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Assessing the effects of farming on water quality of fish farms in Ghana: the case study of Sunyani Municipality

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Abstract

This research examines the effects of farming activities on water quality of fish farms located in the Sunyani Municipality of Ghana. Six fish farms were selected for the study, including three fish farms close to farming activities (WFA) and another three far from farming activities (WOFA). Water samples were obtained monthly between May and September 2023, and analyzed for physicochemical parameters. The results showed that concentrations of nitrate, nitrite, total suspended solids (TSS), and total dissolved solids (TDS) were significantly higher in the farms without farming activities (with averages of 43.28 ± 2.83 mg/L for nitrate, 0.16 ± 0.05 mg/L for nitrite, 187.60 ± 24.30 mg/L for TSS, and 148.70 ± 12.90 mg/L for TDS) compared to farms linked to farming activities (18.40 ± 2.83 mg/L for nitrate, 0.05 ± 0.01 mg/L for nitrite, 103.60 ± 15.90 mg/L for TSS, and 113.60 ± 11.30 mg/L for TDS). Principal Component Analysis (PCA) revealed that pH and sulfate had positive coefficients (0.55 and 0.63, respectively) in farms with farming activities, whereas nitrate had a positive coefficient (0.52) in farms without farming activities. The high levels of water quality parameters in the farms without farming activities were attributed to internal pond mechanisms, while farming activities were observed to significantly influence sulfate concentrations in the fish farms. In conclusion, the study demonstrates that agricultural runoff and nutrient leaching directly increased sulphate concentrations in fish farms, disrupting water chemistry and posing risks to aquatic ecosystems and fish health. Based on the findings, structured water testing schedule can help detect changes in key parameters such as pH, nitrate and ammonia levels should be formulated and implemented. Also, a 100-meter buffer zone between fish farms and farming areas to prevent contamination should be established.

Keywords: Farming Activities, Water Quality, Fish Farms, Aquaculture, Sunyani, Ghana

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INTRODUCTION

The increasing global demand for fish has positioned aquaculture as a vital strategy to supplement dwindling capture fisheries and ensure food security (Agbeko et al., 2019a). In sub-Saharan Africa, aquaculture is largely conducted in earthen ponds, which are generally less intensive and technologically advanced than systems used in Asia, Europe, and the Americas (Frimpong et al., 2014).

Aquaculture production in Ghana has grown from 5,590 tonnes in 2008 to 89,375.48 tonnes in 2021 due to government interventions to the sector by providing free vaccines to fish farms that were affected. Tilapia remains the most popular cultured fish in Ghana, followed by catfish (GSS, 2023). Since 2018, Ghana has emerged as a leading producer of farmed tilapia in sub-Saharan Africa, second only to Egypt in the broader African context (Ragasa et al., 2022). While industrial aquaculture has attracted substantial research and investment, small-scale aquaculture, especially earthen pond farming remains a dominant practice across many regions of Ghana (Kassam

& Dorward, 2017). Pond aquaculture faces multiple constraints including limited technical expertise, high operational costs, and, notably, declining water quality (Ragasa et al., 2022). Water quality plays a critical role in fish health, influencing growth rates, disease resistance, and mortality (Agbeko et al., 2019b). Poor water conditions, often resulting from nutrient buildup, phytoplankton imbalances, and microbial activity, can trigger eutrophication and increase fish vulnerability to pathogens (Otoo et al., 2019).

In the Sunyani Municipality, the proximity of small-scale fish farms to vegetable farms, especially along the banks of the Tano River and its tributaries intensifies this water quality challenges (Obiri et al., 2021). Farmers cultivate crops such as tomatoes, pepper, and cabbage using fertilizers and organic manure, which, through surface runoff and seepage, enter fish ponds and increase nutrient loading (Rashmi et al., 2020). This encourages phytoplankton blooms and supports the growth of harmful microorganisms (Balasuriya et al., 2022). Additionally, microbial breakdown of uneaten fish feed and faeces deplete oxygen and further release substances that destabilize pond ecosystems (Mramba & Kahindi, 2023). These conditions differ from those in other regions, where water sources may be less affected by adjacent farming or where integrated aquaculture-agriculture systems are more systematically managed.

While several studies in Ghana have investigated the impact of fish farming on downstream water bodies (e.g., Saah et al., 2021; Otoo et al., 2019), no study on impact of agricultural activities on water quality parameters within fish ponds has been conducted in Ghana. Absence of such crucial study renders any management measures towards sustainable pond aquaculture in Ghana ineffective. This study therefore seeks to fill this critical gap by assessing the impact of agricultural activities on the water quality parameters of earthen fish ponds in the Sunyani Municipality, Ghana**.** The finding from this study will contribute to the sustainable management of small-scale aquaculture in Ghana, providing insights for policy interventions, fish farmer training, and integrated land-water use strategies.

