problem, followed by saline-sodic (31.2 per cent) and sodic (19.1 per cent). Problem of salinity is acute in Lakhpat, Rapar, Nakhtrana, Bhauchu and Anjar of talukas of Kuchchh district and Vav, Tharad and Santalpur taluka of Banaskatha district. On other hand, the soils of Mandvi, Hadwad, Dasada, Harji, Deodar and Kankraj talukas have twin problems of salinity as well as sodicity.

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 dSm⁻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 (Guruprasad *et al.* 2007).

Marsonia *et al.* (2008) studied the seventy three surfaces (0-15) 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%).

Sharma *et al.* (2008) studied soils of indo gangetic alluvial plain in Amritsar district of Punjab under three major landform units viz. alluvial plain, flood plain and sand bars. They observed that pH of soils varied from 7.0 to 9.76 and nearly 54 per cent soil samples had pH between 7.0 and 8.5 with remaining 46 per cent had pH higher than 8.5. In case of salt concentration, EC of soil varied from 0.1 to 1.0 dSm⁻¹ with an average of 0.34 dSm⁻¹. The majority of soil samples (99 per cent) were in the normal EC range (<0.8 dSm⁻¹). The organic carbon content of soils varied from 0.16 to 0.97 per cent with an average value of 0.61 per cent.

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, CaCO₃ and CEC of soils varied from

Review of Literature

7.20 to 9.01, 0.21 to 2.61 dSm⁻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 dSm⁻¹, 5.32 g kg⁻¹, 42.94 g kg⁻¹ and 41.75 cmol(p⁺)kg⁻¹, respectively.

Ashokkumar and Jagdish (2010). Characterized the sugarcane growing soils of Ahmadnagar district of Maharashtra. The soils were moderately to strongly alkaline in reaction and CEC varied from 21.6 to 67.7 cmol (+) kg⁻¹. Calcium and magnesium were found to be dominant cations on the exchange complex.

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 dSm⁻¹ and 0.7 to 2.4 g kg⁻¹ with mean values of 8.42, 0.78 dSm⁻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 dSm⁻¹ and 0.06 to 0.43 per cent with the mean values of 8.52, 1.05 dSm⁻¹ and 0.21 per cent, respectively.

Srinivas *et al.* (2011) studied the physio-chemical properties of soils of Krishna western delta Andhra Pradesh. The result revealed that the soils were found to be saline in nature. 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.

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 EC_e of these soils ranged from 1.09 to 17.8 dSm⁻¹ with an average value of 6.89 dSm⁻¹. The pHs of these soils ranged from 7.3 to 8.9 with an average value of 7.86 and the CaCO₃ 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, CaCO₃ and CEC of soils varied from 7.66 to 9.01, 0.26 to 3.06 dSm⁻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 dSm⁻¹, 4.97 g kg⁻¹, 54.9 g kg⁻¹ and 36.5 cmol(p⁺)kg⁻¹, respectively.

Patel *et al.* (2012a) found that organic carbon of the soils of different landslopes of meghal irrigation command area of Southern Saurashtra ranged from 0.33 to 0.51 per cent with the overall mean value of 0.40 per cent.

Review of Literature

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 dSm⁻¹ with mean of 0.07 dSm⁻¹ and organic carbon ranged from 6.0 to 25.2 g kg⁻¹ with average of 14.74 g kg⁻¹.

Devdas *et al.* (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 dSm⁻¹ and 0.29 to 0.88 per cent with a mean values 6.24, 0.25 dSm⁻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 dSm⁻¹ and 0.22 to 0.66 per cent with the mean value of 6.53, 0.065 dSm⁻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. The EC of these soils varied from 0.12 to 1.96 dSm⁻¹ with an average value of 0.31 dSm⁻¹. The soils was neutral to alkaline 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 CaCO₃ in these soils varied from 0.66 to 14.26 per cent with an average value of 4.25 per cent.

Gandhi (2013) reported that the pH, EC, organic carbon and CaCO₃ ranged from 7.13 to 8.15, 0.28 to 4.69 dSm⁻¹, 0.46 to 1.01 per cent and 2.30 to 78.78 per cent with overall mean value of 7.70, 1.91 dSm⁻¹, 0.50 per cent and 27.67 per cent, respectively, which indicate that the soils of Girnar toposequence were slightly alkaline in reaction, low in organic carbon content and highly calcareous in nature. The CEC, SSP 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. The order of dominance of exchangeable base was Ca²⁺ > Mg²⁺ > 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

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 dSm⁻¹ and 1.0 to 8.9 per cent with mean value of 6.8, 0.26 dSm⁻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 dSm⁻¹ and with a mean value of 7.6 and 1.21 dSm⁻¹, respectively.

Verma *et al.* (2013) characterized the physico-chemical properties of *Inceptisols* of Malkharauda block, Janjgir Champa district in Chhattisgarh during 2011-12 cover 110 villages. Soil samples were collected and subjected to analysis. The results revealed that the soils having EC_{2.5} varied from 0.05 to 0.75 dSm⁻¹ with a mean value of 0.20 dSm⁻¹, the soils was 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 5.9 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 dSm⁻¹ and 0.26 to 0.92 per cent with a mean value of 7.83, 0.58 dSm⁻¹ and 0.46 per cent, respectively.

Tundup and Akbar (2014) collected 60 surface soil samples from Kishtwar district in Jammu and Kashmir for determining the chemical properties of the soils. The EC of these soils ranged from 0.15 to 0.23 dSm⁻¹ with a mean value of 0.18 dSm⁻¹, the pH of these soils ranged from 6.65 to 7.64 with a mean value of 7.37 and organic carbon of these soils ranged from 0.58 to 0.81 with a mean value of 0.68 per cent, respectively

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.

Review of Literature

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 pH, EC and OC of soils varied from 6.70 to 8.30, 0.20 to 1.20 dSm⁻¹ and 0.49 to 0.88 per cent with the mean value of 7.86, 0.50 dSm⁻¹ and 0.68 per cent, respectively.

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 dSm⁻¹ and 1.12 to 8.1 g kg⁻¹ with mean values of 7.57, 0.23 dSm⁻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 dSm⁻¹ and 4.02 to 7.43 g kg⁻¹ with mean values of 8.4, 0.24 dSm⁻¹ and 5.02 g kg⁻¹, respectively.

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 70 per cent samples alkaline, while EC of soils varied from 0.09 to 1.43 dSm⁻¹ (average 0.37 dSm⁻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 0.23 dSm⁻¹ and 0.039 to 2.388 per cent with mean values of 7.96, 1.139 dSm⁻¹ and 0.36 per cent, respectively.

Reddy and Naidu (2016) studied physico-chemical properties in semi-arid region of Chennur mandal 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 dSm⁻¹ and 1.6 to 8. g kg⁻¹, respectively.

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 dSm⁻¹ and 0.24 to 0.79 per cent with mean values of 8.39, 0.28 dSm⁻¹ and 0.51 per cent, respectively.

2.3 FERTILITY STATUS OF THE SURFACE SOILS

There exists a wide variation amongst soil 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 such as bulk density, moisture retention capacity, infiltration rate and soil aggregation etc. 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.

2.3.1 Available Macronutrient

Akbari *et al.* (1993) collected 107 surface soil samples from Mewar region (84 from Udaipur and 23 from Chittorgarh district) of Rajasthan. They found that the organic carbon, available P and K varied from 0.03 to 1.44 per cent, 13.44 to 132.16 kg ha⁻¹ and 104.8 to 953.7 kg ha⁻¹, respectively. The available S content varied from 2.25 to 69.75 ppm in soils of Udaipur and 2.25 to 43.75 ppm in soils of Chittorgarh district.

Maliwal and Timbadia (1993) collected 76 surface soil samples from coastal areas of Vallabhipur and Maliya and interior area of Amreli, Liliya and Lathi talukas of Saurashtra region of Gujarat and observed the available N, P₂O₅ and K₂O were ranged from 188 to 439, 15.4 to 99.8 and 120 to 2262 with mean values of 313.5, 48.2 and 841 kg ha⁻¹, respectively.

Singaravel *et al.* (1996) studied nutrient status of the coastal saline soils of Tamilnadu. The data on nutrient status showed that the soils were low in organic carbon, low to medium in available nitrogen, variable in available phosphorus status and medium to high in available potassium.

Choudhary and Shukla (2002) collected 140 soil samples belonging to seven soil great groups of arid soils of western Rajasthan varied widely in their characteristics. The available sulphur content of most of the soils was in the high

range, with the mean value of 59.3 mg/kg. Only a few samples (5.7 per cent) recorded low in available sulphur content.

Kundu *et al.* (2005) found that four village of Nadia district of West Bengal were medium in the organic carbon and available nitrogen status in Utter Duttapara, Kurumbalia and Dasdia villages and the available P_2O_5 status for all four villages was high but the available K_2O status was medium.

Savalia (2005) found that the available nitrogen, phosphorus and potassium content ranged from 125.5 to 360.3 kg ha⁻¹, 5.6 to 42.2 kg ha⁻¹ and 21.5 to 1036.7 kg ha⁻¹ with an overall mean of 205.0 kg ha⁻¹, 19.4 kg ha⁻¹ and 236.0 kg ha⁻¹, respectively in the soils of different landforms of Southern Saurashtra.

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 that 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 values of 26.6 mg kg⁻¹.

The soils of Bajara Research Center, Jamnagar was found low (192.9 to 272.9 kg/ha) in N status. The available P_2O_5 was low to medium (21.5 to 69.3 kg ha⁻¹) and available K_2O was high and it was ranging 324 to 513.2 kg ha⁻¹, with mean value of 380.28 kg ha⁻¹, The available S was found low to medium of 1.0 to 7.5 mg kg⁻¹ (Anon., 2007).

The soils of fruit Research station, Mangrol were found low to medium (241.5 to 379.5 kg ha⁻¹) in nitrogen status. The available P_2O_5 was found low to medium (9.75 to 77.68 kg ha⁻¹) and available K_2O was high and it was ranging 428 to 851 kg ha⁻¹, with mean value of 623.4 kg ha⁻¹. The available Sulphur was found medium (2.94 to 19.5 mg kg⁻¹) with mean value 15.24 mg kg⁻¹ (Anon., 2008).

Review of Literature

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 with a mean value of 24.6 mg/kg 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, P₂O₅ and K₂O 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.

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, P₂O₅ and K₂O 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 (<10.0 ppm), 35 per cent were in medium category (10 to 20 ppm) and 48 per cent were in high (> 20 ppm) category.

Patel *et al.* (2012a) found that organic carbon of the soils of different landslopes of Meghal Irrigation Command area of Southern Saurashtra ranged from 0.33 to 0.51% with the overall mean value of 0.40%.

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 in mg kg⁻¹ soils (240 surface soil samples) of

Review of Literature

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 P₂O₅ 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 P₂O₅ kg ha⁻¹) and 98.7 per cent high (>56 P₂O₅ kg ha⁻¹) in status. Available K₂O content varied from 315 to 692 kg ha⁻¹ (mean 505.4 kg ha⁻¹) with only 10 per cent medium (140 to 280 K₂O kg ha⁻¹) and 90 per cent high (> 280 K₂O 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, P₂O₅ and K were varied from 72.1 to 516.2, 2.21 to 85.7 and 38.0 to 990.0 kg/ha with an average value of 312.1, 28.6 and 451.2 kg/ha, respectively.

Singh and Kumar (2012) collected 110 surface soil samples from vegetable growing area of Varanasi district and found that the available N, P₂O₅, K₂O 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 kg ha⁻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, P₂O₅ and K₂O were ranged from 290.20 to 893.17, 24.62 to 64.37, 55.60 to 359.11 and 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, P₂O₅ and K₂O 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 P₂O₅ 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 21.470 mg kg⁻¹, respectively.

Review of Literature

Singh and Munth (2013) studied fertility status of soil under forest and cultivated land use system of Nagaland. The available N, P₂O₅ and K₂O 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, P₂O₅ and K₂O 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, P₂O₅ and K₂O 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 and K 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, P₂O₅ and K₂O 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, K 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.

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, P₂O₅, K₂O 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, P₂O₅, K₂O 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

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 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 ($< 28\ P_2O_5\ kg\ ha^{-1}$), 85 per cent medium (28 to 56 $P_2O_5\ kg\ ha^{-1}$) and 7 per cent high ($> 56\ P_2O_5\ kg\ ha^{-1}$). 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, available potassium and available sulphur of soils varied from 9.99 to 138.82, 105.91 to 940.80 kg/ha 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.

Reddy and Naidu (2016) analyze available nutrient status in semi-arid region of Chennur mandal under Kapada district of Andhra Pradesh and reported that available N, P_2O_5 , K_2O and S in soils ranged from 168 to 477, 22 to 81, 122 to 744 $kg\ ha^{-1}$ and 17 to 62 $mg\ kg^{-1}$, respectively. The soils were low to medium in available N, medium to high in available P, low to high in available K and high in available S.

Panchal *et al.* (2017) collect forty representative surface (0-15 cm) soil samples for studying pH, EC, organic carbon, available N, P_2O_5 , and K_2O in soil of Banaskantha district of Gujarat. The data shows that in soils of Banaskantha district of Gujarat, the content of organic carbon and available nitrogen were classified in low category. Status of available phosphorus and sulphur, was medium while status of available potassium was high. Organic carbon positively correlated with available major nutrients.

Patel *et al.* (2017) collect 240 surface soil samples for studying available major nutrients in soils of Aravalli district of Gujarat. The data shows that in soils of

Aravalli district of Gujarat, the content of available nitrogen was classified in low category. Status of available phosphorus and sulphur, was medium while status of available potassium was high. Based on overall nutrient index value in soils of Aravalli district, available N, P_2O_5 , K_2O and S were classified in low, adequate, high and marginal fertility status, respectively.

Thakur and Patel (2017) they determine that available sulphur status in soils of Mehsana district of Gujarat. Among 371 soil samples of the district, 29.65, 49.87 and 20.49 per cent were found under low, medium and high category for available sulphur, respectively. According to the Nutrient Index Value (NIV) soils of Mehsana district were marginal in available S (1.91). They reported that the soils of Mehsana district have marginal status of available sulphur.

2.3.2 Micronutrient

Timbadia and Maliwal (2000) collected 89 surface soil samples (0-15 cm) of salt affected soils varying from loamy sand to clayey in texture from coastal areas (Jafrabad, Kodinar and Rajula talukas) of Amreli district of Gujarat and analyzed for DTPA extractable micronutrients. The result showed that the Zn, Fe, Cu and Mn were in the range of 0.07 to 2.1, 3.1 to 13.5, 2.0 to 9.6 and 6.9 to 33.6 ppm, respectively. About 36.0 and 7.9 per cent soil samples were found deficient with respect to DTPA extractable Zn and Fe, respectively, but none of the samples for Cu and Mn were found deficient.

Dhage *et al.* (2000) collected the surface soil samples from 69 locations from Shevgaon tehsil of Ahmednagar district and analyzed DTPA extractable micronutrients and reported that the DTPA Fe, Mn, Zn and Cu showed a range of 2.22 to 9.06, 6.08 to 45.83, 0.1 to 2.82 and 2.04 to 11.38 ppm with their mean value of 5.21, 17.34, 0.37 and 3.49 ppm, respectively and concluded that Fe, Mn, and Cu were in sufficient level, while Zn was found to be deficient in these soils.

Prabhuraj *et al.* (2001) collected 40 surface soil sample representing mulberry sites of krishnarajpet of Karnataka and were evaluated for DTPA extractable micronutrients. They found deficiency of Zn in 34 out of 40 soil samples, whereas available Fe, Mn, and Cu were found as dequate.

Sharma *et al.* (2003) studied the status of micronutrients in soil of semi - arid region of Rajasthan. Available Zn, Cu, Fe, and Mn content ranged from 0.1 to 1.7, 0.5

to 3.9, 1.0 to 6.6, and 2.7 to 7.2 mg kg⁻¹ with a mean value of 0.73, 2.11, 4.32, and 5.15 mg kg⁻¹, respectively.

Dwivedi *et al.* (2005) collected surface soil samples from five cultivated field, each from 96 and 50 village of Leh and Kargil districts of Ladakh region and analyzed and found that the DTPA- extractable Zn, Cu ,Fe and Mn were in range from 0.54 to 33.79, 0.43 to 3.52, 0.06 to 16.3 and 0.20 to 32.17 mg kg⁻¹, respectively in soil of Leh district, while the range of Zn , Cu ,Fe and Mn was observed from 0.20 to 38.04, 0.50 to 3.41, 0.14 to 5.17 and 0.34 to 4.74, mg/kg respectively in soils of Kargil district.

Mehra *et al.* (2005) studied of 1110 samples from *Haplustallfs* of sub humid plain and Aravalli of Rajasthan, 18.77 %, 40.63 %, 9.63 %, 2.41 % and 36.12% deficiency of Cu, Fe, Mn, Zn and S, respectively were observed.

Meena *et al.* (2006) collected 120 surface soil samples (0 – 20 cm) from Tonk district of Rajasthan and reported that the DTPA extractable Fe, Zn, Mn and Cu varied from 2.23 to 14.16, 0.19 to 1.93, 6.85 to 45.25 and 0.21 to 1.87 with mean values of 5.38, 0.83, 21.56 and 0.61 mg kg⁻¹, respectively.

Polara *et al* (2006) collected 440 surface soil samples from salt affected area of North-West Agro Climatic Zone of Gujarat, and reported that the soils are low in organic carbon and DTPA extractable Zn, Fe, Mn and Cu status.

Hundal and Singh (2008) studied the nutrient status of rice crops cultivated in low land areas in the vicinity of Satluj 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.

Patel (2010) observed 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.

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.

Review of Literature

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 (Annual Report, 2011-12).

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.

Punith Raj *et al.* (2012) collected 80 surface soil samples (0-15 cm) from Hassan district of Karnataka and reported that the DTPA- Fe, Zn, Mn and Cu ranged from 1.80 to 69.14, 0.15 to 7.61, 1.02 to 68.01 and 0.96 to 9.96 with mean value of 58.12, 1.83, 47.39 and 3.73 mg kg⁻¹, 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 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 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, 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.

A survey work was carried out with 177 surface soil samples from Gandhinagar district of Gujarat to study fertility status of farmer's field and it was

Review of Literature

revealed that DTPA extractable Fe, Mn, Zn and Cu values were ranged between 3.34 to 24.08, 3.28 to 23.70, 0.16 to 1.76 and 0.36 to 1.90 mg kg⁻¹ with mean values of 6.91, 12.93, 0.63 and 0.96 mg kg⁻¹, respectively (Annual Report, 2015).

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 Fe, Mn, Cu and Zn in soils varied from 3.26 to 20.16, 0.94 to 8.26, 0.23 to 10.22 and 0.14 to 1.56 mg kg⁻¹ with mean values of 10.02, 2.83, 2.56 and 0.50 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.

Mahajan *et al.* (2015) studied fertility status of the coastal acid saline soils of Goa and found that available micronutrients Fe, Mn, Cu and Zn ranged from 33.4 to 66.4, 8.71 to 126, 0.60 to 4.41 and 0.54 to 2.48 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 (Yadwad watershed) of Karnataka. They found that 100 per cent Yadwad 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 micro-watershed 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

¹with 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 (mean 0.44 mg kg⁻¹), with 70 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 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/kg 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.

Patel *et al.* (2017b) collect 240 surface soil samples for studying available micronutrients cations in soils of Aravalli district of Gujarat. The data shows that in soils of Aravalli district of Gujarat, they clearly indicate that the status of DTPA-extractable Mn and Cu was high while status of DTPA-extractable Fe and Zn was

medium. Based on overall nutrient index value in soils of Aravalli district, available Fe, Mn, Zn and Cu were classified in adequate, very high, marginal and very high fertility status, respectively.

2.3.3 Nutrient index

Polara and Kabaria (2006) studied the 220 surface soil samples of Amreli district indicates that soils were deficient with respect to available N and S, whereas medium in available P_2O_5 and K_2O status. Among the DTPA extractable micronutrients, Mn and Cu were found sufficient, whereas the soils were medium in Fe and Zn. 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. More or less similar, results were also reported by Polara *et al.* (2006) for the soils of North-West Agro Climatic Zone of Gujarat.

Prakash *et al.* (2008) soil survey was done during the year 2004-05, Bajaj sugar mill Bhasana, Muzaffarnagar district, Uttar Pradesh, India, where 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.

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_2O_5 (1.68), high for K_2O (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.

2.4 QUALITY OF UNDER GROUND WELL/TUBE WELL WATER

2.4.1 Quality of well/tube well water and their suitability

In arid and semi-arid areas, irrigation is very essential for successful agriculture. Whatever may be the source of irrigation water, some soluble salt are always dissolved there in. These constitute mostly of sodium, calcium, magnesium and some times potassium as cations and chloride, sulphate, bicarbonate and little

amount of carbonate and some times nitrate as anions. The suitability of irrigation water should be evaluated on the basis of criteria indicative to their potential to create hazardous soil condition for crop growth.

Bhumbla (1969) 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.

Timbadia (1988) collected 89 under ground well water samples from Jafarabad, Kodinar and Rajula talukas of Amreli district to judge the quality of irrigation water and their effect on soil characteristics. He found that well water were slightly alkaline (7.5 to 9.0) in reaction, saline (0.9 to 11.0 dSm⁻¹) in nature and dominated with Na⁺ and Cl⁻. On an average 57 per cent well water having more than 1 mg L⁻¹ and only 18 per cent samples have more than 1 mg L⁻¹ fluorine. The percentage of samples falling under class I, II and III of SSP were 13, 21 and 66, respectively.

Das *et al.* (1991) collected 97 water samples from Orissa to judge their suitability for irrigation purpose. The quality rating of these water indicated that 8 samples from wells, 3 from perennial stream / canals and 7 from ponds were unsuitable for irrigation purpose. Special attentions are to be given while irrigating these water.

Girdhar (1991) studied the compositions of ground water of 8 different wells were evaluated at coconut plantation farm GAU, Mahuva. It was observed that EC of these wells varies from 1.9 to 9.3 dSm⁻¹ and SAR ranges from 5 to 31.5. These water are also rich in Na⁺ followed by Mg⁺⁺ and Ca⁺⁺, where as Cl⁻ is the dominant anion.

Gupta (1991) carried out an integrated classification of ground water based upon EC, SAR, and RSC values of 4145 water samples from 11 districts of western Rajasthan. It was observed that these ground water were sodic in character due to high SAR or RSC values. The SAR ranges from 0.15 to 176.8 with average value of 13.9 in districts of Barmer, Bikaner and Jaisalmer. More than 33.3 per cent water have SAR greater than 18. High RSC generally occurs in low to medium salinity water and ranges from nil to 68.8 me L⁻¹ with an average value of 3.1 me L⁻¹. The districts viz, Jhunjhunu, Nagaur and Sikar have high RSC in ground water; based upon salinity,

SAR and RSC distribution, the whole region has been divided in six saline-sodic zones.

One hundred six irrigation water samples from four talukas i.e. Porbandar (49), Ranavav (31), Kutiyana (16) and Manavadar (10) were collected during 1991 for monitoring of quality of irrigation water. The data of the chemical analysis of irrigation water revealed that EC ranged from 0.77 to 44.0 with an average of 20.63 dSm^{-1} . The SAR of irrigation water varies from 1.92 to 36.31 with an average of about 10.41. The SSP ranged from 14.22 to 87.57 with an average of 60.62. Na was the predominant cation followed by Ca, Mg and K. The chloride was the dominant anion (Anon. 1992).

Rai *et al.* (1993) collected sixty well water of Suratgarh and Hanumangarh and analyzed for pH, EC, chloride, sulphate, nitrate, fluoride, calcium, magnesium, sodium, potassium, and boron. The EC of water varied from 5.9 to 43.5 dSm^{-1} , SAR from 8 to 37 and boron from 0.1 to 13.0 mg L^{-1} .

Chand *et al.* (1993) collected two hundred twenty water samples from running tube wells in villages, viz., Tihara, Shahpur, Asalwas, Karnawas and Bawal of Mahandragarh district of Haryana. The RSC and SAR were calculated and the water samples were classified into five categories viz. good, normal, sodic, marginally saline and saline-sodic.

Brar and Singh (1993) studied the quality of under ground irrigation water in south western districts of Punjab on the basis of 15468 tube well water samples received from the three districts of these zones. On the basis of EC, 73, 22 and 5 per cent samples fall in the category of <2000, 2000-4000 and >4000 micromohs cm^{-1} , respectively. Where as if we classify the samples on the basis of RSC 36, 23, 23 and 18 per cent samples fall in the category of <2.5, 2.5-5.0, 5.0-7.5 and >7.5 me L^{-1} , respectively. Taking into consideration both EC and RSC, 25, 31 and 44 per cent water samples were found to be fit, marginal and unfit for irrigation purpose.

Patel *et al.* (1993) collected tube well water samples from three talukas of Mehasana district during summer 1989. The results revealed that the water sample had a high salinity hazard but permissible for sandy to sandy loam soil. The SSP and RSC were high and reported to have quicker adverse effect on light textured soils than heavier textured soils. Hence, indiscriminate and excess use of this sodic water is required to be avoided.

Singh *et al.* (1994) studied the quality of ground water in *Samadari-Balotra* region of Western Rajasthan revealed that these water were moderate to highly saline and sodic with EC ranged of 240 to 33213 $\mu\text{S m}^{-1}$ and pH from 7.0 to 9.5. These water have marked concentration of chloride of sodium with high soluble sodium percentage in 97 per cent samples. In all cases, calcium was lower than the magnesium, except in few samples with low salinity of C_1 and C_2 classes. The value of SAR ranges from 1.85 to 96 and 54.4 per cent water samples fall under high SAR classes. The content of RSC in well water ranges from 0.4 to 38.6 me L^{-1} and 29.20 per cent water samples have RSC more than 8 me L^{-1} . The soils irrigated with saline water have pH of 7.1 to 8.5 at surface and 7.3 to 8.6 in subsurface, while EC at these locations varied from 249 to 9565 and 359 to 2123 $\mu\text{S m}^{-1}$, respectively.

The analysis of under ground well water of Junagadh district revealed that the quality of well water of this district had wide range of salinity hazards ranging from the EC value of 0.4 to as high as 11.0 dSm^{-1} with a mean value of 2.11 dSm^{-1} . However, the alkali hazard was negligible in the area. Most of the water had pH range of 7.5 to 8.5 with a mean value of 8.0. Further, it was indicated that there were some of the wells had the problem of RSC. The RSC, SAR and SSP values were ranged from 0.55 to 5.2, 0.60 to 11.2 and 12.2 to 77.4 with their mean values were 2.28 me L^{-1} , 3.40 and 35.81, respectively (Anon., 1994).

Bhamodker *et al.* (1997) carried out analysis of irrigation water under the commands of Kate, Puna and Morna. The result showed that the well water have high to very high salinity with low to very high sodium status. Hence, this well water is not suitable and should not be used for irrigating the crops unless the proper reclamative measures and drainage are provided. The study suggested that the agriculture in the area should be encouraged only under rainfed condition for *kharif* crops or by selecting salt tolerant crops in *Rabi* season with advanced irrigation practices.

An investigation was under taken by Lal *et al.* (1998) to determine the quality of under ground water of non-command area of *Bikaner* district in Rajasthan, their effect on soil properties and to categorize them for their suitability for irrigation. The water is mostly $\text{Na}^+ - \text{Mg}^{++} - \text{Ca}^{++}$ type with dominance of Cl^- followed by CO_3^- , HCO_3^- .

Nilsood *et al.* (1998) suggested that EC of water samples collected from 88 villages of Talwandi sabtensi (Bhatinda district) varied from 0.55 to 13.74 dSm^{-1} . Soluble carbonate, bicarbonate and RSC of these water varied from nil to 3.2, 2.0 to 17.7 and traces to 14.6 me L^{-1} , respectively. Soluble sodium (3.0 to 19.1 me L^{-1}) was

Review of Literature

the dominant cation and SAR ranged from 2.3 to 31.3. Based on EC and RSC of water 15, 38, 12 and 35 per cent were good (low EC and RSC) marginal-saline, marginal-sodic and poor (high EC and RSC), respectively, for irrigation purpose. Salinity is more prevalent than sodicity in the area.

Yadav (1999) studied the chemical composition and quality of irrigation water sample was collected from 64 villages of Mahendragarh district. The pH, EC, SAR and RSC in irrigation water were varied from 7.6-9.7, 0.2-23.4 dSm⁻¹, 0.19-80.49 and nil-33.50 me L⁻¹ with mean values of 8.68, 3.24 dSm⁻¹, 1.56 and 3.57 me L⁻¹, respectively. The cations and anions viz., Ca⁺⁺, Mg⁺⁺, Na⁺, K⁺, CO₃⁻, HCO₃⁻, Cl⁻ and SO₄⁻ in irrigation water were varied from 0.25-26.25, 0.0-80.00, 0.28-234.00, 0.01-2.10, 0.0-10.00, 0.0-29.60, 0.0-203.00 and 0.0-57.10 me L⁻¹ with mean values of 3.19, 4.73, 33.15, 0.25, 0.78, 7.08, 21.48 and 3.70 me L⁻¹, respectively.

Srivastava and Lallanram (2000) collected water samples from kalmeshwar tehsil. They found that 76 per cent of total water sample were moderately suitable and only 3 per cent were unsuitable for irrigation. In case of water sample collected from katol tehsil, 94 per cent of the total samples were unsuitable, only 6.0 per cent of total sample were found moderately suitable for irrigation.

In order to study the nature and extent of salinity and sodicity of under ground well water of Limbdi and Halvad talukas of Surendranagar district, 10 and 6 well water samples from Limbdi and Halvad talukas, respectively, were collected during 2001. The result revealed that EC values were ranged from 1.3 to 14.0 dSm⁻¹ and 2.1 to 7.6 dSm⁻¹ with their mean values of 4.56 and 4.43 dSm⁻¹ for Limbdi and Halvad taluka, respectively. The pH, RSC, SAR and SSP values for Limbdi taluka were ranged from 7.70 to 8.25, 0.0 to 9.4, 4.63 to 28.4 and 60.0 to 89.6 with their mean values of 8.03, 2.3 me L⁻¹, 14.7 and 73.9, respectively, while those for Halvad taluka were 7.13 to 7.43, 0.0-0.0 me L⁻¹, 4.93 to 15.3 and 53.5 to 80.3 with the mean values of 7.29, 0.0 me L⁻¹, 8.84 and 65.42, respectively (Anon., 2001).

