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Groundwater Quality Mapping using Remote Sensing and GIS – A Case Study at Thuraiyur and Uppiliapuram Block, Tiruchirappalli District, Tamilnadu, India

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Abstract Ground water is the major source in India not only for domestic use, but also for agriculture and industrial sector. At present scenario, 85% of domestic water requirement in rural areas, 55% of irrigation water requirement of farmers, 50% of domestic water requirement in urban areas and 50% of process water requirement of industries are met by ground water. Ground water is tapped for the past two decades due to increasing demand of water and mismanagement of water resource. This leads to water scarcity. Ground water level has been falling rapidly day by day. It is very essential to start investigations oriented towards the ground water quantification and qualification which are the basic to form plans for its exploitation, management and conservation. In the present study, the authors have carried out detailed studies by using Survey of India Topographic sheet No (57 O/4) on 1:50,000 scale and Remotely sensed image data from IRS ID (LISS III) (false colour composite (FCC) of bands 321 (rgb), and Landsat 7 ETM (Enhanced Thematic Mapper) (false colour composite (FCC) of bands 457 (RGB), were visually interpreted for tone, texture, size, shape, relief, drainage pattern, vegetation association, and other factors. Field studies were also conducted and corrections were made accordingly to maps of geology, lineaments, and hydromorphogeology. Well inventory, well yield, water table level and groundwater samples were collected during field study. Finally ArcGIS tools were used for analyzing and displaying the spatial data for investigating the ground water quality information.
Keywords *Groundwater; Remote Sensing; ETM; Hydromorphogeology; GIS*

1. Introduction

Many consequences of unsustainable groundwater use are increasingly evident in several parts of the world due to ever-increasing population, urbanization and intensified human activities, and the main concern is how to maintain sustainable groundwater supply on a long-term basis. In India 90% of the rural and nearly 30% of the urban populations depend on groundwater for meeting their drinking and domestic requirements. Unfortunately, water scarcity and over-exploitation of groundwater resources are common in several parts of India. In view of growing water scarcity and the adverse impact of global climate change on water resources, it is imperative that groundwater be used efficiently, equitably, and in an ecologically sound manner for both present and future generations so as to ensure sustainable utilization of this vital resource. Groundwater, being a hidden natural resource, is not amenable to direct observations and, hence, exploration or assessment of this resource plays a pivotal role in determining locations of water supply and monitoring wells, and in controlling groundwater pollution. Test drilling and stratigraphy analysis are the most reliable and standard methods for determining the location and thickness of aquifers and other subsurface formations, quality of groundwater, physical/ hydraulic characteristics of aquifers, etc., in a basin. However, such an approach for groundwater investigation is very costly, time-consuming and requires skilled manpower in developing nations. Alternatively, geophysical techniques and fracture-trace analysis can be used for exploring groundwater. In the era of information technology, modern technologies such as remote sensing (RS) and geographic information systems (GIS), coupled with geophysical surveys are very helpful for the evaluation of groundwater resources in a basin. The RS technology, with its advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas within a short time, has emerged as a powerful tool for the assessment, monitoring and management of groundwater resources. The hydro-geologic interpretation of satellite data has been proved to be a valuable survey tool in areas of the world where little geologic and cartographic information exists or is not accurate as well as in inaccessible regions of the world. Since remote sensors cannot detect groundwater directly, the occurrence of groundwater is judged from different surface features derived from satellite imagery such as geomorphology, soil, land use/land cover, topographic slope, surface water bodies, etc., which act as indicators of groundwater existence. In addition, surface geophysical techniques are non-invasive and relatively less time-consuming, and offer cost-effective alternatives for obtaining information about subsurface formations and groundwater [1; 3; 8].

2. Study Area

The study area, Thuraiyur and Uppiliapuram block, Tiruchirappalli district, Tamilnadu. Their search work is to make a groundwater potential and groundwater quality assessment using GIS, based on the remote sensing and available physico-chemical data from 76 locations in Thuraiyur and Uppiliapuram block of Tiruchirappalli district. Data being used Landsat ETM data (Path 143 and Row 52); Water quality data from CGWB; Soil Map from NBSS & LUP Nagpur Survey of India Toposheet No 58I/7,8,11,12, latitude 78^{o} 28'to 78^{o} 45'E, longitude 11^{o} 5'to 11^{o} 20'N. Software used Arc GIS 9.3.1 surfer 9.0.