MATERIALS AND METHODS

Study Area

The study was performed in Sunyani Municipality which is the capital of the Bono Region, Ghana. The study area is situated between latitudes 7°20′ and 7°05′ N and longitudes 2°10′ and 2°30′ W, covering an area of 506.7 km² and has a population size of 136,022 (Appiah et al., 2018; GSS, 2020). The study area was selected due to the presence of high number of active fish farms (Anokyewaa & Asiedu, 2019).

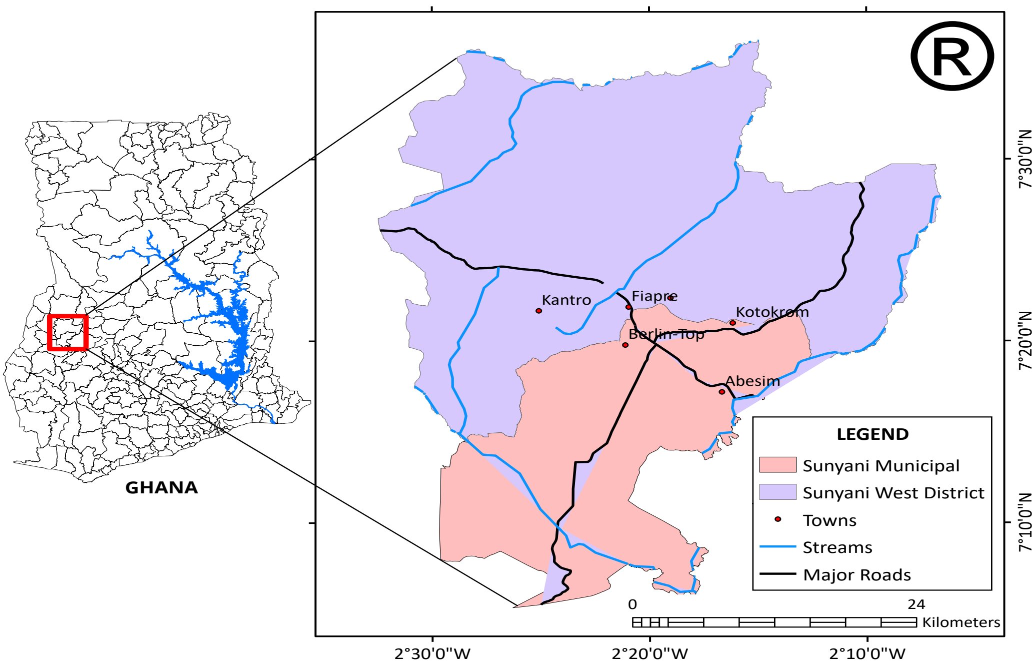

Figure 1. Map showing the study area (Ghana, 2024)

Data Collection

The study was carried out between May and September 2023, coinciding with significant rainy season in the Municipality. This sampling period was chosen because rainfall during these months has a substantial impact on surface runoff, which can transport fertilizers, pesticides, and other agricultural inputs into neighboring water bodies, including fish ponds. As a result, this season offers a significant opportunity to analyze the influence of adjacent farming activities on water quality parameters. The study chose six earthen fish ponds: three within 100 meters of active vegetable farms (e.g., tomatoes, pepper, cabbage), and three more than 500 meters away from any agricultural activity. These classifications were used to distinguish between ponds that were possibly exposed to agricultural runoff and those that had no external influence. Five water samples were obtained monthly from each pond, totaling 25 samples per pond and 150 samples throughout the study period. To guarantee consistency, samples were collected at various points across the pond (center, inlet, outflow, and two midpoints) at depths of 20-30 cm. Water quality measurements were evaluated *in-situ* between 8:00 a.m. and 12:00 p.m. to reduce temperature variability. A multi-parameter probe (Hach HQ40d), calibrated in the laboratory based on standard procedure was utilized to assess dissolved oxygen (DO), pH, temperature, conductivity, salinity, total dissolved solids (TDS), and total suspended solids (TSS). Turbidity was measured separately with a Hach 2100Q turbidity meter. All equipment was calibrated prior to each sampling session in accordance with manufacturer specifications. The detection limits and accuracy ranges for the instruments were: DO: 0.01-20 mg/L ±0.1 mg/L; pH: 0-14 ±0.02 pH units. Turbidity: 0-1000 NTU, ±2%

