

An Investigation on the Quality of Groundwater and Its Suitability to Agriculture in and Around Badvel Taluka of Kadapa District, Andhra Pradesh, India: A GIS Approach

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ABSTRACT: Study was carried out to evaluate the major cation Chemistry, the factors controlling water composition, and suitability of water for irrigation. The problems of water quality have become more important than the quantity, as the environmental problems are getting more serious in several parts of the world. A number of factors like geology, soil, effluents, sewage disposal and other environmental conditions in which the water happens to stay or move and interact with, influences greatly on the groundwater quality of an area. The spatial maps show that the concentration of the chemical constituent in ground water varies spatially and temporarily. Sodium is the most dominant cation with Cl^- and HCO_3^- are the dominant anions. SAR values indicated that both pre and post monsoons water samples are excellent (S1) for irrigation, while electrical conductivity values classified these ground water, respectively under high saline water consist (C3) category. Water quality data are utilized in the present study for the analysis of groundwater chemistry of year 2014, Pre-monsoon (July) and 2014, post-monsoon (December) seasons. Water quality data used in the analysis include Electrical Conductivity (EC), Total Alkalinity (TA), Total Hardness (TH), Calcium, Magnesium, Sodium, Potassium, Sodium Adsorption Ratio (SAR) Sodium and Residual Sodium Carbonate (RSC).

KEYWORDS: Water quality, Agriculture, SAR, TDS, GIS, Remote sensing.

I. INTRODUCTION

Groundwater is an important source of drinking water for many people around the world. The resource in several places becomes contaminated from natural agents or by numerous human activities. There is a tremendous amount of pressure in protecting the water resources available in the country. The disposal of wastewater into the surface water bodies leads to serious problems and affects the people in health aspects. Especially in the urban areas, the pollution of domestic effluent discharges into the nearby surface water bodies created problems for the public. There are many ways of safe disposal of wastewater. But improper management of wastewater generation in the urban areas find its own way of getting into the surface water. Hence, the effluent discharge affects the surface water bodies. Water quality data are utilized in the present study to analyse the groundwater chemistry for the year 2014 during pre-monsoon (July) and post monsoon (December) seasons. Hydro chemical evaluation of groundwater systems is usually based on the availability of a large amount of information concerning groundwater chemistry [6,7] Hydro geochemical data are used in the analysis, including Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Sodium percentage, Residual Sodium Carbonate (RSC) and Sodium Adsorption Ratio (SAR).

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II. STUDY AREA

The study area, Badvel taluka of Kadapa District, Andhra Pradesh, India, has been selected for this study, it is located at 14.858334°N and 15°12'39.93"N latitudes and 79.039167° E and 78°56'15.952"E longitudes (Figure:1). It covers a total geographical area of 1906.80 sq. km (Figure 1). The area is bounded on the North West byPrakasam and Kurnool districtin the West, in the South Chittoordistrict, and in the North East, East by Kurnool District. The District is located in one of the *Jordon bird* researchcentres of the Western Ghats. This region receives rainfall at the time of shifting climatic wind belts, but it is in rain shadow track at the time of the southwest monsoon.

