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Fish Farming Activities in Mbanza-Ngungu: Farmer Socio-Professional Profiles, Production Practices, and Improvement Opportunities for Sustainable Aquaculture

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Abstract: The study describes the distribution of fish farming activities, identifies and characterizes the stakeholders involved, and assesses their level of knowledge and the techniques used for fish farming in the Territory of Mbanza-Ngungu. Furthermore, it proposes avenues to improve the sustainability and profitability of the sector. The methodology relied on a snowball approach to recruit a representative sample of 350 fish farmers. Field visits allowed for detailed data collection through a specially designed questionnaire. The data were analyzed using statistical methods (chi-square test of independence) to identify trends and challenges across the sectors of the territory of Mbanza-Ngungu. The findings revealed that fish farming activities are distributed across the territory of Mbanza-Ngungu, with a male predominance (96%) among fish farmers and a growing trend of this activity among older individuals over 40 years old (48%). Additionally, the results demonstrate that aquaculture is mainly a secondary activity for 97% of respondents, yet it could play a pivotal role in household economic diversification. The study identifies predominant practices, such as extensive farming (89%) and monoculture (92%), while highlighting gaps in pond management and fish farmers' general knowledge. Challenges are mainly related to feed access (28%), financing (27%), training (23%), and water quality monitoring (100%). The commercial orientation of production towards sales (94%) rather than self-consumption offers an opportunity to improve this sector in this territory. Finally, recommendations are made to enhance the sustainability and profitability of aquaculture in the region, including promoting integrated practices, more efficient pond management practices, and aquaculture product processing.

Keywords: fish farming; fish farmer practices; fish species; administrative sectors; territory of Mbanza-Ngungu; DRC

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1. Introduction

The practice of fish farming in the Democratic Republic of the Congo (DRC) was initiated following the conclusion of the Second World War in 1946, originally in the Lubumbashi region. The promising initial outcomes prompted the Belgian authorities to extend this activity to the entire country [1]. From 1945 to 1960, the sector's development was based on establishing 25 main hatchery centers (MHCs), with some secondary centers distributed throughout the country and a very important extension service present in each province [1]. However, the sector declined after 1960 (post-independence period),

despite the efforts of the Ministry of Agriculture and Livestock to revive it. A few years later, bilateral cooperation projects with the United States and Belgium were initiated. In this context, American cooperation (US Agency for International Development, USAID), through the Peace Corps, and Belgian bilateral cooperation, through its General Agency for Development Cooperation (AGCD), developed family fish farming projects in the former Bas-Congo province, presently Kongo Central [1,2]. However, these projects were interrupted in the 1990s due to internal political events. The sector received support from the Aquaculture Sector Redeployment Program in DRC in 1997, but the results were disappointing.

In 1990, the average fish productivity in peasant environments ranged from 180 to 450 kg/ha/year, whereas in hatchery centers, it ranged from 900 to 3600 kg/ha/year [3]. Since the departure of Belgian, French, and American technical assistants who were active during the 1980–1990 period, average pond yields have barely exceeded 3000 kg/ha/year in peri-urban areas and ranged from 1500 to 1800 kg/ha/year in rural settings [4,5].

Reliable statistical production data have not been available for several decades due to the cessation of cooperative projects in 1990, following multiple periods of war and the subsequent abandonment of fish farming activities by most rural populations [2]. Nevertheless, between 2003 and 2007, national aquaculture production was estimated to have reached nearly 3000 tons per year, valued at USD 7.4 million [5]. In 2011, extensive tilapia production in the Kongo Central province reached 1500 tons per hectare per year. From 2014 to 2017, the total tilapia production in the Democratic Republic of Congo ranged from 3795 to 48,157 tons [2].

