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Research Article

EVALUATION OF GROUNDWATER QUALITY FOR IRRIGATED AGRICULTURE IN KARUR TALUK, TAMIL NADU, INDIA: A GIS APPROACH

K. Rutharvel Murthy[1], S. Dhanakumar[2] and *K. Kumaraswamy[3]
[1]Department of Geography, Arignar Anna Government Arts College, Namakkal 637002
[2]Department of Environmental Science, PSG College of Arts and Science, Coimbatore-641014
[3]Department of Geography, School of Geosciences, Bharathidasan University, Tiruchirappalli-620024, Tamil Nadu
**Author for Correspondence*

ABSTRACT
Spatial and temporal variations of groundwater quality in Karur Taluk and its suitability for agriculture have been studied. The results of different seasons in 1997 and 2005 were compared in spatial and temporal manner. The study area spreads over an area of around 504.44 sq km, falls within the semiarid regions of Tamil Nadu and it frequently faces problems like water scarcity and quality. Agriculture and its allied activities are the major sources of employment in the study area. Water quality data was collected from Water Resources Organization, Chennai and the results were subjected to analysis for categorizing its chemical characteristics using ArcGIS software. In addition, suitability of groundwater quality for irrigation is evaluated based on electrical conductivity, sodium adsorption ratio, residual sodium carbonate, sodium percent, salinity hazard and United States Salinity Laboratory diagrams.

***Keywords**: Spatio-Temporal, Groundwater, Agriculture, Pollution, GIS*

INTRODUCTION
Groundwater plays an important role in day to day life, especially in regions like arid and semi-arid. It is widely used for purposes like drinking, irrigation and industrial supplies. Groundwater comprises of two parts – dynamic resource in the zone of water-table fluctuation which reflects seasonal recharge and discharge of aquifers and static resource found below this zone, which remains perennially saturated (Das, 2006).

Today, India stresses that 'exploitation of groundwater resources should be so regulated as not to exceed the recharging possibilities, as also to ensure social equity' (Ministry of Water Resources, 2002). Agriculture is a dominant sector in the economic development of India, as it is the source of sustenance for the majority of the population; it contributes 46% of the gross national product (Singh, 1983).

Groundwater quality can be affected by both natural and anthropogenic activities. In aquifers unaffected by human activity, the quality of groundwater results from geochemical reactions between water and rock matrix as the water moves along flow paths from areas of recharge to areas of discharge. In general, longer the groundwater remains in contact with soluble materials, may leads to enhanced level of dissolved materials in the water.

The quality of groundwater can also be vulnerable to change by the mixing effect, where different aquifer joins together. In aquifers affected by anthropogenic activity, the quality of water can be directly affected by the infiltration of pollutants or indirectly affected by alteration of flow paths or geochemical conditions (Abu-Sharar, 2006).

Geographical Information System (GIS) is an information system that capture, store, manipulate, analyze and display geospatial data. In most of the components, GIS has considered as a part of geoinformatics. GIS is comprised of at least three different components: (i) an information system on geospatial information and data, (ii) a set of georeferenced or geospatial data, and (iii) a management component capable of analyzing and checking the data (Chang, 2004). Geographic Information System (GIS) has emerged as an effective tool for relating and integrating large volumes of different data types obtained from different sources and compiled on different scales.

MATERIALS AND METHODS

The study area, Karur Taluk is located between 10º45'47" N - 11º05'41" N Latitude and 77º55'19" E - 78º13'20" E Longitude. Cauvery and Amaravathi rivers drain the Taluk and normally found to be dry during the summer season. The soil is best suited for raising dry farming crops. The total geographical area of the taluk is about 504.44 sq km (Figure 1).

Figure 1: Study Area

The base map was prepared from SOI 1:50,000 toposheets (58 - E/16, F/13, I/4 and J/1) for delineating relief, drainage, etc. For analyzing the chemical aspects of groundwater, 28 wells (in and around of Karur Taluk) were taken for the study and the data are collected from Water Resources Organisation, Public Works Department, Chennai for spatio-temporal study. Finally, ArcGIS 9.1 software was used for interpolating and overlay analysis. By adopting the United States Salinity Laboratory (USSL) method, the irrigation water is classified into various saline-alkaline classes. The analysis of chemical constituents and their derivatives determine the alkalinity and salinity levels of contamination by select chemical substances (Walton, 1970). Usually, the upper limit of EC used for irrigation water is 5000 mmhos/cm at

25°C (Richards, 1954). But the same quality waters may not suit for all climate conditions. Based on modified Richards's classification of groundwater, Kumaraswamy (1984) has evolved a method to show the different classes of USSL method through spatially, this approach is used in this work to classify the groundwater samples.

