Original Research Article

Delineation and Mapping of Ground Water Quality in Kanchipuram District of Tamil Nadu using GIS Techniques

ABSTRACT

Agriculture relies heavily on irrigation especially with groundwater which is a significant source in many countries. However, excessive use of groundwater can lead to a decrease in groundwater levels and cause scarcity of water. Irrigation requires good-quality water which is governed by dissolved ions. The groundwater quality is greatly influenced by global population growth, climate change and human activities including mining, agriculture, industrial effluents, seawater intrusion, household usage, etc., A study was conducted to evaluate the quality of groundwater for agriculture in various blocks of Kanchipuram district in Tamil Nadu. The sampling was done during March 2023 and about one hundred and fifty groundwater samples were collected from different blocks of the Kanchipuram district viz., Sriperumbudur(32 Nos), Kundrathur (28 Nos), Walajabad (34 Nos), Uthiramerur (29 Nos) and Kanchipuram (27 Nos). The physio-chemical (pH and EC) and chemical characteristics of the groundwater samples, including the cations Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}, as well as the anions CO_3^{2-}, HCO_3^{-}, Cl^{-}, and SO_4^{2-}, were analyzed and the resulting properties were computed (SAR and RSC). The pH and EC values ranged from 3.29 to 8.49 and 0.09 to 5.22 dS m^{-1}, respectively. The Residual Sodium Carbonate (RSC) ranged from nil to 32 meq L^{-1}, while the Sodium Adsorption Ratio (SAR) ranged from 0.19 to 34.78 mmol L^{-1}. According to the CSSRI, Karnal Water Quality Classification about 38 percent of the samples falls in the good quality category, alkali water was about 57.33 percent and Saline water was 4.67 percent in Kanchipuram district. The Good quality water was dominant in Uthiramerur block followed by the Sriperumbudur block. The Saline and Alkali water was dominant in Sriperumbudur and Kanchipuram blocks respectively.

Keywords: Groundwater quality, Delineation, Mapping, Kanchipuram district, GIS

1. INTRODUCTION

Agriculture is an essential aspect of India's political as well as social economy. The majority of agricultural processes rely heavily on irrigation. Water is a critical input for agricultural production and plays an important role in food security. Globally, about 40 percent of irrigation water is supplied from groundwater and in India it is expected to be over 50 percent. Millions of farmers worldwide depend on groundwater irrigation to help produce 40 percent of the world's agricultural production. Further, groundwater reserves are becoming rapidly depleted in many critical agricultural regions across the globe. The quality of both surface and groundwater is currently getting worse. Globally, factors that affect surface as well as groundwater quality include a growing population, changes in water supply and need, a changing climate like drought, increase in sea levels and human activities including mining, agriculture, industrial effluents, excessive groundwater use, seawater intrusion, etc.,[1,2,3] . Therefore, understanding hydrochemistry is essential to evaluate the quality of groundwater that is used for both irrigation and drinking. Water quality assessments can provide detailed