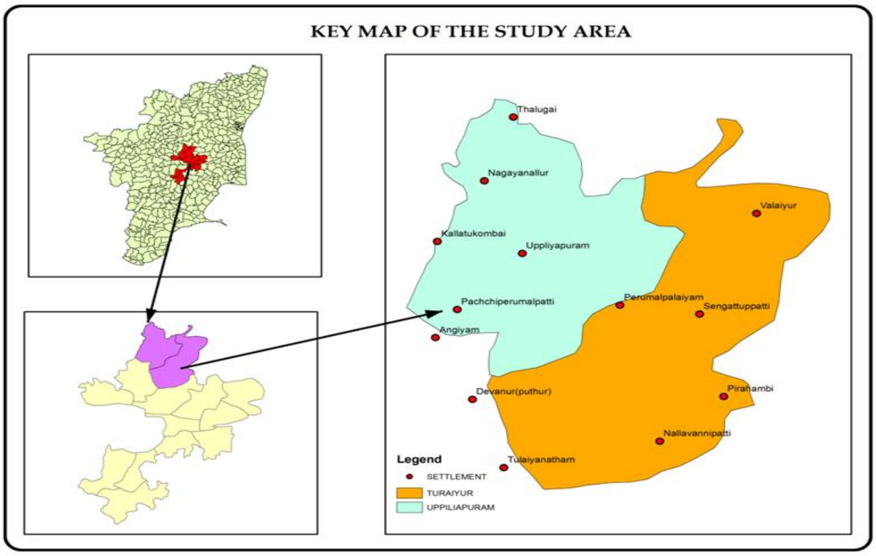

Figure 1: *Study Area*

3. Materials and Methods

Acquisition of Remote sensing and Hydrogeochemical data in order to demarcate groundwater potential zones and ground water quality map in the study area, a multi-parametric dataset comprising satellite data, conventional maps and field data were used. Landsat ETM data were used. Toposheets covering the study area were collected from the Survey of India (SOI). The soil map of the study area was collected from the National Bureau of Soil Science and Land Use Planning (NBSS and LUP). The following schematic diagram shows the methodology of the present work [2].

