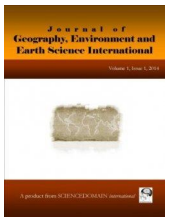

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Identification of Groundwater Quality Zones in Tindivanam Taluk, Tamilnadu with the Integrated Approach of Remote Sensing and GIS

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Authors' contributions

This work was carried out in collaboration between two authors. Author AK designed the study, wrote the protocol, managed the literature searches and wrote the first draft of the manuscript. Author GRS performed Remote sensing and GIS analysis and delineated the Groundwater Quality Zones in the study area. Both the authors read and approved the final manuscript.

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ABSTRACT

Groundwater quality prospective zones of Tindivanam Taluk, Tamil Nadu were investigated and delineated by an integrated approach of remote sensing and geographical information system (gis). Various thematic maps like geology, geomorphology, lineament, drainage, land use/land cover and soil were prepared for the study area. The attribute information pertaining to water quality such as TDS, pH, TH, CR, Cl, have been plotted as point attributes (locations wells) for constructing contours. The selected attributes are based on the purposes of drinking (TDS), domestic (TH), industrial (CR) and agricultural/drinking (CL). The pre and post-monsoon water quality spatial scores are added and the highest positive score is considered as the resulting permissible parameters. The integration of TDS and TH have been done using the command union to obtain the map union1, and CR and Cl integrated to produce union 2 map. By integrating union 1 and

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union 2, union 3 has been produced, that is the final output map of overlay analysis. The final map is the final output map of overlay analysis. The final map has been categorized into three zones, namely good, tolerate and poor. From the final integrated map, it is inferred that freshwater exists in the north, northeastern and southern part of the study area (144.59 sqkm). The tolerate quality water occupies about (300.74 sqkm) and the poor quality water occupied by 154.89 sqkm.

Keywords: Groundwater quality zones; remote sensing; GIS; Tindivanam Taluk; Tamil Nadu.

1. INTRODUCTION

In India, more than 85% of rural and nearly 50% of urban population depend on the groundwater for drinking purpose, while, it accounts for nearly 60% of the total irrigated in the county [1]. Water quality plays an important role in promoting agricultural production and standard of human health [2]. The water quality may yield information about the environment through which the water has circulated. Each groundwater system in the area has a unique chemistry, acquired as a result of chemical alteration of meteoric water recharging the system [3,4]. In the hardrock terrain, availability of groundwater is limited and its occurrence is essentially confined to fractures and weathered zones [5]. Water demand and quality deterioration are common in hardrock terrain [6]. The remote sensing system provide synoptic coverage with accurate and economical spatial information of hydrogeological surveys and rapid development of GIS provides spatial data integration with efficient and successful tool for groundwater studies [7,8,9,10,11,12]. Groundwater quality parameter studies were taken up in the municipal corporation of Hyderabad (India) in 2002 using remote sensing and GIS technique [13]. It is aimed to assess the hydrogeological regime of the study area by adopting an integrated approach including geological, geomorphological, hydrometerological, geophysical, hydrogeochemical and numerical simulation studies.The main objectivie of the present study is to integrate and generate spatial quality zonation map using remote sensing and GIS.

2. STUDY AREA

The study area falls in Villupuram District of Tamil Nadu. It lies between 12° 18' and 12° 24' N latitudes and 79° 30' and 79°52' E longitudes covering an area of 600.14 sq km as shown in the Topographical map of India, sheets 57P/11, 12, 15 & 16. The study area is administratively bounded by Kanchipuram District in the north and northeast, Tiruvannamalai District in the northwest. Marakkanam Block, Vanur Block, Villupuram Block, Gingee Block bounds the area in east, southeast, south and west respectively (Fig. 1). The average annual rainfall is 1100 mm. The average annual temperature is 37°C. The study area rocks belong to meta-sediments, representing, granitic gneiss and charnokite with the intrusion of granite, dolerite dyke and pegmatite. The rock displays variation in their lithology, structure and tectonics from place to place. The granitic gneiss formation is massive forming denudation and residual hills. Feldspar and quartz are essential minerals while hornblende and biotite form as secondary minerals. Dykes occur as concordant intrusive body along the weaker plane within the country rocks. Pegmatites containing feldspar and minor amount of quartz is noticed in a few locations.In the study area (Fig. 2), the potential of the groundwater is poor. Groundwater occurs in the joints, fractures and weathered rocks. Weathering thickness varies from 1 to 19 m, in which the northern part comprises deep thickness ranges from 8 to 19 m whereas southern part ranges 1 to 5 m. The river Thondiyar and Sankarabarani flows in the southern part, the flow water is stored in Veedur dam. From previous hydrogeochemical studies, it is understood that different categories of water exist in groundwater with respect to various geochemical parameters.

