ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 1, Issue 4, August 2016

Hydro chemical Analysis and Evaluation of Groundwater Quality in Kunigal Taluk, Tumkur District, Karnataka State, India

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***Abstract:* -- Kunigal Taluk is located in the southeastern corner of Tumkur district in Karnataka state. The taluk covers an area of 981.55 Sq.km, and average rainfall of 600-817mm. Kunigal Taluk is bounded by Latitude N 12^{0}44$^'$38.74$^{''}$ to13^{0}8$^'$1.16$^{''}$ and longitude E 76^{0}49$^'$43$^{''}$ to 77^{0}9$^'$57''. The main part of the area is covered under Survey of India (SOI) Toposheet numbers 57C/16, 57G/4, 57D/13, 57H/1 and 57H/2 (Scale 1:50,000). Kunigal Taluk falls in the southern dry agro-climatic zone. The semiarid region and frequently facing water scarcity as well as quality problems. The major sources of employment are agriculture, horticulture and animal husbandry, engaging almost 80% of the workforce for the livelihood. Water samples are collected from 98 stations during pre-monsoon and 98 locations during post-monsoon of the year 2014, and were subjected to analysis for chemical characteristics. The type of water that predominates in the study area is Ca-Mg-HCO_3 type during post-monsoon seasons of the year 2014, based on hydro-chemical contents. Besides, suitability of water for irrigation is evaluated based on sodium adsorption ratio, residual sodium carbonate, sodium percent, salinity hazard and USSL diagram.**

***Keywords:* ----Groundwater, chemical characters, chemical classification, SAR, RSC, USSL diagram**

I. INTRODUCTION

Water quality analysis is one of the most important aspects in groundwater studies. The hydro chemical study reveals quality of water that is suitable for drinking, agriculture and industrial purposes. Further, it is possible to understand the change in [1, 2] quality due to rock-water interaction or any type of anthropogenic influence.

Groundwater often consists of seven major chemical elements- Ca^{+2}, Mg^{+2}, Cl^{-1}, HCO_3^{-1} Na^{+1}, K^{+1}, and $SO4^{-2}$.

The chemical parameters of groundwater play a significant role in classifying and assessing water quality. Considering the individual and paired ionic concentration, certain indices are proposed to find out the alkali hazards. Residual sodium carbonate (RSC) can be used as a criterion for finding the suitability of irrigation waters. It was observed that the criteria used in the classification of waters for a particular purpose considering the individual concentration may not find its suitability for other purposes and better results can be obtained only by considering the combined chemistry of all the ions rather than individual or paired ionic characters [3-5]. Chemical classification also throws light on the concentration of various predominant cations, anions and their interrelationships. A number of techniques and methods have been developed to interpret the chemical data. Zaporozee [6] has summarized the various modes of data representation and has discussed their possible uses.

Presentation of chemical analysis in graphical form makes understanding of complex groundwater system simpler and quicker. Methods of representing the chemistry of water like Collin's bar diagram [5], radiating vectors of Maucha [7], and parallel and horizontal axes of Stiff [8], have been used in many parts of the world to show the proportion of ionic concentration in individual samples. Subramanian [9] followed a series of methods to interpret and classify the chemistry of groundwater in hard rock, including coastal zones in the southern parts of India.

The objective of the present work is to discuss the major ion chemistry of groundwater of Kunigal Taluk. In this case the methods proposed by piper, Back and Hanshaw, Wilcox, Eaton, Todd [10] and USSL (US Salinity Laboratory) classification have been used to

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International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
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study critically the hydrochemical characteristics of groundwater of KunigalTaluk.

Study Area

. The major industries are that of chemicals, oil, cotton, soap, tools, food processing, rice mills, stone crushing and mining. Occurrence, movement and storage of groundwater are influenced by lithology, thickness and structure of rock formations. Weathered and fractured granites, granitic gneiss form the main aquifer in Kunigal, Taluk. Ground water in the study area occurs under water table conditions in the weathered and fractured granite, Gneisses. There is no perennial river in the study area. The major ion chemistry of groundwater of kunigal, Taluk has not been studied earlier.

