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Characterization and Mapping of Underground Water Quality in Dadri-II Block of Charkhi Dadri District in Haryana

Rajpaul Yadav[1*]; Anuj[2]; Sarita Rani[3]; Ram Prakash[4]; Pankaj Kumar[5]; Sakshi Bizla[6]

Department of Soil Science, CCS Haryana Agricultural University, Hisar, India-125004
*Corresponding Author

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Abstract— *A study was conducted to characterize the groundwater quality in the Dadri-II block of Charkhi Dadri district, Haryana. A total of 122 groundwater samples were collected from Dadri-II and analyzed for key parameters. Based on Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR), and Residual Sodium Carbonate (RSC), the water samples were classified: 18.85% as good, 28.68% as marginally saline, 50.81% as high SAR-saline, and 1.6% as highly alkali. Electrical conductivity ranged from 0.26 to 13.95 dS m^{-1}, SAR from 1.42 to 36.39 (mmol $L^{-1})^{1/2}$, and RSC from nil to 5.40 me L^{-1}. Sodium was the dominant cation (1.10 to 98.70 me L^{-1}), and chloride was the dominant anion (1.20 to 101.20 me L^{-1}), followed by sulfate, bicarbonate, and carbonate. The spatial variability of these parameters was mapped, confirming that high SAR-saline water is the most widespread quality issue in the block, which has significant implications for irrigation management.*

Keywords— Electrical conductivity, Residual Sodium Carbonate, SAR, Salinity, Sodicity, Groundwater, Spatial mapping.

I. INTRODUCTION

Groundwater is one of the most valuable replenishable natural resources on the planet and a major source of fresh water. A significant share of water resources is used in agriculture (89%). However, estimates indicate that growing demand from municipalities, industries, and other sectors will claim about 22% of the total resource by 2025, thereby reducing the supply of good-quality water for agriculture (Minhas, 1998). In the arid and semi-arid regions of India, including southeastern Haryana, farmers often rely on poor-quality groundwater for irrigation due to the limited availability of canal water and good-quality groundwater.

In Haryana, on average, 37% of tubewell waters are of good quality, 8% are normal, and 55% are of poor quality. Among the poor-quality waters, 11% are saline, 18% are sodic, and 26% are saline-sodic in nature (Manchanda, 1976). While past attempts have been made to establish water quality zones for Haryana (Manchanda, 1976), significant changes in water quality have occurred over the years due to over-exploitation (Phogat et al., 2008). Groundwater quality depends on distinct natural factors (precipitation, rock-water interaction, geology) and anthropogenic activities (agriculture, industry), which can make groundwater vulnerable to contamination (Vrba and Zoporozec, 1994; Adhikary et al., 2014). The suitability of water for agriculture is determined by its effects on crop yield and soil health (FAO, 1985; Zinabu et al., 2010). Therefore, a reappraisal of the nature, properties, and extent of groundwater quality in the Dadri-II block of Charkhi Dadri district is essential for sound irrigation planning in the area.

II. MATERIALS AND METHODS

2.1 Study Area:

The study was conducted in the Dadri-II block of Charkhi district, Haryana. The soils in the block range from sandy to sandy loam in texture. The dominant cropping systems are cotton-wheat and pearl millet-mustard under sprinkle irrigation. Other crops include jowar, bajra, cluster bean, and gram.

2.2 Sample Collection and Analysis:

A total of 122 groundwater samples were collected from running tubewells across the block using random sampling. The geographic coordinates of each sampling point were recorded using a handheld GPS. The location map of the sampling points is presented in Fig. 1.

