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Assessment of groundwater quality in inland blocks of Tirunelveli District of Tamil Nadu

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Abstract

Block wise categorization of groundwater quality in Inland region of Tirunelveli district for its optimal usage to minimize the soil salinity was undertaken during November 2019. A total of 87 underground water samples representing different Inland blocks viz., Palayamkottai (5), Cheranmahadevi (5), Kalakkadu (6), Ambasamudram (8), Tenkasi (5), Shencottai (5), Kadayanallur (5), Vasudevanallur (7), Sankarankoil (6), Keezhapavur (5), Kadayam (4), Pappakudi (4), Alangulam (5), Melaneelithanallur (5), Kuruvikulam (6) and Manur (6) were collected, analyzed for quality parameter and categorized into different water quality as per the standard procedure. The investigation revealed that groundwater samples with respect to pH and EC ranged from 6.50 to 8.10 and 0.77 to 6.91 dS m⁻¹, respectively. Residual Sodium Carbonate (RSC) varied from nil to 9.40 meq L⁻¹ and Sodium Adsorption Ratio (SAR) ranged from 0.34 to 9.46. Frequency of occurrence of good quality water in the blocks surveyed were in the order of Kalakkadu and Pappakudi (100%) > Ambasamudram (87.5%) > Cheranmahadevi (80%) > Alangulam (80%) > Sankarankoil (66.6%) > Tenkasi (60%) > Shencottai (60%) > Kadayanallur (60%) > Melaneelithanallur (60%) > Kadayam (50%) > Manur (49.98%) > Vasudevanallur (42.84%) > Kuruvikulam (33.32%) based on the CSSRI, Karnal water quality classification in Inland blocks of Tirunelveli district, 20 per cent of groundwater samples were in good quality, Saline water was found in Palayamkottai. Alkali water was found in Tenkasi, Manur, Kadayam, Kuruvikulam and Ambasamudram blocks to the extent of 20, 16.6, 25, 16.6 and 12.5 per cent respectively. Among the Inland blocks of Tirunelveli districts surveyed, Keezhapavur block falls under high Alkali (40%) and lowest good quality of groundwater (20%).

Keywords: Groundwater quality, Tirunelveli district, SAR and RSC

1. Introduction

Tirunelveli district has an area of 6810 km², it lies between 08°08'09" and 09°24'30"N and 77°08'30" and 77°58'30" E. This district is bounded on the South by Gulf of Manner, on the Southwest by Kanniyakumari district, on the North by Virudhunagar district, on the West by Western Ghats in Kerala state, on the East by Thoothukudi district. It has coast line measuring about 48.9 kilometers for Tirunelveli district in Tamil Nadu. Physiographically, the entire district is a plain terrain. There are several rivers viz., Tamiraparani, Nambiar, Hanumanthai and Vaippar are the source water for irrigation. In Tirunelveli district, Paddy is main food crop cultivated in more than 62% of the net area sown (Central Ground Water Board, 2009). As reported by Gupta (2008) [2], 70 and 80% of India's irrigation and domestic water supplies come from groundwater rather than from surface water. Rapid urbanization followed by over exploitation of groundwater and improper disposal waste disposal has affected the quality of groundwater. Understanding its importance, numerous studies on groundwater quality about drinking and irrigation purposes have carried out in different parts of the country (Patil *et al.*, 1989) [4]. Due to water scarcity and high demand for agricultural production, irrigation water is used extensively by deepening the wells and tube wells continuously wherever the groundwater resources available. Hence, the present investigation is carried out for assessment and mapping of groundwater quality in Inland blocks of Tirunelveli district.

2. Materials and Methods

Totally 87 groundwater samples were collected based on grid survey by GPS during November 2019 which cover the 16 Inland blocks of Tirunelveli district. Samples were stored at airtight bottles. The samples were analyzed for pH, Electrical conductivity, cations viz.

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Ca²⁺, Mg²⁺ by Versenate method and anions like CO₃²⁻, HCO₃⁻, Cl⁻ by Titrimetric and K⁺, Na⁺ by Flame photometry, SO₄²⁻ by Turbidimetry as per standard procedure outlined by Richards (1954) [6]. Quality parameters like Sodium Adsorption Rate (SAR) and Residual Sodium Carbonate (RSC) were calculated as per the formula depicted as under.

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

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

Screening of groundwater samples for their suitability to irrigation is done on the basis of EC, SAR and RSC values as suggested by Central Soil Salinity Research Institute, Karnal (AICRP, 1991) (Table 1).

