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# Groundwater Suitability for Irrigation in Chickmagaluru District, Southern Karnataka, India using WATCHIT

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## Abstract

The groundwater is the major source of irrigation in the Chickmagaluru district of Southern Karnataka. A multitude of factors, including soil composition, soil texture, the geology of the area and agricultural activity, impacts the water's suitability. The Permeability Index , Salinity and Sodium hazard classification, Sodium Adsorption Ratio, Residual Sodium Carbonate, Sodium Ratio, Adjusted Sodium Adsorption Ratio, United States Salinity Laboratory (salinity USSL), Salinity Hazard, Na- Hazard USSL, Na- Hazard, Kelly's Ratio and Corrosivity Ratio are some of the characteristics that determine the quality groundwater used for the irrigation. The present study focuses on to gain the better understanding of the groundwater quality and its suitability for agriculture in the Chickmagaluru district of the Karnataka state, India. The present work revealed that more than half of the collected samples are confirmed to be appropriate for irrigation purpose.

*Keywords:* Water Quality, Irrigation Suitability, Pollution, Groundwater, wells, Chickamanaluru District, Karnataka

## Introduction

Freshwater resources have the limited availability (Sutanudjaja *et al.*, 2018). Groundwater is an important natural source of freshwater for the world's population, and it is used for domestic, agricultural, manufacturing, and industrial purposes (Treidel *et al.*, 2011). Freshwater resources must therefore be controlled and conserved (Russell and Kelly, 2010). Agriculture, on the other hand, continues to be a significant part of the global economy (Alston *et al.*, 2014). Farming is noteworthy because it is the largest consumer of crisp water and a significant contributor to the depletion of surface and groundwater (Coleman *et al.*, 2004). Assets and quality Groundwater resources are critical for the economic development, especially in dry areas. The natural, physical, and chemical condition of water, as well as any adjustments that may have been caused by anthropogenic action, are all considered to be water quality. The quality of groundwater is determined by all of the procedures and responses that follow water from the moment it is first collected until stored in a well, and is influenced by a variety of physicochemical characteristics (Asadi *et al.*, 2020). The combined consequences of population increase and excessive groundwater use have resulted in widespread groundwater asset exhaustion and corruption (Werner *et al.*, 2013). Furthermore, it is obvious that the quality of agricultural water influences the condition of the soil and, as a result, the harvests that are produced. Due to population development, interest in farming areas and the products produced by these farms has increased rapidly in the last century (Orsini *et al.*, 2013). Experts have stated that certain factors, such as increased urbanization, more industrialised spaces, insufficient land management, and environmental contamination, have placed an additional strain on agricultural production (Bouma *et al.*, 1998). As a result, determining the quality of groundwater is critical. A traditional assessment of groundwater quality is simple, but it necessitates a step-by-step method that considers each individual parameter (Alastal *et al.*, 2015). The purpose of the present study is to assess the quality of groundwater for irrigation purposes in the Chikmagaluru district.

## Study Area

The study area falls within the state of Karnataka. Chikmagalur district is situated in the southwestern part of Karnataka state between 12° 54' 42"-13° 53' 53" North latitudes and 75° 04' 46"-76° 21' 50" East longitudes (Fig.1). The greatest elongation from east to west is ~138km and the greatest breadth from north-south is ~89km. The study area is surrounded by the Tumkur district in the East, the Hassan in the South, the Dakshina Kannada in the West, the Chitradurga in the Northeast, and the Shimoga in the North. The total area of the district is 7201$Km^2$, consisting of seven talukas, namely Chikmagalur, Kadur, Koppa, Mudigere, Narasimharajapura, Sringeri, and Tarikere. The district area is represented on Survey of India topographical map numbers 48 O and 57 C. The district's average annual rainfall is 1762 mm. The Kadur taluka receives the least rainfall in the district (~620 mm), while the Sringeri taluka receives the most precipitation (~3773 mm) annually.

Geologically, the majority of the Chikmagalur region is comprised of schist with the gneissic rocks in the southern section. The potential aquifers in the area include weathered, fractured, and jointed schist and gneiss. The key soil type in the district consists of red loamy and sandy soil. However, hilly soil and mixed red and black soil are often present in the limited areas of the central and north-eastern regions. The groundwater in present study area persists below the water table under the semi-confined conditions (CGWB, 2016).

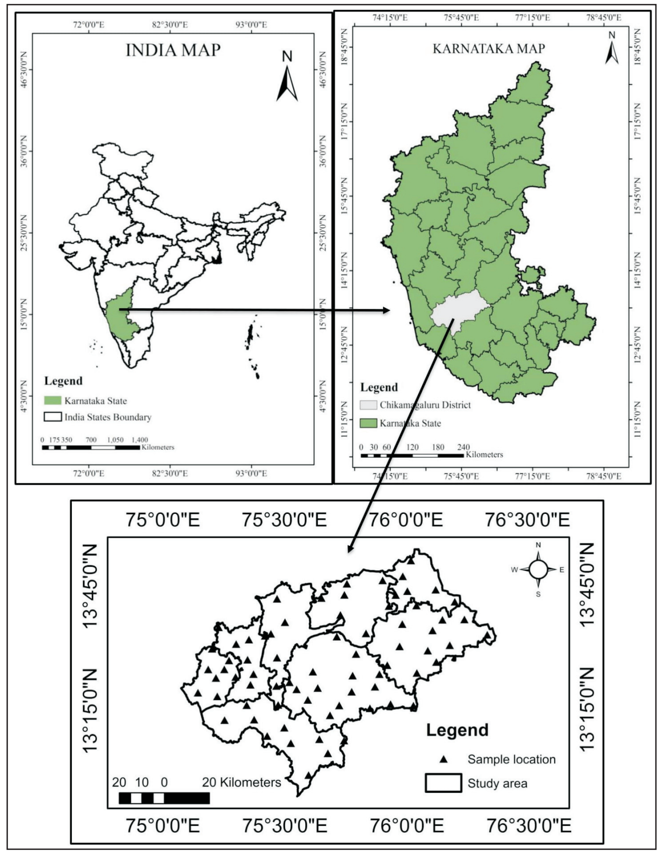


**Fig.1.** Location map of Study area with sampling locations

## Methodology

During the Premonsoon season, 73 representative groundwater samples were collected from the various tube wells in the study area and the locations of the water samples were marked (Fig.1). After 5 minutes of pumping, samples were collected and stored at 4°C in thoroughly washed polythene containers till the beginning the chemical analysis. Calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), chloride (Cl), and sulphate (SO4) concentrations were determined using standard techniques (APHA, 2005). Calcium and magnesium concentrations were determined in the laboratory using volumetric titration methods, whereas chloride concentration was assessed using an auto titrator (MetrohmTitrando, 2020). A flame-photometer (Model No. 128) was used to determine sodium and potassium concentrations, while a spectrophotometer (Model No. 119) was used to evaluate sulphate content. Blanks and standards were run on a regular basis to ensure that the accuracy of analyses. The ion balance error was also calculated to ensure that the results were accurate to within 5%. Following the end of the analysis, the data was processed using WATCHIT and thematic maps were created using ARC GIS software.