3. METHODOLGY

Base map for the study area was prepared using toposheet no's 57P/11, 12, 15 & 16 on 1:50,000 scales, Arc View GIS software was used to digitize the thematic maps prepared from different sources. Groundwater samples were collected from open wells and bore wells in various locations of the study area during pre and post-monsoon periods (July 2013 & February 2014). Chemical analysis were carried in the Regional Laboratory of Tamil Nadu Water And Drainage Board (TWAD),Tindivanam (India). Thirteen groundwater parameters like pH, Electrical Conductivity (EC), TDS, and major ions (Na+, potassium (K)+, Ca2+, magnesium

(Mg)2+, sulfate (SO42–), CO32–, HCO3–, and Cl–) were analysed in the laboratory using standard procedures APHA-AWWA and WPCF (1998) and their results are presented in the Tables 1 & 2. Hydrogen ion activity pH, EC and TDS were measured in-situ using portable meters, pHTestr10 (±0.1 pH accuracy), ECTestr11+ (±1%) and TDSTestr11+ (±1%) (OAKTON). Hardness was determined by titration Erichrome black T indicator and standard (0.01 N) EDTA solution. Ca and Mg were determined using the titration with standard versenate (EDTA) solution, using Eriochrome Black T (EBT) as indicator according to [14]. Na and K were determined using flamephotometry methods [15]. Carbonate and bicarbonate were determined by the potentiometric titration method [16]. Chlorides were determined using a standard solution of silver nitrate and sulfates were spectrophotometer measured using the turbidimetry method [17]. The attribute information pertaining to water quality such as total dissolved solids (TDS), Total hardness (TH), corrosivity ratio (CR) and chloride (Cl), have been plotted as point attributes (locations of wells) for constructing contours.

