

A Case Assessment of the Physico-chemical Properties of Selected Shallow Tube Wells in an Agricultural Field in Barangay Madamba, Dingras, Ilocos Norte

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(Received 5 September, 2025; Accepted 24 October, 2025)

ABSTRACT

This study assessed the physico-chemical properties of groundwater from selected shallow tube wells (STWs) used for irrigation in Brgy. Madamba, Dingras, Ilocos Norte, Philippines. Key physico-chemical parameters and indices were analyzed, including the sodium adsorption ratio (SAR), soluble sodium percentage (SSP), magnesium hazard (MH), residual sodium carbonate (RSC), chloride concentration (Cl⁻), electrical conductivity (EC), and pH. The results were compared with the irrigation water quality standards of the Food and Agriculture Organization (FAO, 1994). The findings indicate that the groundwater samples are generally suitable for irrigation purposes. However, a gradual increase in SSP values emphasizes the importance of continuous monitoring to prevent potential long-term sodicity hazards. Additionally, a decreasing trend in pH was observed over time, possibly due to the influence of rainfall events during the sampling period. These findings highlight the importance of regularly assessing irrigation water to ensure sustained soil productivity and crop health.

Key words: *Water quality, Shallow tube wells, Groundwater, Physico-chemical properties.*

Introduction

Water is a vital natural resource that forms the foundation of the ecological system (Saha *et al.*, 2019). Groundwater has become the primary source of water for the agricultural sector in many countries where river and drainage systems are insufficient (Rawat *et al.*, 2018). Globally, irrigation accounts for the highest consumptive use of groundwater, a de-

mand that continues to rise with the growing global population and escalating food needs (Bruinsma, 2017). In response to these pressures, groundwater from shallow aquifers is increasingly utilized for irrigation, a trend expected to become more critical given the projected 60% increase in food demand by 2050 (FAO, 2009). However, intensive use of shallow aquifers has raised concerns regarding water quality deterioration, groundwater depletion, and

long-term soil degradation (Grogan *et al.*, 2017).

Assessing irrigation water quality is therefore important for sustainable agriculture. Evaluation is typically based on physicochemical parameters that quantify potential adverse effects on agricultural soils and crops, particularly concerning salinity, sodicity, and potential toxicities of certain elements (Hussein *et al.*, 2023). Common indicators in this evaluation include SAR, SSP, MH, RSC, Cl⁻ concentrations, EC, and pH concentrations (Rawat *et al.*, 2018). These parameters reveal specific hazards, including the restriction of water uptake by high EC and the reduction of soil permeability by high SAR (Anuja *et al.*, 2024). To manage these risks, water quality classification systems based on various indices and guidelines are widely used (Stanly *et al.*, 2021).

As a rice community in Dingras, Ilocos Norte, the study site located in Barangay Madamba is heavily dependent on groundwater for irrigation; however, there has been no comprehensive physicochemical evaluation of its STWs using internationally recognized indices. Hence, this study was conducted. Without a proper assessment of critical parameters such as electrical conductivity (EC), pH, sodium adsorption ratio (SAR), and chloride levels, farmers remain unaware of potential hazards, thereby putting their agricultural productivity at risk. This case assessment, therefore, aims to address this knowledge gap by assessing the quality of groundwater from selected shallow tube wells, using the FAO (1994) standards to provide baseline data for developing sustainable irrigation management strategies in the area.

Materials and Methods

Study Area

The study was conducted in a selected rural agricultural community in Barangay Madamba, Dingras, Ilocos Norte, Philippines. The area is characterized by flat to gently sloping agricultural lands, making it suitable for lowland rice and vegetable production. Farming activities are supported by a combination of supplementary water sources during periods of insufficient canal supply.

The study area has a Type I climate defined by a distinct wet season from May to October and a dry season from November to April. Rainfall is at its maximum in August due to the southwest monsoon

(habagat) and at its minimum from December to March. The mean monthly temperature is 27.5 °C, with January as the coldest and May as the hottest. During the dry months, the continued operation of shallow tubewells became essential in sustaining agricultural productivity, allowing farmers to maintain consistent cropping cycles despite fluctuations in rainfall.

Four shallow tube wells (L1-L4) were selected for sampling (Table 1).