Das and Maji (2001) reported that ground water well/tube well water, salinity (EC_{iw}) and SAR decreased from June onwards, attaining minimum (0.65-4.26 dSm⁻¹) and during July-August, increasing from November onwards and reaching maximum during March to May.

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 water samples were ranged from 0.4-19.7 dSm⁻¹. About 32 per cent of water samples

had $EC < 2.0 \text{ dSm}^{-1}$ while 36 per cent water samples showed EC between $2-4 \text{ dSm}^{-1}$. The pH of water samples ranged from $7.2-9.3$. The Cl^- was dominant anion and it ranged from $1.2-200.4 \text{ me L}^{-1}$ while Na was the dominant cation ranging from $1.7-118. \text{ me L}^{-1}$. 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 $RSC < 2.5 \text{ me L}^{-1}$. Whereas 8.8 per cent samples had RSC between 2.5 to 5.0 me L^{-1} and 16.0 per cent samples had $RSC > 5.0 \text{ me L}^{-1}$.

Kabariya (2004) collected 220 well/tube well water samples from the Amreli district of Saurashtra region of Gujarat and reported that almost three fourth of the samples of irrigation water were found saline ($EC \geq 0.75 \text{ dSm}^{-1}$ and above). The EC values ranged between 0.4 and 12.5 with a mean value of 2.32 dSm^{-1} . The water were alkaline in reaction ($pH \geq 8.06$). 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 fall 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 fall 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 fall under S_1 , S_2 , S_3 and S_4 classes of SAR , respectively.

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^- , and, Na^+ , 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) found that to underground water of open wells/tube wells situated at higher elevations have low pH , EC , water soluble Mg^{+2} , Na^+ , CO_3^{2-} , HCO_3^{-2} , Cl^- , SSP and SAR then in lower elevations in deferent 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

Review of Literature

varied from 8.0 to 9.1, EC ranged between 1.70 to 14.10 dSm⁻¹. Cations, like Ca²⁺, Mg²⁺, 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/litre, 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/litre. 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 dSm⁻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.

Prasad and Minhas (2007) collected 1131 well/tube well water samples of Mahboob Nagar district of Andra Pradesh 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 dSm⁻¹ and 6.3 to 9.4, respectively. The soluble carbonate, bicarbonates, RSC and SAR of these water 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 dSm⁻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, where as in few cases it was in the order of Mg > Na > Ca with dominance of bicarbonate followed by chlorides.

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

Patel *et al.* (2012b) studied the underground water quality of different landforms of Meghal Irrigation Command area of Southern Saurashtra region of

Gujarat. They observed lower values of pH, EC, water soluble Mg^{2+} , Na^+ , CO_3^{2-} , HCO_3^- , Cl^- , SSP and SAR at higher elevation than in lower elevation.

Gopal. (2013) reported the underground water samples from different land slopes of Girnar toposequence were placed under different water quality class. As per the Semi-logarithmic USSSL 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 dSm^{-1} with mean values of 2.77 dSm^{-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^{2-} (0.27 me L^{-1}). The overall concentrations of CO_3^{2-} , 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.

Dhiman (2014) collected 27 underground water samples from Rajkot district and reported that majority of sites have $\text{SAR} < 10$ 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 $(\text{Ca}^{++} + \text{Mg}^{++}) > \text{HCO}_3^-$ indicating as base exchanged-hardened water, while remaining 29.63 per cent samples have $\text{HCO}_3^- > (\text{Ca}^{++} + \text{Mg}^{++})$, which may be referred as base exchanged-softened water.

2.5 RELATIONS AMONG AND BETWEEN SOIL FERTILITY AND SALINITY/SODICITY PARAMETERS OF SOILS.

Any increase or decrease in soil salinity will depend mostly upon the relative concentration of salts in irrigation water and that accumulate in soil under equilibrium conditions.

Tripathi *et al.* (1971) reported that there was no relationship between electrical conductivity of irrigation water and EC of saturation extract of the soils of Uttar Pradesh.

Review of Literature

Paliwal and Maliwal (1971) studied the relationship between irrigation water and irrigated soils. They reported significant correlation of SAR and SSP both of irrigation water and ESP of soil. However, no such relation was found between SAR and ESP of The EC of the irrigated soils has fairly good correlation with EC of the irrigation water. In light textured soils which are well drained, EC_e of the irrigated soils is generally less than EC of the irrigation water, at the end of irrigation, particularly in surface layers. In lower depths, EC may be more in hot summer months, EC_e of the soils may be several times high (Singh *et al.*, 1967, Paliwal and Dinesh, 1970, Paliwal and Maliwal, 1971).

Lal and Lal (1977) collected 47 water samples and an equal number of corresponding soil samples were analyzed for different constituents. Almost all the soils were sandy or loamy sand in texture. 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 dSm^{-1}) was 1.12, 2.21 and 3.03 dSm^{-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 dSm^{-1} was 8.3, 8.24, 8.17 and 8.08, respectively.

Padola and Bhalkar (1995) found that the application of saline water ($EC\ 4.2\ dSm^{-1}$) or saline-sodic water ($EC\ 1.5\ dSm^{-1}$ and SAR 8.2 and $EC\ 4\ dSm^{-1}$ and SAR 8.6) increased the soil pH, EC_e , ESP and SAR. Exchangeable Na decreased with the use of saline-sodic water ($EC\ 1.5\ dSm^{-1}$ & SAR 8.2). Pronounced adverse effect of salinity and sodicity at high level was observed on soil organic carbon, available N, available phosphorus and available potassium. The correlation studies showed positive relationship between EC_{iw} and EC_e , SAR_{iw} and ESP and SAR and pH.

Review of Literature

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.

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 pHs ($r = 0.895^{**}$) 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).

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 ($r=$

Review of Literature

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 ($r=0.7637^{**}$) was observed between SSP and SAR of irrigation water.

Baskar *et al.* (2006) investigated the impacted of *tsunami* incident on the ground water of Pondicherry. The analytical results of 203 water samples collected before *tsunami* were compared with the samples analyzed after the incident for studying its impact on ground water of Pondicherry. The results had 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 percentage (RSC), sodium adsorption ratio (SAR), potential salinity (SI), Puri's salt index (PSI), and permeability index (PI) did not shows marked variation between the two stages.

Babar *et al.* (2007) were observed in Vidarbha region of Maharashtra. The forms of potassium except exchangeable and available K_2O , were decreased with increase in depth. The available K_2O , exchangeable K_2O , 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_2O and exchangeable K_2O was also affected by available N ($r=0.9784^{**}$, $r=0.9773^{**}$) respectively, in Vidarbha region. In Central Vidarbha available and exchangeable K_2O influenced by total and available N respectively. In eastern Vidarbha the available K_2O and exchangeable K_2O influenced by total S and available N.

Waghmare *et al.* (2009) collected 100 surface soil samples for studied available N, P_2O_5 , and K_2O 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_2O . Availability of N, P_2O_5 and K_2O shows relationship with chemical characteristics. Further data showed that available N and P_2O_5 showed significant relationship with organic carbon. Available P showed

negative correlation with pH and EC, whereas available K₂O was significantly related with pH, EC, and CaCO₃.

Shirgire (2012) studied the Correlation between soil fertility and salinity/sodicity indices of soils and results indicated that E_{Ce} had highly significantly positive relationships with EC_{2.5} ($r = 0.988^{**}$), SAR ($r = 0.672^{**}$) and ESP ($r = 0.484^{**}$). Similarly, pH_s 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 ($r = 0.626^{**}$), K₂O ($r = 0.179^{*}$) and B.D. ($r = 0.191^{**}$).

Gajare *et al.* (2013) reported that the available P₂O₅ was significantly negative correlated with pH ($r = -0.362^{**}$) and CaCO₃ ($r = -0.253^{*}$), while positively significantly correlated with organic carbon ($r = 0.362^{**}$), while available S had significantly negative relationship with CaCO₃ ($r = -0.311^{**}$).

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 CaCO₃ ($r = -0.302^{*}$). Though, the pH had also positive correlation with CEC, available P₂O₅, Zn and Mn but not significant and showed negative correlation with available N, K₂O, 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.

III. MATERIALS AND METHODS

The general features of Mahisagar district viz, geographic location, physiography, geology, climate, soil, water, vegetation, land use pattern and cropping pattern are described below.

3.1 GENERAL INFORMATION OF MAHISAGAR DISTRICT

3.1.1 Geographic Location

Mahisagar district falls in Middle Gujarat Agro Climatic Zone. The latitude of Mahisagar district is 23.17 and the longitude is 73.55. It has an average elevation of 76 meters (249 ft). It is Surrounded by Aravali district in North West, Kheda district in the South West, Panch Mahals in the South, Dahod district in the East and the State of Rajsthan towards the North. The major river flowing through is Mahi. Kadana Dam located in this district is a major source of water.

3.1.2 Physiography

The district has high variation in topography which represents the diverse geological condition. Mahisagar District consists of 6 talukas with 700 villages. Total district area is 5210 sq.km and total population 9,55,294 as per 2011 census. The average rainfall of district is 831.8 mm. It covers 6 talukas viz., Balasinor, Santrampur, Khanpur, Virpur, Kadana and Lunawada.

3.1.3 Geology

Quaternary, Post Miocene and Tertiary sediments in the area were deposited over a sinking basement. The main formation is of quaternary age, formed by alluvium deposited by Mahi, Sabarmati and Vatrak rivers. They comprise multilayered formations of gravel, sand, clay and kankars intermixed at places. The clay and sand horizons form alternate layers having pinching and swelling nature. The kankars, pebbles and the gravels form lenses. Thickness of alluvium increases from North and North West towards South and South West direction. Alluvium is underlain by Deccan traps in intervening blue clays at some places.

3.1.4 Climate

The district has semi- arid climate. Normal rainfall of this district is 831.8mm from South-West Monsoon with an average of 36.2 rainy days. The normal onset of monsoon is from 3rd week of June and the normal cessation is in the 4th week of September.

The average maximum temperature during summer months recorded was 42 °C and minimum temperature at 21°C. During winter months, the average temperature ranges between 13 °C and 15 °C.

3.1.5 Soils

The following are the main soil types generally found in Mahisagar district.

- Medium black soils
- Shallow black soils
- Clay loam
- Loamy sand (*goralu*)
- Sandy loam

Most of the soils of Mahisagar district is nearly hilly light soil. Very Most soils of the district are composed of alluvium, in talukas viz., Kadana, Khanpur, Lunawada sandy loam with high rainfall, shallow to medium in depth. Balasinor have clay loam, light hilly soil, black soil with medium rainfall. While in Santrampur sandy loam with high rainfall. In Virpur district clay loam, light hilly soil, black soil with medium to low rainfall.

3.1.6 Water

Mahi and Panam are main rivers flowing in Mahisagar district. Source of irrigation water are open well, bore well, Canals and ponds. The status ground water in all six blocks of the district is safe. Mahi river that flow towards South-East and meet the Bay of Khambhat.

3.1.7 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 vegetations observed in surveyed area are as under.

Sr. No.	Common Name	Botanical Name
1	2	3
Trees and shrubs		
1.	Guava	<i>Psidium gujava</i>
2.	Neem	<i>Azadirachta indica</i>
3.	Gandobaval	<i>Prosopis juliflora</i>
4.	Aval	<i>Cassia auriculata</i>
5.	Khakharo	<i>Butea monosperma</i>
6.	Akado	<i>Calotropis procera</i>
7.	Desi Baval	<i>Acacia nilotica</i>
8.	Papaya	<i>Carica papaya</i>
9.	Ber (chania)	<i>Zizyphus nummularia</i>
10.	Mango	<i>Mangifera indica</i>
11.	Amaltas	<i>Cassia fistula</i>
12.	Custared apple	<i>Annona squamosa</i>
13.	Gunda	<i>Cordia maxa</i>
14.	Shisum	<i>Dalbergia sissoo</i>
15.	Gulmohar	<i>Delonix regia</i>
16.	Bamboo	<i>Dendrocalamus strictus</i>
17.	Amla	<i>Emblica officinalis</i>
18.	Nilgiri	<i>Eucalyptus camaldulensis</i>
19.	Glyricidia	<i>Glyricidia maculate</i>
20.	Gorus ambali	<i>Inga dulcis</i>
21.	Mahua	<i>Madhuca longifolia</i>
22.	Sargvo	<i>Morigna oleifera</i>
23.	Karanj	<i>Pongamia pinnata</i>
24.	Ashok	<i>Polyalthia longifolia</i>

Material & Methods

25.	Pipal	<i>Populus ciliate</i>
26.	Khijado	<i>Prosopis cineraria</i>
27.	Teak	<i>Tectona grandis</i>
28.	Aritha	<i>Sapindus mukorossi</i>
30.	Jamun	<i>Syzygium cuminis</i>
31.	Ambli	<i>Tamarindus indica</i>
32.	Sal	<i>Tectona grandis</i>
33.	Indian badam	<i>Terminalia catappa</i>
34.	Kadamb	<i>Anthocephalus chinensis</i>
35.	Pomegranet	<i>Punica granatum</i>
36.	Banana	<i>Musa acuminate</i>
37.	Bilva Patra	<i>Aegle marmilos</i>

Grasses and weeds

1.	Dharo	<i>Cynodon dactylon</i>
2.	Chidho	<i>Cyprus rotundus</i>
3.	Kanajro	<i>Digeria arvensis</i>
4.	Darudi	<i>Argemon maxicana</i>
5.	Chill	<i>Chenopodium album</i>
6.	Kuvadiyo	<i>Cassia tora</i>
7.	Agiya	<i>Striga lutea</i>
8.	Phulni	<i>Vernonin cinaria</i>
9.	Ckokadiyu	<i>Dactyloctenium aegyptium</i>
10.	Popati	<i>Physalis minima</i>
11.	Amar bel	<i>Cuscuta reflexa</i>
12.	Guli danda	<i>Phalaris minor</i>
13.	Dudheli	<i>Euphorbia macrophylla</i>
14.	Samo	<i>Echinichola crusgalli</i>
15.	Lantana	<i>Lantana camera</i>
16.	Bokndu	<i>Commenila benghalnesis</i>
17.	Fulekiya	<i>Venonia bodwini</i>
18.	Congress grass	<i>Parthenium hysterophorus</i>

3.1.7 Agriculture

The main fields crops grow in the district of Mahisagar are maize, wheat, rice, cotton, pearl millet etc. while mango, banana, papaya, sapota, citrus, aonla etc. are the important fruit crops. Potato, onion, brinjal, tomato, cluster bean, cucumber etc. are major cultivated vegetable crops. Jowar, maize lucern etc. are major fodder crops grown in Mahisagar district.

3.1.9 Land use pattern

The land utilization pattern of the district is presented below

Particulars	Area ('000ha.)
Geographical area	253.087
Net cultivated area	128.688
Gross cropped area	159.173
Gross irrigated area	166.563
Net irrigated area	1.31
Rainfed area	90.821
Cultivable waste	6.218
Area under forest	63.75
Pasture land	NIL
Cropping intensity	123.7%

Source: Soil Resource Maps of NBSS & LUP

3.1.10 Cropping pattern

The major field crops cultivated in *kharif* season are maize, soyabean, cotton, pearl millet pulses and castor. Rice is grown in all the talukas. Wheat, gram, fodder maize etc. are *rabi* crops of the area. The two seasonal, namely maize and wheat are spread over the *kharif* and *rabi* seasons.

3.2 COLLECTION OF SOILS AND WATER SAMPLES

Thirty representative surface (0-15 cm) soil samples were collected from each taluka of Mahisagar district, simultaneously thirty irrigation water sample also collected from each taluka of Mahisagar district. These talukas are Balasinor, Virpur, Kadana, Santrampur, Khanpur and Lunawada. Thus, 180 each soil as well as irrigation water samples were collected during April-May, 2018. Sample wise name of the farmer, village and taluka are given in Appendix I.

3.3 PREPARATION OF SOIL SAMPLES

Surface (0-15 cm) soil samples collected from the cultivated fields of the farmer's were allowed to dry completely in the laboratory. The air-dried samples were grounded carefully with a wooden mortar and pestle to break soil lumps. These grounded soil samples were passed through 2 mm sieve and then stored in polyethylene sample bags with proper labels. Working samples were drawn from these bulk samples. These samples were used for chemical analysis as well as for available nutrient.

3.4 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 $EC_{2.5}$, $pH_{2.5}$, water soluble cations *i.e.* Na^+ , K^+ , Ca^{++} and Mg^{++} , as well as anions *i.e.* Cl^- , CO_3^{--} , HCO_3^- and SO_4^{--} were determined as per the methods described by Richard (1954).

For the determination of exchangeable cations (Na^+ , K^+ , Ca^{++} and Mg^{++}) neutral normal ammonium acetate was used as per the methods described by Richard (1954).

Table 3.1: Methods used for analysis of soil samples

Characteristics	Method	Reference
Chemical characteristics		
EC (1: 2.5)	Conductivity method	Richard (1954)
pH (1: 2.5)	Potentiometric method	Richard (1954)

Exchangeable cations

Sodium	Flame photometry	Richard (1954)
Potassium	Flame photometry	Richard (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 nutrient

Organic carbon	Walkley and Black method	Jackson (1973)
Available N	Alkaline KMnO ₄ method	Subbiah and Asija (1956)
Available P ₂ O ₅	0.5 M NaHCO ₃ (pH 8.5) method	Olsen <i>et al.</i> (1954)
Available K ₂ O	1 N NH ₄ OAc method	Jackson (1973)
Available S	Turbidimetry	Williams and Stainbergs (1959)
Available micronutrient	DTPA extractable	Lindsay and Norvell (1978)
Free CaCO ₃ content	Rapid acid neutralization method	Piper (1950)

3.5 SOIL FERTILITY STATUS

Parameters	Low	Medium	High
Organic carbon (g kg ⁻¹)	<5.0	5.0-7.5	>7.5
Available N (kg ha ⁻¹)	<250	250-500	>500
Available P ₂ O ₅ (kg ha ⁻¹)	<28	28-56	>56
Available K ₂ O (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	0.2-0.5	>0.5

(Kanwar, 1976)

3.5.1 Nutrient index (NI)

Nutrient index was calculated utilizing the following formula,

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

Where, Nl, Nm and Nh are the number of 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 no. of sample.

Nutrient index was classified based on class given by Ramamoorthy and Bajaj (1969)

Class		Index
Low	-	<1.67
Medium	-	1.67-2.33
High	-	>2.33

3.6 METHODS OF ANALYSIS OF IRRIGATION WATER SAMPLES

The underground (well/tube well) water samples were collected, filtered and stored in the plastic bottles. The methods used for analysis of different constituents of water are as under.

Table 3.2: Methods Used For Analysis of Irrigation Water

Characteristics	Methods used	Reference
pH	Potentiometric method	Richard (1954)
EC	Conductivity method	Richard (1954)
CO ₃ ²⁻ & HCO ₃ ⁻	Volumetric titration	Reitemeir (1943)
Cl ⁻	AgNO ₃ precipitation method	Richards (1954)
SO ₄ ²⁻	Turbidity method	Chesnin and Yien (1950)
Na ⁺	Flame photometry	Richard (1954)
K ⁺	Flame photometry	Richard (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)

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

(Concentration of all cations are in me L⁻¹)

2) Sodium Adsorption Ratio (SAR)

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

(Concentrations of all cations in me L⁻¹)

3) Residual Sodium Carbonate (RSC)

$$\text{RSC} = (\text{CO}_3^{--} + \text{HCO}_3^-) - (\text{Ca}^{++} + \text{Mg}^{++})$$

(All ionic concentrations are in me L⁻¹)

3.7 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 ratings mentioned below

3.7.1 Rating Used For Water Quality Appraisal

3.7.1.1 Electrical Conductivity (Richards, 1954)

EC (dSm ⁻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

3.7.1.2 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

3.7.1.3 Residual Sodium Carbonate (Eaton, 1950)

RSC (me/L) value	Class
<1.25	Safe
1.25-2.50	Marginal
>2.50	Unsafe

3.7.1.4 Soluble Sodium Percentage (Richards, 1954)

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

3.7.2 Rating used for categorizing the soil

3.7.2.1 Soil Salinity/Sodicity Status

3.7.2.1.1 Electrical Conductivity (EC_{1:2.5} in dSm⁻¹). (Richards, 1954)

Sr. No.	EC _{1:2.5} (dSm ⁻¹)	Salinity class	Effect on plant growth
1.	<1	Normal soil	Salinity effects mostly negligible
2.	1-2	Low saline soil	Yield of very sensitive crops may be restricted
3.	2-4	Moderate saline soil	Yield of many crops restricted
4.	4-8	Saline soil	Only tolerant crops yield satisfactorily
5.	8-16	Highly saline soil	Only a few very tolerant crops yield satisfactorily

3.7.2.1.2 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)

3.7.2.1.3 Soluble Sodium Percentage (SSP)

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

3.7.2.1.4 Sodium Adsorption Ratio (SAR)

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

(Richards, 1954)

3.7.2.3 CLASSIFICATION OF SALT AFFECTED SOILS

By making use of $EC_{1:2.5}$ and exchangeable sodium percentage (ESP) of the soil, the criteria as initially suggested by Richards (1954), the 180 soil samples so collected from the different talukas of Mahisagar district were categorized into three classes viz., saline, saline-sodic and sodic soils as below.

Salt affected soils	EC_{1:2.5} (dSm⁻¹)	pH_{1:2.5}	ESP
Saline	>1	<8.5	<15
Saline-sodic	>1	8.5-10.0	>15
Sodic	<1	>8.5	>15

3.8 STATISTICAL ANALYSIS

Delineation by percentage distribution of soil samples in a particular parameter along with correlation among the variables of soil and water and also soil properties with available nutrient as described by Panse and Sukhatme (1985).

IV. RESULTS AND DISCUSSION

Assessment of soil and water resources of Mahisagar district is our prime object. For this purpose, 180 surface (0-15 cm) soil samples and 180 underground water samples were collected from the cultivated fields from where soil samples were taken. The details of soil samples and underground well/tube well water samples collected from cultivated fields of different talukas of Mahisagar district are given in Appendix I.

The findings of the present investigation are recorded in the following sub-heads;

- 4.1 PHYSICAL PROPERTIES OF SOILS OF MAHISAGAR DISTRICT**
- 4.2 CHEMICAL PROPERTIES OF SOILS OF MAHISAGAR DISTRICT**
- 4.3 SALINITY/SODICITY STATUS OF THE SOILS OF MAHISAGAR DISTRICT**
- 4.4 FERTILITY STATUS AND NUTRIENT INDEX OF THE SOILS OF MAHISAGAR DISTRICT**
- 4.5 INTER-RELATIONSHIPS AMONG AND BETWEEN FERTILITY AND SALINITY/SODICITY PARAMETERS OF THE SOILS**
- 4.6 IRRIGATION WATER QUALITY APPRAISAL OF MAHISAGAR DISTRICT**
- 4.1 PHYSICAL PROPERTIES OF SOILS OF MAHISAGAR DISTRICT**

Maintenance of favorable physical environment in soil is a prerequisite in soil management for the better plant growth in sustainable agriculture. The soil physical condition consisting of different parameters like bulk density, particle density, porosity and MWHC were determined by using the standard methods. Sample wise values for different physical parameters for 180 samples of Mahisagar district are given in Appendix II and the taluka wise range and mean values are given in table 4.1.

4.1.1 Bulk Density

The bulk density is commonly used as an index of soil physical conditions. The bulk density of the soils for the entire district was ranged from 1.23 to 1.45 with a mean value of 1.32 Mg m^{-3} (Table 4.1). The lowest bulk density value of 1.23 Mg m^{-3} was recorded in a sample collected from Lunawada and kadana talukas. The highest bulk density value of 1.45 Mg m^{-3} was recorded in the samples collected from Virpur taluka. The data further revealed that the lowest mean value of 1.31 Mg m^{-3} was

obtained in the soils of Balasinor and Lunawada talukas due to medium black soil of this area. The highest mean value of 1.33 Mg m^{-3} was recorded in the samples collected from Kadana taluka because light texture soils of this area. These results are in conformity with an earlier report of Ogunwale and Isa (2004), Rao *et al.* (2008), Savalia *et al.* (2009), Shirgire (2012) and Singh and Sharma (2013).

4.1.2 Particle Density

The particle density of soil sample was determined by using pycnometer. Overall, it was varied from 2.32 to 2.78 Mg m^{-3} with mean value of 2.53 (Table 4.1). The lowest particle density value of 2.32 Mg m^{-3} was recorded in a sample collected from Balasinor taluka. The highest value of 2.78 Mg m^{-3} was recorded in the samples collected from Virpur taluka. The data further revealed that the lowest mean value of 2.51 Mg m^{-3} was obtained in the soils of Balasinor and Khanpur talukas. The highest mean value of 2.55 Mg m^{-3} was recorded in the samples collected from Virpur taluka. Same result were obtained by Ogunwale and Isa (2004), Savalia *et al.* (2009), Ram *et al.* (2010) and Shirgire (2012).

4.1.3 Porosity

The pore space was worked out by using the value of particle density and bulk density of soil and the data presented in table 4.1. The overall pore space ranged from 37.07 to 51.50 per cent with mean value of 47.97 per cent. The lowest (37.07 %) and highest (51.50 %) pore space value were recorded in a sample collected from Kadana and Khanpur respectively. The data further revealed that the lowest mean value of 46.79 per cent was obtained in the soils of Khanpur taluka and the highest mean value of 48.07 per cent was recorded in the samples collected from Virpur taluka. These finding are parallel to those of Savalia and Gundaliya (2004) and Ram *et al.* (2010).

4.1.4 Maximum Water Holding Capacity

An appraisal of data on MWHC of soils are depicted in table 4.1 showed that the overall MWHC of soils of Mahisagar district varied from 29.25 to 64.23 per cent with mean value of 45.97 per cent. The lowest MWHC value of 29.25 per cent was recorded in a sample collected from Virpur taluka. The highest MWHC value of 64.23 per cent was recorded in the sample collected from Lunawada taluka. The data further revealed that the lowest mean value of 44.01 per cent was obtained in the soils of Kadana taluka due to low bulk density of soils. The highest mean value of 48.41 per cent was recorded in the samples collected from Balasinor taluka due to medium black soil with low bulk density. Similar results were reported for Southern

Saurashtra (Savalia, 2005), for Chittor district of Andhra Pradesh (Rao *et al.*, 2010) and for Jamnagar district (Shirgire, 2012).

Table 4.1: Taluka wise range and mean values for physical properties of soil of Mahisagar district

Name of talukas	Bulk density (Mg m⁻³)	Particle density (Mg m⁻³)	Porosity (%)	MWHC (%)
Balasinor	1.27-1.37 (1.31)	2.32-2.63 (2.51)	45.04-49.62 (47.76)	40.0-62.10 (48.41)
Lunawada	1.23-1.40 (1.31)	2.40-2.69 (2.52)	44.63-49.81 (47.98)	36.0-64.23 (47.22)
Kadana	1.23-1.40 (1.33)	2.36-2.68 (2.53)	37.07-50.19 (47.57)	37.75-52.00 (44.01)
Khanpur	1.26-1.40 (1.32)	2.35-2.74 (2.51)	41.83-51.50 (46.79)	34.67-53.67 (45.18)
Virpur	1.25-1.45 (1.32)	2.39-2.78 (2.55)	44.35-50.37 (48.07)	29.25-58.0 (45.08)
Santrampur	1.24-1.40 (1.32)	2.43-2.67 (2.53)	43.62-49.81 (47.91)	32.98-55.67 (46.94)
Overall	1.23-1.45 (1.32)	2.32-2.78 (2.53)	37.07-51.50 (47.97)	29.25-64.23 (45.97)

Values in parenthesis are mean values

4.2. CHEMICAL PROPERTIES OF SOILS OF MAHISAGAR DISTRICT

Soil samples were analyzed for different 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 180 samples given in Appendix III and the taluka wise range and mean values are given in table 4.2.

4.2.1 $EC_{2.5}$

The $EC_{2.5}$ of soil samples were determined by making use of 1:2.5 soil water ratio. Overall, it was varied widely ranging from 0.11 to 2.1 with a mean value of 0.38 $dS\ m^{-1}$ (Table 4.2). The lowest (0.11 $dS\ m^{-1}$) EC value was recorded in the soil sample collected from Kadana taluka; whereas highest value of (2.1 $dS\ m^{-1}$) was recorded in the soil sample collected from Khanpur taluka. The data further revealed that the lowest mean value of 0.33 $dS\ m^{-1}$ was obtained in the soils of Balasinor taluka and the highest mean value of 0.49 $dS\ m^{-1}$ was registered in the soils of Khanpur. The wide variation in $EC_{2.5}$ could be due to the influence poor quality of ground water (Anon., 1994) prevailing in a particular location. 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 of Nagpur district of Maharashtra.

4.2.2 $pH_{2.5}$

In general, the soils of Mahisagar district are alkaline in reaction. The pH values of the soils for the entire district were ranging from 6.29 to 8.76 with a mean value of 7.60 (Table 4.2). The lowest pH value of 6.29 was recorded in a soil samples collected from Santrampur taluka. The highest value of 8.76 was recorded in the sample collected from Lunawada taluka. 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 and Wagh *et al.* (2016) for of Nagpur district of Maharashtra.

4.2.3 Free Lime ($CaCO_3$)

Free lime (equivalent) content in soil was also estimated by the rapid acid neutralization method and the values are reported in Table 4.2. The overall free lime content was ranging from 3.22 to 6.75 with a mean value of 4.28 per cent. The highest mean value of 4.37 per cent was recorded in Balasinor taluka and the lowest mean value of 4.12 per cent was obtained in Kadana taluka indicate non calcareous soils

prevailing in entire district. Similar results were observed for Girnar toposequence by Gandhi (2013) and Latur district by Gajare *et al.* (2013)

4.2.4 Organic Carbon

Organic carbon content in the soils is important parameter for the fertility, physical, chemical and biological properties points of view. Hence, the samples were analyzed for organic carbon content (Table 4.2). In general, the soils of this district are high to medium in O.C. status. The overall organic carbon content in the soils was ranged from 0.12 to 1.77 per cent having mean value of 0.82 per cent. Highest O.C mean value(0.96) reported in Santrampur taluka and followed by Khanpur taluka with mean value (0.88).Lowest mean value (0.64) of O.C reported in Lunawada taluka. Such low values for organic carbon status of soils are expected because of the semi arid climate and light texture of soil. similar results were obtained 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.