A strategic plan for 2010–2015, supported by the FAO, was developed for the sustainable development of aquaculture. This plan was based on three fundamental pillars: improving the efficiency of production systems (access to inputs, such as fingerlings, animal feed, capital, etc.); enhancing services (extension, training for all stakeholders, research, and marketing support for the industry); and improving management (professionalization, enforcement of the new law, aquaculture component including applied regulations, etc.) [1]. However, the results of the FAO plan indicate a lack of performance in the sector so far [2].

While fish farming is currently experiencing worldwide growth [6,7], many low-income countries in Africa and across the continent are not fully utilizing their potential in this sector. To strengthen sustainable aquaculture where it is most needed, particularly in Africa, it is essential to implement targeted policies, promote technology transfer, build capacity, and encourage responsible investments [8].

It is pertinent to consider the case of Mbanza-Ngungu, located in the Kongo Central province in the DRC. Given the trend in global fish farming development, an analysis of its impact and implementation in specific regions, such as the territory of Mbanza-Ngungu, is relevant. Like other regions, this one is subject to the influence of major urban centers, namely the city of Mbanza-Ngungu (capital of the Mbanza-Ngungu territory), which exerts a significant impact on the development of local economic activities, including fish farming.

Mbanza-Ngungu, a territory renowned for its diverse agricultural practices [9], also benefits from favorable conditions for fish farming, offering promising potential for increasing fish productivity while preserving natural resources. Nonetheless, this development should be based on the current situation of the sector, which remains largely unknown. This is due to the lack of available fisheries data in the region and the almost complete absence of published studies on the subject. What is the current status of fish farming in the Mbanza-Ngungu territory? Has this sector been able to develop at the same pace in different parts of the territory? What are the improvement opportunities to consider for the sector development?

The first objective of this study is to assess the distribution of aquaculture activities across different administrative sectors of the Mbanza-Ngungu territory and to identify the actors involved in this activity. The second objective is to evaluate the general level of knowledge among these actors regarding fish farming activities and to identify the various

production techniques currently used in the region, the main reared fish species, and the challenges and opportunities associated with fish farming.

Therefore, an aquaculture Mbanza-Nungu territory was assessed to understand the key stages from production to marketing or consumption and to identify potential bottlenecks or areas for improvement. Finally, solutions are proposed to improve existing fish farming practices to enhance the sustainability and profitability of food production activities, both locally and in other similar regions.

2. Materials and Methods

2.1. Locality and Study Area

The Democratic Republic of the Congo (DRC) is divided into 145 administrative territories. This study was conducted in one of the ten territories that comprise the Kongo Central province. The study was conducted in the seven sectors of the Mbanza-Ngungu territory, which has its capital in the city of Mbanza-Ngungu. It should be noted that the city of Mbanza-Ngungu is a discrete entity, distinct from the Boko sector. This territory is situated 154 km away from the city of Kinshasa. Its coordinates are 5°16′ South, 14°51′ East. The climate is classified as Aw4 (tropical savannas) according to the Köppen classification system [10]. Fifty-five villages were visited, spread across 24 groupings. The study was conducted over a three-month period, from July to September 2023.

Among them, 350 fish farmers from different areas of the territory were studied to take into account the geographical diversity of the Mbanza-Ngungu region (Figure 1). This allowed for the inclusion of participants from various geographical zones, providing a comprehensive perspective of the fish production situation in the region. The snowball sampling method [11] was employed to select the 350 fish farmers participating in the study. The participants were gradually recruited through recommendations, thus ensuring the representativeness and diversity of the sample. This approach was chosen due to the lack of precise administrative data on the target sample size.

A survey questionnaire was developed to collect detailed data regarding the socio-professional aspects of fish farmers, aquaculture-related activities, knowledge levels of rearing techniques, and various constraints encountered. Furthermore, the survey addresses the evaluation of the fish farming value chain in this region. The questionnaire was designed to meet the specific objectives of the study. Open-ended questions were included to allow participants to provide detailed and contextual information about their practices. Individual interviews and field visits were conducted by the authors to ascertain the dimensions of the ponds and to collect the relevant geographical coordinates.

