Evaluation of groundwater quality for agriculture purpose in some villages around Vallanadu, Tuticorin, Tamilnadu, India

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Abstract

This study was conducted to evaluate factors regulating groundwater quality in an area with agriculture as main use. Under this study thirty six groundwater samples have been collected from various part of around Vallanadu, Tuticorin district. Groundwater samples were chemically analyzed for major physicochemical parameter in order to understand the different geochemical processes affecting the groundwater quality. The analytical results shows higher concentration of total dissolved solids (25.00%), electrical conductivity (27.78%) and magnesium hazard (8.33%) for pre monsoon and total dissolved solids (19.44%), electrical conductivity (22.22%) and magnesium hazard (22.22%) for post monsoon which indicates signs of deterioration as per BIS standards. The other parameters such as percent sodium, Kelley's ratio, Permeability index and Residual sodium carbonate suggest that the groundwater of the study area is suitable for irrigation purpose.
KEYWORDS: Groundwater quality, hydrochemistry, Vallanadu, Irrigation Quality and Tuticorin District

Introduction

Hydro geochemistry of groundwater is a dynamic process, which undergoes a constant change with reference to time and space. The geochemical quality of groundwater is also related to the nature of host rock as well as the overlying rock types (Raymahasay, 1996). Geochemical character of groundwater is an essential component of scientific management of existing groundwater resources. In the present day an attempt has been made to identify the suitability of existing groundwater with reference to drinking, domestic, industrial and irrigational needs (WHO 1984; Trivedy and Goel 1986; ISI 1991; APHA 1998).

Study area

Vallanadu is a major panchayat in the Tuticorin District of Tamilnadu. The study area (Fig.1) is comprised of the toposheet no. 58H/13 and 58H/14 of 1: 50,000 scales published by the Survey of India in the year 1969. Vallanadu lies about 30 Km west of Tuticorin, which has both rail and Airbase connections. The district receives the rain under the influence of both southwest and northeast monsoons. The rainfall was gradually increases towards south, west and north and attains a maximum around Kayattar (722.5 mm) and Kovilpatti (734.8 mm) in the northwestern part. The district enjoys a hot tropical climate. The high relative humidity prevails throughout the year between 60 and 75%. The annual mean minimum and maximum temperature are 23°C and 40°C respectively.

The Vallanadu area is a high grade metamorphic terrain of almandine amphibolite to granulite facies. The area is essentially comprised of different lithotypes i.e., quartzites, calc-silicate rocks, Khondalites, Composite gneisses, Cordierite gneiesses, charnockites, Grey granites and pink granites and veins of pyroxene granulites and amphibolites. Khondalites of vallanadu area of Kerala Khondalite Belt (KKB) are represented by pelitic, Semipelitic, psammitic and calcareous members (Manimaran et al, 2013).

Groundwater potential Scenario of the study area

The geology of the area is mainly composed of hard rocks and the fractured and well jointed nature of the rocks provide good amount of groundwater. Comparatively the gneissic rocks are with high groundwater potential owing to the weathering and fracturing for a considerable depth. Charnockites are low in water potential but well jointed, sheared Charnockites are good for groundwater potential. Quartzites are mostly granular, well jointed, cracked and fissured and these properties are reasons behind Groundwater potential of quartzites9, 10. The open wells of the area vary in depth from 10 to 40 meters. The important aquifer systems in the district are constituted by (i) unconsolidated and semi-consolidated formations and (ii) weathered and fractured crystalline rocks. The porous formations in the district include sandstones and clays of recent to sub-recent and tertiary age (quaternary). The recent formations comprising mainly sands, clays and gravels are confined to major drainage courses in the district. The maximum thickness of alluvium is 45.0m bgl; whereas the average thickness is about 25.0m. Ground water occurs under water table and confined conditions in these formations and is being developed by means of dug wells and filter points11, 12. The productive zones are encountered in the depth range of 29.5 to 62m bgl. Alluvium, which forms a good aquifer system along the Tambraparani river bed which is one of the major sources of water supply to the villages. The water bearing properties of crystalline formations which lack primary porosity depend on the extent of development of secondary intergranular porosity. The occurrence and movement of ground water in these rocks are under unconfined conditions in the joints and fissures and dependent on the nature and extent of pores and interconnection of fractures zones. The yield characteristics of wells vary considerably depending on the topographic set-up, lithology and nature of weathering.