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

Water Quality	EC _{iw} (dS/m)	SAR _{iw} (m mol/L)	RSC (me/L)
A. Good	<2	<10	<2.5
B. Saline			
i. Marginal saline	2-4	<10	<2.5
ii. Saline	>4	<10	<2.5
ii. 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. High 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 Electro chemical properties

The result of the study in table 3 indicated that the pH of the groundwater collected from Inland blocks in Tirunelveli ranged from 6.5 to 8.1 with mean of 7.38 and represent the 57 per cent of good quality of water followed by 20 per cent in Marginal saline water, 12 per cent in Alkali water, 8 per cent Marginally alkali and 3 per cent in Saline water. (Kumar *et al.*, 2014) [7] Electrical conductivity of water shows Inland blocks in Tirunelveli district were ranged from 0.77 to 6.91 dS m⁻¹ with mean of 1.79 dS m⁻¹. Out of 87 samples 2.85, 56.08, 26.83, 14.22 per cent samples had EC 0-1, 1-2, 2-3, >3 dS m⁻¹ respectively.

3.2 Anionic constituents of groundwater

The relative concentration of anions followed the order of Cl⁻ > HCO₃⁻ > CO₃²⁻ > SO₄²⁻. The carbonate content of groundwater ranged from 0 to 8 meq L⁻¹ with mean of 2.82 meq L⁻¹. Bicarbonate content ranged from 1.0 to 14 meq L⁻¹ with mean of 6.29 meq L⁻¹. Chloride was found as the dominant anion and ranged from the 0.34 to 9.46 meq L⁻¹ with mean value of 3.02 meq L⁻¹. Among the anions, dominant of chloride in the irrigation water was reported by (Rathi *et al.*, 2018) [5]. Sulphate content ranged from 0.02 to 7.81 meq L⁻¹ with mean value of 2.03 meq L⁻¹ (Table 3).

3.3 Cationic constituents of groundwater

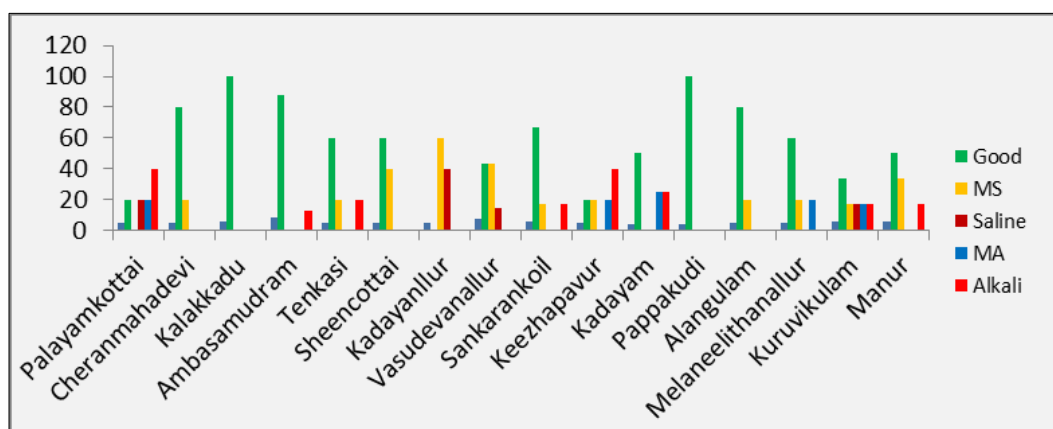
Among the cationic constituents, sodium was found to be dominant cations followed by Mg²⁺ > Ca²⁺ > K⁺ with respect to their concentration in groundwater of Inland blocks. The content of calcium ranged from 0.2 to 15.8 meq L⁻¹ with mean value of 2.82 meq L⁻¹. Magnesium ranged from 0.6 to 25.80 meq L⁻¹ with mean value of 6.96 meq L⁻¹. Sodium concentration ranged from 0.22 to 43.15 meq L⁻¹ with mean value of 7.13 meq L⁻¹. The content of potassium ranged from 0.02 to 7.81 meq L⁻¹ with mean value of 0.78 meq L⁻¹ (Table 3).