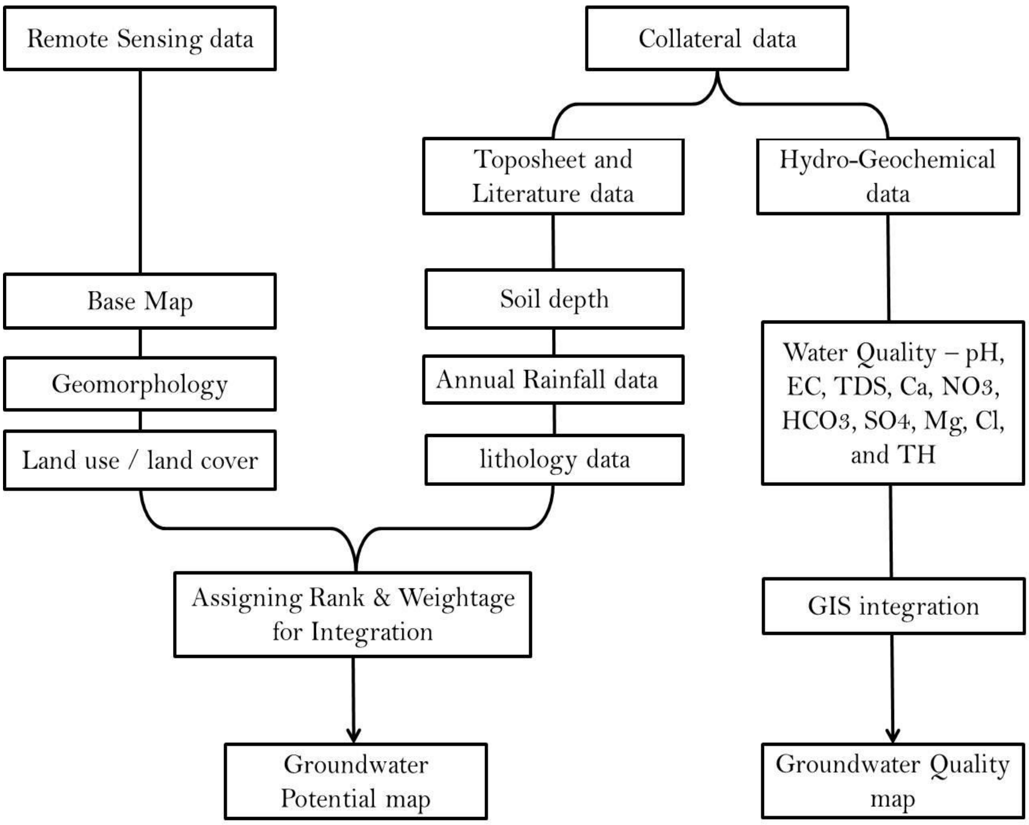

Figure 2: *Flow Chart*

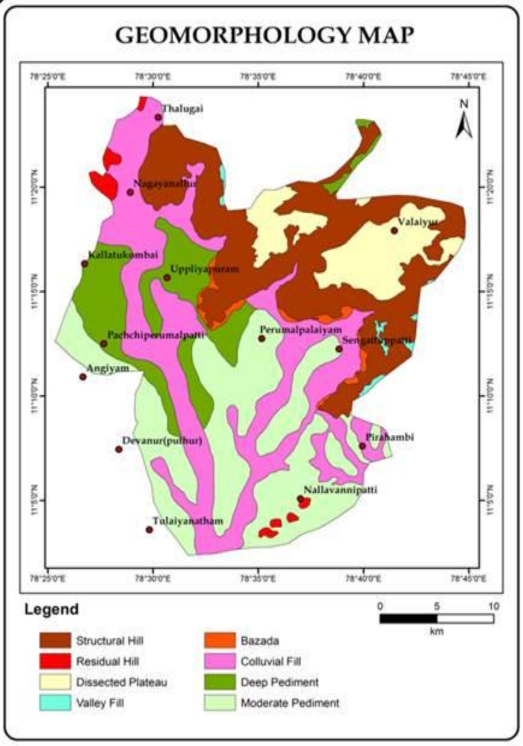

Figure 3: Geomorphology

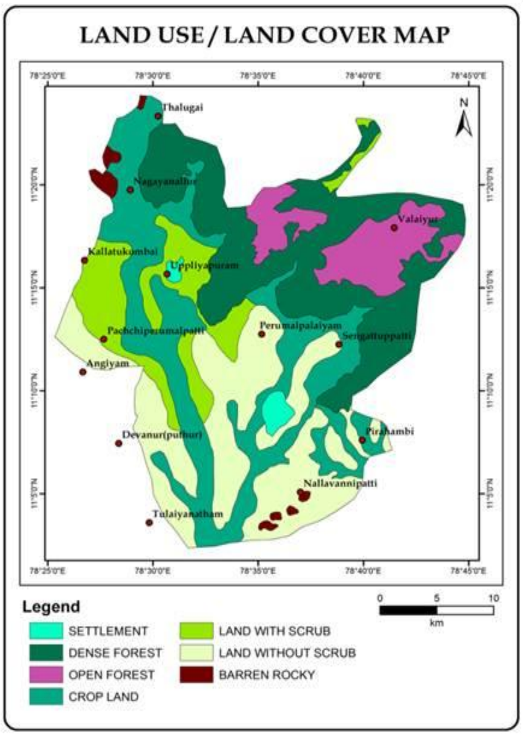

Figure 4: Landuse/Landcover

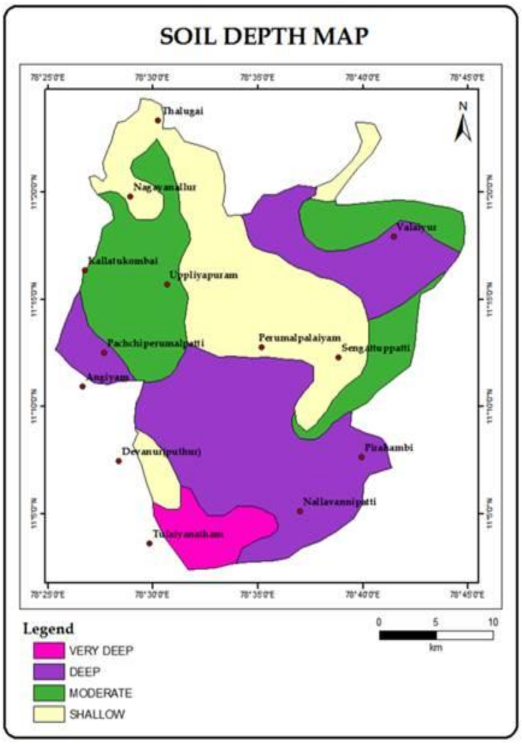

Figure 5: Soil Depth

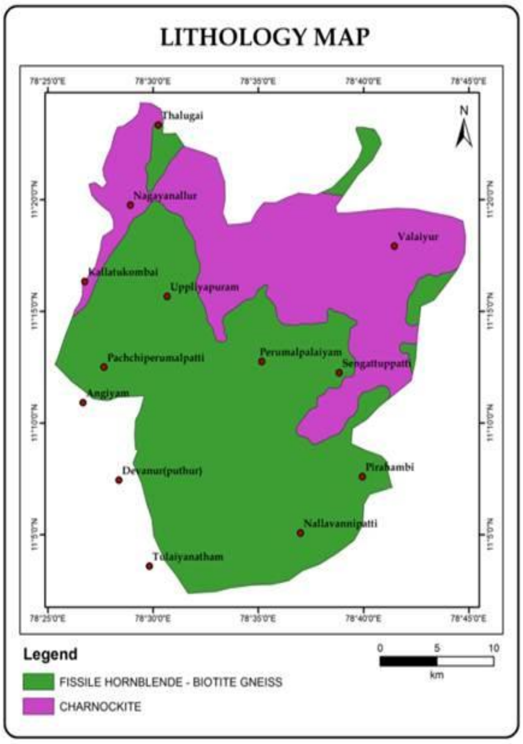

Figure 6: Lithology

Figures 3; 4; 5 and 6: *Geomorphology; Landuse/ Landcover and Soil Depth and Lithology*

