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GIS Based Groundwater Quality Assessment in Tuticorin District Tamilnadu, India

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Abstract Groundwater is widely distributed than surface water and is used for domestic, industrial and agricultural purpose throughout the world. More than 95% of rural population depends on groundwater for all needs. Rapid increase in urbanization and industrialization leads in to deterioration in groundwater quality. In many coastal towns or cities, groundwater seems to be the only source of fresh water to meet domestic, agricultural and industrial needs. But groundwater is under constant threat of saline water incursion, which seems to have become a worldwide concern. Mapping of spatial variability of groundwater quality is of vital importance and it is particularly significant where groundwater is primary source of potable water. In the present study, a detailed investigation was carried out to analyze the spatial variability of groundwater quality for the coastal region of Tuticorin District. Geographical Information System (GIS) based spatial analysis technique has been proven to be a powerful tool to represent the distribution of major ions in the study area. The major water quality parameters such as pH, Electrical conductivity, Total Dissolved Solids, Total Hardness, Calcium, Magnesium, Bicarbonate, Chloride and Sulphate etc. were analyzed. The spatial variation maps of these groundwater quality parameters were derived and integrated through GIS. The final integrated map shows three priority classes such as High, Moderate and Poor groundwater quality zones of the study area and provides a guideline for the suitability of groundwater for domestic purposes.
Keywords *GIS, Surface Water, Groundwater, Spatial Variation, Water Quality, Coastal Region*

1. Introduction

Water is indispensable for the life and it is a very important component for the development of country. Because of the rapidly increasing population, several environmental problems are created which includes groundwater quality degradation. The possibility of groundwater contamination is due to the prevailing drought-prone conditions, the improperly treated and unplanned release of effluents of industry, municipal and domestic into the nearby streams and ponds and the majority usage of groundwater for irrigation are increasing the ionic concentration of the groundwater and making it

more saline. Coastal aquifers constitute an important source of fresh water supply but are often confronted with the problem of seawater intrusion (Lenin et al., 2008). Hence monitoring of groundwater quality has become indispensable. The present study was carried out to evaluate and hydro chemical characteristics of coastal aquifers in Tuticorin District, Tamilnadu. GIS has been applied to visualize the spatial distribution of groundwater quality in the study area. Geographical Information System (GIS) is used for the spatial analysis and it is a powerful tool for representation and analysis of spatial information related to water resources (Rangarajan et al., 2009). A total of 23 groundwater samples were collected and analyzed for various physicochemical parameters in the years 2009 to 2013. The physico-chemical parameters namely pH, Electrical conductivity, Total Dissolved Solids, Total Hardness, Calcium, Magnesium, Bicarbonate, Chloride and Sulphates were analyzed.

2. Description of the Study Area

The study area is located in the coastal tract of southern Tamilnadu. The coastal stretch between Tuticorin and Thiruchendur extends over a distance of about 60 km. Tuticorin is in South Tamilnadu about 540 km south west of Madras (Chennai) and is geographically located in the Gulf of Mannar. The study area is situated in the southeast coast of Tamil Nadu, India and is located between 8°19′ to 9°22′ N latitude and 77°40′ to 78°23′ E longitude covering an area of about 4,590.54 km^2. The location of the study area is shown in Figure 1. Tuticorin city and surrounding areas have considerable presence of industries in several industrial sectors. The study area is chiefly composed of hornblende biotite gneiss, alluvial marine and charnockites in the west (Selvam et al., 2013). The quartzite formations are also found as disseminated patches in the study area. Vaipar, Tambraparani and Karamanaiyar are the major rivers draining the district. All the rivers are ephemeral in nature and run off is generated in heavy rainfall period only. The average annual rainfall of this zone is 877mm. The North-East monsoon contributing to 65.4% of annual rainfall is the major component of recharge into the aquifer. The mean maximum temperature falls in the month of June (37.6^{o}C) and the minimum is seen in January (19.9^{o}C). Evaporation is greater during the months of June, July and August showing the significance of high temperature and radiation. The water quality parameters collected for the study area is shown in Table 1.

