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Integrating Inland Aquaculture and Aquaponics in King Cetshwayo District Municipality: Enhancing Food Security, Economic Resilience, and Sustainable Practice

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Abstract

Aquaponics combines fish farming, hydroponics (growing plants in nutrient-rich water), and microorganisms. The product promotes sustainable growth by growing fish and plants in the same system. Inland aquaculture and aquaponics present promising approaches to strengthen food security, enhance economic resilience, and promote sustainable practices in the King Cetshwayo District Municipality. However, several interrelated challenges must be addressed to realize the full potential of these systems within the local context. A thorough literature review emphasises the need for a more profound investigation into integrating inland aquaculture and aquaponics, particularly in South Africa. By focusing on integrating inland aquaculture and aquaponics, the study aimed to enhance food security, create job opportunities, and promote sustainable practices that can uplift marginalised communities. This paper employed a qualitative approach to collect data to provide a more complex perspective on aquaponics. This study used two collection methods: semi-structured interviews and observations. Four observations were conducted in the establishments involved in aquaculture farming and aquaponics. This paper employed the Sustainable Livelihood Approach (SLA) to provide a comprehensive lens that accommodates complex intersections between environmental, social, and economic aspects of different farming methods. Aquaponics has been revealed to be viable and offers a promising strategy for enhancing aquaculture development. It can also stimulate local economic activities by creating jobs in both the aquaculture and agriculture sectors, enhancing community resilience in KCDM.

Keywords

Aquaponics, Inland Aquaculture

1. Introduction

The aquaponic principle combines producing plants and animals (such as fish) to conserve resources [1]. Aquaponics has gained recognition as a viable method that not only utilizes available resources more efficiently but also reduces dependency on external inputs, offering a sustainable alternative to conventional agriculture that often depletes soil and water resources [2]. In recent years, researchers have underscored the potential of aquaponics to contribute to food security, particularly in regions with limited agricultural land, such as urban areas [3]. This is particularly relevant for the King Cetshwayo District, where food insecurity persists alongside high levels of poverty. By harnessing the symbiotic relationship between fish and plants, aquaponics systems can produce nutrient-rich vegetables and fish simultaneously without the need for synthetic fertilizers, effectively closing the nutrient loop [4]. In addition, the implementation of aquaponics can stimulate local economic activities by creating jobs in both the aquaculture and agriculture sectors, enhancing community resilience [5] [6]. This agricultural technique reduces operational costs by growing plants and fish under one harvesting system, using less labour and a smaller ecological footprint [7]. According to [8], aquaponics has the potential to produce healthy organic food for people, provide income for small-scale farmers, and be environmentally friendly. [9] confirm that aquaponics supports food sovereignty and security. Some of the positive environmental effects of aquaponics include recycling nutrients as the nutrient-rich water is not disposed of, and the low water use requirement, which reduces the pressure on water to supply food. It is expected that the demand for food production will lead to a decrease in arable land, constrained water resources, and soil degradation [10].

According to [10], this type of technology is a promising sustainable food production method that has been considered an innovative response to food security. [11] assert that aquaponics is costly during the system's start-up. It requires a significant capital investment, moderate energy inputs, skilled management, and a niche market that can provide profitability. Based on the previous studies on aquaponics, they have been revealed to be viable in some instances; however, profitability depends on the type of crops grown, the size of the market, and the ability to expand to new markets and locations. Aquaponics offers a promising strategy for enhancing aquaculture development in KCDM. The municipality can ensure the relevance and effectiveness of aquaponics by customising it to local conditions, as demonstrated by the creation of region-specific aquaponics models [12]. Technological developments in aquaponics, such as intelligent control systems and engineering considerations, can improve system productivity and performance even more [13] [14]. Aquaponic systems can be improved for optimum output and efficiency by combining technological advancements with intelligence monitoring, promoting the sustainable development of aquaculture in the area.