4.2.5 Cation Exchange Capacity (CEC)

The CEC was worked out from the values of exchangeable cations (Ammonium acetate extractable and are given in Table 4.2. The overall range of CEC was 13.78 to 46.93 cmol (p⁺) kg⁻¹ with a mean value of 24.47 cmol (p⁺) kg⁻¹. The highest mean value of 25.85 cmol(p⁺) kg⁻¹ was recorded in Khanpur taluka due to medium black texture of soil. Whereas, the lowest mean value of 23.80 cmol(p⁺) kg⁻¹ was recorded in Kadana and Balasinor taluka because of loamy sand texture of soil. Same result were obtained for soils of Gantur of Andhra Pradesh district by Nandy *et al* (2013) and Girnar toposequence by Gandhi (2013).

Table 4.2: Taluka wise range and mean values of chemical properties of soils of Mahisagar district

Name of Taluka	EC _{2.5} (dS m ⁻¹)	pH _{2.5}	CaCO ₃ (%)	O.C. (%)	CEC Cmol (p ⁺)kg ¹
Balasinor	0.13-1.16 (0.33)	7.15-8.47 (7.70)	3.22-6.25 (4.37)	0.25-1.38 (0.80)	16.54-34.2 (23.80)
Lunawada	0.13-1.38 (0.34)	6.33-8.76 (7.78)	3.24-5.75 (4.29)	0.27-1.07 (0.64)	16.67-36.03 (25.15)
Kadana	0.11-0.87 (0.35)	6.31-8.22 (7.41)	3.25-5.29 (4.12)	0.21-1.44 (0.83)	13.78-34.54 (23.80)
Khanpur	0.15-2.1 (0.49)	6.55-8.3 (7.60)	3.25-6.22 (4.25)	0.31-1.77 (0.88)	15.18-46.93 (25.85)
Virpur	0.15-0.75 (0.34)	6.65-8.73 (7.58)	3.23-6.75 (4.36)	0.12-1.30 (0.75)	14.18-31.31 (24.12)
Santrampur	0.16-1.64 (0.44)	6.29-8.75 (7.55)	3.25-6.64 (4.30)	0.96-1.36 (0.96)	14.95-40.5 (24.13)
Overall	0.11-2.1 (0.38)	6.29-8.76 (7.60)	3.22-6.75 (4.28)	0.12-1.77 (0.81)	13.78-46.93 (24.47)

Note: Values in parenthesis are mean values

4.3 SALINITY/SODICITY STATUS OF SOILS OF MAHISAGAR DISTRICT

For characterizing the soils of Mahisagar district for salinity/sodicity status, all the 180 soil samples were analyzed for EC_{1:2.5}, pH_{1:2.5}, water soluble ions (1:2.5 soil: water extract) and exchangeable cations. The salinity /sodicity indices were then worked out. Sample wise values of water soluble ions and exchangeable cations are given in Appendix – IV and V.

4.3.1 Exchangeable Cations

The values for exchangeable cations (Ammonium acetate extractable) estimated from the soils of Mahisagar district are given in table 4.3.

The overall range and mean values (given in bracket) of 2.0-24.7 (5.87) of Ca^{++} , 1.30-21.7 (9.51) of Mg^{++} , 0.58-6.34 (2.70) of Na^+ and 0.04-1.0 (0.22) of K^+ $\text{cmol(p}^+) \text{ kg}^{-1}$ were recorded in entire district. In the soils of Khanpur taluka, mean Ca^{+2} content ($7.20 \text{ cmol(p}^+) \text{ kg}^{-1}$) was highest. As far as, the exchangeable Na^+ content in soil is concerned, Lunawada taluka registered the highest mean value of $2.81 \text{ cmol (p}^+) \text{ kg}^{-1}$. In case of Mg^{++} and K^+ , highest mean values were found in the soils of Lunawada Taluka.

4.3.2 Water Soluble Ions

Water soluble cations (Ca^{+2} , Mg^{+2} , Na^+ and K^+) and anions (CO_3^{-2} , HCO_3^- , Cl^- and SO_4^{-2}) were estimated from the soil: water (1:2.5) extract and the range and mean values are reported in table 4.4 and 4.5, respectively.

4.3.2.1 Water Soluble Cations

The overall range values of Ca^{++} , Mg^{++} , Na^+ and K^+ were 0.30-4.0, 0.40-4.60, 0.11-2.53 and $0.03\text{-}0.21 \text{ me L}^{-1}$, respectively were recorded in the soils of Mahisagar district (Table 4.4). The highest mean values of Ca^{++} and Mg^{++} were found in soils of Khanpur and Balasinor talukas while highest mean value of Na^+ was found in soils of Khanpur taluka. The lowest mean values of Ca^{++} and Mg^{++} were found in Lunawada taluka and lowest Na^+ mean value found in kadana taluka, respectively. This finding is in concurrence with the findings of Polara *et al.*, (2004), 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.

4.3.2.2 Water Soluble Anions

In case of anions, the highest overall mean value of 4.41 me L^{-1} was recorded for Cl^- and it was followed by HCO_3^- (3.2 me l^{-1}) and SO_4^- (0.35 me L^{-1}), while CO_3^- was not found in any collected soil sample of Mahisagar district (Table 4.5). Since the content of chloride and bicarbonate is considerably high, the type of salinization prevailing in these soils can be of Cl^- and HCO_3^- type. The results are in line with those reported by Polara *et al.* (2004), 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.

Table 4.3: Taluka wise range and mean values of exchangeable cations in soils of Mahisagar district

Name of Taluka	Exchangeable cations in $\text{cmol}(\text{p}^+) \text{kg}^{-1}$			
	Ca^{++}	Mg^{++}	Na^+	K^+
Balasinor	2.0-7.2	2.9-15.3	0.63-4.98	0.04-0.46
	(4.67)	(8.43)	(2.62)	(0.24)
Lunawada	3.0-10.8	5.0-19.6	0.58-5.69	0.06-1.0
	(5.74)	(10.53)	(2.81)	(0.28)
Kadana	2.7-14.3	5.2-15.3	0.78-6.34	0.06-0.72
	(6.16)	(10.0)	(2.68)	(0.21)
Khanpur	2.3-24.7	4.2-21.2	0.67-5.69	0.08-0.63
	(7.2)	(10.0)	(2.66)	(0.20)
Virpur	2.8-15.5	4.2-14.5	0.82-4.96	0.07-0.45
	(6.0)	(8.51)	(2.79)	(0.18)
Santrampur	2.7-13.5	1.3-21.7	0.69-4.44	0.07-0.69
	(5.45)	(9.60)	(2.67)	(0.22)
Overall	2-24.7	1.3-21.7	0.58-6.34	0.04-1.0
	(5.87)	(9.51)	(2.70)	(0.22)

Note: Values in parenthesis are mean values

Table 4.4: Taluka wise range and mean values of water soluble cations in soils of Mahisagar district

Name of Taluka	Water soluble cations in me L ⁻¹			
	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺
Balasinor	0.30-4.0	0.50-4.60	0.30-2.43	0.03-0.19
	(0.94)	(1.69)	(0.66)	(0.08)
Lunawada	0.30-1.80	0.40-2.20	0.26-2.11	0.04-0.20
	(0.80)	(1.32)	(0.72)	(0.11)
Kadana	0.30-2.40	0.50-2.40	0.11-1.68	0.04-0.17
	(0.98)	(1.53)	(0.63)	(0.09)
Khanpur	0.30-2.0	0.40-3.0	0.44-2.53	0.04-0.21
	(1.13)	(1.66)	(0.84)	(0.10)
Virpur	0.30-2.10	0.50-2.30	0.47-1.60	0.03-0.18
	(0.84)	(1.46)	(0.70)	(0.08)
Santrampur	0.40-2.60	0.50-3.70	0.53-1.92	0.05-0.17
	(1.08)	(1.72)	(0.77)	(0.10)
Over all	0.30-4.0	0.40-4.60	0.11-2.53	0.03-0.21
	(0.96)	(1.56)	(0.72)	(0.09)

Note: Values in parenthesis are mean values

Table 4.5: Taluka wise range and mean values of water soluble anions in soils of Mahisagar district

Name of Taluka	Water soluble anions in me L ⁻¹			
	CO ₃ ²⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ²⁻
Balasinor	0.0-0.0	2.00-9.00	2.40-10.0	0.15-1.42
	(0.0)	(3.3)	(4.24)	(0.35)
Lunawada	0.0-0.0	1.0-4.00	2.40-12.80	0.06-1.78
	(0.0)	(2.8)	(4.28)	(0.41)
Kadana	0.0-0.0	2.00-5.00	2.40-8.00	0.09-0.77
	(0.0)	(3.3)	(4.11)	(0.26)
Khanpur	0.0-0.0	2.0-5.00	2.80-17.40	0.08-1.83
	(0.0)	(3.4)	(5.39)	(0.49)
Virpur	0.0-0.0	2.00-5.00	2.40-8.40	0.06-1.45
	(0.0)	(3.0)	(4.11)	(0.29)
Santrampur	0.0-0.0	2.00-6.00	2.80-17.60	0.06-1.50
	(0.0)	(3.3)	(4.33)	(0.28)
Overall	0.0-0.0	1.0-9.00	2.40-17.60	0.06-1.83
	(0.0)	(3.2)	(4.41)	(0.35)

Note: Values in parenthesis are mean values

4.3.3 Salinity/Sodicity Indices

Salinity/sodicity indices are very important criteria for classifying salt affected soils into saline, sodic, saline-sodic or normal. Samples wise values for all the 180 samples for salinity/sodicity indices viz., $EC_{2.5}$, $pH_{2.5}$, ESP, SSP and SAR are given in Appendix IV and V and taluka wise range and mean values are presented in Table 4.6.

4.3.3.1 $EC_{2.5}$

The $EC_{2.5}$ of soil samples were determined by making use of 1:2.5 soil water ratio. Overall, it was varied widely ranging from 0.11 to 2.1 with a mean value of 0.38 $dS\ m^{-1}$ (Table 4.6). The lowest (0.11 $dS\ m^{-1}$) EC value was recorded in the soil sample collected from Kadana taluka; whereas highest value of (2.1 $dS\ m^{-1}$) was recorded in the soil sample collected from Khanpur taluka. The data further revealed that the lowest mean value of 0.33 $dS\ m^{-1}$ was obtained in the soils of Balasinor taluka and the highest mean value of 0.49 $dS\ m^{-1}$ was registered in the soils of Khanpur. The wide variation in $EC_{2.5}$ could be due to the influence poor quality of ground water (Anon., 1994) prevailing in a particular location. 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 of Nagpur district of Maharashtra.

4.3.3.2 $pH_{2.5}$

In general, the soils of Mahisagar district are alkaline in reaction. The pH values of the soils for the entire district were ranging from 6.29 to 8.76 with a mean value of 7.60 (Table 4.6). The lowest pH value of 6.29 was recorded in a soil samples collected from Santrampur taluka. The highest value of 8.76 was recorded in the sample collected from Lunawada taluka. 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 and Wagh *et al.* (2016) for of Nagpur district of Maharashtra.

4.3.3.3 Exchangeable Sodium Percentage (ESP)

The highest ESP value of 37.50 per cent was reported in the soils of Khanpur taluka, whereas the lowest value of 2.32 per cent was obtained in soil sample of Santrampur taluka. The highest mean ESP value of 11.8 per cent was obtained in Santrampur and Virpur talukas. Whereas the lowest mean ESP value of 11.0 per cent was recorded in Khanpur taluka. The overall ESP values were ranged from 2.32 to 37.50 per cent with a mean value of 11.4 per cent (Table 4.6). Similar results were

also observed for Southern dry zone of Karnataka by Guruprasad *et al.* (2007), Guntur district of Andra Pradesh by Nandy *et al.* (2013) and Girnar toposequence by Gandhi (2013).

4.3.3.4 Soluble Sodium Percentage (SSP)

The SSP values for all 180 samples were calculated from water soluble cations expressed in me L^{-1} , and the presented in (Table 4.6). The overall mean SSP value was 22.3, which ranged from 3.25 to 49.9 per cent The highest (25.30%) mean value of SSP was recorded with the soils of Lunawada taluka, whereas the lowest (20.66%) in Balasinor taluka. Similar results were also observed for Girnar toposequence by Gandhi (2013).

4.3.3.5 Sodium absorption ratio (SAR)

The SAR values were also calculated from the values of water soluble cations expressed in me L^{-1} and presented in (Table 4.6). The overall mean value of SAR was 0.66 and it was ranged from 0.09 to 1.69. The highest mean value of SAR (0.73) was recorded in the soils of Lunawada taluka, whereas the lowest mean values of SAR (0.57) was recorded in the soils of Kadana taluka. The lowest SAR value (0.09) was registered in the soil sample collected from Kadana taluka and the highest SAR value (1.69) was registered in soil sample collected from Balasinor and Lunawada talukas. Rajput and Polara (2012) were reported same results in soils of North-West Agro Climatic Zone of Gujarat.

Table 4.6: Taluka wise range and mean values of salinity/ sodicity indices of soils of Mahisagar district

Name of Taluka	EC_{2.5} (dS m⁻¹)	pH_{2.5}	ESP	SSP	SAR
Balasinor	0.13-1.16 (0.33)	7.15-8.47 (7.7)	2.64-19.8 (11.2)	11.0-36.80 (20.66)	0.31-1.69 (0.59)
Lunawada	0.13-1.38 (0.34)	6.33-8.76 (7.78)	2.55-22.3 (11.5)	9.02-49.93 (25.30)	0.23-1.69 (0.73)
Kadana	0.11-0.87 (2.35)	6.31-8.22 (7.41)	3.10-23.1 (11.1)	3.10-35.67 (19.74)	0.09-1.39 (0.57)
Khanpur	0.15-2.1 (0.49)	6.55-8.30 (7.60)	2.82-37.50 (11.0)	9.77-42.16 (22.67)	0.31-1.68 (0.72)
Virpur	0.15-0.75 (0.34)	6.65-8.73 (7.58)	2.92-19.75 (11.8)	12.72-37.0 (24.10)	0.43-1.15 (0.68)
Santrampur	0.16-1.64 (0.44)	6.29-8.75 (7.55)	2.32-29.23 (11.8)	12.7-33.66 (21.8)	0.42-1.15 (0.66)
Overall	0.11-2.1 (0.38)	6.29-8.76 (7.60)	2.32-37.50 (11.4)	3.25-49.9 (22.3)	0.09-1.69 (0.66)

Note: Values in parenthesis are mean values

Soil Characterization

By making the use of $EC_{2.5}$ and ESP criteria as initially suggested by Richards (1954), the 180 soil samples collected from the Mahisagar district were categorized into three classes viz., saline, saline-sodic and sodic soils. The soils having EC_e value $> 4.0 \text{ dSm}^{-1}$ and ESP values < 15 were classified as saline, those having EC_e value $< 4.0 \text{ dSm}^{-1}$ and ESP value > 15 as sodic and those having EC_e values $> 4.0 \text{ dSm}^{-1}$ and ESP > 15 as saline-sodic soils. As the samples were collected from the cultivated farmer's fields, some of the samples not found into the said criteria and hence were placed in the non-saline and non-sodic group, which considered as normal soils.

Out of 180 samples 6, 1, 36 and 137 samples were tested as saline, saline-sodic, sodic and normal, respectively. About 3, 1, 20 and 76 per cent soil samples were found saline, saline-sodic, sodic and normal, respectively (Table 4.7). The highest numbers of samples were found under normal class followed by Sodic, saline, and saline-sodic.

After exclusion of non-saline and non-sodic samples, the remaining 43 samples were then grouped into three different salt affected soil classes by adopting USDA norms (Table 4.7). The distribution indicates that 84 per cent soil samples were falling in the sodic, followed by 14 per cent into saline and 2 per cent into saline-sodic group.

The highest percentage (30 %) of sodic soil samples were recorded in Lunawada taluka followed by Balasinor (26 %). The lowest percentage (14 %) of sodic soil sample were recorded in Virpur taluka. Soils of Khanpur have the highest (10 %) proportion of saline soils and soils of Virpur have lowest (0 %) proportion of saline soils. Soils of Balasinor taluka possess highest (4 %) percentage of saline-sodic soil. This finding supported by Basker *et al* (2006), Polara and Kabaria (2006), Marsonia *et al* (2008) and Rajput and Polara (2012).

Table 4.7: Taluka wise percentage distribution of soil samples into different categories of salt affected soils of Mahisagar district

Name of Taluka	Percentage distribution			
	Saline	Saline-Sodic	Sodic	Normal
Balasinor	4	4	26	66
Lunawada	4	0	30	66
Kadana	0	0	16	84
Khanpur	10	0	16	74
Virpur	0	0	14	85
Santrampur	4	0	16	80
Overall (180)	3 (6)	1 (1)	20 (36)	76 (137)
Classification of salt affected soils (43)	14 (6)	2 (1)	84 (36)	---

Note: Values in parenthesis are number of samples.

4.4 FERTILITY STATUS OF SOILS OF MAHISAGAR DISTRICT

For studying the fertility status of soils of Mahisagar district, 180 soil samples collected from the cultivated farmer's field were analyzed for available N, P₂O₅, K₂O, S and DTPA extractable Fe, Mn, Zn and Cu. Sample wise values of fertility parameters (for all the 180 samples) are given in Appendix III and taluka wise range and mean values for these parameters are presented in Table 4.8. and 4.9.

4.4.1 Available Macro Nutrients:

Taluka wise range and mean values for available macronutrients are given in Table 4.8.

4.4.1.1 Available N Status:

The values of available N estimated from the collected soil samples are given in Table 4.8. The overall, available N status for the target district was Low and it was

ranged from 94 to 376 kg ha⁻¹ with mean value of 232 kg ha⁻¹. The highest mean value of available N was found in Balasinor taluka (246 kg ha⁻¹) followed by Santrampur (242 kg ha⁻¹) and Khanpur taluka (239 kg ha⁻¹). The lowest mean value of available nitrogen was found in Lunawada taluka (214 kg ha⁻¹). About 70 per cent samples were tested as low (< 250 kg N ha⁻¹), 30 per cent were under medium classes for available N and no any sample found in high available N classes. Such lower values for available N might be because of lower content of organic carbon (Table 4.2) and poor addition of organic matter as well as less use of organic manures in the semi arid tract. Our research are supported by Punith Raj *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).

4.4.1.2 Available P₂O₅ Status

Taluka wise range and mean values of available P₂O₅ are given in Table 4.8. As like N, the available P₂O₅ was also medium in all talukas. The available P₂O₅ status of soils varied widely (4 to 79 kg ha⁻¹) with mean value of 30 kg ha⁻¹, which was in medium categories. The highest mean value of available P₂O₅ was found in Lunawada taluka (33 kg ha⁻¹) followed by Kadana (31 kg ha⁻¹) and Santrampur (30 kg ha⁻¹) talukas. The lowest mean value was found in Khanpur taluka (28 kg P₂O₅ ha⁻¹). About 51.6, 42.2 and 6.66 per cent soil samples were observed as low, medium and high in available P₂O₅, respectively. The lower status of P in the soil is attributed to the adoption of intensive cropping systems by the cultivators, resulting in absorption of plant nutrients in higher amounts. Our research were supported by Punith Raj *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).

4.4.1.3 Available K₂O Status:

Taluka wise range and mean values of available K₂O are given in Table 4.8. Unlike N and P₂O₅, available K₂O status of the Mahisagar district was medium. It was varied widely from 49 to 758 kg K₂O ha⁻¹ with an average of 228 kg ha⁻¹. The highest

mean value for available K_2O was found in Balasinor (276 kg ha^{-1}) followed by Lunawada (243 kg ha^{-1}) and Santrampur (230 kg ha^{-1}) talukas. The lowest mean value of available K_2O was found in Khanpur taluka (192 kg ha^{-1}). Overall, 21.66, 53.33 and 25 per cent samples were distributed in low medium and high categories for available K_2O respectively. Such medium and high status of available K_2O might be due to presence of potassium bearing minerals (feldspar, muscovite and biotite) which upon weathering slowly release potassium. Similar finding were made by Punith Raj *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).

4.4.1.4 Available S status:

Taluka wise range and mean values of available sulphur are given in Table 4.8. Overall, available sulphur ranged from 0.39 to 56 mg kg^{-1} with mean value of 16 mg kg^{-1} . On the basis of mean values, the soils of Khanpur taluka content highest amount of sulphur (19 mg kg^{-1}) followed by Kadana (19 mg kg^{-1}) and Virpur (16 mg kg^{-1}) talukas. The soils of Lunawada taluka contain the lowest mean value (14.00 mg kg^{-1}) of available sulphur. Almost 33.3, 35.5 and 31.1 per cent samples were rated as low, medium and high in content of the available sulphur, respectively. Such high status of sulphur in soils of Mahisagar district might be because of use of S-bearing fertilizers such as Ammonium Sulphate and Magnesium Sulphate by the cultivators. Such high 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 4.8: Taluka wise range and mean value for available Nutrients in the soils of Mahisagar district

Name of Taluka	Av. N (kg ha ⁻¹)	Av. P ₂ O ₅ (kg ha ⁻¹)	Av. K ₂ O (kg ha ⁻¹)	Av. S (mg kg ⁻¹)
Balasinor	141-360 (246)	6.60-56.1 (29.40)	120-633 (276)	1.57-31.07 (14.29)
Lunawada	156-329 (214)	8.90-59.8 (33.40)	93-563 (243)	0.39-47.56 (14.00)
Kadana	156-329 (228)	6.1-58.6 (31.40)	56-758 (221)	0.98-56.74 (19.06)
Khanpur	172-376 (239)	6.6-61.0 (28.60)	49-534 (192)	1.57-53.38 (19.72)
Virpur	141-345 (221)	5.50-59.8 (29.40)	62-564 (209)	1.18-41.66 (16.98)
Santrampur	94-376 (242)	4.40-79.2 (30.50)	63-627 (230)	2.36-39.74 (16.09)
Overall	94-376 (232)	4.40-79.2 (30.50)	49-758 (228)	0.39-56.74 (16.69)

Note: Values in parenthesis are mean values

4.4.2 DTPA Extractable Micronutrients:

Taluka wise range and mean values for DTPA extractable micronutrients are given in Table 4.9

4.4.2.1 DTPA Extractable Fe:

The overall Fe status of the soils of Mahisagar district was high (Table 4.9). It was ranged from 1.89 to 39.22 mg kg⁻¹ with mean value of 15.44 mg kg⁻¹. Soils of Lunawada taluka recorded the highest mean value of DTPA extractable Fe (19.78 mg kg⁻¹) followed by that of Kadana (19.56 mg kg⁻¹) and Khanpur (17.31 mg kg⁻¹) talukas, whereas, the lowest mean value (10.1 mg kg⁻¹) of DTPA extractable Fe was found in the soils of Balasinor talukas. About 9.44, 27.7 and 62.77 per cent samples rated as low, medium and high in available Fe status, respectively. Same finding

were also observed by 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.

4.4.2.2 DTPA Extractable Mn:

The soils of Mahisagar district were ranged from 3.96 to 32.46 mg kg⁻¹ with mean value of 11.59 mg kg⁻¹ in case of DTPA extractable Mn (Table 4.9). The soils of Balasinor taluka have highest mean value (13.20 mg kg⁻¹) followed by Lunawada (12.23 mg kg⁻¹) and Virpur (11.15 mg kg⁻¹) talukas. The lowest mean value (10.84 mg kg⁻¹) was observed in Kadana taluka. About 4.44, 36.1 and 59.5 per cent samples rated as low, medium and high in available Mn status, respectively. 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.

4.4.2.3 DTPA Extractable Zn:

The available Zn status of the soils of Mahisagar district was high. It was ranged from 0.22 to 5.91 mg kg⁻¹ with a mean value of 1.64 mg kg⁻¹. Lunawada taluka soils have highest mean value (2.05 mg kg⁻¹) of available Zn followed by Balasinor (1.92 mg kg⁻¹) Kadana and Khanpur (1.60 mg kg⁻¹) talukas. Soils of Santrampur taluka have the lowest mean value (1.15 mg kg⁻¹) for available Zn status (Table 4.9). About 7.23, 23.8 and 68.8 per cent soil samples were categorized as low, medium and high in available Zn status, respectively. 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.

4.4.2.4 DTPA Extractable Cu:

In general, the available Cu status of the soils of Mahisagar district was high (Table 4.9). The available Cu ranged from 0.05 to 6.79 mg kg⁻¹ with mean value of 1.72 mg kg⁻¹. The highest mean value of available Cu was observed in Balasinor (2.01 mg kg⁻¹) followed by soils of Santrampur (1.98 mg kg⁻¹) and Lunawad (1.61 mg kg⁻¹) talukas. The lowest mean value was registered in Virpur taluka (1.07 mg kg⁻¹). Almost all taluka have mean value greater than 1.0 mg kg⁻¹ (Table 4.3), hence, it

sufficient in majority soils samples. About 3.34,10.55 86.11 per cent samples were found in low, medium and high categories of available Cu. Results reported in present investigation find supports from the work reported elsewhere 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.

Table 4.9: Taluka wise range and mean values for DTPA extractable micronutrients in the soils of Mahisagar district

Name of Taluka	Fe (mg kg⁻¹)	Mn (mg kg⁻¹)	Zn (mg kg⁻¹)	Cu (mg kg⁻¹)
Balasinor	1.89-30.8 (10.10)	4.20-32.4 (13.20)	0.65-4.09 (1.92)	0.24-6.79 (2.01)
Lunawada	2.80-39.2 (19.78)	6.17-31.3 (12.23)	0.25-5.91 (2.05)	0.05-3.86 (1.61)
Kadana	7.72-34.6 (19.56)	5.15-18.4 (10.84)	0.37-4.16 (1.60)	0.10-4.59 (1.17)
Khanpur	3.94-34.06 (17.31)	4.18-19.18 (10.96)	0.24-3.16 (1.60)	0.34-3.74 (1.37)
Virpur	3.71-32.0 (12.08)	4.99-30.40 (11.15)	0.22-5.73 (1.52)	0.05-3.62 (1.07)
Santrampur	3.56-30.82 (11.9)	3.96-32.18 (11.10)	0.23-5.38 (1.15)	0.15-5.98 (1.98)
Overall	1.89-39.22 (15.14)	3.96-32.46 (11.59)	0.22-5.91 (1.64)	0.05-6.79 (1.53)

Note: Values in parenthesis are mean values

4.4.3 Nutrient Index Values of Available Nutrients In Soils

4.4.3.1 Nutrient Index Ranges of Available Macronutrients

The nutrient index values for available macronutrient are presented in Table 4.10 and appendix -VII. The highest nutrient index values of 1.53 and 1.63 were reported for available N and P_2O_5 in the soils of Balasinor and Lunawada talukas, respectively. While the highest nutrient index values of 2.36 and 2.16 for K_2O and S, respectively were reported in the soils of Balasinor and Khanpur talukas. The lowest nutrient index value of available N (1.2) found in Lunawada taluka. While lowest nutrient index values of P_2O_5 (1.05) and K_2O (2.4) were found in Khanpur taluka. The lowest nutrient index value of S (1.83) was found in soils of Balasinor taluka. Overall, the soils of Mahisagar district had nutrient index values of 1.36, 1.55, 2.03 and 1.97 for available N, P_2O_5 , K_2O and S, respectively. Based on nutrient index values of soils and the criteria suggested by Parker *et al.* (1951) and Ramamurthy and Bajaj (1969), the soils of Mahisagar district found low with respect to available N, while in low fertility class for available P_2O_5 , in Medium fertility class in respect of available K_2O and S status. Similar results were also reported for Muzaffarnagar district of Uttar Pradesh by Prakash *et al.* (2008) and for Bhavnagar district by Rajput and Polara (2012).

4.4.3.2 Nutrient Index Value of Available Micronutrients

The nutrient index values for available micronutrient are presented in Table 4.10 and appendix -VII. The highest nutrient index values of 2.96 for DTPA extractable Fe was found in soils of Kadana taluka. The highest nutrient index values of 2.66 for DTPA extractable Mn was reported in the soils of Lunawada taluka while the highest nutrient index value 2.86 for DTPA extractable Zn was reported in the soils of Balasinor taluka. The soils of Balasinor taluka have same highest nutrient index value 2.96 for DTPA extractable Cu. The lowest nutrient index values 2.3, 2.26, 2.4 and 2.66 of DTPA extractable Fe, Mn, Zn and Cu were found in soils Virpur, Khanpur, Santrampur and Virpur talukas respectively. Overall the soils of Mahisagar district had nutrient index values 2.53, 2.55, 2.61 and 2.81 for DTPA extractable Fe, Mn, Zn and Cu respectively. Based on nutrient index values of soils and the criteria suggested by Ramamoorthy and Bajaj (1969), the soils of Mahisagar district found in high categories for available Cu and Mn, while in medium status of Fe and Zn. Similar results were made for Bhavnagar district by Rajput and Polara (2012).

Table 4.10: Taluka wise nutrient index values of macro and micro nutrients of the soils of Mahisagar district

Name of Taluka	N	P ₂ O ₅	K ₂ O	S	Fe	Mn	Zn	Cu
Balasinor	1.53	1.53	2.36	1.83	2.16	2.53	2.86	2.96
Lunawada	1.2	1.63	2.03	1.86	2.66	2.66	2.53	2.8
Kadana	1.4	1.6	1.9	2.0	2.96	2.63	2.6	2.7
Khanpur	1.3	1.46	1.86	2.16	2.7	2.6	2.76	2.9
Virpur	1.23	1.5	1.93	2.0	2.3	2.5	2.53	2.66
Santrampur	1.5	1.6	2.1	2.0	2.4	2.36	2.4	2.86
Overall	1.36	1.55	2.03	1.97	2.53	2.55	2.61	2.81

Rating of nutrient index:

<1.67 – Low

1.67-2.33 – Medium

>2.33 – High

4.5 INTERRELATIONSHIP AMONG AND BETWEEN FERTILITY AND SALINITY/SODICITY PARAMETERS OF SOILS

4.5.1 Correlation Study

The correlation among fertility parameters of soil (P₂O₅) and with salinity/sodicity parameters (EC_{2.5}, pH_{2.5}, SSP, SAR and ESP) were worked out and presented in Table 4.11. The correlation values were indicates that the highly significant positive relation of EC_{2.5} with pH_{2.5} (r = 0.156*), SSP (r = 0.311**) and SAR (r = 0.675**) Similarly, all the above properties were also correlated with ESP and P₂O₅. Whereas, pH_{2.5} was negatively significant correlated with RSC (r = -

Results and Discussion

0.182*) In case of RSC was positively significant correlated with SAR ($r=0.155^*$) and negatively correlated with ESP ($r = -0.197^{**}$) and P_2O_5 ($r = -0.155$). Whereas SAR was negatively correlated with ESP ($r = -0.302^{**}$). Similar results were also obtained by Pandey *et al.* (2000) and Patel (2004).