Data Analysis

Water samples were collected in clean polyethylene bottles, immediately stored in iceboxes, and transported within 4 hours to the Ghana Water Company Laboratory. Samples were preserved according to APHA (1998) standards. Chemical parameters including ammonia, nitrites, and nitrates, were analyzed using a UV-VIS spectrophotometer at wavelengths of 543 nm and 635 nm, depending on the parameter. Laboratory and field data were compiled and analyzed using Microsoft Excel (2019) and PAST (version 4.13). A Shapiro-Wilk test was performed to assess the normality of data distributions. Only parameters meeting the assumption of normality ($p > 0.05$) were subjected to independent samples T-test to compare means between ponds near and far from agricultural areas. Non-parametric Mann-Whitney U test was used to examine parameters that violated normality assumptions ($p < 0.05$). Additionally, Principal Component Analysis (PCA) was used to discover underlying patterns and correlations between the water quality measures in the two pond groups. Water quality values were compared to Ghana Standards Authority (GSA) and World Health Organization (WHO) aquaculture water quality criteria to assess the impact on fish health and pond sustainability.

RESULTS AND DISCUSSION

The concentrations of water quality parameters from two types of fish farms including fish farms with farming activities and fish farms without farming activities. For parameters such as ammonia, turbidity, and sulphate, the mean concentration was higher in fish farms with farming activities (Table 1). Conversely, the mean concentration of the remaining nutrients was greater in fish farms without farming activities (Table 1). Significant differences were recorded for the mean concentrations of nitrite, nitrate, sulphate, calcium, Total Suspended Solids, Total Dissolved Solids, pH, and ammonia between fish farms with farming activities and fish farms without farming activities, with a p-value < 0.05 (Table 1).

Table 1. Mean concentration of water quality parameters between fish farms with farming (WFA) and without farming activities (WOFA)

Name	Fish farms with farming (n = 8 farms) Mean ± standard error	Fish farms without farming (n = 8 farms) Mean ± standard error	p-value
Dissolved oxygen (mg/L)	1.90 ±0.84	2.33 ± 0.19	0.61
pH	6.71 ± 0.07	7.63 ± 0.18	0.00*
Ammonium (mg/L)	0.25 ± 0.04	0.04 ± 0.01	0.00*
Nitrite (mg/L)	0.05 ± 0.01	0.16 ± 0.05	0.02*
Nitrate (mg/L)	18.40 ± 2.83	43.28 ± 2.83	0.01*
Turbidity (NTU)	23.17±2.91	18.44 ± 1.72	0.17
Temperature (°C)	26.39 ± 0.20	26.43 ± 0.24	0.91
Sulphate (mg/L)	19.56 ± 2.86	11.38 ± 2.41	0.05*
Total Suspended Solids (mg/L)	103.60 ± 15.90	187.60 ± 24.30	0.01*
Total Dissolved Solids (mg/L)	113.60 ± 11.30	148.70 ± 12.90	0.05*
Conductivity (µS/cm)	222.10 ± 22.70	258.10 ± 20.90	0.25

NB: Parameters with asterisk (*) indicate significant difference.

Nutrients play a vital role in aquatic ecosystems as they facilitate metabolic activities (Okomoda 2011). The observed significant difference in nitrate, pH and nitrate concentration between the two categories of fish farms could be linked to algal blooms, low vegetation cover, internal mechanisms of the pond, as well as pH and alkalinity (Saha & Paul 2023; Singh et al. 2022; Naeem et al. 2022). Additionally, Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) were significantly higher in fish farms without farming activities. The high concentration of TSS and TDS could facilitate the intrusion of pollutants into fish ponds (Rahman et al. 2021). In addition, high concentrations of TSS and TDS may reduce the concentration of naturally occurring dissolved oxygen, potentially leading to increased fish kills. Conversely, ammonia concentrations was higher in fish farms with farming activities, which may be due to inadequate abundance of nitrifying bacteria and restricted interactions with the external environment (Nayak & Nanda, 2021).

The concentrations of nitrate, ammonia, TSS, and TDS observed in the study surpassed the levels recommended by World Health Organization (WHO, 2003). Also, mean sulphate concentration from the study was outside the ideal range suggested by Umeh et al. (2020) for growth, maintenance, and enhanced fish production. Elevated water quality parameters could contribute to high mortality of farmed fish if proper management measures are not developed and enforced (Wanja et al. 2020). Furthermore, high levels of ammonia accumulation in fish farms could have negative influence on thealth status of farmed fish (Hargreaves & Tucker 2004). However, average pH and nitrite levels recorded in the study fell within the recommended range by WHO (2003). This suggests that these water quality parameters are suitable for farming fishes of commercial importance.