## Results and Discussion

### *Groundwater Chemistry*

The findings of a statistical examination of the physicochemical markers of groundwater samples are shown in Table 1. The pH of the groundwater in the study area, ranges from 6.5 to 8.71, with an average of 7.33 indicating its alkaline nature. The average total hardness level (TH) was 33.5 mg/L, with a range of 31.5 to 1808 1276.00 mg/L. TH is equal to the sum of $Ca^{2+}$ and $Mg^{2+}$ in groundwater and denotes the presence of alkaline earths. In water distribution systems, hardness can induce encrustation (Mahato and Kafle, 2018). The electrical conductivity of the groundwater ranges from 97 to 2346 µS/cm. The values of EC reflect the wide variations in geochemical processes. The TDS ranges from 108 to 1458 mg/l. It is made up mostly of inorganic salts, along with some organic matter in small amounts dissolved in water. The major minerals that are usually used to calculate the TDS are calcium, magnesium, sodium, potassium, and carbonate, bicarbonate, chloride, and sulfate cations. The concentration of potassium ranges from 2 to 193 mg/l. The general hydrochemical features of groundwater are regulated by major ions (Li *et al.*, 2016). K levels range from 2 to 193 mg/L, with a mean of 15.7 mg/L (Table 1). $Ca^{2+}$, $Mg^{2+}$, and $Na^{+}$ contents range from 353-395, 5.96-6, and 0.52-10.57 mg/L, respectively. Calcium has the greatest SD, indicating a high degree of geographical heterogeneity. $Cl^{-}$ concentrations range from 14 to 678 mg/L, $SO_4^{2-}$ concentrations from 04 to 267 mg/L, and $HCO_3^{-}$ concentrations from 115 to 618 mg/L. These anions have very high spatial variability, with SD values of 162.1, 68.97, and 139, respectively, indicating that they are influenced by a variety of site-specific causes.

**Table 1:** Statistical analysis of physio-chemical parameters of groundwater

| Parameter | Unit | Max | Min | Mean | Standard Deviation |
|---|---|---|---|---|---|
| pH | - | 8.71 | 6.5 | 7.33 | 2.61 |
| TDS | Mg/L | 1458 | 108 | 848 | 512 |
| EC | ?S/cm | 2346 | 97 | 975 | 730 |
| TH | Mg/L | 1808 | 31.5 | 33.5 | 378.9 |
| $SO_4$ | Mg/L | 267 | 4 | 102.6 | 68.97 |
| F | Mg/L | 2.2 | 0.05 | 0.635 | 0.51 |
| Fe | Mg/L | 1.31 | 0.01 | 0.166 | 0.19 |
| Mg | Mg/L | 5.96 | 6 | 63.4 | 65.2 |
| Cl | Mg/L | 678 | 14 | 219.5 | 162.1 |
| $NO_3$ | Mg/L | 79 | 1.3 | 22.6 | 16 |
| $HCO_3$ | Mg/L | 618 | 115 | 245 | 139 |
| K | Mg/L | 193 | 2 | 15.7 | 23 |
| Ca | Mg/L | 353 | 395 | 96.53 | 73.66 |
| Na | Mg/L | 10.57 | 0.52 | 2.5 | 2.26 |

### *Irrigation Water Quality Parameter*

Plain land relies heavily on groundwater for irrigation. The water's appropriateness is determined by a number of factors, including soil composition, soil texture, the geology of the area, and agricultural activities. SSP, Sodocity, Salinity, SAR, RSC, KR, CR, PS, RSB, MAR, PI, and SR are some of the characteristics that determine the quality of irrigation water (Abou El-Defan *et al.*, 2016; Singh *et al.*, 2020).

### *Salinity Hazard Classification*

Plants absorbed less water due to salty soils induced by increased irrigation with saline water. Long-term Saline water use will result in a significant reduction in crop yield. The fertility of the soil will decline over time. Richards (1954) classified irrigation water salinity into four groups and allocated a letter grade to each (Table 2-3). The limits of salinity in each class, as well as their suitability for soil and growing crops, as well as appropriate precautions and crop attributes that must be grown, were stated in front of each class. More than half of the groundwater samples in the research region are classified as good for irrigation and almost 46% of the total was unsuitable. The contamination could be either geogenic or anthropogenic. The groundwater flow through soluble minerals will be the geogenic source, while the industrial and municipal garbage are anthropogenic sources (Mondal, 2019).

**Table 3:** Salinity Hazard (*after* Davis and De Weiest, 1966; Wilcox, 1955)

| Salinity Hazard classes | Remarks on quality | Number of samples | Percentage |
|---|---|---|---|
| C1 | Excellent | 0 | 0 |
| C2 | Good | 39 | 53.4 |
| C3 | Doubtful | 32 | 43.8 |
| C4 | Unsuitable | 2 | 2.8 |

### *Sodium Ratio (SR)*

The quality of irrigation water was assessed using a ratio of dissolved sodium cations to total calcium and magnesium in irrigation water, indicated as (SR) and computed using the equation below (Abou El-Defan *et al.*, 2016). This ratio should not be greater than one in good water. The concentrations of all ions are measured in meq/L.

$$SR = (Na^{+}) / (Ca^{2+} + Mg^{2+})$$

Only 11 of the tested samples in the research region fall into the inappropriate category, leaving the rest as agriculture-ready samples (Table 4). Due to the groundwater circulation through sodium-rich rocks, there is an overabundance of sodium in groundwater. As mentioned in the introduction, the sodium ratio in the research area varies greatly (Fig. 3). It is divided into two categories: mountainous and plain terrain. The regional distribution of sodium ratio revealed that the parts of the Kadur Taluka have a higher sodium ratio as compared to the rest of the study area (Fig. 2).

**Table 2:** Classes of irrigation water salinity(Richards, 1954).

| Class | Description | Salinity meq/l | TDS, (ppm) | Remarks |
|---|---|---|---|---|
| C1 | Low Salinity | < 0.25 | < 200 | Well used for irrigation of most crops on most soils. Some leaching is needed under normal irrigation conditions, but excessive irrigation is required in extremely poor soil or porous soils. |
| C2 | Medium Salinity | Salinity 0.25-0.75 | 200-500 | Can be used when the majority of leaching stays stable. Plants that withstand moderate salt concentrations. can be grown in most regions without special salinity control methods. |
| C3 | High Salinity | 0.75-2.25 | 500-1500 | Not effective in areas with restricted drainage. Even with adequate drainage, special salinity control management is required and plants with good salt tolerance may grow in this area. |
| C4 | Very high Salinity | >2.25 | >1500 | Under normal circumstances, it is not suitable for irrigation. but can be used in special cases. The soil must be permeable, sufficient drainage must be provided, Water from the irrigation system must be used in excess. and crops tolerant of high salt levels should be selected. |

