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Assessment of Groundwater Quality for Irrigation Suitability in Rajangaon Shenpunji and Surrounding Area, Aurangabad, Maharashtra, India.

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Abstract: This study mainly emphasizes assessing the suitability of groundwater quality for irrigation purposes in Rajangaon Shenpunji village and their surrounding area, Aurangabad, Maharashtra, India based on water quality parameters. A total of 30 water samples were collected from dug wells, bore wells and surface water bodies in different locations of the study area.The water quality parameters, viz. sodium adsorption ratio (SAR), percent sodium (%Na), residual sodium carbonate (RSC), residual sodium bicarbonate (RSBC), Kelly's ratio (KR), magnesium adsorption ratio (MAR) and permeability index (PI) have been calculated for understanding water suitability for irrigation purposes. These irrigation parameters were correlated with standard permissible/desirable limits for the prevailing crops to irrigation use. The correlation of water samples with standard water quality indices for irrigation shows that the SAR value for all water samples is <10 and reveals it is suitable for irrigation. About 18 water samples show a %Na value ranging from 60 to 80%, which indicates doubtful for irrigation and sample number 1 indicates it is unsuitable class as the value is > 80%. RSC value of sample numbers 2,8,9,11,12 falls under the doubtful category water samples 1 and 10 are unsuitable and all other samples are found to be good for irrigation. RSBC value is <5 for all water samples this indicates it is satisfactory for irrigation purposes. KR value for sample numbers 1,12 and 24 is >2, which indicates it is unsuitable for irrigation. MAR and PI values for all water samples show they are in a suitable class. A few water samples are exceeding the permissible limits due to various geological and anthropogenic activities within the study area. Overall, SAR, %Na, RSC, RSBC, KR, MAR, and PI values of water samples indicate that they are suitable for irrigation. The result of this study may be helpful to the farmers and policy makers for groundwater resources planning and management.

Keywords: Groundwater Quality, Irrigation, Kelly's ratio (KR), Permeability index (PI), Sodium adsorption ration (SAR), Aurangabad.

1. Introduction

Groundwater is an important source of natural resources on the Earth andcrucial for all living organisms to sustain a supportable environment and ecosystem (Liu et al., 2021; Jabbo et al., 2022; Paneerselvam et al., 2023). Fourty six percent of India's total national product comes from the agricultural sector, which is a major sector of the country's economic growth (Jafar et al., 2013). Fifty percent of the irrigated zone is dependent on groundwater exploration from dug and bore wells. Indian agriculture, particularly in the Marathwada and Vidarbha regions of Maharashtra state faces a deficiency of surface water resources.

In several parts of the country, groundwater quality is more threatening to human health and it is affected by rapid increase in population, industrialization and urbanization in developing countries (Adimalla, 2021; Kom et al., 2021; Paneerselvam et al., 2023). It is a significant concern in addition to the declining water table (Vasanthavigar et al., 2012; Hossain and Patra, 2021). There are usually some soluble salts dissolved in groundwater from recharge sources and the local geological strata, which percolates further through groundwater. As a result, concern about low-quality groundwater for irrigation has grown in recent years. Groundwater pollution is caused by either excessive or insufficient chemical fertilization (Ayers and Westcot, 1985; Rowe and Abdel-Magid, 1995; Singh et al., 2015; Rawat et al., 2018).So, regular assessment of water quality becomes necessary for drinking and irrigation water (Gupta et al., 2009; Gautam et al., 2015; Jacintha et al., 2016 Rawat et al., 2018; Gautam et al., 2018; Mukiza et al., 2021, Islam and Mostafa, 2022; Ikhlef et al., 2024).

Irrigation demands a supply of usable quality water in sufficient quantity. The index based on the concentration and composition of dissolved elements in water can be useful in determining its applicability for irrigation depending on the nature of the mineral elements in the water and their impacts on both the plants and soil (Richards, 1954; Singh et al., 2009; Balamurugan et al., 2020; Bilali and Taleb, 2022).

Usually, Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} (major cations), SO^{4}, NO^{3-} Cl^{-}, HCO_3^{-}, CO_3^{-}, NO_3^{-} (major anions) and heavy metals are indicators of drinking water quality parameters,while primary water quality parameters likesodium adsorption ratio (SAR), percent sodium (%Na), residual sodium carbonate (RSC),residual sodium bicarbonate (RSBC), Kelly's ratio (KR), magnesium adsorption ratio (MAR), permeability index (PI) are frequently used to determine quality of water for irrigation (Singh et al., 2013, Singh et al., 2015; Gautam et al., 2015; Rawat et al., 2018; Sreedevi et al., 2018). The relationship between irrigation and groundwater resources is highly interlinked. In the race to increase agriculture production, irrigation will become dependent on poor quality water sources.

In the present study area of Ranjangaon Shenpunji village and surrounding area of Aurangabad, Maharashtra state, India. Water quality assessment work for drinking purpose was carried out by Deshpande et al., (2022); Kamble and Sirsat (2024) and soil samples analysis by Kadam et al. (2023). Since no records are available for water quality assessment work for irrigation, it is decided to take up the same.