2. Literature Review

Aquaculture Technologies

Aquaculture systems and technology have advanced rapidly over the past fifty

years [15]. Aquaculture technology saves time, increases profit/improves income through increased yield/harvest, and conserves fish farmers' energy (human, material, and finance). Recently, considerable innovation and technology have been developed and geared towards the industry's longevity and sustainability [16]. Technological advancements in production and breeding systems, feeds, nutrition technology, vaccines, species and strain selection, reproductive control, mechanical aeration, water exchange, and an improved regulatory framework and market have enabled the aquaculture sector to expand [17]. [18] asserts that aquaculture technology has supported water quality testing with technological instruments that reduce stress, feed production, reproduction, and the construction of cages, pens, and ponds. According to [19], good water quality and high protein feeds are required for intensive culture systems. Compared to extensive and semi-intensive systems, less land and water are required to produce more fish. Technological improvement is increasing daily, and for instance, a RAS is a technological innovation being adopted as an intensive aquaculture method [20] [21]. By shortening the grow-out period, RAS has significantly increased the efficiency of aquaculture enterprises. It was established that when RAS is involved, the harvest weight of fish may range from 400 g to 500 g after a nursery period of two to three months, compared to 300 g in nine months on farms that do not practice RAS [22]. Adopting modern and relevant technologies in King Cetshwayo will likely enhance smallholder fish farmers' aquaculture production and reduce household food insecurity. In concurrence, [23] opine that developing integrated models of aquaculture production considering private and social costs and benefits, including externalities not captured by market mechanisms, can result in more holistic and sustainable practices.

The technology reduces production costs, is environmentally friendly, and is simple to maintain and operate. Periphyton technology similarly uses attached biofilm communities on water surfaces, and it has also been revealed to increase fish growth and decrease feed requirements. This is primarily owing to the biofilms' high protein content. [24] Have demonstrated that periphyton technology can increase fecundity and delay spawning by up to four weeks in *O. niloticus*. As fish are highly perishable, post-harvest technologies are critical to the success of any aquaculture venture. Several traditional fish post-harvest technologies, for example, have been used in Kenya to extend the shelf life of fish and fish products. Salting, smoking, frying, and drying are just some of these technologies [25]. Model aquaculture parks (aquaparks), high-density intensive production cages in lakes and reservoirs, intensive RAS and tank-based systems, hydroponics, and aquaponics are some of the technologies and innovations [26]. Noticeably, aquaculture is rapidly expanding. New aquaculture production technologies are needed to maximise production and profits. [27] remark that several countries can learn much from China's rapidly changing 'innovation ecosystem' in aquaculture. Aquaculture should use technological processes and equipment to aid faster and better yields and efficiency [28].

3. Theoretical Framework

The SLA offers an all-encompassing perspective that takes into account the complex interplay between the environmental, social, and economic aspects of different farming methods. It focuses on household assets, financial, human, social, physical, and natural factors that affect communities' ability to seek sustainable livelihoods. Since aquaculture and aquaponics provide distinct interdependencies between aquatic and agricultural systems, the SLA skilfully illustrates how these relationships either enhance or diminish sustainable results [29].

The SLA emphasizes the significance of context, especially in areas where there is economic fragility and food poverty. This calls for flexible tactics that efficiently utilize available resources [30]. Additionally, the SLA emphasizes the importance of social capital in creating cooperative efforts to manage aquaculture and aquaponic systems sustainably, improving resilience against economic shocks, and fortifying community bonds [31]. The SLA contributes to a more comprehensive understanding of how communities can successfully negotiate the challenges posed by economic fluctuations and climate change by highlighting both individual talents and the socio-ecological systems that support livelihoods.

4. Methodology

This paper employed a mixed-methods approach to collect data to provide a more collaborative and complex perspective on aquaponics. This study used a qualitative method to collect data: semi-structured interviews and observations, with 12 interviews. The observation was conducted in the establishments involved in aquaculture farming and aquaponics in the City of uMhlathuze and uMlalazi Municipality. The qualitative approach, diverse data collection methods, and various analytical techniques contributed to a comprehensive understanding of Inland Aquaculture and Aquaponics in King Cetshwayo District Municipality to enhance Food Security, Economic Resilience, and Sustainable Practice. For data processing and analysis, the study employed Thematic and content analysis to synthesize the key themes surrounding the economic, policy, and challenges affecting aquaculture development, thereby thematically discussing them.