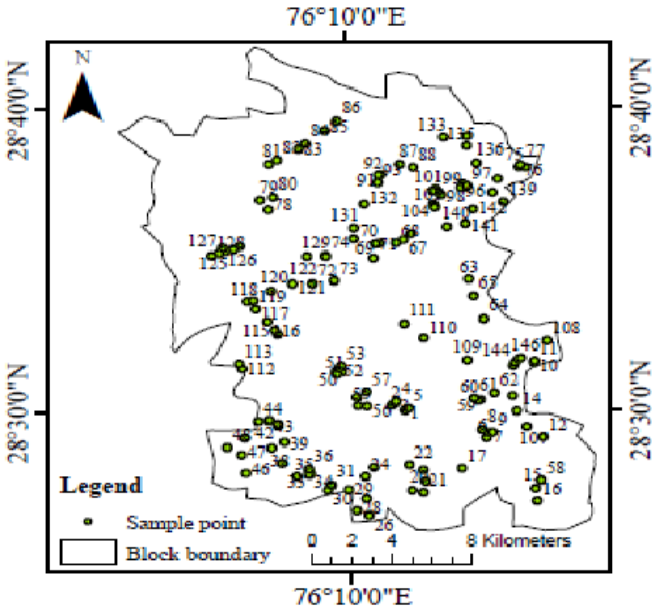

FIGURE 1: Location map of sampling points in Dadri-II block

The water samples were analyzed for pH, Electrical Conductivity (EC), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), and sodium (Na^+) following standard methods (Richards, 1954). Potassium (K^+), chloride (Cl^-), and sulfate (SO_4^{2-}) were also determined. Residual Sodium Carbonate (RSC) and Sodium Adsorption Ratio (SAR) were calculated using the following formulas:

$$\textbf{SAR} = Na^+ / \sqrt{[(Ca^{2+} + Mg^{2+})/2]} \quad (1)$$

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

2.3 Water Quality Classification and Spatial Mapping:

The water samples were classified based on the criteria adopted by the All India Coordinated Research Project (AICRP) on the management of salt-affected soils and use of saline water (Gupta et al., 1994), as detailed in Table 1.

TABLE 1
CRITERIA FOR WATER QUALITY CLASSIFICATION (AICRP, 1989)

Quality Class	EC (dS m^{-1})	SAR [(mmol $L^{-1})^{1/2}$]	RSC (me L^{-1})
Good	<2	<10	<2.5
Marginally saline	2-4	<10	<2.5
Saline	>4	<10	<2.5
High SAR - saline	>4	>10	<2.5
Marginally alkali	<2	<10	2.5-4.0
Alkali	<2	<10	>4.0
Highly alkali	Variable	>10	>4.0

Spatial distribution maps for EC, pH, SAR, RSC, and overall water quality were generated using the Inverse Distance Weighting (IDW) interpolation technique in ArcGIS software based on data from the 122 sampling points.

III. RESULTS AND DISCUSSION

3.1 Hydrochemical Characteristics:

The statistical summary of the analyzed water quality parameters is presented in Table 2. The pH of the water samples ranged from 7.70 to 8.40, indicating a slightly alkaline nature. Electrical Conductivity (EC), a measure of total dissolved salts, showed a wide range from 0.26 to 13.95 dS m^{-1}, with a mean of 4.20 dS m^{-1}, indicating high variability in salinity across the block.

TABLE 2
RANGE OF DIFFERENT WATER QUALITY PARAMETERS IN DADRI-II BLOCK OF CHARKHI DADRI DISTRICT

S.No.	Quality Parameter	Range	Mean
1	pH	7.70 - 8.40	7.95
2	EC (dS m^{-1})	0.26 - 13.95	4.2
3	RSC (me L^{-1})	0.00 - 5.40	0.6
4	SAR [(mmol $L^{-1})^{1/2}$]	1.42 - 36.39	12.5
5	Ca^{2+} (me L^{-1})	0.20 - 11.20	2.74
6	Mg^{2+} (me L^{-1})	0.60 - 23.80	6.49
7	Na^{+} (me L^{-1})	1.10 - 98.70	30.28
8	K^{+} (me L^{-1})	0.12 - 7.60	1.57
9	CO_3^{2-} (me L^{-1})	0.00 - 3.90	0.67
10	HCO_3^{-} (me L^{-1})	0.20 - 8.80	3.76
11	Cl^{-} (me L^{-1})	1.20 - 101.20	28.6
12	SO_4^{2-} (me L^{-1})	0.20 - 26.90	8.31

Sodium (Na^{+}) was the dominant cation, ranging from 1.10 to 98.70 me L^{-1}. Among anions, chloride (Cl^{-}) was dominant (1.20 to 101.20 me L^{-1}), followed by sulfate (SO_4^{2-}), bicarbonate (HCO_3^{-}), and carbonate (CO_3^{2-}). The high concentrations of Na^{+} and Cl^{-} are characteristic of saline groundwater influenced by weathering processes and possibly anthropogenic activities.