Table 4.11: Correlation co-efficient among and between fertility and salinity /sodicity indices of soil of the Mahisagar district

	EC _{2.5}	pH _{2.5}	SSP	RSC	SAR	ESP	P ₂ O ₅
EC _{2.5}	1.00	--	--	--	--	--	--
pH _{2.5}	0.156*	1.00	--	--	--	--	--
SSP	0.311**	0.080	1.00	--	--	--	--
RSC	-0.072	-0.182*	0.349**	1.00	--	--	--
SAR	0.675**	0.139	0.843**	0.155*	1.00	--	--
ESP	0.020	-0.052	-0.419**	-0.197**	-0.302**	1.00	1
P ₂ O ₅	0.141	0.134	-0.005	-0.155*	0.050	0.053	1.00

* Significant at 5 per cent level

** Significant at 1 per cent level

4.6 IRRIGATION WATER QUALITY APPRAISAL

In order to present a water quality appraisal 180 underground water/tube well water samples (30 samples from each taluka) were collected. Irrigation water samples were analyzed for EC, pH, cations (Ca^{++} , Mg^{++} , Na^+ and K^+), anions (CO_3^- , HCO_3^- , Cl^- and SO_4^-) and water quality appraisal was prepared by making use of EC and SAR values as suggested by USDA. Taluka wise range and mean values of EC, pH, RSC, SSP and SAR are given in Table 4.12. Percentage distribution of water samples into different EC and SAR classes are given in Table 4.15. Sample wise values of different parameters (for all the 180 samples) are given in Appendix VI.

4.6.1 Electrical Conductivity (EC)

The overall mean value of EC was found 1.10 dS m^{-1} , which was varied widely from 0.26 to 8.80 dS m^{-1} . The highest mean value (1.70 dS m^{-1}) was obtained in Balasinor taluka followed by Lunawada (1.40 dS m^{-1}) and Khanpur (0.98 dS m^{-1}) talukas due poor quality ground water. The lowest mean value (0.61 dS m^{-1}) was obtained in Santrampur taluka (Table 4.12). The lowest value of EC (0.26 dS m^{-1}) was recorded in a sample taken from Santrampur taluka whereas the highest value of EC (8.80 dS m^{-1}) was reported in Balasinor taluka. The higher mean value of EC is an indicative of potential development of saline soils in Mahisagar district. Similar findings were made by Churu district (Rajasthan) by Verma *et al*, (2003), for Amreli district by Kabaria (2004), for Mahboob Nagar district of Andra Pradesh by Prasad and Minhasand(2007) and for Bhavnagar district by Rajput and Polara (2013).

If we observe the percentage distribution of samples in different EC classes, then 0.00, 45.0, 48.48, 6.11 per cent samples were falling under C_1 , C_2 , C_3 and C_4 classes of EC, respectively. None of the sample falls under C_1 classes of EC. In Mahisagar district 88 samples fall under C_3 class of EC and 9 samples under C_4 and 83 samples fall under C_2 class. So, there is potentiality to develop of secondary salinization in the soils of Mahisagar district (Table 4.15). This finding is in conformity with the findings for Charu district (Rajasthan) by Verma *et al*, (2003), for Amreli district by Kabaria (2004), For Mahboob Nagar district of Andra Pradesh by Prasad and Minhasand (2007) and for Bhavnagar district by Rajput and Polara (2013).

4.6.2 pH

In general, the waters of this district were alkaline in reaction. The pH values were ranged from 6.60 to 9.70 with a mean value of 7.49. The highest mean value of pH 7.86 was recorded in Virpur taluka whereas the lowest mean value of pH 7.0.8 was recorded in Kadana taluka (Table 4.12). This finding is in conformity with the findings for Charu district (Rajasthan) by Verma *et al*, (2003), for Amreli district by Kabaria (2004), For Mahboob Nagar district of Andra Pradesh by Prasad and Minhasand (2007) and for Bhavnagar district by Rajput and Polara (2013).

4.6.3 Residual Sodium Carbonate (RSC)

Taluka wise range and mean values of RSC is given in Table 4.12 and percentage distributions of water samples in different RSC classes (as suggested by USDA) are presented in Table 4.15.

The overall RSC values were ranged from 0 to 1.30 with a mean value of 0.07 me L⁻¹ which was less than 2.5 me L⁻¹. No RSC was found in Balasinor, Kadana, Santrampur, Khanpur and Virpur talukas (Table 4.12). For all talukas, the RSC mean values were lower than permissible limit of 2.5 me L⁻¹. This finding is in conformity with the findings for Charu district (Rajasthan) by Verma *et al*, (2003), for Amreli district by Kabaria (2004), For Mahboob Nagar district of Andra Pradesh by Prasad and Minhasand (2007) and for Bhavnagar district by Rajput and Polara (2013).

Overall 95.5 and 0.5 per cent samples fall under safe and marginal classes of RSC, respectively (Table 4.15). This finding is in concurrence with the findings of Nilsood *et al*. (1998).

4.6.4 Soluble Sodium Percentage (SSP)

Taluka wise range and mean values of SSP is given in Table 4.12 and percentage distributions of water samples in different SSP classes (as suggested by USDA) are presented in Table 4.15.

The overall mean value of SSP was 13.07 and ranged from 0.11 to 65.95 (Table 4.12). The highest mean value (17.49) was recorded in Balasinor taluka whereas, the lowest mean value (7.86) was recorded in Kadana taluka. For all talukas, mean SSP values were less than 60, which is indicative of good quality water. This finding is in conformity with the findings for Charu district (Rajasthan) by Verma *et al*, (2003), for Amreli district by Kabaria (2004), For Mahboob Nagar district of Andra Pradesh by Prasad and Minhasand (2007) and for Bhavnagar district by Rajput and Polara (2013).

Overall, 99 per cent samples fall under safe classes of SSP and 1 per cent sample fall under unsafe classes respectively (Table 4.15). This finding is in concurrence with the findings of Nilsood *et al.*(1998).

4.6.5 Sodium Adsorption Ratio (SAR)

The SAR value is an important criterion for studying the alkali hazards in irrigation water. Therefore, taluka wise, range and mean values of SAR is given in Table 4.12 and per cent distribution of water sample in different SAR classes (as suggested by USDA) are presented in Table 4.15.

The overall mean value of SAR was 0.76 and it was varied from 0.00 to 11.03. The lowest (0.00) and the highest (11.03) SAR value was reported in water samples collected from Khanpur and Lunawada talukas, respectively. The highest (1.17) and the lowest (0.36) mean SAR values were registered in water samples collected from Balasinor and Kadana talukas, respectively. This finding is in conformity with the findings for Churu district (Rajasthan) by Verma *et al*, (2003), for Amreli district by Kabaria (2004), For Mahboob Nagar district of Andra Pradesh by Prasad and Minhasand (2007) and for Bhavnagar district by Rajput and Polara (2013).

About 99 per cent samples fall under S₁, class and 0.5 per cent sample fall under S₂,class of SAR, respectively. (Table 4.15). This finding is in concurrence with the findings of Nilsood *et al.* (1998) and Kabaria (2004).

Table 4.12: Taluka wise range and mean values of EC, pH and different indices of well/tube well water samples of Mahisagar district

Name of Taluka	EC (dS m ⁻¹)	pH	RSC (me L ⁻¹)	SSP	SAR
Balasinor	0.70-8.80 (1.70)	6.60-8.10 (7.40)	0-0 (0)	0.83-38.94 (17.49)	0.04-2.85 (1.17)
Lunawada	0.30-4.90 (1.40)	6.91-8.51 (7.36)	0- 1.30 (0.04)	0.40-65.95 (13.76)	0.01-11.03 (1.13)
Kadana	0.85-5.20 (0.85)	6.63-7.63 (7.08)	0-0 (0)	1.16-22.45 (7.86)	0.05-1.34 (0.36)
Khanpur	0.36-5.20 (0.98)	6.90-9.07 (7.59)	0-0 (0)	0.11-36.84 (11.47)	0.00-2.44 (0.59)
Virpur	0.41-2.20 (0.88)	7.04-8.99 (7.86)	0-0 (0)	0.30-32.93 (13.67)	0.01-1.94 (0.67)
Santrampur	0.26-1.05 (0.61)	6.75-9.70 (7.67)	0-0 (0)	3.62-29.85 (14.38)	0.13-1.41 (0.61)
Overall	0.26-8.80 (1.10)	6.60-9.70 (7.49)	0-1.30 (0.007)	0.11-65.95 (13.07)	0.00-11.03 (0.76)

Note: Values in parenthesis are mean values

4.6.6 Cation Concentration in Well/Tube Well Water Samples

Taluka wise range and mean values of different cations present in well/tube well water samples are given in Table 4.13. Among the cations, overall highest proportion of Mg^{++} (6.34 me L^{-1}) was observed, which was followed by Ca^{++} (1.99 me L^{-1}), Na^{++} (1.68 me L^{-1}) and K^{+} (0.72 me L^{-1}). The overall concentration of Ca^{++} , Mg^{++} , Na^{+} and K^{+} varied from 0.50 to 21.50, 1.50 to 53.00, 0.01 to 29.10 and 0.64 to 4.0 me L^{-1} , respectively (Table 4.15). The highest mean value for Mg^{+} (9.75 me L^{-1}) was found in Balasinor taluka followed by Lunawada (7.40 me L^{-1}) and Khanpur (6.23 me L^{-1}). The lowest mean value for Mg^{+} (3.67 me L^{-1}) was reported in Santrampur taluka. Similar results were also found by Timbadia (1988) for Jafrabad and Rajula talukas of Amreli district.

4.6.7 Anion Concentration In Well/Tube Well Water Samples

In case of anions, the highest overall mean value of 7.39 me L^{-1} was recorded for Cl^{-} and it was followed by HCO_3^{-} (3.24 me L^{-1}), SO_4^{-} (0.15 me L^{-1}) and CO_3^{-} (0.002 me L^{-1}). The highest mean value of Cl^{-} (10.96 me L^{-1}) was observed in Balasinor talukas while the highest mean value of HCO_3^{-} (5.53 me L^{-1}) and SO_4^{-} (0.21 me L^{-1}) were observed in Balasinor taluka, and highest CO_3^{-} (0.03 me L^{-1}) mean value observed in Santrampur taluka. The overall range values for CO_3^{-} , HCO_3^{-} , Cl^{-} and SO_4^{-} were 0.10 to, 0.30, 1.00 to 11.00, 1.70 to 77.0 and 0.01 to 0.89 me L^{-1} , respectively (Table 4.14). Similar results were also found by Timbadia (1988) for Jafrabad and Rajula talukas of Amreli district.

Table 4.13: Taluka wise range and mean values of cations of well/ tube well water samples of Mahisagar district

Name of Taluka	Cations in me L ⁻¹			
	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺
Balasinor	1.0-21.50	4.30-53.00	0.10-13	0.65-0.96
	(3.24)	(9.75)	(3.10)	(0.68)
Lunawada	0.50-11.50	2.0-19.50	0.02-29.80	0.65-4.00
	(3.06)	(7.40)	(2.72)	(0.86)
Kadana	0.70-12.50	2.40-32.30	0.10-6.32	0.65-0.85
	(1.62)	(5.55)	(0.75)	(0.68)
Khanpur	0.60-12.50	2.40-33.1	0.01-5.90	0.65-0.86
	(1.72)	(6.23)	(1.24)	(0.69)
Virpur	0.60-4.90	2.0-12.9	0.08-4.56	0.65-0.74
	(1.42)	(5.44)	(1.39)	(0.68)
Santrampur	0.50-1.50	1.50-6.70	0.01-2.00	0.64-1.32
	(0.88)	(3.67)	(0.88)	(0.71)
Overall	0.50-21.50	1.50-53.00	0.01-29.80	0.64-4.00
	(1.99)	(6.34)	(1.68)	(0.72)

Note: Values in parenthesis are mean values

Table 4.14: Taluka wise range and mean values of anions of well/ tube well water samples of Mahisagar district

Name of Taluka	Anions in me L ⁻¹			
	CO ₃ ⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻
Balasinor	0.00-0.00	1.70-10.00	2.60-77.00	0.05-0.89
	(0.00)	(5.53)	(10.96)	(0.21)
Lunawada	0.00-0.00	1.00-11.00	2.16-37.60	0.03-0.52
	(0.00)	(4.35)	(9.74)	(0.16)
Kadana	0.00-0.00	1.00-8.20	2.80-43.20	0.04-0.77
	(0.00)	(2.45)	(6.03)	(0.13)
Khanpur	0.00-0.00	1.00-6.00	2.40-46.40	0.01-0.68
	(0.00)	(2.74)	(7.02)	(0.14)
Virpur	0.00-0.30	1.10-5.80	2.90-16.20	0.03-0.23
	(0.02)	(2.51)	(6.39)	(0.12)
Santrampur	0.00-0.10	1.00-3.80	1.70-7.60	0.03-0.23
	(0.03)	(1.85)	(4.21)	(0.10)
Overall	0.10-0.30	1.0-11.00	1.70-77.00	0.01-0.89
	(0.002)	(3.24)	(7.39)	(0.15)

Note: Values in parenthesis are mean values

Table 4.15: Percentage distribution of well/tube well water samples into different EC and SAR, RSC and SSP classes

Name of Taluka	EC (dS m ⁻¹)				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
Balasinor	0 (0)	7 (2)	77 (23)	17 (5)	100 (30)	0 (0)	0 (0)	0 (0)	100 (30)	0 (0)	0 (0)	100 (30)	0 (0)
Lunawada	0 (0)	33 (10)	53 (16)	14 (4)	99.5 (29)	0.5 (1)	0 (0)	0 (0)	99.5 (29)	0.5 (1)	0 (0)	94 (28)	6 (2)
Kadana	0 (0)	60 (18)	36 (11)	4 (1)	100 (18)	00 (0)	0 (0)	0 (0)	100 (30)	0 (0)	0 (0)	100 (30)	0 (0)
Khanpur	0 (0)	40 (12)	56 (17)	4 (1)	100 (30)	0 (0)	0 (0)	0 (0)	100 (30)	0 (0)	0 (0)	100 (30)	0 (0)
Virpur	0 (0)	46 (14)	54 (16)	00 (00)	100 (30)	0 (0)	0 (0)	0 (0)	100 (30)	0 (0)	0 (0)	100 (30)	0 (0)
Santrampur	0 (0)	84 (25)	16 (5)	00 (00)	100 (30)	0 (0)	0 (0)	0 (0)	100 (30)	0 (0)	0 (0)	100 (30)	0 (0)
Overall	0 (0)	45 (81)	48.88 (88)	6.12 (11)	99.5 (179)	0.5 (1)	0 (0)	0 (0)	99.5 (179)	0.5 (1)	00 (00)	99 (178)	1 (2)

*Values in parenthesis are number of samples in respective group.

4.7 INTERRELATIONSHIP BETWEEN PROPERTIES OF IRRIGATION WATER AND IRRIGATED SOILS OF MAHISAGAR DISTRICT

4.7.1 Correlation

The correlation is observed between irrigation water properties and soil properties. So, the correlation between the different properties of irrigation waters (EC_{iw} , pH_{iw} , RSC_{iw} , SSP_{iw} and SAR_{iw}) and properties of irrigated soils ($EC_{2.5}$, $pH_{2.5}$, SAR, RSC, SSP, and ESP) were worked out and are presented in Table 4.18. The data indicates, highly significant positive correlation between EC_{iw} with $EC_{2.5}$ ($r = 0.238^{**}$), SSP ($r = 0.148^{*}$), SAR ($r = 0.269^{**}$) and RSC ($r = 0.165^{*}$) in case of ESP is negatively correlated with EC_{iw} ($r = -0.278^{**}$).

The pH_{iw} was significantly positive correlation with ESP ($r = 0.298^{**}$). Almost similar relationship was also obtained by Paliwal and Maliwal (1971), Prasad and Prasad (2001) and Kabaria (2004).

Table 4.16: Correlation coefficients among different properties of irrigation water and irrigated soils of Mahisagar district

	EC _{iw}	pH _{iw}	RSC _{iw}	SSP _{iw}	SAR _{iw}	EC _{2.5}	pH _{2.5}	SSP _{2.5}	SAR _{2.5}	RSC _{2.5}	ESP
EC _{iw}	1.0	--	--	--	--	--	--	--	--	--	--
pH _{iw}	-0.178*	1.0	--	--	--	--	--	--	--	--	--
RSC _{iw}	0.047	-0.051	1.0	--	--	--	--	--	--	--	--
SSP _{iw}	0.297**	0.059	0.382**	1.0	--	--	--	--	--	--	--
SAR _{iw}	0.509**	-0.044	0.397**	0.860**	1.0	--	--	--	--	--	--
EC _{2.5}	0.238**	-0.040	-0.060	0.017	0.01	1.0	--	--	--	--	--
pH _{2.5}	0.010	0.08	-0.143	-0.063	-0.033	0.156*	1.0	--	--	--	--
SSP	0.148*	0.29	0.049	0.026	0.06	0.311**	0.080	1.0	--	--	--
SAR	0.269**	-0.20	0.005	0.01	-0.08	0.675**	0.139	0.843**	1.0	--	--
RSC	0.165*	0.49	0.121	0.073	0.80	-0.072	-0.182*	0.349**	0.155*	1.0	--
ESP	-0.278**	0.298**	-0.068	-0.43	-0.123	0.20	-0.152	-0.419**	-0.302**	-0.197**	1.0

* Significant at 5 per cent level

** Significant at 1 per cent level

V. SUMMARY AND CONCLUSION

For evaluating physical properties and fertility, salinity/ sodicity status of soils and quality of underground well/tube well waters, about 180 surface soil samples (30 soil samples from each taluka) and 180 underground irrigation water samples were collected from the cultivated fields. The soil samples were analyzed for fertility parameters viz., available N, P_2O_5 , K_2O , S, Fe, Mn, Cu and Zn, salinity/sodicity parameters viz., 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 analyzed. For appraising quality irrigation water, water quality parameters like EC, pH, SAR, RSC and SSP were determined from all 180 water samples. The results are summarized here under.

5.1 PHYSICAL PROPERTIES OF SOILS OF ANAND DISTRICT

1. The mean bulk density value of the soils of Mahisagar district was 1.32 Mg m^{-3} and it was ranged from 1.23 to 1.45 Mg m^{-3} . The lowest bulk density value of 1.23 Mg m^{-3} was recorded in a sample collected from Lunawada and Kadana talukas. The highest bulk density value of 1.45 Mg m^{-3} was recorded in the samples collected from Virpur taluka.
2. The mean particle density value of the soils of Mahisagar district was 2.53 Mg m^{-3} and it was ranged widely from 2.32 to 2.78 Mg m^{-3} . The lowest particle density value of 2.32 Mg m^{-3} was recorded in a sample collected from Balasinor taluka. The highest value of 2.78 Mg m^{-3} was recorded in the samples collected from Virpur taluka.
3. The porosity of soils of Mahisagar district ranged from 37.07 to 51.50 per cent with a mean value of 47.97 per cent. The lowest (37.07 %) and highest (51.50 %) pore space value were recorded in a sample collected from Kadana and Khanpur respectively.
4. The overall range of MWHC was 29.25 to 64.23 per cent with a mean value of 45.97 per cent. The lowest MWHC value of 29.25 per cent was recorded in a sample collected from Virpur taluka. The highest MWHC value of 64.23 per cent was recorded in the sample collected from Lunawada taluka.

5.2 CHEMICAL PROPERTIES STATUS OF SURFACE SOILS OF ANAND DISTRICT.

1. The mean $EC_{2.5}$ value in the soils of Mahisagar district was 0.38 dS m^{-1} and ranged from 0.11 to 2.1 dS m^{-1} . Soils of Khanpur (0.49 dS m^{-1}) and Santrampur (0.44 dS m^{-1}) talukas have higher $EC_{2.5}$ mean values.
2. In general, the soils of this district were alkaline (pH value ranging from 6.29 to 8.76 with a mean value of (7.60) in reaction. The lowest pH value of 6.29 was recorded in a soil samples collected from Santrampur taluka. The highest value of 8.76 was recorded in the sample collected from Lunawada taluka.
3. The soils of Mahisagar district were high in organic carbon content. It was ranging from 0.12 to 1.77 per cent with a mean value of 0.82 per cent. Highest O.C mean value(0.96%) reported in Santrampur taluka and lowest mean value (0.64%) of O.C reported in Lunawada taluka
4. The $CaCO_3$ content in these soils varied between 3.22 to 6.75 per cent, with mean value of 4.28 per cent. The highest value of 6.75 per cent was recorded in Virpur taluka and the lowest value of 3.22per cent was obtained in Balasinor taluka
5. The overall range of CEC was 13.78 to 46.93 $\text{cmol (p}^+) \text{ kg}^{-1}$ with mean a value of 24.47 $\text{cmol (p}^+) \text{ kg}^{-1}$.The lowest CEC value 13.78 $\text{cmol (p}^+) \text{ kg}^{-1}$ was reported in Kadana taluka. The highest CEC value 46.93 $\text{cmol (p}^+) \text{ kg}^{-1}$ found in Khanpur taluka.

5.3 SALINITY/SODICITY STATUS OF SURFACE SOILS OF MAHISAGAR DISTRICT

1. The Mg^{++} was the dominant exchangeable cation followed by Ca^{++} , Na^+ and K^+ . The exchangeable Ca^{++} , Mg^{++} , Na^+ and K^+ varied from 2.0 to 24.7, 1.3 to 21.7, 0.58 to 6.34 and 0.04 to 1.0 with their corresponding mean values of 5.87, 9.51, 2.70 and $0.22 \text{ cmol(p}^+) \text{ kg}^{-1}$, respectively.
2. Among water soluble cations, Mg^{++} was the dominant water soluble cation followed by Ca^{++} , Na^+ and K^+ . The water soluble Ca^{++} , Mg^{++} , Na^+ and K^+ ranged from 0.30 to 4.0, 0.40 to 4.60, 0.11 to 2.53 and 0.03 to 0.21 with their mean values of 0.96, 1.56, 0.72 and 0.09 me L^{-1} , respectively.
3. Among water soluble anions, Cl^- was predominant one followed by HCO_3^- , SO_4^- and CO_3^- . The water soluble HCO_3^- , Cl^- and SO_4^- varied between 1.0 to 9.0, 2.40 to 17.60 and 0.06 to 1.83 with mean values of 3.2, 4.41 and 0.35 me L^{-1} , respectively.

No CO_3^- found in any collected soil sample of Mahisagar district. The results of water soluble ions revealed that Mg^{++} and Cl^- were predominant cation and anion in soil solution, respectively.

4. The ESP values ranged from 2.32 to 37.50 with an average value of 11.4, suggesting relatively lower hazard of alkalinity in the soils of Mahisagar district
5. The SSP and SAR values were ranged between 3.25 to 49.9 and 0.09 to 1.69 with mean values of 22.3 and 0.66, respectively.
6. About 3, 1, 20 and 76 percent soil samples were found saline, saline-sodic, sodic and normal, respectively. Sodic soils are the predominant salt affected soils in the district, followed by saline soils in Mahisagar District.
7. Highly significant positive relations were observed between $\text{EC}_{2.5}$ with $\text{pH}_{2.5}$ ($r=0.156^*$), SSP ($r=0.311^*$) and SAR($r=0.675^*$). The $\text{pH}_{2.5}$ was negatively significant correlated with RSC($r = -0.182^*$). RSC was positively significant correlated with SAR($r = 0.155^*$) and negatively correlated with ESP($r = -0.197^{**}$) and SAR was negatively correlated with ESP.

5.4 FERTILITY STATUS OF THE SOILS OF MAHISAGAR DISTRICT.

1. The soils of Mahisagar district were found low in available nitrogen, medium in phosphorus and sulphur. It was ranging from 94 to 376, and 4.40 to 79.2 , 0.39 to 56.4 with their corresponding mean value of 232 kg ha^{-1} , 30.5 kg ha^{-1} and 16.69 mg kg^{-1} , respectively.
2. The available K_2O was Medium and it was ranging from 49 to 758 with a mean value of 228 kg ha^{-1} .
3. The soils of Mahisagar district were high in available Fe, Zn, Mn, and Cu. The available (DTPA extractable) Fe, Mn, Zn and Cu varied from 1.89 to 39.22, 3.96 to 32.46, 0.22 to 5.91 and 0.05 to 6.79 with their corresponding mean values of 15.14, 11.59, 1.64 and 1.53 mg kg^{-1} , respectively.
4. The nutrient index values were low for available N (1.36) and available P_2O_5 (1.55). Medium for available S (1.97) and K_2O (2.03), High for DTPA extractable Fe (2.53) and DTPA extractable Zn (2.61)), DTPA extractable Mn (2.55) and DTPA extractable Cu (2.81) in the soils of Mahisagar district.

5.5 QUALITY OF UNDERGROUND WELL/TUBE WELL WATER AND THEIR CLASSIFICATION

1. In general, underground well/tube well water was neutral to alkaline in reaction. The overall pH values ranged from 6.60 to 9.70 with mean value of 7.49. The lowest Value of pH was recorded in sample recorded from Balasinor taluka whereas highest value of pH (9.70) was reported in Santrampur taluka. The water was saline in nature and overall EC values ranged from 0.26 to 8.80 with mean value of 1.10 dSm^{-1} . The lowest value of EC (0.26 dS m^{-1}) was recorded in a sample taken from Santrampur taluka whereas the highest value of EC (8.80 dSm^{-1}) was reported in Balasinor taluka.
2. The frequency distribution of underground well/tube well water samples in relation to EC showed that overall 45.0, 48.48 and 6.11 per cent samples were falling under C_2 , C_3 and C_4 classes of EC, respectively. No sample was found in C_1 class of EC.
3. The relative proportion of cations showed that overall the highest mean proportion of Mg^{++} (6.34 me L^{-1}) was observed, which was followed by Ca^{++} (1.99 me l^{-1}), Na^+ (1.68 me L^{-1}) and K^+ (0.72 me L^{-1}). The concentration of Ca^{++} , Mg^{++} , Na^+ and K^+ were in the range of 0.50 to 21.50, 1.50 to 53.00, 0.01 to 29.80 and 0.64 to 4.0 me L^{-1} , respectively.
4. The relative proportion of anions showed that the highest overall mean value of 7.39 me L^{-1} was recorded for Cl^- and it was followed by HCO_3^- (3.24 me l^{-1}), SO_4^{--} (0.15 me L^{-1}) and CO_3^{--} (0.00 me L^{-1}). The concentration of CO_3^{--} , HCO_3^- , Cl^- and SO_4^{--} were in the range of 0.10 to 0.30, 1.00 to 11.00, 1.70 to 77.0 and 0.01 to 0.89 me L^{-1} , respectively.
5. The overall residual sodium carbonate (RSC) values ranged from 0.00 to 1.30 with a mean value of 0.007 me L^{-1} . Overall 99.5 and 0.5 per cent samples were found under safe and marginal classes of RSC, respectively.
6. The overall mean value of sodium adsorption ratio was 0.76 and it varied from 0.00 to 11.03. Overall, 99.5 and 0.5 per cent samples fall under S_1 and S_2 and classes of SAR, respectively.
7. The overall mean value of soluble sodium percentage (SSP) was 13.07, which varied from 0.11 to 65.95. Overall 99 and 1 per cent samples were found under safe and unsafe classes of SSP, respectively

5.6 RELATIONSHIP BETWEEN DIFFERENT PROPERTIES OF WELL/TUBE WELL WATER AND SOIL PROPERTIES.

Highly significant positive correlation between EC_{iw} with $EC_{2.5}$ ($r = 0.238^{**}$), SSP ($r = 0.148^*$), SAR ($r = 0.269^{**}$) and RSC ($r = 0.165^*$) in case of ESP is negatively correlated with EC_{iw} ($r = -0.278^{**}$). This indicates the EC_{iw} is increased with $EC_{2.5}$, SSP , RSC & decreased with ESP . The pH_{iw} was significantly positive correlation with ESP ($r = 0.298^{**}$). This indicates the pH_{iw} is increased with ESP .

CONCLUSIONS

The soils of Mahisagar districts have low bulk density (1.32 Mg m^{-3}) and particle density (2.53 Mg m^{-3}). This indicates good physical condition of soil.

The soils of Mahisagar districts are alkaline in reaction with high in organic carbon.

Majority of the soils of Mahisagar district are low in available nitrogen and medium in phosphorus, sulphur and available potassium. The micronutrients status of available iron, manganese, zinc and copper are high. Being the light to medium texture soils, its overall cation exchange capacity is $24.47 \text{ cmol (p}^+) \text{ kg}^{-1}$. Magnesium is the dominant-exchangeable cation, whereas magnesium and chloride are dominant water soluble ions. About 3.0, 1.0, 20 and 76 per cent soil samples are found saline, saline-sodic, sodic and normal, respectively.

More than half of the samples of well/tube well waters from cultivator's fields have low salinity. The problem of salinity will be even increased in Balasinor taluka in this future. Therefore suitable holistic management practices should be implemented for the sustainable agriculture in Balasinor taluka.

The quality parameter of underground water like RSC , SAR and SSP were recorded in range of 0.00 to 1.30 me L^{-1} , 0.00 to 11.03 and 0.11 to 65.95 with average value of 0.007 me L^{-1} , 0.76 and 13.07, respectively.

