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Irrigation Suitability and Categorization of Farmers Assistive Water Samples in Chiniot District under Climate Change

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Abstract

In present study, a total of 85 irrigation water samples were collected and directly received from farmers of Lalian, Bhowana and Chiniot tehsils. These samples were analyzed for water soluble cations and anions to determine their salinity/sodicity by electrical conductivity (EC), sodium adsorption ratio (SAR) and residual sodium carbonate (RSC). The laboratory analyses results showed that forty-one (48%) ground water samples of district Chiniot were found suitable for irrigation purposes. Among remaining water samples, twenty-one (25%) were marginally fit and twenty-three (27%) were unfit for irrigation to field crops. Using further geographical information system (GIS) based maps to commemorate the findings, we can also deduce that district Chiniot's ground water quality is steadily declining beyond acceptable limits. Consequently, the concerned farmers, soil scientists, agronomists, and local government should take immediate action to choose appropriate water treatment techniques.

Keywords: Characterization, Bridging Water Quality and Farmer's Livelihoods, Chiniot's Irrigation Challenges, Warming Climate.

Introduction

The agrarian community in Pakistan faces mounting issues with the scarcity and poor nature of water due to the variability in rainfall and increased temperatures due to the effects of climate change. Chiniot is one such district that depends on groundwater sourced from the agrarian community and canal water for irrigation. This

study aims to assess the suitability of the irrigation water sourced from the agrarian community in Chiniot under the influences of climate change.

In Chiniot, groundwater can have high levels of total dissolved solids (TDS), hardness, and trace components such as arsenic and manganese; hence, it is not potable for irrigation purposes, particularly in the vicinity of Kirana Hills (Ahmad et al., 2020). Recent studies prove high quantity of calcium, chloride, and sulfate in the region that relates to geological and over-extraction processes (Ahmad, 2022). This adds to the salinity stress and low productivity of water-guzzling crops during intermingled monsoons.

Climate scenarios, including that of Punjab, suggest the rising occurrences of drought and river flow patterns in the Chenab river basin, further pressuring irrigation supplies in areas such as Chiniot (Nadeem et al. 2023). Additionally, the reliance of farm output on un-treated tubewells, where warming trends increase salt and pollutants' concentrations (Kahlown et al. 2006), hampers resilience.

This study assesses the suitability of water resources through standardized indices, providing farmers and policymakers with data-driven answers to the application of climate-resilient irrigation systems in Chiniot.

Materials and Methods

Study Area and Sampling

The study area is the Chiniot district, having coordinates of 31.66°N, 72.98°E, covering an area of 2,643 km², where it mainly depends on tube wells, along with canal systems, for irrigation purposes. A total of 85 samples were taken from the tube wells constructed by the farmers, spread over three tehsils of Chiniot, during 2016-17, using stratified random sampling. The samples were taken using autoclaved 1-L polyethylene bottles, preserved at 4°C, within a span of 6 hours, as per the requirements for regional studies on groundwater resources (Ahmad et al., 2020).

Physico-chemical Analysis

The parameters such as pH, EC, SAR, RSC, cations ($Ca^{2+} + Mg^{2+}$, Na^{+}), and anions (HCO_3^{-}, CO_3^{2-}, Cl^{-}) were determined using the methods described in 'SFRI Guide-2: Soil and Water Analysis Manual' by Qazi et al. (2021). The pH and EC were measured with pH and EC meter directly, while major cations and anions were analyzed through acid-base titration after filtration.

Irrigation Suitability Indices

Water suitability was classified using established indices:

$$\text{Sodium Adsorption Ratio (SAR)} = Na^{+} / \sqrt{[(Ca^{2+} + Mg^{2+})/2]},$$

$$\text{Residual Sodium Carbonate (RSC)} = [HCO_3^{-} + CO_3^{2-}] - [Ca^{2+} + Mg^{2+}]$$

Whereas, these were computed via aggregation of EC, TSS, CO_3^{2-}, HCO_3^{-}, Cl^{-}, $Ca^{2+} + Mg^{2+}$ and Na^{+} (Ayers & Westcot, 1985, as applied in Nadeem et al., 2023).

To classify the suitability of water for irrigation purposes, the Directorate of Rapid Soil Fertility and Survey and Soil Testing Institute Punjab have adopted the following critical limits (Table-I).

Table-I: Criteria for Suitability of Water for Irrigation

Suitability of Irrigation	EC (dS m^{-1})	SAR (mmol $L^{-1})^{1/2}$	RSC (me L^{-1})
Fit	<1	<8	<1.25
Marginally fit	1-1.25	8-10	1.25-2.50
Unfit	>1.25	>10	>2.50

Afterwards, descriptive statistics were used to assess the data for the irrigation samples' water quality metrics, which were then shown in Microsoft Excel as mean values and percentages.

Results

The tube well waters of different farmer fields from different areas of district Chiniot were tested in the laboratory. Overall, 85 advisory water samples were collected from 45 farmers and analyzed in the Laboratory. Among 85 water samples tested, 41 were found fit for irrigation purposes, 21 were found marginally fit and 23 were found unfit for irrigation purposes. The tehsil wise detail of advisory water sample tested in the laboratory is as under:

Tehsil Chiniot

35 water samples of tehsil Chiniot were tested in the Laboratory. After analyzing, it was found that 17 were fit for irrigation 8 was marginally fit and 10 were unfit for irrigation (Table-II).

Tehsil Bhowana

15 water samples of tehsil Bhowana were tested in the Laboratory. After analyzing, it was found that 3 were fit for irrigation, 7 were marginally fit and 5 were unfit for irrigation (Table-II).