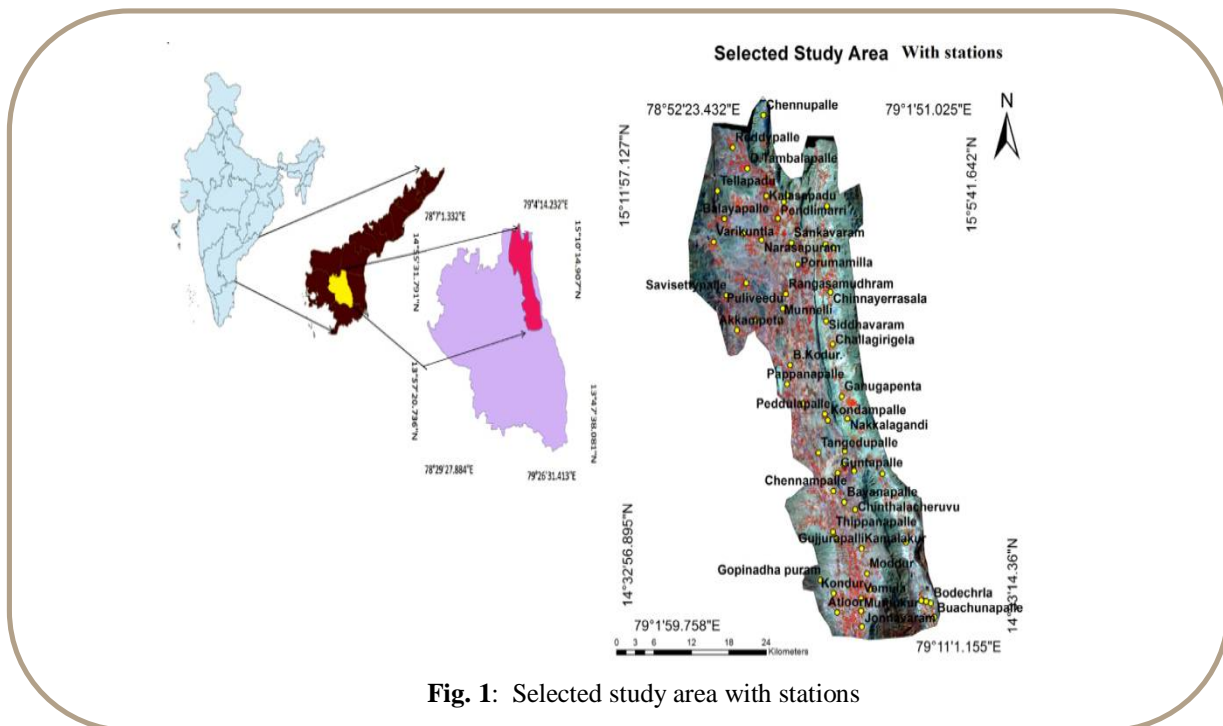


Fig. 1: Selected study area with stations

III. MATERIALS AND METHODOLOGY

The investigation was designed to investigate the conditions of groundwater contamination in the study areas. The hydro geochemistry study was undertaken by randomly collecting 60 groundwater samples from dug and bore well covering Badvel taluka during the months of July and December 2014. Samples were drawn with a pre cleaned plastic polyethylene bottle. Prior to sampling, all the sampling containers were washed and rinsed thoroughly with the groundwater. Water quality parameters such as pH and electrical conductivity (EC) were analysed immediately. Other parameters were analysed later in the laboratories of Yogi Vemana University, Kadapa. Total dissolved solids (TDS) were computed by multiplying the electrical conductivity (Ec) by a factor (0.64). The surface water samples collected at sixty different stations within Badvel Taluka, in a 2 L pre-cleaned polyethylene bottles during period of July and December in 2014. Two times (pre and post monsoon) continuous monitoring is involved by comprehensive physicochemical analysis encompassing estimation of major cations (Ca^{2+} , Mg^{2+} , Na^+ , K^+), besides general parameters (pH, EC, Total alkalinity and Total hardness) Sodium percentage, Residual Sodium Carbonate (RSC) and Sodium Adsorption Ratio (SAR).

GIS-modelling: For creating the spatial distribution maps, GIS has emerged as a powerful tool. GIS can be used for storing, displaying, and analysing spatial data. By using this data, decision making in several areas including

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environmental and engineering field (Stafford 1991; Good child 1993; Burrough and McDonnell 1998a; Lo and Yeung 2003) field can be done. The spatial distribution maps were prepared to show the variation in concentrations of the various chemical parameters using inverse distance weighted (IDW) raster interpolation technique of the spatial analyst module in ArcGIS® 9.1. The general formula used in the IDW interpolation method was

$$\hat{Z}(S_0) = \sum_{i=1}^N \lambda_i Z(S_i)$$

where $\hat{Z}(S_0)$ is the value we are trying to predict for S_0 , N is the number of measured sample points surrounding the prediction location that will be used in the prediction, and λ_i is the weights assigned to each measured point that we are used here. These weights will decrease with distance; $Z(S_i)$ is the observed value at the location S_i . When we compare several interpolation techniques, IDW with a squared distance term gives the more consistent results (Burrough and McDonnell 1998a, b; Mathes and Rasmussen 2006) in this study, spatial distribution maps were generated for the selected water quality parameters, namely Ec , TH, Ca^{2+} , Mg^{2+} , Na^+ , K^+ , SAR, Na% and RSC (Figure-2 to Figure-11).

IV. RESULTS AND DISCUSSION

The seasonal variations of physico-chemical characteristics of the groundwater in the study area in Badvel Taluk of Kadapa District in 2014 are discussed below and presented in Figure 2 to 11. In the present study, assessment of groundwater potability based on physico-chemical analysis and evaluation of groundwater quality indices. The quality standards for drinking water have been specified by the Potability studies (as per BIS) and World Health Organization (WHO) in 2004. It has given the permissible and desirable limits of various elements in groundwater.

1) Electrical Conductivity (EC): Conductivity is the measure of capacity of a substance to conduct the electric current. The Ec values in the present study vary from 876 μ/cm at (S-32) to 2238 $\mu/Mhos$ at (S-20) during pre-monsoon and 814 $\mu/Mhos$ (S-49) to 2180 $\mu/Mhos$ recorded at (S-51) in post-monsoon period (Table-3). During pre-monsoon and Postmonsoon periods, result shows 100% of samples fall under permissible category, the none of the samples fall under good category. During post monsoon period, higher concentration of (> 2220) salts was recorded south-western part, southeast, and central part of the study area.

