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Enhancing fisheries productivity through improved fish pond management in Uasin Gishu County, Kenya: A comprehensive review

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Aquaculture is increasingly recognized as a cornerstone of global food security and economic development. However, its potential remains underexploited in many developing regions, including Uasin Gishu County in Kenya. This review synthesizes local and global research on the challenges and opportunities for enhancing fisheries productivity in the county through improved pond management practices. By examining production systems, water quality variables, and nutritional management, this review presents practical strategies for sustainable intensification of aquaculture in the region. The findings underscore the need for coordinated efforts among stakeholders to unlock the full potential of aquaculture in Uasin Gishu County, positioning it as a viable pathway toward rural development and long-term food security. The recommendations focus on capacity building, resource access, policy support, and integrated farming approaches aimed at improving productivity, profitability, and environmental sustainability.

Key words: Aquaculture, economic development, environmental sustainability, fisheries, yields.

INTRODUCTION

Aquaculture is expected to expand significantly in the coming decades to meet growing demand. Generally, 50% of fish production comes from China and 82% from Asia. The expansion is fueled by declining wild fish populations, rising needs for animal-based protein, and a growing acknowledgment of aquaculture's role in supporting rural economies, alleviating poverty, and enhancing food availability (Khan et al., 2025). Aquaculture has emerged as a critical contributor to Kenya's food production landscape, currently accounting for approximately 14% of the nation's total fish output.
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This growth trajectory reflects deliberate and strategic government efforts to promote the sector as a sustainable alternative to capture fisheries, which have faced increasing pressure in recent years (Fonda et al., 2021). Located in the elevated terrain of the Rift Valley, Uasin Gishu County offers an ideal environment for aquaculture. Its conducive climatic conditions, coupled with a growing focus on farming species such as Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*), position it as a promising hub for fish farming activities (Obwanga et al., 2020).

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Aquaculture in Uasin Gishu has yet to reach its full potential, as evidenced by the county's 1,728 active fish ponds producing only around 593,000 kg of fish per year, an output valued at approximately Ksh. 285.9 million. However, several constraints hamper growth in this sector. Key challenges include poor water quality management, inefficient feeding techniques, limited extension services, and weak disease control (Munguti et al., 2021). Compounding these issues are inadequate access to quality fingerlings, high costs and inconsistent supply of commercial fish feed, and insufficient cold storage infrastructure. Many fish farmers also lack essential technical training, while cultural preferences and relatively low local fish consumption reduce market demand. Additionally, climate variability and limited water resources strain pond operations, and weak farmer group structures limit collective bargaining power and access to credit or inputs. Addressing these barriers comprehensively is crucial to unlocking the sector's full potential and transforming aquaculture into a robust contributor to the county's economy. This review seeks to identify effective fish pond management practices in Uasin Gishu County to improve fisheries productivity while evaluating their social and environmental impacts on local communities.

MATERIALS AND METHODS

This review systematically analyzed literature on enhancing fisheries productivity through improved fish pond management in Uasin Gishu County, Kenya. A comprehensive search was conducted using databases such as Google Scholar, Scopus, and PubMed, along with government reports and policy documents. Relevant studies were selected based on inclusion criteria, focusing on fish pond management, aquaculture productivity, and related socioeconomic factors within the last 10 to 15 years. Key themes analyzed included water quality management, feeding practices, stocking density, disease control, and policy influences. A thematic analysis was conducted to identify trends, challenges, and best practices, with comparative assessments across studies. The findings were synthesized to provide insights and recommendations for improving fish pond management and fisheries productivity in the region.

SYSTEM-BASED AQUACULTURE PRODUCTION IN KENYA

Kenyan aquaculture is structured around three primary systems; extensive, semi-intensive, and intensive. They vary in terms of input levels, management intensity, and productivity (Fonda et al., 2021; Munguti et al., 2024). Each system caters to specific environmental, economic, and technological contexts.

Extensive systems

Extensive systems are characterized by minimal external input, relying on natural productivity within water bodies such as farm dams, reservoirs, and wetlands. This system is primarily practiced in rural areas of Central and Rift Valley regions where infrastructure and capital investment are limited. Fish are usually stocked at low densities, and no supplemental feeding or fertilization is provided. As a result, yields are modest, typically ranging between 500 and 1,500 kg per hectare per year, and contribute approximately 10% of Kenya’s total aquaculture output (Munguti et al., 2024).