2.2. Statistical Analysis of the Data

To compare the different fish farming trends across the sectors, collected data were subjected to statistical analysis using frequency calculations and the chi-square test of independence with $p < 0.05$. These analyses facilitated the identification of trends while providing essential insights for the overall understanding of the current fish farming situation in the Mbanza-Ngungu territory.

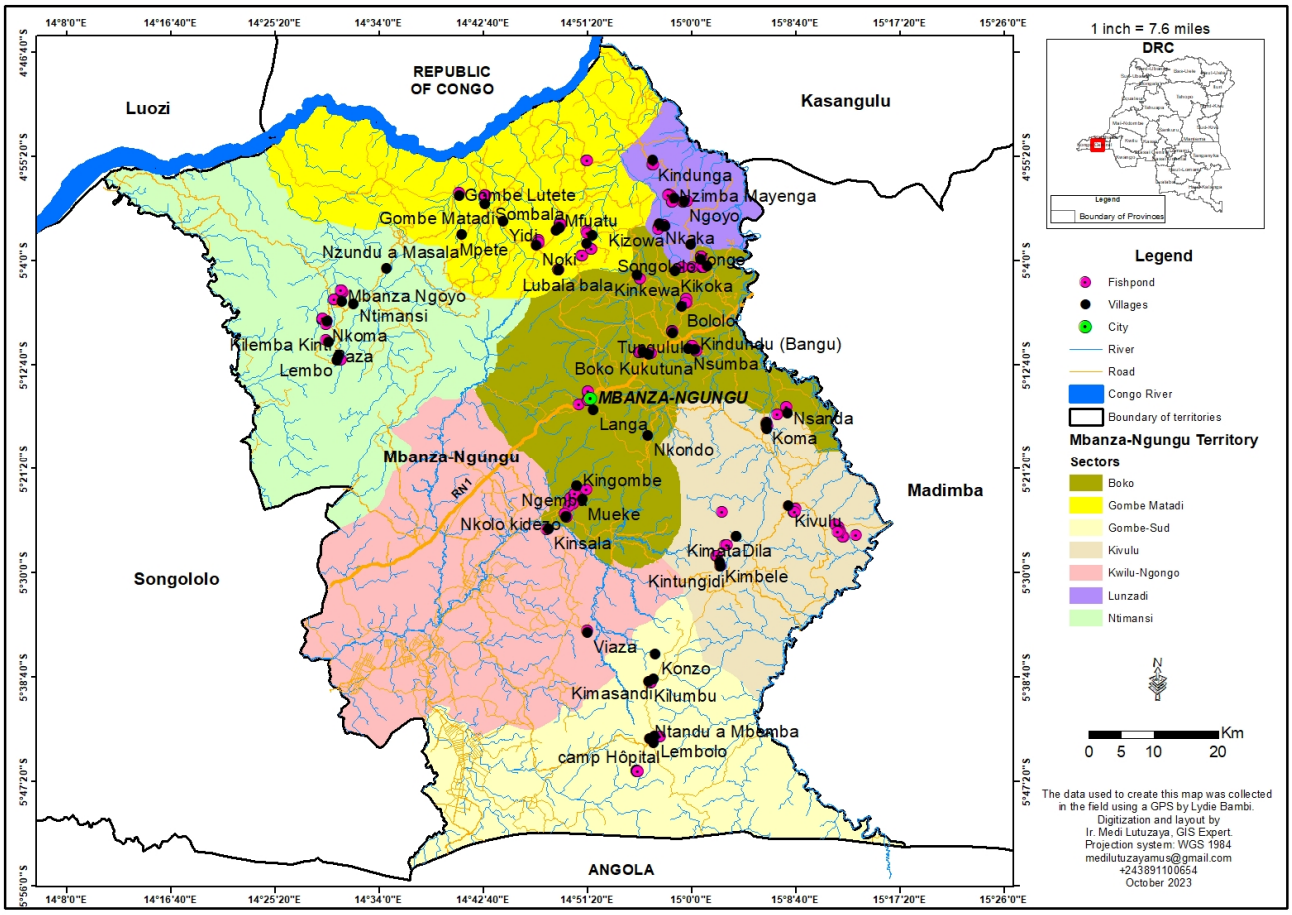

Figure 1. Location of the surveyed fish ponds in the territory of Mbanza-Ngungu: purple dots represent visited ponds, and black dots represent visited villages (Map created from field data).

3. Results

3.1. Repartition of Fish Farmers per Surveyed Administrative Sector