information on the underground geological conditions where the water occurs [1]. Numerous studies have been conducted around the world to evaluate the geochemistry of groundwater [4]. Studies on the quality of groundwater have also been done in India [5,6]. There have also been some groundwater quality investigations done in Tamil Nadu [7,8,9]. The current study was carried out to evaluate the groundwater quality in Kanchipuram district which is one among the 32 districts of Tamil Nadu.
The Kanchipuram district is located in Tamil Nadu's northeast. Its coordinates are 77° 28' to 78° 50' longitude and 11° 00' to 12° 00' latitude. The district covers a total area of 4,43,210 hectares. Kanchipuram is about 72 km southwest of Chennai on the banks of the Vegavathi River, a tributary of the Palar River. It is bordered by the districts of Chengalpattu in the east, Chennai in the northeast, Ranipet and Tiruvannamalai in the west, and Thiruvallur in the north. Generally, there are 5 blocks namely Sriperumbudur, Kundrathur, Kanchipuram, Walajabad and Uthiramerur. The northeast and southwest monsoons are the main contributors, contributing 54 percent and 36 percent, respectively, to the total annual rainfall. The district experiences 1200 mm of rainfall during a typical monsoon. The average summer temperature ranges from about 36.6℃ (97.9℉) and the average winter temperature ranges from about 19.8 ℃ (67.6 ℉). The district covers 23,586 hectares of forest area. Agriculture is the most common occupation, employing 47 percent of the population. The land around Kanchipuram is flat and slopes towards the south and east. The soil in the region is mostly clay, with some loam, clay, and sand. Hardrocks and sedimentary deposits dominates the Kancheepuram district’s geology. These are overlained by laterites and alluvium. Hard rocks includes Granitic gneisses, Ultra basic intrusives of Archaean age and Charnockites. They are mainly comprising of biotite and hornblende and are intrude by amphibolite, dykes of dolorite and occasionally by veins of quartz and pegmites [37]. The main crop grown in this region is paddy and some other important crops like pulses, grains, millets, sugarcane and groundnut are also grown. The Palar River, tanks, and wells are the primary irrigation sources of this district. The block of Kanchipuram has 24 canals, 2809 tanks, 1878 tube wells and 3206 wells. Groundwater is the major source of water supplies used for irrigation in Kanchipuram district. Certain human activities in the Kanchipuram district such as unsustainable groundwater pumping, silk weaving, industrial pollution, seawater intrusion, etc., and certain other global factors like increasing population and climate change viz., increase in global mean temperature, decreasing precipitation, sea level rise etc., will results in groundwater depletion which become an inevitable threat to the food security. An integrated strategy employing ionic chemistry and spatial maps using geographical information system (GIS) was used to create a simple and effective tool for decision-making on groundwater quality. This has produced positive outcomes [10]. The main objective of this study is to establish the quality of groundwater in various blocks of the Kanchipuram district and also mapping of groundwater quality using Arc GIS Software.

2. MATERIAL AND METHODS

The study was conducted in various blocks of Kanchipuram district. The sampling was done during March 2023 and a total of 150 samples were collected based on a grid survey with an interval of about 10 sq. km from different blocks of the Kanchipuram district in Tamil Nadu. Figure 1. shows the study area. The sample site's location was recorded using a portable GPS receiver (GPS, Garmin). Samples were taken in a clean plastic polyethylene bottle. To assess the quality of the irrigation water, laboratory analyses were carried out by following standard analytical techniques. The samples were examined for pH, electrical conductivity, cations like Ca^{2+} and Mg^{2+} using the versenate method, anions like CO_3^{2-}, HCO_3^-, and Cl^- using the Titrimetric Method, K^+, Na^+ using Flame photometry, and SO_4^{2-} using Turbidimetry, all in accordance with the recommended protocol described by Richards. (1954). [12]

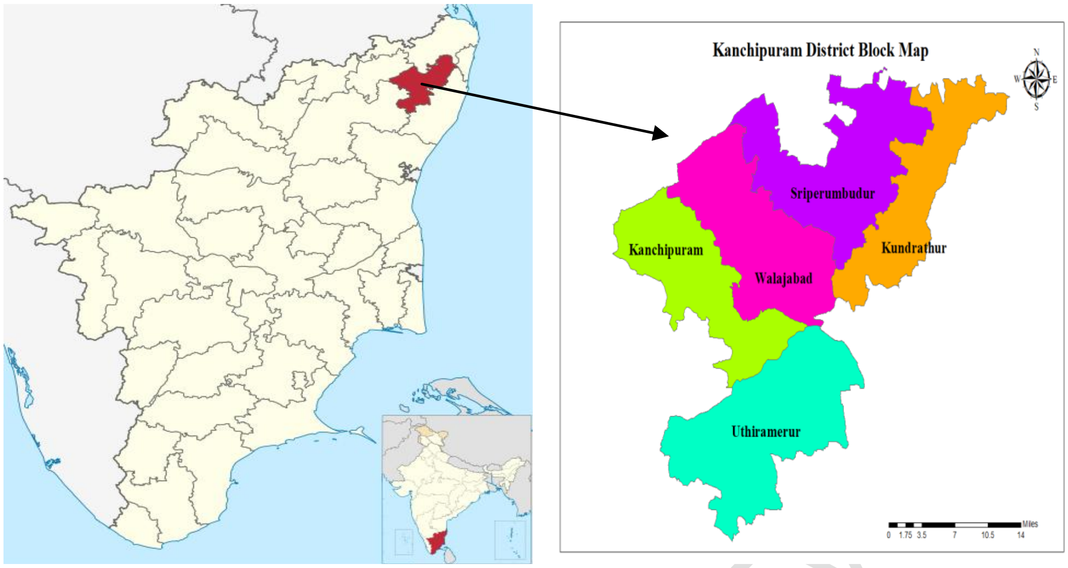


Fig 1. Location Map of the Study area (Kanchipuram district) Adapted from Ref. [11]