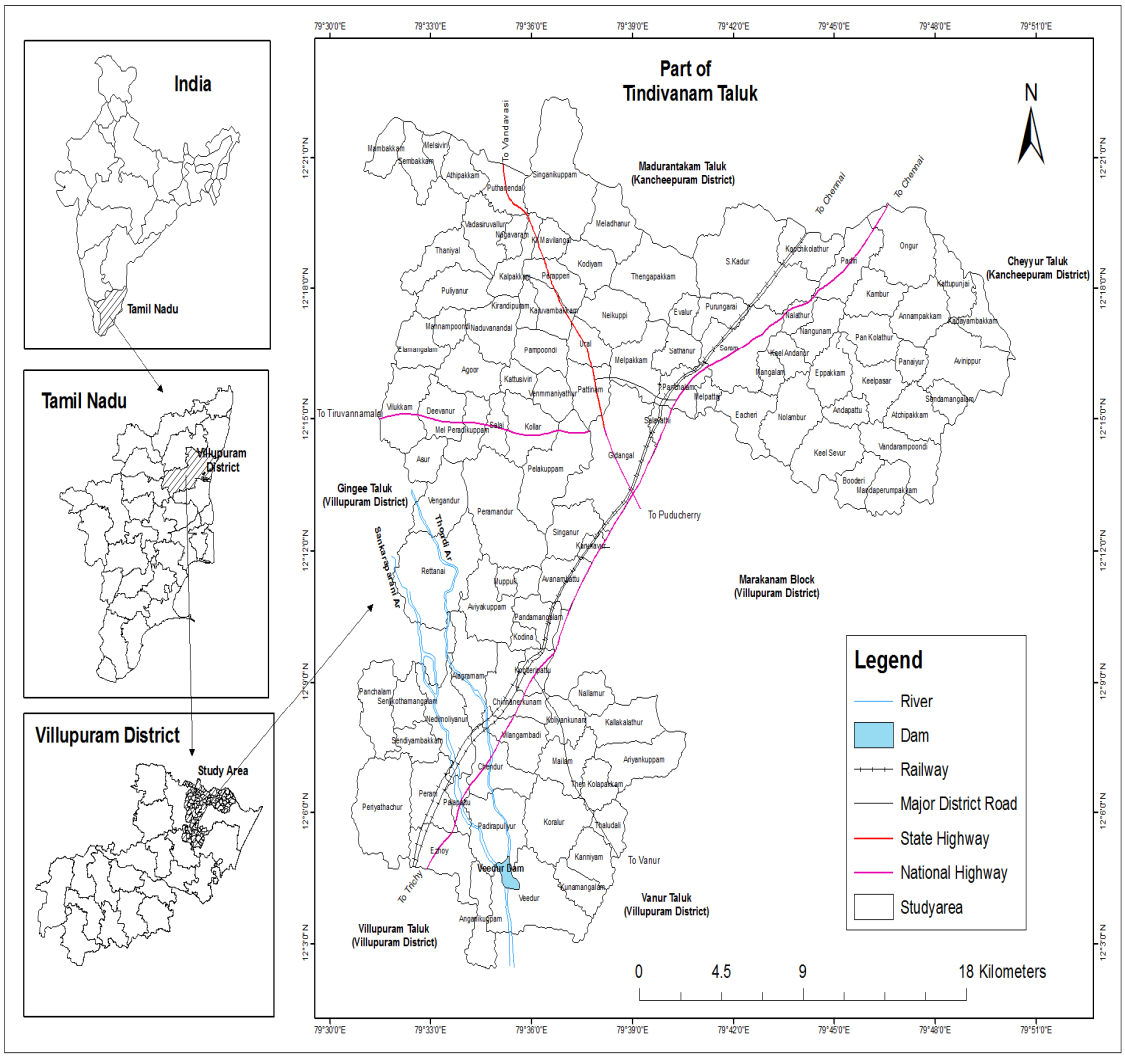

Fig. 1. Location map of Tindivanam Taluk (study area)

Table 1. Results of chemical analysis of parts of Tindivanam Taluk during pre-monsoon period

Loc. no.	Location	EC	pH	Ca	Mg	Na+K	HCO_3	CO_3	Cl	NO_3	SO_4	TDS	TH
		µS/cm		(in mg/l)									
1	Sengenikuppam	850	7.3	78	23	170	291	0	100	6	35	595	289.32
2	Sembakkam	1080	7.0	34	20	185	534	0	126	1	27	756	168.24
3	Neduthondi	570	7.2	53	9	98	504	0	22	3	10	399	168.98
4	Dadapuram	1580	7.2	86	54	426	407	0	253	10	64	1106	437.36
5	Kodiyampudur	1365	7.2	74	14	368	359	0	307	6	67	956	241.49
6	Ongur	2190	7.3	129	92	406	615	0	250	9	81	1533	700.85
7	Kutchikulathur	1540	6.8	80	50	415	160	0	156	8	140	1078	403.71
8	Thenpakkam	595	7.4	40	34	119	762	0	69	2	35	417	240.13
9	Vadampoondi	1030	6.8	59	13	177	313	0	164	2	43	721	202.63
10	Mel Olakkur	1300	6.9	27	51	223	322	0	119	4	40	910	276.44
11	Vairapuram	895	7.1	105	16	175	148	0	82	9	21	627	329.63
12	Puliyanur	725	6.9	12	26	122	1246	0	112	3	12	508	138.15
13	Kalpakkam	570	7.4	54	18	154	299	0	90	6	37	399	208.8
14	Kambur	865	6.9	81	17	173	354	0	58	7	53	606	273.55
15	Vadakalavai	1650	7.2	125	70	445	655	0	336	4	43	1155	601.31
16	Elamangalam	1830	7.3	42	15	487	364	0	446	6	30	1281	168.58
17	Pampundi	1095	7.3	94	19	218	1520	0	123	6	79	767	313.82
18	Sathanur	690	7.0	89	15	128	442	0	46	2	42	483	281.83
19	Saram	2040	7.0	72	107	550	368	0	465	6	26	1428	618.27
20	Avanippur	1285	7.3	137	15	346	254	0	211	4	59	900	403.03
21	Panaiyur	1380	7.5	57	46	372	377	0	192	7	51	966	330.22
22	Melpakkam	510	6.7	29	6	87	253	0	41	2	25	357	97.11
23	Akkur	1210	7.1	139	16	275	455	0	108	5	57	847	410.9664
24	Eppakkam	1755	6.8	190	64	473	207	0	260	5	148	1229	737.7261
25	Vilukkam	1625	6.9	72	43	427	750	0	260	4	67	1138	357.5168
26	Icheri	2540	6.9	199	84	685	171	0	446	3	166	1778	842.4032
27	Melperadikuppam	1800	7.2	73	11	403	417	0	330	9	20	1260	227.2704
28	Salavathi	780	7.1	71	25	156	346	0	84	3	66	546	281.1194
29	Vempundi	1550	7.4	77	48	418	383	0	192	7	68	1085	390.668
30	Vandarampoondi	1375	7.5	44	27	371	336	0	250	6	36	963	220.4224
31	Tindivanam	2720	7.08	216	79	733	437	0	456	9	212	1904	863.9