3.2 Irrigation Suitability Classification:

Based on EC, SAR, and RSC values (Table 1), the 122 water samples were classified. The majority of samples (50.81%) fell into the **High SAR-saline** category (EC >4 dS m^{-1} and SAR >10). This was followed by **marginally saline** (28.68%), **good** (18.85%), and **highly alkali** (1.60%) categories. The predominance of High SAR-saline water is a major concern as it poses a combined salinity and sodicity hazard. Irrigation with such water can lead to the accumulation of salts and exchangeable sodium in the soil, degrading soil structure and reducing crop yields (Isaac et al., 2009).

3.3 Spatial Variability of Key Parameters:

The spatial distribution maps provide a visual assessment of groundwater quality across the block.

- **Electrical Conductivity (EC):** The spatial variability map for EC (Fig. 2) shows zones of high salinity (EC >4 dS m^{-1}) concentrated in specific regions, potentially linked to local geology, evaporation, and irrigation return flows.

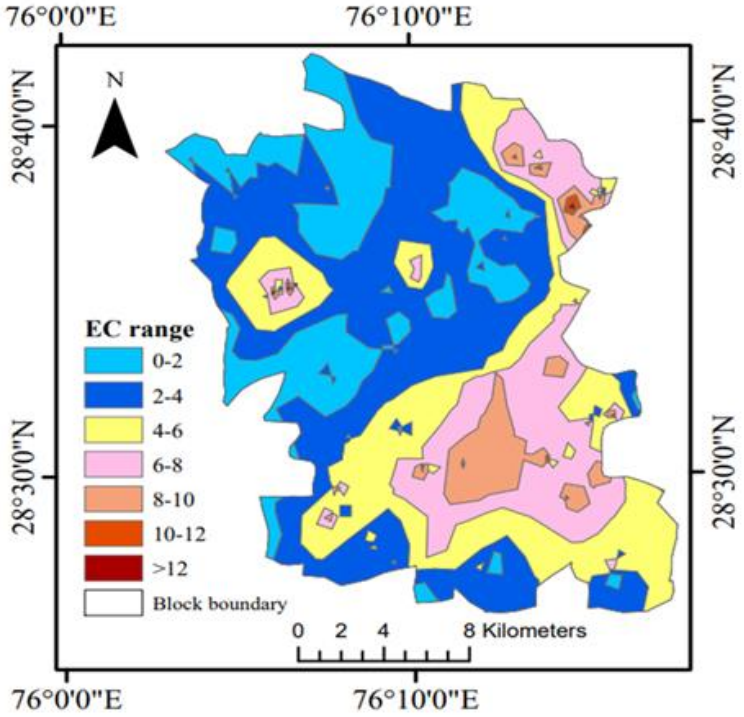

FIGURE 2: Spatial variability map for EC of groundwater in Dadri-II block]

- **pH:** The pH map (Fig. 3) shows slight alkalinity (7.70-8.40) across the block, which is typical for groundwater in arid regions.