Table 1: *Assigning Weightage and Ranks to the Thematic Layers*

S. No.	Themes / Weightages	Ranks		
		3	2	1
1	Rainfall /5	Nil	850 – 900mm (T.W. -10)	800-850mm (T.W.-8)
2	Land Use / Land Cover/4	Crop Land (T.W.- 12)	Open Forest, Land With Scrub, Dense Forest (T.W.- 8)	Barren Rocky, Settlement, Land Without Scrub (T.W.- 4)
3	Geomorphology /3	Bazada, Colluvial Fill (T.W.-15)	Dissected Plateau, Deep Pediment, Valley Fill (T.W.-10)	Residual Hill, Structural Hill And Moderate Pediment (T.W.-5)
4	Soil Depth/2	Very Deep, Deep (T.W.- 6)	Moderate (T.W.-4)	Shallow (T.W.-2)
5	Lithology /1	Nil	Fiddile Hornblende-Biotite Gneiss (T.W.-2)	Charnockite (T.W.-1)

4. Water Quality Mapping

Water samples (13 Nos.) are collected from shallow aquifers for chemical analysis. After chemical analysis, all the results obtained are shown in Table 2 and compare with drinking water set by Bureau of Indian Standard (BIS). The range of chemical parameters in the study area is summarized below [3].

Table 2: *Geochemical Analyzed Data of the Collected Samples in and Around the Study Area*

Location	E.C	PH	Ca	Mg	Na+k	HCo_3	Co_3	Cl	No_3	So_4	TDS
Valaiyur	2260	8.3	17.84	36.47	416.7	427.09	60	389.63	0	96.06	1240
Tulaiyanatham	1810	8.4	81.36	60.78	228.93	244.05	90	283.39	0	192.12	1029
Nallavannipatti	1810	8.3	100.2	36.47	152.12	1189.7	150	1098.9	61.99	398.66	3916
Pirahambi	1700	8.5	46.09	37.69	274.97	366.08	89.71	265.86	14.03	0	907
Devanu (puthur)	1950	8.4	82.97	38.05	284.94	427.09	27	319.04	9.15	129.2	1115
Angiyam	2340	8.3	17.84	85.1	455.28	305.06	120	425.38	62	144.09	1376
Sengattupatti	700	8.6	56.11	26.74	273.74	488.1	90	212.69	0	28.82	953
Pachchiperumalpatti	700	8.3	18.04	21.88	98.85	170.84	30	77.98	1202	28.82	370
Perumalpalaiyam	570	707	26.05	6.08	92.84	128.13	0	106.35	23.56	408	321
Uppliyapuram	450	7.2	14.03	1022	99.52	57.35	0	70.54	27.95	47.55	285
Kallatukombai	2350	8.6	140.28	36.47	363.33	98.23	14.7	602.62	62	144	1453
Nagayanallur	580	7.7	48.1	13.37	53.7	128	0	113.43	0	24.02	318
Thalugai	570	707	26.05	6.08	92.84	128.13	0	106.35	23.56	4.8	321

Table 3: *Quality of Groundwater based on Electrical Conductivity*

EC(µS/cm)	Water Class	Representing Wells	Total No of Wells
<250	Excellent	9,11	2
250-750	Good	1,4,5,6and10	5
750-2000	Permissible	2,3,7,8	4
2000-3000	Doubtful	Nil	Nil
>3000	Unsuitable	Nil	Nil