Extensive aquaculture systems in Kenya are affordable and eco-friendly but often suffer from low productivity due to challenges like poor water quality, predation, and seasonal changes. Despite these drawbacks, they remain vital for smallholder farmers, especially in low-resource settings, and contribute significantly to integrated and subsistence farming (Munguti et al., 2021).

Semi-intensive systems

Semi-intensive systems represent the most common approach in Uasin Gishu County. These systems incorporate moderate external inputs, including supplementary feeding and fertilization, to enhance natural productivity and support higher stocking densities. Fish are cultured in a variety of pond types; earthen, concrete, plastic-lined, and geomembrane-lined, which allow for greater control over the aquatic environment. This model is particularly suited to rural areas with access to reliable water sources and moderate financial resources. Species such as *O. niloticus* and *C. gariepinus* are commonly raised due to their adaptability and market demand. Despite its potential, the semi-intensive system is constrained by challenges such as poor feed quality, limited farmer knowledge on pond management, and inadequate disease control measures (Fonda et al., 2021).

Intensive systems

Intensive aquaculture systems, including raceways and Recirculating Aquaculture Systems (RAS), are technologically advanced operations designed for high-density fish production with optimal efficiency. These systems require substantial capital, specialized infrastructure, and expert management. Raceways, for example, maintain continuous water flow and aeration to support high biomass, while RAS recycles water within closed-loop systems, significantly reducing water use and environmental discharge. Intensive systems offer high yields per unit area, and are increasingly promoted for urban aquaculture and commercial ventures. However, due to their complexity and cost, they remain largely inaccessible to small-scale farmers in Uasin Gishu County and other rural regions (Munguti et al., 2024;

Table 1. Water quality parameters and their standard values.

Parameter	Category	Standard value
Dissolved oxygen (DO)	All	>4.0 mg/L
Temperature	All	Species dependent
pH	All	7.5 – 8.5
Salinity	Fresh water	< 0.5 ppt
	Brackish water	<0.5 – 30 ppt
	Salt water	30 – 40 ppt
	Optimum	15 – 25 ppt
Carbon dioxide (CO_2)	-	< 10 ppm
Ammonia ($NH_4^+/NH_4 - N$)	-	0 – 0.5 ppm
Nitrate: NO_3^-	-	< 50 mg/L
Hardness	-	40 – 400 ppm
Alkalinity	-	50 – 300 ppm
Hydrogen Sulphide (H_2S)	-	0 ppm
Biochemical Oxygen Demand (BOD)	-	< 50 mg/l

Source: Food and Agricultural Organisation (2013).

Fonda et al., 2021).

Nonetheless, they represent a promising model for future development as technology becomes more affordable and local capacity is built.

WATER QUALITY: THE FOUNDATION OF POND PRODUCTIVITY

Water quality is a critical determinant of aquaculture success, directly influencing fish health, growth performance, survival rates, and overall system sustainability (Onyango et al., 2023). In Kenya and other parts of East Africa, poor water management is a common cause of reduced aquaculture productivity (Wanja et al., 2020). Effective management of key water parameters is essential to create optimal conditions for cultured species such as *O. niloticus* and *C. gariepinus.* Table 1 shows water quality parameters and their standard values.

Temperature

Temperature regulates biochemical and physiological processes in aquatic organisms, affecting metabolic rate, feeding activity, immune function, and oxygen solubility. Tropical freshwater fish species like Nile tilapia and African catfish perform best within a temperature range of 25 to 32ºC (Wanja et al., 2020). Temperatures below 10ºC are lethal for both tilapia and African catfish, while prolonged exposure to high temperatures above 35ºC compromises reproductive efficiency and increases disease susceptibility (Mramba and Kahindi, 2023). Furthermore, temperature fluctuations influence oxygen dynamics; a 10°C increase can double metabolic activity and oxygen demand, intensifying the risk of hypoxia in poorly aerated ponds. Research in Uasin Gishu County underscores the temperature sensitivity of nutrient cycling and chemical processes in fish ponds. According to a report by Hildah et al. (2022), county officials and aquaculture experts observed that rising temperatures influence the breakdown of organic matter and fertilizer efficiency, directly affecting oxygen levels and water quality in fish ponds.