Figure 1: Location map

Methodology

Groundwater samples were collected from 98 locationslimits during pre-monsoon period (October 2013). Post-monsoon (April 2014) period samples were collected Kunigal taluk limits (Fig. 2). The collected water samples were transferred into precleaned polythene container for analysis of chemical characters. Chemical analyses were carried out for the major ion concentrations of the water samples collected from different locations using the standard procedures recommended by APHA-1994 [12]. The analytical data can be used for the classification of water for utilitarian purposes and for ascertaining various factors on which the chemical characteristics of water depend.

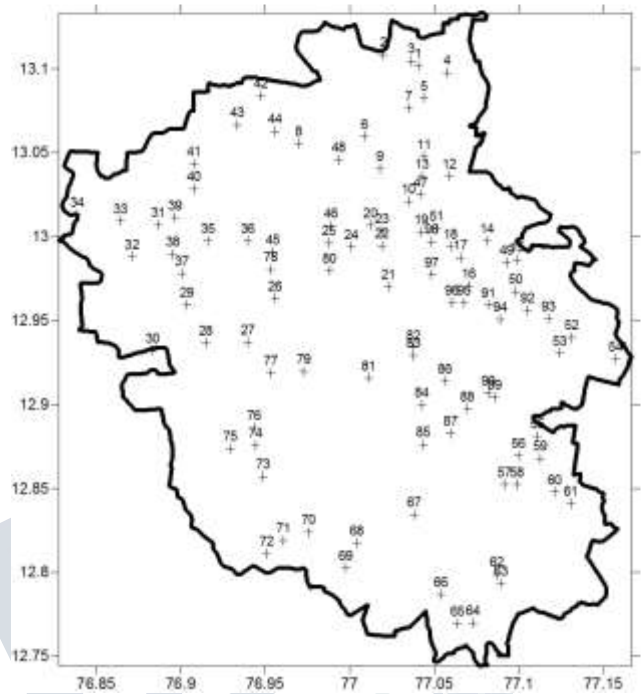

Figure 2: Groundwater sampling locations

Results and Discussion

Maximum and minimum concentration of major ions present in the groundwater from the study area is presented in Table 1. The Piper-Hill diagram [13] is used to infer hydro-geochemical facies. These plots include two triangles, one for plotting cations and the other for plotting anions. The cations and anion fields are combined to show a single point in a diamond-shaped field, from which inference is drawn on the basis of hydro-geochemical facies concept. These tri-linear diagrams are useful in bringing out chemical relationships among groundwater samples in more definite terms rather than with other possible plotting methods.

Chemical data of representative samples from the study area presented by plotting them on a Piper-tri-linear diagram for pre-and post-monsoon (figures 3 and 4).

These diagrams reveal the analogies, dissimilarities and different types of waters in the study area, which are identified and listed in Table 2. The concept of hydrochemicalfacies was developed in order to understand and identify the water composition in

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 1, Issue 4, August 2016

different classes.

Table 1: Maximum and minimum concentration of majorions in groundwater samples

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International Journal of Engineering Research in Mechanical and Civil Engineering
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S. No	Parameters	Minimum	Maximum	Mean	Standard deviation	Variance
1	Ca	8.02	110.62	59.32	8.23	13.88
2	Mg	27.18	190.57	53.54	17.57	32.81
3	Na	15.00	120.00	44.70	21.81	48.79
4	K	1.00	111.00	20.50	28.32	138.14
5	CO_3	0.00	0.00	0.00	0.00	0.00
6	HCO_3	139.84	483.12	311.48	62.82	20.17
7	Cl	51.98	475.85	263.92	66.22	25.09
8	NO_3	4.00	110.00	57.00	22.92	40.21
9	SO_4	7.00	67.00	37.00	16.65	45.00
10	F	0.16	1.50	0.83	0.19	22.61
11	TH	176.00	836.00	506.00	94.78	18.73
12	TDS	286.00	1570.0	928.00	250.4	26.98
13	EC	363.00	2460.0	1411.5	384.0	27.21
14	pH	6.16	6.95	6.57	0.18	2.74
15	Fe	0.10	1.20	0.65	0.18	27.69