2). Total Alkalinity: Total Alkalinity is a measure of the ability of water to neutralize acids. The alkalinity varies from 110 to 260 (mg/L) in pre-monsoon and 132 to 258 (mg/L) during post monsoon period. The alkalinity values in the present study vary from 110 mg/L at (S-32) and 260 mg/L at (S-20) during pre-monsoon and 132 mg/L (S-49) to 258 mg/L, recorded at (S-51) in post-monsoon period (Table 3). All samples were recorded below the standard limit (600 mg/L) as prescribed by BIS in pre monsoon and post monsoon. Water with high alkalinity is said to be "hard". Large amount of alkalinity imparts a bitter taste, harmful for irrigation as it damages soil and hence reduces crop yields (Sunder and Saseetharan 2008).

3) Total Hardness (TH): Generally water with a hardness of less than 50 ppm is rated as a soft water. The hardness below 500 ppm is recommended for drinking purpose. But for agricultural purpose, more than 1000 ppm of hardness is also accepted (Rao, 1975). The Total Hardness value of pre monsoon in 2014 shows concentration from 378 mg/L, at (S-13), to 607 mg/L, at (S-19) and 295 mg/L, at (S-25) to 575 mg/L, at (S-52) during post monsoon (Table.1). During pre and post monsoon seasons of 2014, 100 per cent of samples were recorded under very hard category in the study area. During post monsoon season about 100 per cent of samples fall under very hard category. In 2014, there was no appreciable variation between the pre and post monsoon period water quality. Almost all areas of pre and post monsoon periods fall under the low ion concentration of < 600 mg/L category.

4). Calcium: Calcium may dissolve readily from carbonate rocks and lime stones or be leached from soils. But calcium is an essential nutritional element for human being and aids in the maintaining the structure of plant cells and soils. The concentration of calcium in the present study area ranges from varied 61 mg/L at (S-13) to 115 mg/L, at (S-40), during pre-monsoon and 49 mg/L, at (S-25) to 112 mg/L at (S-52) during post monsoon. In this study area 59 stations were exceeded the permissible limits during pre and post monsoons. (According to BIS, maximum permissible limits are 200 mg/L in groundwater).

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Vol. 6, Issue 1, January 2017

5). Magnesium The concentration of magnesium in the present study area ranges from 43 mg/L at (S-36) to 83 mg/L was recorded at (S-53) during pre-monsoon and 41 mg/L at (S-1) to 80 mg/L was recorded at (S-20), during post monsoon. In pre monsoon, 5 samples and in post monsoon 2 samples were exceeded the permissible limits (According to BIS, maximum permissible limits are 100 mg/L).

6) Sodium (Na^{2+}): Sodium and potassium are naturally occurring elements in groundwater. These two elements are directly added into groundwater from industrial and domestic wastes and contribute salinity of water. The value of sodium for the groundwater samples is recorded in the range is varied from 68 mg/L at (S-32) to 142 mg/L at (S-20), during pre-monsoon season where as in the post-monsoon season it ranges between 61 mg/L was recorded at (S-49) to 132 mg/L was recorded at (S-35) (Table.1). None of samples were above the standard limit in pre monsoon and post monsoon seasons. From this study, it is confirmed that the value of sodium for the groundwater sample is well within the permissible limit (200 mg/L) as suggested by WHO. High concentration of sodium ion in drinking water may cause heart/cardiac problems.

7). Potassium (K^+): Sodium and potassium are the most important minerals occurring naturally. The potassium values for the groundwater samples in the study area varied from (4 mg/l) was recorded at (S-12), to 12 mg/L at (S-4) during pre-monsoon season where as in the post-monsoon season it ranges between 4 mg/L at (S-16), to 12 mg/L at (S-26) (Table 3). All samples were below the standard limit in pre monsoon and nil samples were recorded above the standard limit in post monsoon, as standard limit (12 mg/L) prescribed by WHO. On comparison with the WHO standard value, it is found that the potassium values for all the groundwater samples are well within the maximum permissible limit in both monsoons (12 ppm).

8). Sodium Adsorption Ratio (SAR): The Sodium Adsorption Ratio (SAR) was estimated based on the given formula for the each sample location of the study area. The suitability of the open well and bore well samples were evaluated by determining the SAR value and these were categorized into different irrigation classes based on salinity and alkalinity hazards. Based on these values, isoclines were drawn to understand the spatial pattern of SAR ratio in the study area. Sodium hazard of water classification was proposed by (Richards, 1954).