Table 1. Coordinates of the sampling wells

Location ID	Latitude	Longitude
L1	18.10606	120.69872
L2	18.10543	120.69841
L3	18.10634	120.69766
L4	18.107669	120.69751

Irrigation Water Quality Indicators

Water quality parameters analyzed included major cations (Na⁺, Ca²⁺, Mg²⁺, K⁺) and anions (Cl⁻, CO₃²⁻, HCO₃⁻) along with EC and pH. Computed indices were SAR, SSP, MH, RSC, and chloride hazard (Table 2). Classification followed the FAO (1994) guidelines (Table 3).

Sampling and Analysis

Groundwater samples were collected from each well at five intervals (every two weeks) between September 15 and November 15, 2023. Three replicate samples (1.5 each) were collected per well per period. Wells were purged for two minutes before sampling. Physical parameters (EC and PH) were measured onsite using a portable water quality meter. Chemical analyses for cations and anions were conducted at the Crop Research Laboratory, Mariano Marcos State University, and Ilocos Norte Water District. Data were analyzed using descriptive statistics, and suitability was assessed in accordance with FAO (1994) standards.

Results and Discussion

The physicochemical parameters of irrigation water from the selected wells are summarized in Table 4.

Sodium Adsorption Ratio (SAR)

SAR is a value that represents the relative amount of sodium ions combined with the amount of calcium and magnesium ions in a water sample. Continued

Table 2. Equations used to compute irrigation indices

Criteria	Equation	Sources
SAR	$\frac{Na^+}{\sqrt{(Ca^{2+} + Mg^{2+})/2}}$	Adj. SAR = SAR (1+8.4-phc) Rawat <i>et al.</i> (2018)
SSP	$\frac{Na^+ + K^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100$	Saha <i>et al.</i> (2019)
MH	$\frac{Mg^{2+}}{Mg^{2+} + Ca^{2+}} \times 100$	Raghunath (1987)
RSC	$(CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$	Eaton (1950)

Table 3. FAO water quality standards for irrigation (1994)

Parameters	Class/Restriction	Threshold
EC _w (µmhos/cm)	None	<700
	Slight to moderate	700-3000
	Severe	>3000
SAR	None	<3
	Slight to moderate	3 to 9
	Severe	>9
SSP (%)	Suitable	<60
	Unsuitable	>60
MH (%)	Suitable	<50
	Unsuitable	>50
RSC (meq/l)	Suitable	<1.25
	Marginally suitable	1.25-2.5
	Unsuitable	>2.5
Cl ⁻ (mg/l)	None	<140
	Slight to moderate	140-350
	Severe	>350
pH	Normal	6.0 -8.5

EC_w - electrical conductivity, in micromhos per centimeter (µmhos/cm), SAR- sodium adsorption ratio, SSP -Sodium Soluble Percentage, MH- Magnesium Hazard, RSC - Residual Sodium Carbonate, in milliequivalent per litre (meq/l), Cl⁻ - Chloride, in milligrams per liter, pH -potential of hydrogen

use of irrigation water having a high SAR leads to soil dispersion, reducing infiltration, and negatively impacts plant growth (Saha *et al.*, 2019).

Table 4. Descriptive statistics of sampling wells across 5 sampling periods.

Period	SAR	SSP (%)	RSC (meq/l)	MH (%)	Cl (mg/l)	EC (µmhos/cm)	pH
1	0.42	13.30	-3.35	19.40	5.51	415.00	7.49
2	0.61	35.70	-2.04	3.58	5.22	400.00	7.16
3	0.55	32.30	-2.20	7.73	4.87	418.00	7.01
4	1.05	52.90	-2.30	6.32	19.70	439.00	6.82
5	1.05	54.10	-2.29	8.09	14.90	442.00	6.74

SAR- sodium adsorption ratio, SSP - Sodium Soluble Percentage, MH -Magnesium Hazard, RSC - Residual Sodium Carbonate, in milliequivalent per litre (meq/l), Cl⁻ - Chloride, in milligrams per liter, EC_w - electrical conductivity, in micromhos per centimeter (µmhos/cm), pH - potential of hydrogen

The SAR values of the groundwater samples collected were consistently below 3, indicating minimal risk of soil sodicity and stable soil permeability. It can be used for irrigation on almost all soils with a low risk of developing harmful levels of exchangeable sodium. However, sodium-sensitive crops can accumulate toxic concentrations of sodium (Burger and Celkova, 2003).

