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Original Article

Physicochemical Characterisation of Water Quality in Rice-Growing Irrigated Wetlands of Gbaagi Lafiagi, Kwara State, Nigeria

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ABSTRACT

Intensive rice cultivation in wetland ecosystems poses significant threats to water quality and aquatic biodiversity. This study assessed the physicochemical characteristics of water in the irrigated wetland of Gbaagi Lafiagi, Kwara State, Nigeria, across three sites representing different levels of rice cultivation intensity. Water samples were collected monthly from May to November 2025 from Site A (high-intensity rice cultivation), Site B (control/no cultivation) and Site C (low-intensity rice cultivation). Physical parameters including pH, temperature, electrical conductivity (EC), and turbidity, along with chemical parameters including dissolved oxygen (DO), biochemical oxygen demand (BOD), nitrate (NO_3), and phosphate (PO_4), were analysed using standard methods. Results indicated that Site A exhibited the highest nutrient concentrations with NO_3 values of 8.31±0.51 mg/L and PO_4 of 3.79±0.32 mg/L, compared to Site B (NO_3: 2.56±0.19 mg/L; PO_4: 1.59±0.94 mg/L). Site A also recorded the highest turbidity (76.71±7.01 NTU) and lowest dissolved oxygen (2.71±0.31 mg/L), indicating organic enrichment and potential eutrophication. Water quality parameters fell within acceptable ranges for irrigation but showed clear gradients reflecting the intensity of agricultural practices. These findings establish baseline physicochemical data essential for understanding water quality dynamics in irrigated rice wetlands and inform sustainable wetland management strategies in the region.

Keywords: water quality, physicochemical parameters, rice cultivation, wetlands, irrigation

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INTRODUCTION

Wetlands represent some of the most productive ecosystems on Earth, providing essential ecological services such as water filtration, flood management, biodiversity support, and carbon sequestration [1]. These ecosystems are defined as "areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres" [2]. Beyond water filtration and flood control, wetlands uphold ecological balance by acting as habitats for a variety of diverse flora and fauna, supporting fish species, and functioning as natural water reserves that help mitigate the impacts of climate change [3].

However, the rise in agricultural intensification, particularly in rice farming, has resulted in significant ecological transformations in wetland ecosystems globally [4]. Nigeria, being one of Africa's major rice producers, has experienced rapid growth in paddy farming, especially within wetland regions like Gbaagi Lafiagi in Kwara State. The intensification of rice farming, marked by excessive water usage, extensive agrochemical application and land conversion, poses serious risks to wetland health. High levels of agrochemical input, such as fertilisers and pesticides, result in nutrient accumulation, leading to eutrophication and a decline in water quality [5,6]. Persistent flooding in rice fields disrupts hydrological patterns, diminishes soil fertility, and impairs native aquatic species, contributing to habitat degradation [7].

The Gbaagi-Lafiagi irrigated wetland in Kwara State, Nigeria, represents an ecosystem where agricultural activities, particularly rice farming, have expanded due to its suitability for irrigation. While rice cultivation is crucial for local food security and income, the ecological ramifications of intensive farming practices have not been thoroughly evaluated. This study was undertaken to determine the physical and chemical properties of water in the Gbaagi Lafiagi wetlands across sites with varying levels of rice cultivation intensity, establishing baseline data essential for understanding water quality dynamics and informing sustainable wetland management strategies in the region.

MATERIALS AND METHODS

Study Area

The research was conducted in the Gbaagi-Lafiagi wetlands, located in the Edu Local Government Area of Kwara State, Nigeria. Geographically, this site is positioned between latitudes 8°37′10″N and 8°57′10″N, and longitudes 5°12′10″E and 5°33′20″E. The wetland features two distinct seasons: a wet season (April to October) conducive to rain-fed rice farming, and a dry season (November to March) with minimal to no rainfall. However, artificial irrigation channels enable rice cultivation year round. The study area features three different levels of rice cultivation intensity: Site A (high-intensity: rice cultivated twice yearly with irrigation), Site B (control: no rice cultivation), and Site C (low-intensity: rice grown once annually during the rainy season).

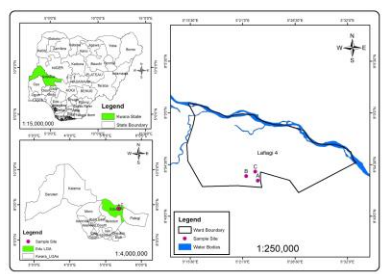

Figure 1: Map of Gbaagi-Lafiagi Wetland showing study sites.