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Appendix I : Taluka/Sample wise name of Farmer, Taluka and Village from where soil and water sample taken			
Sr. No	Name of Farmer	Name of village	Soil/Water sample
		Balasinor	
1	Patel Vijaybhai Rmabhai	Balasinor	YES
2	Patel Ramanbhai Prubhudas	Balasinor	YES
3	Patel Ashwinbhai Dharmeshbhai	Balasinor	YES
4	Valand Dhulabhai Rayjibhai	Pilodra	YES
5	Patel Kantibhai Girdhar	Pilodra	YES
6	Patel Bhaveshkumar Ramanbhai	Pilodra	YES
7	Sharma Magnlal Bhikhabhai	Saroda	YES
8	Chauhan Pratapbhai Laxmanbhai	Saroda	YES
9	Chauhan Sanabhai Rabhabhai	Saroda	YES
10	Patel Manibhai Narayanbhai	Dev	YES
11	Mohhamad Salim Usmangani	Dev	YES
12	Chauhan Umedsinh Bhavsinh	Dev	YES
13	Thakor Rmeshbhai Bhathibhai	Navagundela	YES
14	Thakor Babubhai Koyabhai	Navagundela	YES
15	Thakor Laxmanbhai Bhemabhai	Navagundela	YES
16	Mayavanshi Dahiben Virabhai	Raiyoli	YES
17	Chauhan Vikramsinh Pruthvisinh	Raiyoli	YES
18	Chauhan Narvatsinh Rtansinh	Raiyoli	YES

19	Parmar Hashmukhbhai Motibhai	Gunthali	YES
20	Chauhan Nathabhai Rughbhai	Gunthali	YES
21	Zala Ramanbhai Dayabhai	Gunthali	YES
22	Solanki Vijaysing Mangalsing	Othwad	YES
23	Thakor Vinubhai Somabhai	Othwad	YES
24	Thakor Radhabhai Otharbhai	Othwad	YES
25	Parmar Laxanbhai Saburbhai	Parpadiya	YES
26	Bariya Sanabhai Bhodarbhai	Parpadiya	YES
27	Parmar Ajitsingh Arjunsingh	Parpadiya	YES
28	Patel Jatinbhai Rajnibhai	Vadadala	YES
29	Parmar Bhavjibhai parbhat	Vadadala	YES
30	Parmar Narvatsingg parbhatsingh	Vadadala	YES
		Lunawada	
31	Patel Kalidas Somabhai	Kothamba	YES
32	Vyaskar Jaimin Jothabhai	Kothamba	YES
33	Patel Raijibhi Ramanbhai	Kothamba	YES
34	Pagi Iswarbhai Bhurabhai	Bomanvada	YES
35	Patel Kantibhai Dhuljibhai	Bomanvada	YES
36	Vaghela Laxmansing Baljitsing	Bomanvada	YES
37	Vankar Kanubhai Lebabhai	Chandsar	YES

38	Parmar Lambabhai Poojabhai	Chandsar	YES
39	Patel Harishbhai Bhembhai	Chandsar	YES
40	Suthar Jayeshkumar Muljibhai	Moti Palli	YES
41	Patel Bindubhai Sokalbhai	Moti Palli	YES
42	Khant Nanabhai Galabhai	Moti Palli	YES
43	Ninama Sanabhai Dalabhai	Rampur	YES
44	Patel Jagdishbhai Kaljibhai	Rampur	YES
45	Patel Hiteshbhai Valjibhai	Rampur	YES
46	Bamniya Jayantibhai Somabhai	Napaniya	YES
47	Pagi Bhulabhai Motibhai	Napaniya	YES
48	Vankar Paragbhai Muljibhai	Napaniya	YES
49	Patel Arvinbhai Mangalbhai	Chandpur	YES
50	Patel Pravinbhai Manilal	Chandpur	YES
51	Patel Harshadbhai Jayntilal	Chandpur	YES
52	Vankar Ganeshbhai Ratanbhai	Bhalada	YES
53	Vankar Devabhai Monabhai	Bhalada	YES
54	Vankar Manilal Dhanabhai	Bhalada	YES
55	Taral Amrabhai Banabhai	Charangam	YES
56	Pagi Bhalabhai Motibhai	Charangam	YES
57	Pagi Bhanabhai Motibhai	Charangam	YES
58	Parmar Rajendra Narendra	Lunawada	YES

59	Parmar Mukeshbhai Mavabhai	Lunawada	YES
60	Chauhan Ramanbhai Somabhai	Lunawada	YES
Kadana			
61	Patel Khemabhai Nathabhai	Dhuniya	YES
62	Patel Jethabhai Lalabhai	Dhuniya	YES
63	Godha Shivabhai Lakhabhai	Dhuniya	YES
64	Khant Dhulabhai Hemabhai	Machhiwada	YES
65	Khant Raysingbhai Bathibhai	Machhiwada	YES
66	Khant Hariybhai Bhurabhai	Machhiwada	YES
67	Patel Somabhai Heerabhai	Paniya	YES
68	Khant Manibhai Somabhai	Paniya	YES
69	Patel Ramanbhai Revabhai	Paniya	YES
70	Rohit Klapehkumar Nanubhai	Velanwada	YES
71	Nai Lasabhai Manjibhai	Velanwada	YES
72	Raval Bhadreshkumar Heeralal	Velanwada	YES
73	Damor Nanabhai Dhulabhai	Chhajali	YES
74	Damor Jesingbhai Motibhai	Chhajali	YES
75	Damor Makaubhai Zalabhai	Chhajali	YES
76	Damor Rupabhai valabhai	Ditvas	YES
77	Labana Nimeshbhai Man	Ditvas	YES

78	Damor Rupabhai Lalubhai	Ditvas	YES
79	Rot Bhurabhai Dhulabhai	Kharod	YES
80	Valu Parvatbhai Rupabhai	Kharod	YES
81	Damor Lalabhai Zavrabha	Kharod	YES
82	Damor Kalubhai Gemabhai	Rankakot	YES
83	Khata Laxmanbhai Chatrabhai	Rankakot	YES
84	Khata Ramnbahi Sardarbhai	Rankakot	YES
85	Khant Lalabhai Dhanabhai	Ghaswada	YES
86	Khant bhathibhai Laxmanbhai	Ghaswada	YES
87	Khnat Bhurabhai Dhulabhai	Ghaswada	YES
88	Patel Vaktbhai Bhurabhai	Baluna Muwada	YES
89	Patel Vinodbhai Kalubhai	Baluna Muwada	YES
90	Patel Rameshbhai Lalabhai	Baluna Muwada	YES
Khanpur			
91	Maliwad Nanabhai Rupabhai	Mota Khanpur	YES
92	Maliwad Koyabhai Reshmabhai	Mota Khanpur	YES
93	Patel Rame+shbhai Danabhai	Mota Khanpur	YES
94	Patel Parshotambhai Ambalal	Khuntelav	YES
95	Patel Rameshbhai Virabhai	Khuntelav	YES
96	Patel Dahyabhai Dalabhai	Khuntelav	YES
97	Maliwad Pratapbhai Jesingbhai	Umariya	YES

98	Damor Jurmabhai Laxmanbha	Umariya	YES
99	Damor Kalubhai Laxmanbhai	Umariya	YES
100	Damor Galabhai Rumalbhai	Mor Khakhara	YES
101	Baria Somabhai Kalubhai	Mor Khakhara	YES
102	Damor MOnabhai Somabhai	Mor Khakhara	YES
103	Damor Ramanbhai Heerabhai	Vadhela	YES
104	Khant Lalabhai Anjanbhai	Vadhela	YES
105	Damor Pratapbhai Jesingbhai	Vadhela	YES
106	Khant Rameshbhai Lalabhai	Motipura	YES
107	Pagi Hazurbhai Ratabhai	Motipura	YES
108	Kharadi Pratapbhai Laxmanbhai	Motipura	YES
109	Prajapati Arvindbhai Ranchodbhai	Babaliya	YES
110	Macchar Lilaben Sanjaybahi	Babaliya	YES
111	Damor Kalubhai Heerabhai	Babaliya	YES
112	Valand Revabhai Lalabhai	Naroda	YES
113	Valand Ranchodbhai Koyabhai	Naroda	YES
114	Patel Kalubhai Manjibhai	Naroda	YES
115	Patel Ambalal Daljibhai	Bedvalli	YES
116	Patel Jigneshkumar Heerabhai	Bedvalli	YES
117	Patel Rameshkumar Rupabhai	Bedvalli	YES
118	Maliwad Jashvantbhai Sanabhai	Bhevada	YES

119	Maliwad Bhikhabhai Shankarbhai	Bhevada	YES
120	Maliwad Kalubhai Heerabhai	Bhevada	YES
Virpur			
121	Prajapati Ranchodbhai Nathabhai	Bhanjini Vav	YES
122	Solankai Rameshbhai Udabhai	Bhanjini Vav	YES
123	Solanki Rahulkumar Maheshbhai	Bhanjini Vav	YES
124	Baria Dahyabhai Ramanbhai	Rasulpur	YES
125	Khant Amrabhai Punabhai	Rasulpur	YES
126	Baria Bharatbhai Fatabhai	Rasulpur	YES
127	Khant Bijalabhai Laxmanbhai	Alampur	YES
128	Khant Jesingbhai Navabhai	Alampur	YES
129	Khant Somabhai Haribhai	Alampur	YES
130	Khant Amrutbhai Ramabhai	Chharvangi	YES
131	Khnat Khatubhai Bhurabhai	Chharvangi	YES
132	Khnat Somabhai Manilal	Chharvangi	YES
133	Parmar Vajesing Gababhai	Bar	YES
134	Parmar Kalubhai Dahyabhai	Bar	YES
135	Valand Mohanbhai Jethabhai	Bar	YES
136	Parmar Sardarbhai Lakhabhai	Dholawada	YES
137	Thakor Dalpatsingh Bhemsigh	Dholawada	YES

138	Thakor Ramsingh Lalabhai	Dholawada	YES
139	Patel Jayantibhai Shankarbhai	Koydam	YES
140	Patel Gordhanbhai Somabhai	Koydam	YES
141	Patel Chandrakant Jesingbhai	Koydam	YES
142	Parmar Dolabhai Rabhabhai	Jodhpur	YES
143	Parmar Poonamsing Raysing	Jodhpur	YES
144	Parmar Jagdishbhai Motibhai	Jodhpur	YES
145	Baria Mathurbhai Kanubhai	Rojhar	YES
146	Thakor Bhavanbhai Heerabhai	Rojhar	YES
147	Parmar Diyalbhai Dulabhai	Rojhar	YES
148	Baria Ranjitbhai Bhgvabhai	Bhatpur	YES
149	Baria Parvathai Jujarbhai	Bhatpur	YES
150	Rohit Somabhai Panabhai	Bhatpur	YES
Santrampur			
151	Pargi Shantilal Lalabhai	Sarad	YES
152	Pargi Maheshkumar Bhembhai	Sarad	YES
153	Pargi Himmatbhai Vaghabhai	Sarad	YES
154	Damor Jaydipkumar Champabhai	Bhandara	YES
155	Damor Somabhai Poojabhai	Bhandara	YES
156	Damor Dharmendra Shankarbhai	Bhandara	YES

157	Baria Nathabbhia Koyabhai	Timbharva	YES
158	Charpoat Rakeshbhai Sanabhai	Timbharva	YES
159	Dindor Sagjibhai Nathabhai	Timbharva	YES
160	Parmar Jivahai Koyabhai	Hirapura	YES
161	Chamar Kanabhai Dayabhai	Hirapura	YES
162	Thakor Mahendrasing Laxmansinh	Hirapura	YES
163	Baria Rameshbhai Galabhai	Khodadra	YES
164	Valvai Kanjibhai Zalubhau	Khodadra	YES
165	Katara Jesingbhai Poojabhai	Khodadra	YES
166	Seloat Deepsingbhai Chandubhai	Anjnwa	YES
167	Seloat Shankarbhai Lalabhai	Anjnwa	YES
168	Seloat Narvatbhai Heerabahi	Anjnwa	YES
169	Baria Babubhai Jesingbhai	Satkunda	YES
170	Baria Laxmanbhai Gemabhai	Satkunda	YES
171	Baria Anandbhai Galabhai	Satkunda	YES
172	Patel Sureshbhai Kanjibhai	Nani Sarsan	YES
173	Patel Harshadbhai Kanjibhai	Nani Sarsan	YES
174	Patel Sureshbhai Motibhai	Nani Sarsan	YES
175	Damor Manilal Bharabhai	Amba	YES
176	Damor Shankarbhai Heerabhai	Amba	YES

177	Damor Devabhai Motibhai	Amba	YES
178	Maliwad Rupabhai Lalabhai	Dahela	YES
179	Maliwad Somabhai Valabhai	Dahela	YES
180	Maliwad Surtabhai Ramsingbhai	Dahela	YES

Appendix II: Taluka wise value of some important physical properties of soils of Anand district

Sr. No	MWHC (%)	B.D (Mg m ⁻³)	P.D. (Mg m ⁻³)	Porosity (%)
1	2	3	4	5
Balasinor				
1	45.87	1.31	2.60	49.62
2	57.00	1.32	2.58	48.84
3	46.53	1.32	2.54	48.03
4	49.49	1.31	2.57	49.03
5	47.15	1.35	2.55	47.06
6	41.00	1.27	2.48	48.79
7	40.00	1.31	2.58	49.22
8	39.20	1.31	2.54	48.43
9	41.32	1.27	2.46	48.37
10	40.00	1.37	2.63	47.91
11	52.00	1.35	2.59	47.88
12	47.05	1.33	2.42	45.04
13	56.12	1.27	2.38	46.64
14	62.10	1.31	2.32	43.53
15	48.40	1.32	2.45	46.12
16	45.60	1.29	2.54	49.21
17	53.00	1.32	2.58	48.84
18	55.00	1.30	2.53	48.62
19	40.51	1.32	2.48	46.77
20	47.40	1.28	2.45	47.76
21	49.54	1.27	2.48	48.79
22	52.00	1.34	2.54	47.24
23	52.00	1.31	2.45	46.53
24	54.61	1.32	2.56	48.44
25	51.20	1.28	2.48	48.39
26	53.18	1.33	2.54	47.64

1	2	3	4	5
27	45.00	1.34	2.55	47.45
28	53.40	1.35	2.58	47.67
29	43.50	1.31	2.46	46.75
30	43.20	1.31	2.54	48.43
Mean.	48.41	1.31	2.51	47.76
Max.	62.10	1.37	2.63	49.62
Min	40.0	1.27	2.32	45.04

Lunawada

31	38.46	1.30	2.56	49.22
32	52.00	1.34	2.42	44.63
33	47.41	1.32	2.60	49.23
34	46.15	1.23	2.44	49.59
35	56.50	1.28	2.40	46.67
36	60.00	1.33	2.54	47.64
37	36.00	1.32	2.54	48.03
38	34.20	1.30	2.48	47.58
39	40.45	1.31	2.55	48.63
40	49.02	1.28	2.42	47.11
41	45.20	1.32	2.52	47.62
42	47.00	1.27	2.45	48.16
43	46.40	1.26	2.43	48.15
44	58.00	1.25	2.44	48.77
45	50.00	1.33	2.45	45.71
46	51.36	1.30	2.59	49.81
47	42.00	1.31	2.58	49.22
48	36.00	1.32	2.57	48.64
49	43.59	1.35	2.61	48.28

1	2	3	4	5
50	63.20	1.30	2.46	47.15
51	64.23	1.29	2.52	48.81
52	53.00	1.40	2.69	47.96
53	53.45	1.31	2.54	48.43
54	39.88	1.35	2.56	47.27
55	40.50	1.32	2.48	46.77
56	56.12	1.34	2.52	46.83
57	44.00	1.39	2.67	47.94
58	40.00	1.31	2.55	48.63
59	50.00	1.31	2.59	49.42
60	32.49	1.39	2.66	47.74
Mean.	47.22	1.31	2.52	47.98
Max.	64.23	1.40	2.69	49.81
Min.	36.0	1.23	2.40	44.63
Kadana				
61	38.00	1.28	2.36	45.76
62	46.73	1.23	2.45	49.80
63	45.70	1.30	2.51	48.21
64	42.15	1.39	2.70	48.52
65	45.00	1.37	2.68	48.88
66	49.70	1.25	2.44	48.77
67	47.00	1.35	2.60	48.08
68	50.00	1.28	2.48	48.39
69	47.47	1.32	2.46	46.34
70	41.40	1.33	2.64	49.62
71	43.38	1.35	2.67	49.44
72	37.75	1.31	2.57	49.03
73	40.00	1.34	2.67	49.81
74	36.21	1.31	2.58	49.22

1	2	3	4	5
75	40.00	1.28	2.57	50.19
76	47.40	1.29	2.37	37.07
77	47.00	1.40	2.65	47.17
78	44.00	1.29	2.47	47.77
79	42.00	1.37	2.48	44.76
80	39.00	1.29	2.56	49.61
81	43.00	1.37	2.39	42.68
82	42.90	1.33	2.60	48.85
83	41.41	1.33	2.54	47.64
84	48.00	1.37	2.62	47.71
85	44.00	1.35	2.45	44.90
86	52.00	1.29	2.55	49.41
87	46.00	1.37	2.60	47.31
88	47.90	1.39	2.63	47.15
89	43.00	1.32	2.42	45.45
90	42.20	1.34	2.66	49.62
Mean.	44.01	1.33	2.53	47.57
Max.	52.00	1.40	2.68	50.19
Min.	37.75	1.23	2.36	37.07
Khanpur				
91	37.65	1.26	2.35	49.79
92	38.99	1.37	2.52	45.63
93	46.40	1.41	2.74	48.54
94	41.18	1.35	2.63	48.67
95	51.23	1.35	2.59	47.88
96	42.50	1.35	2.54	46.85
97	49.17	1.25	2.38	47.48
98	51.50	1.40	2.68	44.40
99	50.00	1.35	2.54	46.85

1	2	3	4	5
100	47.66	1.33	2.53	47.43
101	46.00	1.36	2.55	46.67
102	39.68	1.37	2.63	47.91
103	47.00	1.35	2.66	49.25
104	45.17	1.26	2.43	48.15
105	51.21	1.30	2.45	46.94
106	40.00	1.33	2.40	44.58
107	42.15	1.37	2.46	44.31
108	48.40	1.35	2.57	47.47
109	47.50	1.41	2.48	43.15
110	42.20	1.29	2.66	51.50
111	46.26	1.28	2.36	45.76
112	43.17	1.32	2.38	44.54
113	41.75	1.31	2.45	46.53
114	52.87	1.36	2.34	41.88
115	50.00	1.33	2.38	44.12
116	52.12	1.38	2.68	48.51
117	53.67	1.32	2.54	48.03
118	39.43	1.39	2.67	47.94
119	34.67	1.32	2.54	48.03
120	36.00	1.31	2.38	44.96
Mean.	45.18	1.32	2.51	46.79
Max.	53.67	1.40	2.74	51.50
Min.	34.67	1.26	2.35	41.83
Virpur				
121	42.93	1.35	2.63	48.67
122	58.00	1.31	2.50	47.60
123	47.40	1.32	2.54	48.03
124	40.70	1.34	2.58	48.06

1	2	3	4	5
125	52.14	1.34	2.51	46.61
126	45.05	1.32	2.52	47.62
127	40.50	1.32	2.54	48.03
128	50.36	1.33	2.39	44.35
129	44.61	1.26	2.49	49.40
130	43.70	1.31	2.40	45.42
131	39.00	1.33	2.57	48.25
132	41.50	1.33	2.64	49.62
133	42.83	1.32	2.57	48.64
134	43.83	1.30	2.58	49.61
135	39.00	1.32	2.52	47.62
136	48.25	1.45	2.78	49.65
137	50.00	1.35	2.68	49.63
138	49.00	1.35	2.60	48.08
139	34.50	1.25	2.47	49.39
140	52.69	1.34	2.57	47.86
141	39.00	1.33	2.56	48.05
142	29.25	1.32	2.54	48.03
143	50.43	1.31	2.57	49.03
144	50.00	1.34	2.58	48.06
145	48.00	1.33	2.57	48.25
146	39.00	1.33	2.68	50.37
147	37.12	1.36	2.64	48.48
148	35.40	1.31	2.39	45.19
149	38.48	1.32	2.54	48.03
150	49.75	1.37	2.57	46.69
Mean.	44.08	1.32	2.55	48.07
Max.	58.0	1.45	2.78	50.37
Min.	29.25	1.25	2.39	44.35

Santrampur

1	2	3	4	5
151	46.70	1.37	2.58	46.90
152	54.45	1.35	2.57	47.47
153	45.37	1.32	2.52	47.62
154	47.78	1.40	2.67	47.57
155	43.44	1.31	2.52	48.02
156	38.34	1.32	2.56	48.44
157	34.98	1.35	2.54	46.85
158	42.85	1.33	2.64	49.62
159	44.87	1.31	2.48	47.18
160	57.77	1.38	2.58	46.51
161	53.00	1.34	2.52	46.83
162	52.73	1.31	2.43	46.09
163	44.00	1.32	2.58	48.84
164	32.98	1.27	2.50	49.20
165	42.40	1.32	2.54	48.03
166	46.97	1.29	2.45	47.35
167	48.00	1.36	2.64	48.48
168	44.90	1.32	2.45	46.12
169	42.78	1.28	2.48	48.39
170	55.67	1.35	2.67	49.44
171	46.78	1.37	2.43	43.62
172	42.00	1.27	2.49	49.00
173	55.17	1.32	2.63	49.81
174	47.63	1.30	2.55	49.02
175	45.80	1.31	2.59	49.42

1	2	3	4	5
176	52.00	1.32	2.54	48.03
177	48.90	1.31	2.58	49.22
178	47.76	1.24	2.37	47.68
179	49.80	1.31	2.54	48.43
180	52.26	1.30	2.52	48.41
Mean.	46.94	1.32	2.53	47.91
Max.	55.67	1.40	2.67	49.81
Min.	32.98	1.24	2.43	43.62

Appendix III: Taluka/Sample wise values of EC_{2.5}, pH_{2.5}, O. C., fertility status, and CaCO₃ of soil

Sr. NO	EC _{2.5}	pH _{2.5}	O.C	Kg ha ⁻¹			Mg kg ⁻¹					CaCO ₃
				N	P ₂ O ₅	K ₂ O	S	Fe	Mn	Zn	Cu	(%)
1	2	3	4	5	6	7	8	9	10	11	12	13
Balasinor												
1	0.15	7.55	0.25	172	21.9	233	24.1	6.36	15.8	0.91	0.96	4.6
2	1.12	7.9	1.06	282	32.9	236	29.4	1.89	8.12	1.80	0.61	4.75
3	0.38	7.76	1.05	282	12.8	499	2.56	4.92	5.73	2.14	1.56	3.22
4	0.49	7.74	0.95	266	50.7	296	6.96	4.60	6.63	2.13	0.37	5.25
5	0.32	7.29	0.45	141	14.5	193	1.57	20.7	35.4	3.80	0.69	3.22
6	0.21	7.48	0.48	156	10.6	320	2.76	5.83	24.1	0.90	0.37	4.23
7	1.16	7.72	0.56	203	23.6	193	3.35	5.75	13.1	2.33	0.24	3.23
8	0.24	7.7	0.59	219	33.5	141	15.6	9.84	24.2	2.49	0.73	3.25
9	0.15	7.15	0.41	219	35.2	183	11.0	7.72	30.4	2.75	0.67	4.5
10	0.52	7.87	0.72	219	44.1	663	18.8	5.07	9.91	0.65	1.46	6.25
11	0.31	7.28	0.71	188	12.2	182	12.7	27.1	4.82	0.77	2.18	5.75
12	0.27	7.22	0.64	203	35.2	295	7.77	9.84	14.5	4.09	1.16	3.74
13	0.15	7.82	0.68	235	6.6	206	16.0	11.6	10.2	0.93	2.91	4.5
14	0.25	7.89	0.87	250	7.8	237	13.7	13.6	8.12	3.37	2.87	5.74
15	0.24	8.22	1.14	313	24.2	208	24.9	14.9	12.4	1.16	2.09	3.52
16	0.16	7.62	0.40	188	20.2	287	9.00	7.72	14.2	2.25	3.28	6.25
17	0.39	8.12	0.78	313	34.0	174	19.9	5.74	6.30	1.95	6.79	4.68
18	0.24	7.53	1.30	297	56.1	210	2.16	30.8	16.2	1.56	5.19	3.25
19	0.17	7.2	0.71	235	49.5	149	26.5	2.27	8.19	1.65	0.98	3.75
20	0.38	8.47	0.74	282	41.1	279	10.8	13.2	12.7	1.16	4.07	4.5
21	0.22	7.65	1.07	266	53.1	120	31.0	14.6	8.39	1.24	3.68	4.52
22	0.29	7.96	1.38	345	32.9	359	3.15	4.54	6.19	1.34	2.2	5.22
23	0.41	7.2	0.43	188	24.8	517	4.55	13.3	12.1	1.96	2.23	4.5
24	0.49	7.5	0.56	250	23.6	432	3.55	14.0	16.1	1.56	0.98	4.51
25	0.13	7.83	1.16	297	34.0	171	19.7	13.4	12.2	2.01	1.78	3.25

1	2	3	4	5	6	7	8	9	10	11	12	13
26	0.31	7.95	0.98	282	16.8	288	30.8	4.09	6.19	1.46	3.25	4.52
27	0.26	8.02	1.18	297	27.6	244	24.5	3.48	4.20	2.07	1.98	3.75
28	0.26	7.38	1.06	235	45.9	370	21.6	13.7	12.1	2.09	0.73	4.68
29	0.17	7.75	0.95	360	25.9	277	11.4	8.03	14.1	1.77	3.52	3.52
30	0.33	8.3	0.69	188	30.0	330	18.0	5.38	28.3	3.38	0.82	4.5
Mean.	0.33	7.70	0.80	246	29.4	276	14.2	10.1	13.2	1.92	2.01	4.37
Max.	1.16	8.47	1.38	360	56.1	633	31.0	30.8	32.4	4.09	6.79	6.25
Min.	0.13	7.15	0.25	141	6.60	120	1.57	1.89	4.20	0.65	0.24	3.22
Low			6	14	15	1	11	7	2	0	0	
Medium			10	16	14	17	13	11	10	4	1	
High			14	0	1	12	6	12	18	26	29	
Lunawada												
31	0.26	7.7	0.87	203	13.4	125	47.5	6.51	12.6	0.67	0.53	4.22
32	0.22	7.64	0.77	188	49.5	102	24.5	25.3	14.4	2.06	1.86	4.25
33	0.57	8.1	0.51	219	30.0	324	6.36	6.36	14.4	1.21	2.85	3.78
34	0.15	7.62	0.43	203	8.9	211	0.39	26.2	24.5	0.49	1.37	4.5
35	0.29	8.23	0.51	172	32.3	147	3.15	14.5	11.9	0.42	3.19	5.25
36	1.38	8.03	1.04	329	51.9	198	22.3	37.0	12.1	5.91	2.01	4.22
37	0.34	8.46	0.33	156	26.5	127	0.98	8.78	10.9	1.40	0.05	3.5
38	0.19	7.53	0.35	188	38.8	224	15.8	18.9	15.7	3.18	0.29	3.65
39	0.32	7.34	0.51	203	27.6	259	15.4	15.37	9.19	0.82	1.57	4.5
40	0.21	7.28	0.63	188	10.0	191	12.5	54.8	13.1	3.10	1.97	3.73
41	0.31	7.99	0.49	156	11.1	211	13.1	17.8	10.2	1.89	2.07	5.21
42	0.33	7.86	0.60	172	48.3	278	31.0	35.2	14.2	0.51	2.87	4.45
43	0.15	8.03	0.63	235	14.5	169	6.56	25.8	9.76	1.79	1.82	4.5
44	0.24	8.08	0.69	219	17.9	258	27.8	5.98	6.17	0.25	1.86	4.23
45	0.32	7.78	0.56	250	25.9	93	13.3	32.1	12.1	2.58	3.01	3.24
46	0.41	7.99	1.04	235	18.5	120	2.56	8.34	10.5	0.35	0.95	4.21
47	0.17	6.73	0.45	188	51.3	123	12.0	28.5	8.16	1.65	1.72	3.25
48	0.13	6.33	0.48	219	11.7	150	14.1	39.2	31.3	2.58	0.21	3.75

1	2	3	4	5	6	7	8	9	10	11	12	13
49	0.38	6.77	1.07	235	59.8	530	4.15	45.0	8.30	4.13	2.61	4.25
50	0.82	8.55	0.78	250	39.9	563	14.6	31.2	10.7	4.19	3.52	5.25
51	0.59	8.05	0.63	188	45.9	416	11.6	9.01	7.45	0.90	0.21	4.75
52	0.37	8.76	0.94	266	50.7	169	6.36	12.5	7.78	2.28	1.82	3.75
53	0.36	7.98	1.00	297	45.9	519	5.75	7.27	16.9	3.74	3.86	5.75
54	0.53	7.8	0.46	250	51.9	275	13.1	2.80	6.42	1.10	1.22	4.25
55	0.3	7.9	0.51	172	27.6	305	23.8	7.12	8.38	0.65	1.86	3.74
56	0.25	7.2	0.27	156	32.9	142	15.4	30.5	10.3	1.25	0.23	5.37
57	0.17	8.1	0.62	219	41.7	197	14.6	27.5	14.1	3.98	0.59	5.25
58	0.25	7.72	0.93	219	43.5	350	1.37	13.7	8.18	3.54	0.55	3.45
59	0.31	7.8	0.52	219	41.7	259	1.77	16.5	14.3	3.78	1.65	4.2
60	0.14	8.23	0.67	219	32.3	248	37.3	13.1	11.9	0.97	0.14	4.34
Mean.	0.34	7.78	0.64	214	33.4	243	14	19.7	12.2	2.05	1.61	4.29
Max.	1.38	8.76	1.07	329	59.8	563	47.5	39.2	31.3	5.91	3.86	5.75
Min.	0.13	6.33	0.27	156	8.90	93.0	0.39	2.80	6.17	0.25	0.05	3.24
Low			7	24	12	6	11	1	0	4	1	
Medium			14	6	17	17	12	8	10	6	4	
High			9	0	3	7	7	21	20	20	25	
Kadana												
61	0.38	7.43	0.73	250	31.1	113	4.75	13.8	8.38	1.12	0.38	4.45
62	0.42	7.63	0.94	250	41.7	72.2	16.9	12.8	10.4	0.37	1.43	3.73
63	0.11	7.33	0.85	250	32.9	73.1	1.77	30.8	11.9	2.02	1.14	3.25
64	0.27	7.46	0.56	172	39.9	203	15.6	33.4	8.38	2.59	4.59	4.22
65	0.33	6.91	0.48	219	37.6	79.4	19.9	31.0	12.5	0.86	1.13	5.22
66	0.87	8.03	0.94	250	50.7	128	48.0	17.0	7.14	0.75	0.88	5.24
67	0.33	7.96	0.99	250	31.7	138	1.57	25.3	12.4	0.41	0.64	4.5
68	0.21	7.4	0.56	203	21.3	90.3	2.16	21.2	8.99	3.31	0.67	5.29
69	0.28	7.7	0.49	172	11.1	68.0	8.39	19.8	12.3	2.76	2.32	3.65
70	0.34	7.61	0.71	203	26.5	200	2.16	26.0	10.3	4.16	2.52	3.52
71	0.36	7.23	0.54	188	49.5	285	29.0	12.2	9.71	1.12	0.96	3.51