5. Findings and Discussions

5.1. Protected Areas

The researcher sought to learn from the participants about their concerns about protected areas. The participants' findings acknowledged that the KCDM coastal belt is protected, and therefore, restrictions will limit aquaculture development and cause conflicts. The participants emphasised that the focus should not only be on marine aquaculture but on inland freshwater aquaculture and aquaponics, as they can significantly contribute towards the growth of the ocean's economy. The participants affirmed:

Transnet has restricted community access to the coastal area from Port

> Durnford to Icubhu by designating it as a protected zone, effectively preventing aquaculture farming in that corridor. Despite the Spatial Development Framework allowing for commercial aquaculture, Transnet does not issue permits for such activities. Additionally, the Department of Forestry, Fisheries and the Environment (DFFE) has only issued non-commercial fishing permits, limiting communities to subsistence fishing and preventing them from pursuing profitable, job-creating aquaculture ventures (Siboniso Shange, 2023).

The assertion that Transnet claims the coastal corridor from Port Durnford to Esikhaleni as a protected area indicates a critical barrier to aquaculture development. Participants expressed concerns that the designation of this stretch as a protected zone effectively locks out local communities from engaging in potentially profitable aquaculture activities. The participants' observations suggest an operational dichotomy between the mandates of Transnet to manage cargo shipments and the need for local livelihoods centred on aquaculture. Shange's comment highlights that Transnet restricts the issuance of permits for establishing aquaculture projects. This prohibition not only affects immediate revenue-generating opportunities for local fishing communities but also reflects a broader trend wherein government policies favor large-scale commercial interests (e.g., shipping and logistics) over local sustainable practices. By limiting participation in aquaculture, Transnet undermines the potential economic benefits that could arise from utilizing local marine resources sustainably. Shange emphasizes that, while the DFFE has awarded non-commercial fishing permits, the limitations of these permits to livelihood activities alone hinder the growth of sustainable economic ventures. The lack of opportunities for commercial aquaculture stifles local entrepreneurship and the ability for these communities to elevate their economic status. By allowing only non-commercial fishing, there is a missed opportunity to cultivate a productive aquaculture sector that can enhance both food security and job creation. The participants further stipulated:

> "There was a fish farm, farming Kob, but I believe it has closed down. Also, there was a potential of a tilapia project the province was investigating at Port Dunford, but that bordered a Marine Protected Area, and the current legislation NEM: PAA states no aquaculture may be conducted in Marine Protected Areas. There is one project in the vicinity of Richards Bay, which is an Aquaponics project farming Mozambique Tilapia and vegetables that I am aware of (David Reed, 2023).
>
> "And then the other thing was that because aquaculture development is low, we do not have a comparative advantage in aquaculture development. But I think a comparative advantage, if you look at China, if you look at your Eastern countries, for them, I'm just gonna like, I'm just like, go sideways here. Within China, they've been doing aquaculture for like three, four, 500 years, and they found methods of actually doing aquaculture or breeding fish in the

> rice pellies to decrease your costs. So they do have a comparative advantage in this. And they have, because they've been doing it for so long, they've managed to be able to decrease your costs to more costs (Jennifer Craig, 2023)".

5.2. Aquaculture Projects within KCDM

The aquaculture projects within the KCDM have not been sustainable nor successful, and the reasons can be attributed to considerable red tape, particularly compliance and minimal technical support provided by DFFE. Participants revealed that although RBIDZ incentivises prospective aquaculture producers, the fragmented system complicates it for emerging and small-scale farmers to thrive. The participants shared their concerns regarding the aquaculture projects below:

> Aquaculture development in the region has faced significant challenges due to bureaucratic red tape, lack of compliance support, and limited technical assistance, particularly from national bodies like DFFE, which has delayed progress for over two years. Although a current project supplies vegetables and fish, it remains semi-commercial because of this lack of support (Siboniso Shange, 2023).
>
> The aquaculture sector in KwaZulu-Natal is still in its early stages but holds strong potential for investment and job creation across the King Cetshwayo District (KCD). Institutions like RBIDZ offer incentives to attract such investment (Sizwe Buthelezi, 2023).
>
> Specialist support is largely based in the Western Cape. However, there are some aquaculture-related activities in uMhlathuze, such as the Sobusa Community Aquaponics Project, although no fully established aquaculture project exists there yet (Siboniso Shange, 2023).