Methodology

Thirty six groundwater samples were collected from various locations in pre-monsoon (PRM) and post monsoon (POM) of each. The water samples were collected in 1000 ml for major cation and anion study, which were corked immediately to make them airtight. The physical parameters such as pH, EC, TDS and temperature were measured in the field. The major cations and anions were analysed at Spic Research Centre, Tuticorin.

Ground water quality analysis

The groundwater samples were analysed for total dissolved solids (TDS), Sodium (Na), Calcium (Ca) and Magnesium (Mg). TDS was utilization groundwater for irrigational use depends on many factors, such as texture, composition of soil, type of crop, climate, irrigational practices and chemical quality of ground water. The ground water samples were analysed and to judge their suitability for irrigational use. Various irrigational parameters like Sodium Adsorption Ratio (SAR), Percentage of Sodium (% Na), Kelly's ratio (KR), Permeability Index (PI) and Magnesium hazard (HR) are calculated and shown in table 1.

Results and Discussions

Total dissolved solids

In the study area total dissolved solids (TDS) value ranges from 130 mg/l to 4130 mg/l with an average of 1399.39% in pre-monsoon period and 183 mg/l to 7940 mg/l with an average of 1536.78% in post-monsoon period (Table 1). Groundwater can be divided based on the distribution of TDS; Wilcox (1948) and BIS (1998). Above permissible limits are 25% in N-NW and 19.44% N-NW-SE of samples represent in pre-monsoon and post-monsoon respectively. **Figure 2** shows the permissible and not permissible area. High TDS in groundwater is due to anthropogenic activities.

pH

The pH is a measure of the intensity of acidity or alkalinity and measures the concentration of hydrogen ions in water. It has no direct adverse affect on health, however, a low value, below 4.0 will produce sour taste and higher value above 8.5 shows alkaline taste. A pH range of 6.5 – 8.5 is normally acceptable as per guidelines suggested by BIS. In the present study, the fluctuation of pH in the samples was from 6.2 to 8.0. The pH below 7 indicates that the sample water were slightly acidic may be due to the presence of minerals in the groundwater. In the present study, pH < 7 was found in the groundwater samples.

Electrical Conductivity (EC)

Electrical Conductivity is the measure of capacity of a substance or solution to conduct electric current. It is an excellent indicator of TDS which is a measure of salinity that affects the taste of potable water (WHO, 1984). The variation in Electrical Conductivity is based on sedimentary structure and composition of rock. Chemically pure water does not conduct electricity. Any rise in the Electrical Conductivity of water indicates pollution. It is a good and rapid measure of the Total Dissolved Solids. The groundwater samples showed variation in EC in different seasons of the year (Fig.3). It was varied from 210 to 6770 (µs/cm) during PRM and 300 to 8000 (µs/cm) in POM period (Table 2).

Corrosivity Ratio (CR)

According to Rengarajan et al (1990) the groundwater with corrosivity ratio more than 1 are considered to be corrosive water and it cannot be transported through metal pipes. It can only be transported through PVC pipes. The corrosivity ratio in the study area lies between 0.23mg/l to 5.37 mg/l in pre-monsoon and 0.16mg/l to 34.85 mg/l in post monsoon season. Corrosive water exists in most of the location in the study area as shown in Fig.4. During post-monsoon season, the groundwater gets diluted and this leads to lesser concentration of CO3 and HCO3. Due to the dilution of these anions, it is noticed that there is an increase in corrosivity ratio in post-monsoon period. About 18% samples of pre-monsoon and 26% samples of post-monsoon indicates corrosive nature, while 81 % samples pre-monsoon and 74% samples of post-monsoon season are good for irrigation purpose.