Loc. no.	Location	EC	pH	Ca	Mg	Na+K	HCO_3	CO_3	Cl	NO_3	SO_4	TDS	TH
		µS/cm						(in mg/l)					
32	Kilsevur	2480	6.9	140	36	668	289	0	577	10	103	1736	495.8256
33	Venganthur	1650	7.2	99	18	445	277	0	280	12	59	1155	321.3
34	Mandaperumbakkam	575	6.6	48	15	115	511	0	69	4	18	403	180.8304
35	Peramandur	960	7.2	40	19	259	314	0	173	4	47	672	180.5072
36	Jakkampettai	1240	6.9	53	25	213	524	0	171	3	57	868	235.744
37	Rettanai	1345	6.9	127	43	231	431	0	164	7	23	942	493.2307
38	Avvaiyarkuppam	860	7.2	41	35	147	571	0	126	10	34	602	243.6134
39	Kenipattu	1870	6.9	85	64	504	711	0	260	10	145	1309	472.76
40	Se.Kottamangalam	1120	7.2	95	41	302	491	0	223	6	41	784	404.3264
41	Kolliyangunam	530	7.4	66	9	106	694	0	74	10	31	371	202.9094
42	Kallakulathur	4450	7.1	288	148	1199	320	0	1116	9	230	3115	1325.763
43	Nedimoliyanur	1140	6.9	51	28	196	385	0	149	0	20	798	244.0205
44	Kuralur	440	7.3	34	18	85	228	0	30	8	22	308	159.8989
45	Periyathatchur	905	6.9	44	15	244	868	0	164	4	19	634	172.8224
46	Padaraipuliyur	2820	7.4	234	23	484	652	0	316	3	161	1974	678.6736
47	Thazhudali	920	7.4	54	23	180	613	0	74	9	55	644	231.6397
48	Ezhai	1840	7.1	79	26	527	242	0	292	10	83	1288	302.2976
49	Konamangalam	2340	7.4	161	76	631	218	0	484	29	139	1638	715.712
50	Ganapathipattu	1200	6.8	61	26	323	172	0	250	2	43	840	260.8547

Table 2. Results of chemical analysis of parts of Tindivanam Taluk during post-monsoon period

