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Research Article

Water Salinity in Agriculture: Analyzing Irrigation Water Quality for Farmers

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Abstract: The primary aim of this study is to assess irrigation water's salinity levels and categorize them as regular, slightly to moderately saline, or severely saline, using the salinity parameters established by Ayers and Westcot as a reference. This practice plays a substantial role in global agriculture, accounting for 20% of total cultivated land and contributing 40% of the world's food production. It falls under the classification of water usage known as Class C, which encompasses Fishery Water for the propagation and growth of aquatic resources, Recreational Water Class II for boating and similar activities, and Agriculture, including irrigation and livestock watering. This classification underscores irrigation water's profound influence on agriculture as a whole. Salinity, often considered one of humanity's earliest environmental challenges, is paramount. Excessive salinity in agriculture, particularly in the context of rice (Oryza sativa L.) cultivation, a staple crop that nourishes half of the global population, poses a formidable threat. High salinity levels can potentially hinder plant growth, reduce crop yields, and compromise the quality of agricultural products. This research seeks to illuminate the critical issue of salinity in irrigation, specifically focusing on its implications for rice cultivation, which plays a pivotal role in global food security. By delineating the salinity status of irrigation water, it aims to provide valuable insights into the challenges confronted by agricultural communities and lay the groundwork for informed decision-making in sustainable agriculture.

Keywords: Agriculture; Environmental Science; Irrigation Water; Rice Cultivation; Palay.

1. Introduction

Most productive agricultural areas in Malolos, Bulacan, depend on irrigation water. Irrigation is the artificial water distribution to the solid by various tubes, pumps, and sprinkler systems. It is widely utilized in locations with inconsistent rainfall or forecast droughts. For over a thousand years, farmers have relied on irrigation water as a source of agricultural production.

Water is critical in agriculture. Irrigated agriculture accounts for 20% of total cultivated land and 40% of worldwide food production. It shows that irrigation water significantly influences agriculture [1]–[3].

The concerns about the water quality used in irrigation should be addressed because there are other clean water sources that the farmers can use. However, irrigation water has essential minerals that can improve plant growth and is inexpensive, so farmers prefer to use this [4].

As per the classification of irrigation water in the Philippines, the Department of Environmental and Natural Resources (DENR) identifies it under Class C (Fishery Water for the propagation and growth of fish and other aquatic resources, Recreational Water Class II – For boating, fishing, or similar activities and Agriculture, irrigation, and livestock watering). This classification follows DENR Administrative

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Order Number 2016-08 (Water Quality Guidelines and General Effluent Standards).

A research university revealed that recently, there has been increasing evidence for the occurrence of geogenic contaminants in water. The appearance of trace elements and an increase in the use of wastewater have highlighted the vulnerability and complexities of the composition of irrigation water and its role in ensuring proper crop growth and long-term food quality [5], [6].

The said contaminants are one of many problems seen while using irrigation water for crops. It is undeniable that salinity is also present, being man's oldest environmental problem. It was reported that salinity is one of the most brutal ecological factors affecting crops' prolificacy [7], [8]. Crops' sensitivity is caused by the high salt concentration in the soil from the water used. Salinity is one of the long-term problems of the soils and crops on many farms. It affects not only the crops and soil but also the fishery and agriculture regarding income and productivity [9].

Variable salinity levels impact aquatic biological organisms that have evolved to the current salinity concentrations; salinity can be a chemical stressor in the marine environment. One of the main criteria used to determine if a particular study site is a member of an estuary or coastal system is salinity, as it also becomes a significant issue in irrigated agriculture. Salinity-related water quality degradation endangers the sustainability of agriculture by lowering yields and profits. Salinity is the augmentation of salts in soil and water, usually dominated by sodium chloride, to concentrations that affect both natural and human resources, including plants, animals, aquatic ecosystems, water supplies, agriculture, and infrastructure. Salts may render water hazardous for drinking, irrigation, and cattle watering. They can also be poisonous to freshwater plants and animals. Excessive salinity can develop in regions with high evaporation, exacerbated by recurrent irrigation or water withdrawals, de-icer use on roads, mining, oil and gas drilling, and wastewater discharges [10].

Rice (Oryza sativa L.) is a major food crop that feeds half the world's population. It is one of the most widely consumed staple crops in developing and equatorial nations. However, it is a thirsty crop that takes water to cultivate [11]. In tropical coastal areas, salinization and salt-water intrusion severely threaten rice cultivation and agriculture in general [12], [13].