2.Material and methods

2.1 Study area

The study area falls in the survey of India toposheet No. 47M/1. It lies between 75º 10’ 40” E to 75º 16’ 24” E longitude and 19º 48’ 43” N to 19º 51’ 46” N latitudes (Figure 1) in Aurangabad district, which is the part of drought-prone areas of Maharashtra, India. The average annual rainfall of the area is 734.1mm spread over 54 rainy days and the maximum temperature is 39.8ºC (CGWB, 2019). The district receives very unreliable precipitation and it has characteristics of short precipitation and the time gap between the two successive rains.

Geologically the Ranjangaon Shenpunji village and surrounding area of Aurangabad are covered by basaltic deccan trap lava flows having age of upper Cretaceous to lower Eocene age. The lava traps of basaltic rocks are horizontal to the surface and separated by two units of lava flow. The upper layer of vesicular and amygdaloidal basalt has a cavities filled with secondary minerals, whereas the bottom layer consists of hard and compact/ massive basalt (Deshpande et al., 2022; Kadam et al., 2023).

From an agricultural point of view, soil fertility is determined by the texture and structure of the soil, that regulates the holding and transmitting capacity of the soil to keep moisture and other nutrients such as nitrogen, phosphorous, and potassium found in the parent rock (CGWB, 2019). It is found that geology, topography, climate, and vegetation all have an impact on the soil formation process within the study area. The area of the study is covered by black cotton soil or regur soil, and this soil type is produced by the weathering and erosional activities of the upper layer of basaltic lava flows. It is high in plant nutrients such as iron, lime, alkalis and iron, which allow cotton and dry crops such as jowar, pearl millets, wheat and gram. Soybean and cotton are common practices within the study area.

Study area location and sample locations maps prepared in Arc GIS 10.3. A spatial map was prepared in the Arc GIS 10.3 software using the arc tools box. Based on the results of the agriculture parameter, the spatial map was created by using IDW interpolation techniques.

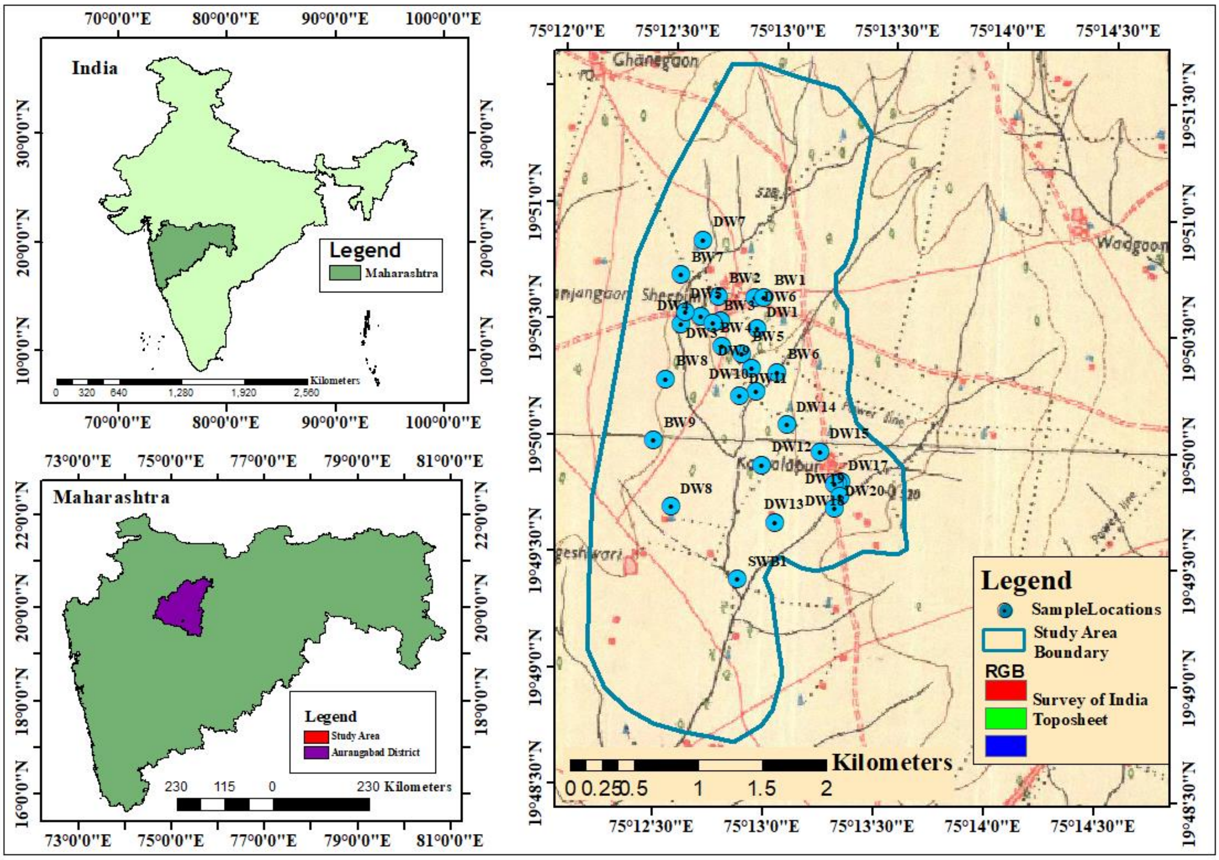

Figure 1. Study area Location map.