A total of 350 fish farmers were selected for the survey. Figure 2 presents the distribution of fish farmers across the various surveyed sectors.

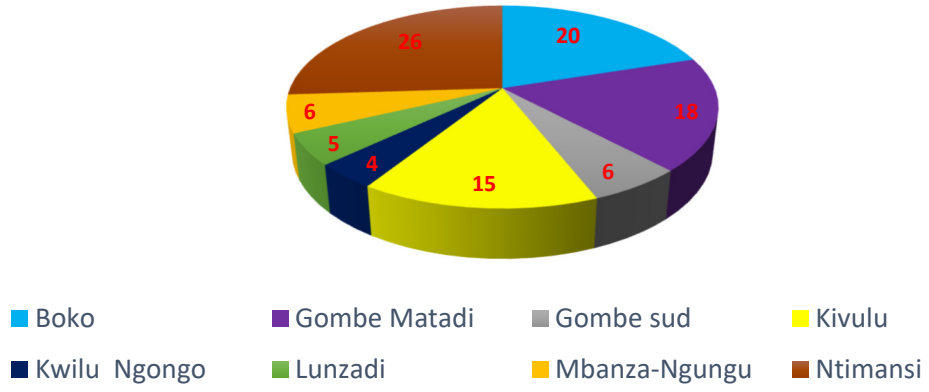

Figure 2. The percentage of fish farmers per surveyed administrative sector.

A total of 342 ponds were surveyed, including 12 natural ponds (Boko sector: Nkolo axis and Kwilu-Ngongo sector). Figure 3 illustrates the distribution of ponds by surveyed sector.

The total surface of artificial ponds was 55,385 m^2, with a mean surface of 213 ± 454 m^2, demonstrating a high variability in pond sizes. Additionally, natural ponds were visited,

particularly in the Nkolo area, the Boko sector, and the Kwilu Ngongo sector, representing a total surface of 252,700 m^2 with a mean of 126,350 m^2.

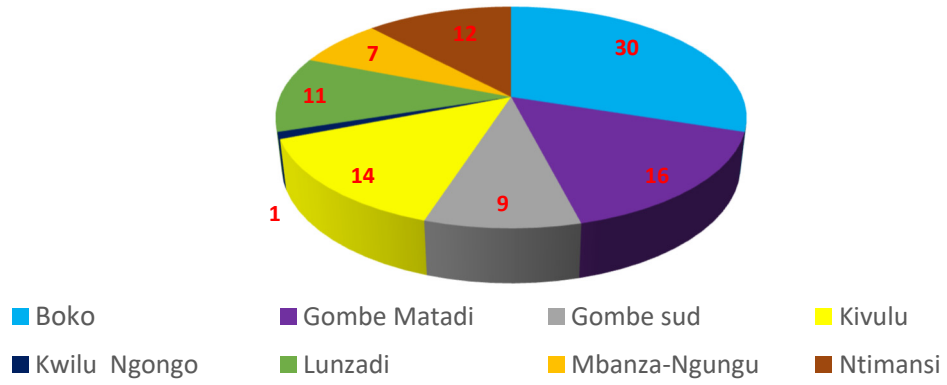

Figure 3. The percentage of ponds per administrative sector visited.