3.4 Water quality parameter

The RSC in the water ranged from nil to 9.40 meq L⁻¹ and SAR ranged from 0.34 to 9.46 with mean SAR value of 3.02. However the mean SAR and RSC values in all the Inland blocks of Tirunelveli were lesser than 10 and 2.5 meq L⁻¹ respectively which are good in soil upon irrigation (Table 3). The spatial distributions of different quality parameters of groundwater in Inland blocks of Tirunelveli district are presented (Fig. 2a, 2b, 2c). The distribution of water samples in different water quality classes reveals that the samples of good quality groundwater was found in Fifteen Inland blocks viz., Kalakkadu and Pappakudi (100%), Ambasamudram (87.5%), Cheranmahadevi (80%), Alangulam (80%), Sankarankoil (66.6%), Tenkasi (60%), Shencottai (60%), Kadayanallur (60%), Melaneelithanallur (60%), Kadayam (50%), Manur (49.98%), Vasudevanallur (42.84%) and Kuruvikulam (33.32%) and Palayamkottai (20%). The Marginal saline was found highest in Kadayanallur (60%) followed by Vasudevanallur (42.84%), Shenkottai (40%), Manur (33.32%), Cheranmahadevi (20%), Ambasamudram (20%), Keezhapavur (20%), Alangulam (20%), Melaneelithanallur (20%), Sankarankoil (16.66%) and Kuruvikulam (16.66%). The saline water found in four blocks viz., Kadayanallur (40%), Palayamkottai (20%), Kuruvikulam (16.66%) and Vasudevanallur (14.28%). The alkali water was found highest in Palayamkottai (40%) and Keezhapavur (40%) followed by Kadayam (25%), Tenkasi (20%), Kuruvikulam (16.66%) Sankarankoil (16.66%), Melaneelithanallur (16.66%), Manur (16.66%) Ambasamudram (12.5%) and the marginal alkali water was found in Kadayam (25%), Palayamkottai (20%), Keezhapavur (20%), Melaneelithanallur (20%), Kuruvikulam (16.66%) (Table 2 and Fig 1). Manchand (1976) [3] classified the water quality and found that the water falling under category "good" can be used safely for almost all the crops, whereas, water which is marginally saline can be used for pearl millet and mustard crops in area having coarse textured soil. Also the ground water rated as marginally alkali (RSC 2.5-4.0) can be used effectively with gypsum application for mustard and pearl millet crops. The groundwater rated as saline and alkali water are unfit for irrigation and their indiscriminate use will cause secondary salinization and sodication. The enhanced levels of different categories of saline/sodic problem in Inland blocks of Tirunelveli district may be due to low rainfall, prolonged drought and over exploitation of groundwater

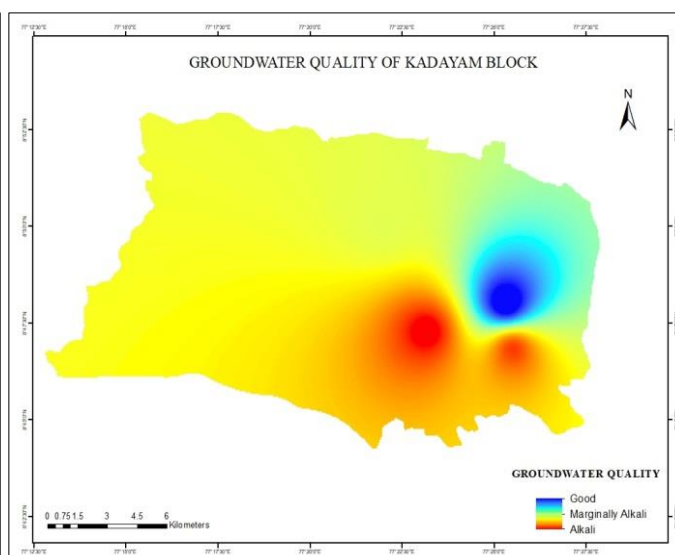
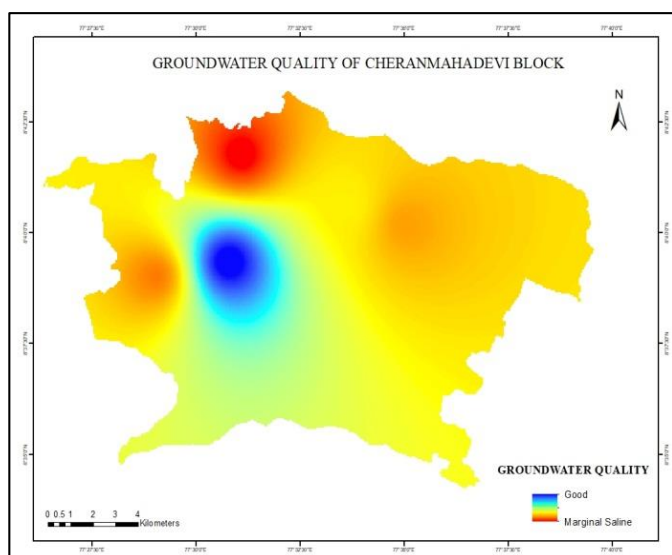
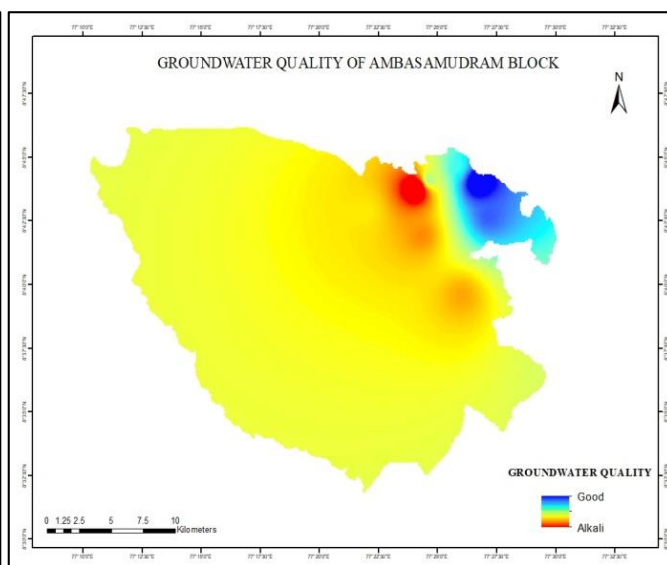
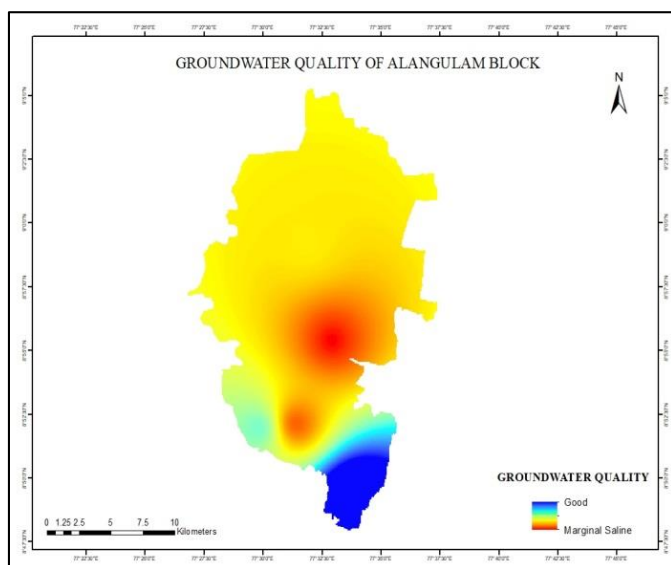
Table 2: Water quality distribution (%) in Inland blocks of Tirunelveli district