Figure 3: Post-monsoon groundwater samples plotted inpiper-Trilinear diagram

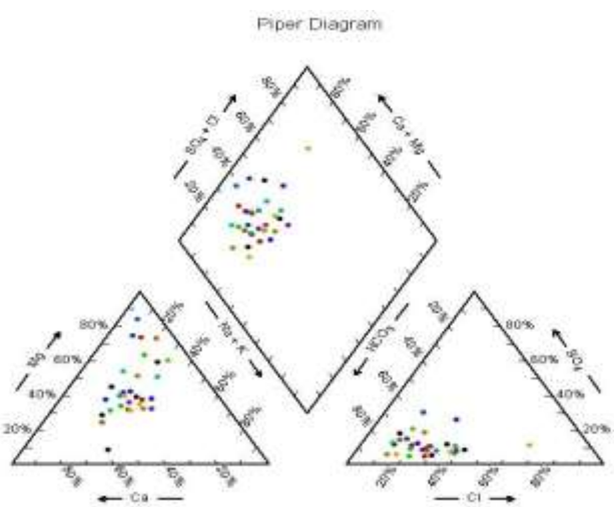

Figure 4: Pre-monsoon groundwater samples plotted inpiper-Trilinear diagram

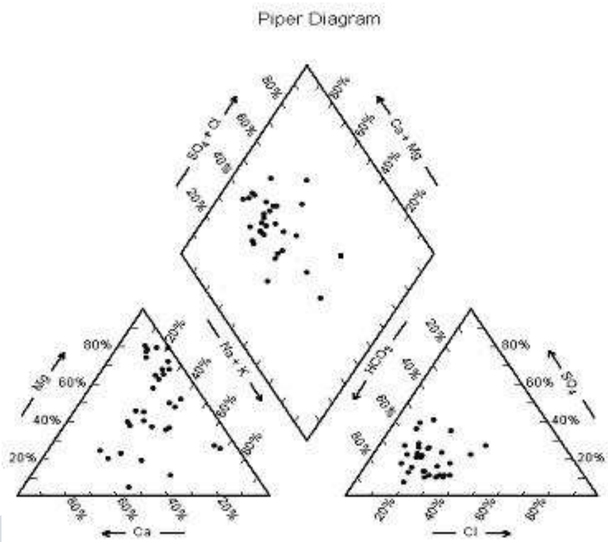

Table 2: Characterization of groundwater of Kunigaltalukof Karnataka on the basis of Piper tri-linear diagram

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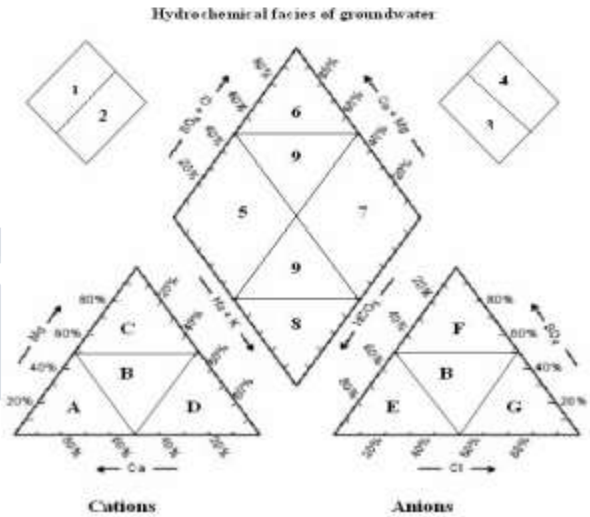
Subdivision of the diamond	Characteristics of corresponding subdivisions of diamond-shaped fields	Percentage of samples in this category	
		Pre-Monsoon	Post-Monsoon
1	Alkaline earth (Ca+Mg) Exceed alkalies (Na+K)	38	60
2	Alaklies exceeds alkaline earths	10	20
3	Weak acids (CO_3+HCO_3) exceed Strong acids (SO_4+Cl)	27	72
4	Strong acids exceeds weak acids	10	12
5	Magnesium bicarbonate type	52	46
6	Calcium-chloride type	10	25
7	Sodium-chloride type	30	20
8	Sodium-Bicarbonate type	10	5
9	Mixed type (No cation-anion exceed 50%)	28	32