3.2. Socio-Professional Characteristics of the Producers

Socio-professional characteristics of the fish producers in the Mbanza-Ngungu area are summarized in Table 1. In all sectors, males are predominant in aquaculture activities (96%) compared to females (4%), with no significant difference (p = 0.171) between sectors. In terms of age, 48% of the respondents were over 41 years old, with a high representation of middle-aged people. The 31–40 age group is similarly represented across all regions with 37% of the samples, while the youngest age group (20–30) is less represented with 15%.

Table 1. Socio-professional characteristics of the respondents: gender, age, marital status, education.

Variables	Surveyed Areas	Frequency (%)									*p*-Value
		Boko	Gombe Matadi	Gombe Sud	Kivulu	Kwilu Ngongo	Lunzadi	Mbanza-Ngungu	Ntimansi	General Total	
Gender	F	6	6	0	0	14	0	10	3	4	0.171
	M	94	94	100	100	86	100	90	97	96	
Age	20–30 years	0	21	14	17	36	6	10	21	15	0.008 *
	31–40 years	38	34	41	31	29	31	55	40	37	
	41 years and older	62	45	45	52	35	63	35	39	48	
Marital status	Single	28	34	32	28	21	19	35	38	31	0.554
	Divorced	1	3	0	3	0	0	5	1	2	
	Married	61	52	64	54	79	81	60	56	59	
	Widower	10	11	4	15	0	0	0	5	8	
Education	Certificate of Primary Education	5	45	50	6	36	25	10	39	26	<0.0001 *
	State diploma	85	36	41	81	50	56	70	47	59	
	Higher Education Diploma	7	8	5	6	0	13	20	3	7	
	Never enrolled in school	3	11	4	7	14	6	0	11	8	
Number of farmers by sector		72	62	22	54	14	16	20	90	350	

p value: chi-square test of independence, $\alpha = 0.05$. * Significantly different between areas. N = 350 respondents.

The results show significant differences in the age groups of fish farmers across sectors, with the absence of the 20–30 age group in the Boko sector and a predominance of individuals aged 41 years and over (62%). In addition, the Kwilu-Ngongo sector displayed a significantly higher percentage of individuals aged from 20 to 30 years (35%) compared to other sectors. The distribution of marital status shows no significant difference across sectors ($p = 0.554$), with the majority of individuals being married (59%).

In terms of education, 59% of respondents had completed high school, 26% had completed primary school, and 8% had completed higher education. There was a significant difference ($p < 0.0001$) in the educational level of respondents across sectors, with a prevalence of high school graduates in some sectors (Boko, Gombe Matadi, Kivulu, and Ntimansi). The town of Mbanza-Ngungu stands out with a high percentage of high school graduates (70%) and individuals with tertiary education (20%).

3.3. Experience, Characterization of Fish Farming Site, and Fish Farming Activities

Fish farming is a second activity for mainly all of the respondents (97%), while only 3% practice it as their main activity, with no difference between areas ($p = 0.563$, Table 2). In addition, 44% of the respondents had more than five years of experience in fish farming, while others had recently (4 years or less) started their activity. The duration of the production was significantly different between geographic sectors, with long durations for Gombe Matadi, Lunzadi, and Ntimansi.

Water supply permanence was the main consideration for site selection for 80% of respondents, followed by accessibility (13%) and relief (7%), with no significant difference among the sectors. The number of ponds per operator varied significantly ($p < 0.01$) across sectors, with 75% of producers owning a single pond in Mbanza-Ngungu and 60% owning more than five ponds in the Gombe Matadi sector (Table 2).

Derivation of surface water was the main pond water supply (up to 80%) for all areas except for Kwilu Ngongo where water was mainly provided by groundwater (64%). Globally, 11% of the respondents collected underground water.

