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Feasibility of hydropower reservoirs for fish cage Aquaculture: A strategy for fish farming in drought risk areas in Kenya

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A B S T R A C T

A significant portion of the Arid and Semi-Arid Lands rural population in Kenya suffers from social challenges linked to hunger, starvation, and malnutrition. The existing hydropower dams in these areas can be leveraged upon for fish production through the adoption of cage culture. This study sought to assess the suitability and feasibility of these dams for cage culture as a strategy for socio-economic and nutritional empowerment of the rural communities. In this study, a survey was conducted including fish farmers, fishermen, and communities who use the dam waters for domestic and agricultural purposes. The main research approaches were semi-structured questionnaires for in-depth, one-on-one interviews with participants. Descriptive and inferential statistics were used to summarize the data sets on socio-demographic indicators, such as age, economic status, education, and economic activities. The Majority of the respondents 49.6% cited fishing from the dam as the most important benefit accrued although the dams have been overfished and the harvests are dwindling from the observation. In the survey, 26.8% of the respondents identified water level fluctuation as the main challenge to cage establishment, followed by theft (25%) and wild animal menace (16.07%). Water quality analysis revealed both in situ parameters (Dissolved oxygen, temperature and pH) and nutrient concentrations as within levels acceptable for fish farming.

INTRODUCTION

Food insecurity is a major global concern while eliminating extreme poverty and hunger is the first Millennium Development Goal (MDG 1), therefore, fulfilling it is essential to achieving the other seven MDGs (Lomazzi et al., 2014). Aquaculture, often known as fish farming, is a practical and cutting-edge method for boosting food security in Kenya's drought-prone regions. Fish farming is quickly gaining popularity among other rural livelihoods, such as agriculture, due to its unexplored potential to create employment and enhance food security since it offers vulnerable households with highly nutritious animal protein and crucial micronutrients (Golden et al., 2017). Kenyans are extremely vulnerable to food insecurity due to climate change's manifestations in periodic droughts, floods, and the drying up of water resources. A significant portion of the arid and semi-arid lands (ASALs) rural population suffers from ailments linked to hunger, starvation, and malnutrition (Ngaira, 2009).

The ASALs counties of Embu and Machakos harbour great opportunities for cage culture investment for improved community livelihoods for example, the River Tana has five hydropower reservoirs in its upper watershed, with more reservoirs (including those for Karura, Mutonga, Low Grand Falls, Usheni, Adamsons Falls, Kora, and High Grand Falls)

still planned downstream of the current reservoirs (Okuku et al., 2016). In other studies, small water bodies SWBs in the two counties have been found to have the highest carrying capacities with Masinga dam constituting about 51217 Tons (Aura et al., 2022). Despite these opportunities, there has never been a feasibility study conducted to assess their suitability for the venture bordering socioeconomic and ecological parameters. While it is well recognized that reservoirs have negative socioeconomic and environmental effects on the nearby riparian communities, it is crucial to establish solutions that will reduce these effects so that these hydropower projects dams can bring economic empowerment to the communities and alleviate poverty.

The concept of "blue economy," which emphasizes the valuation and wise use of resources connected to rivers, lakes, and seas holistically, is crucial for both economic growth and sustainable development (Wenhai et al., 2019). Fish plays significant role for dietary variety and nutritional security, particularly for lower-income households in both urban and rural regions. For example, fish provide 7% of all proteins and 17% of animal protein for the more than 3 billion people living in developing nations (FAO, 2022). The capture fisheries catches in Kenya has been on the decline overtime due to challenges such as climate change and variability, invasive species, overfishing, declining stocks and postharvest losses (Muringai et al., 2022). In response to this scenario, Kenya's freshwater aquaculture industry is quickly growing as a result of the nation's growing fish demand. The growth in the sub-sector, though modest, has been steady, rising from 4,452 Metric tonnes (MT) (in 2008) to a high record of 24,096 MT in 2014. Currently the national production is approximately 22000 MT (Kenya National Bureau of Statistics 2020). However, as reported by Odende et al. (2022) there is a lot of room for growth by adopting sustainable technologies and practices. Such technology would center around aquaculture systems that use less water especially in ASAL areas where due to variability in climate, poor soils structure and diverse environmental challenges, uptake of land-based aquaculture system is not possible. However, there is an opportunity for fish production through cage culture in the hydropower dams and small water bodies in these areas.