The corrosivity ratio is calculated by the following formula. The values are in mg/L.

$$CR = \frac{\frac{Cl\left(\frac{mg}{l}\right)}{35.5} + \frac{2SO_4\left(\frac{mg}{l}\right)}{96}}{2\left(\frac{CO_3 + HCO_3\left(\frac{mg}{l}\right)}{100}\right)}$$

Percent Sodium (% Na)

It is an important parameter to classify the groundwater samples for irrigation purpose. It is calculated by the formula proposed by Doneen (1962) as under;

$$\%\,Na = \frac{(\mathrm{Na} + \mathrm{K})}{(\mathrm{Ca} + \mathrm{Mg} + \mathrm{Na} + \mathrm{K})} \times 100$$

Sodium and carbonate forms alkaline soil, while sodium and chloride forms saline soil are not suitable for the growth of plants (Pandian and Sankar, 2007). Classification of irrigation water based on the values of sodium percentage against EC as proposed by Wilcox (1955), where 58.33% samples of pre-monsoon season and 55.56% samples of post-monsoon season (fig.5) fall in good to permissible limit (Table 3).

Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio is the proportion of sodium to calcium and magnesium, which affect the availability of the water to the crop. SAR is computed by the equation and given in table 4.

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

The U.S. salinity Laboratory of the Department of Agriculture (1954) has proposed a diagram in which EC taken as index of salinity hazard and SAR as an index of sodium hazard. Figure 6 and 7 shows the majority of the water samples both pre-monsoon and post-monsoon respectively fall in the category of C_3S_1 class indicating good to medium typed water which can be used for irrigation (Manimaran, 2012). As per classification of Wilcox (1955), Water with SAR values < 10 is considered as of excellent quality, between10 to 18 is good, between 18 to 26 is fair and above 26 is said to be unsuitable for irrigation.

Kelley's Ratio (KR)

It is the ratio of sodium ion to calcium and magnesium ion. Kelly's ratio is determined for sodium hazard. Water having KR values < 1 is considered to be good for irrigation, whereas water with KR values >1 are not suitable (Kelley, 1951). Out of the total water samples, 100% of samples are in pre-monsoon KR values <1, whereas 88.89% of samples are in KR values <1and 11.11% of samples are in KR values >1 in post-monsoon season (Table 5).

$$K.R = \frac{Na}{Ca + Mg}(epm)$$

Permeability Index (PI)

The soil permeability is affected by long term use of irrigation water. It is influenced by sodium, calcium, magnesium and bicarbonate contents of soil. Doneen (1964) has evolved a criterion for assessing the suitability of water for irrigation based on Permeability Index (PI). :

$$P.I = \frac{Na + \sqrt{HCO_3}}{Ca + Mg + Na} \times 100(epm)$$

The majority of the samples that is 88.89% fall under class-I during pre-monsoon and post-monsoon period and 11.11% of samples fall under class-II during pre-monsoon and post-monsoon period (Fig.8) under sampling programs as per Doneen's classification (Table 7), which indicates that groundwater is good for irrigation.

Magnesium Ratio (MR)

Magnesium ratio is calculated by the formula-

$$M.R = \frac{Mg}{Ca + Mg} \times 100(epm)$$

MR values < 50 are suitable for irrigation and MR values >50 are unsuitable (Lloyd and Heathcote, 1985). Excess amount of magnesium reduces the yield of crop.

High magnesium content in water can affect the quality of soil. 91.67% samples of pre-monsoon and 77.78% of post-monsoon season are suitable, while the remaining 8.33% samples of pre-monsoon and 22.22% of post-monsoon are unsuitable for irrigation (Table 7). High Mg ratio is due to surface water and subsurface water more reacted and passage through the limestone, kankar and granitic rock formation in the study area (Pandian et. al., 2007).