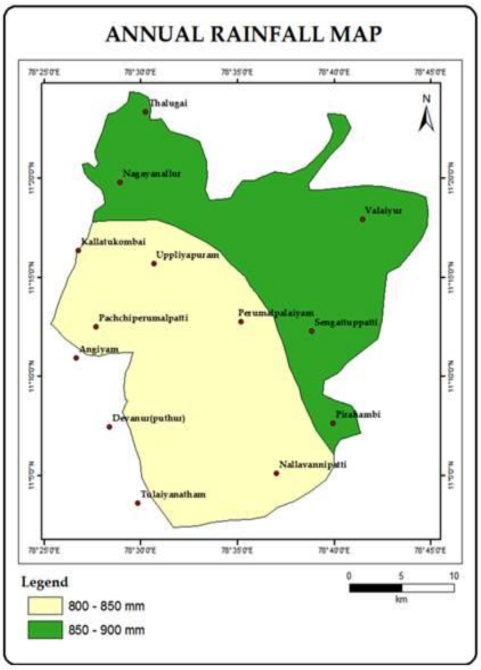

Figure 7: Annual Rainfall

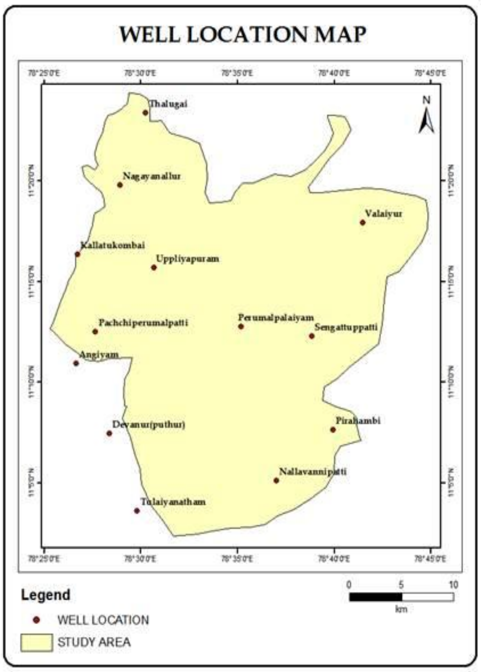

Figure 8: Well Location

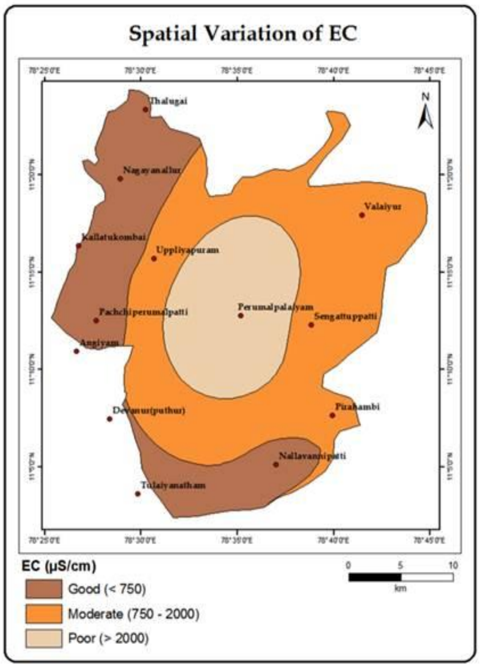

Figure 9: Spatial Variation of EC

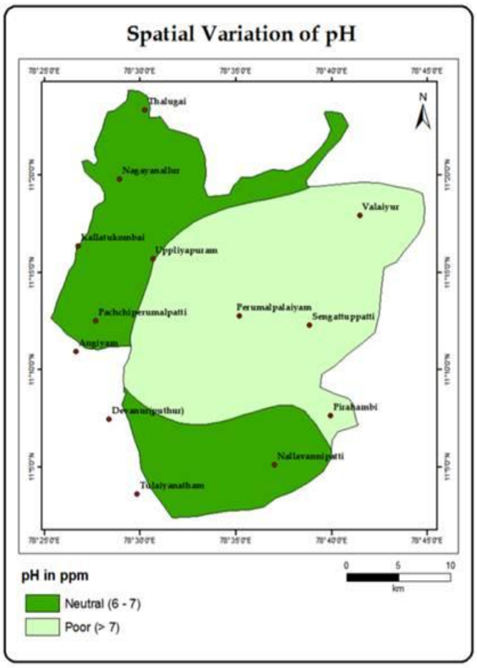

Figure 10: Spatial Variation of pH

Figures 7; 8; 9 and 10: *Annual Rainfall; Well Location; Spatial Variation of EC and Spatial Variation of P*H