Cage culture is relatively new fish farming system which is becoming an investment choice and preference amongst the fish farmers in Kenya. The practice is more pronounced in Lake Victoria and apart from conserving the dwindling indigenous wild fish stock, cage culture has emerged as a promising new socioeconomic frontier (Aura, 2020). Kenya attempted to implement fish cage culture for the first time in Lake Victoria in 2005. Trials had setbacks, but in 2010 cage fish farming was revitalized thanks to increased research efforts and involvement from the community through Beach Management Units by the Association for Strengthening Agriculture Research in East and Central Africa (ASARECA) project (Aura et al., 2018). It has been recognized as a game-changer since then and has sporadically developed in Lake Victoria primarily involving the monoculture of *Oreochromis niloticus* (Opiyo et al., 2018).

This study was carried out to assess the feasibility of cage aquaculture in the seven folks dams particularly the Kiambere dam and Masinga in Embu and Machakos counties respectively. There is need to understand the socio economic profile of the riparian communities to the two dams as well as the Spatio-temporal physico-chemical parameters of the dam waters to determine their suitability for the culture of tilapia. The results from this study could motivate other people from different part of the country to practice cage fish farming in small water bodies and get benefits of it through improved food supply, employment, and income generation and ultimately improve the livelihood of the marginalized communities.

MATERIALS AND METHODS

Study area

The investigation was carried out amongst residents' riparian to Kiambere and Masinga Dams located in Embu and Machakos counties respectively (Figure 1). These two dams are hydropower generation projects but can still provide opportunities for cage culture to enable food security to the riparian communities in Embu and Machakos counties. The dams are located in ASALs counties which have limitations in variety of economic activities hence relegated to livestock keeping, subsistence crop farming. The demography in these areas is also associated with low population density.

Data collection

The main sampling populations included fish farmers, fishermen, and communities who used the dam waters for domestic and agricultural purposes. Key informants included staff from government organizations involved in the management of the dams, such as the Tana-Athi River Development Authority, Kenya Electricity Generating Company (KenGen), Kenya Wildlife Services (KWS), county fisheries officers (FOs), were also targeted in data collection. The sampling population was 29 respondents fewer than expected due to low population density of the target groups, characteristic of ASAL areas.

The research approaches used were semi-structured questionnaires for in-depth, face to face interviews with participants, which made it much simpler to explain non-verbal behavior (Awuor et al., 2021).