RESULTS AND DISCUSSION

Geology

Geologically, the Karur Taluk can be broadly classified into hard rock and sedimentary formations. The major portion of the study area is underlain by hard rock of Archaean age. The gneissic type of formation is the major formation among the various types of hard rocks. Charnockite occurs as pockets and the quartzites, which are resistant to weathering are also seen as patches in charnockite and gneissic varieties. Recent alluvial deposits such as sand, silt, clay and gravel were found on floodplain regions of Cauvery and Amaravathi rivers.

Groundwater Status

Naturally, groundwater contains mineral ions. These ions slowly dissolve from soil particles, sediments, and rocks as the water travels along mineral surfaces in the pores or fractures of the unsaturated zone and the aquifer. They are referred as dissolved solids. In general the water quality is discussed with Total Dissolved Solids (TDS); in Karur Taluk it is moderate in the shallow open well and bore hole with TDS values ranging averagely 2940 mg/l (1997) and 700 mg/l (2005) in pre-monsoon seasons and 1580 mg/l (1997) and 1450 mg/l (2005) in post-monsoon seasons.

Electrical Conductivity (EC)

The total amount of dissolved ions in water is mainly controlled by geological factors and leaching activities by numerous sources of pollutants (Table 1). In overall, the EC in 2005 seems to be lesser than it was in 1997, mostly this may be occurred due to some seasonal variations in the amount of rainfall received. It is well known that the eastern states of south India always receive greater rainfall in northeast monsoon season. This impact can be easily observed in pre and post monsoon seasons and the results shows greater concentration of ion in pre-monsoon season and lesser in post-monsoon season due to infiltration process may happened in large scale. In 1997, EC was observed higher in southern part of the study area (Paganatham, K. Pichampatti & Velliyanai) and in 2005, the western portion is observed with higher amount of EC (Vettamangalam and Kombupalayam) were the Noyyal River confluences with Cauvery River (Figure 2a).

Percent Sodium (% Na)

The concentration of sodium is an important parameter in classifying the irrigation water, because sodium reacts with soil to reduce its permeability. Soils containing a large proportion of sodium with carbonate as the predominant anion are termed as alkali soils; sodium with chloride or sulfate as the predominant anion is saline soils.

The role of sodium in the classification of groundwater for irrigation was emphasized because of the fact that sodium reacts with soil and as a result clogging of particles takes place, thereby reducing the permeability (Todd, 1980; Domenico and Schwartz, 1990).

Sodium content is usually expressed in terms of percent sodium (also known as sodium percentage and soluble-sodium percentage) and it is computed to evaluate the suitability for irrigation (Wilcox, 1948) (Table 2); it is defined by

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

where, all ionic concentrations are expressed in milliequivalents per litre

In 1997, there was not any major variation between the pre and post monsoon seasons, but in 2005, the greater level of % Na was found in post-monsoon season over western part of the study area. The lowest level was found in Athur village in pre-monsoon and highest level was observed in some parts of Athur and Manmangalam villages in post-monsoon (Figure 2b).