The following equation is employed to obtain SAR values

$$SAR = \frac{Na^+}{\sqrt{Ca + Mg/2}} * 100$$

(Where, all ionic concentrations are expressed in milli equivalents per litre.)

There were no much variations in SAR concentration between two seasons of 2014. In 2014, pre monsoon period SAR value varied 3.21 Meq/L at (S-32) to 6.66 Meq/L recorded at (S-13), were observed in pre monsoon and 2.85 Meq/L at (S-49) to 6.33 Meq/L recorded at (S-32) during post monsoon. In both monsoons the values are within the permissible limits (10 Meq/L) category. This result indicates that a maximum area suitable for irrigation (Table 5). In 2014, SAR shows no appreciable difference between pre monsoon and post monsoon periods. Therefore SAR results shows that most of the study area falls under the excellent to good water quality category and found to be suitable for irrigation purpose. If the SAR ratio of the water samples in the study area is less than 10, it is excellent for irrigation purposes. The SAR value for each water sample was calculated using the following equation (Richards 1954). According to classification given in Table-1, both Pre and Post monsoons showed mean SAR value below 10 (Meq/L), indicating that ground waters are excellent (S1) for irrigation.

9) Residual Sodium Carbonate: The sodium hazard also increases, if the water contains a high concentration of bicarbonate ion. As the soil solution becomes more concentrated, there is a tendency for calcium and magnesium to precipitate as carbonates thus, increasing the relative proportion of sodium as a consequence. RSC can be calculated using the equation below employing data of alkalinity, calcium and magnesium.

$$RSC = (\text{Alkalinity} * 0.0333) - (\text{Ca}^{2+} + \text{mg}^{2+})$$

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Vol. 6, Issue 1, January 2017

(Where concentration of Ca^{2+} and Mg^{2+} are in meq/L and alkalinity values in mg/L).

In 2014, in pre monsoon period RSC value varied -1.44Meq/Lat (S-7), to 1.78 Meq/L at(S-38) during post monsoon - 0.56Meq/Lat (S-16) to 2.16 Meq/Lat (S-12) value recorded at during post monsoon 2014 (Table.1).

10. CSSRI Classification for Irrigation Suitability. As per CSSRI classification, out of sixty stations, all the stations are found to be good in quality for the purpose of irrigation. In general, these waters were of Ca-Na-Mg type with the dominance of HCO_3^- and CO_3 in case of good quality waters. The poor water quality belonged to categories of A1, B2, B3, C1, C2 and C3 which are either having accumulation of salts (high Ec) or high Sodium Absorption Ratio (SAR) or Residual Sodium Carbonate (RSC). Under the category of Saline Waters, There are thirty eight stations were come under Marginally Saline (B1) category there is no within Saline (B2) category and in high SAR Saline (B3) Category. While classify the water with respect to Alkali category, No station is identified under Marginally alkali (C1) category and three stations are in Alkali (C2) category. Four stations are observed in Highly Alkali (C3) category. The thematic map shows the representation of classification of different waters with respect to CSSRI for irrigation suitability.

XI. CONCLUSION

Sixty groundwater samples were collected from different parts of Badvel taluka and analysed for, EC, Total hardness, Total Alkalinity, Ca^{2+} , Mg^{2+} , Na^+ , and K^+ , using standard procedures. The values of all the groundwater samples are compared with the standard permissible value. Total Hardness are not exceeding the permissible limit in most of the groundwater samples. The EC value during pre-monsoon season of 2014 varies from 876 to 2238 and in post monsoon season the difference ranges between 814 and 2180. According to classification of drinking water on the basis of TDS values, all the groundwater samples are found to be non-saline. The results of total dissolved solids of both the seasons fall under the fresh water and slightly saline categories. Total hardness of both the seasons fall under very hard category. Hardness in 2014, there was no appreciable variation between the pre and post monsoon period water quality. Almost all areas of pre and post monsoon periods fall under the low ion concentration of < 500 mg/L category. In premonsoon, 5 sample and in post monsoon 2 samples were exceeded the permissible limits (According to BIS, maximum permissible limits are 200mg/l except in study area). In all the stations calcium were recorded within the permissible limits during pre and post monsoon, None of samples were above the standard limit in pre monsoon and post monsoon seasons, from this study, it is confirmed that the value of sodium for the groundwater sample is well within the permissible limit (200 mg/L) suggested by WHO. The results of sodium percentage of both the seasons fall 28 samples under permissible and 36 samples under doubtful during pre-monsoon and 32 stations permissible 24 samples were recorded under doubtful. In 2014, SAR shows no appreciable difference between pre monsoon and post monsoon periods. The output of SAR shows 100 per cent of the samples fall under excellent to good category (<10) (Meq/L) under permissible category. The irrigation water quality was classified based on USSL Fig.11 indicating that in 2014 out of 60 samples, 100 % (in pre monsoon) and out of 100 per cent (in post monsoon) of the water samples belong to good category while other samples fall under moderate to poor water category. The study was carried out in entire Badvel Taluk. GIS technologies can provide appropriate platform for convergent analysis of large volume of multi-disciplinary data and decision making for ground water studies can be effectively done. The GIS bare zoning of groundwater quality map may be used as a guideline for predicting the groundwater quality to new areas. The present study provides a guideline for solving water quality problem in Badvel Taluk. From the obtained results, it is suggested to monitor the groundwater quality and to assess periodically in this study area to prevent the further contamination.