Sampling Strategy and Water Collection

Water samples were collected monthly from three sampling sites (A, B and C) over a seven-month period from May to November 2025, coinciding with peak rice farming activities. GPS coordinates were recorded for each site: Site A (8.8800114°N, 5.3765678°E), Site B (8.8879271°N, 5.3562980°E), and Site C (8.8959243°N, 5.3719557°E). Water samples for physicochemical analysis were collected in clean 2-litre plastic containers by submerging the bottles without entrapping air bubbles.

Physicochemical Analysis

pH was determined using a calibrated pH meter (model AG75pH). The electrode was calibrated with buffer solutions before immersion in water samples, and readings were recorded.

Temperature was measured in the field by dipping a thermometer directly into the water and recording readings in degrees Celsius (°C).

Electrical Conductivity (EC) was measured in μS/cm using a conductivity meter (model LF90) after calibration. The meter's electrodes were immersed in water samples, and conductivity values were recorded.

Turbidity was determined by using a portable nephelometer (Hach 2100P) calibrated before use. Water samples were poured into sample cells and readings were recorded in Nephelometric Turbidity Units (NTU).

Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) were determined using the modified Winkler-Azide method. Water samples were collected in 250 mL stoppered bottles and fixed in the field with 1 mL manganous sulphate and 1 mL alkaline-iodide azide solution. In the laboratory, 2 mL of sulphuric acid was added, and samples were titrated with 0.0125N sodium thiosulphate using starch as indicator. DO was calculated using the formula: DO (mg/L) = [Volume ($Na_2S_2O_3$) × Normality × 8 × 1000] / Sample volume (mL). BOD was determined by incubating samples in darkness for five days, then analysing as for DO; the difference represented BOD.

Nitrate (NO_3) was determined by heating 50 mL of samples and standards to dryness in crucibles. Residues were dissolved in 2 mL phenol disulphonic acid and diluted to 50 mL in Nessler's tubes. Ammonia solution (6 mL) was added to develop yellow colour, and absorbance was read at 410 nm using a spectrophotometer.

Phosphate (PO_4) was determined by adding 2 mL ammonium molybdate solution and 5 drops of stannous chloride reagent to 50 mL water samples. Blue colour development was proportional to phosphate concentration and was read at 690 nm using a spectrophotometer.

Data Analysis

Mean values and standard deviations were calculated for all physicochemical parameters. The Duncan Multiple Range Test was used to separate means and identify significant differences between sites. Principal Component Analysis (PCA) was performed to examine relationships among physicochemical parameters and sampling sites.

RESULTS

Physical and Chemical Characteristics of Water Samples

The physical and chemical characteristics of water samples collected from rice cultivation fields in the Gbaagi-Lafiagi Irrigated Wetlands are presented in Table 1. Water pH values ranged from 6.51 ± 0.19 at Site C to 6.93 ± 0.14 at Site B. Temperature values varied between 27.59 ± 0.30°C (Site B) and 28.70 ± 0.30°C (Site A). Electrical conductivity (EC) ranged from 226.00 ± 9.39 μS/cm at Site B to 514.43 ± 21.88 μS/cm at Site A, while turbidity values ranged from 26.71 ± 2.14 NTU at Site B to 76.71 ± 7.01 NTU at Site A.

Dissolved oxygen (DO) concentrations ranged from 2.71 ± 0.31 mg/L at Site A to 5.71 ± 0.32 mg/L at Site B. Biochemical oxygen demand (BOD) values varied between 4.43 ± 4.43 mg/L and 8.97 ± 0.47 mg/L at Sites B and A, respectively. Nitrate (NO_3) concentrations ranged from 2.56 ± 0.19 mg/L at Site B to 8.31 ± 0.51 mg/L at Site A, while phosphate (PO_4) concentrations ranged from 1.59 ± 0.94 mg/L at Site B to 3.79 ± 0.32 mg/L at Site A.

Table 1. Physical and chemical properties of water samples from rice cultivation fields in Gbaagi-Lafiagi Irrigated Wetlands

	SITES		
Parameters	**SITE A**	**SITE B**	**SITE C**
pH	6.61±0.77(6.10-8.30)^{b}	6.93±0.14(6.80-7.10)^{c}	6.51±0.19(6.30-6.80)^{a}
Temp (°C)	28.7±0.3(28.20-29.10)^{b}	27.59±0.30(27.10-27.90)^{a}	28.54±0.51(27.90-29.50)^{b}
EC (µS/cm)	514.43±21.88(480.0-542.0)^{c}	226.0±9.39(210.0-236.0)^{a}	346.29±14.96(320.0-365.0)^{b}
Turbidity (NTU)	76.71±7.01(64.0-84.0)^{c}	26.71±2.14(23.0-29.0)^{a}	47.43±4.12(41.0-52.0)^{b}
BOD (mg/L)	8.97±0.47(8.30-9.60)^{a}	4.43±4.43(3.60-5.59)^{c}	5.93±0.84(4.20-6.50) ^{b}
DO (mg/L)	2.71±0.31(2.30-3.10)^{a}	5.71±0.32(5.30-6.10)^{b}	5.07±0.96(4.10-6.50)^{b}
NO3 (mg/L)	8.31±0.51(7.40-8.80)^{c}	2.56±0.19(2.20-2.80)^{a}	5.34±0.33(4.70-5.70)^{b}
PO4 (mg/L)	3.79±0.32(3.20-4.10)^{c}	1.59±0.94(2.10-3.80)^{a}	2.60±0.55(2.10-3.80)^{b}

Note: Values are means, standard deviation, minimum and maximum. Values with the same superscript in the same row are not significant.