Table 4: *Suitability of Drinking Quality for Calcium Ions*

Concentration of Ca	Suitable Zone
<30ppm	Good
30-120ppm	Moderate
>120ppm	Poor

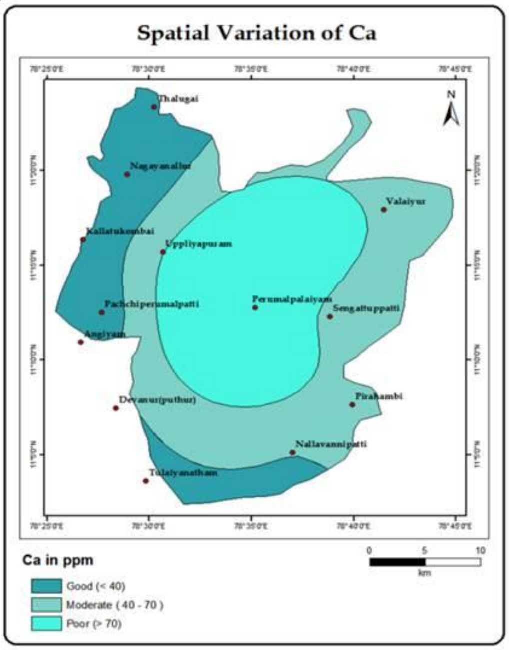

Figure 11:*Spatial Variation of Ca*

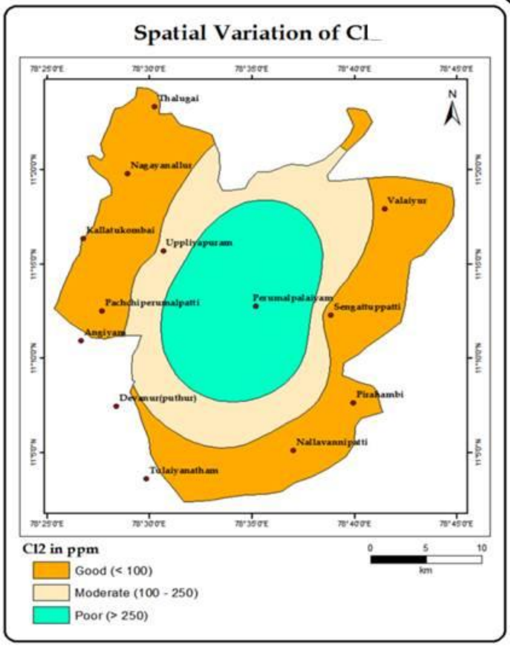

Figure 12: *Spatial Variation of Cl*

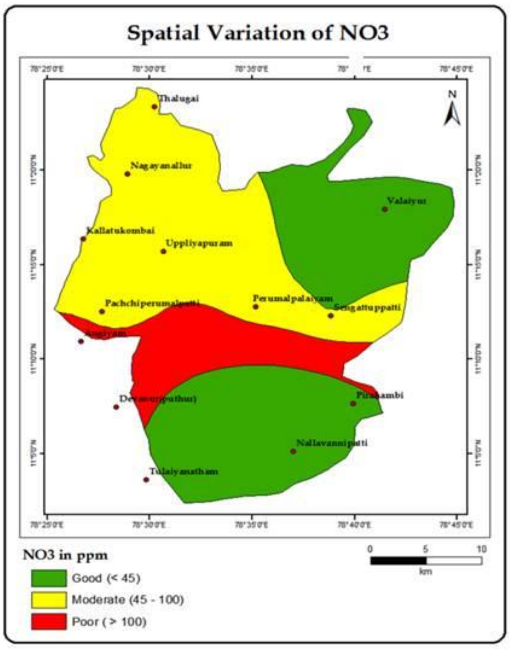

Figure 13: *Spatial Variation of NO3*

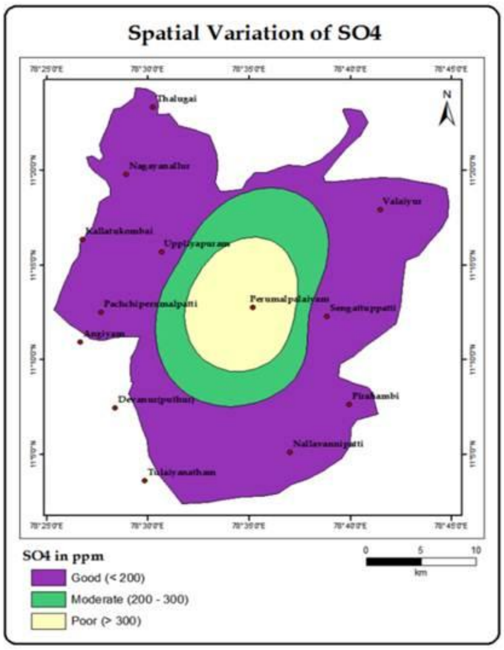

Figure 14: *Spatial Variation of SO4*

Figures 11; 12; 13 and 14: *Spatial Variation of Ca; Spatial Variation of Cl; Spatial Variation of NO3and Spatial Variation of SO4*

Table 5: *Suitability of Drinking Quality for Chloride Ions*

Concentration of Chloride	Suitable Zone
<100ppm	Good
100-250ppm	Moderate
>250ppm	Poor