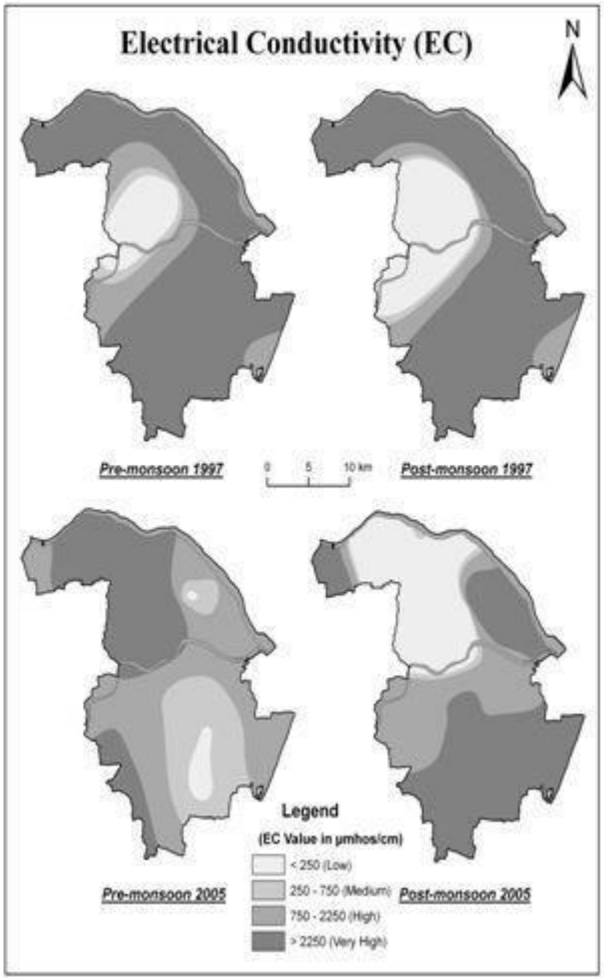

Figure 2a: Distribution of Electrical Conductivity Figure 2b: Distribution of Percent Sodium

Residual Sodium Carbonate (RSC)

The excess sum of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium also influences the unsuitability for irrigation. This is denoted as residual sodium carbonate (RSC) index which is calculated as (Ragunath, 1987).

$$RSC = (HCO_3 + CO_3) - (Ca + Mg)$$

where, all ionic concentrations are expressed in milliequivalents per litre

The classification of groundwater based on RSC values are summarized in Table 3, where in 1997, western parts of the study area were found as unsuitable (Athur and Andankoil villages) in both the seasons. In 2005, the northern parts were found as higher level of concentration in pre-monsoon season and in post-monsoon season northern and western parts were found as unsuitable for irrigation (Figure 3a).

Sodium Adsorption Ratio (SAR)

Irrigation waters are classified based on sodium adsorption ratio (WHO, 1989). The suitability of the well and bore well water samples was evaluated by determining the SAR value and they were categorized under different irrigation classes based on salinity and alkalinity hazards. Sodium adsorption ratio (SAR) was computed by using values of major constituent cation (Table 4).

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

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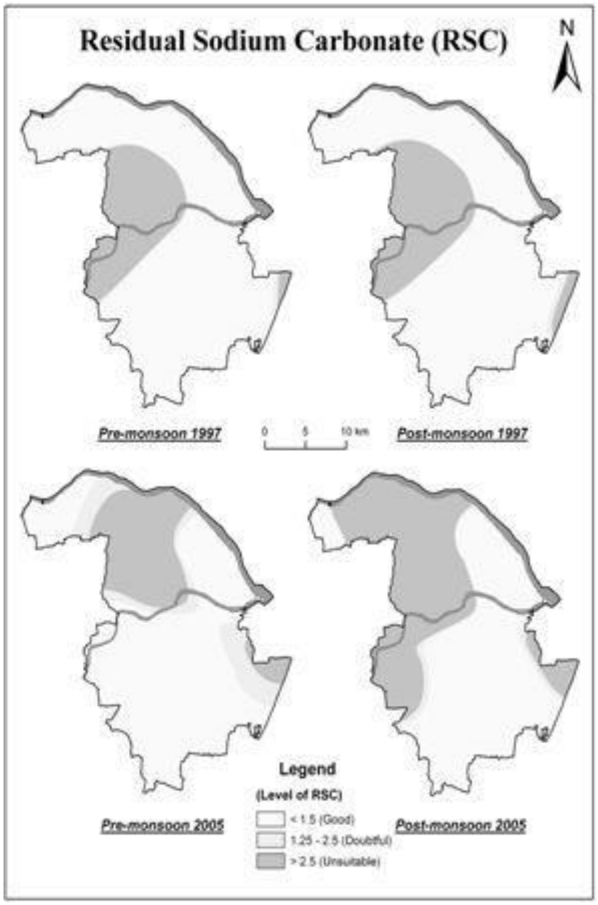
where, all ionic concentrations are expressed in milliequivalents per litre

Most of the water samples of two seasons in 1997 and 2005 fall in excellent to good and good to permissible areas indicating their usefulness for irrigation. No water sample is strictly unsuitable for irrigation (Figure 3b).