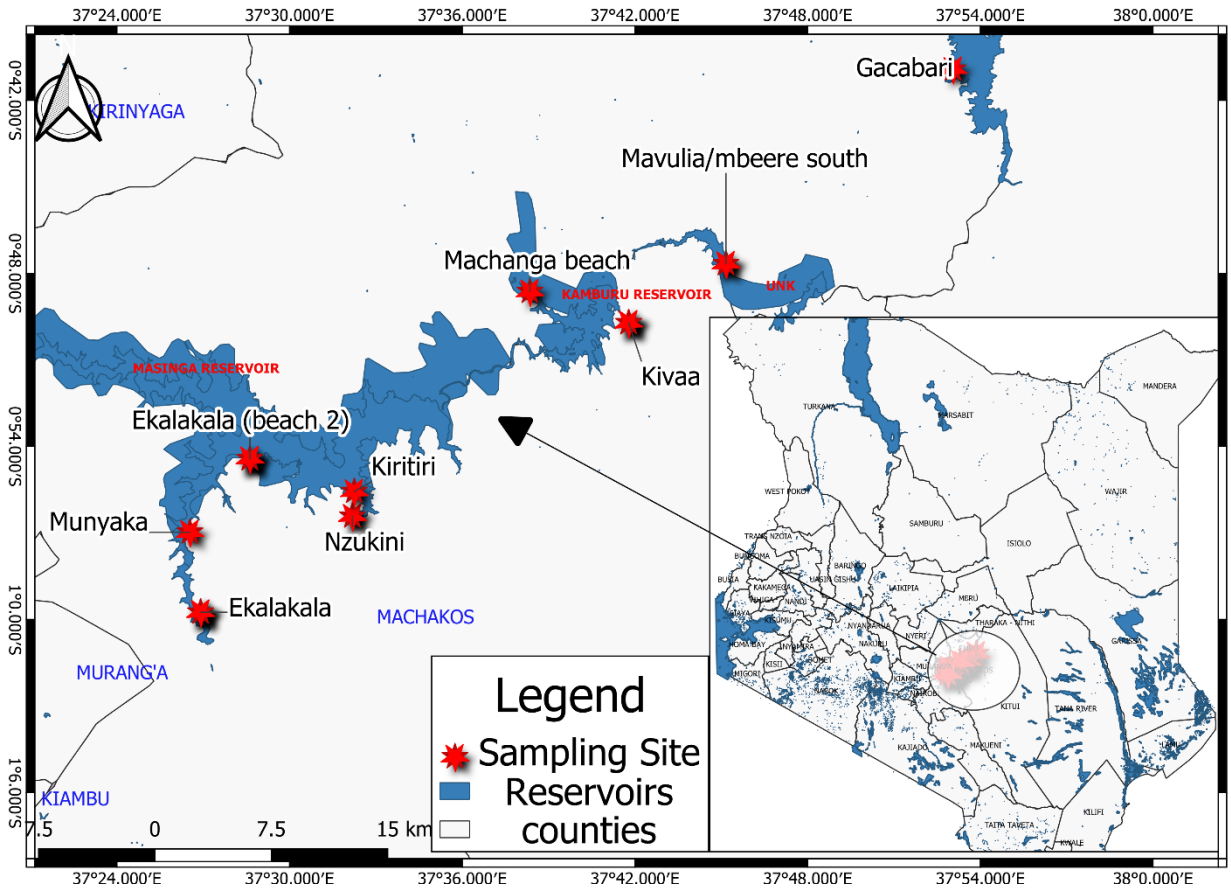

Figure 1. Data collection points amongst the respondents and stakeholders benefiting from the Masinga and Kiambere Dams.

In designing the questionnaire, the goals of the study were taken into consideration. Global positioning system (GPS) was used to mark out the data collection points in Kiambere and Masinga dams in Embu and Machakos counties respectively. Water quality parameters were recorded from specified sampling point; at the dam intake, mid areas and outflow points. Dissolved oxygen, pH, temperature, salinity and conductivity were measured in situ using YSI industries, yellow springs, OH, USA, multiparameter water quality meter while concentrations of nitrites (NO_2), ntrates (NO_3) posphates (PO_4) and ammonium concentrations were at analyzed at the Kenya Marine and Fisheries Research Institute (KMFRI), Sagana laboratory using standard methods (APHA, 2005).

Data analysis

The collected data was recorded in Microsoft Excel of Microsoft suite of 2016, coded and then transferred into Statistical Package for Social Sciences (IBM-SPSS Inc. version 23.0 IBM Corp.) and R statistical software. Both descriptive and inferential statistics were employed to determine the distribution of data and to explore relationships between variables respectively. Descriptive statistics included frequencies and percentage proportions for categorical variables such as social demographic factors while means and standard deviations were used to illustrate continuous variables such as nutrient concentrations and physical-chemical parameters. Tests of statistical significance that include chi-square tests of independence, analysis of variance and t tests were employed to determine statistical significance at 95% confidence interval or 0.05 critical alpha level. Open ended parts of the data were coded into common themes and expressed in bar graphs. Summaries were illustrated in tables while distributions were illustrated using bar graphs.

RESULTS AND DISCUSSION

Socio demographic indicators

Majority of the respondents were males (96%) Considering that majority of the respondents practiced fish farming which is male dominated (Table 1). Similar outcomes have been reported in other studies such as Aura et al. (2018), Abwao and Fonda (2019), Awuor et al. (2021). At least the respondents have some level of formal education to be able to articulate and understand cage culture technology with additional hands on training on the activities. Majority of the respondents (70%) had primary education, 26% had secondary education while only one individual had higher education. Most of the respondents were fish farmers, crop and livestock farmers due to the proximity of the communities to the dams thus benefiting from the dam waters to carry out these activities.