Loc. no.	Location	EC	pH	Ca	Mg	Na+K	HCO_3	CO_3	Cl	NO_3	SO_4	TDS	TH
		µS/cm						(in mg/l)					
1	Sengenikuppam	780	7.4	69	22	156	218	0	91	5	32	546	260.97
2	Sembakkam	860	7.4	60	28	147	313	0	31	2	12	602	264.77
3	Neduthondi	625	7.1	40	23	107	228	0	15	4	18	438	194.30
4	Dadapuram	1860	7.0	126	11	501	521	0	442	3	11	1302	358.85
5	Kodiyampudur	1260	7.5	69	14	340	353	0	291	5	63	882	229.48
6	Ongur	1460	7.1	184	16	332	409	0	223	9	56	1022	524.17
7	Kutchikulathur	1090	7.1	79	20	294	305	0	161	8	67	763	281.44
8	Thenpakkam	540	7.2	39	26	108	151	0	81	2	27	378	204.29
9	Vadampoondi	910	7.4	78	25	156	306	0	123	2	24	637	297.28

Loc. no.	Location	EC	pH	Ca	Mg	Na+K	HCO_3	CO_3	Cl	NO_3	SO_4	TDS	TH
		µS/cm		(in mg/l)									
10	Mel Olakkur	1110	7.1	57	44	190	373	0	73	5	40	777	320.29
11	Vairapuram	785	6.8	66	8	154	275	0	73	8	9	550	197.44
12	Puliyanur	700	6.12	69	11	118	245	0	31	4	14	490	217.45
13	Kalpakkam	500	7.4	46	12	135	140	0	76	5	27	350	165.58
14	Kambur	780	7	79	17	156	268	0	44	6	48	546	267.67
15	Vadakalavai	540	7.2	45	16	146	151	0	100	4	10	378	180.70
16	Elamangalam	1700	7.2	65	16	452	571	0	384	6	31.32	1190	225.21
17	Pampundi	990	6.9	90	21	198	312	0	131	6	28	693	313.70
18	Sathanur	630	6.7	52	16	117	221	0	61	2	35	441	192.89
19	Saram	1940	7.1	63	28	523	543	0	461	5	31	1358	272.85
20	Avanippur	1750	6.7	121	30	472	490	0	346	3	67	1225	426.24
21	Panaiyur	1350	7.5	66	44	364	378	0	188	8	50	945	344.53
22	Melpakkam	450	6.7	45	14	77	151	0	38	3	12	315	168.78
23	Akkur	1020	7.0	129	4	232	343	0	100	4	40	714	338.90
24	Eppakkam	1360	6.8	84	36	367	381	0	215	4	64	952	357.17
25	Vilukkam	1475	7.0	74	37	387	413	0	207	4	22	1033	336.90
26	Icheri	1960	6.9	198	61	528	549	0	413	3	103	1372	743.36
27	Melperadikuppam	1735	7.2	68	16	389	486	0	346	9	20.88	1215	233.29
28	Salavathi	670	6.9	84	8	181	188	0	115	3	26	469	241.88
29	Vempundi	1590	7.1	94	46	429	445	0	207	7	88	1113	421.16
30	Vandarampundi	1285	7.7	47	30	346	360	0	242	6	21	900	240.40
31	Tindivanam	2320	6.9	194	24	625	650	0	384	4	223	1624	584.18
32	Kilsevur	1955	7.4	100	29	527	547	0	499	10	88	1369	369.74
33	Venganthur	1540	7.4	79	22	415	431	0	255	10	53	1078	286.57
34	Mandaperumbakkam	480	6.8	41	14	96	134	0	62	3	14	336	159.08
35	Peramandur	955	7.1	45	17	257	267	0	184	4	48	669	184.68
36	Jakkampettai	1120	6.8	129	15	192	376	0	84	2	22	784	382.83
37	Rettanai	1280	6.8	121	4	220	358	0	200	8	27	896	318.90
38	Avvaiyarkuppam	735	7.3	74	17	126	247	0	86	10	19	515	257.40
39	Kenipattu	1800	6.8	78	65	485	504	0	288	11	149	1260	460.27
40	Se.Kottamangalam	1115	7.0	84	37	300	312	0	230	7	47	781	361.14
41	Kolliyangunam	695	7.0	42	17	187	195	0	115	9	32	487	176.60
42	Kallakulathur	3890	7.1	218	15	1048	1089	0	1037	13	74	2723	605.03