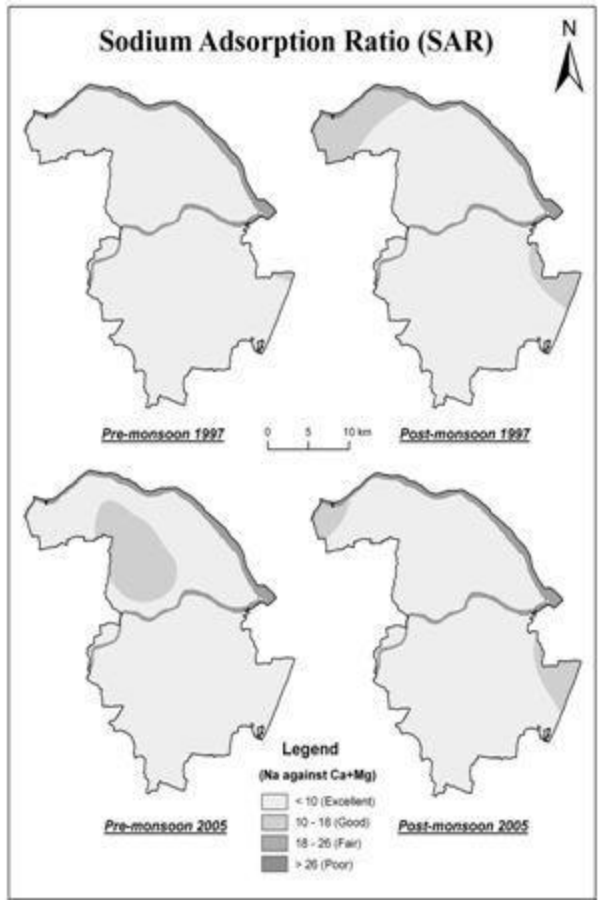


Figure 3a: Distribution of Residual Sodium Carbonate Figure 3b: Distribution of Sodium Adsorption Ratio

Table 1: Classification of Groundwater on the Basis of EC Suggested by U.S. Salinity Laboratory

Sl. No.	Electrical Conductivity (mmhos / cm)	Salinity Condition	Quality of Water
1	Less than 250	Low	Excellent
2	205 – 750	Medium	Good
3	750 – 2250	High	Doubtful
4	More than 2250	Very High	Unsuitable

Table 2: Classification of Percent Sodium in the Groundwater for Irrigation

Sl. No.	% Sodium	Water Class
1	Less than 20	Excellent
2	20 – 40	Good
3	40 – 60	Permissible
4	60 – 80	Doubtful
5	More than 80	Unsuitable

Table 3: Groundwater Classification of Based on Residual Sodium Carbonate

Sl. No.	Residual Sodium Carbonate	Water Class
1	Less than 1.25	Good
2	1.25 – 2.50	Doubtful
3	More than 2.50	Unsuitable

Table 4: Groundwater Classification for Irrigation

Salinity Class	Electrical Conductivity (micromhos / cm)	Sodium Class	Alkalinity Hazard (SAR)
C1	Less than 250	S1	Less than 10
C2	205 – 750	S2	10 – 18
C3	750 – 2250	S3	18 – 26
C4	2250 – 6750	S4	More than 26
C5	More than 6750	S5	-

U.S. Salinity Laboratory Water Classification (USSL)

The U.S. Salinity Laboratory (1954) has prepared a diagram for classification of irrigation waters with reference to SAR as an index of sodium (alkali) hazard and EC as an index of salinity hazard. Electrical conductivity in mmhos per centimetre at 25°C is plotted on X-axis and SAR on Y-axis. Based on these water types it has been divided into C1 to C4 types on the basis of salinity hazard and S1 to S4 types on the basis of sodium hazard. The analytical data were plotted on the US salinity diagram proposed by USSL (Figure 4 a & b).

i) 1997 – pre-monsoon samples illustrates that 49.99% of the groundwater samples fall in the classes of C2-S1 and C3-S1, indicating water of medium-high salinity and low sodium, which can be used for irrigation in all types of soil with little danger of exchangeable sodium, where 35.7% of groundwater samples fall in moderate category, salt resistant crops may be sown in the moderate areas and 14.28% of the groundwater samples fall in the field of C4-S3, indicating very high salinity and high alkalinity hazard. This water will be suitable for good salt tolerance plants and it restricts suitability for irrigation, especially in soils with restricted drainage. In post-monsoon season, 35.71% of the groundwater samples belongs to the category of good C2-S1 and C3-S1, indicating medium-high salinity and low sodium, 42.84% of the groundwater samples fall in moderate category and others fall in poor - very poor category.

ii) 2005 – pre-monsoon samples illustrates that 57.13% of the groundwater samples fall in good category with the indication of medium-high salinity, low sodium, 32.17% in moderate category and others come in poor - very poor category.

