Jurnal Perikanan S4

Fisheries Journal, 16 (3), 1479-1493 (2026)
http://doi.org/10.29303/jp.v16i3.2283

LITERATURE REVIEW: FRESHWATER QUALITY AS A DETERMINANT OF SUSTAINABLE NILE TILAPIA (*Oreochromis niloticus*) AQUACULTURE: FOOD SECURITY POTENTIAL ON LOMBOK ISLAND, INDONESIA

Tinjauan Pustaka: Kualitas Air Tawar sebagai Penentu Budidaya Ikan Nila (*Oreochromis niloticus*) Berkelanjutan: Potensi Ketahanan Pangan di Pulau Lombok, Indonesia

Awan Dermawan[1*], Abd Saddam Mujib[2]

[1]Aquaculture Study Program, Faculty of Agriculture, University of Mataram
[2]Marine Science Study Program, Faculty of Agriculture, University of Mataram

Jl. Pendidikan No. 37 Mataram, Nusa Tenggara Barat

*Corresponding Author: awan.dermawan@unram.ac.id

(Received May 11th 2026; Accepted June 16th 2026)

ABSTRACT

Tilapia (*Oreochromis niloticus*) aquaculture is an important source of animal protein with the potential to support local food security in island regions such as Lombok Island; however, the sustainability of its production is heavily influenced by the quality of the freshwater used as the aquaculture medium. This study aims to analyze the role of water quality as a determining factor for the sustainability of tilapia farming and its contribution to regional food security. The research was conducted using a systematic literature review approach with a PRISMA-based selection procedure for scientific publications since 2014. The synthesis results indicate that key water quality parameters, such as temperature, pH, dissolved oxygen, organic load, and nitrogen nutrient content, are consistently associated with the growth, health, and productivity of tilapia. Water quality degradation due to anthropogenic pressures has the potential to reduce the stability of aquaculture production and disrupt the availability of protein sources for the community. These findings underscore that water quality management is a key component of sustainable aquaculture systems and has strategic implications for efforts to strengthen local food security. This study provides a conceptual foundation for integrating water management policies with the development of adaptive and sustainable tilapia aquaculture.

Keywords: Fisheries Policy, Food Security, Freshwater Fish Farming, Water Quality, Watershed

ABSTRAK

Budidaya ikan nila (*Oreochromis niloticus*) merupakan sumber protein hewani penting yang berpotensi mendukung ketahanan pangan lokal di wilayah kepulauan seperti Pulau Lombok; namun, keberlanjutan produksinya sangat dipengaruhi oleh kualitas air tawar yang digunakan sebagai media budidaya. Studi ini bertujuan untuk menganalisis peran kualitas air sebagai faktor penentu keberlanjutan budidaya ikan nila dan kontribusinya terhadap ketahanan pangan regional. Penelitian ini dilakukan dengan menggunakan pendekatan tinjauan pustaka sistematis dengan prosedur seleksi berbasis PRISMA untuk publikasi ilmiah sejak tahun 2014. Hasil sintesis menunjukkan bahwa parameter kualitas air utama, seperti suhu, pH, oksigen terlarut, beban organik, dan kandungan nutrisi nitrogen, secara konsisten berhubungan dengan pertumbuhan, kesehatan, dan produktivitas ikan nila. Degradasi kualitas air akibat tekanan antropogenik berpotensi mengurangi stabilitas produksi budidaya dan mengganggu ketersediaan sumber protein bagi masyarakat. Temuan ini menggarisbawahi bahwa pengelolaan kualitas air merupakan komponen kunci dari sistem budidaya berkelanjutan dan memiliki implikasi strategis untuk upaya memperkuat ketahanan pangan lokal. Studi ini memberikan landasan konseptual untuk mengintegrasikan kebijakan pengelolaan air dengan pengembangan budidaya ikan nila yang adaptif dan berkelanjutan.

Kata Kunci: Kebijakan Perikanan, Ketahanan Pangan, Budidaya Ikan Air Tawar, Kualitas Air, Daerah Aliran Sungai

INTRODUCTION

The cultivation of *Oreochromis niloticus* is one of the most common and globally significant freshwater aquaculture commodities due to its rapid growth, high adaptability to various environmental conditions, and its role in providing an economical and nutritious source of animal protein for communities (Rossignoli et al., 2023). Globally, the aquaculture sector is one of the largest contributors to fisheries food production, capable of addressing shortages in animal protein-based food supplies, particularly in developing countries (Haque, 2025). Indonesia, as an archipelagic nation with abundant aquatic resources, possesses significant potential to develop freshwater fish farming such as tilapia—as a strategy to enhance local and national food security (Mendrofa et al., 2025). However, the sustainability of this aquaculture is highly dependent on the quality of the rearing water, which can affect fish health, production efficiency, and overall ecological impacts (Abd et al., 2022).

In the context of academic research and aquaculture practice, there is a significant gap between the numerous studies that identify individual water quality parameters affecting fish growth and a holistic understanding of how these conditions determine the overall sustainability of aquaculture systems and their contribution to local food security. Although several studies have investigated the effects of temperature, pH, and dissolved oxygen concentration on tilapia aquaculture performance, systematic mapping of how water quality plays a role in aquaculture sustainability that contributes to food security remains limited, particularly in regions with socio-ecological characteristics such as Lombok Island (Dermawan et al., 2025). This gap highlights the need for a structured literature synthesis to integrate existing empirical evidence and lead to more contextual and sustainable policy recommendations and aquaculture practices.