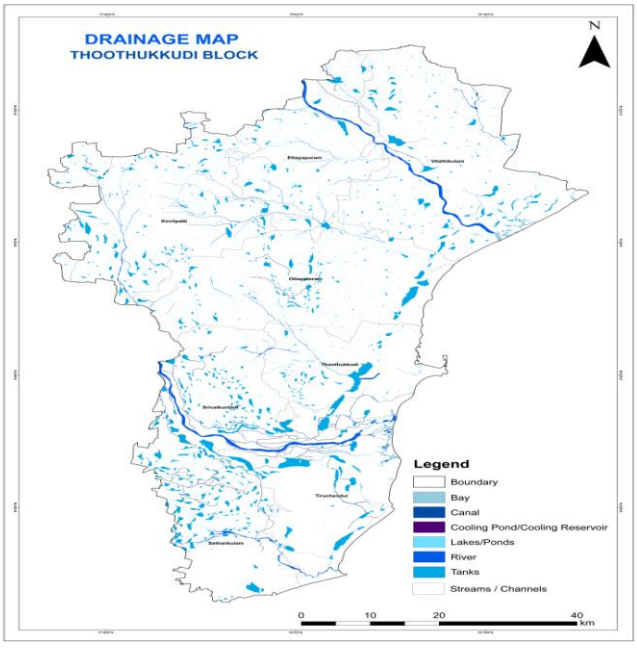

Figure 1: *Location Map of Study Area*

Table 1: *Water Quality Parameters for the Study Area*

Sample Location	Latitude	Longitude	pH	EC	TDS	Mg	Ca	HCO3	Cl
Pudukottai	8.752	77.844	8.5	11000	9568	2405.2	497	146	19273
Thoothukudi	8.798	78.12	7.6	1265	1346	89	120	179	569
Kurukusalai	8.928	78.096	7.1	450	312	24.3	68	207	89
Kadambur	8.992	77.853	7.3	230	196	22	46	146	56
Ettayapuram	9.153	77.986	8.5	3563	4562	189	332	656	5698
Vembar	9.106	78.345	8.6	15623	12356	869	265	532	6536
Nagalapuram	9.224	78.147	8.2	5465	6598	798	423	265	3652
Vaippar	9.048	78.256	8.4	12598	21565	2569	568	222	20365
Eppodumventran	9.036	78.042	7.8	9863	11000	422	965	198	4213
Maniachi	8.884	77.886	7.9	2896	3265	196	221	401	2132
Sawyerpuram	8.684	78.027	7.3	199	236	56	98	198	102
Nazareth	8.546	77.952	7.4	569	986	102	56	96	198
Vilathikulam	9.108	78.074	7.9	11235	18659	1986	356	236	16538
Srivaikundam	8.644	77.922	7.1	263	365	63	26	121	102
Kovilpatti	9.211	77.872	7.9	815	1236	96	160	365	212
Karunkulam	8.791	77.869	7.8	265	198	46	36	98	265
Udangudi	8.422	78.0249	7.6	569	1236	56	89	569	465
Tiruchendur	8.491	78.025	8.4	9865	12356	569	265	789	6598
Sathankulam	8.408	78.958	7.5	369	756	56	45	132	102
Ottapidaram	8.856	78.040	7.5	569	986	48	36	98	89
Kayathar	9.089	77.674	7.2	236	362	86	23	145	59
Alwarthirunagari	8.502	77.841	7.1	136	156	46	56	123	39

3. Integration of Spatial and Attribute Database

The groundwater samples were collected from 23 wells and tested for physico-chemical parameters are compared with the permissible limits. The major water quality parameters of the samples were analyzed. The layout map with sample station location in Tuticorin district is shown in Figure 2. The base map of the Tuticorin district is derived from the thematic map collected from Institute of Remote Sensing, Anna University on 1:50,000 scale. The base map was georeferenced and digitized by using MapInfo software and exported to Arc View software for spatial analysis. Spatial interpolation technique through Inverse Distance Weighted (IDW) approach has been used in the present study to delineate the distribution of water pollutants. This method uses a defined or selected set of sample points for estimating the output grid cell value.

4. Results and Discussion

The spatial and the attribute database generated are integrated for the generation of spatial variation maps of major water quality parameters like pH, electrical conductivity, total dissolved solids, total hardness, calcium, magnesium, bicarbonate, chloride and sulphates. Based on these spatial variation maps of major water quality parameters, an integrated groundwater quality map of the study area was prepared using GIS. This integrated groundwater quality map helps us to know the existing groundwater condition of the study area.