Site A recorded the highest values of temperature (28.70 ± 0.30°C), EC (514.43 ± 21.88 µS/cm), turbidity (76.71 ± 7.01 NTU), BOD (8.97 ± 0.47 mg/L), nitrate (8.31 ± 0.51 mg/L) and phosphate (3.79 ± 0.32 mg/L). Site B recorded the highest pH (6.93 ± 0.14) and dissolved oxygen concentration (5.71 ± 0.32 mg/L), while Site C exhibited intermediate values for most parameters. Site A recorded numerically higher temperatures (28.70°C) than other sites, though this difference was not statistically significant ($P = 0.72$).

The PCA biplot (Figure 2) further illustrates the relationships among physicochemical parameters and sampling sites.

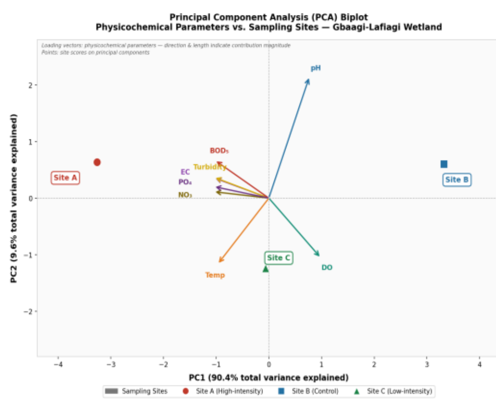

Figure 2: Principal Component Analysis (PCA) biplot showing relationships among physicochemical parameters (loading vectors) and sampling sites (scores) in the Gbaagi-Lafiagi Irrigated Wetland. Vector direction and length indicate the direction and magnitude of each parameter's

contribution to the principal components. Site A = high-intensity rice cultivation; Site B = control (no cultivation); Site C = low-intensity rice cultivation. PC1 explained 90.4% and PC2 explained 9.6% of the total variance.

DISCUSSION

This study characterised the water quality of three sites within the Gbaagi-Lafiagi irrigated wetland, with findings demonstrating distinctions in physicochemical parameters corresponding to different intensities of rice cultivation.

Physical Parameters

The pH values recorded across all sites (6.51–6.93) remained within the slightly acidic to near-neutral range, consistent with the FAO recommended range of 6.5–8.5 for irrigation water [8]. These slightly acidic conditions are optimal for rice growth as they ensure the availability of essential micronutrients [9]. The lack of significant pH variation across sites suggests that rice farming in the study area has not yet considerably altered the acid-base balance of the wetland water, in contrast to some heavily polluted tropical systems where pH shifts are dramatic.

Mean temperatures ranging from 27.59 to 28.7°C are characteristic of tropical wetlands in Kwara State and are conducive to both rice cultivation and the metabolic activities of aquatic organisms. The absence of significant temperature differences across sites ($P=0.72$) is expected, as all sites are within the same geographic area and would experience similar atmospheric heating patterns. These temperatures align with findings from Eleyele Lake in southwestern Nigeria [10], where similar tropical water body temperatures promote microbial decomposition processes.

Electrical conductivity values showed a clear intensity gradient, with Site A (514.43 µS/cm) exhibiting more than double the conductivity of Site B (226.0 µS/cm). Elevated EC in intensively cultivated areas typically reflects accumulation of dissolved salts and inorganic ions derived from fertiliser application, soil leaching and mineral weathering [11]. High EC can potentially increase osmotic stress on aquatic organisms and promote salinization over time if not managed carefully [12]. The intermediate EC value at Site C suggests a dose-dependent relationship between cultivation intensity and ionic concentration in wetland waters.

Turbidity values followed the same gradient, with Site A recording 76.71 NTU compared to 26.71 NTU at Site B. Elevated turbidity in rice fields is typically attributed to suspended sediment loads generated by tillage operations, soil disturbance, and organic matter from decomposing plant material [13]. These suspended particles reduce light penetration, potentially inhibiting photosynthetic activities of aquatic plants and contributing to reduced dissolved oxygen.