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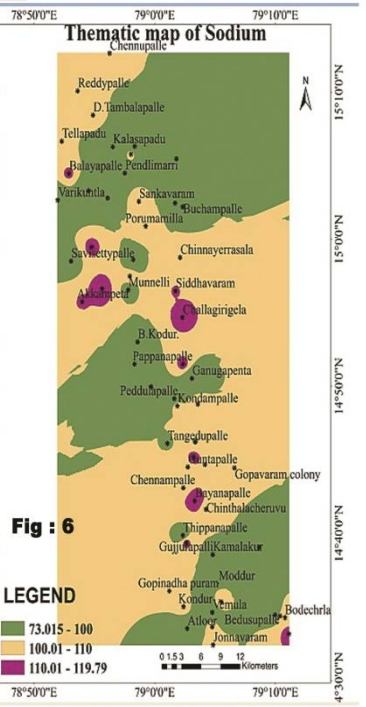
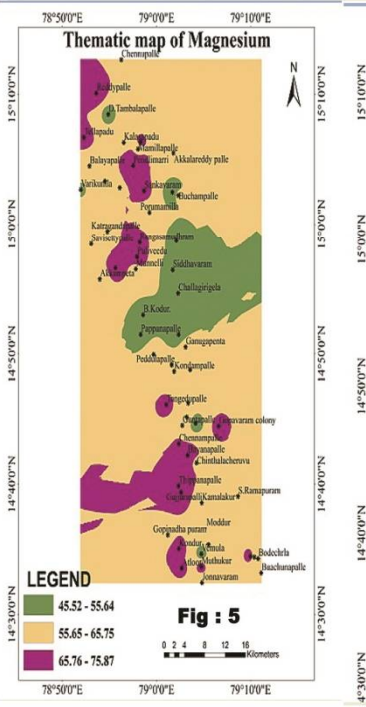
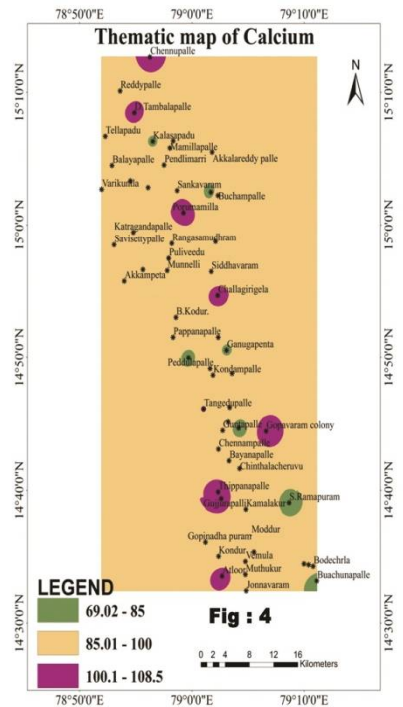
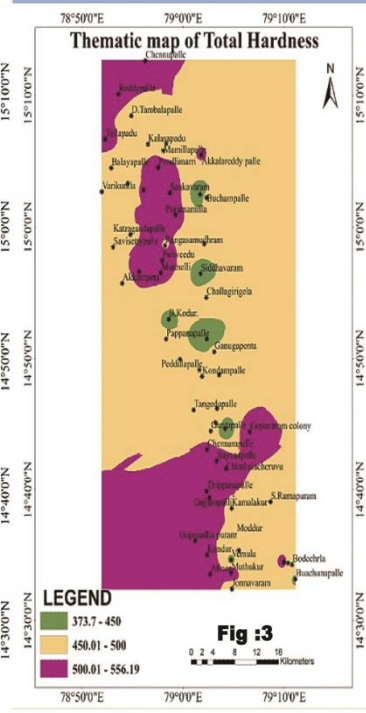
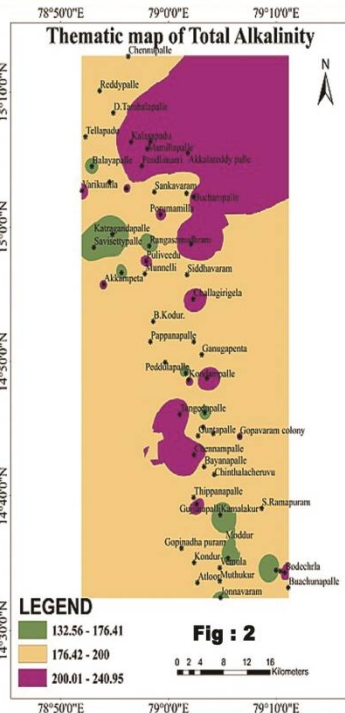