In post-monsoon season, 28.57% of the groundwater samples fall in good category with the indication of medium-high salinity, low sodium and 57.13% in moderate category and 14.28% come in poor to very poor category. All the sampling points were plotted on US salinity diagram - shown in Figure 4 a & b and summarized in Table 5.

Groundwater Quality Zones

Kumaraswamy (1984) has evolved a technique to demonstrate the USSL method of identifying groundwater quality in spatial manner. This method has been adopted to bring out the logarithmic model into spatial model and to find out suitable locations for better agriculture as per their salinity and alkalinity levels. In 1997, the northern parts of the study area is identified as good quality (Kadambankurichi, Tottakurichi, Manmangalam & Kuppuchipalayam) in pre-monsoon season and the western central parts are classified as good quality (Athur, Kadapari, Inam Karur and Andankovil). But in both the seasons, there were no area to say as poor water quality for irrigated agriculture. In 2005, the southern most parts of the study area are identified as good water quality (Velliyanai, Manavadi and K.Pichampatti) and other parts comes under as moderate quality in pre-monsoon season and in post-monsoon the western parts (Kadambankurichi, Tottakurichi & Athur) and some of areas around Thantoni village are identified as good quality water for irrigated agriculture (Figure 5).

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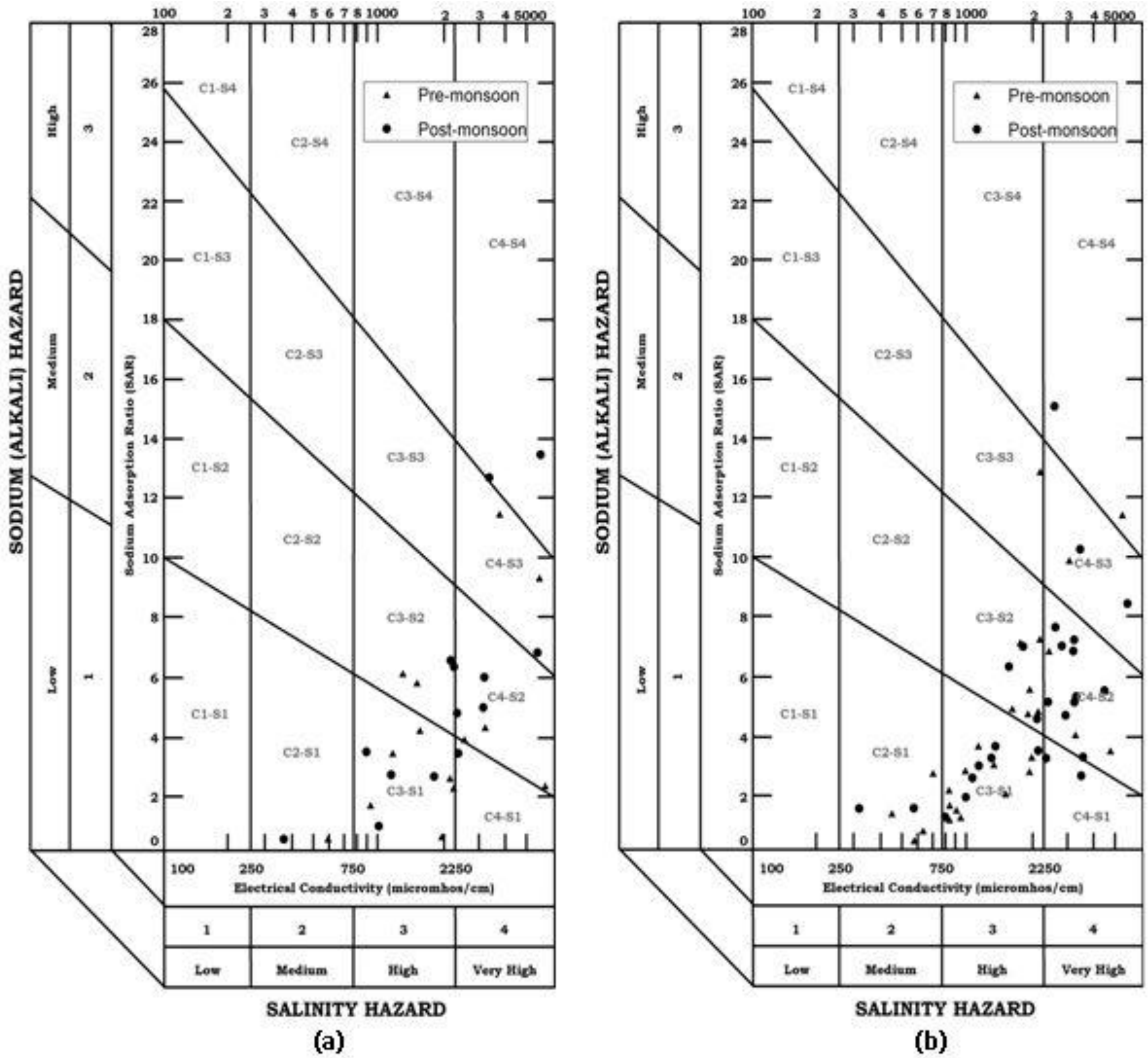