2.2 Sampling Techniques

A total 30 water samples (29 groundwater samples from dug and bore wells, whereas 01sample from surface water body) were collected during post-monsoon season 2023 and analyzed their water quality parameters.

Sampling and analysis were carried out using the International standard method by APHA, 2012 and BIS, 2003. Generally, water quality parameters and anions and heavy metals are the signals of drinking water used, while water quality parameters such as sodium adsorption ratio (SAR), percent sodium (% Na), residual sodium carbonate (RSC), residual sodium bicarbonate (RSBC), Kelly's ratio (KR), magnesium adsorption ratio (MAR), and permeability index (PI). Based on primary water quality parameters like pH, Electric conductivity (EC), Total Dissolved Solid (TDS), Chloride (Cl), Total Hardness (TH), Magnesium (Mg), Calcium (Ca), Bicarbonates (HCO3), Sodium (Na). Potassium (K) and sulfate (SO4) are normally used to measurethe water qualityfor irrigation (Singh et al., 2013, 2015; Gautam et al., 2015).

Parameter pH was measured by (Lapman Model LMHP-12), EC and TDS were measured by using a Cond/ TDS meter (Deluxe Model 641E.) whereas Cl, Th, Ca and HCO3 were measured using a volumetric titration method. Mg was measured with the help of Total Hardness (TH) and Calcium (Cl) concentrations. Potassium (Na) and Sodium (Na) were measuredby using a flame photometer, whereas with the help of a spectrophotometer, SO_4 was measured.

2.2 Irrigation parameters

Irrigation water quality parameters such as SAR, %Na, RSC, RSBC, KR, MAR and PI were calculated by using standard formulae as given in Table 1.

2.2.1 (SAR) Sodium Adsorption Ratio

The (SAR) sodium adsorption ratio is a percentage of Na^+ ions to C_a^{2+} and Mg^{2+} ions in a water sample. the sodium adsorption ratio is used to predict the potential for Na^+ to build in the soil principally at the expense of Ca_2^+, Mg_2^+, and K^+ due to the regular use of sodic water. The SAR is calculated by the equation given in (Table 1). Based on irrigation water quality SAR values are classified into four categories (Table 2) if SAR value is 10 (excellent), SAR value 10 to 18 (Good), SAR value 18 to 26 (Doubtful), and if SAR value greater than 26 (Unsuitable) (Rawat et al., 2018).SAR also has an cause to percolation time of water in the soil. As a result, irrigation water with low SAR values is desirable.

2.2.2 (% Na) Percent sodium carbonate

High Na^+ concentration in irrigation water can lead to sodium hazards (26). The SAR is calculated with the equation given in Table 1. Based on % Na values, water is classified into five classes (Table 2) like value <20% it is (Excellent), 20-40% (Good), 40-60% (permissible), 60-80% (Doubtful), >80% (Unsuitable) (Khodapanah et al., 2009). When Na^+ levels are too high in irrigation water, it can have adverse effects on soil permeability and soil properties, as well as impede plant growth. Therefore, the percentage of sodium carbonate present in irrigation water is a critical factor in assessing its suitability for use.

2.2.3 (RSC) Residual Sodium Carbonate

RSC is characterized as the excess of carbonate and bicarbonate quantity above the alkaline earth, primarily the concentration of $Ca_2^+$and Mg_2^+ over allowable limits, which impacts irrigation unfavorably (Eaton, 1950; Richards, 1954).The RSC is calculated with the equation given in Table 1.

On the basis of RSC ranges the sodium hazards are classified into three classes as follows: (Table 2) RSC < 1.25 (Good), 1.25- 2.5 (doubtful) and > 2.5 (unsuitable) as discussed by Rawat et al. (2018). An increase in sodium adsorption in the soil is indicated by a high range of RSC in irrigation water. It is not advised to use water with an RSC of more than 5 for irrigation as it may cause harmful impacts on the growth of plants. Typically, any source of water with an RSC greater than 2.5 is not considered appropriate for agricultural use, however, water having less than 1.25 RSC is advised as safe for irrigation. A poor value of RSC shows the levels of Ca^{2+} and Mg^{2+} are too much. An elevated RSC indicates the presence of Na^+ in the soil is conceivable.

2.2.4 (RSBC) Residual Sodium Bicarbonate

An amount of carbonate and bicarbonate decides suitability for irrigation. High pH is found in water with high RSBC. RSBC was classified into three classes i.e., < 5 meq/l (satisfactory), 5 to 10 (marginal) and >10 meq/l (unsatisfactory) (by Gupta and Gupta, 1987) (Table 2). The RSBC is calculated by the equation given in Table 1.

2.2.5 (KR) Kell's Ratio

To evaluate and categorize water for irrigation purposes, it included a new component on the basis of ratio of Ca^{2+} to Na^+ and Mg_2^+ concentrations (Kelly, 1940). The Kelly's ratio (KR) is calculated by the equation given in Table 1. Waters with an overabundance of Na^+ are indicated by a KR > 1. Because of the potential for alkali risks, generally water has KR<1 is recommended for irrigation and water with KR 1 to 2 is marginally suitable, whereas water with KR>2 is not suitable for irrigation (Ramesh and Elango, 2012; Karanth, 1987).