S. No	Block	No. of samples	Good	MS	Saline	MA	Alkali
1	Palayamkottai	5	20		20	20	40
2	Cheranmahadevi	5	80	20			
3	Kalakkadu	6	100				
4	Ambasamudram	8	87.5				12.5
5	Tenkasi	5	60	20			20
6	Shenkottai	5	60	40			
7	Kadayanallur	5		60	40		
8	Vasudevanallur	7	42.84	42.84	14.28		
9	Sankarankoil	6	66.64	16.66			16.66
10	Keezhapavur	5	20	20		20	40
11	Kadayam	4	50			25	25
12	Pappakudi	4	100				
13	Alangulam	5	80	20			
14	Melaneelithanallur	5	60	20		20	
15	Kuruvikulam	6	33.32	16.66	16.66	16.66	16.66
16	Manur	6	49.98	33.32			16.66
	Average	87	57	20	3	8	12

**Fig 1:** Percentage distribution of different categories of water quality**Table 3:** Mean Chemical composition of groundwater in Inland blocks of Tirunelveli district

Blocks	No. of Samples	Range/Mean/ SD	pH	EC (dS m ⁻¹)	(Meq L ⁻¹)									
					Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	CO ₃ ²⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ²⁻	SAR	RSC
Palayamkottai	5	Max	6.8	1.07	1.4	1.20	2.22	0.05	2.0	4.0	1.60	0.71	1.75	Nil
		Min	7.8	6.91	15.8	25.80	43.15	0.87	4.0	11.0	86.80	16.60	9.46	6.40
		Mean	7.18	2.64	5.0	7.92	13.55	0.25	3.2	6.6	20.76	5.53	4.63	Nil
Cheranmahadevi	5	Min	6.60	1.42	1.4	2.80	3.30	0.05	2.0	4.0	5.20	0.89	1.82	Nil
		Max	7.60	2.79	4.4	10.0	14.30	7.15	6.0	7.0	14.40	3.86	5.99	2.40
		Mean	7.32	1.87	2.96	6.52	6.76	1.56	3.6	6.0	8.52	1.84	3.02	0.12
Kalakkadu	6	Min	6.70	0.77	0.20	0.60	0.22	0.03	0	1.0	0.80	0.14	0.34	Nil
		Max	7.70	1.99	4.20	8.40	12.52	1.95	4.0	7.0	12.60	2.84	5.78	1.00
		Mean	7.25	1.38	2.63	3.83	4.70	0.41	2.0	3.83	5.17	1.10	2.33	Nil
Ambasamudram	8	Min	7.0	0.85	0.6	0.8	0.74	0.03	0	2.0	1.20	0.30	0.70	Nil
		Max	7.7	1.64	4.8	6.8	7.00	3.94	4.0	6.0	6.80	1.37	4.83	4.80
		Mean	7.32	1.24	2.35	3.18	3.02	0.55	2.25	4.5	3.53	0.91	1.86	1.23
Tenkasi	5	Min	6.80	1.52	2.0	3.80	4.93	0.04	4.0	2.0	4.20	1.00	1.94	Nil
		Max	7.70	2.25	3.0	10.0	13.48	3.46	4.0	9.0	11.60	2.25	5.80	7.20
		Mean	7.36	1.86	2.48	6.84	7.13	0.91	4.0	5.8	8.72	1.48	3.34	0.48
Shenkottai	5	Min	7.30	1.38	1.4	5.40	5.70	0.07	2.0	5.0	4.00	0.38	2.57	Nil
		Max	7.70	3.27	2.6	15.40	21.57	7.81	6.0	8.0	24.80	8.27	7.35	2.20