Figure 4: USSL Classification of Irrigation Water in Relation to Salinity and Sodium Hazard (a) 1997 (b) 2005

Conclusion

The groundwater quality in the region is generally alkaline and shows minor seasonal changes. The groundwater samples are dominated by alkaline earth metals like Ca and Mg with higher content of alkalis and prevailing sulphate like SO_4 and Cl ions. The EC of both the seasons in 1997 and 2005 illustrate that the post-monsoon results are better than pre-monsoon results (< 750 µmhos/cm). This may be due to higher amount of rainfall received and the occurrence of greater infiltration process in about 40% area of the study area. The results of Percent Sodium and Residual Sodium Carbonate for all periods shows that more than three-fourth of the study areas were identified as good to permissible limit for different agriculture activities (for Percent Sodium < 60 and < 1.5 for Residual Sodium Carbonate).

The SAR results reveal that the entire study area falls between excellent and good groundwater category (< 18). The irrigation water quality, classified based on USSL groundwater classification method, indicates that in 1997 out of 14 samples, 50% (in pre-monsoon) and 35.71% (in post-monsoon) of the water samples belong to good category (C2S1 & C3S1) while others are classified as moderate (C2S2, C3S2, C4S1 & C4S2) and poor (C3S3 & C4S3) category in both the seasons. In 2005, out of 28 samples, 57.13% (in pre-monsoon) and 28.57% (in post-monsoon) of the water samples belongs to good category and others categorized as moderate to poor. Graphical representation of the chemical data is illustrated on the irrigation suitability diagram (USSL, 1954). The groundwater quality of the study area is greatly harmful for irrigated agriculture and this may due to the seepage of the treated effluents from the textile industries and paper industry located in the central and northern part of the study area. The treatment process on effluents and sewages before entering into adjoining rivers, irrigation channels and the reduction of anthropogenic pollution stress on groundwater resources are recommendations to preserve and improve the groundwater quality.