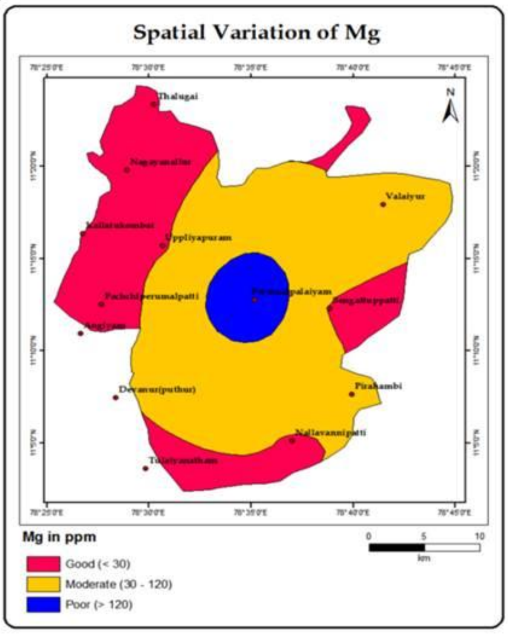

Figure 15: *Spatial Variation of Mg*

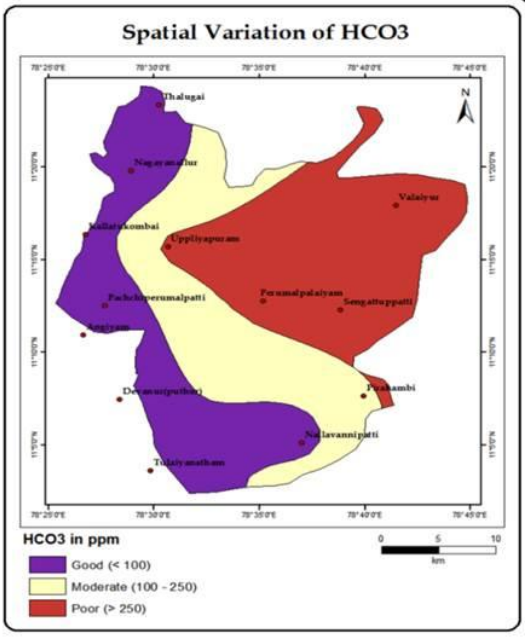

Figure 16: *Spatial Variation of HCO3*

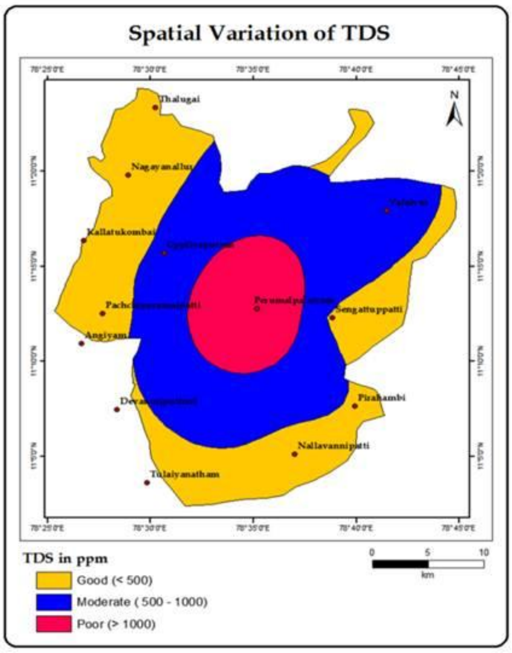

Figure 17: *Spatial Variation of TDS*

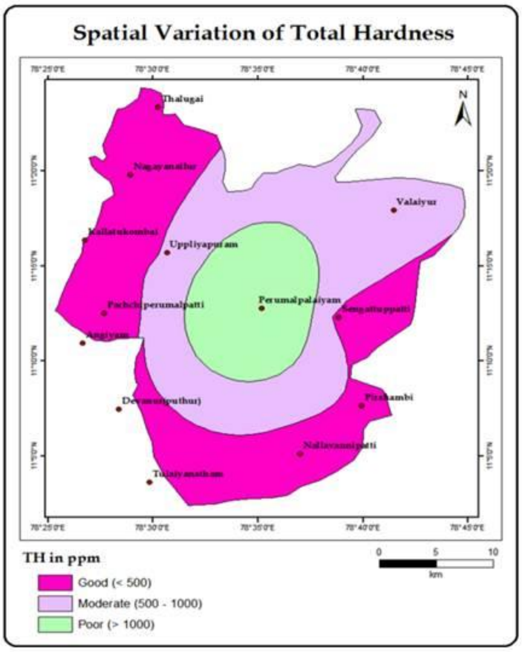

Figure 18: *Spatial Variation of Total Hardness*

Figures 15; 16; 17 and 18: *Spatial Variation of Mg; Spatial Variation of HCO3; Spatial Variation of TDS and Spatial Variation of Total Hardness*

Table 6: *Suitability of Drinking Quality for Mg*

Concentration of Mg	Suitable Zone
<30ppm	Good
30-120ppm	Moderate
>120ppm	Poor

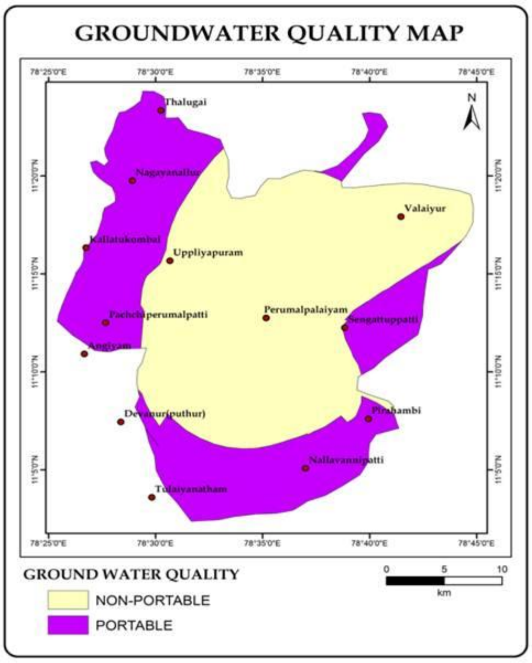

Figure 19: *Groundwater Quality Map*

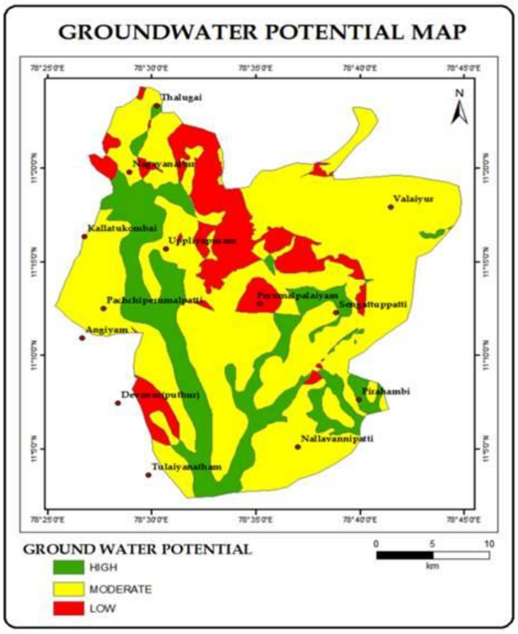

Figure 20: *Groundwater Potential Map*

Figures 19 and 20: *Ground Water Quality Map and Ground Potential Map*

Table 7: *Suitability of Drinking Quality for HCO3*

Concentration of HCO_3	Suitable Zone
<100ppm	Poor
100-250ppm	Moderate
>250ppm	Good