Based on the cationic and anionic concentration, the water quality parameters are derived such as Residual Sodium Carbonate (RSC) and Sodium Adsorption Ratio (SAR)

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

$$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$$

Using EC, SAR, and RSC values, the Central Soil Salinity Research Institute (CSSRI) in Karnal [13] assesses groundwater samples for irrigation suitability (Table 1). Based on CSSRI water quality classification, Groundwater quality-related thematic maps of the Kanchipuram district were produced using Arc GIS software.

Table 1: Grouping of low-quality ground waters for irrigation in India

Water quality	**EC (dS/m)**	**SAR (m mol/L)**	**RSC (meq/L)**
A. Good	<2	<10	<2.5
B. Saline			
i. Marginal saline	2-4	<10	<2.5
ii. Saline	>4	<10	<2.5
iii. High – SAR Saline	>4	>10	<2.5
C. Alkali water			
i. Marginally Alkali	<4	<10	2.5 – 4.0
ii. Alkali	<4	<10	>4.0

iii. Highly Alkali	Variable	>10	>4.0
D. Toxic water	The toxic water has variable salinity, SAR and RSC but has excess of specific ions such as chloride, sodium, nitrate, boron, fluoride or heavy metals such as selenium, cadmium, lead and arsenic etc.		

3. RESULTS AND DISCUSSION

3.1 Cationic Concentration

The concentration of cations and anions in different blocks of Kanchipuram district are depicted in Table 2. According to the research findings, the concentration of cations *viz*., Calcium, Magnesium, Sodium and Potassium in the Kanchipuram district varied from 0.2 to 11.2 meq L^{-1}, nil to 7.8 meq L^{-1}, 0.17 to 41.15 meq L^{-1} and 0.001 to 2.00 meq L^{-1} respectively. Whereas average calcium levels in groundwater samples of various blocks viz., Kundrathur, Sriperumbudur, Walajabad, Uthiramerur and Kanchipuram are 3.72 meq L^{-1}, 3.1 meq L^{-1}, 3.06 meq/L, 2.98 meq L^{-1} and 2.47 meq L^{-1} respectively. The average magnesium concentration in groundwater samples of Kundrathur, Sriperumbudur, Walajabad, Uthiramerur and Kanchipuram blocks are of 2.14 meq L^{-1}, 1.97 meq L^{-1}, 1.71 meq L^{-1}, 1.38 meq L^{-1} and 1.65 meq L^{-1} respectively. The average sodium levels in groundwater samples of Kundrathur, Sriperumbudur, Walajabad, Uthiramerur and Kanchipuram blocks were found to be 7.77 meq L^{-1}, 9.04 meq L^{-1}, 10.13 meq L^{-1}, 5.55 meq L^{-1} and 9.67 meq L^{-1} respectively. The mean potassium content in groundwater samples of Kundrathur, Sriperumbudur, Walajabad, Uthiramerur and Kanchipuram blocks were detected to be 0.20 meq L^{-1}, 0.06 meq L^{-1}, 0.16 meq L^{-1}, 0.10 meq L^{-1} and 0.29 meq L^{-1} respectively.

The sodium ion was found to be the most dominant cation in almost all blocks. This may be due to erosion of salt deposits, sodium-bearing rock minerals, saltwater intrusion into wells, irrigation and precipitation leaching through soils high in sodium or infiltration of leachate from industrial sites. The second most dominant cation was found to be calcium. The primary sources for increased calcium content in groundwater are limestone, dolomite, and gypsum, and their breakdown causes an increased level of calcium [14]. Potassium was the least prevalent element reported in the groundwater samples of the study area. This may be due to the slower weathering of potassium-bearing rocks than sodium-bearing rocks, the concentrations of potassium (K^+) are lower than those of sodium. Potassium may be introduced into groundwater through fertilizer usage and breakdown of animal or waste products[15]. Dolomite, ferromagnesian minerals including olivine, pyroxene, amphiboles, and dark-colored micas are the main sources of magnesium in groundwater. Chlorite, montmorillonite, and serpentine are examples of metamorphic rocks that include magnesium in their structural makeup [16].