Conceptually, this study is based on the recognition that the sustainability of fish farming is not merely about short-term productivity, but also involves long-term environmental, social, and economic balance. The conceptual framework of aquaculture sustainability integrates social-ecological systems theory, which emphasizes the importance of water quality management as an environmental component that influences production dynamics, fish health, and food security (Radosavljevic et al., n.d.). This perspective aligns with the notion that aquatic environmental quality serves as the foundational capital for ecosystem functions that support sustainable fish production, which in turn impacts the stability of food supply and the well-being of aquaculture communities (Rossignoli et al., 2023).

The main scientific contribution of this article lies in providing a comprehensive and systematic empirical synthesis of water quality in the context of tilapia aquaculture focused on sustainability and food security. This study not only fills a gap in the existing literature but also provides a knowledge base for sustainable aquaculture practices and relevant policy recommendations for decision-makers and stakeholders in Indonesia's fisheries sector. It is hoped that this contribution will facilitate the formulation of effective water quality management strategies to support food security in the Lombok Island region and its surroundings.

RESEARCH METHODS

The understanding of water quality and aquaculture sustainability in the context of freshwater *Oreochromis niloticus* aquaculture is rooted in the theory of production ecosystems and environmental management within a holistic socio-ecological system. This concept emphasizes that water quality is not merely a physical-chemical variable, but a dynamic component that influences the overall function of the ecosystem, including productivity, the health of farmed organisms, and long-term sustainability (Boyd & Mcnevin, 2024). The production ecosystem perspective emphasizes the complex interactions between water quality parameters such as temperature, pH, dissolved oxygen, and nutrient concentrations and fish physiological processes, which in turn impact aquaculture yields and the stability of environmental functions (Makori et al., 2017). This theory serves as the primary foundation of this article because it provides a conceptual framework for examining the relationship between water quality and aquaculture outcomes, as well as its contribution to local food security. Based on this understanding, this article is designed as a systematic literature review (SLR) to describe the current state of freshwater quality on the island of Lombok as a driver of the sustainability of tilapia (*Oreochromis niloticus*) aquaculture.

RESULT

This conceptual synthesis of the literature indicates that water quality acts as a mediator between environmental factors and tilapia aquaculture outcomes. Optimal parameter conditions not only ensure fish growth and health but also impact long-term production, thereby supporting the stability of fish-based food supplies (Dermawan et al., 2025). In the context of food security, water quality is a key variable linking environmental inputs, aquaculture practices, management technologies, and long-term production outcomes. A summary of the reviewed literature is presented in Table 1.

Table 1. Summary of the Reviewed Literature

No	Research/Year	Location	Variable	Method	Result
1	Study on Water Pollution in the Babak River Caused by Leachate Discharge from the Kebon Kongok Regional Landfill in West Lombok Regency (Dindasari, 2023)	Babak River & Kebon Kongok Regional Landfill, West Lombok (NTB)	Leachate and river water parameters: temperature, TDS, TSS, DHL, COD, BOD, NO_2, NO_3, Cd, total coliforms; pollution load; pollution level; management strategies	Surveys, sampling, and observation purposive river sampling; laboratory testing; analysis of pollutant loads and levels; and strategy formulation	Leachate: BOD and COD exceed quality standards; Babak River: several parameters (pH, BOD, Cd, total coliforms) exceed quality standards; highest pollution load (total coliforms, BOD, Cd); water quality status: moderately polluted; strategy: optimize leachate treatment facilities, community-based waste management, leachate discharge

No	Research/Year	Location	Variable	Method	Result
					monitoring, and river quality monitoring
2	A Study on the Development Potential of the Jangkok River Basin in the City of Mataram (BRIDA, 2024)	Jangkok River in the city of Mataram	Watershed utilization; potential–issues–guidelines; water quality classification (Class II); biotic indicators (FBI reference); priority development sites	Mixed-methods approach (quantitative + qualitative); identification of uses and formulation of guidelines; visualization of "SPOT" development	Development guidelines are based on Class II water quality standards under the "Sustainable Jangkok Watershed" concept; priority potential locations: Kebunsari, Dasan Agung, Karangbaru, Selagalas; priority areas for issue resolution: Ampenan Tengah and Banjar; emphasizing multi-stakeholder collaboration in watershed management
3	Mataram Urban Study Report (Urban Analysis Report, 2020) (Mulyana & Pratiwi, 2020)	Mataram City (Cross-Sectoral Urban Study)	Climate vulnerability and risks; municipal policies and programs; sectoral issues (including sanitation and surface water quality)	Policy and urban conditions review/analysis (evidence-based and involving stakeholder consultation)	Provides a comprehensive overview of the city's characteristics and recommendations for climate adaptation and mitigation strategies; discusses how Mataram is vulnerable to climate impacts such as drought and water pollution and requires inclusive adaptation and mitigation strategies
4	Water Quality Monitoring Based on Physical, Chemical, and Biological Parameters in the Belimbing River, East Lombok.(Jupri et al., 2025)	Belimbing River, East Lombok (sections: upper–middle–lower)	Physical: TSS; Chemical: pH, DO, BOD, COD, nitrate, phosphate; Biological: fecal coliform; season (dry vs. rainy)	Grab sampling; 3 replicates per sample point; analysis within 24 hours; standard method SNI 6989.72:2009; UV-Vis (nitrate/phosphate), oven (TSS), titration (BOD/COD), MPN (fecal coliform)	Most parameters exceed Class II water quality standards (Government Regulation No. 22 of 2021), particularly downstream during the dry season: TSS 134 mg/L, BOD 12 mg/L, COD 115 mg/L, fecal coliform 9,600 MPN/100 mL; primary sources: domestic wastewater, agricultural runoff, poor sanitation; indication of moderate–severe pollution