Residual Sodium Carbonate (RSC)

It refers to the residual alkalinity and is calculated for irrigation water by the following formula;

$$RSC = (HCO_3 + CO_3) – (Ca + Mg) \text{ (epm)}$$

The RSC values < 1.25 mg/l are considered as safe for irrigation while those from 1.25 mg/l to 2.5mg/l are marginally suitable for irrigation. If RSC values are > 2.5 the groundwater is unsuitable for irrigation (Eaton, 1950; Richards, 1954). The RSC values of groundwater samples of the study areas ranges from -40 to 522.59 mg/l in pre-monsoon and
-42.40 to -537.60 mg/l, hence suitable to safe for irrigation purpose.

Conclusion

The groundwater suitability for irrigation purpose in and around Vallanadu have been studied and found suitable on the basis of calculated chemical parameters such as sodium percentage, permeability index, and residual sodium carbonate. The sodium absorption ratio fall in good to medium type water also suggest that the water is suitable for irrigation. The above parameters suggest that the area is not having any saline soil. The TDS and EC value decrease while there is increase in magnesium hazard from pre-monsoon to post monsoon period. In an average 70% of the well site in Vallanadu area are very suitable agricultural usages for all crops. 30% well sites located at north, northwest and southeast area with high TDS and magnesium ratio are suitable for coconuts, drumstick, lemon and other saline withstanding crops.

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Table 1 Groundwater classification based on TDS

TDS	Water category	PRM		POM	
		Number of samples	Percentage of samples	Number of samples	Percentage of samples
< 500	Desirable Limit	2	5.56	1	2.78
500-2000	Permissible Limit	25	69.44	28	77.78
> 2000	Not Permissible	9	25.00	7	19.44

Table 2 Groundwater classification based on EC

EC (µS/cm)	Water category	PRM		POM	
		Number of samples	Percentage of samples	Number of samples	Percentage of samples
<1500	Permissible	11	30.56	12	33.33
1500-3000	Not Permissible	15	41.67	16	44.44
>3000	Hazardous	10	27.78	8	22.22

Table 3 Groundwater classification based on %Na for irrigation purpose

Na % Wilcox	Water category	PRM		POM	
		Number of samples	Percentage of samples	Number of samples	Percentage of samples
<40	Good	5	13.89	2	5.56
40-60	Permissible	16	44.44	18	50.00
60-80	Doubtful	6	16.67	7	19.44
>80	Unsuitable	9	25.00	9	25.00

Table 4 SAR based groundwater classification for irrigation

SAR	Water category	PRM		POM	
		Number of samples	Percentage of samples	Number of samples	Percentage of samples
<10	Excellent	36	100	5	13.89
10-18	Good	-	-	31	86.11
>18	Doubtful	-	-		

Table 5 Irrigation water quality based on KR

KR	Water category	PRM		POM	
		Number of samples	Percentage of samples	Number of samples	Percentage of samples
< 1	Good	36	100	32	88.89
> 1	Unsuitable	-	-	4	11.11

Table 6 PI based irrigation water quality

PI	Water category	PRM		POM	
		Number of samples	Percentage of samples	Number of samples	Percentage of samples
Class I	Very Good	32	88.89	32	88.89
Class II	Good	4	11.11	4	11.11
Class III	Bad	-	-	-	-

Table 7 Groundwater classification based on MR for irrigation purpose

MR	Water category	PRM		POM	
		Number of samples	Percentage of samples	Number of samples	Percentage of samples
< 50	Suitable	33	91.67	28	77.78
> 50	Unsuitable	3	8.33	8	22.22