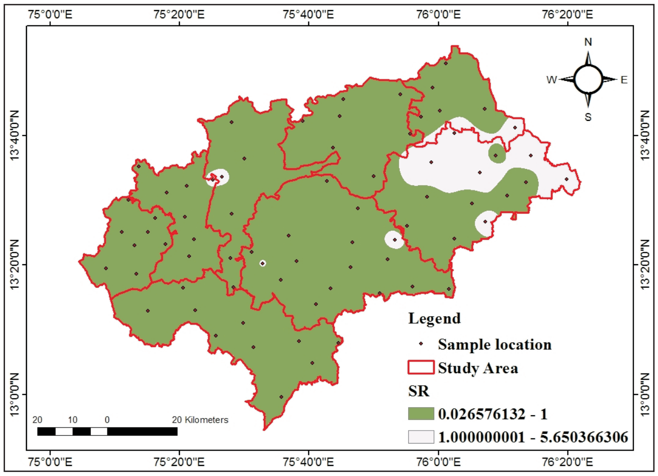


**Fig. 2.** Spatial distribution Sodium ratio of the groundwater samples in the study area

**Table 4:** Sodium ratio (SR) classification (*after* Abou-El-Defan *et al.*, 2016)

| Sl. No. | Values meq/l | Remarks on quality | Number of samples |
|---|---|---|---|
| 1 | >1 | Unsuitable for agriculture | 11 |
| 2 | <1 | Suitable for agriculture | 62 |

**Table 5:** Soluble Sodium Percentage (SSP) classification (*after* Wilcox, 1954)

| Category | SSP Range (%) | No. of samples | % |
|---|---|---|---|
| Excellent | < 20 | 16 | 21.9 |
| Good | 20 - 40 | 36 | 49.3 |
| Permissible | 40 - 60 | 15 | 20.5 |
| Doubtful | 60 - 80 | 4 | 5.6 |
| Unsafe | >80 | 2 | 2.7 |

### *Soluble Sodium Percentage (SSP)*

For assessing Sodium Hazard, SSP is a crucial feature. It is used to sort irrigation water into soft and hard categories, with a high value indicating soft water and a low value indicating hard water. The high sodium content water affects soils, resulting in reduced permeability and poor internal drainage (Subramani *et al.*, 2005). The classification of groundwater based on Na% is >20% (excellent), 20 – 40% (good), 40 – 60% (permissible), 60 – 80% (doubtful) and >80% (unsafe). The SSP is computed using the below given equation

$$Na\% = (Na^{+} + K) / Ca^{2+} + Mg^{2+} + Na^{+} + K) \times 100$$

67 groundwater samples in the research area are categorized as suitable to excellent (Table 5). The percentage of soluble sodium in some portions of the Kadur taluka is greater (Table 14). The spatial distribution of soluble sodium % in study area divulged that the central part of the Chickmagaluru and region bordered by the Chitradurga district shows permissible limits of the SSP (Fig. 4). Apart from six groundwater samples, the remaining samples are acceptable for cultivating crops with salt tolerance, adequate drainage, and special salinity control management.

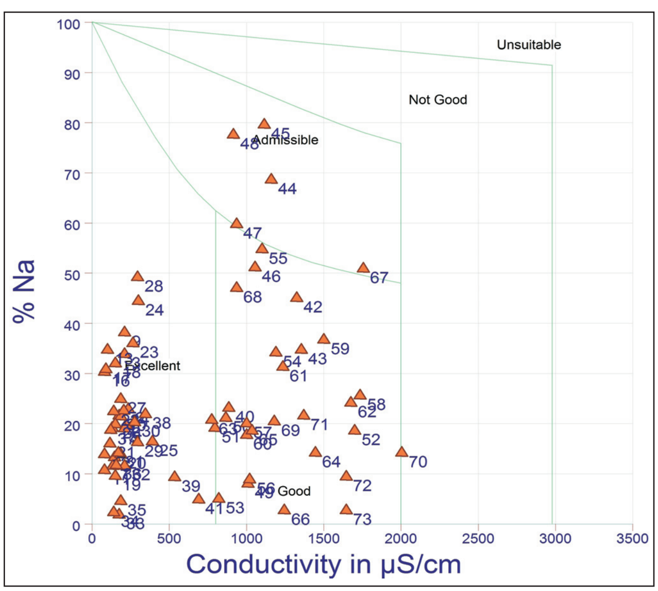


**Fig. 3.**Wilcox diagram demonstrating irrigation water quality (*after* Wilcox, 1955)

### *Permeability Index (PI)*

Irrigation techniques may have a negative impact on soil permeability. The permeability of the soil is affected by several components such as sodium, calcium, magnesium, and bicarbonate. Based on the PI, Doneen (1964) devised a criterion for determining the suitability of water for irrigation. Waters are categorized into three categories: Class I, Class II, and Class III. The ions' concentrations are all expressed in meq/L (Table 6). The equation below was used to calculate PI.

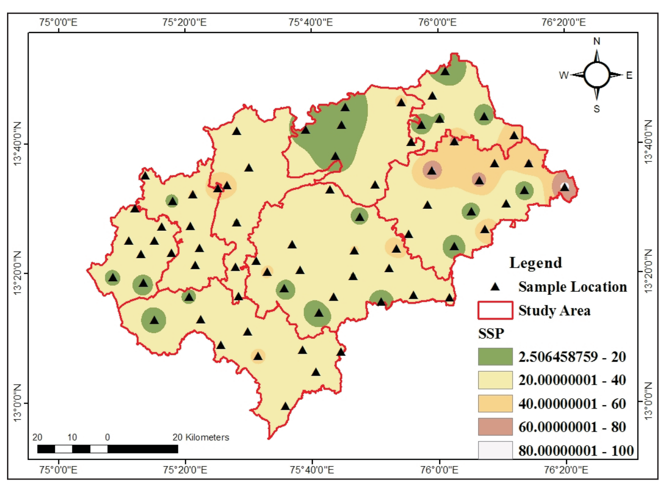


**Fig. 4.** Spatial distribution Soluble Sodium Percentage of the groundwater samples in the study area

**Table 6:** Permeability Index (Doneen, 1964)

| S.No. | Class | Remarks on quality | No. of samples | % |
|---|---|---|---|---|
| 1 | Class, I Class II | Water is classified as having a high probability of providing irrigation benefits. | 48 | 65.75 |
| 2 | Class III | Water is unsuitable with a 25% overall permeability. | 25 | 34.25 |

$$PI = \frac{(Na + \sqrt{HCO_3}\ X\ 100)}{Ca + Mg + Na}$$

Permeability is often measured in a saturated state. Permeability refers to the ability of a soil to transfer water. Long-term soil permeability will be affected by greater levels of ions such as sodium, calcium, and magnesium. The regional distribution of the permeability index in the research area showed that the majority of the Malnad area in the research area has better permeability than plain land. The parts of Mudigere and Sringeri have the highest soil permeability index, whereas the middle area of the Tarikere Taluka has the lowest (Fig.5).

### *Kelly's Ratio (KR)*

Kelly took into account the ratio of sodium to calcium and magnesium (Pophare and Sadawarti, 2019). If the Kelly's index is larger than one, the salt content of the water is too high. When the Kelly's ratio is more than one, the water contains too much sodium. Anything with a Kelly's ratio of less than one is good for irrigation, while anything with a Kelly's ratio of more than one isn't. The regional distribution of the Kelly's Ratio indicates that except for the Kadur taluka, all other talukas in the research region are within the permissible limit and approximately 85% of the groundwater samples are suitable for irrigation (Fig. 6; Table 7). The high percentage of salt in irrigation water in sections of the Kadur taluka causes a higher Kelly's Ratio.