3.2 Anionic Concentration

With respect to anionic concentration (Table 2.) the Carbonate, Bicarbonate, Chloride and Sulphate contents in the Kanchipuram district varied from 0 to 6 meq L^{-1}, 1 to 29 meq L^{-1}, 1 to 40 meq L^{-1} and 0.02 to 2.15 meq L^{-1} respectively. Whereas the average carbonate content in groundwater samples of various blocks *viz.,* Kundrathur, Sriperumbudur, Walajabad, Uthiramerur and Kanchipuram blocks were found to be of 2.07 meq L^{-1}, 2.19 meq L^{-1}, 2.94 meq L^{-1}, 1.72 meq L^{-1} and 2.81 meq L^{-1} respectively. The mean bicarbonate levels in groundwater samples of Kundrathur, Sriperumbudur, Walajabad, Uthiramerur and Kanchipuram blocks are 7.29 meq L^{-1}, 5.69 meq L^{-1}, 6.85 meq L^{-1}, 5.79 meq L^{-1} and 6.63 meq L^{-1} respectively. The average chloride concentration in groundwater samples of

Kundrathur, Sriperumbudur, Walajabad, Uthiramerur and Kanchipuram blocks were found to be of 4.29 meq L^{-1}, 5.88 meq L^{-1}, 5.41 meq L^{-1}, 2.56 meq L^{-1} and 4.11 meq L^{-1} respectively. The mean sulphate content in groundwater samples of Kundrathur, Sriperumbudur, Walajabad, Uthiramerur and Kanchipuram blocks were detected to be 0.15 meq L^{-1}, 0.29 meq L^{-1}, 0.16 meq L^{-1}, 0.08 meq L^{-1} and 0.12 meq L^{-1} respectively.
The bicarbonate ion was found to be the most dominant anion in almost all blocks. One of the possible sources of bicarbonate is organic matter in the aquifer that oxidizes to generate carbon dioxide, which accelerates the dissolution of minerals[17]. According to Gastmans *et al*. (2010),[18] silicate minerals may weather and produce bicarbonate ions. The presence of chlorides from rocks, evaporates, saltwater intrusion, connate and juvenile water, or pollution by industrial waste or residential sewage may be the cause of the groundwater's chloride(Cl^-) content [16].
Sulphate was found in groundwater as a result of the oxidation of igneous rock, sulphur and the dissolution of other sulfur-bearing minerals. By oxidizing marcasite and pyrite, sedimentary rocks like organic shale may be crucial in this regard [19,20,21].

Table 2. Cationic and anionic concentration of water in various blocks of Kanchipuram district

Name of the blocks	No. of Samples	Range / Mean	Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2}
			(meq/L)							
Kundrathur	28	**Min**	0.6	0.2	0.2	0.009	0	1	1	0.03
		Max	11.2	5.4	24.42	1.63	6	13	34	0.33
		Mean	3.72	2.14	7.77	0.20	2.07	7.29	4.29	0.15
Sriperumbudur	32	**Min**	0.2	0	0.17	0.001	0	1	1	0.02
		Max	8	6.4	29.83	0.62	6	14	30	2.15
		Mean	3.1	1.97	9.04	0.06	2.19	5.69	5.88	0.29
Walajabad	34	**Min**	0.8	0.2	0.34	0.001	0	1	1	0.05
		Max	9.8	7.8	41.15	2.00	6	29	40	0.82
		Mean	3.06	1.71	10.13	0.16	2.94	6.85	5.41	0.16
Uthiramerur	29	**Min**	0.2	0.2	0.73	0.005	0	1	1	0.03
		Max	8.6	3	17.92	1.66	4	18	18	0.19
		Mean	2.98	1.38	5.55	0.10	1.72	5.79	2.56	0.08
Kanchipuram	27	**Min**	0.8	0.4	1.12	0.004	0	2	1	0.04
		Max	5.2	3.4	19.32	1.99	6	12	12	0.39
		Mean	2.47	1.65	9.67	0.29	2.81	6.63	4.11	0.12