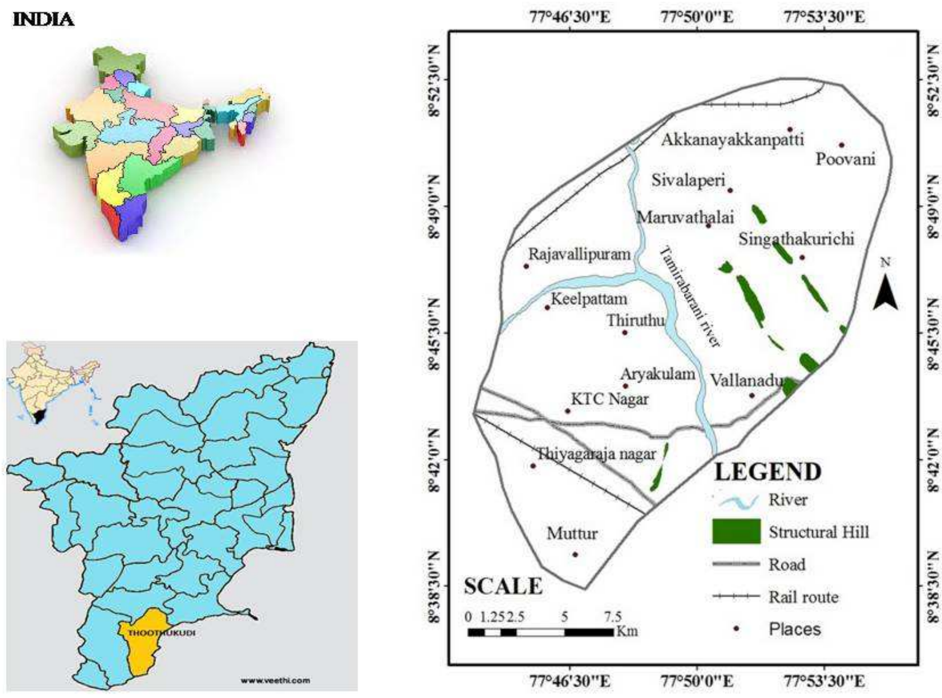
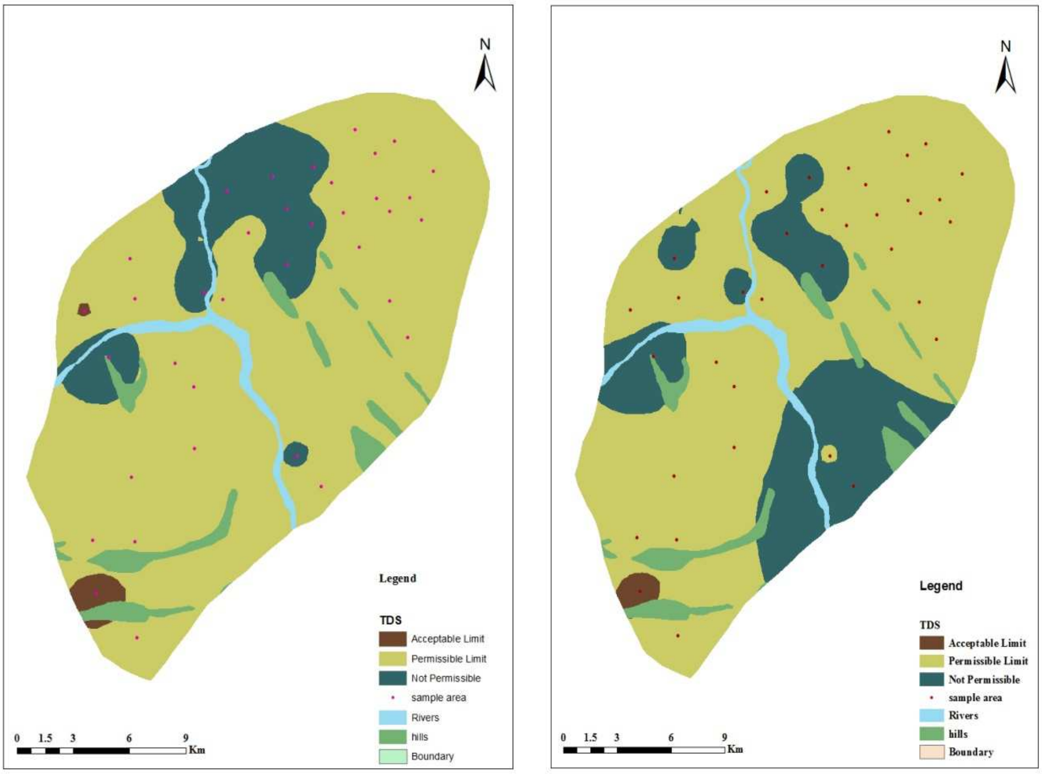