No	Research/Year	Location	Variable	Method	Result
5	Monitoring Water Quality in the Aik Ampat River Using Biotic Macroinvertebrate Indexes. (Zamroni et al., 2017)	Aik Ampat River, East Lombok (Suntalangu/Jorong–Esot–Labuhan Haji Estuary)	Macroinvertebrates/macrozoobenthos; Family Biotic Index (FBI)	Macroinvertebrate collection (aquatic nets, dip nets, Eckman grabs, brushes, hand collection); preserved in 70% alcohol; FBI calculation; period: May–July 2017	FBI value = 2.02 → the river is slightly polluted with organic matter; sanitation facilities, sand mining, and domestic wastewater are cited as factors contributing to the decline in water quality
6	Nutrient Pollution and Water Quality in the Batujai and Pengga Cascade Reservoirs on the Island of Lombok. (Brahmana et al., 2010)	Batujai Reservoir & Pengga Reservoir (a cascade in the Dodokan River Basin), Lombok Island	Water quality & nutrients: BOD, COD, detergents; total nitrogen, total phosphorus; pollution load; eutrophication status	Descriptive method (secondary and primary data, water quality measurements); evaluation of Government Regulation No. 82/2001; eutrophication status based on Minister of Environment Decree No. 28/2009; observations of the rainy and dry seasons (2009)	Reservoir water quality is moderately polluted; high pollution load: Batujai (total N ±191 kg/day; total P 69.5 kg/day) and Pengga (total N 232.6 kg/day; total P 16.7 kg/day); parameters not meeting Class 1 standards: BOD, COD, detergents; trophic status: mesotrophic–eutrophic
7	A Study of the Physical and Chemical Water Quality of the Ancar River – Mataram City (Wiadnya et al., 2019)	Ancar River, Mataram City (Gontoran–Bertais; Karang Bedil–East Mataram; Gerisak–Tanjung Karang)	Physical: temperature, pH, color, turbidity; Chemical: dissolved oxygen (DO), biochemical oxygen demand (BOD), ammonia, nitrite, total organic matter,	Descriptive study; three-point sampling; comparison of quality standards (Government Regulation No. 20/1990; Ministry of Health Regulation No. 416/1990)	It was concluded that the water quality of the Ancar River still meets Class B standards for raw water; the impact of agricultural and domestic wastewater has not yet shown any serious signs.

No	Research/Year	Location	Variable	Method	Result
			alkalinity, acidity		
8	A Study on Determining Water Quality Status Using the Pollution Index Method and the Water Quality Index (WQI) in the Dodokan River, Lombok, West Nusa Tenggara. (Mandalika, 2018)	Dodokan River, Lombok (West Nusa Tenggar)	Water quality status: Pollution Index (PI) & WQI; (also water quality modeling: QUAL2Kw)	Calculation of PI and WQI (multiple monitoring points); QUAL2Kw modeling/simulation; comparison with water quality standards	Determining water quality status based on PI and WQI at several monitoring points and QUAL2Kw simulation scenarios (existing conditions vs. compliance with water quality standards), to serve as the basis for recommendations on management and reduction of pollutant loads
9	Analysis of Water Quality in the Ancar River Using Macroinvertebrate Bioindicators (Khairuddin. et al., 2016)	Ancar River, Mataram City	Macroinvertebrates (bioindicators); Lincoln Index (based on species identification and counting)	Surveys and laboratory analysis; identification of macroinvertebrate species; calculation of the Lincoln Index to determine water quality	The water quality of the Ancar River is classified as poor (based on pollution levels indicated by bioindicators).
10	A Study of Water Quality in Batujai Reservoir as Part of Efforts to Control Water Pollution in Central Lombok Regency, West Nusa Tenggara Province. (Melinda & Siswandi, 2021)	Batujai Reservoir, Central Lombok Regency (West Nusa Tenggar)	Physical, chemical, and microbiological parameters (e.g., TSS, BOD, COD, Fe, MPN for coliforms/fecal coliforms); water quality status (Pollution Index); control strategies (SWOT); sources and	Testing of water quality parameters against Government Regulation No. 82 of 2001; water quality status using the Pollution Index (Ministry of Environment Decree No. 115 of 2003); SWOT analysis for control strategies	Reservoir water quality is polluted: TSS 527 mg/L, BOD 6.6 mg/L, average COD 48.5 mg/L, Fe 0.39 mg/L, MPN coliform 14,000/100 mL, coliform 3,300/100 mL (exceeding quality standards); mildly polluted status (highest PI 6.34); sources: domestic wastewater, agricultural fertilizer residues, livestock feed, dead fish; strategies: source inventory, waste management, load capacity, education &