Soluble Sodium Percentage (SSP)

The soluble sodium percentage (SSP) is a crucial criterion for classifying water quality for irrigation purposes. The water-containing sodium reacts with the soil, accumulates in the soil’s void spaces, and reduces the soil’s permeability. The maximum permissible limit of SSP is 60% for irrigation water (Fipps, 2024). The SSP values of the water samples collected increased from 13.30% to 54.10% yet remained below the 60% threshold. Monitoring is recommended as long-term irrigation with rising SSP can cause dispersion.

Magnesium Hazard (MH)

Magnesium and calcium ions are essential for plant growth, although these ions may be added with the soil aggregation and cause soil friability (Rawat *et al.*, 2018). High concentrations of calcium and mag-

nesium in irrigation water can increase the soil's pH, potentially leading to phosphorus loss. Magnesium ions are also crucial for soil productivity. The results of the MH of the water samples collected remained less than 50% across all periods, indicating suitability for irrigation (Anyango *et al.*, 2024).

Residual Sodium Carbonate (RSC)

The concentration of bicarbonate and carbonate controls the suitability of water for irrigation, determining the hazardous effects of carbonate and bicarbonate on the quality of water for agricultural purposes (Saha *et al.*, 2019). A high range of RSC in irrigation water indicates an increase in sodium adsorption on the soil (Rawat *et al.*, 2018), which can disrupt soil structure, block pores, and reduce water infiltration and aeration, thereby hindering root growth and nutrient uptake. Generally, any source of water in which RSC is higher than 2.5 is not considered suitable for agricultural purposes, and water with an RSC of less than 1.25 is recommended as safe for irrigation purposes based on the FAO (1994) guidelines. All the water samples collected had negative RSC values, indicating the suitability of the groundwater. The negative results indicate an excess of calcium and magnesium.

Chloride (Cl⁻)

The chloride (Cl⁻) concentration of groundwater may be attributed to the presence of chlorides from rocks, evaporates, seawater intrusion, connate and juvenile water, or contamination by industrial waste or domestic sewage.

The Cl⁻ concentration in the study area is from 4.87 to 19.7 mg/l, which is all below the FAO threshold of 140 mg/l, posing no toxicity risks to crops. High concentrations of Cl⁻ in irrigation water can cause corrosion and soil salinization in agricultural irrigation systems, hinder plant growth, and lead to wilting or burning of the plant's leaves.

Electrical Conductivity (EC)

EC is a measure of the water salinity. The EC ranged from 400 to 442 imhos/cm, classifying the water as having no restriction (<700 imhos/cm), as indicated in the FAO guidelines (1994). This indicates low salinity hazards, which is generally favorable for most crops. However, the long-term use of low to moderate salinity water may still contribute to gradual soil alteration, depending on factors such as soil texture, fertility, plant growth, crop yield, and the presence

of microorganisms (Tarolli *et al.*, 2024).

pH

The pH values of the studied groundwater samples are between 6.74 and 7.49, which were within the acceptable range (6.0-8.5) (FAO, 1994), ensuring compatibility with most soils and crops. The pH values of the groundwater samples are indicative that the groundwater aquifer conditions vary from slightly acidic to slightly alkaline. The pH of natural water is an important parameter and a key indicator of the toxicity of any compounds (Haque, 2009). Moreover, it was observed that there was a decreasing trend in the pH values as the period progressed; this may be due to the presence of rainfall during the observation period.

Conclusion

The physicochemical properties of the groundwater from the selected STWs are within the acceptable values set by FAO (1994) standards. Low EC, SAR, MH, RSC, chloride, and neutral pH values indicate minimal risk to soil structure and crop productivity. However, the increasing trend in soluble sodium percentage (SSP) indicates the need for continuous monitoring to prevent long-term soil degradation and reduce water infiltration.

The findings provide baseline data for sustainable water resource management in the barangay and can guide local policymakers and farmers in planning irrigation practices that safeguard both crop yields and soil health.

Acknowledgement

The authors would like to thank the Mariano Marcos State University for its support of the study. Additionally, they would like to thank the reviewers and editors of the journal for their constructive feedback and acceptance of the manuscript.

Conflict of Interest- None.

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