1	2	3	4	5	6	7	8	9	10	11	12	13
72	0.28	7.17	1.06	235	58.6	262	21.9	14.0	14.3	1.24	1.05	4.21
73	0.12	6.41	0.68	156	16.2	389	37.8	33.4	8.32	0.63	0.14	5.25
74	0.54	7.35	0.94	235	27.6	56.4	56.2	16.4	10.4	1.35	0.10	4.28
75	0.63	7.42	0.82	313	51.9	163	56.7	26.3	16.3	1.69	1.51	3.5
76	0.78	7.68	1.39	329	32.3	93.8	25.6	19.1	10.7	3.47	3.16	3.78
77	0.21	6.9	1.07	266	38.8	201	19.7	33	5.15	3.24	1.27	3.38
78	0.31	7.23	1.38	313	43.5	758	15.8	13.6	7.30	0.96	0.76	4.5
79	0.54	7.54	1.16	266	31.1	428	22.1	14.9	14.1	1.91	0.43	4.48
80	0.46	7.58	1.24	219	10.0	269	19.5	13.7	12.3	1.67	1.57	3.41
81	0.19	6.7	0.92	219	25.3	261	31.7	22.7	18.4	2.06	0.59	4.12
82	0.27	6.31	1.04	219	41.7	279	0.98	34.6	6.32	1.83	2.00	3.55
83	0.22	8.06	0.62	188	8.9	154	1.57	13.4	8.39	0.76	0.50	4.24
84	0.52	7.52	1.44	329	22.5	358	5.15	11.5	12.2	1.30	1.17	3.75
85	0.41	8.22	0.68	203	58.0	399	6.96	8.44	14.3	1.49	1.27	3.45
86	0.33	7.6	1.11	250	25.9	225	32.6	13.6	7.20	0.63	0.30	4.15
87	0.46	7.46	0.63	203	17.3	235	15.8	10.5	10.1	0.90	1.11	3.65
88	0.18	7.36	0.23	156	6.1	196	8.59	24.7	12.3	1.10	0.44	5.25
89	0.15	7.33	0.21	172	7.2	154	25.6	7.72	14.1	0.69	0.46	4.22
90	0.22	7.88	0.45	172	45.9	295	16.5	10.7	8.38	1.70	0.49	3.91
Mean.	0.35	7.41	0.83	228	31.4	221	19.0	19.5	10.8	1.60	1.17	4.12
Max.	0.87	8.22	1.44	329	58.6	758	56.7	34.6	18.4	4.16	4.59	5.29
Min.	0.11	6.31	0.21	156	6.1	56.4	0.98	7.72	5.15	0.37	0.10	3.25
Low			4	18	13	10	10	0	0	2	2	
Medium			8	12	16	13	10	1	11	8	5	
High			18	0	1	7	10	29	19	20	23	

Khanpur

91	0.24	7	0.55	219	54.9	106	15.4	30.5	12.1	1.62	0.78	4.35
92	0.41	8.3	0.94	235	6.6	243	12.7	14.1	6.18	2.92	1.19	5.21
93	0.21	8.16	0.76	219	27.1	131	24.2	7.80	19.1	1.92	3.74	3.75

1	2	3	4	5	6	7	8	9	10	11	12	13
94	0.23	7.2	0.58	172	21.9	150	17.1	8.40	6.24	0.59	2.98	4.35
95	0.38	8.13	0.96	219	11.7	211	8.79	31.5	14.2	1.57	1.65	3.25
96	0.37	7.92	1.03	219	23.6	97.3	7.77	26.8	12.2	1.49	2.38	4.51
97	0.65	7.83	1.40	313	39.9	157	37.3	30.3	8.20	3.16	2.23	5.25
98	0.38	7.47	1.09	297	45.9	170	32.2	23.5	10.2	1.44	2.01	3.25
99	0.22	7.9	1.19	297	51.3	257	4.35	14.5	14.3	1.12	1.15	3.7
100	0.31	6.9	1.77	329	37.6	278	16.9	27.9	12.1	1.75	0.34	4.02
101	0.44	7.74	0.96	235	39.9	370	48.5	20.0	6.14	1.85	2.27	6.22
102	0.46	7.95	1.03	266	10.6	156	5.55	12.2	6.24	0.74	1.28	3.73
103	0.33	8.13	1.54	376	61.0	189	34.0	25.5	14.3	2.88	0.70	4.5
104	0.31	7.74	0.85	219	14.5	105	30.8	20.9	6.18	1.95	0.63	3.5
105	1.69	7.15	1.40	266	45.3	228	53.3	13.7	8.40	1.11	2.27	4.52
106	2.1	7.78	0.41	219	38.2	135	29.0	3.94	12.8	1.33	0.82	3.5
107	0.51	7.38	0.64	172	32.7	137	4.95	10.7	14.2	2.92	0.79	5.21
108	0.35	7.75	0.31	172	7.8	148	15.4	10.5	10.2	1.28	0.43	4.5
109	0.54	7.2	0.78	235	38.8	147	18.2	30.1	12.2	2.93	1.86	3.45
110	0.36	7.32	0.74	235	48.3	161	2.56	6.06	8.38	0.24	1.22	4.22
111	0.91	7.84	0.99	219	10.0	156	28.8	13.7	10.1	1.11	0.59	4.35
112	0.47	7.8	1.24	282	26.5	178	15.4	34.0	4.18	1.38	1.27	4.3
113	1.09	7.45	0.78	235	12.2	95.8	20.8	9.16	13.9	1.75	0.39	4.25
114	0.35	7.18	0.81	250	24.8	176	27.2	7.72	16.0	1.00	1.13	4.24
115	0.15	7.46	0.92	235	20.2	49.2	16.3	12.7	12.2	0.87	2.44	4.25
116	0.51	7.79	0.55	172	21.9	534	22.3	12.1	10.3	0.80	1.22	3.75
117	0.25	7.46	0.92	219	26.5	330	13.7	11.5	17.8	2.53	0.41	3.65
118	0.21	7.92	0.48	219	32.9	109	15.0	8.93	14.1	1.56	1.17	4.28
119	0.31	7.68	0.37	203	15.6	406	10.8	8.14	7.18	0.71	0.84	5.25
120	0.17	6.55	0.55	219	10.0	156	1.57	32.0	8.39	1.44	0.79	4.21
Mean.	0.49	7.60	0.88	239	28.6	192	19.7	17.3	10.9	1.60	1.37	4.25
Max.	2.1	8.30	1.77	376	61.0	534	53.3	34.0	19.1	3.16	3.74	6.22
Min.	0.15	6.55	0.31	172	6.60	49.2	1.57	3.94	4.18	0.24	0.34	3.25

1	2	3	4	5	6	7	8	9	10	11	12	13
Low			3	21	17	8	7	1	1	1	0	
Medium			7	9	12	18	11	7	10	5	3	
High			20	0	1	4	12	22	19	24	27	
					Virpur							
121	0.15	8.12	0.50	188	11.7	147	4.35	7.65	10.1	1.71	1.63	3.51
122	0.19	7.31	0.59	156	11.7	225	9.00	23.9	7.19	0.45	1.43	3.73
123	0.26	7.87	0.82	235	20.2	62.9	33.3	22.4	11.8	0.48	1.10	4.35
124	0.31	7.18	0.85	203	25.9	316	32.9	4.24	12.3	1.41	0.87	4.21
125	0.52	7.74	1.30	282	13.9	236	22.3	4.39	4.99	0.75	0.50	4.26
126	0.23	6.85	0.59	203	27.1	166	13.1	4.92	7.20	1.90	0.75	5.22
127	0.29	7.46	0.62	172	39.9	99.2	11.6	15.3	10.2	1.37	0.52	5.73
128	0.52	7.29	1.23	345	52.5	564	30.8	13.5	13.1	3.13	1.27	6.75
129	0.34	7.84	0.98	266	35.2	296	13.1	14.6	8.20	3.43	0.98	5.22
130	0.34	7.79	0.88	219	5.5	125	1.57	24.3	17.1	0.87	1.74	4.52
131	0.31	7.45	0.77	203	56.1	289	9.41	9.61	12.2	1.30	0.24	4.5
132	0.21	8.2	0.91	250	12.8	129	31.7	4.17	6.57	1.32	0.66	4.36
133	0.39	7.89	0.89	250	59.8	282	34.0	11.2	9.96	1.46	1.01	4.5
134	0.53	7.68	0.91	219	54.9	83.3	7.17	7.34	6.17	0.90	0.84	3.25
135	0.39	8.14	0.90	203	45.9	190	5.55	6.36	8.18	3.18	3.13	3.23
136	0.46	7.75	0.74	203	8.9	154	6.36	7.87	6.17	0.34	0.73	4.38
137	0.51	7.53	0.66	203	20.2	244	11.0	5.32	6.23	1.64	2.02	4.35
138	0.44	7.63	0.58	219	45.9	214	15.4	11.5	10.2	1.44	1.94	3.74
139	0.25	7.73	0.41	172	42.3	172	1.18	3.71	8.50	1.30	0.81	3.52
140	0.44	7.46	1.12	250	43.5	343	6.96	6.36	14.2	5.73	1.40	4.22
141	0.25	7.83	0.64	235	58.0	122	16.5	4.47	12.4	1.70	0.52	4.29
142	0.39	8.04	0.12	141	24.8	261	1.37	8.33	12.7	0.65	0.17	4.51
143	0.33	6.84	0.75	203	17.9	184	2.16	32.0	6.59	1.89	1.57	5.27
144	0.75	7.09	1.04	313	12.2	305	27.2	31.9	29.9	1.24	3.62	5.29
145	0.37	7.94	0.96	219	47.1	248	20.8	7.76	14.1	0.28	1.16	3.5
146	0.24	8.73	0.64	219	12.8	206	9.00	16.0	30.4	0.66	0.05	4.51

1	2	3	4	5	6	7	8	9	10	11	12	13
147	0.15	6.8	0.90	297	21.3	234	41.6	23.7	14.1	3.18	0.76	4.5
148	0.31	6.97	0.35	156	7.8	68.3	22.7	13.7	10.1	0.94	0.12	3.73
149	0.34	7.77	0.62	188	20.7	112	25.4	8.63	7.39	0.70	0.29	3.65
150	0.22	6.65	0.29	203	25.9	190	41.1	6.59	5.44	0.22	0.32	4.25
Mean.	0.34	7.58	0.75	221	29.4	209	16.9	12.0	11.1	1.52	1.07	4.36
Max.	0.75	8.73	1.30	345	59.8	564	41.6	32.0	30.4	5.73	3.62	6.75
Min.	0.15	6.65	0.12	141	5.50	62.9	1.18	3.71	4.99	0.22	0.05	3.23
Low			4	23	18	8	12	5	1	3	3	
Medium			11	7	9	16	6	11	13	8	4	
High			15	0	3	6	12	14	16	19	23	
Santrampur												
151	0.28	7.11	1.26	282	44.7	255	30.8	7.04	31.9	2.36	2.24	5.25
152	0.65	7.17	1.14	266	8.9	255	6.36	16.8	8.19	0.77	2.62	4.5
153	0.39	6.93	1.36	313	13.9	142	12.7	28.3	6.28	0.97	3.86	4.45
154	0.16	7.62	0.75	250	29.4	99.5	6.76	15.3	10.3	0.74	0.73	3.75
155	0.4	7.7	1.05	219	58.0	226	6.36	5.76	12.1	1.12	1.86	5.21
156	0.29	7.53	0.92	188	37.0	187	39.7	12.1	30.1	1.04	0.15	4.21
157	0.48	7.56	0.73	203	21.3	132	31.7	5.98	10.2	0.23	0.92	5.25
158	0.8	8.75	1.11	376	64.1	323	16.7	11.9	32.1	5.38	2.00	4.35
159	0.44	7.9	1.12	203	61.0	273	19.5	8.38	10.1	1.62	2.07	3.75
160	0.34	7.91	1.11	235	32.9	63.0	10.8	30.8	14.0	1.57	5.98	3.51
161	0.59	7.5	0.58	188	10.6	137	20.5	22.9	14.2	1.54	2.23	4.22
162	0.21	6.29	0.78	219	7.8	89.2	14.6	30.8	10.1	0.42	2.96	3.5
163	0.24	6.9	0.81	219	6.1	313	4.35	10.8	8.18	0.74	1.63	3.75
164	0.18	7.04	0.54	235	13.9	150	13.7	4.24	4.38	0.77	2.21	6.64
165	0.21	7.63	1.02	235	24.8	110	2.36	5.82	7.19	0.96	1.08	5.28
166	0.31	7.88	1.17	266	21.3	287	13.3	4.01	7.29	0.31	0.64	4.48
167	0.41	8.2	0.69	94.1	15.6	169	3.55	3.56	6.58	0.84	0.95	4.25
168	0.38	7.66	1.02	235	79.2	296	18.4	5.00	8.16	1.53	1.85	3.5
169	0.45	7.34	1.16	282	22.5	627	26.1	6.21	4.21	0.68	1.05	3.75

1	2	3	4	5	6	7	8	9	10	11	12	13
170	0.33	7.49	0.74	250	25.9	306	27.8	7.19	3.96	0.74	0.76	4.45
171	0.21	6.98	0.98	250	4.4	263	15.6	16.9	12.1	1.00	0.18	4.25
172	0.44	7.76	1.26	282	13.9	170	30.8	5.07	6.18	1.00	2.62	3.25
173	1.64	7.81	0.99	219	35.2	190	22.7	15.6	14.1	0.84	2.76	4.25
174	0.23	7.78	0.51	156	56.8	382	11.6	5.91	4.39	0.81	2.17	4.38
175	0.77	7.45	0.73	250	12.2	282	11.6	6.81	5.38	1.82	2.24	4.5
176	0.47	7.32	1.00	266	6.1	166	6.36	16.5	12.3	0.46	0.82	3.78
177	0.32	7.81	0.62	203	45.9	201	29.0	10.376	8.38	0.98	2.38	3.73
178	0.31	7.88	1.08	282	43.5	234	11.2	12.0	10.1	1.03	3.19	4.22
179	0.84	7.56	1.32	297	52.5	265	9.41	7.95	7.59	0.83	3.02	4.35
180	0.56	8.22	1.31	297	47.1	301	7.37	18.0	12.1	1.57	2.17	4.4
Mean.	0.44	7.55	0.96	242	30.5	230	16.0	11.9	11.1	1.15	1.98	4.30
Max.	1.64	8.75	1.36	376.	79.2	627	39.7	30.8	32.1	5.38	5.98	6.64
Min.	0.16	6.29	0.96	94.1	4.40	63.0	2.36	3.56	3.96	0.23	0.15	3.25
Low			0	15	17	5	9	3	4	3	0	
Medium			9	15	8	15	12	12	11	12	2	
High			21	0	5	9	9	15	15	15	28	

Appendix IV: Taluka/Sample wise values of EC2.5, pH2.5, exchangeable cations different indices and salinity- sodicity classes of soil.

Sample No.	EC2.5	pH2.5	Exchangeable cations (cmol (p+) kg ⁻¹)				Indices of soil		Salinity/ Sodicity Class
							CEC		
			Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	(cmol (p+) kg ⁻¹)	ESP	
1	2	3	4	5	6	7	8	9	10
Balasinor									
1	0.15	7.55	3.6	9.0	3.17	0.37	20.8	15.2	SO
2	1.12	7.9	6.0	13.	3.50	0.21	27.6	12.6	S
3	0.38	7.76	4.0	9.2	3.72	0.33	21.9	16.9	SO
4	0.49	7.74	3.7	4.8	1.91	0.35	18.3	10.4	N
5	0.32	7.29	7.2	8.7	3.28	0.32	23.0	14.2	N
6	0.21	7.48	6.2	15.3	1.70	0.26	29.9	5.60	N
7	1.16	7.72	4.8	6.7	2.85	0.20	18.1	15.6	SSO
8	0.24	7.7	2.3	4.4	0.63	0.13	23.9	2.64	N
9	0.15	7.15	3.4	7.8	1.32	0.15	23.5	5.62	N
10	0.52	7.87	3.7	9.7	2.99	0.46	26.8	11.1	N
11	0.31	7.28	6.8	7.1	2.89	0.36	20.4	14.1	N
12	0.27	7.22	5.4	6.9	4.98	0.16	25.0	19.8	SO
13	0.15	7.82	3.2	8.3	2.70	0.18	17.6	15.2	SO
14	0.25	7.89	7.0	12.5	3.64	0.39	27.2	13.3	N
15	0.24	8.22	5.5	8.3	1.77	0.13	26.6	6.63	N
16	0.16	7.62	2.9	6.9	1.04	0.15	23.1	4.50	N
17	0.39	8.12	6.2	7.7	3.52	0.15	20.8	16.9	S0
18	0.24	7.53	4	7.5	0.79	0.25	26.2	3.00	N
19	0.17	7.2	5.9	13.9	3.31	0.13	29.7	11.1	N
20	0.38	8.47	7	14.8	4.74	0.14	26.6	17.7	SO
21	0.22	7.65	4.7	8.7	2.80	0.33	16.5	16.9	SO

1	2	3	4	5	6	7	8	9	10
22	0.29	7.96	5.3	8.4	0.90	0.30	24.0	3.73	N
23	0.41	7.2	4.5	6.0	3.95	0.39	29.1	13.5	N
24	0.49	7.5	4.3	7.8	1.68	0.18	19.9	8.41	N
25	0.13	7.83	2.7	4.5	3.67	0.16	26.1	14.0	N
26	0.31	7.95	4.1	9.5	1.70	0.28	22.9	7.39	N
27	0.26	8.02	4.2	8.6	2.44	0.25	34.2	7.13	N
28	0.26	7.38	4.5	8.9	2.73	0.04	23.6	11.5	N
29	0.17	7.75	2	5.2	3.63	0.22	21.0	17.2	SO
30	0.33	8.3	5.1	2.9	0.67	0.38	18.4	3.64	N
Mean.	0.33	7.7	4.67	8.43	2.62	0.24	23.80	11.21	
Max.	1.16	8.47	7.2	15.3	4.98	0.46	34.2	19.80	
Min.	0.13	7.15	2	2.9	0.63	0.04	16.54	2.64	
Lunawada									
31	0.26	7.7	6.2	7.7	1.39	0.09	27.1	5.12	N
32	0.22	7.64	10.8	12.4	3.95	0.07	30.4	12.9	N
33	0.57	8.1	9	16.2	1.39	0.12	28.8	4.82	N
34	0.15	7.62	4.5	6.4	1.61	0.11	22.6	7.12	N
35	0.29	8.23	6.3	12.3	3.55	0.09	22.24	15.9	SO
36	1.38	8.03	3.7	8.8	1.79	0.06	27.6	6.49	S
37	0.34	8.46	7.2	13.1	4.43	0.10	28.4	15.6	SO
38	0.19	7.53	4	6.2	2.01	0.20	23.4	8.56	N
39	0.32	7.34	7	11.4	2.13	0.18	20.7	10.3	N
40	0.21	7.28	5.4	11.8	2.70	0.15	20.0	13.4	N
41	0.31	7.99	7.2	19.6	1.01	0.27	36.0	2.88	N
42	0.33	7.86	6.8	12.6	3.63	0.27	23.3	15.5	SO
43	0.15	8.03	3.2	6.5	5.69	0.47	26.9	21.1	SO
44	0.24	8.08	4	12.8	1.90	0.21	18.9	10.0	N
45	0.32	7.78	7.2	18.6	2.35	0.20	32.6	7.20	N
46	0.41	7.99	6.9	16.9	2.96	0.85	34.1	8.68	N
47	0.17	6.73	9	10.8	4.00	0.21	27.2	14.6	N

1	2	3	4	5	6	7	8	9	10
48	0.13	6.33	3.2	6	3.72	0.17	16.6	22.3	SO
49	0.38	6.77	3.7	8.8	2.83	0.85	20.5	13.7	N
50	0.82	8.55	7.3	12.5	1.87	0.46	22.1	8.45	N
51	0.59	8.05	7.3	14.6	0.58	0.41	22.9	2.55	N
52	0.37	8.76	6.1	9.1	2.04	0.16	26.1	7.82	N
53	0.36	7.98	5.9	8.9	3.88	0.59	22.5	17.2	SO
54	0.53	7.8	5.2	8.6	2.62	0.26	16.6	15.7	SO
55	0.30	7.9	3	5	4.41	0.23	32.6	13.5	N
56	0.25	7.2	4.8	6.4	2.48	0.13	23.8	10.4	N
57	0.17	8.1	3.5	10	4.54	0.18	26.0	17.4	SO
58	0.25	7.72	4.6	6.7	3.18	1.01	19.8	16.0	SO
59	0.31	7.8	3.1	5.9	2.17	0.21	28.4	7.64	N
60	0.14	8.23	6.1	9.3	3.34	0.19	25.4	13.1	N
Mean.	0.34	7.78	5.74	10.53	2.81	0.28	25.15	11.55	
Max.	1.38	8.76	10.8	19.6	5.69	1.01	36.0	22.1	
Min.	0.13	6.33	3.0	5.0	0.58	0.06	16.67	2.55	
Kadana									
61	0.38	7.43	3.5	9.4	1.90	0.15	24.9	7.60	N
62	0.42	7.63	4.2	9.5	0.93	0.11	27.3	3.39	N
63	0.11	7.33	2.7	5.2	3.19	0.07	24.4	13.0	N
64	0.27	7.46	4.7	7.1	3.29	0.17	19.2	17.1	SO
65	0.33	6.91	3	5.2	3.48	0.14	26.1	13.3	N
66	0.87	8.03	4.9	8.5	5.02	0.17	28.5	17.5	SO
67	0.33	7.96	4.9	12.7	0.81	0.14	22.9	3.54	N
68	0.21	7.4	4.7	9.5	2.77	0.06	21.3	12.9	N
69	0.28	7.7	3.2	7.2	0.90	0.06	17.5	5.11	N
70	0.34	7.61	3	9.4	1.20	0.18	13.7	8.73	N
71	0.36	7.23	4.2	9.5	2.91	0.23	23.3	12.4	N
72	0.28	7.17	4.9	11.5	3.47	0.17	24.3	14.2	N
73	0.12	6.41	4.3	11.1	1.83	0.12	23.8	7.66	N

1	2	3	4	5	6	7	8	9	10
74	0.54	7.35	7	14.04	2.80	0.06	23.9	11.7	N
75	0.63	7.42	10.8	12.1	2.46	0.15	32.0	7.67	N
76	0.78	7.68	11	9	3.36	0.29	29.0	11.5	N
77	0.21	6.9	4.3	7.6	3.25	0.18	22.7	14.3	N
78	0.31	7.23	4.7	8.4	1.17	0.72	16.0	7.29	N
79	0.54	7.54	5.2	7.7	3.09	0.23	26.2	11.7	N
80	0.46	7.58	5.1	10.2	1.33	0.24	16.8	7.89	N
81	0.19	6.7	7	11.4	5.34	0.24	23.9	22.2	SO
82	0.27	6.31	10.9	15.3	3.78	0.22	34.5	10.9	N
83	0.22	8.06	9.5	10.9	6.34	0.67	27.4	23.1	SO
84	0.52	7.52	14.3	8.6	3.21	0.46	30.9	10.3	N
85	0.41	8.22	9.8	14.4	0.78	0.32	25.3	3.10	N
86	0.33	7.6	8	12.4	3.13	0.21	23.7	13.1	N
87	0.46	7.46	6	12.4	2.00	0.07	20.4	9.78	N
88	0.18	7.36	7.9	9	1.89	0.19	25.5	7.43	N
89	0.15	7.33	4	11.4	1.72	0.14	17.2	9.98	N
90	0.22	7.88	7.2	9.5	3.16	0.27	20.1	15.6	SO
Mean.	0.35	7.41	6.16	10	2.68	0.21	23.8	11.1	
Max.	0.87	8.22	14.3	15.3	6.34	0.72	34.5	23.1	
Min.	0.11	6.31	2.7	5.2	0.78	0.06	13.78	3.10	
Khanpur									
91	0.24	7	7.5	9.4	0.72	0.13	25.3	2.82	N
92	0.41	8.3	6	15.4	2.85	0.19	29.8	9.53	N
93	0.21	8.16	4.9	9	2.01	0.11	16.0	12.5	N
94	0.23	7.2	5	13	1.98	0.15	26.6	7.43	N
95	0.38	8.13	4.3	17.6	3.61	0.16	25.6	14.0	N
96	0.37	7.92	4.9	10.3	2.73	0.11	24.5	11.1	N
97	0.65	7.83	7.2	6.6	3.37	0.19	23.8	14.1	N
98	0.38	7.47	4.1	10.7	1.65	0.15	22.0	7.47	N
99	0.22	7.9	2.3	5.5	2.90	0.22	23.9	12.1	N

1	2	3	4	5	6	7	8	9	10
100	0.31	6.9	5	4.2	2.42	0.21	31.8	7.60	N
101	0.44	7.74	15.8	8.9	3.02	0.32	33.4	9.03	N
102	0.46	7.95	7.9	12.5	5.32	0.16	25.8	20.5	SO
103	0.33	8.13	3.2	6.2	5.69	0.35	15.1	37.5	SO
104	0.31	7.74	4.8	8.1	0.67	0.15	20.2	3.32	N
105	1.69	7.15	12.5	7.1	2.03	0.35	27.4	7.41	S
106	2.1	7.78	24.7	11.8	2.98	0.11	39.6	7.54	S
107	0.51	7.38	6	8.5	3.28	0.12	24.4	13.4	N
108	0.35	7.75	3.9	7.8	4.06	0.12	19.1	21.1	N
109	0.54	7.2	5	13.4	2.81	0.12	21.3	13.1	N
110	0.36	7.32	6.2	11.2	0.85	0.13	23.1	3.68	N
111	0.91	7.84	17.2	21.2	2.97	0.13	46.9	6.32	N
112	0.47	7.8	8.9	10.5	2.43	0.15	21.9	11.0	N
113	1.09	7.45	19.7	15.1	3.78	0.08	38.6	9.78	S
114	0.35	7.18	2.9	9.2	3.07	0.14	18.5	16.5	SO
115	0.15	7.46	3.2	5.2	3.00	0.34	19.3	15.5	SO
116	0.51	7.79	6.3	6.6	1.79	0.52	25.2	7.11	N
117	0.25	7.46	6	14.3	0.77	0.63	22.5	3.41	N
118	0.21	7.92	3.9	7.5	4.99	0.10	26.4	18.8	SO
119	0.31	7.68	4.2	8.5	0.88	0.35	27.1	3.24	N
120	0.17	6.55	2.5	5.2	1.22	0.13	29.0	4.20	N
Mean.	0.49	7.6	7.2	10	2.66	0.20	25.85	11	
Max.	2.1	8.3	24.7	21.2	5.69	0.63	46.93	37.50	
Min.	0.15	6.55	2.3	4.2	0.67	0.08	15.18	2.82	

1	2	3	4	5	6	7	8	9	10
124	0.31	7.18	6	11.8	3.36	0.24	25.7	13.0	N
125	0.52	7.74	7.2	6.6	1.44	0.07	16.7	8.62	N
126	0.23	6.85	2.8	8.0	1.86	0.18	24.5	7.55	N
127	0.29	7.46	5	4.20	2.95	0.10	22.2	13.2	N
128	0.52	7.29	4.5	7.9	3.10	0.45	18.3	16.8	SO
129	0.34	7.84	6	9.70	3.27	0.23	22.8	14.3	N
130	0.34	7.79	6.2	10.6	3.03	0.13	25.4	11.9	N
131	0.31	7.45	5.6	11.8	1.91	0.20	26.0	7.35	N
132	0.21	8.2	3	5.7	0.82	0.10	28.2	2.92	N
133	0.39	7.89	10.8	11.7	2.10	0.19	31.3	6.71	N
134	0.53	7.68	7.3	14.5	4.84	0.18	26.8	18.0	SO
135	0.39	8.14	9	9.2	2.88	0.32	26.8	10.7	N
136	0.46	7.75	5.8	8.6	3.01	0.16	21.9	13.7	N
137	0.51	7.53	4.6	7.8	2.12	0.16	22.2	9.52	N
138	0.44	7.63	15.5	8.4	2.68	0.15	26.7	10.0	N
139	0.25	7.73	5.8	8	2.80	0.16	22.2	12.6	N
140	0.44	7.46	6.2	8.7	3.31	0.27	28.4	11.6	N
141	0.25	7.83	9.2	5.6	2.38	0.11	29.2	8.15	N
142	0.39	8.04	5.1	5.6	3.12	0.18	24.2	12.9	N
143	0.33	6.84	5.9	10.5	3.16	0.15	25.1	12.5	N
144	0.75	7.09	7.3	12.1	3.24	0.22	26.1	12.4	N
145	0.37	7.94	6.3	9.3	2.94	0.18	25.2	11.6	N
146	0.24	8.73	3.9	7.3	2.80	0.18	14.1	19.7	N
147	0.15	6.8	4.7	6.1	1.98	0.22	26	7.60	N
148	0.31	6.97	3.8	9	3.00	0.32	21.5	13.9	N
149	0.34	7.77	5.2	5.2	2.62	0.12	17.4	14.9	N
150	0.22	6.65	3.5	6.3	1.55	0.14	21.4	7.21	N
Mean.	0.34	7.58	6.0	8.51	2.79	0.18	24.12	11.84	
Max.	0.75	8.73	15.5	14.5	4.96	0.45	31.3	19.75	
Min.	0.15	6.65	2.8	4.2	0.82	0.07	14.18	2.92	