Table 1. Some of the socio-demographic indicators of the riparian population in Masinga and Kiambere Dams

Indicators		*n* (Proportion %)
GENDER	Female	1 (4.3%)
	Male	22 (96%)
AGE	<40	11 (48%)
	40-50	6 (26%)
	>50	6 (26%)
EDUCATION	Certificate	1 (4.3%)
	Primary	16 (70%)
	Secondary	6 (26%)
MAIN OCCUPATION	Fishing	13 (57%)
	Farming	3 (13%)
	Fishing and farming	2 (9%)
	Fish trading	3 (13%)
MONTHLY INCOME (Kenya shillings)	<20,000	10 (43.5%)
	20,000 to 40,000	10 (43.5%)
	40,001 to 60,000	2 (8.7%)
	>60,000	1 (4.3%)

**One United States dollars (USD) is equivalent to 126.5 Kenya shillings (KES) (current exchange rates)*

Some of the Socio-demographic indicators of community's riparian to Masinga and Kiambere dams is presented in Table 1. The average age for all respondents was 41 years old with a standard deviation (SD) of 10 years. The average monthly income for all the respondents was KES 26,000 while only 4.3% earned more than KES. 60,000 per month. There was no significant association between the level of education and monthly earning of the respondents (p=0.4). Therefore, reasons for low earnings per months could be related to other factors including use of traditional fishing methods which are poor and rudimentary like wooden boats with no engines and an overexploited fishery of the dams hence less earnings from the activity. This is affirmed by Martin, et al. (2013) in their assessment of the relationship between fishing, livelihood diversification and poverty in rural Laos. The study revealed that the relative household wealth was largely influenced by gear type and location of fishing.

Secondly, climate change aspects could be affecting water levels in the dams as recorded in figure 4 where water fluctuation was given as the biggest challenge to cage culture in the study areas due to aridity. This therefore leads to more expenditure in water extraction which reduces profit margins. While fishing groups in such areas at times are not extremely income poor, Simmance et al. (2022) confirms that these communities may experience multiples shock such climate variability, environmental degradation, poor regulation and marketing aspect which then erodes their wealth.

Benefits of the dams to the local community

Establishment of dams often come with negative environmental and ecological impacts which lead to secondary deprivation of the community livelihood (Okuku et al., 2016), if prior environmental and social impact assessment (EISA) is not carried out. However, in the present survey, it was realized that every respondent draws some benefits from the dams including fishing, water for irrigation, livestock and domestic use, sand harvesting and navigation as presented in Figure 2.

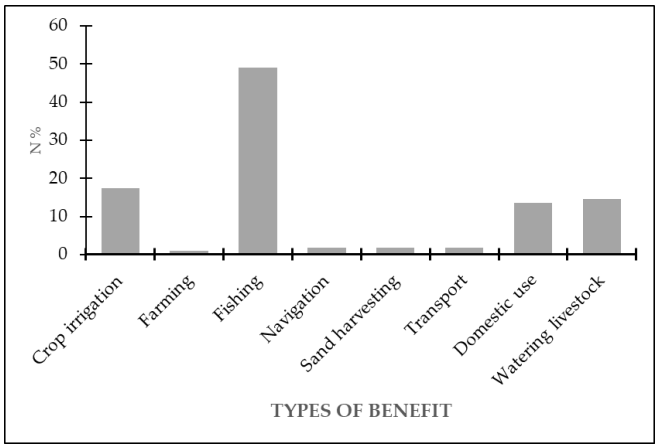

Figure 2. Benefits of Masinga and Kiambere Dams to the local communities

The majority of the respondents 49.6% cited fishing from the dams as the most important benefit accrued although the dams have been overfished and the harvests were dwindling from the observation. The riparian communities can leverage on the experiences and the nutritional benefits they get from the fish in order to establish modern fish farming systems for more fish production. At least 17.5% of the respondents used the water for crop irrigation while 13.5% each used the dam waters for domestic and livestock use.