No	Research/Year	Location	Variable	Method	Result
			loads of pollutants		participation, supervision and monitoring
11	Nitrogen and Phosphorus Eutrophication and Its Management Through Fisheries in Sermo Reservoir. (Rustadi., 2009)	Sermo Reservoir, Yogyakarta Special Region (Indonesia)	N & P parameters (ammonia, nitrite, nitrate, phosphate; total N & total P) + physicochemical parameters (temperature, turbidity, TDS, TSS, dissolved oxygen, pH, free CO_2, alkalinity) + plankton	Survey/purposive sampling; monthly sampling from June 2006 to May 2007; reservoir sites (upper–middle–lower reaches) and inflow/outflow rivers; depths of 0, 2, 4 m and the bottom; analysis of total N and total P balances	Assessing eutrophication levels and water pollution based on nitrogen and phosphorus concentrations and balances; recommending eutrophication control through fisheries (utilizing fish populations to control nitrogen and phosphorus)
12	Coinfections of Aeromonas spp., Enterococcus faecalis, and Vibrio alginolyticus … with a focus on poor water quality (Abdelsalam et al., 2021)	A polyculture earthen pond in the Lake Manzala/ Port Said district, Egypt (water sources: Lake Manzala and the Bahr El-Baqar drainage channel)	Water quality (pH, hardness, Cl^-, NH_3, NO_2^-, NO_3^-, PO_4^{3-}, SO_4^{2-}) + water microbiology (TPC, coliforms, etc.) + identification of pathogenic bacteria in fish/water + mortality & histopathological lesions	Outbreak investigation: sampling of 90 fish (tilapia and African catfish) + water sampling (farm and source); physicochemical (APHA) and microbiological analysis; bacterial identification (biochemical/ Vitek2, 16S rRNA) + challenge test (experimental) + histopathology	Co-infections with major pathogens (V. alginolyticus, E. faecalis, A. caviae, A. veronii) and abnormal water quality parameters were detected; challenge tests showed the highest cumulative mortality with E. faecalis; water isolates showed high similarity or were identical to fish isolates, suggesting that the water was the source of infection
13	Impacts of water additives on water quality, production efficiency,	Ponds using a zero-water exchange system,	Water quality (DO, pH, temperature; NH_3, NO_2^-, NO_3^-) + production	8-week field trial: administration of several commercial probiotics as	The addition of probiotics to drinking water reduced toxic nitrogen compounds (NH_3/NO_2^-/NO_3^-) and improved production performance (biomass,

No	Research/Year	Location	Variable	Method	Result
	intestinal morphology, gut microbiota, and immunological responses of Nile tilapia fingerlings under a zero-water-exchange system. (Kord et al., 2022)	Egypt (Abbassa, Sharqia; research on tilapia farming ponds)	performance (biomass, SGR, FCR, survival) + gut and water microbiota (Vibrio/Bacillus counts) + gut histomorphometry + antioxidant and immune biomarkers (SOD, CAT, IgM, lysozyme, phagocytosis, protein/globulin)	water additives; periodic measurement of water quality; measurement of growth/production; microbiological analysis, intestinal histology, and immune/antioxidant parameters	SGR), enhanced intestinal morphometry and microbiota composition, and increased antioxidant biomarkers and immune response compared to the control group
14	Nitrogen and phosphorus turnover and coupling in ponds with different aquaculture species. (Bai et al., 2023)	Traditional aquaculture ponds around Lake Honghu, China (crab, fish, and crayfish ponds)	N and P in the water column (TN, TP, SRP, inorganic N forms, N:P ratio) + DOC/DO + extracellular enzyme kinetics (alkaline phosphatase/AP, leucine aminopeptidase/LAP: Km, Vmax, turnover time) + sediment P adsorption experiments (EPC_0, sediment P forms)	Multi-tank observational study; monthly measurements of nutrients and environmental parameters; enzyme kinetics analysis to assess N and P regeneration; sediment P adsorption/desorption experiments (EPC_0) and characterization of sediment P forms	P accumulation and N:P imbalance are most pronounced in fish ponds; SRP is the dominant component of TP; excess P limits DOP hydrolysis but enhances NH_4^+ regeneration through LAP activity, leading to the accumulation of NH_4^+/NO_2^-; sediments generally absorb phosphate during the cultivation months, but there is a risk of P release during certain periods
15	Assessing the impacts of zeolite on water quality,	Tilapia farm pond in Mymensi	Water quality (particularly NH_3 and NO_2^-) +	Control pond vs. zeolite treatment experiment;	Zeolite reduces ammonia and nitrite levels, improves growth performance and several