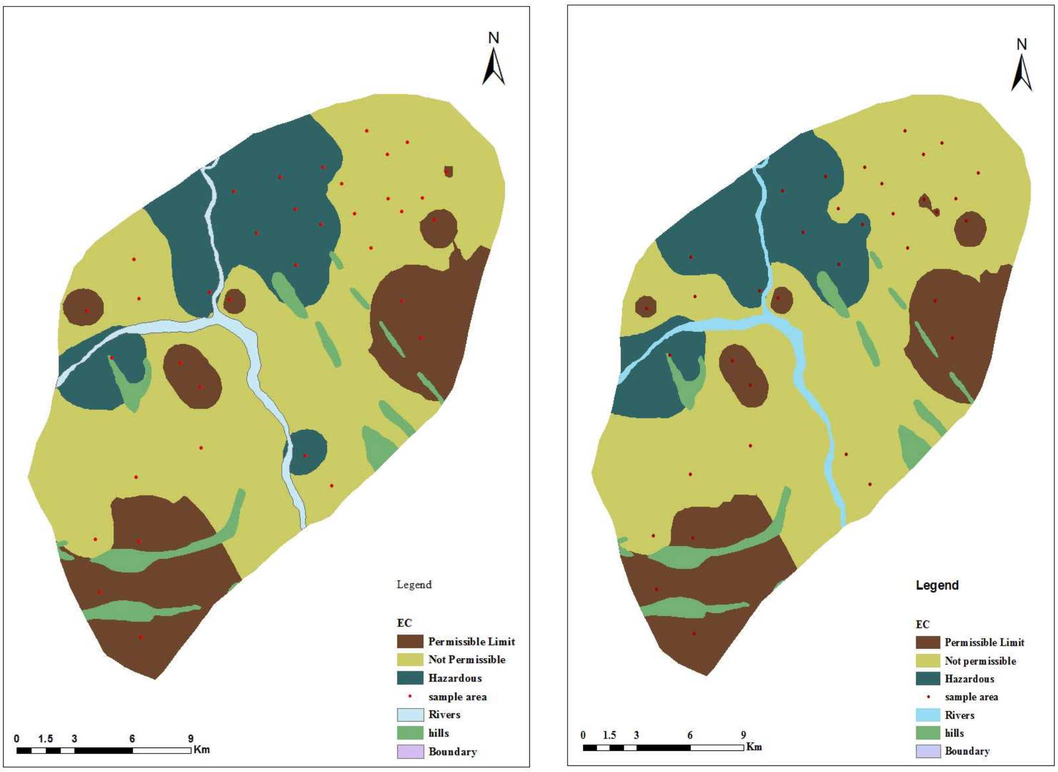