Salinity has various effects on crops, including reduced growth due to high osmotic potential and ion toxicity, photosynthesis inhibition due to decreased CO_2 availability and pigment content, reduced nutrient and water uptake, and root damage; all these phenomena eventually result in yield reduction. Salinity has various effects on crops, including reduced growth due to high osmotic potential and ion toxicity, photosynthesis inhibition due to decreased CO2 availability and pigment content, reduced nutrient and water uptake, and root damage; all these phenomena eventually result in yield reduction [14].

Salt affects the plant through plant roots that usually absorb moisture by osmosis via membranes in root cells. Osmosis is a natural process where water travels from a solution with low dissolved salts to a higher salt level by passing through a semi-permeable membrane. This mechanism permits water to travel from a relatively low-concentration (irrigation water) to a relatively high-concentration solution (in plant root cells) to achieve equilibrium in the two solutions. This process is repeated until the plant cells become full or turgid. The plant must work harder to absorb water from the soil when the irrigation water is somewhat salty, which slows growth and lowers yields [15], [16].

Moderate salinity increases abscisic acid (ABA) production, which is known to induce or sustain seed dormancy, resulting in a decrease in germination level and a delay in germination time, particularly in halophyte species. High salinity levels are also responsible for more severe hormonal changes and other impacts, such as decreased water uptake and cell damage, which lower embryo viability and impede germination in sensitive species or delay germination in resistant species [17].

Osmosis can be reversed if water with a high salt concentration is used. When the salt level of the solution exceeds that of the root cells, water will migrate from the roots into the surrounding solution. The plant is stressed and loses moisture. As a result, the indicators of high moisture stress and high salt damage are interchangeable [18], [19].

Previous research in rice has shown that salinity acts primarily on delaying seed germination rather than reducing germination percentage; additionally, salt tolerance in rice increases with time, being lowest during the early seedling stage (2-3 leaf stage), with some variability among rice varieties [20], [21].

Irrigation water naturally contains sodium chloride, calcium, magnesium bicarbonates, chlorides, and sulfates. However, it does not concern the crops as long it is bearable, but once it surpasses the tolerance level of crops in handling salt water, it can influence plant growth.

Salinity intrusion in rice cultivation can result in yield loss and decreased quality [22]–[24]. The salt concentration is so dense that it dehydrates and destroys rice cultivation. Farmers in Malolos Bulacan get their water from irrigation without knowing its salinity level. It poses a risk to their crops as they possibly experience crop damage and lose invested capital and effort.

This paper intends to understand better the irrigation water's salinity content used by farmers in the City of Malolos, Bulacan. It is crucial to investigate and develop an in-depth perspective of its salinity level, as the data from the laboratory result and analysis will assist in determining how it affects crops.

2. Material and Method

This chapter deals with the procedures and methods used in the study. It briefly discusses the research design, sampling method, and data analysis procedure. The chapter also included the process of obtaining the results from the laboratory.

2.1. Research Design

The research design of the study is quasi-experimental, allowing for the investigation of cause-and-effect relationships within the constraints of a natural agricultural setting. As delineated by Creswell, a quasi-experimental design is particularly suited for studies where controlled experiments are not feasible, but the understanding of the impact of an independent variable on a dependent one is still sought [25], [26]. In this case, the independent variable is the salinity level of irrigation water, while the dependent variables are the growth parameters of rice crops in Malolos, Bulacan.

By employing this design, the researchers can observe the effects of salinity on the growth of rice crops, providing a practical perspective on how salinity levels, as an environmental stressor, affect crop yield and quality. This approach is advantageous in agricultural research, where replicating exact experimental conditions is often challenging [27]. The quasi-experimental design, therefore, bridges the gap between controlled laboratory experiments and the variable conditions of field studies, as it acknowledges and incorporates natural variations within the research framework [28], [29].

This methodology aligns with the pragmatic needs of agricultural research, which often requires the examination of environmental factors in situ. As such, it contributes to a more profound understanding of agronomic practices and their outcomes, which is essential for formulating effective agricultural policies and interventions [30].

2.2. Sampling

The current study scrutinizes the salinity levels of irrigation water used by farmers in Bulacan, with a particular focus on its implications for rice cultivation in the region. The primary objective is to ascertain whether the salinity levels are within acceptable limits or if they pose a risk to agricultural productivity. To achieve accurate measurements, the researchers collected two samples, each contained in 500 ml Polyethylene terephthalate (PET) bottles, from Santor, City of Malolos, Bulacan.