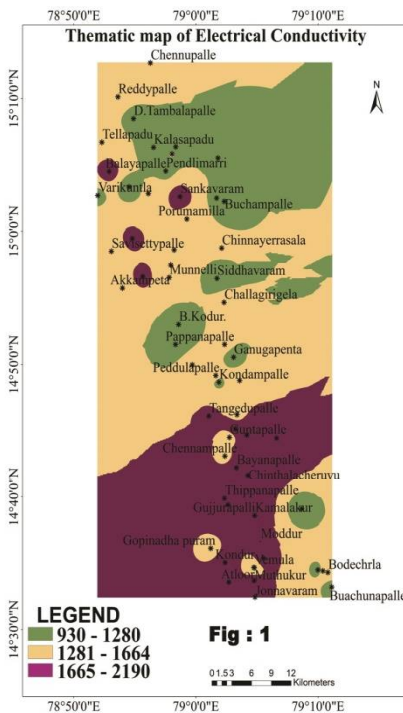
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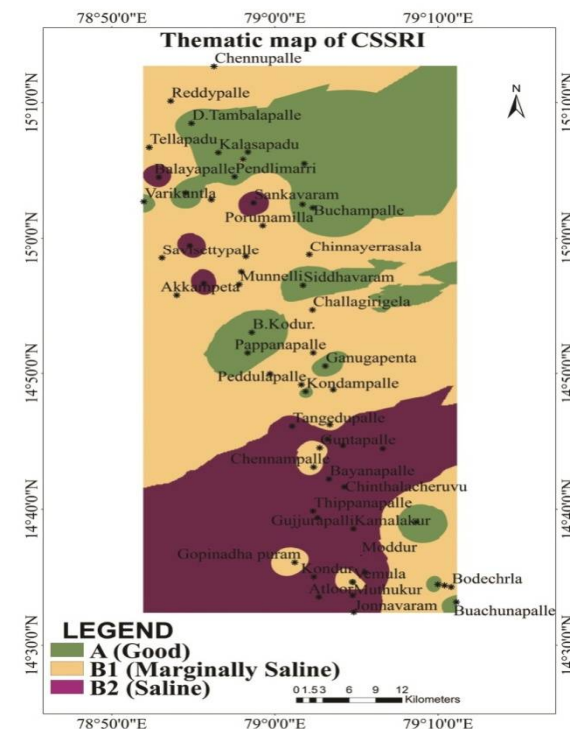
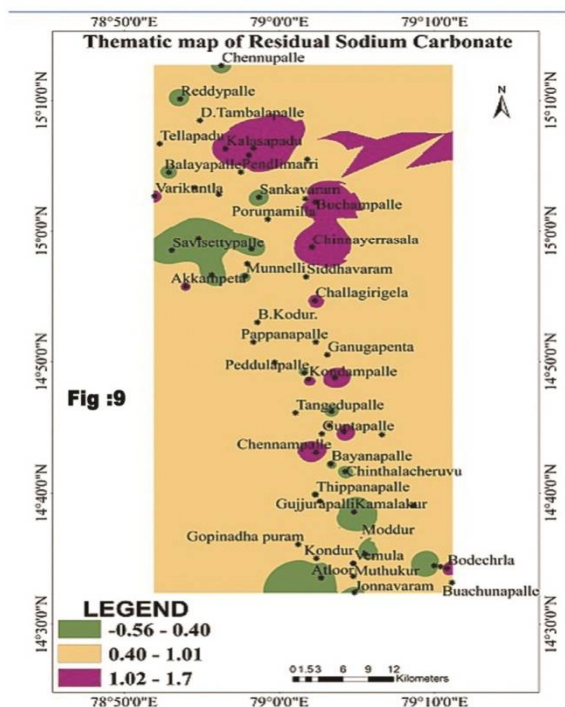
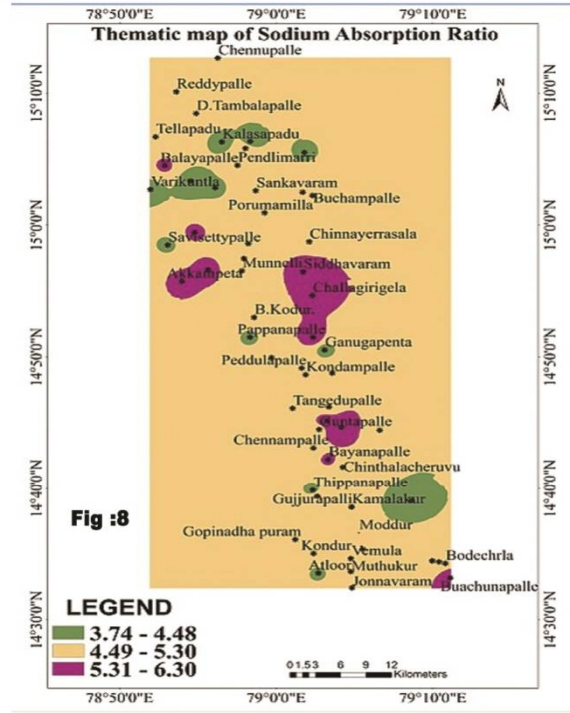
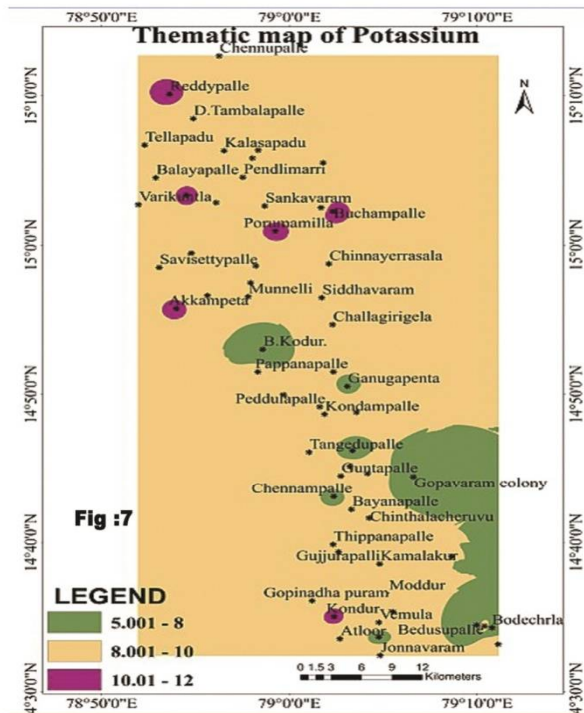