Santrampur									
1	2	3	4	5	6	7	8	9	10
151	0.28	7.11	4.9	10.5	2.54	0.34	24.8	10.2	N
152	0.65	7.17	3.4	7.7	2.81	0.16	19.5	14.4	N
153	0.39	6.93	4.5	9.2	3.16	0.12	22.4	14.1	N
154	0.16	7.62	4.2	11.2	3.14	0.08	18.6	16.8	SO
155	0.4	7.7	5	4.4	2.95	0.25	20.2	14.5	N
156	0.29	7.53	4.7	7.2	2.67	0.15	19.0	14.0	N
157	0.48	7.56	4.9	14.2	2.85	0.10	27.4	10.3	N
158	0.8	8.75	13.5	16.9	1.60	0.39	37.8	4.24	N
159	0.44	7.9	4.6	7.8	2.35	0.21	21.4	10.9	N
160	0.34	7.91	6.1	9.8	1.28	0.07	21.0	6.10	N
161	0.59	7.5	5.2	13.5	1.94	0.13	27.2	7.11	N
162	0.21	6.29	3.5	10.6	2.45	0.08	22.0	11.1	N
163	0.24	6.9	6.7	4.8	2.33	0.23	21.6	10.7	N
164	0.18	7.04	2.7	5.3	0.69	0.18	29.9	2.32	N
165	0.21	7.63	3.7	6.1	4.49	0.10	25.6	17.5	SO
166	0.31	7.88	5	5.4	4.37	0.18	14.9	29.2	SO
167	0.41	8.2	4.2	13.2	4.16	0.26	21.8	19.0	N
168	0.38	7.66	5.7	10.2	3.28	0.24	19.4	16.8	SO
169	0.45	7.34	4.6	9.8	2.21	0.54	20.4	10.8	N
170	0.33	7.49	4.8	7.9	1.04	0.29	24.1	4.31	N
171	0.21	6.98	4.9	8.5	2.43	0.20	22.3	10.8	N
172	0.44	7.76	6.5	1.3	1.39	0.14	21.3	6.53	N
173	1.64	7.81	11.7	21.7	3.24	0.17	40.5	8.00	S
174	0.23	7.78	5.7	6.20	3.25	0.69	25.8	12.5	N
175	0.77	7.45	7.7	11.0	2.42	0.30	28.0	8.63	N
176	0.47	7.32	4.9	9.8	3.51	0.13	24.8	14.1	N
177	0.32	7.81	3.2	6.6	2.60	0.18	16.9	15.3	SO

1	2	3	4	5	6	7	8	9	10
178	0.31	7.88	3.4	7.1	2.80	0.20	18.9	14.7	N
179	0.84	7.56	8.46	15.7	2.96	0.37	35.1	8.43	N
180	0.56	8.22	5.2	14.4	3.13	0.13	30.4	10.2	N
Mean.	0.44	7.55	5.45	9.60	2.67	0.22	24.1	11.8	
Max.	1.64	8.75	13.5	21.7	4.44	0.69	40.5	29.2	
Min.	0.16	6.29	2.7	1.3	0.69	0.07	14.9	2.32	

Appendix V: Taluka/Sample wise values of EC_{2.5}, pH_{2.5}, water soluble ions (me l⁻¹), and indices of soil

Sr. No.	EC _{2.5}	pH _{2.5}	Water soluble cations and anions in me/L								SSP	SAR	RSC (me /L)
			Cations				Anions						
			Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	CO ₃ ⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻⁻			
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Balasinor													
1	0.10	7.82	0.60	1.40	0.47	0.05	0	3.0	2.80	0.19	18.65	0.47	1.00
2	1.24	7.00	4.0	4.60	1.34	0.06	0	4.0	8.00	1.42	13.39	0.65	0.40
3	0.36	8.30	1.0	1.70	0.66	0.11	0	3.0	3.80	0.17	19.06	0.57	0.30
4	0.75	7.75	0.80	1.20	0.91	0.14	0	2.0	6.80	0.40	29.80	0.91	0.00
5	0.33	7.95	0.7	1.20	0.52	0.04	0	3.0	3.40	0.65	21.05	0.53	1.10
6	0.25	8.10	1.20	1.90	0.41	0.12	0	2.0	4.00	0.18	11.18	0.33	0.90
7	1.43	7.60	1.40	2.70	2.43	0.07	0	4.0	10.0	0.24	36.80	1.69	0.90
8	0.20	7.60	0.40	0.50	0.33	0.07	0	2.0	3.20	0.33	25.32	0.49	1.10
9	0.21	8.03	0.90	2.10	0.38	0.04	0	3.0	3.60	0.20	11.05	0.31	0.00
10	0.65	8.00	0.80	1.30	0.81	0.03	0	2.0	6.80	0.28	27.62	0.79	0.90
11	0.13	7.96	0.40	0.50	0.30	0.04	0	3.0	2.40	0.37	24.42	0.45	2.10
12	0.25	8.11	0.50	1.40	0.44	0.10	0	2.0	3.60	0.18	18.17	0.45	0.10
13	0.20	8.14	0.60	0.90	0.58	0.19	0	2.0	2.80	0.15	25.46	0.67	0.50
14	0.34	8.26	0.80	2.30	0.53	0.05	0	3.0	6.00	0.38	14.42	0.43	0.90
15	0.31	8.30	0.80	1.20	0.58	0.05	0	2.0	3.60	0.20	22.01	0.58	0.00
16	0.29	8.00	1.00	1.50	0.76	0.05	0	3.0	4.80	0.41	22.88	0.68	0.50
17	0.73	8.05	1.00	2.00	0.81	0.08	0	3.0	7.20	0.17	20.91	0.66	0.00
18	0.25	7.68	0.70	1.50	0.86	0.04	0	1.0	2.40	0.29	27.80	0.82	0.80
19	0.52	7.74	0.90	1.40	0.67	0.13	0	3.0	5.60	0.42	21.69	0.63	0.70
20	0.35	8.48	0.40	0.60	0.58	0.04	0	2.0	2.80	0.25	35.95	0.82	1.00
21	0.29	7.90	0.80	4.40	0.71	0.11	0	1.0	2.80	0.51	11.84	0.44	0.80
22	0.29	8.26	1.40	1.90	0.62	0.13	0	3.0	3.20	0.24	15.24	0.48	0.70

1	2	3	4	5	6	7	8	9	10	11	12	13	14
23	0.49	7.51	1.40	2.40	0.65	0.06	0	2.0	2.80	0.60	14.37	0.47	0.20
24	0.36	8.20	1.00	1.50	0.66	0.06	0	3.0	5.60	0.34	20.53	0.59	0.50
25	0.29	8.30	1.50	2.00	0.60	0.14	0	3.0	3.20	0.38	14.14	0.45	0.50
26	0.35	8.48	0.60	0.90	0.37	0.17	0	3.0	3.40	0.65	18.03	0.43	1.50
27	0.33	8.25	0.30	0.50	0.40	0.10	0	2.0	4.00	0.24	30.77	0.63	1.20
28	0.26	7.71	0.50	1.60	0.45	0.03	0	2.0	3.00	0.17	17.48	0.44	0.90
29	0.28	8.30	0.80	1.60	0.49	0.12	0	3.0	2.80	0.18	16.44	0.45	0.60
30	0.17	8.02	0.90	2.00	0.47	0.12	0	3.0	2.80	0.36	13.47	0.39	0.10
Mean.	0.40	7.99	0.94	1.69	0.66	0.08	0	3.3	4.24	0.35	20.66	0.59	0.83
Max.	1.43	8.48	4.00	4.60	2.43	0.19	0	9.0	10.0	1.42	36.80	1.69	2.10
Min.	0.10	7.00	0.30	0.50	0.30	0.03	0	2.0	2.40	0.15	11.05	0.31	0.00
Lunawada													
31	0.30	8.05	0.70	0.40	0.66	0.17	0	3.0	3.20	0.28	34.20	0.89	1.90
32	0.33	7.71	0.70	1.10	0.67	0.07	0	3.0	4.00	0.22	26.35	0.71	1.20
33	0.66	8.35	0.40	0.50	0.82	0.06	0	3.0	5.60	0.72	46.08	1.22	2.10
34	0.28	7.48	0.80	1.20	0.66	0.07	0	2.0	4.00	0.17	24.21	0.66	0.00
35	0.14	6.90	1.10	1.60	0.47	0.10	0	3.0	3.20	0.28	14.48	0.41	0.30
36	1.76	7.89	1.00	2.10	2.11	0.13	0	2.0	12.80	1.78	39.47	1.69	0.90
37	0.35	8.00	0.70	1.10	0.73	0.06	0	4.0	4.60	0.28	28.16	0.77	2.20
38	0.14	7.98	0.80	1.40	0.43	0.10	0	3.0	2.40	0.24	15.64	0.41	0.80
39	0.51	8.05	1.10	1.90	0.88	0.17	0	3.0	5.60	0.13	21.71	0.72	0.00
40	0.22	7.80	0.50	2.00	0.71	0.05	0	1.0	3.20	0.34	21.88	0.64	0.50
41	0.37	8.30	0.70	1.20	0.65	0.10	0	2.0	4.00	0.45	24.49	0.66	0.10
42	0.54	9.11	1.30	1.70	0.95	0.12	0	2.0	3.60	0.14	23.28	0.77	0.00
43	0.21	7.80	1.10	1.60	0.60	0.15	0	3.0	2.40	0.17	17.49	0.52	0.30
44	0.37	8.20	0.70	1.10	0.75	0.20	0	2.0	4.00	0.41	27.22	0.79	0.20
45	0.46	8.22	0.60	1.20	0.86	0.17	0	3.0	4.80	0.31	30.39	0.91	1.20
46	0.60	7.82	1.70	1.20	0.97	0.12	0	3.0	6.00	0.40	24.22	0.80	0.10
47	0.23	8.02	0.60	0.90	0.58	0.06	0	3.0	4.80	0.12	27.23	0.67	1.50
48	0.11	7.53	0.50	0.60	0.34	0.17	0	1.0	2.40	0.06	21.12	0.46	0.90

1	2	3	4	5	6	7	8	9	10	11	12	13	14
49	0.44	8.00	0.90	2.20	0.67	0.13	0	2.0	3.20	0.65	17.25	0.54	0.90
50	0.68	8.64	0.30	1.00	1.34	0.04	0	2.0	6.60	0.63	49.93	1.66	0.70
51	0.56	8.29	0.40	1.00	1.05	0.06	0	3.0	4.80	0.40	41.86	1.26	1.60
52	0.43	8.17	0.80	1.20	0.68	0.12	0	3.0	4.40	0.30	24.37	0.68	1.00
53	0.17	7.35	0.40	0.60	0.43	0.07	0	1.0	2.80	0.28	28.40	0.60	0.00
54	0.58	7.74	1.80	2.10	0.83	0.08	0	3.0	4.40	0.46	17.33	0.60	0.10
55	0.25	7.60	0.80	1.10	0.62	0.13	0	2.0	2.80	0.55	23.36	0.63	0.10
56	0.30	7.58	0.90	1.90	0.56	0.06	0	3.0	3.60	0.46	16.28	0.47	0.20
57	0.15	7.60	0.70	1.80	0.26	0.09	0	2.0	2.80	0.39	9.02	0.23	0.50
58	0.38	8.27	0.70	1.80	0.42	0.10	0	3.0	4.80	1.12	13.96	0.38	0.50
59	0.37	7.86	0.90	1.70	0.47	0.11	0	3.0	4.40	0.54	14.78	0.41	0.40
60	0.17	7.79	0.50	0.40	0.54	0.11	0	1.0	3.20	0.18	34.97	0.81	0.10
Mean.	0.40	7.93	0.80	1.32	0.72	0.11	0	2.8	4.28	0.41	25.30	0.73	0.68
Max.	1.76	9.11	1.80	2.20	2.11	0.20	0	4.0	12.80	1.78	49.93	1.69	2.20
Min.	6.90	0.30	0.30	0.40	0.26	0.04	0	1.0	2.40	0.06	9.02	0.23	0.00
Kadana													
61	0.47	7.10	1.70	1.30	0.55	0.06	0	3.0	4.00	0.19	15.29	0.45	0.00
62	0.45	7.62	0.80	2.30	0.11	0.10	0	2.0	4.00	0.15	3.25	0.09	0.90
63	0.21	7.75	0.80	2.20	0.51	0.13	0	3.0	2.80	0.20	14.07	0.42	0.00
64	0.43	7.90	0.90	1.50	0.60	0.07	0	3.0	3.20	0.55	19.63	0.55	0.60
65	0.57	7.70	0.70	2.40	0.66	0.09	0	2.0	6.00	0.21	17.17	0.53	0.90
66	0.95	8.18	0.90	2.00	1.68	0.13	0	3.0	6.40	0.35	35.67	1.39	0.10
67	0.76	8.09	0.70	1.50	0.69	0.17	0	3.0	4.00	0.17	22.59	0.66	0.80
68	0.59	8.12	0.80	1.20	0.60	0.11	0	3.0	2.80	0.23	22.16	0.60	1.00
69	0.34	7.78	0.70	1.10	0.62	0.08	0	3.0	4.40	0.20	24.68	0.65	1.20
70	0.38	7.26	1.10	1.60	0.66	0.11	0	1.0	3.60	0.26	18.91	0.57	0.30
71	0.29	8.00	0.70	1.80	0.47	0.13	0	3.0	4.00	0.34	15.25	0.42	0.50
72	0.21	7.23	0.60	1.00	0.42	0.11	0	2.0	3.00	0.62	19.79	0.47	0.40
73	0.16	7.80	0.50	1.50	0.33	0.05	0	5.0	4.40	0.77	14.00	0.33	3.00
74	0.72	7.75	2.10	2.20	0.82	0.06	0	2.0	5.20	0.40	15.85	0.56	0.70

1	2	3	4	5	6	7	8	9	10	11	12	13	14
75	0.74	7.98	0.90	1.80	0.77	0.05	0	3.0	6.40	0.18	21.94	0.67	0.30
76	0.85	7.57	2.40	2.00	1.07	0.07	0	3.0	7.00	0.57	19.24	0.72	0.60
77	0.22	7.71	0.60	1.70	0.56	0.04	0	3.0	3.20	0.22	19.31	0.52	0.70
78	0.45	7.69	0.80	1.40	0.53	0.06	0	3.0	4.40	0.16	18.87	0.50	0.80
79	0.59	7.80	0.70	1.20	0.66	0.11	0	2.0	3.20	0.14	24.70	0.68	0.10
80	0.69	8.04	1.00	0.60	0.71	0.05	0	3.0	6.00	0.14	30.12	0.80	1.40
81	0.27	7.68	0.60	1.40	0.53	0.12	0	4.0	2.80	0.09	19.99	0.53	2.00
82	0.40	7.75	1.00	1.50	0.51	0.08	0	3.0	3.20	0.15	16.58	0.46	0.50
83	0.39	8.58	1.10	2.00	0.54	0.05	0	2.0	2.40	0.13	14.62	0.43	0.90
84	0.37	7.07	1.20	1.80	0.58	0.10	0	1.0	3.60	0.15	15.85	0.48	0.00
85	0.42	7.69	1.30	1.10	0.59	0.11	0	3.0	4.00	0.23	18.90	0.54	0.60
86	0.39	7.85	0.90	1.50	0.53	0.14	0	2.0	2.80	0.15	17.28	0.48	0.60
87	0.95	7.70	1.60	1.60	1.23	0.12	0	3.0	8.00	0.23	26.95	0.97	0.80
88	0.20	8.25	0.40	0.50	0.44	0.07	0	2.0	2.40	0.39	31.34	0.66	1.10
89	0.11	7.18	0.30	0.50	0.29	0.05	0	2.0	3.20	0.25	25.24	0.45	1.20
90	0.23	8.07	1.50	1.70	0.49	0.10	0	3.0	2.80	0.12	12.87	0.38	0.80
Mean.	0.46	7.76	0.98	1.53	0.63	0.09	0	3.3	4.11	0.26	19.74	0.57	0.76
Max.	0.95	8.58	2.40	2.40	1.68	0.17	0	5.0	8.00	0.77	35.67	1.39	3.00
Min.	0.11	7.07	0.30	0.50	0.11	0.04	0	2.0	2.40	0.09	3.25	0.09	0.00
Khanpur													
91	0.26	7.59	0.30	0.40	0.54	0.04	0	2.0	2.80	0.19	42.16	0.91	1.30
92	0.54	7.46	1.40	1.10	0.66	0.04	0	3.0	4.80	0.23	20.63	0.59	0.50
93	0.23	7.98	0.50	1.60	0.64	0.07	0	3.0	2.80	0.14	22.90	0.63	0.90
94	0.22	7.70	1.60	1.60	0.62	0.12	0	2.0	3.20	0.19	15.67	0.49	0.80
95	0.33	7.80	1.00	1.60	0.66	0.09	0	3.0	4.40	0.57	19.63	0.58	0.40
96	0.54	8.11	1.30	0.90	0.70	0.15	0	2.0	5.60	0.29	23.02	0.67	0.80
97	0.86	7.88	1.70	1.50	1.08	0.21	0	2.0	8.40	0.42	24.10	0.86	0.80
98	0.38	7.91	1.00	1.40	0.56	0.04	0	3.0	3.60	0.11	18.67	0.51	0.60
99	0.24	8.01	0.80	1.40	0.51	0.06	0	3.0	3.60	0.41	18.49	0.49	0.80
100	0.38	7.47	1.10	1.50	0.60	0.07	0	3.0	5.60	0.08	18.45	0.53	0.40

1	2	3	4	5	6	7	8	9	10	11	12	13	14
101	0.40	8.35	0.70	1.30	0.60	0.07	0	2.0	4.40	0.29	22.44	0.60	0.00
102	0.63	7.80	1.50	1.70	0.87	0.04	0	1.0	7.60	0.48	21.09	0.68	0.80
103	0.71	7.89	1.70	2.30	0.44	0.10	0	2.0	6.00	0.31	9.77	0.31	0.00
104	0.24	7.09	1.10	2.10	0.49	0.11	0	1.0	3.60	1.66	12.81	0.38	0.80
105	2.10	7.80	1.80	2.70	2.53	0.17	0	2.0	15.20	1.83	35.11	1.68	0.50
106	1.89	8.02	1.90	2.40	2.21	0.14	0	3.0	17.40	1.74	33.20	1.51	0.70
107	0.39	8.14	1.50	3.00	0.58	0.19	0	2.0	4.00	0.14	10.93	0.38	0.50
108	0.65	7.54	1.40	1.60	0.68	0.19	0	3.0	3.20	0.24	17.53	0.55	0.00
109	0.57	7.05	1.10	2.50	0.73	0.05	0	2.0	3.20	0.19	16.68	0.54	0.40
110	0.50	7.49	0.60	1.60	0.90	0.06	0	3.0	4.80	0.37	28.55	0.86	0.80
111	1.03	7.90	0.90	1.40	1.53	0.16	0	4.0	8.40	1.38	38.31	1.43	1.70
112	0.42	8.10	2.00	2.40	0.90	0.12	0	3.0	4.80	0.25	16.66	0.61	0.60
113	1.24	7.96	0.50	2.10	1.69	0.09	0	3.0	10.40	1.25	38.63	1.48	0.40
114	0.28	7.89	1.10	1.10	0.54	0.06	0	2.0	3.20	0.50	19.32	0.52	0.80
115	0.26	8.14	1.00	0.90	0.64	0.12	0	1.0	2.80	0.11	24.16	0.66	0.10
116	0.53	7.71	0.70	2.00	0.70	0.05	0	3.0	4.40	0.54	20.41	0.61	0.30
117	0.34	8.26	0.40	0.80	0.60	0.08	0	2.0	3.20	0.40	32.04	0.78	0.80
118	0.27	8.20	1.20	2.50	0.54	0.13	0	1.0	2.80	0.15	12.42	0.40	0.30
119	0.34	8.25	1.00	1.10	0.66	0.06	0	3.0	3.60	0.27	23.44	0.64	0.90
120	0.44	8.23	1.10	1.30	0.73	0.06	0	3.0	4.00	0.13	22.97	0.67	0.60
Mean.	0.57	7.85	1.13	1.66	0.84	0.1	0	3.4	5.39	0.49	22.67	0.72	0.61
Max.	2.1	8.35	2.00	3.00	2.53	0.2	0	5.0	17.40	1.83	42.16	1.68	1.70
Min.	0..22	7.05	0.30	0.40	0.44	0.04	0	2.0	2.80	0.08	9.77	0.31	0.0

Virpur

121	0.20	8.10	0.80	1.30	0.54	0.06	0	2.0	3.20	0.14	19.90	0.52	0.90
122	0.33	8.23	0.30	1.40	0.67	0.11	0	3.0	3.20	0.22	26.97	0.72	2.30
123	0.34	8.01	0.50	1.50	0.66	0.08	0	1.0	2.40	0.18	24.09	0.66	0.00
124	0.31	7.99	0.30	0.90	0.71	0.13	0	1.0	5.20	0.10	34.84	0.91	0.80
125	0.41	8.20	0.80	2.10	0.76	0.13	0	3.0	5.60	0.54	19.97	0.63	0.10

1	2	3	4	5	6	7	8	9	10	11	12	13	14
126	0.21	7.90	0.60	0.90	0.60	0.09	0	2.0	3.60	0.10	27.58	0.70	0.50
127	0.45	8.16	1.00	1.70	0.78	0.07	0	3.0	4.00	0.18	22.05	0.67	0.30
128	0.57	7.91	0.50	1.30	0.84	0.05	0	3.0	5.00	0.39	31.19	0.88	1.20
129	0.30	7.97	2.10	2.10	0.62	0.06	0	2.0	4.00	0.36	12.72	0.43	0.80
130	0.43	8.10	0.90	2.20	0.78	0.12	0	3.0	4.80	0.19	19.54	0.63	0.90
131	0.36	7.75	1.00	2.00	0.54	0.06	0	1.0	3.60	0.12	15.04	0.44	0.00
132	0.57	7.46	1.00	1.30	0.77	0.06	0	3.0	4.00	0.14	24.55	0.72	0.70
133	0.38	6.37	0.70	0.90	0.73	0.06	0	1.0	2.80	0.42	30.62	0.82	0.40
134	0.23	7.52	1.00	1.40	0.56	0.10	0	3.0	3.60	0.44	18.34	0.51	0.60
135	0.40	8.31	1.70	2.20	0.62	0.05	0	1.0	3.20	0.29	13.51	0.44	0.10
136	0.56	7.94	0.80	1.40	0.73	0.13	0	3.0	4.80	0.36	23.90	0.70	0.80
137	0.58	8.05	0.50	1.30	0.73	0.05	0	3.0	6.20	0.35	28.44	0.77	1.20
138	1.16	7.51	1.60	2.30	1.60	0.03	0	2.0	8.40	1.45	28.99	1.15	0.10
139	0.23	7.94	0.50	0.80	0.56	0.06	0	1.0	3.20	0.15	29.15	0.70	0.70
140	0.44	7.90	0.80	2.30	0.73	0.04	0	3.0	4.80	0.20	18.97	0.59	0.90
141	0.37	8.05	0.40	0.80	0.77	0.11	0	3.0	3.20	0.23	37.06	1.00	1.80
142	0.38	8.06	1.50	2.20	0.67	0.13	0	2.0	4.20	0.12	14.95	0.50	0.30
143	0.32	8.21	0.80	1.60	0.60	0.07	0	1.0	3.20	0.36	19.53	0.55	0.60
144	0.69	8.05	0.50	1.30	0.78	0.18	0	3.0	6.00	0.34	28.24	0.82	1.20
145	0.13	7.54	0.40	0.50	0.47	0.05	0	2.0	3.20	0.11	33.31	0.71	1.10
146	0.19	7.80	1.10	1.60	0.56	0.11	0	1.0	2.80	0.25	16.51	0.48	0.30
147	0.50	7.70	0.80	1.10	0.63	0.06	0	3.0	3.60	0.32	24.35	0.65	1.10
148	0.31	7.79	0.40	0.60	0.58	0.07	0	2.0	4.40	0.37	35.01	0.82	1.00
149	0.29	8.03	0.80	1.40	0.66	0.13	0	1.0	3.40	0.25	22.19	0.63	0.80
150	0.25	7.31	1.00	1.50	0.70	0.06	0	1.0	3.60	0.06	21.60	0.63	0.50
Mean.	0.39	7.86	0.84	1.46	0.70	0.08	0	3.0	4.11	0.29	24.10	0.68	0.73
Max.	1.16	8.31	2.10	2.30	1.60	0.18	0	5.0	8.40	1.45	37.06	1.15	2.30
Min.	0.13	6.37	0.30	0.50	0.47	0.03	0	2.0	2.40	0.06	12.72	0.43	0.0
Santrampur													
151	0.25	8.26	0.90	2.00	0.64	0.08	0	2.0	3.20	0.21	17.76	0.53	0.10

1	2	3	4	5	6	7	8	9	10	11	12	13	14
152	0.58	8.00	0.50	1.50	0.79	0.08	0	3.0	4.20	0.24	27.54	0.79	1.00
153	0.25	7.68	1.00	0.50	0.62	0.07	0	2.0	3.20	0.13	28.24	0.72	0.50
154	0.17	7.85	0.50	1.40	0.56	0.05	0	1.0	2.80	0.13	22.22	0.57	0.10
155	0.40	7.48	0.70	1.50	0.79	0.06	0	2.0	5.60	0.35	25.90	0.75	0.80
156	0.22	8.45	0.40	0.70	0.58	0.05	0	3.0	3.80	0.18	33.66	0.79	1.90
157	0.47	8.29	0.90	1.30	0.72	0.12	0	2.0	3.20	0.14	23.60	0.68	0.80
158	0.91	7.71	2.60	3.20	1.30	0.13	0	4.0	6.00	0.25	17.92	0.76	0.20
159	0.45	7.90	1.00	1.20	0.67	0.10	0	3.0	4.00	0.20	22.55	0.64	0.80
160	0.29	8.00	0.80	1.70	0.70	0.11	0	2.0	3.20	0.08	21.26	0.63	0.50
161	0.44	7.78	0.80	2.10	0.76	0.06	0	3.0	4.00	0.06	20.43	0.63	0.10
162	0.27	7.81	0.70	1.40	0.66	0.08	0	2.0	2.80	0.23	23.27	0.64	0.90
163	0.37	8.02	0.90	1.10	0.64	0.07	0	3.0	5.20	0.21	23.62	0.64	1.00
164	0.31	7.80	1.00	1.20	0.60	0.12	0	3.0	4.00	0.07	20.58	0.57	0.80
165	0.29	8.29	0.70	1.80	0.66	0.05	0	2.0	3.20	0.08	20.59	0.59	0.50
166	0.53	8.07	2.30	1.70	0.82	0.07	0	3.0	5.20	0.43	16.79	0.58	0.00
167	0.26	7.85	0.50	1.00	0.64	0.10	0	2.0	3.60	0.32	28.58	0.74	0.50
168	0.47	7.30	0.90	2.10	0.77	0.12	0	2.0	2.80	0.19	19.90	0.63	0.00
169	0.30	8.28	1.10	1.40	0.65	0.14	0	2.0	3.60	0.10	19.70	0.58	0.50
170	0.37	7.68	1.10	1.30	0.69	0.14	0	2.0	2.80	0.24	21.26	0.63	0.60
171	0.27	8.10	0.80	1.40	0.64	0.12	0	3.0	3.60	0.11	21.75	0.61	0.80
172	0.47	7.60	1.40	1.80	0.87	0.14	0	3.0	4.80	0.19	20.57	0.68	0.80
173	1.81	7.99	1.90	3.70	1.92	0.17	0	3.0	17.60	1.50	24.97	1.15	0.40
174	0.21	8.18	0.60	0.90	0.53	0.13	0	2.0	3.20	0.34	24.50	0.61	0.50
175	1.01	7.50	2.20	3.40	1.49	0.15	0	3.0	6.40	1.33	20.54	0.89	0.40
176	0.49	7.40	1.80	2.10	0.72	0.13	0	3.0	3.60	0.21	15.10	0.51	0.10
177	0.45	7.42	0.80	1.60	0.71	0.10	0	2.0	3.20	0.19	22.05	0.64	0.60
178	0.38	8.16	0.90	1.70	0.62	0.06	0	2.0	3.60	0.28	18.90	0.54	0.40
179	0.22	7.85	1.70	2.10	0.57	0.12	0	3.0	2.80	0.15	12.76	0.42	0.20
180	0.65	8.20	1.10	2.80	0.86	0.13	0	3.0	4.80	0.28	17.59	0.62	0.10
Mean.	0.45	7.89	1.08	1.72	0.77	0.10	0	3.3	4.33	0.28	21.80	0.66	0.53

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Max.	1.81	8.45	2.60	3.70	1.92	0.17	0	6.0	17.60	1.50	33.66	1.15	1.90
Min.	0.17	7.30	0.40	0.50	0.53	0.05	0	2.0	2.80	0.06	12.76	0.42	0.00

Appendix VI: Taluka/Sample wise values of EC, pH, cations, anions, different water quality indices and water quality class