		Mean	7.46	2.04	2.12	8.96	10.90	1.88	4.0	6.4	11.52	2.64	4.51	Nil
Kadayanallur	5	Min	7.2	1.0	1.0	1.20	1.41	0.05	1.80	0.16	2.0	4.0	1.15	Nil
		Max	7.9	2.38	3.2	16.0	14.2	0.77	16.6	2.34	4.0	7.0	5.58	3.60
		Mean	7.46	1.72	2.04	7.44	7.57	0.29	10.0	0.97	2.8	5.2	3.25	Nil
Vasudevanallur	7	Min	6.90	1.32	1.6	5.0	2.10	0.03	2.0	4.0	2.40	0.19	1.16	Nil
		Max	7.70	4.18	3.0	20.2	28.70	1.50	4.0	14.0	38.60	8.96	9.03	2.20
		Mean	7.12	2.32	2.42	10.37	13.07	0.32	2.57	9.28	15.26	3.54	4.93	Nil
Sankarankoil	6	Min	6.80	1.04	1.6	2.2	1.73	0.11	2.0	3.0	1.80	0.09	1.25	Nil
		Max	8.00	2.48	3.6	11.0	14.50	6.53	8.0	11.0	22.0	3.61	6.62	9.40
		Mean	7.27	1.95	2.66	7.50	8.84	1.40	3.33	6.66	11.33	1.60	3.82	Nil
Keezhapavur	5	Min	6.60	1.42	1.6	4.2	3.09	0.08	2.0	7.0	5.60	0.37	1.58	Nil

		Max	7.30	2.11	5.0	12.6	6.87	0.42	4.0	10.0	14.6	1.06	3.84	6.20
		Mean	6.98	1.61	2.84	6.24	5.49	0.17	2.4	8.4	9.16	0.79	2.74	1.72
Kadayam	4	Min	6.5	0.88	0.4	1.2	0.73	0.02	0	3.0	1.0	0.09	0.60	1.40
		Max	7.7	1.92	2.6	7.0	4.28	7.42	4.0	10.0	8.0	1.97	1.96	4.80
		Mean	7.13	1.25	1.65	3.7	2.42	1.91	2.0	6.25	3.3	0.77	1.39	2.90
Pappakudi	4	Min	7.30	1.06	1.6	2.20	1.67	0.03	2.0	3.0	2.8	0.85	0.72	Nil
		Max	8.10	1.72	2.6	9.20	10.48	0.07	4.0	8.0	10.8	3.37	5.11	1.60
		Mean	7.75	1.39	2.15	6.05	3.92	0.05	2.5	5.5	5.35	1.71	1.98	Nil
Alangulam	5	Min	8.0	1.07	1.8	1.20	1.66	0.06	2.0	3.0	1.80	0.68	0.94	Nil
		Max	7.5	2.34	2.8	12.0	12.37	1.44	4.0	7.0	12.80	2.62	4.64	2.0
		Mean	7.72	1.49	2.32	6.16	4.89	0.46	2.4	4.4	5.96	1.21	2.23	Nil
Melancelithanallur	5	Min	7.40	1.43	1.6	6.6	5.0	0.15	2.0	4.0	2.40	1.07	2.01	Nil
		Max	8.00	2.51	4.4	16.8	6.54	1.34	4.0	8.0	20.8	1.62	2.47	3.80
		Mean	7.76	1.82	2.88	10.28	5.65	0.50	2.8	6.0	10.2	1.31	2.24	Nil
Kuruvikulam	6	Min	7.2	1.16	0.8	2.2	0.99	0.07	2.0	6.0	2.0	0.85	0.60	Nil
		Max	7.7	4.27	13.0	23.2	24.57	3.10	6.0	11.0	33.0	17.81	5.77	4.60
		Mean	7.47	2.22	4.6	9.97	9.38	1.29	2.66	8.0	12.3	5.19	3.11	Nil
Manur	6	Min	7.3	1.12	1.6	1.60	2.52	0.06	2.0	6.0	2.40	0.68	1.35	Nil
		Max	7.9	2.6	7.4	14.4	8.50	4.15	4.0	10.0	24.2	2.40	4.10	8.80
		Mean	7.67	1.74	3.76	6.43	5.29	0.82	3.0	7.5	9.3	1.36	2.40	0.30