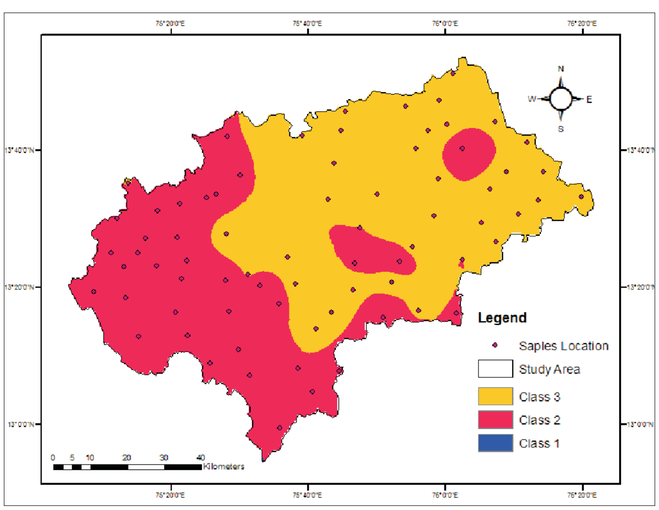


**Fig. 5.** Spatial distribution Permeability Index of the groundwater samples in the study area

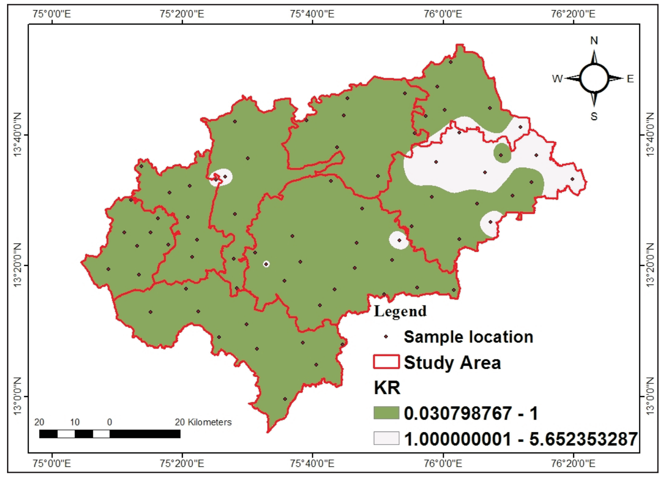


**Fig. 6.** Spatial distribution Kelly's Ratio of the groundwater samples in the study area

### *Corrositivity Ratio (CR)*

To preserve the water supply systems, the qualities of groundwater delivered through metallic or PVC pipes, such as corrosion, must be examined. Corrosion is a type of electrolysis in which metal surfaces are attacked and corroded away. Corrosion rates are affected by a number of chemical equilibrium reactions as well as physical factors such as temperature and flow velocity (Malpe *et al.*, 2021). Groundwater with a corrosivity ratio of less than one is safe to transport in any type of pipe, while groundwater with a corrosivity ratio more than one is corrosive and should not be transported in metal pipes. The CR was calculated using the equation below.

$$CR = \frac{\left(\frac{Cl^-}{35}\right) + 2\left(\frac{SO_4^{2-}}{96}\right)}{\left(\frac{CO_3^{2-} + HCO_3^-}{100}\right)}$$

The spatial distribution of the Corrositivity Ratio of groundwater the study area points that the parts of the Malnad region have a lower Corrosivity Ratio (Fig. 7; Table 8), which means that water can pass through metallic pipes without corroding them. However, because the majority part from the Tarikere and Kadur talukas has a high corrosivity ratio, water cannot be transported through copper pipes.

### *Sodium Adsorption Ratio (SAR)*

Is a key water quality metric for determining whether or not water is suitable for irrigation. It is also to blame for the risk of salt poisoning. Based on the Sodium Adsorption Ratio value

**Table 7:** Kelly's Ratio (Kelly, 1940) of the groundwater samples in the study area

| KR | Remarks | No. of samples |
|---|---|---|
| >1 | Suitable | 62 |
| <1 | Unsuitable | 11 |

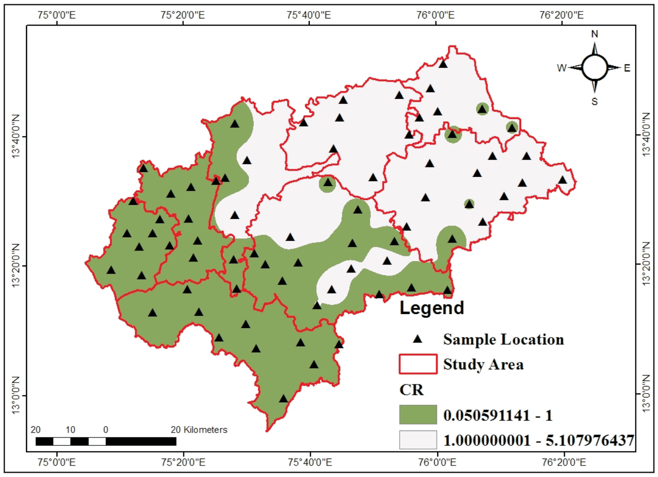


**Fig. 7.** Spatial distribution Corrositivity Ratio of the groundwater samples in the study area

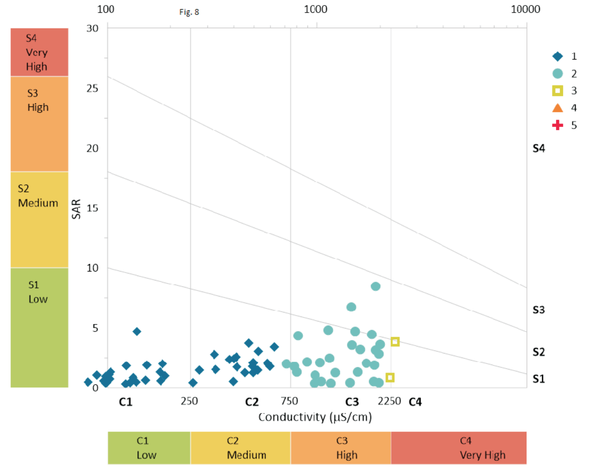


**Fig. 8.** USSL diagram demonstrating irrigation water quality of the groundwater samples in the study area (USSLS, 1954)

ranges, the waters were classified for irrigation. The SAR is the ratio of sodium to calcium and magnesium in water extract. It's one-half divided by the Na concentration divided by the square root (Uma Mohan and Krishnakumar, 2021). The following formula is used to calculate it, with all ions being given in meq/l.

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}$$

The USSL diagram was plotted to analyze the water quality, and it shows that more than half of the samples are appropriate for irrigation (Fig. 8). The spatial distribution of Sodium Adsorption Ratio (SAR) in the study area revealed that all of the groundwater samples in the study area are in good condition (Fig. 9; Table 9-10).