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(An ISO 3297: 2007 Certified Organization)

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Vol. 6, Issue 1, January 2017

S.No	Stations	Ec	TA	TH	Ca	Mg	Na	K	SAR	Na%	RSC
		μ/Mhos	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Meq/L	Meq/L	Meq/L
1	S-1	1462	185.00	412.38	88.70	46.50	115.00	8.00	6.02	62.96	1.00
2	S-2	1707	167.50	477.60	91.00	61.00	102.00	10.00	5.02	57.04	0.31
3	S-3	1958	200.50	531.20	98.50	69.50	102.50	7.00	4.80	55.20	0.65
4	S-4	1780	177.00	538.45	105.50	67.00	94.50	9.00	4.37	52.50	0.09
5	S-5	1928	182.00	514.50	91.00	70.00	102.00	10.50	4.86	55.28	0.42
6	S-6	1189	195.50	432.95	92.00	49.50	87.50	9.00	4.49	55.21	1.08
7	S-7	2055	166.00	478.25	97.00	57.50	105.20	8.50	5.14	57.75	0.23
8	S-8	1458	182.00	504.55	98.50	63.00	101.00	9.00	4.85	55.43	0.41
9	S-9	1793	162.00	489.20	94.00	62.00	92.00	8.50	4.48	54.29	0.12
10	S-10	1584	163.00	446.20	85.00	57.00	113.50	10.00	5.80	61.18	0.42
11	S-11	930	192.00	449.30	80.50	60.50	73.00	8.00	3.74	51.00	1.02
12	S-12	1479	238.00	496.60	94.50	63.50	104.50	5.50	5.08	57.86	1.60
13	S-13	1135	175.00	439.00	69.00	65.00	119.00	10.00	6.29	63.70	0.82
14	S-14	1386	197.00	482.35	97.00	58.50	101.50	10.00	4.96	56.08	0.83
15	S-15	1148	132.00	514.50	91.00	70.00	91.00	6.00	4.36	53.75	-0.58
16	S-16	2047	200.50	556.20	108.50	69.50	102.50	5.00	4.67	54.46	0.45
17	S-17	1451	166.00	483.15	96.50	59.00	99.00	6.50	4.81	56.08	0.21
18	S-18	2070	214.00	542.00	102.00	70.00	115.00	9.00	5.33	57.41	0.84
19	S-19	1878	188.00	534.70	104.00	67.00	87.30	10.00	4.05	50.51	0.34
20	S-20	2191	189.00	554.10	97.00	76.00	117.50	8.00	5.41	57.40	0.32
21	S-21	2020	177.00	503.65	96.50	64.00	107.00	9.50	5.14	57.15	0.33
22	S-22	2177	175.00	491.95	91.00	64.50	115.50	8.50	5.63	59.92	0.39
23	S-23	1444	241.00	514.70	96.00	67.00	106.50	7.50	5.08	56.94	1.56
24	S-24	1339	196.00	464.95	92.50	57.00	103.50	9.00	5.15	58.05	0.93
25	S-25	2112	188.00	373.60	74.00	46.00	108.50	10.00	6.09	64.18	1.36
26	S-26	1504	220.50	478.35	99.50	56.00	106.00	9.00	5.18	57.60	1.30
27	S-27	1812	219.00	486.65	100.50	71.50	98.50	9.50	4.55	53.32	0.94
28	S-28	1174	209.50	466.35	86.50	61.00	103.00	10.00	5.19	57.96	1.24
29	S-29	1430	159.00	466.75	96.50	55.00	92.50	10.00	4.58	54.88	0.15
30	S-30	1482	188.50	452.60	81.00	61.00	94.50	8.50	4.84	57.14	0.93
31	S-31	1072	194.00	454.45	96.50	52.00	87.50	8.50	4.35	53.85	0.91
32	S-32	1019	185.00	440.90	96.00	49.00	92.00	6.00	4.77	55.60	0.80
33	S-33	1315	176.50	502.40	96.00	64.00	96.00	8.50	4.61	54.73	0.33
34	S-34	1046	179.00	460.45	82.50	62.00	79.50	7.50	4.04	52.60	0.69
35	S-35	1420	209.50	477.75	105.00	52.50	117.00	10.00	5.66	59.50	1.04
36	S-36	1081	181.00	418.85	88.00	48.50	110.50	8.00	5.75	61.84	0.90
37	S-37	1303	221.00	455.80	99.50	50.50	103.80	9.50	5.15	57.91	1.42
38	S-38	1666	216.00	544.40	100.50	71.50	103.00	8.50	4.78	54.80	0.88
39	S-39	1390	159.00	497.45	85.00	69.50	91.40	8.50	4.48	54.33	0.09