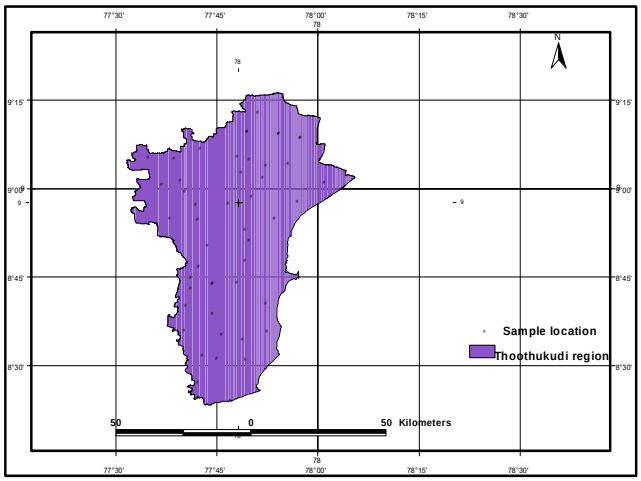

Figure 2: *Layout Map with Sample Station Location in Tuticorin District*

4.1. pH

pH is one of the important parameters of water and determines the acidic and alkaline nature of water. The pH value of water ranged between 7.1 to 8.6. The pH of the samples was well within the prescribed standards for drinking water. The spatial variation map for pH was prepared and presented in Figure 3.

4.2. Electrical Conductivity (EC)

The salt concentration is generally measured by the determining the electrical conductivity of water. The EC of water samples varies from 136 to 15623 µs/cm. The spatial variation map for Electrical Conductivity (EC) was prepared and presented in Figure 4. From the map it has been observed that very small portion of the study area, the EC value is within the prescribed range. The major portion of the study area is having poor range and northern part is having moderate range of Electrical Conductivity.

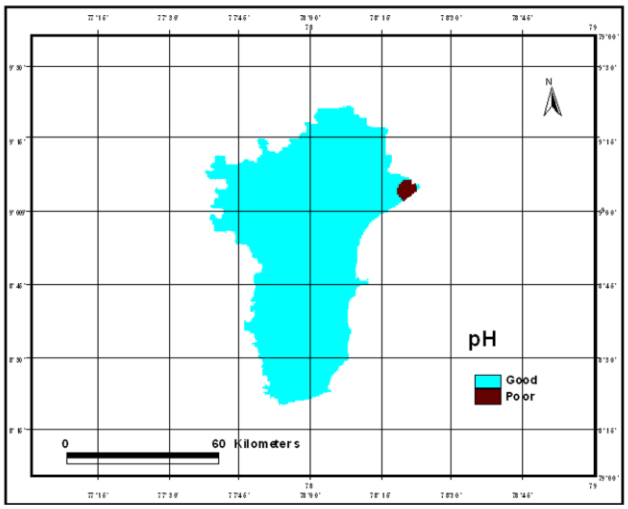

Figure 3: *Spatial Variation Map of pH*

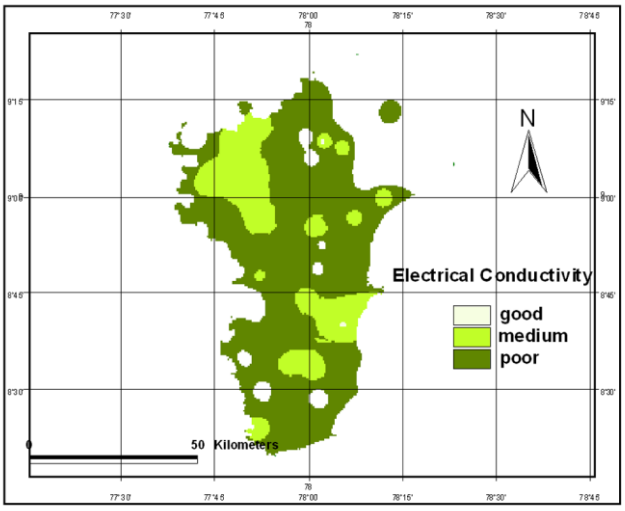

Figure 4: *Spatial Variation Map of Electrical Conductivity*

4.3. Total Dissolved Solids

The weight of the residue consisting of pollutants (dissolved ions) left behind after all the water from a water sample is evaporated is a measure of the TDS and gives the general nature of groundwater quality and extent of contamination (Udayalaxmi et al., 2010). The Total Dissolved Solids (TDS) was classified into three ranges (0-500 mg/l, 500-1000 mg/l and >1000 mg/l). The TDS of water samples ranges from 156 to 21565 mg/l. The spatial variation map for TDS was prepared based on these ranges and presented in Figure 5. From the map it has been observed that very small portion of the study area, the EC value is under the good range (0-500 mg/l). The major portion of the study area is having poor range (>1000 mg/l) and northern part is having moderate range (500-1000 mg/l).