2.2.6 (MAR) Magnesium Adsorption Ratio

An excess amount of (Mg) magnesium in groundwater changes the soil's pH, making it more alkaline and reducing crop productivity (Gowd, 2005; Singh et al., 2013; Gautam et al., 2015). The magnesium adsorption ratio (MAR) is calculated by the equation given in Table 1.Farmers claim that high concentrations of Mg^{2+} ions in water degrade soil quality, which lowers crop yields (Ramesh and Elango, 2012; Narsimha et al., 2013). The values of MAR < 50% suitable whereas the values of MAR > 50% is not suitable for the irrigation purposes (Khodapanah et al., 2009).

Table 1. Irrigation quality parameter indices (modified after Sreedevi et al., 2018).

Parameter	Formulae	References
Sodium adsorption ratio (SAR)	SAR= Na^+/ (√$Ca^{2+}Mg^{2+}$/ 2)	Richard (1954)
Percent sodium carbonate (RSC)	%Na = (Na^+ + K^+)/ (Ca^{2+}+Mg^{2+} + Na^+ + K^+) × 100	Wilcox (1948)
Residual sodium carbonate	RSC = (CO_3+ HCO_3)– (Ca^{2+} + Mg^{2+})	Eaton (1950) and Richards (1954)
Residual Sodium Bicarbonate (RSBC)	HCO_3-Ca^{2+}	Gupta and Gupta (1987)
Kelly's ratio (KR)	Na^+/ Ca^{2+}+ Mg^{2+}	Kelly (1940)
Magnesium adsorption ratio (MAR)	MAR= (Mg^{2+}/ Ca^{2+}+ Mg^{2+}) x 100	Paliwal (1972)
Permeability Index (PI)	PI = (Na + √HCO_3 / Ca + Mg + Na) × 100	Doneen (1964)

Table 2. Irrigation parameter of water samples.

Parameters	Water Class	Range	Number of samples observed in class
SAR	Excellent	< 10	30
	Good	10 to 18	Nil
	Fair	18 to 26	Nil
	Poor	> 26	Nil
%Na	Excellent	< 20 %	Nil
	Good	20 to 40%	01
	Permissible	40 to 60%	10
	Doubtful	60 to 80%	18
	Unsuitable	>80%	01
RSC	Good	< 1.25	24
	Doubtful	1.25 to 2.5	04
	Unsuitable	> 2.5	02
RSBC	Satisfactory	< 5	30
	Marginal	5-10	Nil
	Unsatisfactory	> 10	Nil
KR	Suitable	< 1	07
	Marginal	1-2	20
	Unsuitable	> 2	03
MAR	Suitable	< 50	30
	Unsuitable	> 50	Nil
PI	Suitable	> 75	09
	Good	50 to 25	21
	Unsuitable	< 25	Nil

2.2.7Permeability index (PI)

The permeability index (PI) can be used as an indication to determine if water is suitable for irrigation. The permeability, or the capacity of soil to flow water, is impacted by the ions Na^+, Ca_2^+, Mg_2^+ and HCO_3^- in the soil and is altered by long-term usage of irrigation water (which has a high concentration of salt). The PI formula to evaluate soil water suitability and water movement capacity of any type of water source for irrigation (Doneen, 1964). The permeability index (PI) is calculated by the equation given in Table 1. The PI values are > 75% (suitable), 25 to 75 % (good) and <25% (unsuitable), the value of PI > 75% and between 25 to 75 % is recommended for irrigation purposes, whereas PI values < 25% is not suitable for irrigation (Doneen, 1964).

3. Result and discussion

The study area indicates that, SAR values are ranges from 2.88- 8.48 in post-monsoon while the mean levels of SAR were 5.01 for the same season (Table 3 and Figure 2), it falls under the excellent category, i.e., the SAR values < 10 (Richards, 1954). On the basis of SAR value Irrigation classification of water; all the water samples (Thirty) fall under the category of excellent. Excellent categorized samples are used for irrigation purpose. So, the Hundred percent water samples are appropriate or suitable for irrigation and planting.