Fish farming as an economic activity

This study sought to find out if the communities around the Masinga and Kiambere dams were already practicing aquaculture. This is due to the fact that, the Kenyan government launched the Economic Stimulus Programme (ESP) between 2009 and 2013, which identified and mapped out potential sites for pond development as part of a commitment to revive the economy (Musa et al., 2012). Fish farming was expected to contribute to greater income and food security, particularly for ASALs. However, the project did not take off in ASALs counties due to scarcity of water and poor soil structure. Some Fish farmers domiciled around the Masinga and Kiambere dams were supported in the project due to availability of the water. From the survey, 17% of the respondents were involved in fish farming while 83% were not involved in the activity. Those practicing fish farming were motivated by its role as a source of income and food for household consumption. Those not involved fish farming (83%) highlighted challenges emanating from lack of technical skills (16%), (5.3%) cited lack of startup capital and high input cost, competition from cheap fish imports from

china (5.3%) and unfavorable business environment (5.3%). As reported by Ombwa et al. (2018), pond based system, in particular, require a lot of water, which makes them ineffective and susceptible to climate change, hence lowers their output. They are also characterized by both functional and technical challenges such as land scarcity, flooding menace, rapid water quality deterioration amongst others. All these factors perhaps contributed to low or lack of uptake of fish farming in areas around Masinga and Kiambere dams despite availability of water.

Aquaculture training

In this study majority of respondents 87% did not have trainings on aquaculture while 13% had been trained on pond construction, hatchery design, fish feed formulation, record keeping and enterprise budgeting (Table 2). This is linked to the low uptake of aquaculture amongst the communities' riparian to the two dams as described by Obiero et al. (2019). There was no mention on any trainings on cage culture amongst the respondents considering it is a new fish farming system, however, the knowledge gained from the pond based system could be leveraged upon to implement the cage culture investment.

Table 2. Training in aquaculture amongst the residents of Masinga and Kiambere dams

Characteristic	N = 23
RECEIVED TRAINING (Y/N)	
NO	20 (87%)
YES	3 (13%)
SOURCES OF TRAINING	
County fisheries Extension Department	2 (67%)
Private Service Provider	1 (33%)
ASPECTS OF AQUACULTURE TRAINED ON	
Pond construction and design	1 (33%)
Pond construction and design, Hatchery management practices	1 (33%)
Pond construction and design, Record keeping and Enterprise Budgeting, Fish feed formulation, storage and administration, Fish breeding and genetics	1 (33%)

Sustainable aquaculture in the ASALs will be influenced to a large extent by implementation of the best aquaculture practices. Identification of training needs as well as implementation points are important in enhancing fish productivity in these areas (Das 2019). Extension officers play important role in imparting knowledge and enhancing adoption of technology, innovation and management practices (TIMPS) to the farmers and in this survey it was revealed that 67% training and capacity building was performed by the local County Fisheries Extension Department as well as private sector players such as the local Non-governmental organization (NGOs).

Cage as an alternative culture system

In seeking to evaluate farmers' awareness and interest in the adoption of cage culture as an alternative fish production, 65% of the respondents reported interest to start cage culture while 35% did not demonstrate interest in cage culture investment (Table 3).

Table 3. Communities' interest in cage aquaculture in Masinga and Kiambere Dams

Characteristic	N = 23
INTEREST IN CAGE FARMING (Y/N)	
NO	8 (35%)
YES	15 (65%)
REASONS FOR INTEREST IN CAGE CULTURE	
As an alternative source of income	3 (13%)
Easier to manage, Assured fish catch	3 (13%)
There is low fish catch from wild	4 (17%)
To increase fish production	5 (22%)
REASONS FOR LACK OF INTEREST IN CAGE CULTURE	
There is already fish in the dams	1 (8%)
Insecurity/theft	3 (25%)
Lack of knowledge	2 (16%)
Needs high initial capital	2 (16%)

The respondents were motivated by the need to diversify income sources (13%) hence improved livelihoods, increased fish production (22%) for enhanced nutritional security while the dwindling catches from the dams (17%) triggered the need for investment in cage aquaculture as an alternative way of fish production. The 35% of the respondents that did not report interest for cage culture gave the availability of wild fish in the dam (8%), insecurity and theft (25%), and high initial capital (16%) as some of the reasons that impede the desire to start cage culture. The interest in cage fish farming in the dams by respondents in this study correspond to many affirmations by different authors on the socio economic impacts and sustainability of cage culture to improved livelihoods on the communities, (Aura et al., 2018; Ombwa et al. 2018; Abwao and Fonda 2019; Orina et al., 2021).