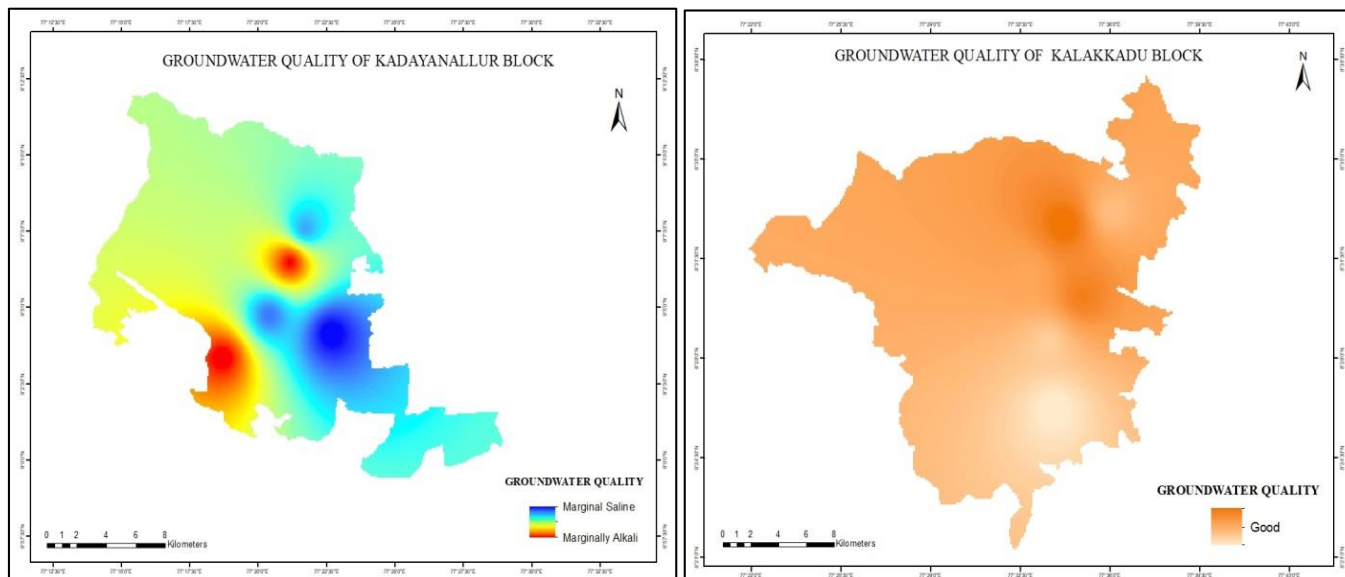
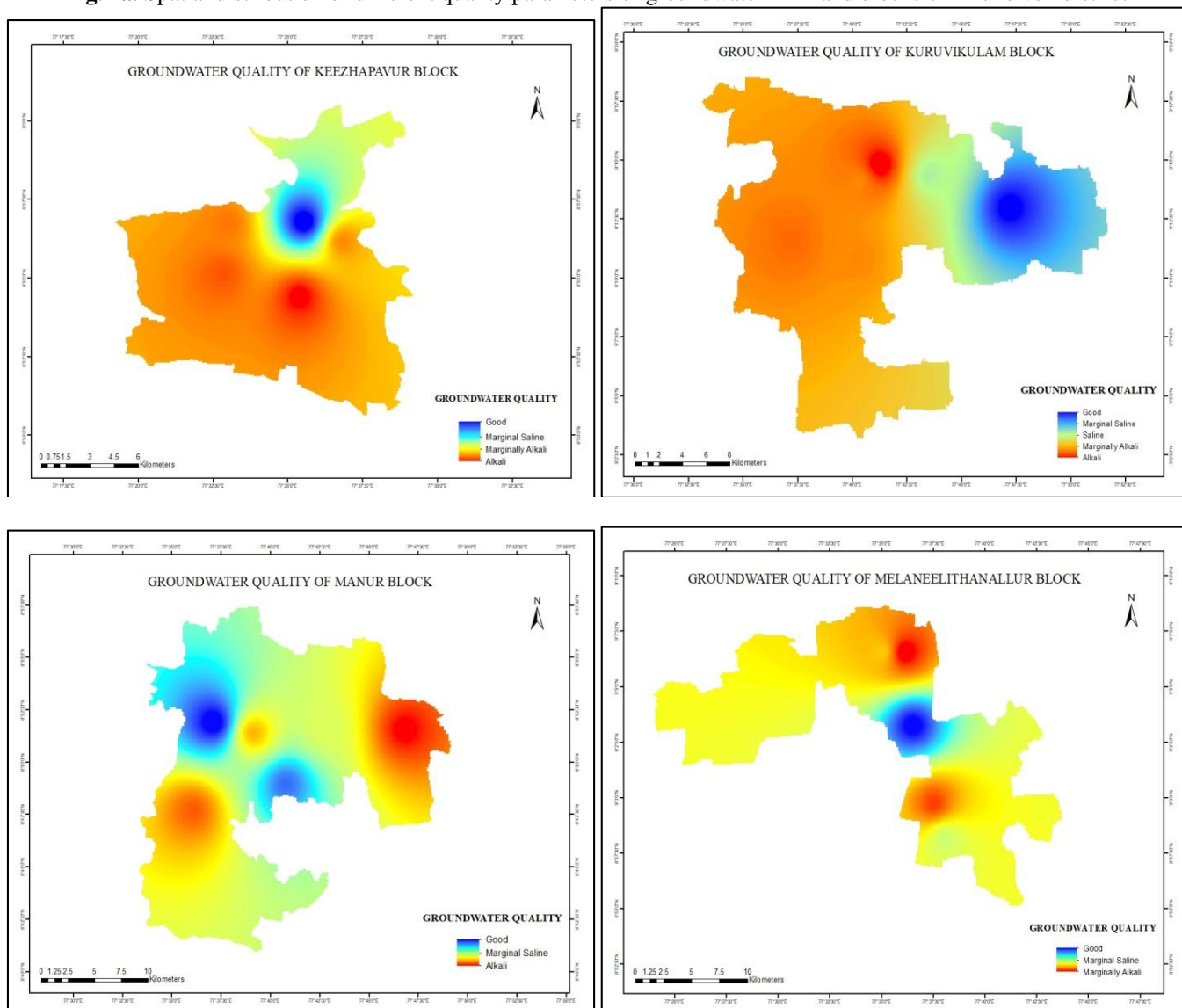