***Residual Sodium Carbonate (RSC)***

The appropriateness of water for irrigation is influenced by the concentration of bicarbonate and carbonate ions in it. The assumption that all $Ca^{2+}$ and $Mg^{2+}$ precipitate as carbonate mineral species is one of the empirical techniques. As a result, the idea of residual sodium carbonate (RSC) for assessing high carbonate waters was established. Due to sodium carbonate chemical deposition, water with a high RSC has a high pH, and land irrigated with it becomes unproductive. The effects of bicarbonate ($HCO^{3-}$) and carbonates ($CO^{3-}$) are calculated using the RSC formula (Eaton, 1950). The following formula is used to calculate it, with all ions being given in meq/l.

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

The regional distribution of the RSC values in the research area ranges from 27.20 to 2.70 and around 90% of the samples fall into the "good" category (Fig. 10; Table 11).

***Residual Sodium Bicarbonate (RSBC)***

Water's appropriateness for irrigation is influenced by bicarbonate and carbonate concentrations. A high pH is seen in water with a high RSBC. As a result of the deposition of Sodium Carbonate, land irrigated with such water has become unproductive (Eaton, 1950). Water from the study area has residual sodium bicarbonate levels of -10.2 to 2.8meq/L (Table- 12). Irrigation is considered safe if the RSBC levels are fewer than 5Meq/L (Gupta and Gupta, 1987; Oladeji *et.al.*,

**Table 8:** Corrosivity Ratio of the groundwater samples in the study area (*after* Balasubramanian and Nagaraju, 2019)

| Sl. No. | Values meq/l | Remarks on quality | No. of samples |
|---|---|---|---|
| 1 | >1 | Water transport in any type of pipe is completely safe. | 45 |
| 2 | <1 | corrosive and should not be transported in metal pipes | 28 |

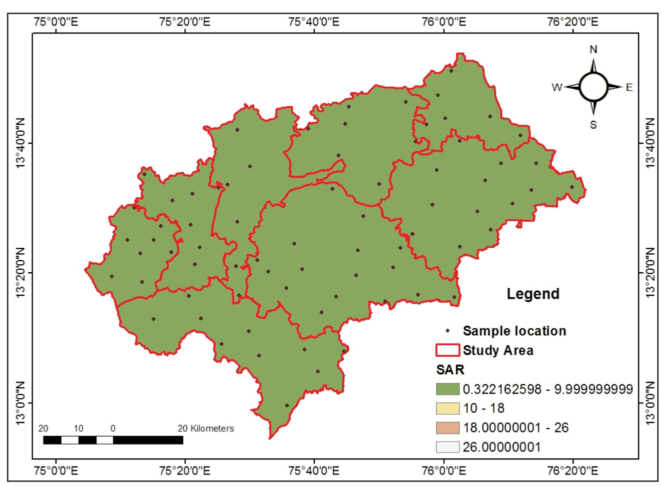


**Fig. 9.** Spatial distribution SAR Rangeof the groundwater samples in the study area

**Table 9:** Irrigation water classes and description as SAR values (*after* Abou-El-Defan *et al.,* 2016)

| Class | Description | SAR Value(meq/l) | Remarks |
|---|---|---|---|
| S1 | Low sodium Water | < 10 | Irrigation can be used on almost any soil with little risk of exchangeable sodium development. Sodium-sensitive crops, on the other hand, may accumulate harmful sodium levels. |
| S2 | Medium sodium Water | 10-18 | Unless gypsum is present in the soil, there is a significant sodium hazard in fine-textured soil with CEC, especially under low leaching conditions. However, it can be used on soil with a coarse texture or that is organic and has good permeability. |
| S3 | High sodium Water | 18-26 | Most crops consider it unsatisfactory, and it may produce harmful levels of exchangeable sodium. The majority of soils will necessitate special soil management, such as adequate drainage, high leaching, and organic matter additions. Such water may not cause harmful levels of exchangeable sodium in gypsiferous soils. Replacement exchangeable sodium may require chemical amendments. |
| S4 | Very high sodium Water | > 26 | Is generally unsuitable for irrigation of most crops, except for low and likely medium salinity, where calcium from the soil or the use of gypsum may make the use of this water possible. |

**Table 10:** Sodium Hazard classification (Richarads, 1954)

| Sodium Hazard Class | SAR range meq/l | Remark | Number of samples |
|---|---|---|---|
| S1 | <10 | Excellent | 73 |
| S2 | 10 - 18 | Good | 0 |
| S3 | 18 - 26 | Doubtful | 0 |
| S4 | > 26 | Unsuitable | 0 |

2012). Using the following formula the values of residual sodium bicarbonate are calculated.

$$RSBC = HCO_3^- - Ca^{2+},$$

It can classify alkalinity risk of irrigation water into six groups based on (RSBC) values (Table 12). The spatial distribution of the RSBC in the study area showed that the non-alkaline water is present in parts of the Tarikere Taluka and water with low alkalinity is available in the parts of the Kadur, Mudigere, Chickamagaluru, and N R Pura Taluka (Fig.11).

### *Magnesium Adsorption Ratio (MAR)*

The amount of magnesium in water is an important

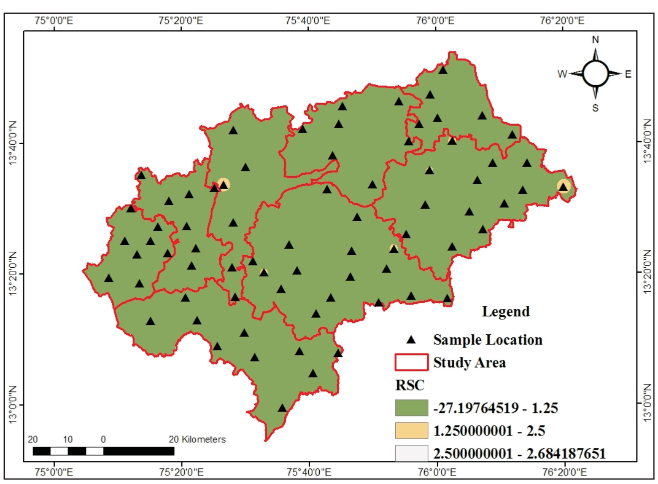


**Fig. 10.** Spatial distribution RSC Rangeof the groundwater samples in the study area

criterion for determining irrigation water quality. In most water, calcium and magnesium maintain a condition of equilibrium. As soils grow increasingly salty, an excess of magnesium in irrigation water will have a negative impact on agricultural production (Joshi *et al.*, 2015). The MAR was calculated by the equation

$$MAR = \frac{Mg \ X \ 100}{Ca + Mg}$$

The regional distribution of the MAR in the study area revealed that the water sample ranges from 11.11 to 90.58 percent (Fig. 12; Table 13). It is above the permitted

**Table 11:** Residual Sodium Carbonate of the groundwater samples in the study area (*after* Abou-El-Defan *et al.,* 2016)

| Category | RSC range (meq/l) | Water Quality | No. of samples |
|---|---|---|---|
| Good | <1.25 | Water probably safe for irrigation. | 65 |
| Medium | 1.25 - 2.50 | Water marginally suitable for irrigation and can be used with certain conducts. | 7 |
| Bad | >2.50 | Water unsuitable for irrigation purposes. | 1 |