The study utilizes the salinity parameters established by Ayers and Westcot to evaluate the suitability of the irrigation water for rice cultivation [31]. According to these guidelines, water exhibiting electric conductivity of less than 0.7 dS/m and total dissolved solids (TDS) below 450 mg/l is deemed safe for crop irrigation. Conversely, readings between 0.7 dS/m to 3.0 dS/m for electric conductivity or 450 mg/l to 2000 mg/l for TDS suggest a slight to moderate risk to crops. Water with salinity levels greater than 3.0 dS/m in electric conductivity or more than 2000 mg/l in TDS is considered highly saline and, hence, unsuitable for irrigation purposes. The research is pivotal in identifying the salinity status of the irrigation water in this specific area and informing appropriate agricultural practices.

2.3. Data Collection Procedures.

The flowchart outlines a systematic procedure for analyzing water samples, which is common in environmental monitoring, quality control in water treatment facilities, or scientific research.

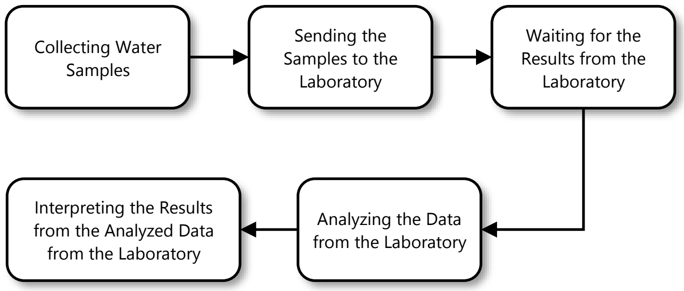

Figure 1. Flowchart of the Data-collecting Procedure.

Collection of Water: The researchers collected two (2) 500 ml Polyethylene terephthalate (PET) bottles of water samples at Santor, City of Malolos, Bulacan. Both water samples were from the same source: irrigation water. The water samples were collected last December 2, 2022, at 6 AM.

Figure 2. The Site Where Water Samples Were Collected

Preparing for Laboratory Testing: After collecting, the researchers went to the laboratory center to give the water samples. ECHEM Environmental Testing Laboratory Corporation, located in ASCORP Building, Mc Arthur Highway, Dolores, City of San Fernando, Pampanga, performed the water analysis, and the researchers waited for 20 working days for the laboratory results.

The laboratory used the electrometric method in testing the water samples. The electrometric method detects the surface effects of electric current flow in the ground [17]. It determines the pH of drinking, surface, and saline water, domestic and industrial wastes, and acid rain (atmospheric deposition) and is preferably used in the field [18].

2.4. Data Analysis

The instrument used in this study is a laboratory test. Since the study is experimental, the chosen instrument will give the researchers their expected absolute accuracy and reliable data. Laboratory tests are often referred to as evaluations or measurements. In this paper, the irrigation water used in Malolos, Bulacan, is being evaluated for its salinity level in ECHEM Environmental Testing Laboratory Corp. The results of water tests are frequently compared to regulations, and regulators should use laboratories to increase public trust in the accuracy of the information they use to make decisions. The table below interprets the water salinity for Irrigation. It will be used as the parameters by the researchers to identify the restricted saltiness of water for crops based on the laboratory results data.

Table 1 provides a deeper interpretation of water salinity for irrigation purposes. Water salinity refers to the concentration of dissolved salts in irrigation water. The level of water salinity can affect the availability of water for plant growth.

Table 1. Interpretation of Water Salinity for Irrigation.

	Units	Degree of Restriction on Use		
		None	Slight to Moderate	Severe
EC_w (Electric Conductivity)	ds/m	< 0.7	0.7 – 3.0	> 3.0
TDS (Total Dissolved Solids)	mg/l	< 450	450 – 2000	> 2000

Note: Salinity (effects of crop water availability)

Salinity based on Electrical Conductivity (EC_w):

- EC_w < 0.7 ds/m: No restrictions
  If EC_w is below 0.7 ds/m, the water salinity is considered low and will not cause significant restrictions on water availability for plants.
- 0.7 ds/m ≤ EC_w ≤ 3.0 ds/m: Slight to Moderate
  If EC_w is within this range, water salinity is considered moderate. This salinity level can slightly affect water availability for plants, but its restrictions can be overcome with proper water management, such as controlling drainage or using efficient irrigation methods.
- EC_w > 3.0 ds/m: Severe
  If EC_w exceeds 3.0 ds/m, the water salinity is considered severe. This high level of salinity will impose significant restrictions on water availability for plants. Water with high salinity can hinder the plant's ability to absorb water, causing disruptions in growth and plant production.