Siboniso Shange discusses the hindrances to successful aquaculture projects, specifically citing "red tape" associated with regulatory compliance as a major hindrance. It emphasises a systemic challenge where local initiatives can be stifled by cumbersome regulations that, although intended for ecological and operational safety, result in delayed project timelines and increased costs. The comment about the Department of Forestry, Fisheries, and the Environment's (DFFE) anticipated technical assistance brings to light even another level of complexity. The gap between local project demands and national resources is evident in the two-year wait for essential support. Local projects have limited growth potential since they find it difficult to make the shift from semi-commercial to fully commercial endeavors without prompt support. While the aquaculture sector is still developing, the mention of the Sobusa Community Aquaponics project in uMhlathuze brings attention to local initiatives that exist. The dual focus on vegetable and fish production using aquaponics indicates a sophisticated approach to resource use and agricultural integration. However, the acknowledgment of existing projects in a largely undeveloped sector points to the need for more widespread community engagement and replication of successful models across the KCDM. [32] suggests that

aquaculture support be housed in one department for ease of development in the aquaculture sector, and stability does not overlook that obtaining water rights, permits, conducting EIAs, and all certifications and land authorisation required are all necessary. [32] Proposes a centralised office (one-stop shop) to obtain all these documents to allow aquaculture to develop as it has been in China, Egypt, Norway, and several other countries.

5.3. Opportunities for Aquaculture Farmers

The findings display enormous opportunities within the aquaculture sector, and KCDM is strategically positioned because it is located closer to the N2, Richards Bay Harbour, and King Shaka International Airport. The opportunities include exporting, various market access, and tourism. The probing of participants resulted in the responses reflected below:

> "The district is rich in oceans, enough rivers for natural waters, and a good road network linking both Richards Bay harbour and King Shaka airport, which will make it easier for exporting of the final product (Sipho Gumede, 2023)".
> "Opportunities for KCD prevail through import substitution of current imports of fish and marine-related products, and additional opportunities can be explored for aquaponics that integrates aqua and agrifarming, aquaculture tourism from the district (Sizwe Buthelezi, 2023)".

Other responses provided as opportunities for the aquaculture farmers are as follows:

> 1) "Aquaculture opportunities may include the use of dams and ocean/coastal water 2) Nile crocodile farming for meat, skin and also contribute to tourism 3) Exporting opportunities through the local sea port 4) Since we have sea tourism, sea food supplies is essential and fresh fish sales market and export 5) Organic fertilisers can also benefit and that is an opportunities 6) Ornamental fish 7) Fish trainings is amongst the opportunities 8) Fish must be maintained and kept alive 9) Refrigerators and cooler boxes can be used to store fish for informal fish markets 10) The DTIC offers various market access opportunities and mechanisms for entrepreneurs across sectors (Sizwe Buthelezi, 2023)"

The district's proximity to Richards Bay Harbour and King Shaka Airport is advantageous for exporting aquaculture products. This logistical advantage can enhance the district's competitiveness in international markets. Abundant rivers and coastal waters provide many opportunities for freshwater and marine aquaculture. The DTIC's market access mechanisms can help local entrepreneurs navigate market entry and expansion, providing crucial support for scaling aquaculture ventures. It was learnt that the district's rich natural water resources and excellent road connections to Richards Bay Harbour and Shaka Airport enhance export potential. Key opportunities include import substitution of fish and marine

products, integrating aquaponics, and developing aquaculture tourism. Using dams and coastal waters, farming Nile crocodiles for meat, skin, and tourism, and leveraging local sea ports for exports are significant prospects. Other opportunities include supplying fresh fish to sea tourism markets, producing organic fertilisers, ornamental fish farming, fish training programmes, and using refrigeration for informal markets. Support from DTIC provides additional market access opportunities for entrepreneurs across various sectors.

Table 1 below displays opportunities for aquaculture and related sectors. It further provides a clear and structured overview of potential benefits for development. This table can help in making informed decisions and developing targeted strategies for advancing the aquaculture sector.

Table 1. Diverse aquaculture opportunities.