Table 3. Irrigation parameter of water samples

Water Sample No	SAR (Unit)	%NA	RSC (meq/l)	RSBC (meq/l)	KR (meq/l)	MAR (%)	PI (%)
1	4.78	91.70	3.99	4.08	2.90	6.25	118.58
2	3.82	79.63	1.03	1.11	1.28	1.90	79.35
3	5.46	72.80	-1.13	-1.05	1.47	1.22	73.60
4	5.10	66.26	-2.87	-2.70	1.22	1.90	67.34
5	5.23	66.00	-2.05	-1.97	1.22	0.91	68.03
6	4.58	56.01	-2.75	-2.67	1.15	1.06	66.88
7	4.53	67.05	-0.53	-0.45	1.18	1.14	70.37
8	4.17	60.55	1.63	1.80	1.24	2.94	76.59
9	4.94	70.15	1.48	1.56	1.33	1.21	75.06
10	5.60	70.26	2.93	3.01	1.73	1.61	83.43
11	4.79	73.79	2.34	2.50	1.60	3.73	83.92
12	5.47	75.43	2.36	2.61	2.21	8.20	92.53
13	4.89	59.29	1.20	1.28	1.22	1.04	71.97
14	4.64	59.68	0.29	0.46	1.15	2.07	70.14
15	6.12	61.83	-2.21	-2.12	1.46	0.96	73.17
16	4.62	53.41	-4.41	-4.24	0.95	1.40	60.43
17	5.45	55.51	-5.33	-5.24	1.17	0.77	63.83
18	5.98	62.35	-3.52	-3.43	1.36	0.87	68.51
19	3.32	59.80	-6.45	-6.28	0.81	1.98	53.88
20	6.33	60.84	-5.58	-5.49	1.34	0.75	66.30
21	5.21	60.99	-2.38	-2.30	1.21	0.91	67.63
22	4.11	48.50	-14.52	-14.44	0.73	0.53	46.31
23	5.42	61.62	-6.27	-6.19	1.25	0.89	63.86
24	8.48	74.20	-2.48	-2.31	2.24	2.36	78.51
25	6.41	68.66	-1.57	-1.49	1.71	1.19	75.33
26	4.42	52.74	-11.08	-11.00	0.78	0.53	51.62
27	2.88	43.42	-11.17	-11.00	0.51	1.03	42.78
28	6.27	62.07	-7.41	-7.32	1.29	0.70	64.03
29	2.88	34.36	-23.09	-23.01	0.39	0.30	33.45
30	4.51	43.75	-17.72	-17.64	0.70	0.40	46.07
Min	**2.88**	**34.36**	**-23.09**	**-23.01**	**0.39**	**0.30**	**33.45**
Max	**8.48**	**91.70**	**3.99**	**4.08**	**2.90**	**8.20**	**118.58**
Mean	**5.01**	**62.42**	**-3.91**	**-3.80**	**1.29**	**1.69**	**68.45**

The sodium percentage (% Na) values of the study area vary from 34.36- 91.70 meq/l, with the mean value of 62.42 meq/l for the post-monsoon 2023 season, (Table 3 and Figure 3). Based on %Na irrigation waters are classified (Wilcox, 1948), as shown in Table 2. The Bureau of Indian Standards (BIS, 2003) suggests that, irrigation water should have a maximum 60% Na^+ content. Presence of % Na higher than 60% may lead to an accumulation of Na^+, which will decline the physical characteristics of the soil (Ramesh and Elango, 2012). %Na excellent class (<20%) is not observed, %Na good class (20-40%) is observed at sample number 29 (34.36%), %Na permissible class (40-60%) is observed at sample number 6, 13, 14, 16, 17, 19, 22, 26, 27, 30, %Na doubtful class (60-80%) is observed at sample number 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 15, 18, 20, 21, 23, 24, 25, 28 and %Na unsuitable class (> 80 %) is observed at sample number 1 (Table 3). It is clear that 10 water samples falls below the permissible class, but the doubtful class also reports the maximum percent (18 no. water samples) of the total water samples. It can be the result of minimum rainfall, which slows down the diluting process. Sample number 1 has a high %Na value (91.70), which could be the result of more Na^+ leaching into the water from the rock. The majority of water samples fall within the permissible and doubtful category of irrigation water.

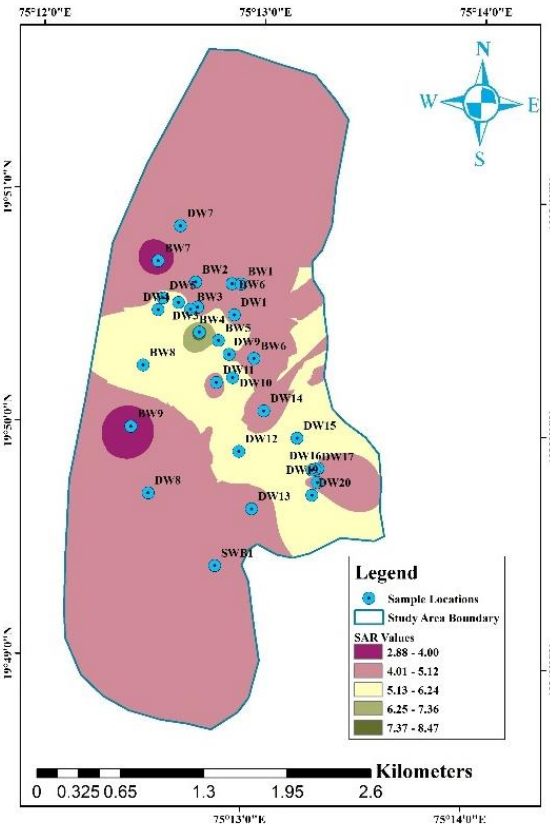

Figure 2. RSC spatial distribution map of the study area.