No	Research/Year	Location	Variable	Method	Result
	growth performance, heavy metal content and health condition of farmed tilapia (Oreochromis niloticus). (Hasan et al., 2023)	ngh, Bangladesh	growth/performance (various rearing stages) + hematology (blood glucose, RBC, WBC) + gut microbiota (TVC) + heavy metal content in water/sediment/fish meat & health risk assessment (EDI/THQ/HI/CR)	application of zeolite during pond preparation and periodically throughout the cultivation period; staged monitoring (0–42, 43–84, 85–126 days); analysis of heavy metals, health parameters, and consumption risks	health indicators; reduces the risk of heavy metal exposure for consumers (THQ < 1; HI < 1), and increases the safe daily intake limit for fish
16	Relationship between Nitrogen Dynamics and Key Microbial Nitrogen-Cycling Genes in an Intensive Freshwater Aquaculture Pond. (Yan et al., 2024)	Three intensive freshwater ponds (hybrid snakehead) in Sanjiao Town, Zhongshan City, China; sampling from June to November 2022	N dynamics (NH_4^+-N, NO_2^--N, NO_3^--N, TNS, nutrient flux) + SPM & Chl-a + abundance of functional nitrogen cycle genes (AOA amoA, AOB amoA, narG, nirS, nirK, anammox 16S rRNA) in the water column and sediment	Periodic (mid-month) sampling of water and sediment; quantification of nitrogen cycle genes (qPCR) and multivariate statistical analysis (RDA, ridge regression) to correlate environmental variables with genes	The abundance of N cycle genes exhibits spatial-temporal patterns and correlates with N flux variables; the main factors influencing gene distribution in sediments include NH_4^+-N and NO_3^--N fluxes as well as N/TN flux in suspended particulate matter (SPM); the results are used to inform management recommendations for intensive ponds
17	The health risk assessment of heavy metals to human health through the consumption of Tilapia spp and catfish	Lake Mariut, Egypt	Heavy metal concentrations in fish meat (As, Cd, Pb, Hg, Al) + muscle biochemical composition + antioxidant	Sampling of several species of tilapia (O. niloticus, O. aureus, T. zillii) and catfish (C. gariepinus); analysis of	Average metal concentration order: Pb > As > Cd > Al > Hg; Cd and Pb (all species) as well as Hg (some tilapia) exceeded the maximum limits; the THQ for As > 1 and the CR for As exceeded the permitted

No	Research/Year	Location	Variable	Method	Result
	caught from Lake Mariut, Egypt. (Hasanein et al., 2022)		activity (SOD, CAT, GPx, GR, GSH) + health risk assessment (EDI, THQ, CR) in different age groups	heavy metals and biomarkers; calculation of dietary risk indices/parameters (THQ, CR) compared to FAO/WHO/regulatory thresholds	values → indicating a potential health risk to consumers
18	A comprehensive review on potential heavy metals in the environment: Persistence, bioaccumulation, ecotoxicology, and agricultural impacts.(Shehu et al., 2025)	Global (review/literature review)	Heavy metals in the environment (persistence, bioaccumulation, toxicity/ecotoxicology) + impacts on agriculture/soil + remediation approaches/environmental management	A comprehensive review of the scientific literature on sources, environmental behavior, bioaccumulation mechanisms, health and ecological impacts, and remediation/management options.	Summarizing the sources and risks of heavy metals, mechanisms of accumulation in the food chain, ecological and agricultural consequences, and recommended mitigation/remediation strategies.

DISCUSSION

Water Quality as a Direct Determinant of Biological Performance and Productivity in Tilapia Aquaculture

Physiologically, water quality (temperature, pH, dissolved oxygen (DO), and inorganic nitrogen forms such as ammonia–nitrite–nitrate) plays a direct role in regulating metabolism, appetite, feed conversion, stress response, and disease susceptibility in Oreochromis niloticus. Evidence from recent reviews indicates that deviations in temperature and DO from optimal aquaculture conditions can trigger chronic stress that reduces growth and increases the risk of mortality, particularly in intensive systems with high organic loads. Water quality is also a key component in the modern tilapia welfare framework, where parameters such as DO, ammonia, pH, and stocking density are viewed as management “drivers” that must be monitored to prevent declines in welfare and production performance (Muahiddah et al., 2023).

In aquaculture practice, the accumulation of total ammonia nitrogen (TAN) and nitrite often becomes a critical issue because these substances are toxic and can rise rapidly in ponds with high feed inputs and limited water exchange (Abd et al., 2022). An open-access study based on hematological indices in tilapia also showed that low DO and high ammonia levels correlate with changes in blood parameters (indicators of stress and physiological disturbances), so that water quality is not only an “environmental” issue but also a “fish health” issue that affects production stability (Scabra et al., 2022). In the context of sustainability, production stability (consistent production per cycle and low risk of harvest failure) is a prerequisite for tilapia aquaculture to truly contribute to the sustainable availability of local animal protein (Simanjuntak et al., 2021).

Nitrogen, Phosphorus, and Organic Matter: The Most Relevant Mechanisms of Water Quality Degradation in Lombok's Pond and Freshwater Systems

From the perspective of pond ecosystem processes, feed inputs are the primary sources of nitrogen and phosphorus, which are subsequently transformed into ammonia, nitrite, and nitrate, and trigger an increase in dissolved/suspended organic matter that reduces dissolved oxygen (DO) by increasing biological oxygen demand (BOD) (Dermawan et al., 2025). In intensive aquaculture systems, nitrogen dynamics are also determined by microbial communities and functional genes involved in the nitrogen cycle in the water–sediment system, which respond to changes in nutrient flux and suspended particles; thus, water quality control requires an understanding of biogeochemical processes, not merely "momentary parameter testing" (Yan et al., 2024). Findings regarding the relationship between nitrogen dynamics and the abundance of nitrification/denitrification genes provide a scientific basis that pond management (aeration, feed regulation, sediment management, biofilters/probiotics) can shift nitrogen transformation pathways toward a safer direction for fish.