Nearly 90% of respondents practiced extensive farming, while only 11% applied semi-intensive farming ($p < 0.0001$, Table 3). In the Gombe Matadi, Kivulu, Kwilu Ngongo, Lunzadi, and Mbanza-Ngungu rearing systems are only extensive. Only producers from Boko, Gombe sud, and Ntimansi used semi-intensive rearing systems (from 7% to 33%, Table 3).

The majority of producers (79%) exclusively reared Nile tilapia (*Oreochromis niloticus*), with 13% focusing solely on African catfish (*Clarias gariepinus*) and 8% raising both species. There were significant differences among the different sectors, with the town of Mbanza-Ngungu displaying the highest rate of producers rearing both species (35%).

Most of the producers (83%) did not consider the density and the average weight of the fish when stocking, with no significant difference among them.

Significant ($p < 0.01$) differences were observed in all the sectors in terms of the fry supply. Self-sufficient restocking, involving fry harvesting from on-growing ponds, was practiced by 67% of producers, whereas 29% depended on hatcheries and only 4% sourced their fry from local producers.

Regarding fish feeding practices (Table 4), a high preference (90%) for agricultural wastes as a feed source was observed and was significantly different between the surveyed sectors ($p < 0.01$). Up to 65% of producers did not fertilize their ponds, with significantly lower values for the Gombe Sud (14%) and Kwilu-Ngongo (0%) sectors. The regular pond maintenance was similar ($p > 0.05$) between the different sectors. Aquaculture water quality management was not widely practiced across sectors. Finally, the duration of rearing cycles significantly ($p < 0.05$) varied across sectors, with a 12-month cycle predominantly applied.

Table 2. Experience, site selection, number of ponds, and pond water supply method in surveyed fish farming sites.

Variables	Surveyed Areas	Frequency (%)									*p*-Value
		Boko	Gombe Matadi	Gombe Sud	Kivulu	Kwilu Ngongo	Lunzadi	Mbanza-Ngungu	Ntimansi	General Total	
Activity	Primary	4	0	0	4	0	0	0	4	3	0.563
	Secondary	96	100	100	96	100	100	100	96	97	
Duration of fish farming production	1 year	3	0	9	5	0	19	0	33	11	<0.001 *
	2 years	16	10	18	13	14	0	30	11	14	
	3 years	21	8	23	19	14	6	25	10	15	
	4 years	14	27	32	15	0	19	5	11	16	
	5 years or more	46	55	18	48	72	56	40	35	44	
Site selection	Accessibility	14	18	14	6	14	19	0	14	13	0.218
	Permanent water	81	74	68	89	86	75	80	80	80	
	Relief	5	8	18	5	0	6	20	6	7	
Number of ponds	1 pond	42	10	55	46	29	25	75	43	39	<0.001 *
	2 ponds	40	5	11	4	71	50	20	9	19	
	3 ponds	13	18	27	15	0	19	5	5	12	
	4 ponds	1	1	0	18	0	0	0	0	3	
	5 ponds	4	6	0	4	0	0	0	43	14	
	More than 5 ponds	0	60	5	13	0	6	0	0	13	
Water supply	Derivation	79	95	95	93	36	81	90	98	89	<0.0001 *
	Groundwater	21	5	5	7	64	19	10	2	11	
Number of farmers by sector		72	62	22	54	14	16	20	90	350	

p value: chi-square test of independence, $\alpha = 0.05$. * Significantly different between areas. N = 350 respondents.

Table 3. Production practices: farming system, reared species, culture method, average weight/density consideration at loading, and fry supply.