Organic matter are recognizable parts of different characters belonging to any genetically related system. Hydro chemical matter are distinct zones that possess action and anion concentration categories. To define composition class, Back and co-workers [14] suggested subdivisions of the tri-linear diagram (figure 5). The interpretation of distinct matter from the 0 to 15% and 85 to 100% domains on the diamond-shaped cation to anion graph is more helpful than using equal 15% increments. It clearly explains the variations or domination of cation and anion concentrations during pre-monsoon and post-monsoon. Ca-Mg-type of water predominated during pre-monsoon. The percentage of samples falling under Ca-Mg-type was 90 during pre-monsoon season. Similar type of water is predominated during post-monsoon also with 100 % water samples. For anion concentration, HCO_3-type of water predominated during pre-monsoon with 88% samples and during post-monsoon with 91% samples. There is no significant change in the hydro-chemical matter noticed during the study period (pre- and post-monsoon), which indicates that most of the major ions are natural in origin. The reason is groundwater passing through igneous rocks dissolves only small quantities of mineral matters because of the relative insolubility of the rock composition.



Legend

A- Calcium type
B- No Dominant type
C- Magnesium type
D- Sodium and potassium type
E- Bicarbonate type
F- Sulphate type
G- Chloride type

Figure 5: Classification diagram for anion and cationfacies in the form of major-ion percentages. Water types are designed according to the domain in which they occur on the diagram segments.

Water hardness is caused primarily by the presence of cations such as calcium and magnesium and anions such as carbonate, bicarbonate, chloride and sulfate in water. Water hardness has no known adverse effects; however, some evidence indicates its role in heart disease [15]. Hard water is unsuitable for domestic use. In Kunigal region, the total hardness varies between 70 to176ppm for the pre-monsoon (May 2014) period. For the post-monsoon period (Nov 2013), the value varies from 55 to 836 ppm.

According to Sawyer and McCarty's[16] classification for hardness, 26 samples fall under moderately hard class and 98 samples fall under hard and very hard class for pre-monsoon water samples. The hardness classification is given in Table 3. The suitability of groundwater for irrigation purposes depends upon its mineral constituents. The general criteria for judging the quality are: (i) Total salt concentration as measured by electrical conductivity (EC) (ii) Relative proportion of sodium to other principal cations as expressed by SAR, (iii) Bicarbonate (HCO_3^-) .

Table 3: Classification of water based on hardness bySawyer and McCarthy

Hardness as $CaCO_3$(ppm)	*Water class*	*Pre-monsoon samples*	*Post monsoon samples*
0-75	Soft	70	55-70
		(1 sample)	(3 samples)
75-150	Moderate	104 - 150	95-150
		(26 samples)	(56 samples)
150-300	Hard	155 - 300	152-300
		(16 samples)	(29 samples)
>300	Very hard	304-1060	305-824
		(2 samples)	(10 samples)

Wilcox [17] classified groundwater for irrigation purposes based on per cent sodium and Electrical conductivity. Eaton [18] recommended the concentration of residual sodium carbonate to determine the suitability of water for irrigation purposes. The US Salinity Laboratory of the Department of Agriculture adopted certain techniques based on which the suitability of water for agriculture is explained.

The sodium in irrigation waters is usually denoted as per cent sodium and can be determined using the following formula .

$$\% Na = (Na^+) X 100/ (Ca^{2+} + Mg^{2+} + Na^{+1} + K^{+1})$$

where the quantities of Ca^{2+}, Mg^{2+} Na^+ and K^+ are expressed in milliequivalents per litre (epm).

The classification of groundwater samples with respect to per cent sodium is shown in Table 4. It is observed that about 85 samples are excellent to good during pre-monsoon and 92 samples are excellent to good during post- monsoon. In waters having high concentration of bicarbonate, there is tendency for calcium and magnesium to precipitate as the water in the soil becomes more concentrated. As a result, the relative proportion of sodium in the water is increased in the form of sodium carbonate. RSC is calculated using the following equation.

$$RSC = (HCO_3^- + CO_3^{2-}) – (Ca^{2+} + Mg^{2+})$$

where all ionic concentrations are expressed in epm.