pH

The pH of pond water reflects its acidity or alkalinity and should be maintained within the optimal range of 7.5 to 8.5 for most warm-water species. pH levels in aquatic systems fluctuate daily, rising during the day due to photosynthesis and falling at night as respiration increases CO_2 levels. Water with low buffering capacity is especially vulnerable to drastic swings, which can stress fish, impair nutrient uptake, and reduce feed efficiency. In fish ponds within Uasin Gishu County, pH levels generally range between 6.3 and 8.5, which align with recommended safe limits for aquaculture. However, seasonal changes and runoff from nearby agricultural activities can cause fluctuations, potentially stressing fish if values fall below 6 or rise above 9. Regular monitoring is therefore essential to maintain optimal pond conditions.

Dissolved oxygen (DO)

Dissolved oxygen is essential for fish respiration and the aerobic breakdown of organic matter. Ideal DO levels range between 5 to 6.5 mg/L, with values below 3.5 mg/L being critical for fish survival. DO is influenced by water temperature, biomass load, photosynthetic activity, and organic inputs. In Uasin Gishu and other highland counties, oxygen depletion often results from overstocking, unregulated use of organic fertilizers, and poor aeration practices. Excessive phytoplankton or algal blooms driven by nutrient overload can exacerbate oxygen crashes, especially at night when photosynthesis ceases and respiration dominates (Eze and Ajmal, 2020). Mitigation strategies include proper pond design, use of aerators or paddle wheels, regulated feeding, and water exchange.

Nitrogen Compounds (Ammonia, Nitrites, Nitrates)

Nitrogenous compounds; ammonia, nitrites, and nitrates, are common in aquaculture systems and can be harmful if not well managed. Ammonia is the most toxic, especially in warm, high-pH water, and should be kept below 0.5 ppm.

Nitrites, which disrupt oxygen transport in fish, are dangerous even at low levels and should remain under 1 ppm. Nitrates, though less toxic, contribute to eutrophication and oxygen depletion. Controlling these compounds requires proper feeding, stocking, and aeration, along with biofiltration to support beneficial bacteria that convert harmful waste into less toxic forms (Mramba and Kahindi, 2023; Ivan et al., 2024).

Salinity

While aquaculture in Uasin Gishu primarily involves freshwater systems, salinity can vary due to groundwater composition, fertilizer runoff, or proximity to saline soils. Tilapia and catfish exhibit tolerance to moderate salinity, but early life stages, particularly fry, are vulnerable. Studies show survival drops significantly at salinities above 5 ppt, with mortality occurring beyond 10 ppt in some species (Abbas et al., 2023).

Microbial contamination

Microbial contamination, especially by fecal coliforms and Escherichia coli, is a major threat to pond health. High bacterial loads degrade water quality, reduce DO, and increase disease risks. Pathogenic bacteria have been linked to hemorrhagic septicemia, skin lesions, and poor growth performance (Kongprajug et al., 2021; Mzula et al., 2021).

Contamination sources include livestock runoff, poor pond hygiene, and overcrowding. Preventive measures include regular water testing, use of probiotics, pond liming, organic debris removal, and isolation from livestock farming zone (Milijasevic et al., 2024).

FEEDING PRACTICES AND NUTRITIONAL MANAGEMENT

Feeding represents the largest operational cost in aquaculture, accounting for 40 to 60% of total production expenses in semi-intensive systems, and up to 70% in intensive operations (Munguti et al., 2021; Zlaugotne et al., 2022). In Uasin Gishu County, many farmers rely on low-cost, single-ingredient feeds such as maize bran, wheat bran, or cassava peels, which are readily available but nutritionally imbalanced. Others use poultry or pig feeds, which are not formulated for fish and often lack the essential nutrients needed for optimal growth.