**Table 12:** RSBC Classification of the groundwater samples in the study area (*after* Abou-El-Defan *et al.,* 2016)

| Sl. No. | Category | RSBC range(meq/l) | No. of samples |
|---|---|---|---|
| 1 | Non-alkaline water | - value | 22 |
| 2 | Normal water | 0-1 | 18 |
| 3 | Low alkalinitywater | 1 - 2.5 | 27 |
| 4 | Medium alkalinity water | 2.5-5.0 | 6 |
| 5 | High alkalinity water | 5.0-10.0 | 0 |
| 6 | Very high alkalinity water | > 10.0 | 0 |

**Table 13:** MAR Classification of the groundwater samples in the study area (*after* Gupta and Gupta, 1987)

| MAR (%) | Water Quality | No. of samples |
|---|---|---|
| > 50 | Unsuitable for agriculture | 30 |
| < 50 | Suitable for agriculture | 43 |

**Table 14:** Irrigation water quality parameters of the study area

| Location | X | Y | MAR (%) | RSC meq/l | RSBC meq/l | CR meq/l | SSP (%) | KR meq/l | SR meq/l | SAR meq/l | PI (%) | USSL Salinity | Na. Hazard | Pot. Salinity meq/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jannapura | 13.0803083 | 75.6758333 | 68.15 | -0.48 | 1.23 | 0.3 | 28.76 | 0.42 | 0.423 | 1.51 | 33.579 | C2 | S1 | 0.88 |
| Gowthahalli | 13.1314222 | 75.7425 | 52.36 | -0.27 | 0.851 | 0.29 | 29.36 | 0.43 | 0.433 | 1.29 | 40.048 | C2 | S1 | 0.74 |
| Hosakere | 12.9931278 | 75.5963889 | 39.06 | 0.792 | 1.134 | 0.24 | 40.23 | 0.71 | 0.708 | 1.04 | 57.031 | C2 | S1 | 0.63 |
| DurgadaHalli | 13.1502944 | 75.4272222 | 59.06 | 0.528 | 1.513 | 0.19 | 25.32 | 0.36 | 0.357 | 0.95 | 57.715 | C2 | S1 | 0.52 |
| Innare | 13.2161111 | 75.3738889 | 55.28 | 0.952 | 1.919 | 0.13 | 23.86 | 0.33 | 0.331 | 1.13 | 57.732 | C2 | S1 | 0.41 |
| Hornadu | 13.2742889 | 75.3433333 | 61.28 | 0.669 | 2.244 | 0.2 | 17.09 | 0.22 | 0.216 | 1 | 47.869 | C2 | S1 | 0.84 |
| Kuduremukha | 13.2143861 | 75.2525 | 61.99 | -1.1 | 1.025 | 0.18 | 15.77 | 0.19 | 0.191 | 0.82 | 28.741 | C2 | S1 | 0.85 |
| Nidduvale | 13.183697 | 75.497499 | 52.36 | 0.27 | 1.715 | 0.25 | 29.01 | 0.42 | 0.415 | 1.3 | 40.596 | C2 | S1 | 0.85 |
| Kottigehara | 13.121422 | 75.524134 | 53.13 | 1.252 | 1.824 | 0.23 | 44.71 | 0.89 | 0.894 | 1.85 | 50.674 | C2 | S1 | 0.74 |
| Mudigere | 13.137205 | 75.641227 | 61.71 | -0.77 | 0.936 | 0.33 | 28.37 | 0.41 | 0.405 | 2.41 | 28.453 | C2 | S1 | 1.29 |
| Kerekatte | 13.3098056 | 75.2227778 | 48.3 | 0.659 | 2.402 | 0.1 | 13.88 | 0.17 | 0.166 | 0.55 | 50.489 | C2 | S1 | 0.45 |
| Nemmaru | 13.3246444 | 75.1436111 | 11.11 | -0.04 | 1.074 | 0.27 | 17.55 | 0.22 | 0.22 | 0.6 | 45.804 | C2 | S1 | 0.9 |
| Sringeri | 13.3835333 | 75.2172222 | 52.36 | 0.841 | 1.495 | 0.3 | 39.39 | 0.74 | 0.738 | 0.73 | 47.625 | C2 | S1 | 0.86 |
| Kavadi | 13.4181167 | 75.2516667 | 22.63 | 0.11 | 1.195 | 0.37 | 27.26 | 0.4 | 0.399 | 0.59 | 46.848 | C2 | S1 | 1.06 |
| Begar | 13.4540278 | 75.2711111 | 13.35 | 0.176 | 1.426 | 0.38 | 25.7 | 0.35 | 0.353 | 0.35 | 48.377 | C2 | S1 | 1.16 |
| Kigga | 13.5009 | 75.2016667 | 15.16 | 0.52 | 1.242 | 0.41 | 35.19 | 0.58 | 0.581 | 0.49 | 47.265 | C2 | S1 | 1.3 |
| Kuntur | 13.417807 | 75.185669 | 17.75 | 0.964 | 1.834 | 0.32 | 36.51 | 0.62 | 0.62 | 0.51 | 47.163 | C2 | S1 | 1.12 |
| Hariharapura | 13.387129 | 75.297965 | 25.94 | 0.559 | 1.231 | 0.52 | 38.02 | 0.66 | 0.663 | 0.58 | 47.58 | C2 | S1 | 1.46 |
| Kalkere | 13.5196556 | 75.3002778 | 90.58 | 0.151 | 2.897 | 0.17 | 14.8 | 0.18 | 0.178 | 0.32 | 47.901 | C2 | S1 | 0.61 |
| Jayapura | 13.4566139 | 75.3472222 | 92.95 | 0.369 | 2.701 | 0.05 | 21.06 | 0.28 | 0.276 | 0.45 | 47.334 | C2 | S1 | 0.18 |
| Guddethotha | 13.3987583 | 75.3713889 | 50.75 | 0.343 | 2.2 | 0.32 | 20.54 | 0.27 | 0.268 | 0.43 | 40.063 | C2 | S1 | 1.55 |
| Shivapura | 13.3560583 | 75.3588889 | 22.93 | 0.146 | 0.85 | 0.43 | 24.73 | 0.36 | 0.364 | 0.58 | 49.611 | C2 | S1 | 1.08 |
| Koppa | 13.537528 | 75.353055 | 24.11 | 0.789 | 1.214 | 0.38 | 41.57 | 0.76 | 0.765 | 0.62 | 50.382 | C2 | S1 | 1.03 |
| Kudregundi | 13.552321 | 75.419141 | 46.34 | 0.724 | 1.296 | 0.49 | 52.08 | 1.16 | 1.158 | 2 | 36.86 | C2 | S1 | 1.43 |
| Magudi | 13.586755 | 75.228816 | 67.41 | -2.84 | -0.46 | 0.58 | 20.83 | 0.27 | 0.269 | 1.28 | 22.257 | C2 | S1 | 2.68 |
| Balehonnur | 13.2752139 | 75.4725 | 22.41 | -0.25 | 0.28 | 0.59 | 24.81 | 0.34 | 0.345 | 1.46 | 28.941 | C2 | S1 | 2.18 |
| Seethur | 13.3510056 | 75.4655556 | 24.34 | -0.01 | 0.445 | 0.61 | 28.72 | 0.42 | 0.418 | 1.74 | 41.452 | C2 | S1 | 1.8 |
| N R Pura | 13.5605444 | 75.4430556 | 33.85 | 2.7 | 3.24 | 0.24 | 49.34 | 1.21 | 1.213 | 2.38 | 45.272 | C2 | S1 | 1.17 |
| Muttinakoppa | 13.6067556 | 75.5011111 | 50.75 | -1.52 | 0.317 | 1.21 | 21.2 | 0.28 | 0.279 | 2.07 | 28.922 | C2 | S1 | 3.68 |
| ChikkaAgrahara | 13.7010944 | 75.4686111 | 54.27 | -1.17 | 0.637 | 0.43 | 25.8 | 0.36 | 0.361 | 2.59 | 27.495 | C2 | S1 | 1.67 |
| Lakkavalli | 13.464609 | 75.468157 | 57.19 | -11.3 | -4.83 | 3.07 | 19.1 | 0.24 | 0.24 | 2.17 | 9.3258 | C3 | S1 | 9.53 |
| GanteKaneve | 13.7036889 | 75.6508333 | 24.55 | -7.2 | -3.65 | 3.04 | 14.72 | 0.18 | 0.176 | 1.3 | 13.818 | C3 | S1 | 9.62 |
| Cheeranahalli | 13.7606194 | 75.7558333 | 64.94 | -19.2 | -3.98 | 3.13 | 2.43 | 0.03 | 0.025 | 0.41 | 8.5839 | C3 | S1 | 16.38 |
| Beeranahalli | 13.8527917 | 76.0191667 | 64.12 | -22.2 | -8.63 | 3.25 | 3.11 | 0.03 | 0.032 | 0.55 | 7.4397 | C3 | S1 | 15.85 |
| Ajjampura | 13.6354639 | 75.7288889 | 57.86 | -27.2 | -11.2 | 4.23 | 6.04 | 0.07 | 0.065 | 1.34 | 6.0846 | C4 | S1 | 21.15 |
| Doranalu | 13.730275 | 76.0044444 | 61.92 | -15.2 | -3.76 | 4.39 | 17.08 | 0.21 | 0.208 | 3.19 | 8.2921 | C3 | S1 | 18.39 |