Fig.1 Study area



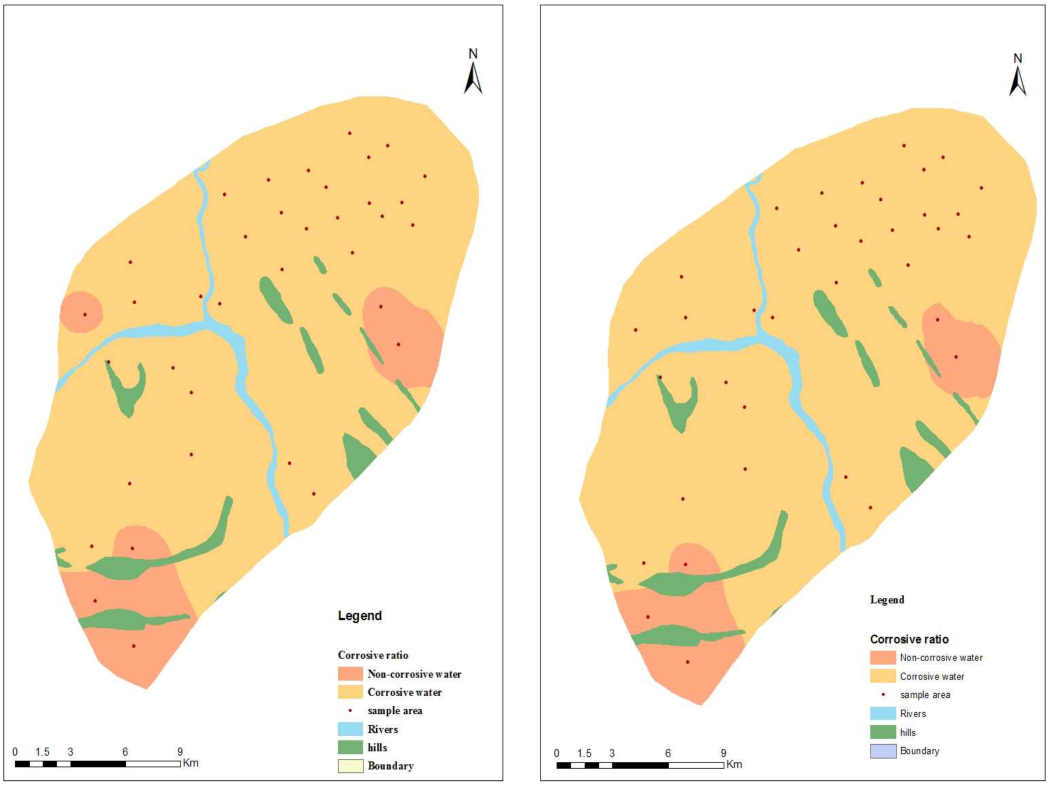
PRM POM

Fig.2: Spatial variation of TDS in the study area



PRM POM

Fig.3: Spatial variation of EC in the study area



PRM POM

Fig.4: Spatial variation of Corrosivity ratio in the study area

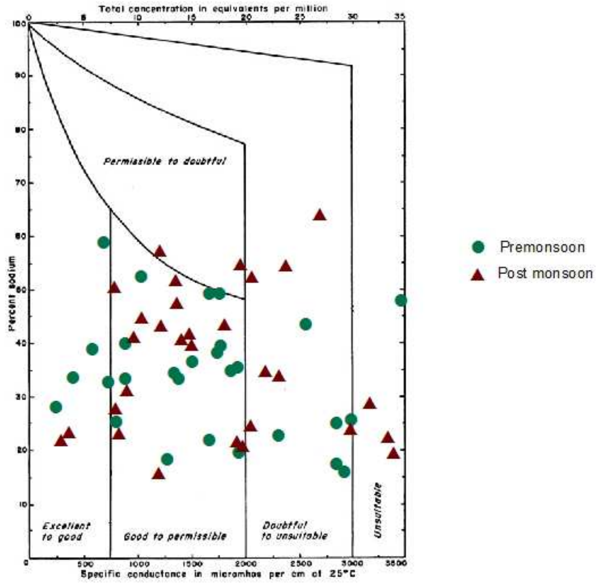


Fig.5: Percent sodium vs EC plot (After Wilcox, 1995)