3.3 Water Quality Parameters

The quality of irrigation water is an indicator of its appropriateness for agricultural usage. When assessing salinity or alkalinity levels in an agricultural area water quality is a significant concern. Good quality water may contribute to beneficial changes in the soil and aid in achieving the highest agricultural yield [22]. Table 3 shows the range of pH, EC, RSC, SAR values in different blocks of Kanchipuram district. Water quality and the degree of salinity hazard in the research area are both significantly influenced by the pH of the water [23].The results of the study shows that the pH and EC values of Kanchipuram district ranged from 3.29 to 8.49 and 0.09 dS m^{-1} to 5.22 dS m^{-1}, respectively. Whereas the pH of the groundwater samples in different blocks of Kanchipuram district viz., Kundrathur, Sriperumbudur, Walajabad, Uthiramerur and Kanchipuram was in the range of 7.03 to 8.34 with an average of 7.70, 3.29 to 8.21 with an average of 7.58, 7.46 to 8.49 with an average of 7.93, 7.46 to 8.45 with an average of 7.97 and 7.42 to 8.27 with an average of 7.93, respectively. It indicates that majority of the samples comes under neutral and slightly alkaline nature.

EC is a measurement of the total dissolved solids and ionised species in water that provides insight into the level of inorganic contamination[24]. The mean EC values of various blocks of Kanchipuram district varied from 1.38 dS m^{-1}, 1.38 dS m^{-1}, 1.48 dS m^{-1}, 1.01 dS m^{-1} and 1.37 dS m^{-1} in Kundrathur, Sriperumbudur, Walajabad, Uthiramerur and Kanchipuram, respectively. Maximum EC was recorded in Walajabad followed by Sriperumbudur and Kanchipuram blocks. The differences in EC values may be associated to the elemental makeup of the aquifer rocks as well as the geochemical reactions such as reverse exchange, ion exchange, silicate weathering, rock–water interaction, evaporation, sulphate reduction and oxidation processes that occurs in the parent rock [25].

Table 3. The groundwater quality in different blocks of Kanchipuram district.

Name of the blocks	No. of Samples	Range / Mean	pH	EC (dSm^{-1})	SAR (m mol/L)	RSC (meq/L)
Kundrathur	28	**Min**	7.03	0.2	0.19	nil
		Max	8.34	3.88	33.14	17.2
		Mean	**7.70**	**1.38**	**6.20**	**3.49**
Sriperumbudur	32	**Min**	3.29	0.09	0.23	nil
		Max	8.21	4.27	31.65	10.2
		Mean	**7.58**	**1.38**	**7.46**	**2.81**
Walajabad	34	**Min**	7.46	0.42	0.26	nil
		Max	8.49	5.22	34.78	32
		Mean	**7.93**	**1.48**	**7.25**	**5.02**
Uthiramerur	29	**Min**	7.46	0.25	0.73	nil
		Max	8.45	2.86	29.14	12.8
		Mean	**7.97**	**1.01**	**4.67**	**3.16**
Kanchipuram	27	**Min**	7.42	0.56	0.81	0.2
		Max	8.27	2.56	20.11	10.8
		Mean	**7.93**	**1.37**	**7.37**	**5.32**

The overall range of Residual Sodium Carbonate (RSC) in Kanchipuram district varied from nil to 32 meq L^{-1}, while the Sodium Adsorption Ratio (SAR) ranged from 0.19 to 34.78 mmol L^{-1}. Whereas the Sodium Absorption Ratio (SAR) in various blocks viz., Kundrathur, Sriperumbudur, Walajabad, Uthiramerur and Kanchipuram blocks were found to be in the range of 0.19 to 33.14 mmol L^{-1}, 0.23 to 31.65 mmol L^{-1}, 0.26 to 34.78 mmol L^{-1}, 0.73 to 29.14 mmol $L^{-1}$and 0.81 to 20.11 mmol $L^{-1}$with an average of 6.20 m mol L^{-1}, 7.46 mmol L^{-1}, 7.25 mmol L^{-1}, 4.67 mmol $L^{-1}$and 7.37 mmol L^{-1}respectively. The Residual Sodium Carbonate (RSC) of Kundrathur, Sriperumbudur, Walajabad, Uthiramerur and Kanchipuram blocks were found to be in the range of nil to 17.2 meq L^{-1}, nil to 10.2 meq L^{-1}, nil to 32 meq L^{-1}, nil to 12.8 meq L^{-1} and 0.2 to 10.8 meq L^{-1} with an average of 3.49 meq L^{-1}, 2.81 meq L^{-1}, 5.02 meq L^{-1}, 3.16 meq L^{-1} and 5.32 meq L^{-1}respectively.