*Contd. ...*

*Table 14: Contd. ...*

| Location | X | Y | MAR (%) | RSC meq/l | RSBC meq/l | CR meq/l | SSP (%) | KR meq/l | SR meq/l | SAR meq/l | PI (%) | USSL Salinity | Na. Hazard | Pot. Salinity meq/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Shivapura | 13.67057 | 75.928145 | 16.71 | -9.81 | -3.52 | 5.11 | 23.51 | 0.32 | 0.323 | 3.58 | 9.8074 | C3 | S1 | 16.36 |
| Udevu | 13.561127 | 75.833785 | 46.11 | -8.47 | -3.14 | 2.15 | 28.14 | 0.4 | 0.402 | 2.45 | 11.12 | C3 | S1 | 8.22 |
| Duglapura | 13.7161111 | 75.7455556 | 128.9 | -19.5 | -6.36 | 2.74 | 10.32 | 0.12 | 0.123 | 2.1 | 7.9052 | C3 | S1 | 15.85 |
| Chikkanvangla | 13.789652 | 75.985672 | 63.97 | -3.62 | 0.552 | 1.35 | 31.3 | 0.47 | 0.471 | 3.04 | 17.065 | C3 | S1 | 3.51 |
| Sokke | 13.714557 | 75.956475 | 4.678 | -14.1 | -10.2 | 3.75 | 5.77 | 0.06 | 0.062 | 1.24 | 9.6809 | C3 | S1 | 13.39 |
| Chowlahiriyur | 13.6865139 | 76.1988889 | 33.74 | 0.014 | 1.442 | 0.86 | 51.33 | 1.11 | 1.113 | 4.7 | 20.851 | C3 | S1 | 4.06 |
| Yalambaise | 13.7735972 | 75.9027778 | 57.62 | -3.66 | 0.498 | 1.32 | 44.16 | 0.81 | 0.807 | 4.44 | 14.209 | C3 | S1 | 6.11 |
| Panchanahalli | 13.57195 | 76.1072222 | 27.18 | 1.258 | 1.879 | 1.59 | 73.24 | 2.91 | 2.911 | 8.44 | 15.72 | C3 | S2 | 7.54 |
| Jadakanakatte | 13.5536361 | 76.3313889 | 43.85 | 2.347 | 2.887 | 1.64 | 82.93 | 5.67 | 5.668 | 6.75 | 18.245 | C3 | S2 | 6.73 |
| Hirenalluru | 13.4452361 | 76.1219444 | 34.75 | -0.08 | 1.28 | 1.44 | 57.98 | 1.44 | 1.444 | 4.8 | 18.098 | C3 | S1 | 6.18 |
| Birur | 13.672175 | 76.0413889 | 38.2 | 2.449 | 2.676 | 0.11 | 65.14 | 2.05 | 2.054 | 2.82 | 47.918 | C2 | S1 | 0.44 |
| Nidagatta | 13.5977833 | 75.9827778 | 47.8 | 1.758 | 2.347 | 1.95 | 82.29 | 5.13 | 5.132 | 3.42 | 17.91 | C3 | S2 | 6.73 |
| Sakkarayapattana | 13.4014583 | 76.0416667 | 7.226 | -2.15 | -0.78 | 0.54 | 8.35 | 0.09 | 0.093 | 1.25 | 25.175 | C3 | S1 | 4.73 |
| Singatigere | 13.433305 | 75.920493 | 13.49 | -3.52 | -1.86 | 1.59 | 24.42 | 0.33 | 0.335 | 3.14 | 19.568 | C3 | S1 | 7.3 |
| Saraswathipura | 13.512231 | 76.177418 | 41.8 | -5.86 | -2.81 | 2.61 | 24.47 | 0.33 | 0.332 | 2.03 | 13.197 | C3 | S1 | 6.84 |
| Mathigatta | 13.508463 | 75.971455 | 9.911 | -3.23 | -2.49 | 1.2 | 22.66 | 0.3 | 0.301 | 1.98 | 15.849 | C3 | S1 | 6.73 |
| Yagati | 13.49101 | 76.087019 | 36.56 | -4.32 | -1.29 | 0.86 | 4.96 | 0.05 | 0.054 | 0.43 | 21.652 | C3 | S1 | 4.11 |
| Hochigalli | 13.614622 | 76.147686 | 41.51 | -2.89 | -0.54 | 1.89 | 41.18 | 0.73 | 0.729 | 3.59 | 16.857 | C3 | S1 | 6.1 |
| Antharagatta | 13.615203 | 76.238118 | 32.47 | -0.25 | 1.078 | 1.07 | 61.51 | 1.66 | 1.66 | 3.84 | 15.897 | C3 | S1 | 4.93 |
| Kalasapura | 13.735426 | 76.120633 | 14.61 | -6.08 | -1.33 | 0.8 | 9.08 | 0.1 | 0.105 | 0.83 | 17.554 | C3 | S1 | 9.18 |
| K B Hal | 13.27685278 | 75.93333333 | 19.06 | -3.14 | -1.69 | 0.63 | 22.65 | 0.3 | 0.302 | 1.78 | 20.7 | C3 | S1 | 4.08 |
| Mavinahalla | 13.27058889 | 76.02722222 | 34.75 | -1.05 | 0.543 | 0.71 | 31.64 | 0.47 | 0.473 | 2.11 | 26.903 | C2 | S1 | 3.25 |
| Sirivase | 13.39191111 | 75.77833333 | 40.06 | -0.29 | 0.547 | 0.69 | 42.39 | 0.79 | 0.791 | 2.78 | 28.485 | C2 | S1 | 2.12 |
| Aladagudde | 13.40791111 | 75.61527778 | 85.5 | -3.31 | 1.131 | 1.41 | 26.78 | 0.37 | 0.371 | 1.8 | 18.831 | C2 | S1 | 3.68 |
| Lakya | 13.27237778 | 75.72305556 | 62.6 | -4.28 | 0.638 | 1.34 | 40.5 | 0.69 | 0.693 | 4.32 | 14.231 | C3 | S1 | 7.49 |
| Kichevi | 13.34694444 | 75.86972222 | 11.79 | -3.63 | -3.29 | 1.57 | 26.59 | 0.37 | 0.374 | 1.87 | 17.639 | C2 | S1 | 4.26 |
| Chikkamagaluru | 13.3656944 | 75.51916667 | 13.28 | -2.06 | 0.335 | 0.98 | 23.49 | 0.33 | 0.33 | 1.87 | 22.006 | C3 | S1 | 5.91 |
| Magadi | 13.327004 | 75.774168 | 52.5 | -4.94 | -0.55 | 1.05 | 19.31 | 0.24 | 0.244 | 1.46 | 17.488 | C3 | S1 | 3.74 |
| Kabbinasethuve | 13.26051 | 75.848751 | 27.95 | -0.17 | 0.422 | 0.27 | 10.39 | 0.15 | 0.148 | 0.56 | 42.614 | C2 | S1 | 1.04 |
| Uddeboranahalli | 13.232641 | 75.685054 | 40.48 | -11.4 | 0.846 | 1.01 | 3.59 | 0.04 | 0.038 | 0.39 | 13.925 | C4 | S1 | 17.87 |
| Sangameshwarapetdevadana | 13.397259 | 75.888315 | 52.92 | 2.215 | 3.016 | 0.13 | 58.98 | 1.55 | 1.548 | 4.73 | 34.741 | C2 | S1 | 0.68 |
| Avathi | 13.337504 | 75.548135 | 17.3 | 1.955 | 2.246 | 0.47 | 49.37 | 1.1 | 1.098 | 3.71 | 35.733 | C2 | S1 | 2.61 |
| HosapetTogarihanklu | 13.342479 | 75.634916 | 54.34 | -2.47 | 1.023 | 0.57 | 25.8 | 0.36 | 0.363 | 2.06 | 20.742 | C3 | S1 | 3.18 |
| Kesavinamane | 13.478601 | 75.792671 | 28.71 | -1.87 | 0.658 | 0.56 | 13.94 | 0.18 | 0.176 | 1.06 | 25.035 | C3 | S1 | 4.78 |
| kanathi | 13.54863333 | 75.71388889 | 48.02 | -1.88 | 0.093 | 0.65 | 25.57 | 0.36 | 0.363 | 1.78 | 24.08 | C2 | S1 | 2.66 |
| Kammaradi | 13.295 | 75.59416667 | 26.44 | -2.02 | 0.754 | 0.84 | 10.07 | 0.12 | 0.119 | 0.59 | 29.182 | C3 | S1 | 4.26 |
| Guddadamallenalli | 13.0803083 | 75.6758333 | 60.92 | -16.3 | -3.84 | 2.66 | 4.12 | 0.04 | 0.043 | 0.4 | 9.5726 | C3 | S1 | 12.34 |