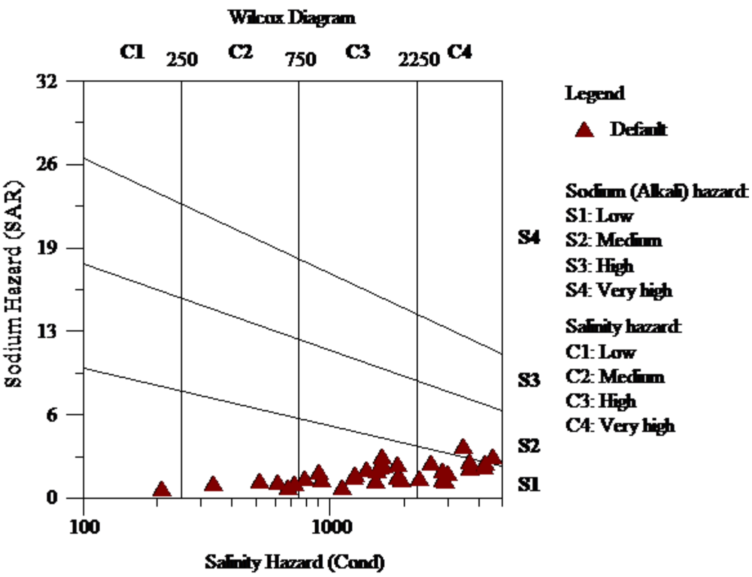


Fig. 6 Groundwater suitability for irrigation-PRM-USSL Diagram

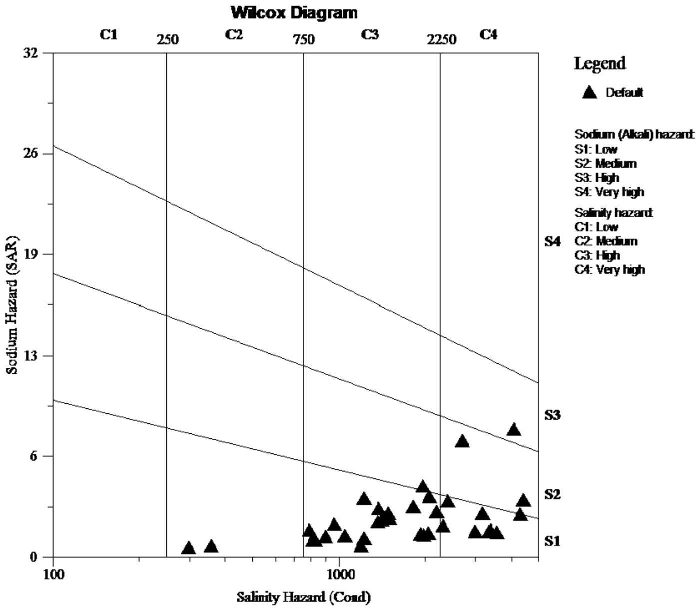


Fig. 7 Groundwater suitability for irrigation-POM-USSL Diagram

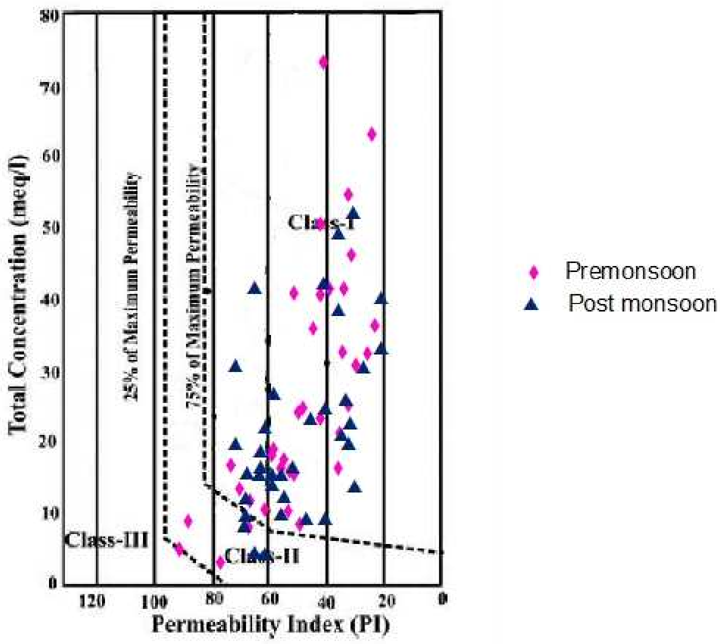


Fig.8 Classification of irrigation water (Doneen, 1962)