Salinity based on Total Dissolved Solids (TDS):

- TDS < 450 mg/l: No restrictions
  If TDS is below 450 mg/l, the water salinity is considered low and will not impose significant restrictions on plant water availability.
- 450 mg/l ≤ TDS ≤ 2000 mg/l: Slight to Moderate
  If TDS is within this range, water salinity is considered moderate. This salinity level can affect water availability for plants from slight to moderate, but it can still be managed with proper water management.
- TDS > 2000 mg/l: Severe
  If TDS exceeds 2000 mg/l, the water salinity is considered severe. High levels of salinity like this will impose significant restrictions on water availability for plants. Water with high salinity can inhibit plant growth and reduce crop yield.

3. Result and Discussion

3.1. Water Salinity

Tables 2 and 3 present the salinity measurements of two irrigation water samples collected from Santor, City of Malolos, Bulacan. The testing employed the electrometric method and yielded salinity levels of 318 mg/L for the irrigation water sample (1) and 306 mg/L for the irrigation water sample (2).

Table 2. Result of Sample 1 Water Salinity

Sample ID	: S22-L02-006G	
Sample Description	: Irrigation Water (1)	
Sample Matrix	: Surface Water	
Sample Date	: 02 Dec 2022	
Sampling Time	: 06:00 AM	
Sampling Location	: Santor, City of Malolos, Bulacan	
Parameters	**Results**	**Unit**
Salinity	318	mg/L
Method	**Date Analyzed**	**Analyst**
Electrometric	05 Dec 2022	TGG

Table 3. Result of Sample 2 Water Salinity

Sample ID	: S22-L02-007G	
Sample Description	: Irrigation Water (2)	
Sample Matrix	: Surface Water	
Sample Date	: 02 Dec 2022	
Sampling Time	: 06:00 AM	
Sampling Location	: Santor, City of Malolos, Bulacan	
Parameters	**Results**	**Unit**
Salinity	306	mg/L
Method	**Date Analyzed**	**Analyst**
Electrometric	05 Dec 2022	TGG

The assessment of these measurements against the standard values provided by Ayers and Westcot suggests that both samples fall within the low salinity category, below the threshold of 450 mg/L. At this concentration, the salinity is not considered hazardous to rice crops (Oryza sativa L.), which is significant given that rice is typically sensitive to high salinity levels.

According to the standards, salinity levels ranging from 0.7 ds/m to 3.0 ds/m or 450 mg/L to 2000 mg/L might exert a slight to moderate adverse effect on the crops, manifesting as reduced water uptake, stunted plant growth, and impaired reproduction. Levels exceeding 3.0 ds/m or 2000 mg/L are deemed severe and can lead to crop mortality.

Despite the farmers' reports of compromised crop yields and quality, the low salinity results from the water samples were unanticipated. To elucidate this discrepancy, the researchers are investigating additional factors that may influence salinity levels at the site, such as temperature variations, precipitation patterns, seasonal changes, and human activities. These elements are known to impact water salinity potentially and, consequently, could affect agricultural productivity in ways not directly reflected by the salinity measurements alone.

3.2. Temperature

The interrelation of temperature and salinity levels in water bodies emphasizes the role of dissolved oxygen in this dynamic. It explains that as water temperature decreases, its capacity to hold dissolved oxygen increases. This inverse relationship implies that cooler water can contain higher dissolved oxygen levels. Concurrently, an increased dissolved oxygen concentration is associated with decreased water salinity [32]–[34].

The implication of this relationship is pertinent to the study mentioned, particularly in the context of the time and conditions under which the water samples were collected. The samples were obtained early at 6 AM on the 22nd of December 2022, during which the ambient temperature ranged from 23°C to 31°C. This is a relatively low-temperature range for tropical regions, which could have resulted in higher dissolved oxygen levels in the water, subsequently contributing to the lower salinity readings observed.

The mentioned temperature range also indicates that the early morning hours before the day's heat can significantly warm the water. This period typically sees the highest dissolved oxygen concentrations, which may have affected the lower salinity levels detected in the water samples. The study cited presumably utilizes these observations to support the findings or hypotheses regarding the effects of temperature on water salinity, especially in the context of irrigation water, which is critical for agricultural practices.