High sodium ion concentrations in water have an impact on soil permeability which causes infiltration problems, and replace calcium and magnesium ions adsorbed on clays, resulting in soil particle dispersion[26]. Increased SAR of irrigation water leads to an increase in exchangeable sodium in the soil [27]. Fig 2. represents the overall Percentage distribution of groundwater samples Kanchipuram district. Whereas Fig.3 represents the Percentage distribution of groundwater samples in various blocks of Kanchipuram district.

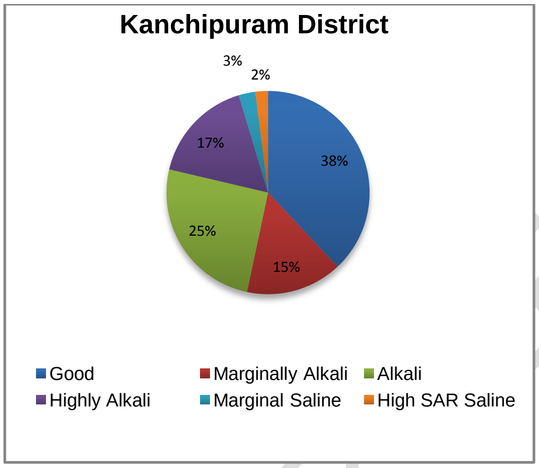


Fig 2. Overall Percentage distribution of groundwater quality in Kanchipuram district

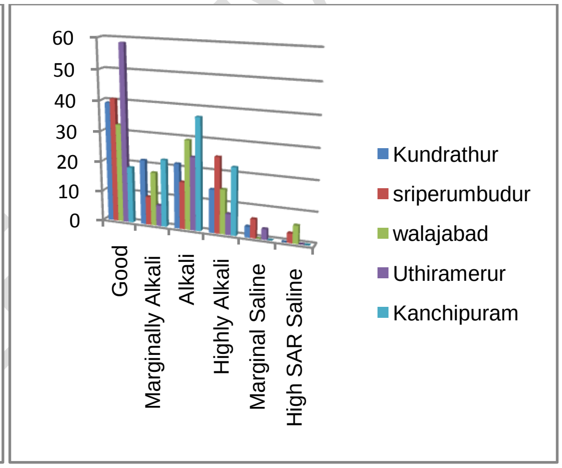


Fig 3. Percentage distribution of groundwater quality in various blocks of Kanchipuram district