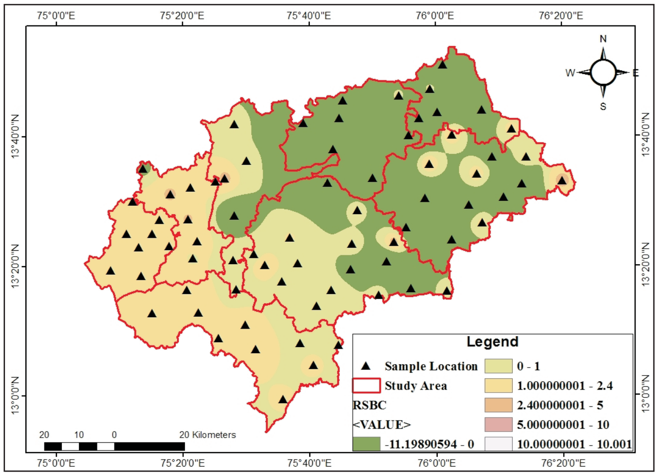


**Fig.11.** Spatial distribution RSBC Rangeof the groundwater samples in the study area

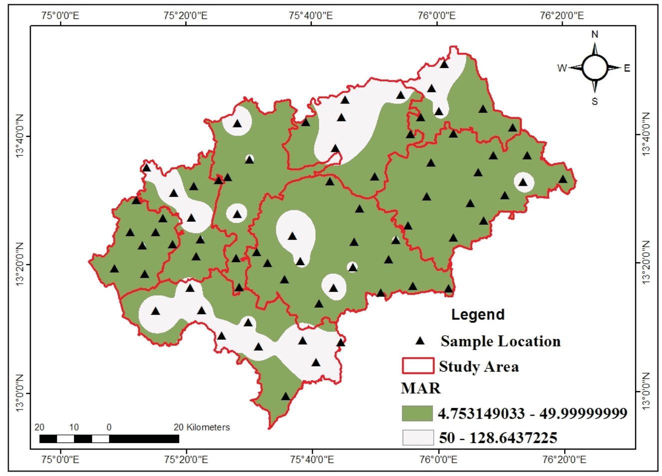


**Fig. 12.** Spatial distribution MAR Range Range of the groundwater samples in the study area

limit of 50% in 30 water samples. As a result, the water is regarded as unfit for irrigation in terms of the MAR. This is due to the fact that when the magnesium adsorption ratio exceeds 50%, it damages the soil quality (Ayers and Dennis, 1985).

## Conclusions

In the Chikmagaluru district, groundwater quality was assessed for irrigation purposes. In more than half of the cases, the groundwater samples from the district were determined to be alkaline. According to the values indicated on the USSL diagram, the groundwater samples fell into the $C_1S_1$ and $C_3S_1$ groups, implying medium to high salinity and low sodium hazard. Although, some water samples are good, the Wilcox diagram shows that the majority of groundwater samples are excellent to good. Based on, the Sodium Absorption Ratio (SAR), the Residual Sodium Carbonate (RSC), and the Permiability Index (PI), most groundwater samples were determined to be suitable for irrigation. The thirty groundwater samples were inappropriate for irrigation as determined on the basis of the magnesium hazard values.

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## Authors' contributions

**Pramoda G:** Investigation, Data Analysis, Writing-Original Draft, Methodology, Software, **A. Balasubramanian:** Supervision, Reviewing and Editing, **D. Nagaraju:** Supervision, Reviewing and Editing. **Vybhav K:** Conceptualization, Formatting, Writing- Reviewing, Software and Editing.

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