This relationship becomes particularly relevant when the quality of source water (rivers, reservoirs, irrigation canals) has already been impacted by pollutants from domestic and agricultural activities, as ponds will "inherit" baseline nutrient levels and microbial indicators of pollution. An open-access study in Lombok using the Pollution Index revealed that microbiological parameters (total/fecal coliforms) exceeded quality standards in certain river waters, thereby reinforcing the argument that source water quality in Lombok needs to be addressed as part of a sustainable aquaculture strategy. (Prayitno et al., 2023). At the risk level, microbiological contamination and increased organic load can increase the likelihood of opportunistic diseases and reduce product quality, which ultimately disrupts the reliability of fish supply as a local food source (Emam, 2018).

Evidence of Effective and Context-Appropriate Water Quality Management Interventions for Aquaculture Farmers

The literature from the past five years indicates that interventions based on "water additives" can improve water quality while enhancing tilapia performance, primarily by reducing toxic nitrogen compounds and improving the environmental microbiota (Saleh et al., 2025). One intervention consistently reported as effective is the application of zeolite, which can reduce ammonia and nitrite levels and is associated with improved growth and health indicators in tilapia in pond trials, while also reducing some of the risk of heavy metal exposure in the food chain (Hasan et al., 2023). These findings are important for Lombok because several tilapia farming sites in West Nusa Tenggara (NTB) operate in small-scale pond systems and water bodies vulnerable to agricultural runoff, making practical "low-cost water treatment" approaches easier to adopt than expensive technologies.

On the other hand, water quality monitoring and control based on monitoring systems (e.g., temperature–pH–DO–ammonia sensors) are increasingly recommended to enable a rapid response to parameter deviations, particularly during periods of extreme weather and fluctuations in water flow (Dermawan et al., 2025). Evidence from open-access studies at tilapia farming/hatchery sites in Indonesia also indicates that the key parameters routinely measured are temperature, pH, DO, and ammonia, which align with the primary biological determinants in the latest tilapia review (Abd et al., 2022). In the context of Lombok, a monitoring approach becomes increasingly important because several water quality studies in the NTB region (including Lombok) indicate spatial variability in water quality and the presence of sites classified as "lightly to moderately polluted" according to pollution indices;

thus, water withdrawal without adaptive controls risks causing fluctuations in pond water quality (Prayitno et al., 2023).

The Relationship Between Water Quality, Aquaculture Sustainability, and Food Security in Lombok: Causal Pathways and Implications

Conceptually, the strongest causal pathway in this SLR synthesis is as follows: the quality of the source water and the quality of the pond water determine the health, growth, and survival of tilapia, which in turn determine productivity, inter-seasonal production stability, and the economic sustainability of farming households. It is this production stability that bridges tilapia farming with local food security, as the availability of fish as a source of animal protein becomes more assured, prices are more stable, and community access to food improves when the risk of crop failure decreases (Stetkiewicz et al., 2022). The literature identifies environmental management (including water quality) as a prerequisite for aquaculture's contribution to the food system, as without controlling environmental impacts, production expansion could instead lead to counterproductive degradation of water resources (Obirikorang & Quagrainie, 2024).

In the context of Lombok Island an archipelago facing pressures from urbanization and intensive agriculture in several watersheds issues related to source water quality (organic load, nutrients, and microbiological contamination) can become a "bottleneck" for the sustainability of tilapia farming if not integrated into watershed management (Prayitno et al., 2023). Therefore, your SLR discussion logically points to the urgency of integrating water management policies (domestic wastewater control, sanitation, fertilizer runoff reduction) with aquaculture practices (feed management, aeration, biofilters/zeolites, sensor monitoring) to maintain "water quality carrying capacity" for stable fish production (Yan et al., 2024). At the household level, improvements in water quality are also linked to product quality and food safety, as the quality of the aquatic environment can influence the risk of contaminants and the health status of fish, ultimately affecting consumer acceptance (Hasan et al., 2023).

CONCLUSION

Freshwater quality is a key determinant of the sustainability of tilapia aquaculture because it governs physiological processes, health, and productivity, which ultimately determine the stability of the fish supply as a source of protein for the community. The key parameters that most consistently emerge as determinants are temperature, pH, dissolved oxygen (DO), as well as nitrogen (ammonia, nitrite, nitrate) and organic load, which affect BOD and DO depletion. In the context of Lombok Island, the literature indicates that some river waters face water quality pressures (particularly microbiological indicators such as coliforms) that must be addressed as an upstream–downstream issue, as they have the potential to affect the baseline water quality for aquaculture systems. Realistic water quality management interventions supported by current literature include strengthening parameter monitoring (both manual and sensor-based), controlling feed inputs and organic loading, and applying water quality improvement materials or agents such as zeolite or additives proven to reduce toxic nitrogen compounds and enhance aquaculture performance.

Strategically, tilapia farming's contribution to Lombok's food security will be most significant if it is developed through the integration of watershed management (control of domestic waste and agricultural runoff) with adaptive farming practices based on water quality monitoring and the prevention of environmental degradation. Moving forward, the most urgent research need is an integrated study linking water quality, aquaculture productivity, and food security indicators (availability, access, utilization, stability) specifically at the regional scale of Lombok so that policy recommendations become more precise and measurable.

ACKNOWLEDGEMENT

The author would like to express his gratitude to all parties who have helped ensure the smooth running of this research, both in the process of data collection and preparation of the manuscript until the research was completed.