Nutrient Dynamics and Eutrophication Risk

The essential differences in nutrient concentrations represent one of the most significant findings of this study. Nitrate levels at Site A (8.31 mg/L) were three-fold higher than at the control site (Site B: 2.56 mg/L). In Nigeria, rice farmers commonly apply urea and NPK fertilisers to enhance productivity [14], and these nitrogen-based inputs readily leach into water bodies through runoff during rainfall and irrigation [15]. While these nitrate levels remain below the WHO guideline of 50 mg/L for drinking water, they are concerning for aquatic ecosystem health as they exceed the natural background levels that characterise undisturbed tropical wetlands.

Phosphate concentrations similarly showed a clear intensity-related pattern, with Site A (3.79 mg/L) approximately 2.4-fold higher than Site B (1.59 mg/L). Phosphorus accumulation in agricultural runoff typically originates from both applied phosphatic fertilisers and the decomposition of organic matter enriched in this element [16]. The combination of elevated nitrogen and phosphorus creates conditions that are favorable for the excessive enrichment (eutrophication) of water bodies with nutrients that stimulates algal overgrowth.

The risk of eutrophication is further supported by the low dissolved oxygen levels observed at Site A, as discussed below. The cascade of nutrient enrichment, algal blooms, decomposition and oxygen depletion represents a well-documented sequence in agricultural wetlands globally [17,18]. This phenomenon has been documented in numerous Nigerian freshwater systems, where agricultural nutrient runoff has degraded water quality and aquatic communities [19,20].

Dissolved Oxygen and Organic Pollution

The markedly low dissolved oxygen at Site A (2.71 mg/L) compared to Sites B and C (>5.0 mg/L) indicates significant organic enrichment and potential hypoxic stress. Low DO values coupled with the highest BOD at Site A (8.97 mg/L) suggest intensive microbial decomposition of organic matter, likely from algal senescence, rice residues and soil organic matter mobilized during tillage. DO concentrations below 5 mg/L are generally considered suboptimal for supporting diverse aquatic macroinvertebrate communities and can stress sensitive fish species [21].

The correlation between high BOD and low DO at Site A reflects the oxygen deficit created by microbial respiration exceeding oxygen recharge through atmospheric diffusion and photosynthetic oxygen production. In tropical wetlands with stagnant water and high temperatures, this oxygen depletion can become severe, as observed in this study. The persistent flooding characteristic of intensive rice farming may limit water circulation and oxygen transfer, exacerbating these conditions [22]. The intermediate conditions at Site C suggest that single-season, rainfall-dependent rice cultivation allows greater water circulation and oxygen dynamics during fallow periods.

Implications for Wetland Management

The physicochemical gradient observed from Site A through Site C mirrors the intensity of human disturbance and demonstrates the ecological responsiveness of wetland water quality to cultivation practices. While water parameters at the study sites have not yet reached critically polluted levels, the trajectory is concerning. High nutrient inputs combined with persistent flooding and reduced oxygen creates a trajectory toward the eutrophic state characteristic of severely degraded agricultural wetlands.

The findings stress the importance of implementing best management practices to reduce fertiliser runoff, maintain adequate water circulation and protect riparian vegetation that can act as nutrient filters. In many tropical developing nations, including Nigeria, such practices remain underutilized despite their proven effectiveness in mitigating agricultural water pollution [23].

CONCLUSION

This study demonstrated clear water quality gradients corresponding to rice cultivation intensity. Site A, with high-intensity twice-yearly rice cultivation, showed elevated nutrient concentrations (NO_3: 8.31 mg/L; PO_4: 3.79 mg/L), high turbidity (76.71 NTU), elevated electrical conductivity (514.43 μS/cm) and reduced dissolved oxygen (2.71 mg/L) with correspondingly high BOD. These parameters indicate organic enrichment and eutrophication risk. In contrast, the control site (Site B) with no rice cultivation maintained lower nutrient levels, better oxygenation and lower turbidity, establishing a reference condition for this wetland ecosystem. Site C, with low-intensity single-season cultivation, showed intermediate water quality parameters.

While water quality parameters remain within acceptable ranges for irrigation according to FAO standards, the concentration of pollutants at Site A relative to the control site indicates that intensive rice farming is already measurably degrading water quality. These findings establish critical baseline data for monitoring long-term ecological changes and for informing sustainable agricultural management strategies that balance rice production needs with wetland ecosystem protection.

Ethics Approval and Informed Consent

This study did not use human or animal subjects. Therefore, ethical consideration was not applicable.

Authors' Contributions

YM conceptualized and designed the study. YM participated in fieldwork and data collection, performed the data analysis, interpreted the findings together with MAZ and prepared the first draft of the manuscript. The manuscript was reviewed by MAZ and AYI. All authors contributed to the development of the final manuscript and approved its submission.

Conflict of Interest

The authors declare no conflict of interest.

Disclosure of Funding

The study did not receive any external funding.

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