Fig. 2a. Spatial distribution of different quality parameters of groundwater in Inland blocks of Tirunelveli district



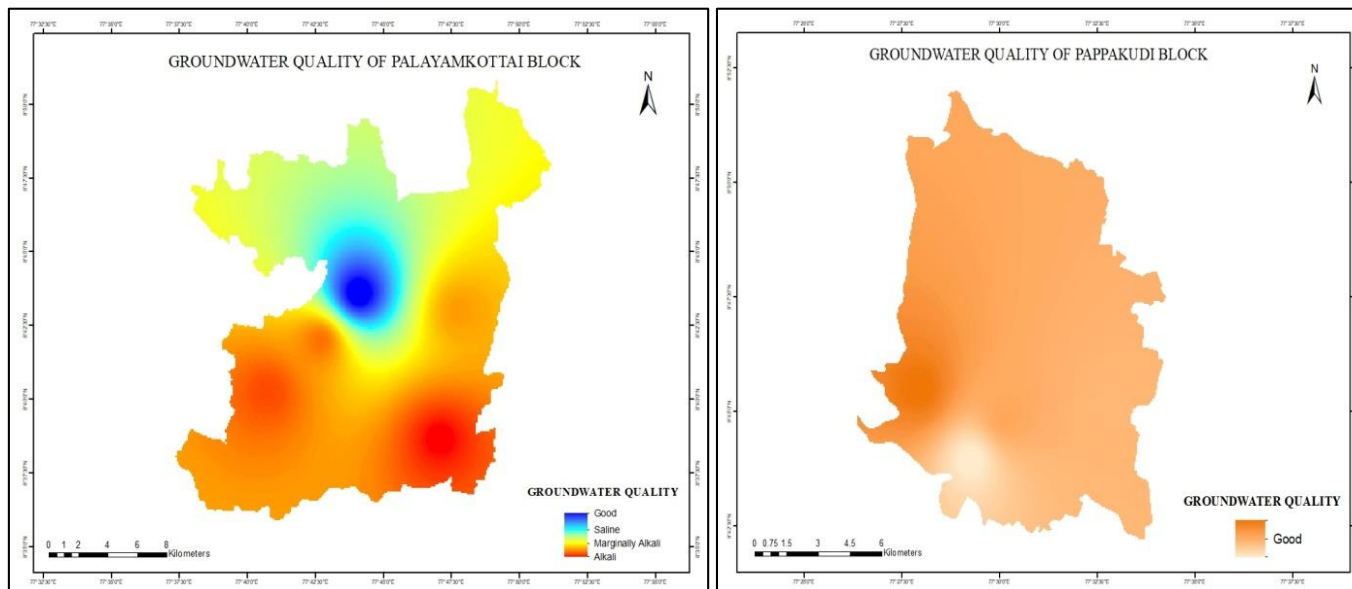


Fig. 2b. Spatial distribution of different quality parameters of groundwater in Inland blocks of Tirunelveli district