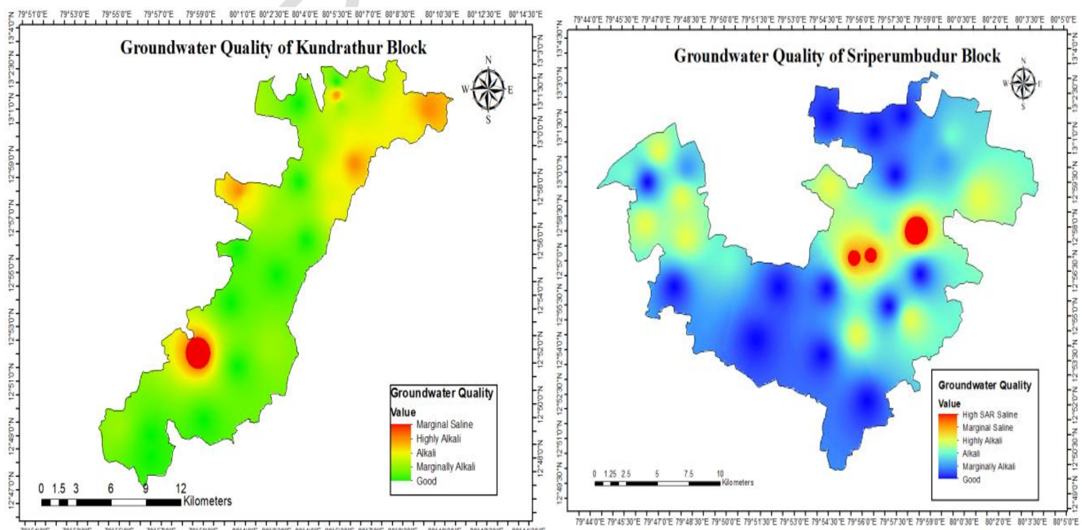
According to the CSSRI, Karnal water quality classification in Kanchipuram district, the percentage distribution of groundwater was found to be 38 percent of good quality water, 57.33 percent of alkali water and 4.67 percent of saline water. Whereas on the Kundrathur block, good quality water (39.29 percent), marginally alkali water (21.43 percent), alkali water (21.43 percent), highly alkali water (14.28 percent) and marginal saline water (3.57 percent) were located. In Sriperumbudur block, good quality water (40.63 percent), marginally alkali water (9.37 percent), alkali water (15.63 percent), highly alkali water (25 percent), marginal saline water (6.25 percent), high SAR saline water (3.12 percent) were detected. In Walajabad, good quality water (32.35 percent), marginally alkali water (17.65 percent), alkali water (29.41 percent), highly alkali water (14.71 percent), high SAR saline water (5.88 percent) were observed. In Uthiramerur, good quality water (58.62 percent), marginally alkali water (6.9 percent), alkali water (24.14 percent), highly alkali water (6.9 percent), marginal saline water (3.44 percent) were located and in Kanchipuram block it is found to be 18.52 percent of good quality water, 22.22 percent of marginally alkali water, 37.04 percent of alkali water and 22.22 percent of highly alkali water.

Saline water was found to be highest in the Sriperumbudur block (9.37 percent) followed by the Walajabad block(5.88 percent). The alkali water was found highest in the Kanchipuram block(81.48 percent) followed by Walajabad(61.77 percent) and Kundrathur(57.14 percent) blocks. The highest amount of good-quality water was found to be in Uthiramerur block (58.62 percent). High RSC values imply that a significant portion of the calcium and some of the magnesium ions precipitate from the solution, raising the sodium content of water and soil particles results in increasing the risk of sodium hazard[28]. A high RSC may impede air and water flow through the soil pore space, resulting in soil degradation and making the soil unsuitable for irrigation [29]. Saline/Sodic problems might become more problematic due to low rainfall, droughts, and overuse of groundwater [34].

Additionally, this will lead to a decline in soil permeability and infiltration of water, as well as a loss of soil structure. Agricultural production is impacted negatively. It may be necessary to use soil additives during irrigation with high SAR water to prevent long-term soil damage since sodium in the water can displace calcium and magnesium [31,32]. Because of osmotic pressures in the soil, which tend to lower the quantity of nutrients taken up by the plant, saline irrigation has a detrimental impact on plant growth. A vital approach to overcome this problem is to implement various irrigation management strategies like drip, sprinkler, and pitcher irrigation [33]. Organic manures such as FYM and compost, minimize salinity effects by releasing organic acid during decomposition. Green manure crops should be grown to reduce alkalinity hazards. To account for salt leaching from irrigation with saline and alkaline water, rainwater conservation practices should be modified [34].

3.4 Groundwater quality mapping using GIS software

The groundwater samples were divided into various categories based on EC, SAR, and RSC (table 1). The ground water quality map for different blocks of Kanchipuram district was produced using arc map software. The spatial distribution for different quality parameters of groundwater in various blocks of Kanchipuram district was represented in fig 4.inverse distance weighted (IDW) interpolation in a GIS tool is shown to be especially useful for comparing the geographical distribution of water quality metrics [28,35,36]. From the different quality parameters of groundwater samples the map shows that the good quality groundwater was found in almost all the blocks.