Loc. no.	Location	EC	pH	Ca	Mg	Na+K	HCO_3	CO_3	Cl	NO_3	SO_4	TDS	TH
		µS/cm		(in mg/l)									
43	Nedimoliyanur	1020	7.3	74	32	175	343	0	115	1	22	714	317.03
44	Kuralur	460	6.9	40	8	85	160	0	15	7	17	322	132.80
45	Periyathatchur	830	7.4	87	12	224	232	0	138	4	14	581	265.86
46	Padaraipuliyur	2070	7.7	141	73	355	551	0	307	4	92	1449	651.65
47	Thazhudali	860	7.2	48	8	169	301	0	38	8	45	602	153.00
48	Ezhai	1930	6.8	129	19	527	534	0	422	11	87	1351	402.71
49	Konamangalam	2020	7.1	206	17	544	566	0	557	8	60	1414	584.67
50	Ganapathipattu	1120	6.9	59	22	302	314	0	240	2	37	784	238.52

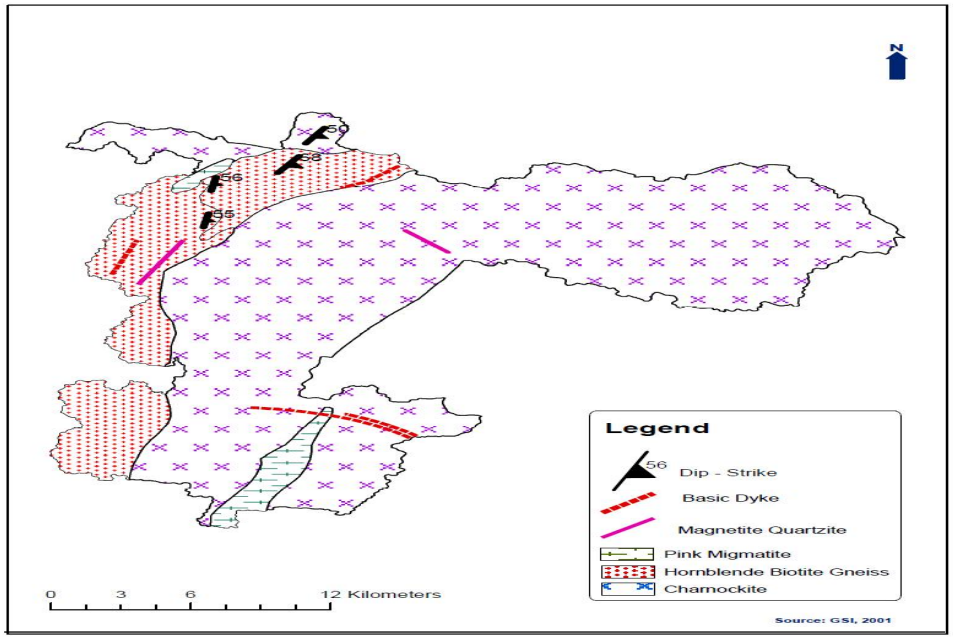

Fig. 2. Geology map of Tindivanam Taluk (study area)

4. RESULTS AND DISCUSSION

4.1 Integrated GIS Groundwater Quality Study

In the present study, the integrated geochemical model for groundwater has been developed together and the parameters considered are total dissolved solids, corrosivity ratio and hardness. The geochemical model precisely categorises the groundwater into three zones, viz. Good, Tolerate and Poor, which would enable the user to locate potable groundwater (good) zones without difficulty. The data used for the Integrated Geochemical Modeling for groundwater adopted in the present study is furnished in the form of flow chart (Fig. 3). The ranks assigned to different groundwater classes are presented in Table 3.