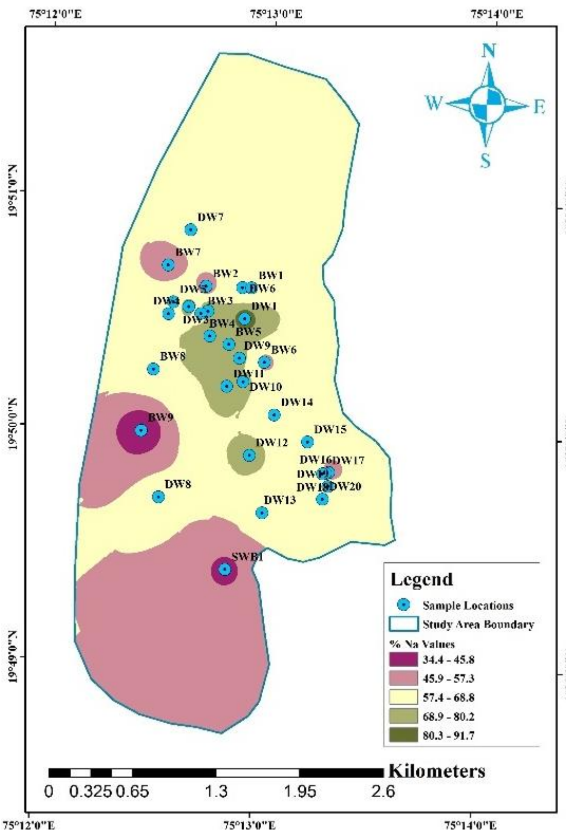

Figure 3. % Na spatial distribution map of the study area

The water of the study area shoes variations on the RSC between -23.09 to 3.99 meq/l with a mean of -3.91, in post-monsoon season (Table 3 and Figure 4). According to Richards (1954) classification, 24 water samples (sample numbers 2, 3, 4, 5, 6, 7, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29 and 30) falls below good class, 04 water samples (sample numbers 8,9,11 and 12) falls below doubtful class and 02 water samples (sample numbers 1 and 10) falls below unsuitable class (Table 3). Water with an RSC > 2.5 is generally not recommended for use in agriculture, while water with an RSC < 1.25 is suggested for irrigation. Water sample number 3, 4, 5, 6, 7, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29 and 30 observed negative values (Table 3) due to an excess of Ca_2^+ and Mg_2^+ concentration is indicated by a negative RSC value. A positive RSC indicates the possibility of Na^+ occurrences in the soil. In the study area, water sample number 1 and 10 show high RSC values i.e., 3.99 meq/l and 2.93 meq/l respectively and it is not suitable for irrigation purposes. An increase in sodium adsorption on the soil is indicated by a high range of RSC in irrigation water. Because of the harmful effects on plant growth, irrigation with it is not recommended for irrigation.

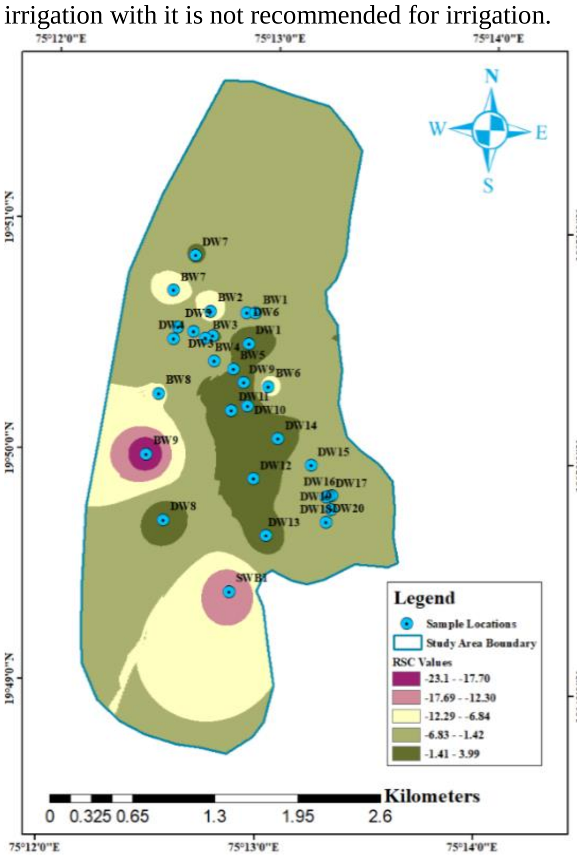

Figure 4. RSC spatial distribution map of the study area

(RSBC) Residual Sodium Bicarbonate standards of water from the study area varies as -23.01 to 4.08 meq/l with a mean of -3.80 (Table 3 and Figure 5). The excess concentration of HCO_3^- over Ca_2^+ is shown by RSBC (Hussain and Hussain, 2004). Excess HCO3- is present in the water, as shown by the negative values (Table 3) of each water group in the research area. RSBC value of the study area is less than 5 meq/l for all the water samples, while it is recommended for safe irrigation (Gupta and Gupta, 1987; Oladeji et al., 2012).