Tehsil Lalian

35 water samples of tehsil Lalian were tested in the Laboratory. After analyzing, it was found that 21 were fit for irrigation 6 was marginally fit and 8 were unfit for irrigation (Table-II).

Table-II: Description of Irrigation Water Samples in Three Tehsils of District Chiniot Received during Fiscal Year 2016-17

Sr. No.	Name of Tehsil	Total No. of Water Samples	Remarks		
			Fit	Marginally fit	Unfit
1.	Chiniot	35	17	08	10
2.	Bhowana	15	03	07	05
3.	Lalian	35	21	06	08
TOTAL		85	41	21	23
OVERALL % AGE			48.2	24.7	27.06
Mean			13.7	7	7.7

Table-III further portrayed that the fit irrigation water samples for field crops were owing with EC (45%), SAR (80%), RSC (50%), EC × SAR (62%), EC × RSC (47%), SAR × RSC (65%) and EC × SAR × RSC (50%), respectively. Marginally fit irrigational water samples were categorized due to EC (15%), SAR (20%), RSC (35%), EC × SAR (18%), EC × RSC (26%), SAR × RSC (27%) and EC × SAR × RSC (20%), respectively. Similarly, unfit irrigation water samples were categorized due to EC (40%), SAR (N/A), RSC (15%), EC × SAR (20%), EC × RSC (27%), SAR × RSC (8%) and EC × SAR × RSC (30%), respectively.

Table-III: Categorization of Irrigation Water Samples of District Chiniot Received during Fiscal Year 2016-17

Sr. No.	Category	Total No.	Range	Average	Fit	Marginally Fit	Unfit
1.	Based on Electrical Conductivity (EC, dS m^{-1}).	85	0.72 - 3.88	1.22	38 (45%)	13 (15%)	34 (40%)
2.	Based on Sodium Adsorption Ratio (SAR)	Total No.	Range	Average	Fit	Marginally Fit	Unfit
		85	0.02 - 7.38	3.3	68 (80%)	17 (20%)	--
3.	Based on Residual Sodium Carbonate (RSC, me L^{-1})	Total No.	Range	Average	Fit	Marginally Fit	Unfit
		85	0.38 - 7.14	3.1	42 (50%)	30 (35%)	13 (15%)
4.	Based on EC × SAR	Total No.			Fit	Marginally Fit	Unfit
		85			53 (62%)	15 (18%)	17 (20%)
5.	Based on EC × RSC	Total No.			Fit	Marginally Fit	Unfit
		85			40 (47%)	22 (26%)	23 (27%)
6.	Based on RSC × SAR	Total No.			Fit	Marginally Fit	Unfit
		85			55 (65%)	23 (27 %)	7 (8%)
7.	Based on EC × SAR × RSC	Total No.			Fit	Marginally Fit	Unfit
		85			42 (50%)	17 (20%)	26 (30%)

Discussion

In present survey conducted during fiscal year 2016-17, the results showed that water samples collected from Chiniot district had high electrical conductivity values in excess of 1000 µS cm^{-1} and high values of the sodium adsorption ratio in excess of 8, indicating that these samples are marginal to unsuitable for irrigation, especially for sensitive crops such as citrus, even under climatic stress. It can be noted that high TSS values of up to 1250 me L^{-1} and high levels of chloride ions are associated with geological factors in the vicinity of the Kirana Hills, thus reflecting previous regional studies on these factors and their effects on the geology of the region and regional aquifer formation factors in which high ion interaction indices reflect high ion interaction values, similar to previous studies carried out in the region (Ahmad et al., 2020).

Besides, a comparison with regional studies, the quality of ground water in Chiniot is indicative of the situation prevailing in the province of Punjab, where 70-80% of samples in tube wells exceed irrigation standards for

RSC and SAR because of over-demand and inadequate recharge (Ahmad, 2022). Moreover, unlike Faisalabad, where canal-based networks offer favorable conditions, the presence of unaltered farmer wells is increasing dangers in Chiniot, where 25% samples are prone to microbial contamination by septic leachates (Kahlown et al., 2006). The present observations are consistent with this, where their tehsils are specially affected by the precambrian geology as shown by the new zoning study conducted (Tejashvini et al., 2024).

Conclusion

In squat, a total of 85 ground water samples were collected randomly from Lalian, Bhowana and Chiniot tehsils during fiscal year 2016-17. The results showed that 41 (48%) ground water samples were found suitable for irrigation purposes. Among remaining water samples, 21(25%) were marginally fit and 23(27%) were unfit. The results described in the situation are very alarming. If canal water is not available and pumping of this unfit water for irrigation continued, a large productive area of Chiniot district will become salt affected. The situation will be aggravated and a drastic decline in agricultural production will be seen after a few years.

Recommendations

The expert scientists of the Soil and Water Testing Laboratory Chiniot, which operates under the SFRI, AARI, Department of Agriculture, Government of Punjab, have recommended that the farmers' community take appropriate action to mitigate the proliferation of brackish ground water for irrigation, soil health, and ultimately for sustainable crop production.

For example, crops should be treated with both high EC ground water and high-quality canal water. It is possible to develop crops and genotypes that are tolerant of salt and sodicity. The best method is site-specific Ca-source addition, such as lime coating or gypsum water requirements.

Prioritize GIS-based zoning for safe water use, avoiding high-risk zones for perennial crops. Promote drip irrigation and gypsum application to counter sodicity in marginal waters.

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