Nutritional deficiencies

The use of unbalanced or low-protein feeds results in poor growth performance, high feed conversion ratios, and contributes to pond pollution through excess waste (Musyoka et al., 2020). Essential nutrients like proteins, lysine, methionine, and fatty acids are often deficient in farm-made feeds. Most commonly farmed fish species require 25 to 32% dietary protein, with higher levels needed in early growth stages. Lipids, ideally ranging from 8 to 12%, serve as a dense energy source and support immune function. While carbohydrates are not essential, they spare protein for tissue development and energy metabolism.

Local feed innovations

Farmers have experimented with local feed combinations such as Omena (*Rastrineobola argentea*) meal, freshwater shrimp (*Caridina niloticus*), termites, and rice bran, often mixed to form semi-balanced pellets. While promising, these formulations typically lack standardization and quality control, limiting their effectiveness (Fregene et al., 2020; Nwuba et al., 2022). There is a pressing need for training in feed formulation, investment in mini-feed mills, and access to affordable commercial feeds tailored to local conditions.

Ethical and economic concerns

The heavy reliance on fishmeal and animal by-products for high-protein feed raises economic and ethical concerns. Fishmeal is highly digestible and rich in essential amino acids, but its price volatility and limited supply make it inaccessible for many smallholder farmers

(Singh et al., 2025). There are also growing sustainability and food security concerns about using wild-caught fish to feed farmed fish, particularly in food-insecure regions (Munguti et al., 2021; Das and Ghosh, 2023). As a result, attention is shifting toward plant-based proteins (e.g., soybean meal) and insect-based feeds (e.g., black soldier fly larvae), which offer potential for cost-effective and sustainable feed alternatives (Kandathil et al., 2020; Opiyo et al., 2023). However, more research, capacity building, and policy support are required to mainstream these innovations in local aquaculture systems.

CONCLUSION

Improved fish pond management is a cornerstone for enhancing fisheries productivity in Uasin Gishu County. This review underscores that targeted interventions, particularly in water quality regulation, feed optimization, and disease control, can significantly elevate fish growth rates, survival, and overall yield. Addressing water quality issues such as dissolved oxygen levels, pH balance, and nutrient loading ensures a stable and healthy aquatic environment, which is fundamental for optimal fish performance. Similarly, adopting scientifically formulated feeds and implementing efficient feeding regimes not only reduces waste and production costs but also maximizes feed conversion efficiency, leading to better growth outcomes. Moreover, strengthening disease prevention through regular pond monitoring, biosecurity measures, and timely treatment protocols minimizes losses and enhances the resilience of aquaculture systems. Collectively, these management improvements empower fish farmers to operate more sustainably and profitably. Beyond individual farm gains, the broader implications are substantial. Enhanced pond management contributes to national goals of food security by increasing the availability of affordable, high-quality protein, supports rural livelihoods, and stimulates local economies through job creation, value chain development, and increased market participation. As Kenya continues to prioritize the blue economy, investing in improved aquaculture practices, especially at the pond level, will be vital for unlocking the sector's full potential.

LIMITATION

While this review provides valuable insights into enhancing fisheries productivity through improved fish pond management in Uasin Gishu County, its geographical focus presents a limitation. Although Uasin Gishu offers a relevant context for examining pond management practices in Kenya, its distinct climatic conditions, water resources, and aquaculture systems may not mirror those found in other regions. As such, the applicability of the findings to broader national or regional settings may be limited. Acknowledging this constraint is important for accurately interpreting the review’s conclusions and for guiding future research aimed at promoting sustainable and productive aquaculture practices across diverse Kenyan contexts.

RECOMMENDATIONS

To enhance fish farming productivity in Uasin Gishu County, it is crucial to focus on several key areas. First, capacity building for farmers through training on water quality monitoring, feed formulation, and disease management will help improve their technical skills. Access to quality resources, such as water testing kits, aerators, and high-quality feeds, should be made more affordable through subsidies or credit facilities. Policymakers should also support research on locally adapted fish species and cost-effective aquaculture technologies to promote innovation. Encouraging sustainable practices, such as integrating aquaculture with agriculture and adopting polyculture systems, can help optimize resource use and boost productivity. Additionally, strengthening disease management through better biosecurity measures, vaccination programs, and improved access to veterinary services will minimize fish mortality and improve farm yields. By addressing these areas, the fish farming sector in Uasin Gishu can thrive, contributing to increased productivity, sustainability, and food security.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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