Table 3. Quality parameters used for integration

Sl. no	Geochemical parameter	Parameter range	Classification	Rank
1.	Total Dissolved Solids (TDS) in ppm	< 1000	Good	3
		> 1000	Poor	1
2.	Total Hardness (TH) in ppm	< 150	Good	3
		>150	Poor	1
3.	Corrosivity Ratio (CR)	<1	Good	3
		>1	Poor	1
4.	Chloride (Cl) in ppm	< 150	Good	3
		>150	Poor	1

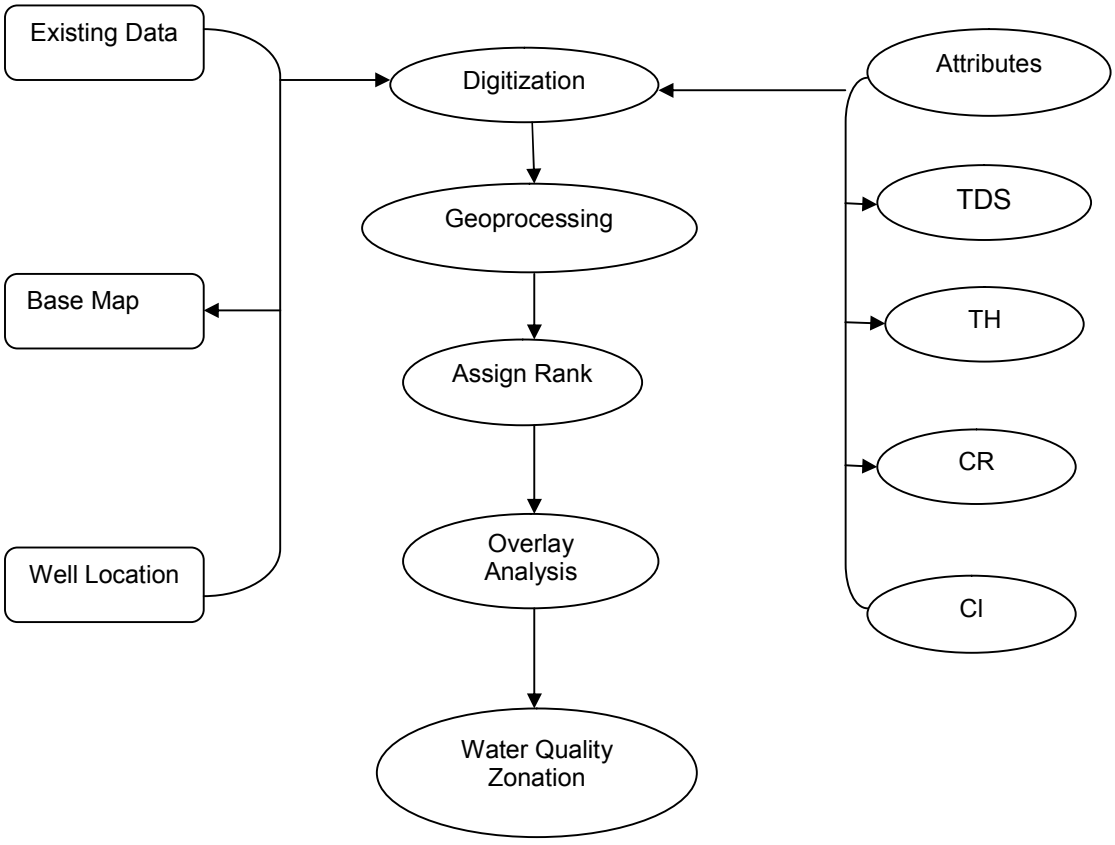

Fig. 3. GIS Flow Chart

Groundwater in the study area is classified as per the standards mentioned below:

- Total Dissolved Solids (TDS) [18]
- Total Hardness (TH) [19]
- Corrosivity Ratio (CR) [20]
- Chloride (Cl) [21]

The references mentioned are modified for the purpose of ranking. The parameter values less than the permissible limit have been considered as good and the values more than the permissible limit have been considered as poor, in order to reduce the number of layers. Subsequently the rating has been provided to obtain the GIS based model.

The pre- and post monsoon spatial scores are added and the highest positive score is considered as the resultant with permissible parameter. The integration of TDS and TH have been done using the command UNION to obtain the map Union 1, and CR and Cl are integrated to produce Union 2 map. By integrating Union 1 and Union 2, Union 3 has been produced which is a final output map of overlay analysis (Fig. 4). The final map has been categorized into three zones, namely Good, Tolerable and Poor (Fig. 5). Similar zonation has been attempted by [22]. They used GIS analysis to demarcate the freshwater zone of Ramanathapuram coastal groundwater.