REFERENCES

Abd, M. E., Hack, E., El, M. T., Maha, S., Heba, M. N., Amira, M. S., Tahan, M. El, Soliman, S. M., & Khafaga, A. F. (2022). Effect of environmental factors on growth performance of Nile tilapia (Oreochromis niloticus). *International Journal of Biometeorology*, 2183–2194. https://doi.org/10.1007/s00484-022-02347-6

Abdelsalam, M., Ewiss, M. A. Z., Khalefa, H. S., Mahmoud, M. A., Elgendy, M. Y., & Abdel-moneam, D. A. (2021). Microbial Pathogenesis isolated from farmed Nile tilapia and African catfish in Egypt , with an emphasis on poor water quality. *Microbial Pathogenesis*, *160*(September), 105213. https://doi.org/10.1016/j.micpath.2021.105213

Bai, D., Li, X., Liu, Z., Wan, L., Song, C., & Zhou, Y. (2023). Nitrogen and phosphorus turnover and coupling in ponds with different aquaculture species. *Aquaculture*, *563*(P2), 738997. https://doi.org/10.1016/j.aquaculture.2022.738997

Boyd, C. E., & Mcnevin, A. A. (2024). Reviews in Fisheries Science & Aquaculture Resource Use and Pollution Potential in Feed- Based Aquaculture Resource Use and Pollution Potential in Feed-Based Aquaculture. *Reviews in Fisheries Science & Aquaculture*, *32*(2), 306–333. https://doi.org/10.1080/23308249.2023.2258226

Brahmana, S., Achmad, F., & Sumarriani, Y. (2010). PENCEMARAN NUTRIEN (ZAT HARA) DAN KUALITAS AIR WADUK KASKADE BATUJAI DAN PENGGA DI P . LOMBOK. *Jurnal Sumberdaya AIr*, *6*(1), 1–100.

BRIDA. (2024). *JUDUL KAJIAN PENGEMBANGAN POTENSI DAERAH ALIRAN SUNGAI (DAS)*. https://brida.mataramkota.go.id/

Dermawan, A., Bagus, S., Scabra, A. R., Marzuki, M., Fitria, S., & Suhendri, S. (2025). *Study of Water Quality Suitability in Sub-Watersheds for Tilapia , Gurame , and Catfish Farming in Lingsar Subdistrict , West Lombok Regency*. *11*(10), 513–517. https://doi.org/10.29303/jppipa.v11i10.12981

Dindasari, N. (2023). *KAJIAN PENCEMARAN PERAIRAN SUNGAI BABAK AKIBAT BUANGAN AIR LINDI TPA REGIONAL KEBON KONGOK*.

Emam, W. (2018). The welfare of farmed Nile tilapia : a review. *Frontiers in Veterinary Science*, *7*, 13. https://doi.org/10.3389/fvets.2025.1567984

Haque, M. M. (2025). *Review Article Potential Role of Aquaculture in Advancing Sustainable Development Goals (SDGs) in Bangladesh*. *2025*. https://doi.org/10.1155/are/6035730

Hasan, M., Mahfujul, M., Hasan, N. A., Bashar, A., Ahammad, S., & Tofazzal, M. (2023). Assessing the impacts of zeolite on water quality , growth performance , heavy metal content and health condition of farmed tilapia (Oreochromis niloticus). *Aquaculture Reports*, *31*(December 2022), 101678. https://doi.org/10.1016/j.aqrep.2023.101678

Hasanein, S. S., Mourad, M. H., & Haredi, A. M. M. (2022). Heliyon The health risk assessment of heavy metals to human health through the consumption of Tilapia spp and cat fi sh caught from Lake Mariut , Egypt. *Heliyon*, *8*(7), e09807. https://doi.org/10.1016/j.heliyon.2022.e09807

Jupri, A., Aisyah, N., Hidayati, L., & Husain, P. (2025). MONITORING KUALITAS AIR BERDASARKAN PARAMETER FISIKA, KIMIA DAN BIOLOGI DI SUNGAI BELIMBING, LOMBOK TIMUR. *Educatorial : Jurnal Ilmiah Ilmu Pendidikan*, *5*(3), 262–271.

Khairuddin., Yamin, M., & Syukur, A. (2016). Analisis Kualitas Air Kali Ancar dengan Menggunakan Bioindikator Makroinvertebrata. *Jurnal Biologi Tropis*, *16*(2), 10–22.

Kord, M. I., Maulu, S., Srour, T. M., Omar, E. A., Farag, A. A., Aziz, A., Nour, M., Hasimuna, O. J., Abdel-tawwab, M., & Khalil, H. S. (2022). Impacts of water additives on water quality , production efficiency , intestinal morphology , gut microbiota , and immunological responses of Nile tilapia fingerlings under a zero-water-exchange system. *Aquaculture*, *547*(September 2021), 737503. https://doi.org/10.1016/j.aquaculture.2021.737503

Makori, A. J., Abuom, P. O., Kapiyo, R., Anyona, D. N., & Dida, G. O. (2017). Effects of water physico-chemical parameters on tilapia (Oreochromis niloticus) growth in earthen ponds in Teso. *Fisheries and Aquatic Sciences*, *20*(30), 1–10. https://doi.org/10.1186/s41240-017-0075-7

Mandalika, B. A. (2018). *Studi Penentuan Status Mutu Air Dengan Menggunakan Metode Indeks Pencemaran dan Water Quality Index (WQI) Di Sungai Dodokan Lombok, Nusa Tenggara Barat*. Universitas Brawijaya.