Opportunity	Description	Potential benefits
Import Substitution	Reduce reliance on imported fish and marine products by increasing local production.	Cost savings, increased local supply, and reduced foreign dependency.
Aquaponics	Integration of aquaculture with agrifarming to create a sustainable farming system.	Resource efficiency, increased sustainability, dual-product outputs.
Nile Crocodile Farming	Farming Nile crocodiles for meat, skin, and tourism.	High-value products, tourism potential, diverse revenue streams.
Exporting Opportunities	Utilise local sea ports for exporting aquaculture products.	Access to international markets, increased revenue.
Seafood Supply	Enhance fresh fish supply for local markets and exports.	Increased local availability, potential for new markets.
Organic Fertilisers	Produce organic fertilisers from aquaculture by-products.	Sustainable waste management is, additional revenue source.
Ornamental Fish	Cultivation of ornamental fish for sale.	Niche market potential, additional revenue streams.
Fish Training	Provide training in fish farming techniques.	Skills development, improved local expertise.
Refrigeration and Storage	Use refrigerators and cooler boxes for storing fish, especially for informal markets.	Extended market reach, better quality preservation.
Aquaculture Tourism	Develop tourism related to aquaculture, such as farm tours or interactive experiences.	Increased awareness, additional revenue from tourism.

Source: Author's construct (2024).

5.4. Aquaponics

The responses elucidate the potential benefits and risks associated with implementing aquaponics and other aquaculture projects in the district municipality. The participants' perspectives on aquaponics are expressed below:

> "Aquaponics is an example of integrated and sustainable farming that uses fish waste to naturally fertilize plants, while purifying water through a closed system, making it environmentally friendly and suitable for areas with water shortages, like municipalities facing water shedding. However, caution is ad-

vised when introducing such projects to rural communities, as imposing large-scale initiatives without proper assessment can place undue risk on them. It is more beneficial to focus on feasible, low-cost projects that truly serve community needs".

The aquaponic principle combines the production of plants and animals (such as fish) to conserve resources [1] and has the potential to produce healthy organic food for people, income for small-scale farmers, and be environmentally friendly [33]. The participant's assertions were confirmed above by participants during interviews. Although aquaponics, according to [11], is costly during the system's start-up and requires a large capital investment, moderate energy inputs, skilled management, and a niche market that can provide profitability, [7] contend that aquaponics reduces operational costs. In agreement, Patrick Omotoso claims that:

"Although Aquaponics is relatively more capital intensive, but remains one of the most sustainable and climate-friendly aquaculture systems for sustainable aquaculture development in South Africa; therefore, it is highly recommended (Patrick Omotoso, 2023)".

The aquaponics project is the first of its kind and currently lacks a feasibility study, which is needed for future expansion. There are challenges in selling the fish, especially in formal markets. Aquaponics systems are rare in KwaZulu-Natal and take a long time to be implemented. In uMhlathuze, where a similar project exists, technicians and economists have been requested to investigate and support its expansion (Siboniso Shange, 2023).

"Aquaponics can be developed anywhere within the district if electricity and water supply are available (Patrick Omotoso, 2023)".

The adoption of aquaponics in the district municipality has the potential to be a transformative intervention for maximising aquaculture development. By leveraging the principles of aquaponics, including nutrient recycling, decoupled systems, economic feasibility, and technological advancements, the municipality can promote sustainable aquaculture practices, enhance food security, and stimulate economic growth in the district.

When viewed through the lens of the Sustainable Livelihood Approach (SLA), the findings on aquaponics reveal several key dimensions impacting community livelihoods. Human capital is highlighted by the need for skilled management and technical knowledge to operate and maintain aquaponics systems sustainably, as discussed to the system's complexity and required expertise [11]. Social capital emerges through the involvement and cooperation of stakeholders such as technicians, economists, and community members, which is critical for knowledge exchange, feasibility assessments, and market development. Financial capital considerations are apparent in the concerns over the initial high capital investments and ongoing operational costs, although potential cost reductions through integrated nutrient recycling present opportunities for economic viability [7] [11]. Physical capital is represented by infrastructure requirements, including reliable

electricity and water supply, which are prerequisites for successful project implementation in the municipality. Finally, natural capital is central to aquaponics, which promotes sustainable resource use by integrating fish and plant production, conserving water, and reducing environmental impacts [1]. By systematically addressing these SLA capitals, aquaponics projects can be tailored to the local context and community needs, enhancing livelihood resilience and promoting sustainable aquaculture development in the district municipality.