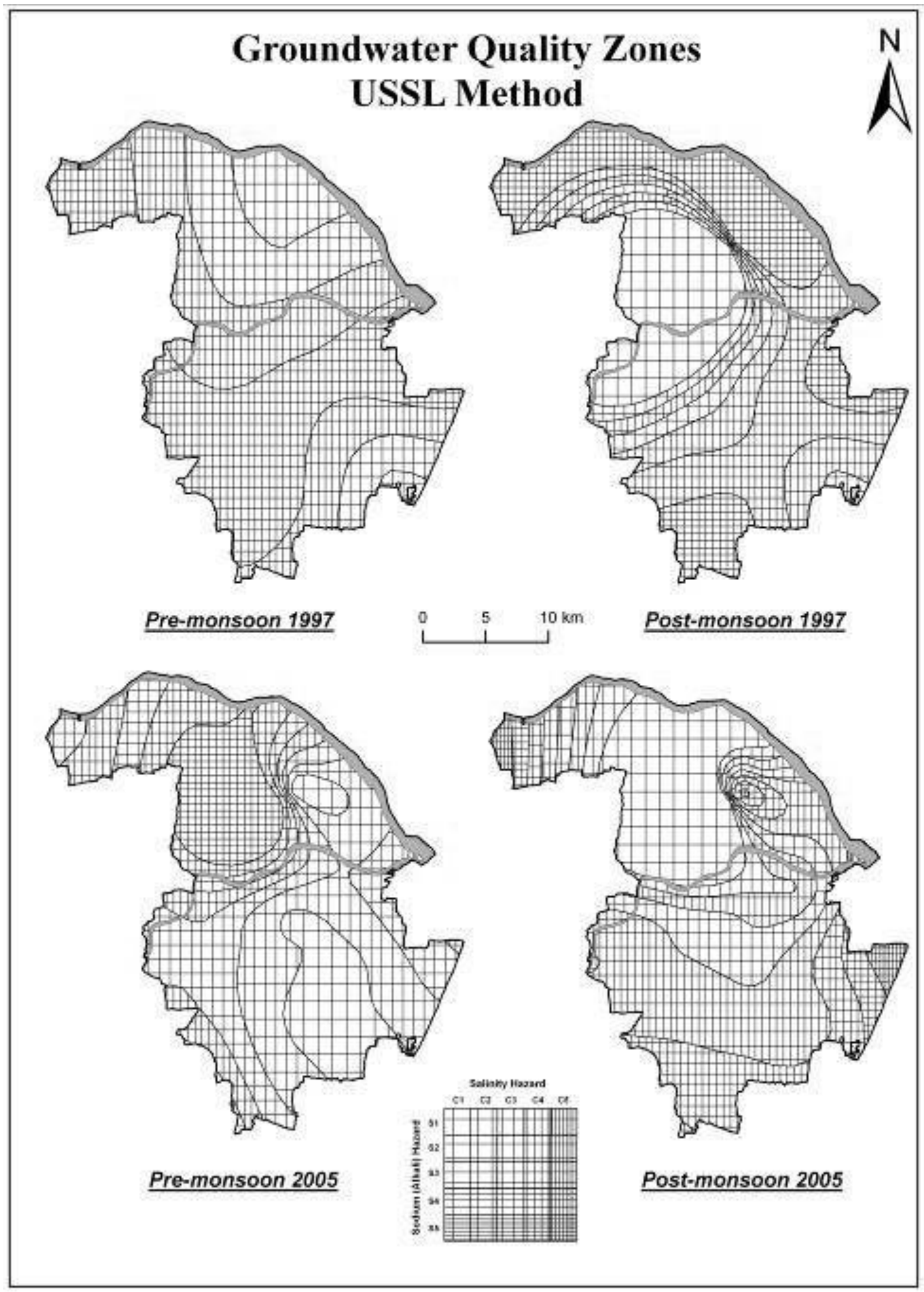

Figure 5: Groundwater Quality Zones – USSL Method

Table 5: Quality of Irrigation Water Based on U.S. Salinity Diagram for 1997 and 2005

Water Class	**Category**	**1997**				**2005**			
		Pre-Monsoon		**Post-Monsoon**		**Pre-Monsoon**		**Post-Monsoon**	
		No. of Samples	**Percentage %**	**No. of Samples**	**Percentage %**	**No. of Samples**	**Percentage %**	**No. of Samples**	**Percentage %**
Good	C2S1	1	7.14	1	7.14	5	17.85	1	3.57
	C3S1	6	42.85	4	28.57	11	39.28	7	25.00
Moderate	C2S2	-	-	2	14.28	-	-	-	-
	C3S2	2	14.28	-	-	6	21.42	4	14.28
	C4S1	-	-	1	7.14	-	-	2	7.14
	C4S2	3	21.42	3	21.42	3	10.71	10	35.71
Poor	C3S3	-	-	-	-	1	3.57	-	-
	C4S3	2	14.28	1	7.14	1	3.57	2	7.14
Very Poor	C4S4	-	-	2	14.28	1	3.57	1	3.57
	C5S4	-	-	-	-	-	-	1	3.57
Total		14	100	14	100	28	100	28	100

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