Table 4: Sodium percent water class

Sodium (%)	Water class	Pre-monsoon Samples	Post-monsoon samples
<20	Excellent	3.34-19.80 (90 samples)	7.38-19.94 (65 samples)
20-40	Good	20.04-39.92 (16 samples)	20.25-39.88 (49 samples)
40-60	Permissible	40.07-57.25 (18 samples)	40.48-59.90 (25 samples)
60-80	Doubtful	61.29-61.46 (1 samples)	63.16 (1 sample)
>80	Unsuitable	-	-

According to the US Department of Agriculture, water having more than 2.5 epm of RSC is not suitable for irrigation purposes. Groundwater of the study area is classified on the basis of RSC and the results are presented in Table 5 for both pre- and post-monsoon seasons. Based on RSC values, over 96 samples have values less than 1.26 and are safe for irrigation during pre-monsoon. During post-monsoon 95 samples were safe for irrigation. Only 3samples in the pre-monsoon and 4 samples in the post-monsoon are fair.

Table 5: Groundwater quality based on RSC (Residualsodium carbonate)

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International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
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RSC (epm)	*Remark on quality*	*Pre-monsoon samples*	*Post-monsoon samples*
<1.25	Good	16.47 - 1.24	7.03 to 1.20
		(267 samples)	(272 samples)
1.25-2.5	Doubtful	1.46-1.55	1.27 to 1.60
		(2 samples)	(7 samples)
>2.5	Unsuitable		

The most important characteristics of irrigation water in determining its quality are: (i) Total concentration of soluble salts; ii) Relative proportion of sodium to other principal cations; (iii) Concentration of boron or other element that may be toxic, and (iv) Under some condition, bicarbonate concentration as related to the concentration of calcium plus magnesium. These have been termed as the salinity hazard [19], sodium hazard, boron hazard and bicarbonate hazard. In the past, the sodium hazard has been expressed as per cent sodium of total cations. A better measure of the sodium hazard for irrigation is the SAR which is used to express reactions with the soil. SAR is computed as

$$SAR = \frac{Na^{+}}{\left\{\frac{Ca^{2-} + Mg^{2+}}{2}\right\}^{1/2}}$$

where all ionic concentrations are expressed in epm

The classification of groundwater samples from the study area with respect to SAR is represented in Table 6. During Pre- and post-monsoon, the SAR value of all the samples are found to be less than 10, and are classified as excellent for irrigation When the SAR and specific conductance of water are known, the classification of water for irrigation can be determined by graphically plotting these values on the US salinity (USSL) diagram (figure 6 & 7). The groundwater of Kunigaltaluk is in general Ca-Mg-HCO_3 type during both pre- and post monsoon seasons of the year 2014. About 98% of the samples are grouped within C2S1 and C3S1 classes in both pre- and post-monsoon (figure 6 & 7).

Table 6: Sodium hazard classes based on USSL classification

Sodium Hazard class	*SAR in Equivalents per mole (Alakalinity)*	*Remark on quality*	*Pre-monsoon samples*	*Post-monsoon samples*
S1	10	Excellent	0.11-3.54	0.30-3.52
			(all 92 samples)	(all 90 samples)
S2	10 - 18	Good		
S3	18-26	Doubtful		
S4 and S5	>26		Unsuitable	