3.3. Precipitation

During the "ber" months, typically from September to December, the Philippines experiences significant rainfall, influenced by La Niña, the Northeast Monsoon, and Low-Pressure Areas, often leading to thunderstorms. The influx of rainfall has an inverse relationship with salinity levels; as precipitation increases, it naturally dilutes the concentration of salts in bodies of water, thus reducing salinity [33], [35]. This dilution process is critical in agricultural areas, where excessive salinity can be detrimental to crop health and yield.

3.4. Changes in Season

Seasonal variations also play a pivotal role in altering the salinity of water used for irrigation. The evaporation process, more pronounced during the hotter and drier periods of the year, tends to increase water salinity, as it leaves salts behind when water vaporizes and ascends into the atmosphere. Conversely, during wetter seasons, when precipitation is more abundant, the resulting rainfall can decrease salinity by diluting the saline concentrations in the water [36], [37]. Understanding these patterns is crucial for farmers who must adjust their irrigation practices to the changing salinity levels throughout the year to maintain optimal crop health.

3.5. Anthropogenic Activities

In examining the role of anthropogenic activities on irrigation salinity, we find that human-induced environmental modifications can have unintended consequences on agricultural practices. The proximity of agricultural water sources to industrial plants in the Philippines has resulted in a heightened risk of salinity contamination due to industrial pollution [38]–[40]. This issue is compounded by the threat of salt-water intrusion, especially in coastal areas where reservoirs are susceptible to saline encroachment.

The reliance on irrigation systems for achieving monthly rice yields makes this an issue of economic viability for Filipino farmers [41], [42]. The affordability and accessibility of irrigation water, especially during critical growing months such as September and October, are essential for the sustenance of rice production. However, the cumulative effect of salinity, alongside global warming, financial limitations, and the spread of pests and diseases, is precipitating a decline in the rice industry [43], [44]. Such multifaceted challenges necessitate a comprehensive strategy that encompasses environmental management, economic support, and climate adaptation measures to safeguard the future of rice cultivation in the Philippines [45].

4. Conclusion

The salt concentration is a growing threat, primarily due to human-caused activities such as inefficient resource utilization. The supplementary assessment showed that it significantly reduces soil nutrients and, thus, agricultural land productivity.

High-salt irrigation water would impact the leaching process, but water with less than 600 mg/L is considered good quality. According to the results, the water the farmer uses for their crops (i.e., palay) has an average salinity level, which means it is safe to use. However, with the investigations that researchers execute, variables (i.e., temperature, precipitation, seasonal changes, and anthropogenic activities) influence salinity in the sample site, and waterways from the site to the fields also affect the water quality as industrial companies surround it.

The amount of yield losses incurred by saline water irrigation depends on various factors, including soil type, sewage, irrigation recurrence, process, and time. Regardless, though the sensitivity of the plant to the water quality is uncontrollable, contrariwise, the quality can be manipulated.

5. Recommendation

5.1. To Future Researchers

The assessment of water quality for irrigation purposes is of paramount importance in the current era. The findings of this study are intended to pave the way for future inquiries, serving as both a guide and a foundation for a more in-depth analysis of the salinity levels in irrigation water farmers utilize. It is encouraged that future researchers undertake similar studies, incorporating various variables to obtain a more comprehensive understanding of the environmental dynamics at play. Additionally, there is a call for research to develop guidelines to mitigate salinity's impact on crops. A rigorous and extensive research timeframe is advocated to yield precise and reliable results.

5.2. To Farmers

Farmers play a vital role in enhancing agricultural practices, and their active participation is crucial to addressing longstanding water-related challenges in farming. Their experiences and insights are invaluable to the scientific community, contributing to sustainable solutions and advancements in agricultural science.

5.3. To the Government

It is recommended that a symbiotic relationship be established between the government and the farming community to foster the enhancement of crop quality and farmers' livelihoods. Providing adequate funding and educational programs for farmers is essential to enable them to achieve sustainable incomes and thrive in their practices.

5.4. To the People in the Community

Disposing of waste from domestic activities has a pronounced impact on the water systems that underpin our communities. The public is urged to reduce waste production and use water conservation practices to protect these critical resources. This collective effort is essential for the preservation of our environment and the well-being of all community members.

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