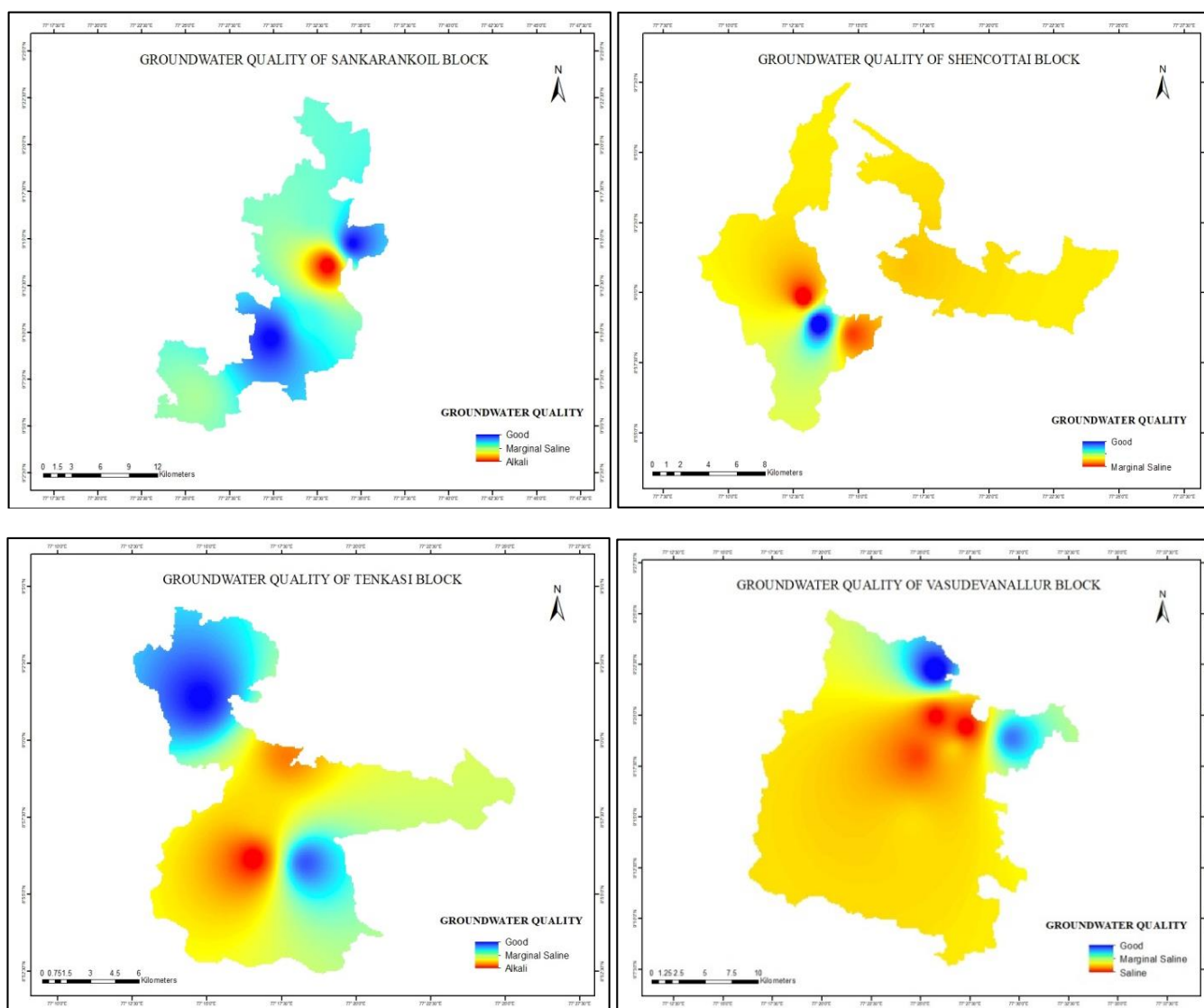


Fig. 2c. Spatial distribution of different quality parameters of groundwater in Inland blocks of Tirunelveli district

Conclusion

Based on the present investigation, it could be concluded that 57 per cent of samples were good quality irrespective of different Inland blocks in Tirunelveli district. Among the different categories of water quality, Marginal saline (20%),

Alkali (12%), Marginally Alkali (8%) and Saline (20%). Among the different blocks in Inland regions of Tirunelveli district, Kadayanallur, Palayamkottai, Kuruvikulam and Vasudevanallur are recorded the highest percentage of samples were Saline water. Keezhpavur recorded the

maximum percentage of High Alkali water (40%). Equal percentage of Saline and Alkali water was found in Palayamkottai block. Although all Inland blocks of good quality of water, the Kalakkadu and Pappakudi recorded the maximum good quality of 100 per cent. In Inland blocks of Tirunelveli district, 43.0 per cent samples found to have different categories of salinity level, which may be due to prolonged drought prevails in district.

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