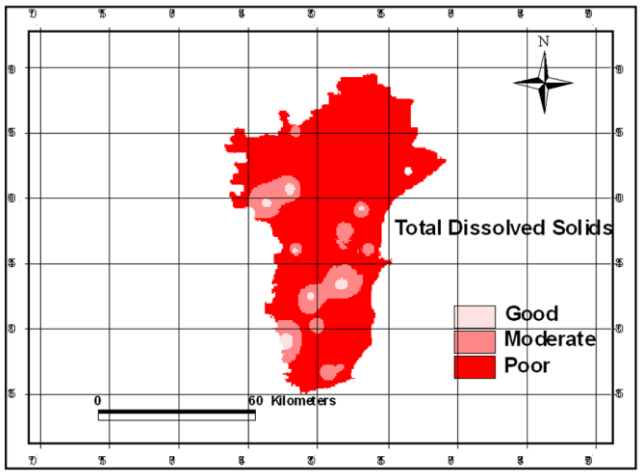

Figure 5: *Spatial Variation Map of TDS*

4.4. Total Hardness

Total hardness, an important property indicating the quality of groundwater is mainly caused by calcium and magnesium cations and is defined as the sum of their concentrations expressed in mg/l. The total hardness was classified in to three ranges (0-300 mg/l, 300-600 mg/l and >600 mg/l) and based on these ranges the spatial variation map for total hardness has been obtained and presented

In Figure 6. Total hardness (TH) of water samples ranges from 145 to 3391 mg/l. From the map it was observed that for major areas, the total hardness value is in the moderate range (300-600 mg/l) and smaller portion having poor and good range.

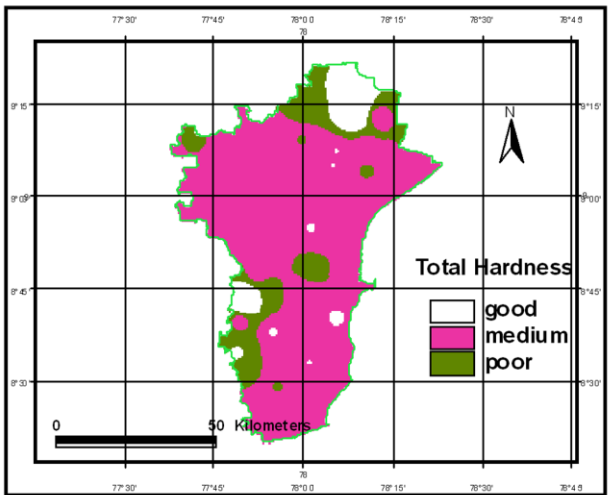

Figure 6: *Spatial Variation Map of Total Hardness*

4.5. Calcium

Calcium was classified in to three ranges (0-75 mg/l, 75-200 mg/l and >200 mg/l) and based on these ranges the spatial variation map for Calcium has been obtained and presented in Figure 7. Calcium of Water samples ranges from 23 to 965 mg/l. From the spatial variation map, it was observed that Northern part of the study area, the sulphates value is in the poor range ((>400 mg/l). For the Southern part of the study area, sulphate value is in the moderate and only smaller portion is having good range.

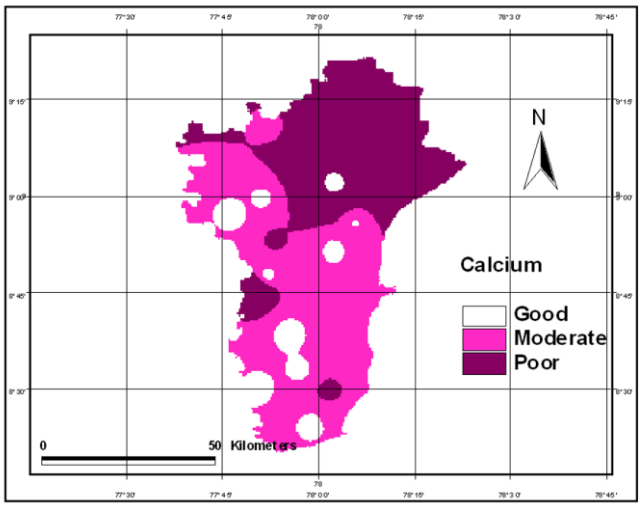

Figure 7: *Spatial Variation Map of Calcium*

4.6. Magnesium

Magnesium also is one of the abundant elements in rocks. It causes hardness in water. Magnesium concentration of water samples ranges from 22 to 2405.2 mg/l. The spatial variation map for magnesium has been obtained and presented in Figure 8. From the spatial variation map, it was observed that Northern part of the study area, the magnesium concentration is in the poor range. The most part of the study area has moderate range and only smaller portion is having good range.