5. Results and Discussion

Groundwater quality was essential for drinking and domestic purposes and Ground Water Quality maps are also very useful in assessing the usability of the water for different purposes. Similarly, the spatial distribution of chloride, total hardness, total dissolved solids distribution and nitrate concentrations in study area are generated. Finally, by integrating the entire above maps groundwater quality map was prepared and has been classified.

Electrical Conductivity (EC)

Electrical Conductivity can be defined as the ability of a solution to conduct an electric current and measured in micro mhos /cm and reported at 25°C. Electrical Conductivity is a function of concentration of ions, charge and ionic mobility Electrical Conductivity is approximately indicative of ionic strength. The EC in the study area ranges from <250 to >3000 and the area has been classified as 5 classes as shown in Table 3 and Figure 9. [4], [5], [6]

pH

The pH is a numerical scale which express the degree of acidity or alkalinity of solution and represented by the equation pH= $\log 1/aH^{+}$= $-\log aH^{+}$ or in other words pH may be defined as negative logarithmic of Hydrogen ion concentration. In study area, the overall range of pH in ground water varies from <7.2 to >70 and the area has been classified as 5 classes as shown in Figure 10. [4], [6]

Calcium (Ca)

The calcium is a major constituent of various rocks. Calcium minerals associated with sodium, aluminum, silica, sulphate, carbonate and Fluoride. Maximum permissible limit for calcium is <40 mg/l. Maximum concentration in ground water is >70 mg/l and the study area has been classified as 5 classes as shown in Table 4 and Figure 11. [4], [5]

Chloride (Cl)

Chloride is one of the most common constituent in groundwater and very stable as compared to other ions like SO_4, HCO_3, and NO_3 etc. It varies from <100 to >250 and the area has been classified as 5 class as shown in Table 5 and Figure 12.[4], [5], [7]

Nitrate (NO_3)

Nitrate is one of the important pollution related parameter. Nitrate is the end product of the aerobic oxidation of nitrogen compounds. Mainly it is contributed by nitrogenous fertilizers, decomposition of organic matter in the soil, fixation of nitrogen by bacteria etc. Human and animal excreta may also add nitrate to water by bacterial decomposition. For drinking water maximum permissible limit of nitrate is 45 mg/l as per BIS 1991-Rev-2007. In the study area, maximum concentration of Nitrate in ground water is recorded from the Valayur and Nallavannipatti. The range of Nitrate ranges from <45 to >100 and the area has been classified as 5 classes as shown in Figure 13. [5], [7]

Sulphates (SO_4)

Sulphates was classified in to three ranges (0-200 mg/l, 200-300 mg/l and >300 mg/l) and based on these ranges the spatial variation map for sulphates has been obtained and presented in Figure 14. Sulphate of water samples ranges from 0 to 408 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 (>300 mg/l). For the Southern part of the study area, sulphate value is in the moderate and good range. [4], [6]

Magnesium (Mg)

Magnesium also is one of the abundant elements in rocks. It causes hardness in water. Magnesium concentration of water samples ranges from 6.08 to 85.1 mg/l. The spatial variation map for magnesium has been obtained and presented in Table 6 and Figure 15. 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 [5; 6].

Bicarbonate (HCO_3)

Bicarbonate (HCO3) concentration of water samples ranges from 57.35 to 488.1 mg/l. The spatial variation map for Bicarbonate has been obtained and presented in Table 7 and Figure 16. 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 [6].

Total dissolved solids (TDS)

Total Dissolved Solids is a measure of organic and inorganic substances which are in suspended condition in a liquid. TDS of 500 mg/L or lesser is desirable for drinking water and varies from 50 mg/L to 200 mg/L for industrial use Total dissolved solids in water could be controlled by reverse osmosis, electro dialysis, exchange and solar distillation process (Figure 17) [5; 6; 7].

Total hardness (TH)

Total Hardness of water is the capacity to neutralize soap and is mainly caused by carbonates and bicarbonates of calcium, magnesium. In study area, Maximum concentration in ground water is >1000 mg/l and Minimum concentration in ground water is <500 mg/l and the study area has been classified as 5 classes as shown in Figure 18, [5; 6; 7].

6. Conclusion

After the overlay of critical parameters for portable and non-portable zones in study area, the final Ground-water Quality Map derived shows only a small region in the North-Western and Southern part of the study area where the groundwater is portable. Similarly, high groundwater potential of the study area also lies in the North-Western and Southern part. This justifies that ground water quality depends on the amount of the natural recharge.

Acknowledgement

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