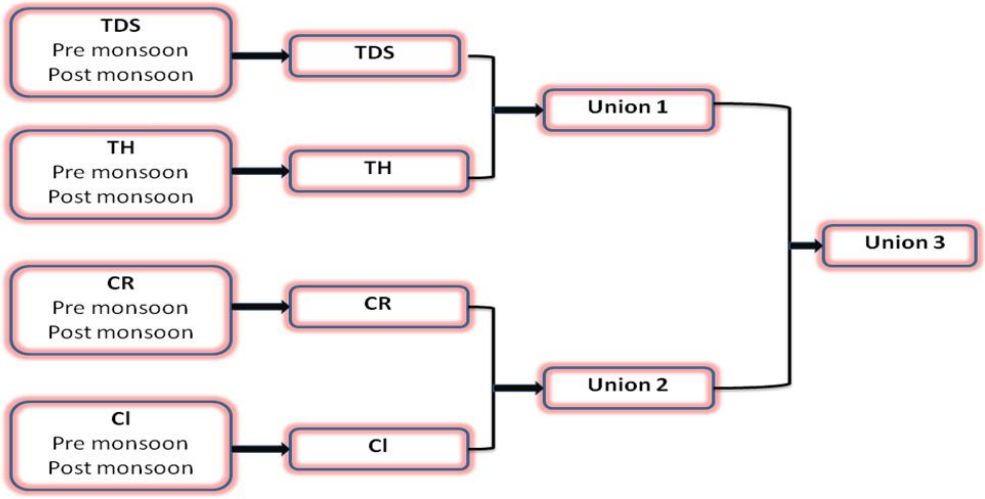

Fig. 4. The integration model for groundwater quality

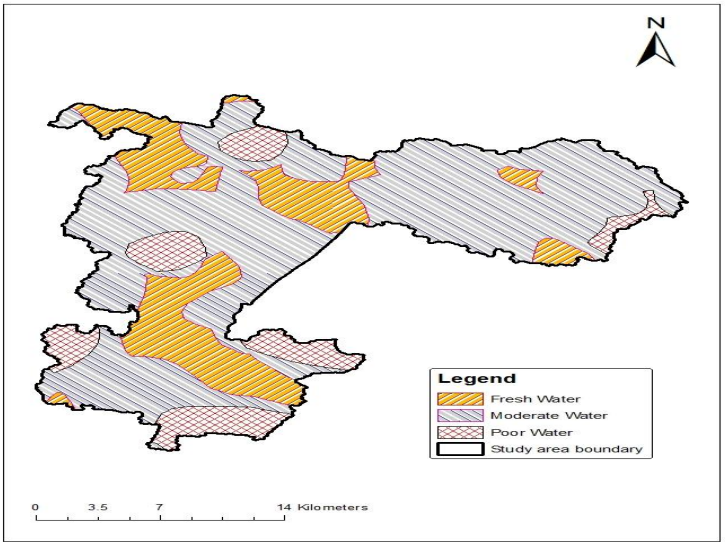

Fig. 5. Integrated water quality zoniation map of the study area

5. CONCLUSION

From the overall interpretation and discussion, it is to conclude that, according to standards of WHO 1994, fresh water occurs in the central part of the study area during pre- and post- monsoon seasons. It supports claims by Sawyer and McCarty (1967) that hard to very hard water exists in the study area in both the seasons. The corrosive water occurs as sporadic pockets in all regions of the study area. Most of the regions are characterized by non-corrosive water. Oligohaline to fresh water occurs around north and central portion of the area in both seasons. According to Stuyfzand's classification, the majority of the groundwater locations remains stable as non-corrosive in both the seasons and minor locations show difference between pre- and post monsoon periods. The resultant quality perspective of the study area revealed that about 144.59 sqkm of the area have fresh water. Tolerable quality water occupies about 300.74 sqkm and the poor quality water zone occurs around 154.81 sqkm of the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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