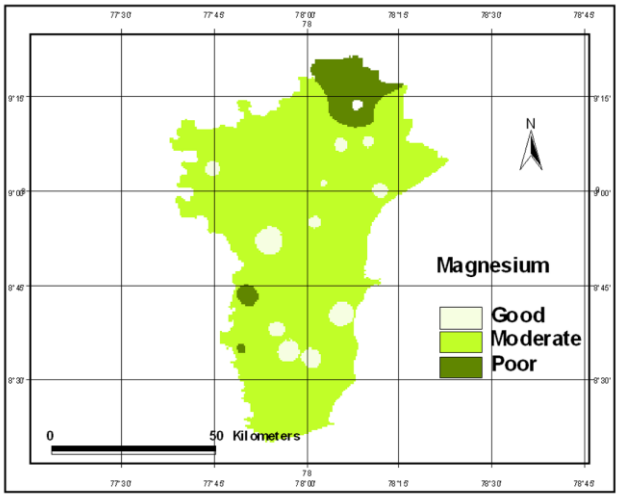

Figure 8: *Spatial Variation Map of Magnesium*

4.7. Bicarbonate (HCO_3)

Bicarbonate (HCO_3) concentration of water samples ranges from 96 to 789 mg/l. The spatial variation map for Bicarbonate has been obtained and presented in Figure 9. From the spatial variation map, it was observed that most part of the study area is in moderate and poor range and only smaller portion is having good range.

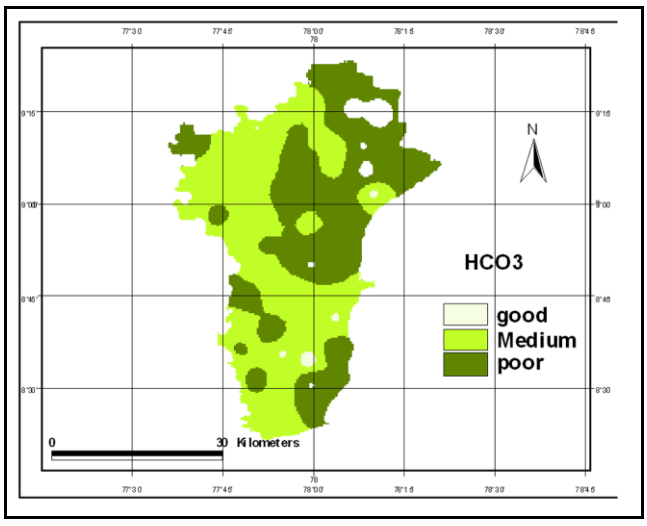

Figure 9: *Spatial Variation Map of Bicarbonate*

4.8. Chloride (Cl)

Chloride (Cl) concentration of water samples ranges from 56 to 20365 mg/l. The spatial variation map for chloride has been obtained and presented in Figure.10. From the spatial variation map, it was observed that most part of the study area is in the poor range and only smaller portion is having good and moderate range.

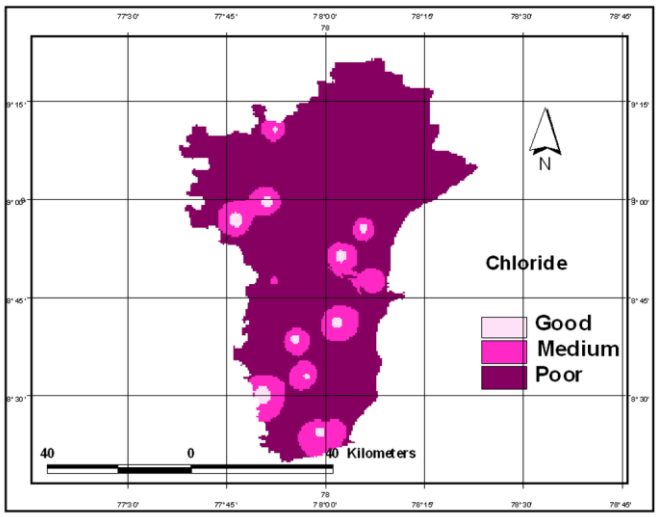

Figure 10: *Spatial Variation Map of Chloride*

4.9. Sulphates

Sulphates was classified in to three ranges (0-200 mg/l, 200-400 mg/l and >400 mg/l) and based on these ranges the spatial variation map for sulphates has been obtained and presented in Figure 11. Sulphate of water samples ranges from 12 to 1361 mg/l. From the spatial variation map, it was observed that Northern part of the study area, the sulphates value is in the poor range (>400 mg/l). For the Southern part of the study area, sulphate value is in the moderate and good range.