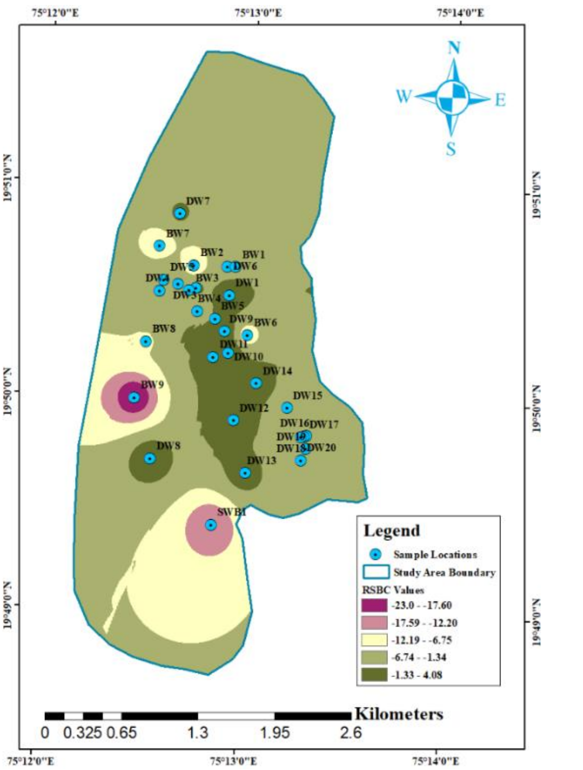

Figure 5. RSBC spatial distribution map of the study area

To assess irrigation water quality suitability, Kelly's ratio (KR) is an indicator and it is allowed from the result of the K^+ parameter, which purely depends on Ca_2^+, Mg_2^+ and Na^+. From Table 3, the mean value of KR during the study period was 1.29 meq/l with a range from 0.39 to 2.90 meq/l. Rainfall was found to have less of an impact on KR because, because of the diluting process, the average value of KR falls within the suitable range (Table 3 and Figure 6). Most water samples fall under the suitable category (07 water sample) and marginal suitability (20 water sample) range due to dilution process. It means that 27 water samples are suitable for irrigation purposes within the study area only 3 water samples are not suitable for irrigation i.e., 1, 12 and 24.

MAR is Mg_2^+ and Ca_2^+ based, and it also denotes in percent and contains only two categories i.e., MAR < 50 % (suitable) and > 50 (unsuitable). The MAR values range from 0.30 % to 8.20 % with a mean of 1.69 in the study period time within study area (Table 3 and Figure 7). Throughout the study period, every water sample is below the permissible limit (< 50%). It suggests that declining the soil alkalinity in the samples with low MAR would not hurt crop yield. All water samples are suitable for irrigation due to MAR value ranges below the permissible limit. Irrigation water affects long term use to soil permeability.

It depends on various factors like the total soluble salt, sodium, calcium, magnesium, and bicarbonate content of the water. The PI values of the study area vary between 33.45 % to 118.58 % with a mean of 68.45 % (Table 3 and Figure 8). As per the PI values, it is classified into three classes of water samples i.e., > 75% (suitable), 75-25 % (good) and < 25 (unsuitable) (Doneen, 1964), whereas the study area falls in the suitable and good class of PI range. These classes have excellent to good permeability of soils and are recommended for irrigation.