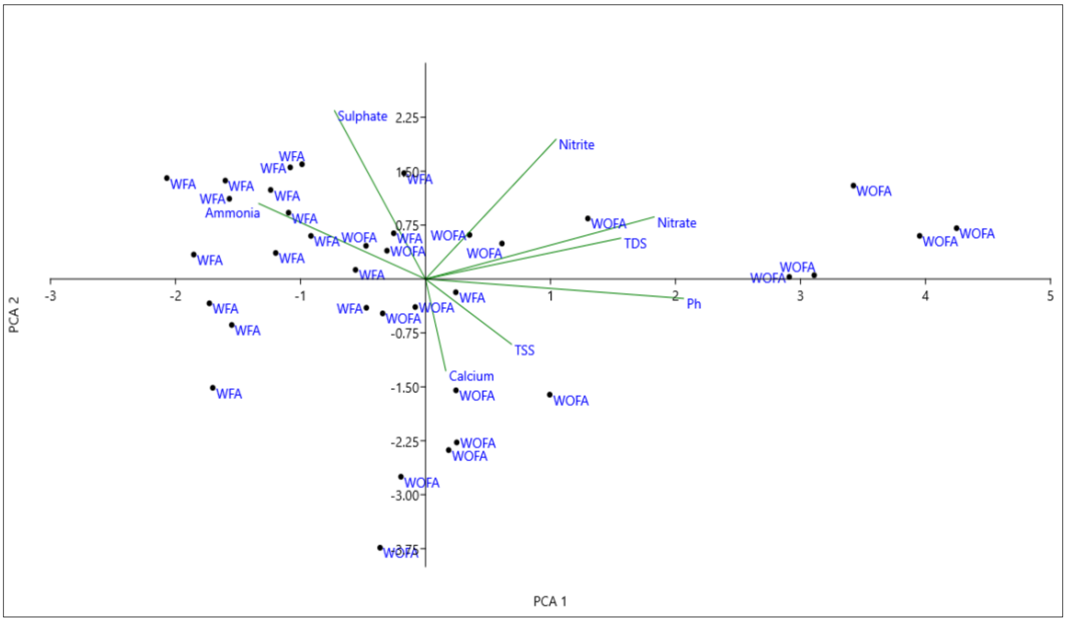

Figure 2. PCA output of significant water quality parameters and fish farms with and without farming activities.

From the PCA output, axes 1 and 2 collectively accounted for more than 50% of the variation (see Figure 2). Based on PCA 1, pH with a coefficient of 0.55, increased in fish farms with farming activities. Conversely, nitrate having a coefficient of 0.52, increased in fish farms without farming activities (Figure 2). In PCA 2, sulphate increase in fish farms with farming activities, having a coefficient of 0.63 (Figure 2). Positive correlation implied that increase in one variable translates into increase in the other variable or vice versa while a negative corelation suggested as one parameter increases, the other variable declines or vice versa. The concentration of pH showed a positive correlation with fish farms close to farming activities. A study by Wanja et al. (2020) indicated that farming activities tend to increase pH concentration owning to rising nutrient input from waste and feed. Additionally, positive correlation of sulphate in fish farms with farming activities may be linked to the existence of sulphate-containing organic fertilizers and waste runoff (Numbere et al., 2023). According to Vehanen et al. (2022), sulphate in fish farms increase may be due to drainage of acid sulphate soils and oxidation of metal sulphides. On the other hand, nitrates exhibited a positive correlation with fish farms without farming activities. This finding was in variance to study by Hejazy (2023), who reported rising nitrate concentrations in fish farms with farming activities. The variation may be reliant on the absence of industrial effluent and the distance from farming activities (Sahare, 2014).

CONCLUSION

This study sheds light on the impact of farming activities on water quality parameters of fish farms in the Sunyani Municipality, Ghana. Findings from the study showed that farming activities significantly affects the concentration of sulphate in fish farms close to farm lands. This suggests that runoff and nutrient leaching from farming areas contribute to alterations in water qaulity parameters, affecting aquatic ecosystems and fish health. However, changes in the concentration of ammonia, nitrates, TSS and TDS of fish farms far from farming activities are mostly due to the internal mechanisms of the ponds rather than contribution from farming activities. As part of recommendations from this study, it is crucial to continuously monitor water quality parameters, especially nitrate, pH and ammonia because increase in these parameters may result in euphrophication and high fish kills. Also, implementing policies that establish buffer zones between fish farms and farmlands is essential, mostly 100 m interval between fish farms and agricultural lands. Such policies should be formulated after proper consultations with stakeholders to ensure feasibility and effectiveness of the policies.

Compliance with Ethical Standards
Peer-review
Externally peer-reviewed.
Declaration of Interests
The authors have no conflicts of interest to declare.
Author contribution
All authors contributed to the design and conceptualization of study. The first draft of the manuscript was done by Mohammed, A.M. and Amponsah, S.K.K, while İncoom, A.B.W reviewed the manuscript. All authors approved the final manuscript.
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