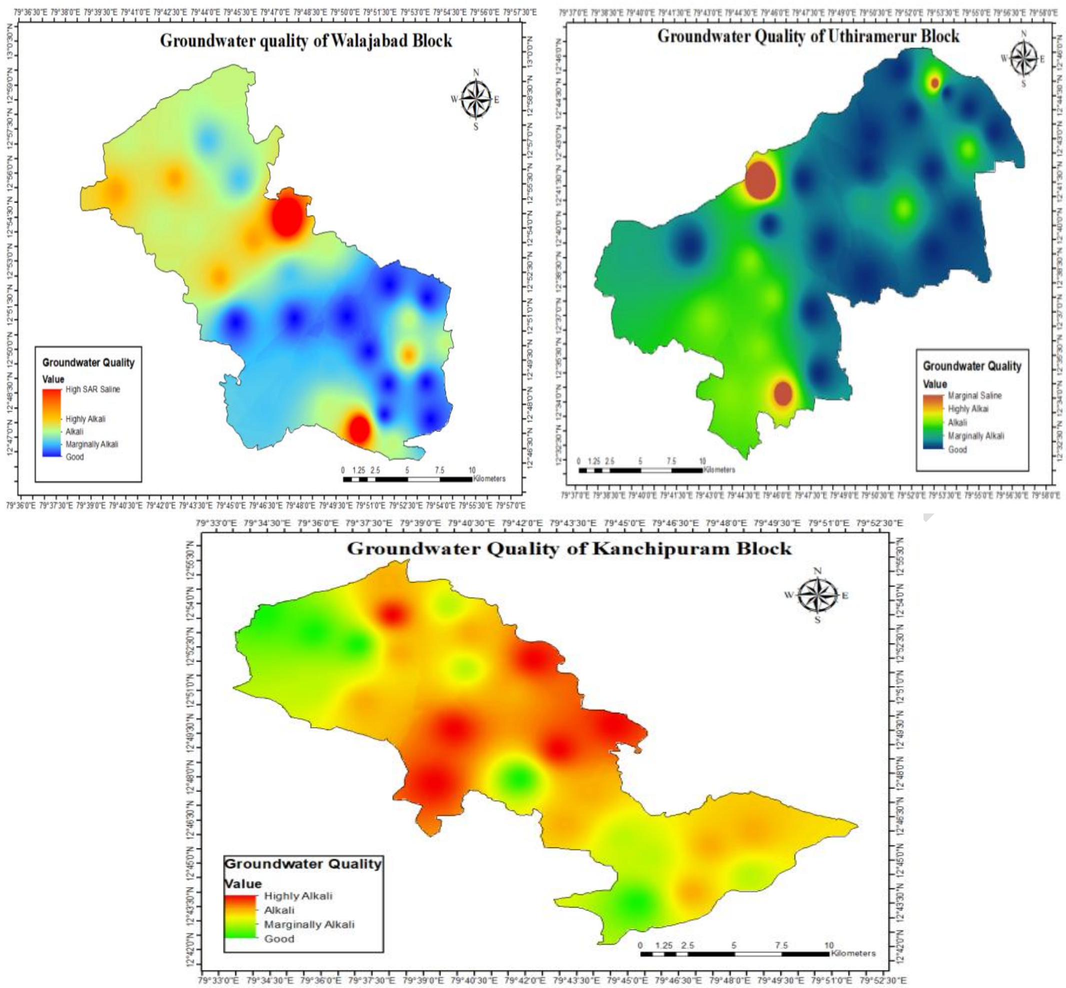


Fig 4. Spatial Distribution for different quality parameters of Groundwater in various blocks of Kanchipuram District

4. CONCLUSION

From the present investigations, it can be stated that the overall percentage distribution of water quality in Kanchipuram district were found to be 38 percent of good quality water, 57.33 percent of Alkali water and 4.67 percent of Saline water. Whereas the high amount of good quality water (58.62 percent) were observed in Uthiramerur block. The percentage of alkali water (81.48 percent) was highest in Kanchipuram block. Highly alkali water accounted for about 25 percent in Sriperumbudur block followed by Kanchipuram (22.22 percent) and walajabad (14.71 percent). Marginally alkali water accounted for about 22.22 percent in Kanchipuram block followed by Kundrathur (21.43 percent) and Walajabad (17.65 percent). The high amount of saline water (9.37 percent) were observed in Sriperumbudur block. Also, the distribution of groundwater samples in different water quality classes showed that the samples of good quality subsurface water were observed in almost all the blocks. So that the problems of salinity and alkalinity do not have any detrimental effects on good quality water samples.

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