Other economic activities

As demonstrated in figure 3 in this survey, 25% of the respondents engaged in commercial crop farming as a source of livelihood, 20% subsistence crop farming while 11.4 % engaged in commercial livestock farming. The dominance of crop farming amongst the population is due to the availability of water for irrigation. Only 2.9 % recorded as fish

traders probably due to the dwindling stock and low catch from the dams hence little fish to sell. More fish would be available for food, improving both health and wealth, if cage culture is used in the dams. Furthermore, integrating various farming endeavors with aquaculture will ensure the expansion of various commercial and non-commercial activities for better livelihoods for ASALs populations.

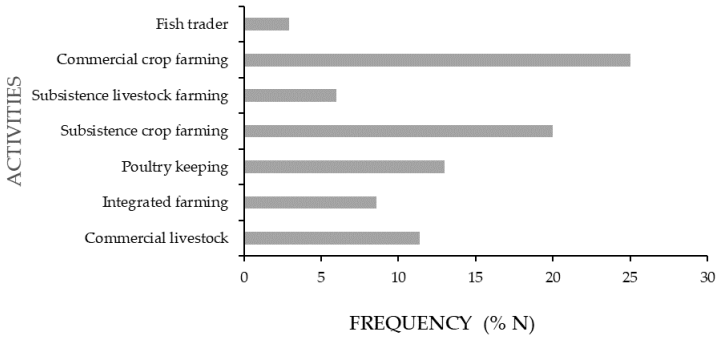

Figure 3. Other economic activities performed by the communities living around Masinga and Kiambere Dams

Challenges hindering cage culture establishment

Despite the numerous opportunities in cage culture investments, there exists several challenges to the establishment of cage culture as illustrated in Figure 4. That include insecurity, lack of technical skills and general information, lack of capital, wild animals and fluctuations in water levels.

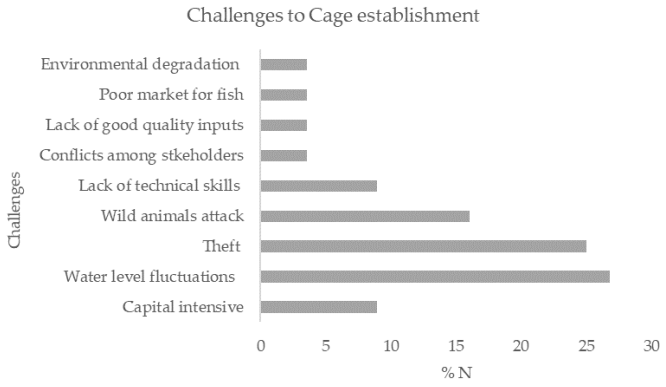

Figure 4. Challenges hindering establishment of cage culture

In this survey, majority of the respondents (26.8%) cited water levels fluctuation as a major constraint in the establishment of cages in the two dams. Fluctuation in water levels is common in the dams located in ASALs regions in Kenya due to climate change resulting from prolonged drought and reduced precipitation (AECOM, 2021). Theft of fish from cages and insecurity was mentioned as another impediment (25%), linked to the investment in cage fish culture in the dams as confirmed by Mary et al. (2021) and Charo-karisa et al. (2009) in a study on cages in lake Victoria. The authors indicated poverty as the contributing factor to the theft of fish and cages. Poverty levels are equally highest amongst the communities bordering the dams due to extreme climatic conditions.

The dams under survey are located in areas neighbouring game parks and reserves hence the interference by wildlife has a bearing on the establishment of cages. At least 16% of the respondents reported wildlife such as hippopotamus and crocodiles as a hindrance to cage culture investment. These animals can destroy cages and cause fish escapes (Charo-karisa et al., 2009). Other challenges included lack of capital (8.9%) considering investment in cage is an expensive venture, lack of technical skills (8.9%) and lack of quality inputs (3.6%) amongst other constraints. Although lack of quality inputs was ranked lowly amongst the challenges, quality seeds and feeds are very important for a successful cage fish aquaculture production (Munguti et al., 2022). Conflicts amongst the dam water users is likely to also have a considerable impediment to investment in cage culture by the riparian communities. Stakeholders such as the department of fisheries, Kenya wildlife services (KWS), Kenya Electricity Generating Company (KENGEN), Tana-Athi river development authority (TARDA) need to have an agreement with the local communities so as to mitigate on conflicts that arise from the use of the dams and reservoirs.