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Vol. 6, Issue 1, January 2017

40	S-40	1461	203.00	516.00	108.00	60.00	105.70	10.50	4.96	55.53	0.70
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S.No	Stations	Ec	TA	TH	Ca	Mg	Na	K	SAR	Na%	RSC
		mhos/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Meq/L	Meq/L	Meq/L
41	S-41	1040	215.00	484.85	98.00	58.50	94.50	10.50	4.59	54.49	1.17
42	S-42	1240	173.00	381.55	78.00	45.50	97.00	9.50	5.31	60.63	0.99
43	S-43	1130	209.50	503.30	98.00	63.00	91.30	8.50	4.38	53.39	0.97
44	S-44	1361	202.00	468.50	89.00	60.00	110.90	10.50	5.54	59.61	1.06
45	S-45	1870	173.00	519.85	91.50	71.00	120.00	8.00	5.73	59.87	0.21
46	S-46	1831	156.00	495.80	95.00	63.00	114.50	9.50	5.55	59.09	-0.04
47	S-47	1313	201.00	501.95	95.00	64.50	90.50	9.50	4.36	53.21	0.83
48	S-48	1371	170.00	490.10	96.00	61.00	89.00	8.50	4.31	53.19	0.26
49	S-49	1002	181.00	480.55	93.00	60.50	80.00	10.50	3.99	50.15	0.55
50	S-50	1185	206.00	463.90	97.00	54.00	83.50	8.50	4.13	52.61	1.10
51	S-51	1984	169.00	480.65	95.50	59.00	113.00	8.50	5.54	59.37	0.29
52	S-52	2114	177.50	537.00	100.00	70.00	106.00	8.50	4.96	55.85	0.15
53	S-53	1184	214.00	546.60	94.00	76.00	100.00	9.00	4.68	54.32	0.88
54	S-54	1058	214.00	493.90	88.50	66.50	82.50	8.50	4.04	51.75	1.18
55	S-55	1303	237.50	483.65	88.50	64.00	104.00	9.00	5.12	57.73	1.70
56	S-56	1070	203.00	469.90	83.00	64.00	83.00	8.00	4.22	52.84	1.12
57	S-57	1536	188.50	516.55	91.00	70.50	103.50	10.00	4.96	56.15	0.54
58	S-58	1124	198.00	467.50	105.00	50.00	107.30	8.50	5.25	58.28	0.86
59	S-59	1578	184.00	542.05	93.00	75.50	100.40	10.50	4.70	54.30	0.31
60	S-60	1573.5	183.00	511.70	103.00	62.00	107.00	8.50	5.06	56.66	0.36