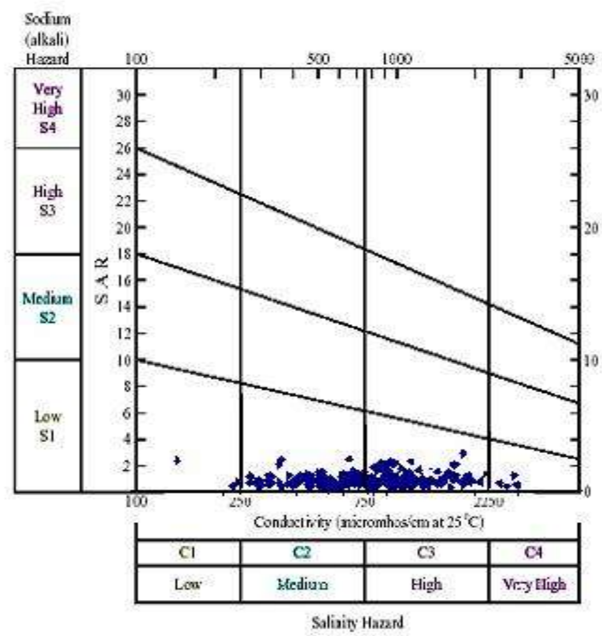

Figure 6: USSL classification of groundwater during pre-monsoon

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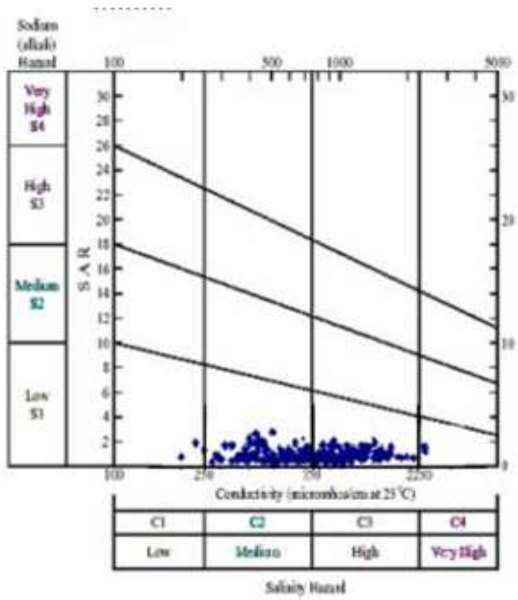

Figure 7: USSL classification of groundwater duringpost-monsoon

For the purpose of diagnosis and classification, the total concentration of soluble salts (salinity hazard) in irrigation water can be expressed in terms of specific conductance. Classification of groundwater based on salinity hazard is presented in table 7. It is found from the EC value, only 14 samples during pre-monsoon and 10 samples during post-monsoon were found to be unsuitable for irrigation purposes.

Table 7: Salinity hazard classes

Salinity hazard class	*EC in (micro-mohs/cm)*	*Remark on quality*	*Pre-monsoon samples*	*Post-monsoon samples*
C1	100-250	Excellent	130-230 (3 samples)	200-230 (2 samples)
C2	250-750	Good	260-750 (129samples)	270 – 750 (147 samples)
C3	750-2,250	Doubtful	760-2200 (133samples)	760 – 2050 (127 samples)
C4 & C5	>2,250	Unsuitable	2500-3000 (4 samples)	2270-2300 (3 samples)

In Kunigal Taluk, the groundwater is generally Ca-Mg-HCO_3 type, which is mainly due to the geology of the area which comprises igneous rocks of crystalline nature, in which the major units are gneisses and granites. Ground water in the study area occurs under water table conditions in the weathered and fractured granite, Gneisses, and 480 surface storage water tanks are available in topography, the concentration of partials may be diluted with maximum extent.

Conclusions:

Based on the above research following conclusions arrived

1. The type of water that predominates in the study area is Ca-Mg-HCO_3 type during both pre-and post-monsoon seasons of the year 2014, based on hydro-chemical materials.
2. Though the suitability of water for irrigation is determined based on SAR, %Na, RSC and Salinity hazard, it is only an empirical conclusion. In addition to water quality, other factors like soil type, crop type, crop pattern, frequency and recharge (rainfall), climate, etc. have an important role to play in determining the suitability of water.
3. Water is suitable based on the above classification may be suitable in well-drained soils.
4. The suitability of water for irrigation is evaluated based on SAR, %Na, RSC and salinity hazards. Most of the samples in Kunigal Taluk fall in the suitable range for irrigation purpose either from SAR, % Na or RSC values.
5. About 68% of the samples are grouped within C2S1 and C3S1 classes in both pre- and post-monsoon season (figure 6 & 7).
6. Most of the samples in Kunigal Taluk fall in the suitable range for irrigation purpose from USSL diagram.

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