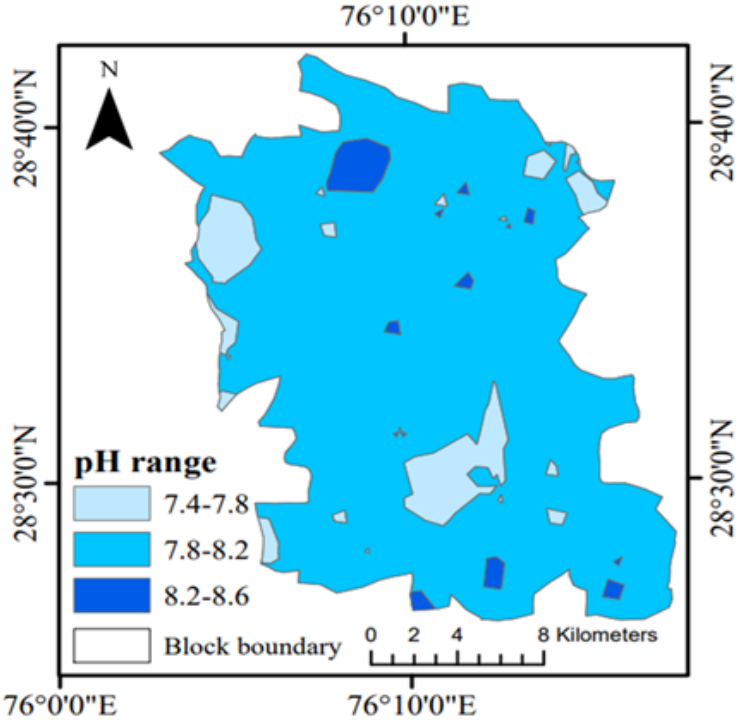

FIGURE 3: Spatial variability map for pH of groundwater in Dadri-II block]

- **Sodium Adsorption Ratio (SAR):** The SAR map (Fig. 4) reveals significant spatial variation (1.42 to 36.39). High SAR values (>10) correlate well with areas of high EC, confirming the prevalence of High SAR-saline water. Bhat et al. (2016) reported a similar SAR range (4.03-24.16) in the Gohana block of Haryana.

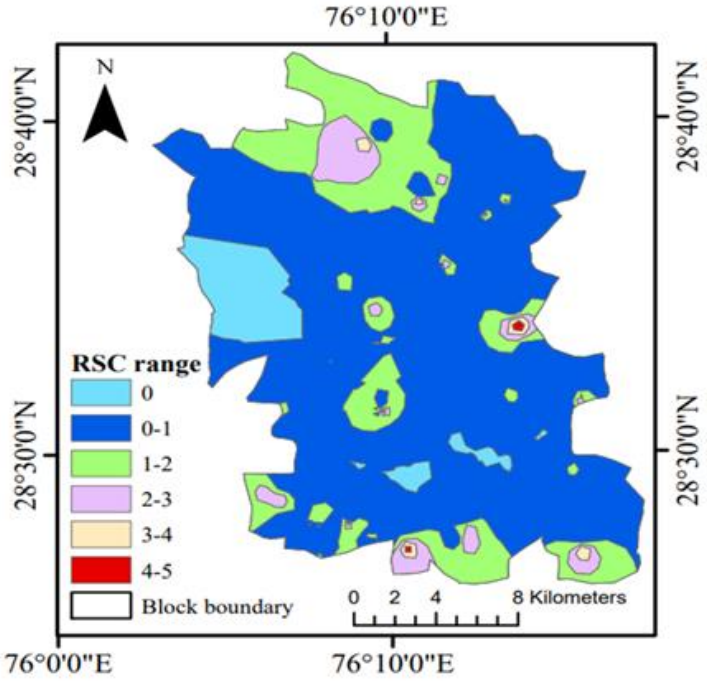

FIGURE 4: Spatial variability map for SAR of groundwater in Dadri-II block]

- **Residual Sodium Carbonate (RSC):** The RSC map (Fig. 5) shows most areas have low RSC (<2.5 me L^{-1}), consistent with the low percentage of alkali-classified waters. Sporadic patches of higher RSC exist. RSC significantly influences the pH, EC, and SAR of irrigation water (Naseem et al., 2010).