Melinda, T., & Siswandi, E. (2021). KAJIAN KUALITAS AIR WADUK BATUJAI DALAM UPAYA PENGENDALIAN PENCEMARAN AIR DI KABUPATEN LOMBOK. *Jukung Jurnal Teknik Lingkungan*, *7*(2), 211–224.

Mendrofa, K. H., Zebua, E. K., Studi, P., Daya, S., Sains, F., Teknologi, D., & Nias, U. (2025). *Analisis Faktor-Faktor yang Mempengaruhi Produktivitas Budidaya Ikan Nila di Indonesia : Studi Literatur*. *1*.

Muahiddah, N., Azhar, F., Marzuki, M., Rachmat, A., & Rangga, S. (2023). Penyuluhan Penanggulangan Penyakit Ikan Bagi Pembudidaya Nila. *Jurnal Teknologi Dan Pengabdian Masyarakat*, *3*(2), 53–58. https://doi.org/http://dx.doi.org/10.36526/tekiba.v3i2.3228

Mulyana, W., & Pratiwi, N. A. H. (2020). *Laporan Kajian Perkotaan Mataram*. https://mataramkota.go.id/

Obirikorang, K. A., & Quagrainie, K. (2024). Editorial : Sustainable aquaculture production for improved food security. *Frontiers in Veterinary Science*, 3. https://doi.org/DOI 10.3389/fsufs.2024.1485956

Prayitno, G. H., Irawan, J., & Gunawan, L. A. (2023). *Analysis of River Water Quality Based on Pollution Index Water Quality Status , Lombok District , NTB*. *9*(3), 1602–1608. https://doi.org/10.29303/jppipa.v9i3.4591

Radosavljevic, S., Venturino, E., Acotto, F., Wang, Q., Su, J. I. E., Gasparatos, A., & Feb, P. E. (n.d.). *depends on the local context and characteristics of producers*. 1–24.

Rossignoli, C. M., Manyise, T., Mashisia, K., Nasr-allah, A. M., Brako, E., Henriksson, P. J. G., Dam, R., Lozano, D., Tran, N., Roem, A., Badr, A., Sbaay, A. S., Moruzzo, R., Tilley, A., Charo-karisa, H., & Gasparatos, A. (2023). Tilapia aquaculture systems in Egypt : Characteristics , sustainability outcomes and entry points for sustainable aquatic food systems. *Aquaculture*, *577*(March), 739952. https://doi.org/10.1016/j.aquaculture.2023.739952

Rustadi. (2009). Eutrofikasi Nitrogen dan Fosfor Serta Pengendaliannya Dengan Perikanan Di Waduk Sermo. *Jurnal Manusia Dan Lingkungan*, *16*(3), 176–186.

Saleh, H. H. E., Attia, E. I., Abdel-aziz, M. F. A., Abdelwarith, A., Younis, E. M., Helal, A. M., Davies, S. J., & Soaudy, M. R. (2025). Evaluation of some commercial water additives of probiotics and yucca on water quality , blood biochemistry , sex hormones , reproductive and fry performance of Nile tilapia (Oreochromis niloticus) that were reared under unchanged water. *Italian Journal of Animal Science*, *24*(1), 1224–1238. https://doi.org/10.1080/1828051X.2025.2506735

Scabra, A. R., Afriadin, A., & Marzuki, M. (2022). Efektivitas Peningkatan Oksigen Terlarut Menggunakan Perangkat Microbubble Terhadap Produktivitas Ikan Nila (Oreochromis niloticus). *Jurnal Perikanan Unram*, *12*(1), 13–21. https://doi.org/10.29303/jp.v12i1.269

Shehu, L., Victoria, O., & Shola, K. (2025). A comprehensive review on potential heavy metals in the environment : Persistence , bioaccumulation , ecotoxicology , and agricultural impacts. *Ecological Frontiers*, *September*, 16. https://doi.org/10.1016/j.ecofro.2025.10.009

Simanjuntak, F. J., Nirmala, K., & Yuliana, E. (2021). Pengaruh Sistem Resirkulasi Terhadap Kualitas Air, Kelulushidupan Benih Ikan Gurame (Osphronemus Goramy), Serta Kelayakan Usaha. *Pelagicus*, *2*(1), 23. https://doi.org/10.15578/plgc.v2i1.9303

Stetkiewicz, S., Norman, R. A., Allison, E. H., Andrew, N. L., Ara, G., Banner-stevens, G., Belton, B., & Beveridge, M. (2022). *Seafood in Food Security : A Call for Bridging the Terrestrial-Aquatic Divide*. *5*(January), 1–11. https://doi.org/10.3389/fsufs.2021.703152

Wiadnya, I. B., Gunati., & Dinasia, S. W. (2019). STUDI KUALITAS AIR SECARA FISIKADAN KIMIA SUNGAI ANCAR –KOTA MATARAM. *Jurnal Pengabdian Masyarakat Sasambo*, *17*(1), 1–11. https://doi.org/10.32807/jpms.v1i1.371

Yan, Y., Zhou, J., Du, C., Yang, Q., Huang, J., Wang, Z., Xu, J., & Zhang, M. (2024). *Relationship between Nitrogen Dynamics and Key Microbial Nitrogen-Cycling Genes in an Intensive Freshwater Aquaculture Pond*.

Zamroni, Y., Hadi, I., Muspiah, A., & Candri, D. A. (2017). *Monitoring kualitas air sungai aik ampat menggunakan makroinvertebrata biotik indeks*. *3*(3), 105–109.