5.5. Aquaculture Technologies

When asked about the developing technologies that both improve production and preserve ecological integrity. The participants provided insights into the potential for leveraging international expertise, particularly from China, and the function of technology and government support in enhancing aquaculture in the district municipality. The responses are articulated below:

> "Yes, RAS and Aquaponics" (Patrick Omotoso, 2023).
> "We can invest in those since we are in trade with China and are experts in Aquaculture. The technology used is not at the level used by commercial farmers like RAS. Integrated farming is recommended, and water is harvested from the rain. Aquaponics has many health benefits (Sam Ngidi, 2023).

Further responses are articulated below:

> "The government supports investment attraction by promoting technology transfers and conserving natural resources as mandated by the Constitution. It also provides innovation and technology-based incentives to address equipment and skills gaps, encouraging local technology development and adoption in the aquaculture sector (Sizwe Buthelezi, 2023).

The recirculating aquaculture system (RAS) is a technological innovation being adopted as an intensive aquaculture method [20] that shortens the grow-out period and has significantly increased the efficiency of aquaculture enterprises. Considering that aquaculture is rapidly expanding, a need exists for developing new aquaculture production technologies to maximise production and profits. [27] Note that several countries can learn a great deal from China's rapidly evolving "innovation ecosystem" in aquaculture. The Sustainable Livelihood Approach (SLA) emphasizes the importance of human, social, and financial capital in promoting aquaculture technologies and ecological integrity. Innovative systems like Recirculating Aquaculture Systems (RAS) and aquaponics can enhance production efficiency and environmental sustainability by controlling waste outputs and maximizing resource use [34]. The government plays a crucial role in facilitating technology transfers and promoting local adaptation, bridging the gap between technology and community engagement. Effective aquaculture advancement in community development must prioritize human capacity development and community participation [35].

5.6. Participant Observation

This section presents the observation analysis of the data collected for the study. The researcher used content analysis to expedite the interpretation of the data collected. The observations were conducted to understand the aquaculture settings at the farms in uMlalazi and City of uMhlathuze using a checklist as a guideline, which contained the following:

Is there any concern about visible pollution?

Is the aquaculture infrastructure in good condition (pumps, hatcheries, ponds, buildings, processors, feed supplies?

Are there any visible technologies used?

What complexities can be physically witnessed on-site as barriers to sustainable aquaculture development?

Subtheme 1: Pollution

Figure 1. Polluted pond Mthunzini (uMlalazi Local Municipality). Source: Fieldwork (2023).

Figure 1 demonstrates the visible water pollution concerns. The pollution conditions are one of the obstacles observed for sustainable aquaculture development within KCDM. The water pollution of waste in the coastal zone caused adverse effects on the health of coastal communities and coastal ecosystems. According to the KCDM IDP, such effects can be minimised by establishing regulatory mechanisms for waste and wastewater disposal in the coastal zone. In this instance, the KCDM should design and implement an ongoing integrated pollution monitoring system for the coast based on monitoring structures and consider integrated estuarine monitoring programmes. The IDP Plan further stipulates that pollution conditions should be incorporated into coastal development approvals. Managing waste by manufacturing companies should support using coastal resources in a socially, economically, and ecologically justifiable manner. Conversely, new de-

velopments should ensure they conduct necessary preventative measures to minimise the changes and effects of pollution events.

Subtheme 2: Underground fish ponds

Figure 2. Underground fish ponds at Mthunzini (uMlalazi Local Municipality). Source: Fieldwork (2023).