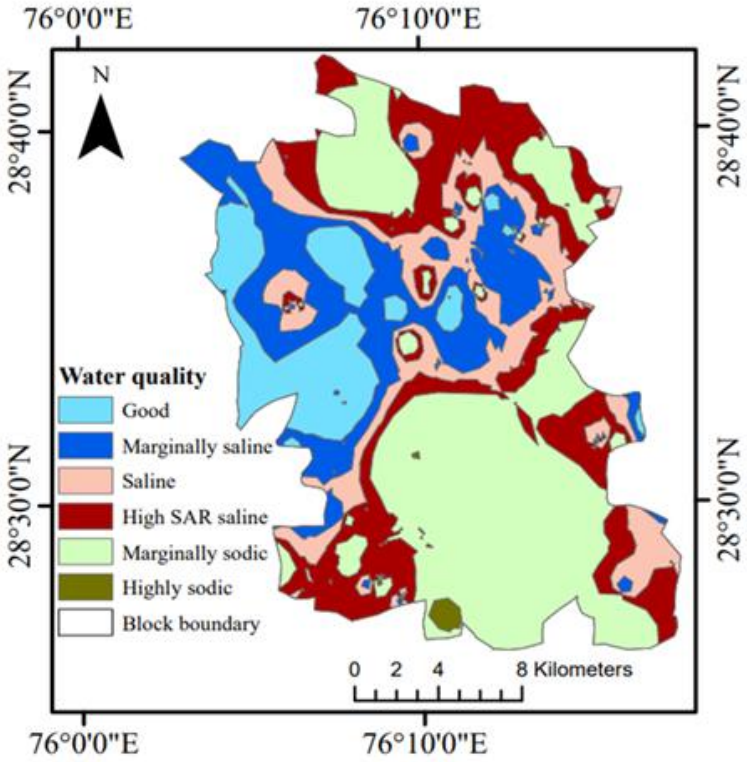

FIGURE 5: Spatial variability map for RSC of groundwater in Dadri-II block]

3.4 Integrated Groundwater Quality Zonation:

The final integrated water quality classification map (Fig. 6) synthesizes the criteria from Table 1. It visually confirms the findings from section 3.2: the **High SAR-saline** class (50.81% of samples) is the most extensive, covering large contiguous areas. Zones of **good** and **marginally saline** water are interspersed, while **highly alkali** water is very localized.

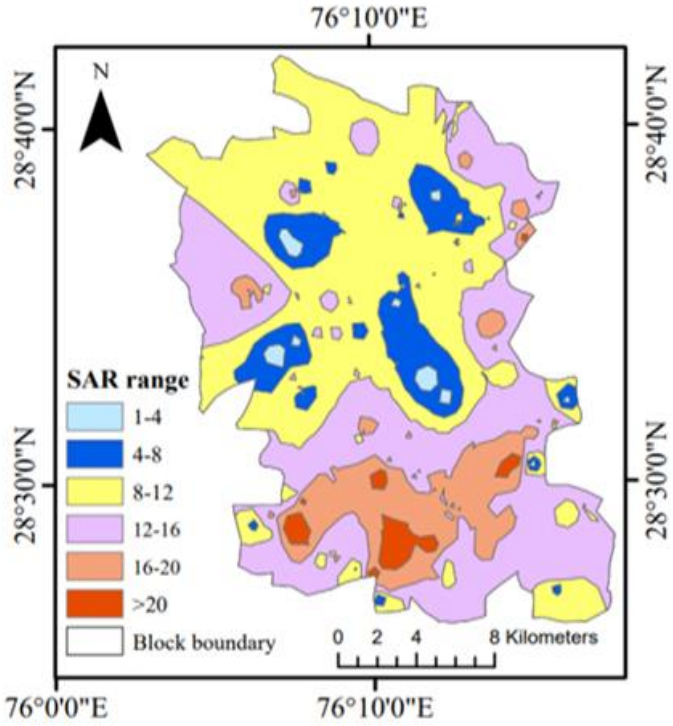

FIGURE 6: Spatial variability map of groundwater quality classification in Dadri-II block]

IV. CONCLUSION

The groundwater quality assessment of the Dadri-II block in Charkhi Dadri district reveals that the water is predominantly **High SAR-saline** (50.81% of samples), posing a significant combined salinity and sodicity hazard for irrigation. Good quality water is limited to only 18.85% of the samples. The spatial maps effectively delineate zones of different water quality hazards, which is crucial for site-specific agricultural planning.

Good and marginally saline waters can be used for irrigation with minimal management. However, the widespread High SAR-saline water requires careful management strategies, such as the application of gypsum or other calcium-based amendments to counteract sodicity, the use of salt-tolerant crop varieties, and blending with good quality water if available. The highly alkali waters, though limited in extent, require specific reclamation approaches. This study provides a foundational geospatial dataset for sustainable groundwater resource management and precision agriculture in the block.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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