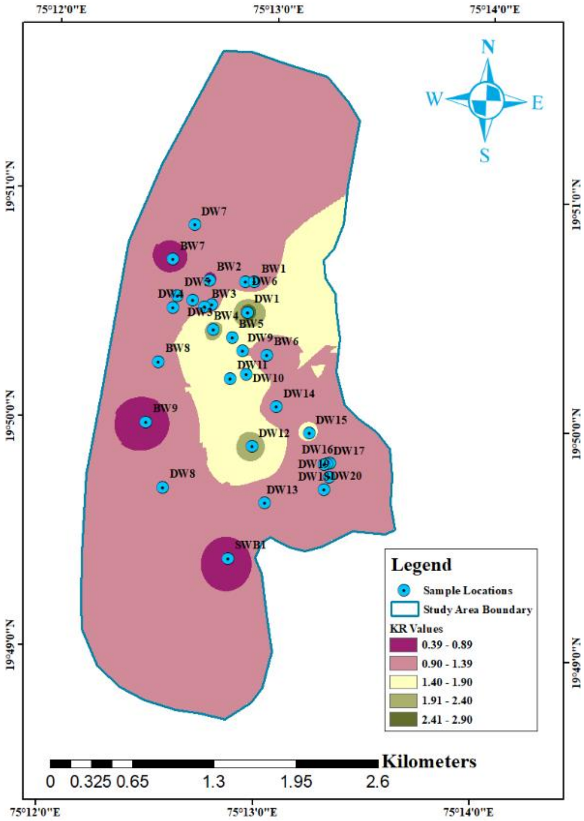

Figure 6. KR spatial distribution map of the study area

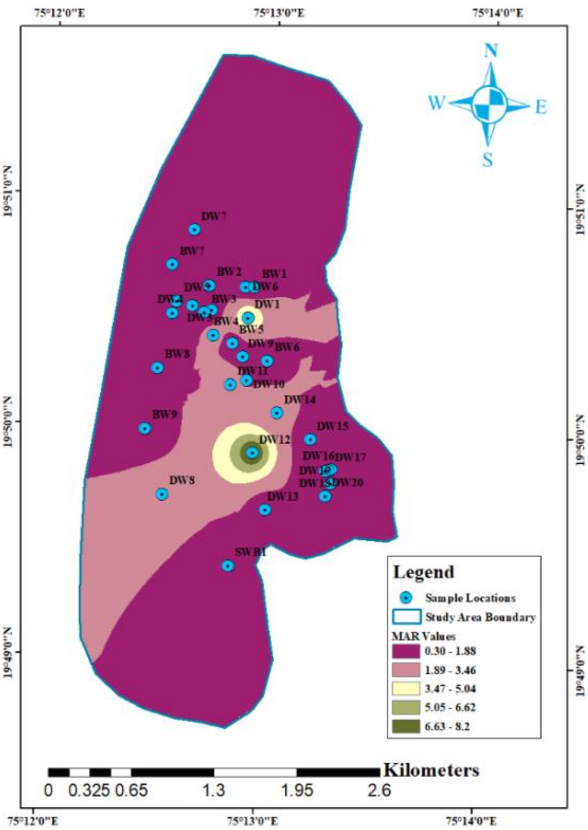

Figure 7. MAR spatial distribution map of the study area.

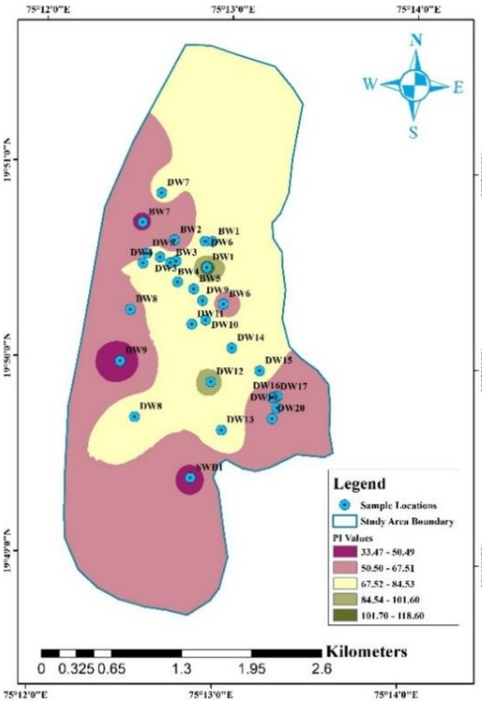

Figure 8. PI spatial distribution mapof the study area

3.1 Groundwater infiltration rate capacity estimation

The SAR and EC values of irrigation water are used to evaluate its infiltration qualities (Sreedevi et al., 2018). The effects of high SAR on irrigation water are determined by the waters EC. Irrigation water has a higher EC and SAR index, which causes infiltration issues. On the other hand, the lower the EC and the higher the SAR, the more the chance of infiltration. On the other hand, the higher the SAR and lower the EC, the more the chance of infiltration.

More than 50% of water samples fit into the low to moderate category decrease in the rate of infiltration (Rhoades, 1977; Oster and Schroer, 1979), which is slightly increased through the study period (Table 4). Rainfall can lower soil salinity, increasing the SAR index value and reducing infiltration of water into the soil resulting in excessive runoff (Kar et al., 2015).

Table 4. Water infiltration capacity classification after Rhoades, 1977; Oster and Schoer, 1979, and Sreedevi et al., 2018.

Water infiltration problem classification				**Different infiltration problems fall under the % samples**		
SAR	EC of Water samples µS/cm					
	Low	Moderate	High	Low	Moderate	High
0-3	> 700	700-200	< 200	02	-	-
3-6	> 1200	1200-300	< 300	23	-	-
6-12	> 1900	1900-500	< 500	05	-	-
12-20	> 2900	2900-1300	< 1300	-	-	-
20-40	> 5000	5000-2900	< 2900	-	-	-

4. Conclusions

The cations and anions concentrations are within the permitted range for irrigation water samples except for an insufficient water sample. The water suitability for irrigation is assessed based on SAR, % Na, RSC, RSBC, KR, MAR and PI parameters values. The values of SAR (2.88-8.48), %Na (34.36-91.70 meq/l), RSC (-23.09-3.99 meq/l), RSBC (-23.01-4.08 meq/l), KR (0.39-2.90 meq/l.), MAR (0.30-8.20 %) and PI (33.45-118.58 %) were observed for water samples within the study area. All SAR, RSBC and MAR water sample values are observed below the permissible limit within the study area and it is suitable for irrigation. %Na concentration values of the study area are under the good (1water sample) permissible (10 water samples) and doubtful (18 water samples) categories except for water sample 1 is exceeds the permissible limit i.e., 91.70 and is unsuitable for irrigation purposes. The RSC value for the study area is under the good to doubtful category and it is suitable for irrigation except water samples number 1 and 10. KR values for the water sample within the study area are suitable for the marginal class and it is suitable for irrigation except for the water samples 1,12 and 24. The PI values for water samples are under the suitable to good category and it is suitable for irrigation.

Based on these irrigation parameters maximum water samples fall under the suitable category, which suggests water for irrigation purposes. A few numbers of water samples that exceed permissible limits have been found within the study area due to various geological and anthropogenic activities. Artificial recharge methods might be adopted to suitable crops or lower chemical concentrations in groundwater could be grown to maintain the existing water quality. The outcome of this study is helpful to the farmers and policy makers for groundwater resources management and planning.

Conflict of interest

There is no conflict of interest from all the authors.

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