Figure 2 depicts one aquaculture pond developed by small-scale farmers practising integrated farming using freshwater ponds. The ponds need upgrading to expand production and aquafeed because they use brown bread to feed the cultivated species; if not supported, this could lead to unsustainable aquaculture practices and certainly lead to environmental degradation and upset the ecosystems' natural equilibrium [36]. Open-net pens by KCDM small-scale farmers are correctly used; [37], in concurrence, states that open-net are frequently employed because local conditions permit [37], particularly for inland aquaculture production. The potential for increasing freshwater pond yields and expanding freshwater aquaculture by converting agricultural land to fish ponds is significant [38]. Aquaculture requires knowledge and skills in various production areas, including spawning, feed production, pond construction, and management [39] [40]. To enable the aquaculture sector to expand within KCDM, the existing small-scale farmers should be supported with technological instruments that reduce stress, feed production, reproduction, and the construction of cages, pens, and ponds [41].

Figure 3 illustrates catfish harvesting by one of the small-scale farmers who uses integrated farming. Some of the positive environmental effects of aquaponics include recycling nutrients as the nutrient-rich water is not disposed of, and the low water use requirement, which reduces the pressure on water to supply food. Fish has primarily been beneficial to local communities in nutrients and as an income source; therefore, providing healthy organic food capable of providing people with healthy living and income for small-scale farmers, and being environmentally

friendly. The quality of food produced is suitable for human consumption.

Subtheme 3: Catfish harvesting

(a) (b)

Figure 3. Catfish harvesting in Mthunzini (uMlalazi Local Municipality). Source: Fieldwork (2023).

Subtheme 4: Integrated farming and aquaponics

(a) (b)

Figure 4. Images of water tanks in Port Durnford (City of uMhlathuze). Source: Fieldwork (2024).

Figure 4 pictures above are of inland integrated farming, aquaponics, and recirculating systems, and they demonstrate the integration aspects, promoting capital investment and establishing partnerships, people development, skills development, and economic development. This establishment practises sustainable aquaculture by considering the environment, economy, and social sustainability to increase capacity and effectively use the land for the aquaculture business [42]. The technologies used are more advanced for healthy organic food, capable of providing people with healthy living and income for small-scale farmers, and are environmentally friendly.

The results stipulated above show the intertwined issues of protected areas, reg-

ulatory red tape, and the identified opportunities create a complex landscape for aquaculture development in the King Cetshwayo District Municipality (KCDM). The establishment of protected zones has effectively limited aquaculture potential, locking local communities out of economic opportunities that could drive sustainable growth and enhance food security [43]. Regulatory challenges, particularly the difficult compliance protocols imposed by national authorities such as the DFFE, intensify this situation by stifling local initiatives and delaying project implementations. However, acknowledgment of diverse opportunities within the sector, such as inland aquaculture, aquaponics, and community-based projects, presents a pathway forward. Strategically leveraging KCDM's geographical advantages alongside innovative aquaculture technologies could mitigate the impacts of regulatory constraints and ecological restrictions, enabling local communities to engage in sustainable practices that align with broader conservation goals [44]. Overall, a concerted effort to reconcile these competing demands through careful planning and collaboration could unlock the full potential of aquaculture, ultimately benefiting both economic development and environmental preservation in the region [45].

6. Recommendation

The DFFE needs to strengthen support mechanisms for economic development in aquaculture, including investment in research and development, facilitating access to affordable financing, and enacting supportive government policies. In collaboration with the KCDM, the DFFE should initiate a feasibility study focusing on aquaculture development and inland aquaponics. The three coastal municipalities must engage in land and water zoning initiatives, prioritising aquaculture development. By methodically identifying and designating suitable areas for aquaculture, these municipalities can reinforce investor confidence and optimise local resource use. Municipal planning should incorporate stakeholder engagement processes to ensure that the interests of local communities are considered in the zoning process and that the selected zones are accessible for prospective aquaculture projects. The implementation of ADZs should be aimed at bringing economic benefits to local communities through incentives for local ownership and partnerships. Municipalities must collaborate with environmental agencies to develop robust protocols for EIAs, ensuring that aquaculture operations are designed with minimal ecological footprint. Outcomes from these assessments must be transparently communicated to the public and other stakeholders to promote trust and collaborative oversight.

7. Conclusion

Aquaponics is supported as it combines the production of plants and animals/integrated farming, thereby preserving ecological integrity. In collaboration with the KCDM, the DFFE should initiate a feasibility study focusing on aquaculture development and inland aquaponics. This study is crucial for identifying the most

effective approaches to maximizing the productivity of local resources and providing insights for informed policy and investment decisions.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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