Water quality assessment

Fish culture systems require water as the only medium to live in and carry out all life functions such as feeding, growth, waste excretion reproduction and osmotic balance (Sibomana et al., 2022). Therefore, there is need to consider biological, chemical and physical characteristic of the water. The in-situ water quality measurements for this study are presented in Table 4. Temperature, dissolved oxygen (DO) and pH are very important parameters for fish growth and in this study, all these parameters were within optimum range for the growth of tilapia in Kiambere and Masinga dams. Temperature ranged between minimum 24.30 and maximum 28.39^{o}C, DO ranged between 5.57 and 7.71 mg/l while pH ranged between 7.44 and 8.66 According to El-Sayed and Kawanna (2008), *Orechromis niloticus* experience better performance in growth and survival at an optimum temperature of 26-30^{o}C while temperatures below 24^{o}C significantly reduce growth rate and feed utilization.

The impact of DO in culture systems cannot be over emphasized because at low level it causes mortality, susceptibility to diseases, stress, poor appetite and slow growth rate. Results recorded for the DO levels in the two dams is sufficient for fish culture as the values concur with recommendations by Abd El-Hack et al. (2022).

Table 4. Physico-chemical parameters (in situ) in Kiambere and Masinga Dams

Month	Site	Temps (°C)	D.O(mg/L)	Conductivity	TDS	Salinity	pH
March	Kitui side	27.90±0.10	5.85±0.06	147.80±0.78	92.83±3.18	0.06	7.71±0.05
March	Kiambere mid	28.13±0.06	5.78±0.21	149.67±0.31	96.35±0.26	0.06	7.76±0.02
March	Kiambere Embu	27.90±0.10	5.89±0.24	146.10±0.52	88.90±0.85	0.06	7.69±0.09
March	Wamboo	28.25±0.05	7.56±0.13	136.71±0.38	83.90±0.18	0.06	8.36±0.14
June	Kitui side	28.16±0.10	5.64±0.13	146.71±0.80	94.33±3.18	0.06	7.46±0.05
June	Kiambere mid	28.39±0.06	5.57±0.21	148.67±0.31	97.85±0.26	0.06	7.51±0.02
June	Kiambere Embu	28.16±0.10	5.68±0.24	145.10±0.52	90.40±0.85	0.06	7.44±0.09
June	Kiengeli	27.27±0.34	7.55±0.12	138.14±1.77	85.79±1.07	0.06	8.38±0.29
June	Kakuku	26.77±0.10	7.71±0.33	130.79±1.11	82.25±0.00	0.06	8.60±0.17
September	Kitui side	24.35±0.05	6.67±0.35	108.77±0.23	71.50±0.00	0.05	7.76±0.04
September	Kiambere mid	24.60±0.06	7.00±0.49	109.87±0.16	71.50±0.00	0.05	8.00±0.10
September	Kiambere Embu	24.75±0.05	6.54±0.24	110.40±0.00	72.15±0.00	0.05	8.11±0.04
September	Kiengeli	24.67±0.05	6.81±0.28	122.33±2.44	80.31±1.53	0.06	8.24±0.21
September	Wamboo	24.30±0.00	7.04±0.43	101.85±1.07	66.98±0.53	0.06	7.68±0.11
September	Kiembeni	26.13±0.55	7.31±0.12	112.70±0.20	71.50±0.00	0.06	8.26±0.05
September	Kakuku	27.10±0.17	7.43±0.12	118.33±0.12	74.10±0.00	0.06	8.66±0.05
September	Thagana	24.37±0.21	7.57±0.26	107.30±1.85	69.55±0.00	0.06	8.25±0.05