Sr. No.	EC (dS m ⁻¹)	pH	Anions (me l ⁻¹)				Cations (me l ⁻¹)				SSP	RSC (me L ⁻¹)	SAR	Water Quality Class
			CO ₃ ²⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺				
Balasinor														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	3.00	7.06	0.00	7.00	22.6	0.46	8.20	17.00	5.00	0.68	16.19	0	1.41	C ₄ S ₁
2	1.98	7.09	0.00	8.00	11.2	0.49	4.90	12.10	2.00	0.68	10.16	0	0.69	C ₃ S ₁
3	1.20	7.84	0.00	5.00	8.20	0.11	2.20	6.70	3.30	0.84	25.31	0	1.56	C ₃ S ₁
4	1.44	7.31	0.00	5.00	9.20	0.19	2.40	8.60	3.00	0.69	20.43	0	1.28	C ₃ S ₁
5	1.73	6.97	0.00	9.00	8.20	0.26	2.70	10.30	3.80	0.84	21.55	0	1.49	C ₃ S ₁
6	0.85	7.13	0.00	3.20	5.20	0.05	1.10	5.70	0.95	0.66	11.29	0	0.52	C ₃ S ₁
7	8.80	6.62	0.00	10.00	77.0	0.89	21.50	53.00	13.00	0.72	14.74	0	2.13	C ₄ S ₁
8	0.92	7.23	0.00	3.00	6.00	0.12	1.90	6.50	0.10	0.65	1.05	0	0.05	C ₃ S ₁
9	0.96	7.35	0.00	3.00	6.80	0.15	1.50	6.60	1.00	0.67	10.23	0	0.50	C ₃ S ₁
10	1.03	7.64	0.00	6.00	4.40	0.21	2.50	6.30	1.00	0.96	9.29	0	0.48	C ₃ S ₁
11	2.40	7.87	0.00	8.00	16.0	0.17	3.70	12.10	8.00	0.66	32.70	0	2.85	C ₄ S ₁
12	0.74	7.33	0.00	2.70	4.60	0.09	1.40	4.30	1.10	0.65	14.76	0	0.65	C ₂ S ₁
13	0.83	7.42	0.00	1.70	6.40	0.09	1.50	4.70	1.45	0.66	17.45	0	0.82	C ₃ S ₁
14	0.87	7.19	0.00	3.00	5.60	0.15	1.90	6.00	0.30	0.66	3.38	0	0.15	C ₃ S ₁
15	0.71	7.34	0.00	4.30	2.60	0.25	1.60	4.40	0.60	0.66	8.26	0	0.35	C ₂ S ₁
16	1.52	7.37	0.00	5.00	10.0	0.24	1.90	8.90	3.80	0.65	24.92	0	1.64	C ₃ S ₁
17	3.70	7.57	0.00	9.00	28.0	0.31	7.90	19.90	9.00	0.66	24.03	0	2.41	C ₄ S ₁
18	1.20	8.08	0.00	6.00	6.40	0.21	2.10	5.70	4.00	0.65	32.14	0	2.03	C ₃ S ₁
19	2.60	7.11	0.00	8.00	18.0	0.55	5.20	15.60	5.20	0.66	19.50	0	1.61	C ₄ S ₁
20	0.95	7.94	0.00	5.00	4.60	0.11	1.00	5.40	2.40	0.67	25.33	0	1.34	C ₃ S ₁
21	1.36	8.08	0.00	7.10	6.50	0.19	1.30	8.50	3.10	0.65	22.88	0	1.40	C ₃ S ₁
22	1.05	7.52	0.00	3.20	7.00	0.06	1.10	6.90	2.10	0.67	19.50	0	1.05	C ₃ S ₁
23	1.22	7.43	0.00	5.00	7.00	0.19	1.20	7.10	3.20	0.65	26.34	0	1.57	C ₃ S ₁
24	1.22	7.09	0.00	5.10	7.20	0.07	3.50	8.20	0.10	0.65	0.83	0	0.04	C ₃ S ₁

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
25	0.78	7.34	0.00	3.20	4.40	0.09	2.40	4.60	0.11	0.65	1.40	0	0.06	C ₃ S ₁
26	1.46	7.15	0.00	6.40	7.80	0.18	3.10	9.10	1.50	0.66	10.45	0	0.61	C ₃ S ₁
27	1.30	7.36	0.00	6.00	7.30	0.14	2.00	5.50	5.20	0.65	38.94	0	2.69	C ₃ S ₁
28	0.89	7.31	0.00	3.90	4.80	0.12	1.10	6.30	0.01	0.65	11.05	0	0.52	C ₃ S ₁
29	1.17	7.25	0.00	4.50	7.30	0.10	1.60	6.60	2.90	0.65	24.67	0	1.43	C ₃ S ₁
30	1.81	7.27	0.00	9.60	8.40	0.16	2.80	9.90	4.70	0.66	26.03	0	1.87	C ₃ S ₁
Mean.	1.7	7.40	0.00	5.53	10.9	0.21	3.24	9.75	3.10	0.68	17.49	0	1.17	
Max.	8.8	8.10	0.00	10.00	77.0	0.89	21.50	53	13	0.96	38.94	0	2.85	
Min.	0.70	6.60	0.00	1.70	2.60	0.05	1.00	4.30	0.10	0.65	0.83	0	0.04	
Lunawada														
31	0.77	7.73	0.00	3.20	4.60	0.12	1.40	5.1	0.70	0.65	8.92	0	0.39	C ₃ S ₄
32	0.55	7.37	0.00	2.40	3.20	0.09	1.10	3.6	0.10	0.65	1.89	0	0.07	C ₂ S ₁
33	2.10	7.45	0.00	9.00	11.6	0.32	3.90	12.9	0.08	4.00	0.40	0	0.03	C ₃ S ₄
34	0.31	7.11	0.00	1.00	2.10	0.07	0.50	2	0.10	0.67	3.08	0	0.09	C ₂ S ₁
35	0.58	7.57	0.00	2.40	3.40	0.14	1.00	3.5	0.70	0.65	11.97	0	0.47	C ₂ S ₁
36	0.66	7.52	0.00	1.90	4.80	0.07	1.10	3.8	1.20	0.66	17.76	0	0.77	C ₂ S ₁
37	0.75	7.73	0.00	3.70	3.80	0.14	1.00	4.7	1.20	0.66	15.87	0	0.71	C ₂ S ₁
38	0.37	7.61	0.00	1.20	2.50	0.10	0.60	2.5	0.02	0.69	0.42	0	0.01	C ₂ S ₁
39	1.16	7.31	0.00	3.50	8.00	0.04	2.80	7.2	1.10	0.69	9.33	0	0.49	C ₃ S ₁
40	1.08	7.15	0.00	3.70	7.00	0.17	1.60	6.9	0.47	1.73	4.39	0	0.23	C ₃ S ₁
41	1.00	7.47	0.00	3.00	7.00	0.21	1.70	6.6	1.10	0.71	10.88	0	0.54	C ₃ S ₁
42	0.44	7.37	0.00	1.50	3.00	0.07	0.60	2.4	0.87	0.67	19.17	0	0.71	C ₂ S ₁
43	0.61	7.06	0.00	2.70	3.40	0.07	1.00	3.9	0.60	0.66	9.74	0	0.38	C ₃ S ₁
44	1.15	7.31	0.00	4.00	7.40	0.20	1.40	7.6	1.60	0.96	13.84	0	0.75	C ₃ S ₁
45	1.01	7.14	0.00	3.30	6.80	0.14	1.90	6.7	0.80	0.71	7.92	0	0.39	C ₃ S ₁
46	0.83	7.15	0.00	3.40	4.60	0.18	0.90	6	0.60	0.71	7.31	0	0.32	C ₃ S ₁
47	1.68	7.15	0.00	5.90	10.8	0.03	1.30	3.3	9.60	0.68	64.50	1.30	6.33	C ₃ S ₁
48	0.42	8.51	0.00	1.20	3.10	0.03	0.60	2.8	0.04	0.67	0.88	0	0.03	C ₃ S ₁
49	2.60	7.07	0.00	6.00	19.8	0.30	9.60	14.9	0.85	0.70	3.26	0	0.24	C ₄ S ₁
50	3.10	7.68	0.00	8.00	22.9	0.28	7.20	19	4.30	0.67	13.79	0	1.19	C ₄ S ₁

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
51	3.50	7.64	0.00	10.90	24.0	0.17	8.00	19.5	7.10	0.69	20.12	0	1.91	C ₄ S ₁
52	1.43	7.96	0.00	6.30	8.00	0.13	4.00	8	1.76	0.67	12.20	0	0.72	C ₃ S ₁
53	1.41	6.91	0.00	5.00	9.00	0.16	3.20	7.7	2.39	0.75	17.02	0	1.02	C ₃ S ₁
54	1.49	7.02	0.00	3.70	11.0	0.27	3.90	7.7	2.70	0.76	17.93	0	1.12	C ₃ S ₁
55	3.50	7.07	0.00	6.00	28.6	0.27	10.20	18.3	5.45	1.08	15.56	0	1.44	C ₄ S ₁
56	0.86	7.04	0.00	3.00	5.30	0.19	0.90	6.4	0.70	0.68	8.06	0	0.37	C ₃ S ₄
57	1.45	6.99	0.00	6.00	8.20	0.16	3.50	10.1	0.10	0.73	0.70	0	0.04	C ₃ S ₄
58	4.90	7.0	0.00	11.00	37.6	0.52	11.50	3.1	29.80	0.79	65.95	0	11.03	C ₄ S ₂
59	1.91	7.52	0.00	5.00	13.9	0.29	3.00	9.9	5.50	0.71	28.78	0	2.17	C ₃ S ₄
60	0.92	7.26	0.00	2.50	6.70	0.10	2.40	6.1	0.10	0.68	1.11	0	0.05	C ₃ S ₄
Mean.	1.40	7.36	0.00	4.35	9.74	0.16	3.06	7.40	2.72	0.86	13.76	0.04	1.13	
Max.	4.90	8.51	0.00	11.0	37.6	0.52	11.50	19.5	29.80	4.0	65.95	1.30	11.03	
Min.	0.30	6.91	0.00	1.0	2.16	0.03	0.50	2.00	0.02	0.65	0.40	0	0.01	
Kadana														
61	0.58	7.05	0.00	1.30	4.50	0.07	1.00	4	0.10	0.68	1.79	0	0.07	C ₂ S ₁
62	0.66	7.24	0.00	1.20	5.40	0.09	1.00	3.5	1.50	0.68	22.45	0	1.00	C ₂ S ₁
63	0.50	7.63	0.00	1.50	3.60	0.05	0.70	3.6	0.10	0.67	2.05	0	0.07	C ₂ S ₁
64	1.06	6.95	0.00	3.30	7.20	0.24	2.40	6.6	0.90	0.69	8.50	0	0.42	C ₃ S ₁
65	0.89	6.94	0.00	2.60	6.40	0.12	1.40	6.8	0.10	0.69	1.16	0	0.05	C ₃ S ₁
66	0.66	7.25	0.00	3.00	3.40	0.15	0.90	4	1.10	0.66	16.51	0	0.70	C ₂ S ₁
67	0.51	7.24	0.00	1.57	3.40	0.06	1.30	3	0.11	0.66	2.08	0	0.07	C ₂ S ₁
68	0.44	6.94	0.00	1.20	3.30	0.13	0.90	2.4	0.60	0.65	13.18	0	0.47	C ₂ S ₁
69	0.45	7.22	0.00	1.20	3.40	0.09	0.90	2.6	0.30	0.66	6.73	0	0.23	C ₂ S ₁
70	0.94	7.09	0.00	3.80	5.55	0.11	1.20	6.6	1.00	0.73	10.50	0	0.51	C ₃ S ₁
71	1.08	7.20	0.00	3.10	7.60	0.19	1.40	7.1	1.70	0.67	15.65	0	0.82	C ₃ S ₁
72	0.55	7.14	0.00	1.20	4.10	0.29	1.20	3.6	0.10	0.70	1.87	0	0.07	C ₂ S ₁
73	5.20	7.07	0.00	8.20	43.2	0.77	12.50	32.3	6.32	0.85	12.16	0	1.34	C ₄ S ₁
74	0.97	7.11	0.00	2.80	6.80	0.18	1.40	7.5	0.20	0.66	2.05	0	0.09	C ₃ S ₁
75	0.85	7.23	0.00	3.00	5.40	0.05	1.70	5.4	0.80	0.66	9.34	0	0.42	C ₃ S ₁
76	1.04	6.80	0.00	2.90	7.40	0.21	2.20	7.1	0.68	0.65	6.39	0	0.32	C ₃ S ₁

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
77	0.63	7.42	0.00	1.20	5.10	0.06	1.20	3.8	0.55	0.67	8.84	0	0.35	C ₂ S ₁
78	0.66	7.10	0.00	2.00	4.60	0.05	1.30	4.7	0.10	0.66	1.44	0	0.06	C ₂ S ₁
79	0.76	6.86	0.00	3.20	4.20	0.06	0.90	5.2	0.80	0.68	10.56	0	0.46	C ₃ S ₁
80	0.90	6.95	0.00	3.60	5.40	0.07	1.00	6.2	1.20	0.70	13.19	0	0.63	C ₃ S ₁
81	0.66	7.59	0.00	2.70	4.00	0.04	1.30	3.7	0.86	0.68	13.15	0	0.54	C ₂ S ₁
82	0.56	7.15	0.00	2.20	3.40	0.06	0.80	3.3	1.00	0.65	17.39	0	0.70	C ₂ S ₁
83	0.57	7.00	0.00	1.30	4.40	0.06	1.00	4	0.10	0.65	1.81	0	0.07	C ₂ S ₁
84	0.70	7.01	0.00	2.50	4.30	0.06	1.60	4.6	0.10	0.66	1.46	0	0.06	C ₂ S ₁
85	0.65	6.77	0.00	2.30	4.00	0.12	0.80	4.6	0.37	0.65	5.76	0	0.23	C ₂ S ₁
86	0.57	7.05	0.00	1.60	4.10	0.06	0.90	3.4	0.78	0.66	13.59	0	0.53	C ₂ S ₁
87	0.54	6.95	0.00	1.40	4.00	0.07	0.80	3.3	0.59	0.67	11.02	0	0.41	C ₂ S ₁
88	0.39	6.63	0.00	1.00	2.80	0.20	0.70	2.6	0.11	0.67	2.65	0	0.08	C ₂ S ₁
89	0.82	7.08	0.00	2.70	5.30	0.11	2.00	5.3	0.10	0.79	1.24	0	0.05	C ₃ S ₁
90	0.87	7.00	0.00	4.00	4.60	0.04	2.20	5.7	0.11	0.67	1.23	0	0.05	C ₃ S ₁
Mean	0.85	7.08	0.00	2.45	6.03	0.13	1.62	5.55	0.75	0.68	7.86	0	0.36	
Max.	5.20	7.63	0.00	8.20	43.2	0.77	12.50	32.3	6.32	0.85	22.45	0	1.34	
Min.	0.85	6.63	0.00	1.00	2.80	0.04	0.70	2.4	0.10	0.65	1.16	0	0.05	
Khanpur														
91	0.81	6.90	0.00	2.70	5.20	0.09	1.90	5.1	0.42	0.67	5.19	0	0.22	C ₃ S ₁
92	0.70	7.39	0.00	2.20	4.80	0.10	1.30	4.4	0.63	0.65	9.02	0	0.37	C ₂ S ₁
93	0.44	8.00	0.00	1.30	2.90	0.05	1.00	2.8	0.11	0.66	2.35	0	0.08	C ₂ S ₁
94	0.68	8.90	0.00	1.30	5.50	0.08	1.00	3.9	1.22	0.70	17.89	0	0.78	C ₂ S ₁
95	1.17	7.14	0.00	3.90	7.60	0.27	2.40	6.8	1.79	0.67	15.35	0	0.83	C ₃ S ₁
96	1.14	7.53	0.00	3.70	7.70	0.14	1.80	7.1	1.87	0.72	16.28	0	0.89	C ₃ S ₁
97	0.84	7.01	0.00	2.20	5.90	0.20	1.70	6.1	0.01	0.72	0.11	0	0.00	C ₃ S ₁
98	0.67	7.23	0.00	2.70	4.10	0.04	1.20	4.3	0.70	0.66	10.21	0	0.42	C ₂ S ₁
99	0.63	8.08	0.00	2.00	4.00	0.19	1.30	4.2	0.10	0.70	1.59	0	0.06	C ₂ S ₁
100	1.15	7.80	0.00	4.10	7.50	0.01	2.10	6.9	2.00	0.66	17.15	0	0.94	C ₃ S ₁
101	1.28	7.74	0.00	6.00	6.80	0.14	1.60	5.8	4.70	0.66	36.84	0	2.44	C ₃ S ₁
102	0.66	8.10	0.00	1.30	5.20	0.19	1.00	4.2	0.75	0.66	11.35	0	0.47	C ₂ S ₁

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
103	0.84	7.70	0.00	2.30	5.90	0.15	1.20	5.2	1.27	0.66	15.25	0	0.71	C ₃ S ₁
104	1.02	6.97	0.00	4.20	6.00	0.14	1.70	6.5	1.38	0.68	13.44	0	0.68	C ₃ S ₁
105	5.20	7.58	0.00	4.70	46.4	0.68	12.50	33.1	5.90	0.73	11.30	0	1.24	C ₄ S ₁
106	0.54	7.15	0.00	1.40	3.80	0.06	0.70	3.4	0.52	0.71	9.76	0	0.36	C ₂ S ₁
107	1.01	8.38	0.00	3.90	6.10	0.07	1.20	6.8	1.44	0.65	14.28	0	0.72	C ₃ S ₁
108	0.91	7.00	0.00	2.90	6.20	0.12	1.00	7.1	0.33	0.66	3.63	0	0.16	C ₃ S ₁
109	0.77	7.14	0.00	2.60	5.00	0.05	0.80	5.2	1.00	0.66	13.05	0	0.58	C ₃ S ₁
110	1.07	7.18	0.00	3.00	7.50	0.18	1.40	6.9	1.70	0.66	15.95	0	0.83	C ₃ S ₁
111	0.82	7.48	0.00	2.30	5.90	0.12	1.40	5.2	1.00	0.66	12.11	0	0.55	C ₃ S ₁
112	1.19	7.18	0.00	3.70	8.30	0.12	1.70	7.2	1.64	0.66	14.64	0	0.78	C ₃ S ₁
113	0.89	7.65	0.00	2.80	5.90	0.11	1.70	6.2	0.17	0.76	1.93	0	0.09	C ₃ S ₁
114	1.38	6.95	0.00	4.00	9.50	0.18	3.00	7.1	2.77	0.86	20.17	0	1.23	C ₃ S ₁
115	0.63	6.94	0.00	1.80	4.60	0.10	0.70	4.3	0.57	0.68	9.11	0	0.36	C ₂ S ₁
116	0.77	9.07	0.00	2.50	5.00	0.26	0.80	5.3	0.78	0.78	10.19	0	0.45	C ₃ S ₁
117	0.76	8.89	0.00	1.90	5.50	0.21	0.90	5.5	0.35	0.78	4.65	0	0.20	C ₃ S ₁
118	0.36	8.20	0.00	1.00	2.40	0.08	0.60	2.4	0.10	0.67	2.73	0	0.08	C ₂ S ₁
119	0.75	7.22	0.00	2.30	5.00	0.15	1.20	4.8	0.87	0.70	11.50	0	0.50	C ₂ S ₁
120	0.58	7.47	0.00	1.50	4.40	0.05	0.80	3.3	1.00	0.71	17.20	0	0.70	C ₂ S ₁
Mean.	0.98	7.59	0.00	2.74	7.02	0.14	1.72	6.23	1.24	0.69	11.47	0	0.59	
Max.	5.20	9.07	0.00	6.00	46.4	0.68	12.50	33.1	5.90	0.86	38.84	0	2.44	
Min.	0.36	6.90	0.00	1.00	2.40	0.01	0.60	2.4	0.01	0.65	0.11	0	0	
Virpur														
121	0.69	7.81	0.00	2.60	4.40	0.06	1.00	4.3	0.86	0.67	12.60	0	0.53	C ₂ S ₁
122	0.62	8.80	0.00	1.30	4.80	0.11	0.60	3.3	1.50	0.70	24.59	0	1.07	C ₂ S ₁
123	0.52	7.61	0.00	1.30	3.90	0.09	0.80	3.2	0.57	0.67	10.88	0	0.40	C ₂ S ₁
124	0.50	8.63	0.00	1.20	3.90	0.05	0.80	3.2	0.29	0.69	5.82	0	0.21	C ₂ S ₁
125	1.17	7.47	0.00	2.80	8.50	0.23	2.00	6.9	2.10	0.74	17.89	0	1.00	C ₃ S ₁
126	0.68	7.36	0.00	2.10	4.50	0.05	0.90	4.3	0.92	0.66	13.56	0	0.57	C ₂ S ₁
127	0.72	7.19	0.00	4.50	7.00	0.07	1.90	6.7	0.10	0.66	1.08	0	0.05	C ₂ S ₁
128	0.79	7.51	0.00	2.30	5.60	0.17	1.30	5.2	0.67	0.67	8.55	0	0.37	C ₃ S ₁

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
129	1.18	7.64	0.00	3.20	8.60	0.20	2.10	7.4	1.57	0.66	13.39	0	0.72	C ₃ S ₁
130	0.63	7.56	0.00	1.40	5.10	0.05	0.90	4.3	0.45	0.66	7.13	0	0.28	C ₂ S ₁
131	0.43	7.52	0.00	1.10	3.10	0.04	1.00	2.3	0.08	0.67	2.04	0	0.06	C ₂ S ₁
132	0.51	8.85	0.00	1.20	4.10	0.03	0.80	3.8	0.10	0.70	1.88	0	0.07	C ₂ S ₁
133	0.92	7.61	0.00	3.10	6.00	0.21	1.10	6.1	1.35	0.69	14.60	0	0.71	C ₃ S ₁
134	1.37	8.01	0.00	3.90	9.70	0.19	2.10	8.1	2.78	0.73	20.27	0	1.23	C ₃ S ₁
135	1.11	8.12	0.30	3.70	7.20	0.14	2.50	8	0.08	0.73	0.74	0	0.04	C ₃ S ₁
136	0.91	7.68	0.00	3.00	6.00	0.16	1.30	6.5	0.65	0.67	7.13	0	0.33	C ₃ S ₁
137	0.59	7.70	0.00	1.80	3.80	0.20	0.80	3.2	1.20	0.68	20.42	0	0.85	C ₂ S ₁
138	0.41	7.57	0.00	1.20	2.90	0.05	0.60	2.3	0.61	0.67	14.59	0	0.51	C ₂ S ₁
139	0.65	7.74	0.00	1.60	4.90	0.09	0.90	3.7	1.38	0.66	20.80	0	0.91	C ₂ S ₁
140	1.20	7.40	0.00	5.00	6.80	0.07	1.70	6.3	3.30	0.73	27.43	0	1.65	C ₃ S ₁
141	0.59	7.04	0.00	1.90	4.00	0.11	0.80	4.7	0.10	0.65	1.67	0	0.06	C ₂ S ₁
142	1.61	7.48	0.00	3.80	12.0	0.13	2.40	8.6	4.56	0.71	28.03	0	1.94	C ₂ S ₁
143	0.70	8.99	0.10	2.40	4.30	0.07	0.90	4.7	0.70	0.68	10.03	0	0.42	C ₂ S ₁
144	2.20	8.71	0.00	5.80	16.2	0.21	4.90	12.9	3.58	0.73	16.19	0	1.20	C ₃ S ₁
145	1.49	7.84	0.00	3.00	11.6	0.19	2.00	9	3.20	0.68	21.50	0	1.36	C ₃ S ₁
146	0.85	8.69	0.10	1.40	7.00	0.06	1.00	5.9	0.79	0.68	9.44	0	0.43	C ₃ S ₁
147	0.76	7.55	0.00	1.70	5.90	0.15	1.00	4.3	1.57	0.71	20.72	0	0.96	C ₃ S ₁
148	1.07	7.80	0.00	2.00	8.60	0.18	2.50	5.5	2.00	0.65	18.78	0	1.00	C ₃ S ₁
149	0.86	8.01	0.00	2.50	6.00	0.21	1.10	4.3	2.50	0.65	29.23	0	1.52	C ₃ S ₁
150	0.79	7.92	0.00	2.50	5.40	0.15	0.90	4.2	2.10	0.66	26.71	0	1.32	C ₃ S ₁
Mean.	0.88	7.86	0.02	2.51	6.39	0.12	1.42	5.44	1.39	0.68	13.67	0	0.67	
Max.	2.20	8.99	0.30	5.80	16.2	0.23	4.90	12.9	4.56	0.74	32.93	0	1.94	
Min.	0.41	7.04	0.00	1.10	2.90	0.03	0.60	2.00	0.08	0.65	0.30	0	0.01	
Santrampur														
151	0.26	7.67	0.00	1.00	1.70	0.04	0.50	1.5	0.06	0.66	2.33	0	0.06	C ₂ S ₁
152	0.61	7.45	0.00	1.70	4.50	0.12	1.00	3.0	1.54	0.66	24.85	0	1.09	C ₂ S ₁
153	0.60	7.81	0.00	1.50	4.60	0.14	0.90	3.1	1.27	1.32	19.27	0	0.90	C ₂ S ₁
154	0.39	7.69	0.00	1.20	2.80	0.07	0.70	2.5	0.17	0.66	4.22	0	0.13	C ₂ S ₁

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
155	0.68	8.13	0.00	1.90	4.60	0.18	0.80	4.1	1.24	0.66	18.23	0	0.79	C ₂ S ₁
156	0.40	7.56	0.00	1.00	2.80	0.14	0.80	2.2	0.16	0.66	4.19	0	0.13	C ₂ S ₁
157	0.58	7.65	0.00	1.50	4.30	0.08	1.00	2.2	1.90	0.67	32.93	0	1.50	C ₂ S ₁
158	0.51	7.44	0.00	2.00	3.20	0.07	0.80	3.4	0.09	0.70	1.87	0	0.06	C ₂ S ₁
159	0.45	7.93	0.00	1.10	3.50	0.05	0.80	3.1	0.01	0.67	0.30	0	0.01	C ₂ S ₁
160	0.78	7.02	0.00	1.90	5.80	0.01	1.10	5.3	0.85	0.64	10.77	0	0.48	C ₃ S ₁
161	0.69	7.53	0.00	2.30	4.30	0.18	0.90	4.2	1.28	0.66	18.18	0	0.80	C ₂ S ₁
162	0.65	7.75	0.00	1.80	4.60	0.02	0.80	4.4	0.58	0.66	9.00	0	0.36	C ₂ S ₁
163	0.67	7.63	0.00	1.90	4.80	0.09	1.00	3.0	2.00	0.70	29.85	0	1.41	C ₂ S ₁
164	0.92	7.15	0.00	3.80	5.40	0.10	1.40	6.1	1.00	0.66	10.92	0	0.52	C ₃ S ₁
165	0.64	7.72	0.00	2.10	4.10	0.03	0.70	3.5	1.40	0.70	22.22	0	0.97	C ₂ S ₁
166	0.71	7.27	0.00	1.60	5.60	0.04	0.80	4.6	1.00	0.71	14.07	0	0.61	C ₂ S ₁
167	1.05	7.78	0.00	2.90	7.60	0.22	1.50	6.7	1.67	0.68	15.82	0	0.82	C ₃ S ₁
168	0.95	7.88	0.00	3.00	6.80	0.16	1.30	6.2	1.34	0.72	14.01	0	0.69	C ₃ S ₁
169	0.50	8.04	0.00	1.90	2.90	0.10	0.70	3.2	0.34	0.68	6.90	0	0.24	C ₂ S ₁
170	0.57	7.36	0.00	1.70	3.80	0.06	0.80	3.3	0.90	0.69	15.82	0	0.63	C ₂ S ₁
171	0.51	7.81	0.00	1.50	3.60	0.05	0.80	3.3	0.18	0.69	3.62	0	0.13	C ₂ S ₁
172	0.56	7.81	0.00	1.90	3.50	0.10	0.90	3.1	0.92	0.68	16.43	0	0.65	C ₂ S ₁
173	0.66	6.75	0.00	2.10	4.40	0.23	0.90	3.3	1.70	0.69	25.81	0	1.17	C ₂ S ₁
174	0.69	7.51	0.00	1.80	5.10	0.17	0.90	4.2	1.20	0.69	17.17	0	0.75	C ₂ S ₁
175	0.55	7.61	0.00	2.40	3.00	0.07	0.80	3.3	0.55	0.69	10.29	0	0.38	C ₂ S ₁
176	0.47	7.68	0.00	1.20	3.30	0.11	0.60	2.9	0.56	0.66	11.86	0	0.42	C ₂ S ₁
177	0.54	7.59	0.00	2.00	3.40	0.09	0.80	3.2	0.80	0.69	14.56	0	0.57	C ₂ S ₁
178	0.51	7.73	0.00	1.30	3.80	0.14	0.80	3	0.70	0.69	13.48	0	0.51	C ₂ S ₁
179	0.41	9.7	0.10	1.00	2.80	0.07	0.70	2.3	0.50	0.67	11.99	0	0.41	C ₂ S ₁
180	0.85	7.61	0.00	2.60	5.60	0.15	1.00	5.9	0.47	1.00	5.62	0	0.25	C ₃ S ₁
Mean.	0.612	7.67	0.002	1.85	4.21	0.10	0.88	3.67	0.88	0.71	14.38	0.007	0.61	
Max.	1.05	9.70	0.30	3.80	7.60	0.23	1.50	6.70	2.00	1.32	29.85	1.30	1.41	
Min.	0.26	6.75	0.10	1.00	1.70	0.01	0.50	1.5	0.01	0.64	3.62	0	0.13	

Appendix VII: Taluka wise nutrient index of the available macro and micro nutrients

Sr. No.	Name of Taluka	Status	N	P ₂ O ₅	K ₂ O	S	Fe	Mn	Zn	Cu
1	Balasinor	Low	14	15	1	11	7	2	0	0
		Medium	16	14	17	13	11	10	4	1
		High	0	1	12	6	12	18	26	29
		Values	1.53	1.53	2.36	1.83	2.16	2.53	2.86	2.96
		N Index	L	L	H	M	M	H	H	H
2	Lunawada	Low	24	12	6	11	1	0	4	1
		Medium	6	17	17	2	8	10	6	4
		High	0	1	7	7	21	20	20	25
		Values	1.2	1.63	2.03	1.86	2.66	2.66	2.53	2.8
		N Index	L	L	M	M	H	H	H	H
3	Kadana	Low	18	13	10	10	0	0	2	2
		Medium	12	16	3	10	1	11	8	5
		High	0	1	7	10	29	19	20	23
		Values	1.4	1.6	1.9	2.0	2.96	2.63	2.6	2.7
		N Index	L	L	M	M	H	H	H	H
		Low	21	17	8	7	1	1	1	0
		Medium	9	12	18	11	7	10	5	3

4	Khanpur	High	0	1	4	12	22	19	24	27
		Values	1.3	1.46	1.86	2.16	2.7	2.26	2.76	2.9
		N Index	L	L	M	M	H	H	H	H
		Low	23	18	8	12	5	1	3	3
		Medium	7	9	16	6	11	13	8	4
5	Virpur	High	0	3	6	12	14	16	19	23
		Values	1.23	1.5	1.93	2.0	2.3	2.5	2.53	2.66
		N Index	L	L	M	M	H	H	H	H
		Low	15	17	6	9	3	4	3	0
		Medium	15	8	15	12	12	11	12	2
6	Santrampur	High	0	5	9	9	15	15	15	28
		Values	1.5	1.6	2.1	2.0	2.4	2.36	2.4	2.86
		N Index	L	L	M	M	H	H	H	H
		Low	115	92	39	60	17	8	13	6
		Medium	65	76	96	64	50	65	43	23
7	Overall	High	0	12	45	56	113	107	124	156
		Values	1.36	1.55	2.03	1.97	2.53	2.55	2.61	2.81
		N Index	L	L	M	M	H	H	H	H

C E R T I F I C A T E

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Date: 30 / 07 /2019

(Paragi Nileshkumar S.)