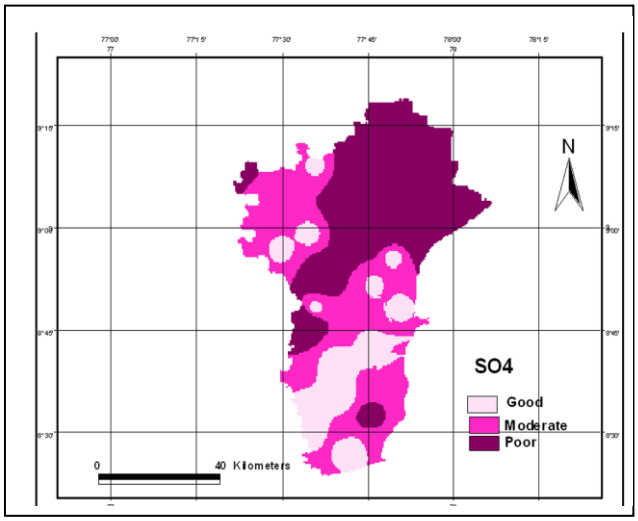

Figure 11: *Spatial Variation Map of Sulphate*

5. Data Integration Using GIS

The spatial variation map of major groundwater quality parameters were integrated and integrated groundwater quality map of Tuticorin District was prepared and shown in Figure 12. The integrated map shows the broad idea about good, moderate and poor groundwater quality zones in the study area. The groundwater quality has been classified quantitatively as good, moderate and poor depending on the final weightage values assigned to polygons in the final layer. From the map, it is evident that the groundwater quality in the Northern part of the study area is in the moderate and poor condition while the Southern side of the study area groundwater quality is in the good condition.

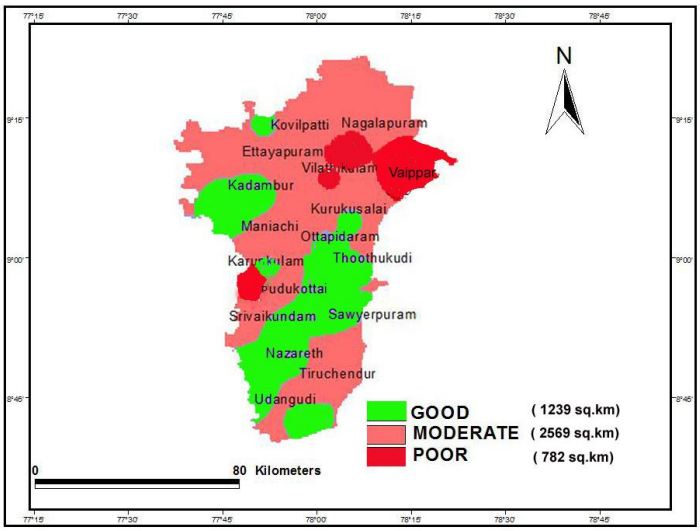

Figure 12: *Spatial Variation Map of Integrated Water Quality*

6. Conclusion

The dependence on groundwater is increasing in many regions because of limited surface water as perennial rivers and frequent failure of monsoon. The groundwater quality is equally important as that of quantity. Groundwater continues to be exploited at ever increasing rates, especially in the rapidly expanding urban areas of the country. The present study has been undertaken to analyze the spatial variation of major groundwater quality parameters such as pH, Electrical conductivity, Total Dissolved Solids, Total Hardness, Calcium, Magnesium, Bicarbonate, Chloride and Sulphates using GIS approach. The groundwater quality of 23 wells randomly distributed in Tuticorin district, Tamil Nadu was selected for the present study. The spatial variation maps of major groundwater quality parameters were prepared and finally all these maps were integrated. The integrated groundwater quality map shows the broad idea about good, moderate and poor groundwater quality zones in the study area.

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