Table 5. Nutrient concentration in Kiambere and Masinga Dams

Month	Site	PO_4 (µg/L)	NO_2 (µg/L)	NO_3 (µg/L)	NH_4 (µg/L)
March	Kitui side	1.69±0.03	0.67±0.03	1.11±0.04	3.72±0.16
March	Kiambere mid	1.60±0.03	0.70±0.01	0.94±0.03	3.39±0.24
March	Kiambere Embu	1.77±0.03	0.66±0.01	1.16±0.06	3.79±0.11
March	Wamboo	2.01±0.05	0.77±0.13	1.34±0.02	5.05±0.19
June	Kitui side	1.91±0.03	0.81±0.00	1.28±0.01	4.15±0.19
June	Kiambere mid	1.77±0.03	0.70±0.07	1.15±0.04	3.74±0.8
June	Kiambere Embu	1.97±0.03	0.75±0.05	1.24±0.01	4.70±0.11
June	Wamboo	2.19±0.05	0.89±0.09	1.24±0.01	3.99±0.11
June	Kakuku	2.38±0.03	0.85±0.07	1.46±0.01	4.12±0.15
September	Kitui side	2.21±0.05	0.78±0.01	1.38±0.02	3.37±0.15
September	Kiambere mid	2.38±0.03	0.85±0.07	1.46±0.01	4.12±0.15
September	Kiambere Embu	1.74±0.07	0.69±0.03	1.13±0.02	3.99±0.11
September	Kiengeli	1.93±0.03	0.61±0.02	1.00±0.01	3.47±0.11
September	Wamboo	2.30±0.07	0.62±0.01	1.22±0.02	3.47±0.04
September	Kiembeni	2.60±0.05	0.75±0.03	1.29±0.02	3.87±0.23
September	Kakuku	2.46±0.05	0.64±0.01	1.21±0.01	3.29±0.23
September	Thagana	2.26±0.03	0.75±0.01	1.32±0.01	3.84±0.09

The authors have indicated that the optimum DO level should be kept above 5mg/L to ensure good growth while pH of the water is best for the growth of tilapia at an optimum of between 7 and 8.

Nutrient concentration in the dams

Nutrient concentrations in Masinga and Kiambere Dams were analysed and presented in Table 5. Cage culture is an intensive fish farming system characterized by overuse of proteinaceous feeds and high stocking density which lead to increased loading of nitrogenous and other metabolites in the water (Ciji and Akhtar 2020). Exposure of fish to nitrites can cause adverse effects on fish health and growth. In this study, nitrite concentration ranged between 0.66 to 0.89 µg/L. Since the optimum nitrite concentration for tilapia in freshwater is 0.3 mg/L, the levels of nitrite in the two dams are minimal and have no impact on the fish's growth or physiological processes.

In intensive culture systems ammonia and nitrites are critical parameters and should be monitored regularly. This is because intensive culture systems like cage fish farming require high quality feed coupled with high stocking densities which can contribute to increased levels of unionized ammonia (NH_3) and nitrites (NO_2) (Bahnasawy et al., 2009). Analysis of nitrates (NO_3) and phosphate (PO_4) concentration is critical in aquatic system due to their contribution to primary productivity. The supply of these

nutrients is affected by both enteral inputs and biogeochemical processes within the ecosystem (Howarth et al., 2021). In this study, the phosphates and nitrates ranges between 1.60 to 2.60 µg/L and 0.94 to 1.46±0.01 µg/L respectively. A proper balance of N and P is important in ensuring increased primary productivity of an ecosystem while information on the trophic status is critical in determination of the potential the dams have in accommodating cage culture (Guo and Li, 2003). The quantities of nitrates and phosphates are negligible and therefore there is need to provide the fish with high quality diet for improved growth and yields.

CONCLUSION

Adoption of cages for fish farming in the hydropower dams and reservoirs is a promising venture that can be used to transform socio-economic wellbeing of the rural communities. Cage culture is capital intensive, associated with theft of fish and also conflict with wild animals that can destroy the cages leading to losses. The government and private sector need to leverage on the opportunities existing in these dams to initiate fish farming in the ASALs areas to promote affirmative action in these marginalised communities. Proper siting of the cages and carrying capacities of the two water bodies will be an important consideration to mitigate against the effects of dam water fluctuations and quality. Community sensitization and stakeholder participation and engagement will be important in curbing arising conflicts between the riparian communities and government agencies managing the dams. Extensive services and capacity building will also ensure that cage fish farming in the dams is done based on good aquaculture practices for increased productivity, income and nutritional security.

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Compliance with Ethical Standards

Authors' Contributions

All authors have contributed equally to the work. All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

The authors declare that formal consent is not required for this type of study.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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