Variables	Surveyed Areas	Frequency (%)									*p*-Value
		Boko	Gombe Matadi	Gombe Sud	Kivulu	Kwilu Ngongo	Lunzadi	Mbanza-Ngungu	Ntimansi	General Total	
Livestock farming system	Extensive	93	100	91	100	100	100	100	67	89	<0.001 *
	Semi-intensive	7	0	9	0	0	0	0	33	11	
Raised species	*Clarias gariepinus*	25	5	0	22	0	25	20	6	13	<0.001 *
	Oreochromis niloticus	68	90	91	63	100	75	45	91	79	
	Both	7	5	9	15	0	0	35	3	8	

Table 3. *Cont.*

Variables	Surveyed Areas	Frequency (%)									*p*-Value
		Boko	Gombe Matadi	Gombe Sud	Kivulu	Kwilu Ngongo	Lunzadi	Mbanza-Ngungu	Ntimansi	General Total	
Breeding method	Monoculture	93	95	91	85	100	100	65	97	92	0.000 *
	Polyculture	7	5	9	15	0	0	35	3	8	
Average weight/ density at loading	No	83	84	86	89	86	75	85	80	83	0.886
	Yes	17	16	14	11	14	25	15	20	17	
Supply of fry	Fish hatchery	43	15	5	69	0	31	65	7	29	<0.001 *
	Producer	6	0	5	9	0	13	0	2	4	
	Restocking	51	85	90	22	100	56	35	91	67	
Number of farmers by sector		72	62	22	54	14	16	20	90	350	

p value: chi-square test of independence, α = 0.05 * Significantly different between areas. N = 350 respondents.

Table 4. Pond management in terms of the feeding mode, pond fertilization, regular maintenance of ponds, water quality monitoring, and breeding cycle.

Variables	Surveyed Areas	Frequency (%)									*p*-Value
		Boko	Gombe Matadi	Gombe Sud	Kivulu	Kwilu Ngongo	Lunzadi	Mbanza-Ngungu	Ntimansi	General Total	
Feeding mode	Imported artificial foods	4	0	9	0	0	0	5	33	10	<0.001 *
	Agricultural activities debris	96	100	91	100	100	100	95	67	90	
Pond fertilization	No	58	74	86	61	100	50	75	58	65	0.004 *
	Yes	42	26	14	39	0	50	25	42	35	
Regular maintenance of ponds	No	53	48	77	63	43	50	70	53	56	0.194
	Yes	47	52	23	37	57	50	30	47	44	
Water quality monitoring	No	99	100	100	100	100	100	100	100	100	0.794
	Yes	1	0	0	0	0	0	0	0	0	
Breeding Cycle	12 months	61	53	32	76	64	75	50	62	61	<0.001 *
	6 months	26	37	14	22	14	25	35	23	26	
	>12 months	13	10	54	2	22	0	15	15	13	
Number of farmers by sector		72	62	22	54	14	16	20	90	350	

p value: chi-square test of independence, α = 0.05. * Significantly different between areas. N = 350 respondents.

3.4. Aquaculture General Knowledge

Results indicated a level of unfamiliarity among respondents regarding production, agro-fishery integration, and its benefits in all sectors ($p > 0.05$, Table 5). None of the participants mentioned any knowledge of effluent management, and 77% ignored the

quantity of effluent produced on their farms, with only 23% claiming to understand these data. Concerning agro-fishery integration, the results revealed a significant ($p < 0.05$) disparity in understanding associated concepts. Moreover, 84% of farmers demonstrated a lack of familiarity with agro-fishery integration concepts, while only 16% exhibited a degree of knowledge in this area.

Table 5. Assessment of the respondents' general knowledge level based on fish farming and agro-fishery practices.

Variables	Surveyed Areas	Frequency (%)									*p*-Value
		Boko	Gombe Matadi	Gombe Sud	Kivulu	Kwilu Ngongo	Lunzadi	Mbanza-Ngungu	Ntimansi	General Total	
Knowledge of production	No	78	82	86	72	64	88	80	71	77	0.451
	Yes	22	18	14	28	36	12	20	29	23	
Management of pond effluents	No	100	100	100	100	100	100	100	100	100	N/A
	Yes	0	0	0	0	0	0	0	0	0	
Agro-piscicultural integration	No	85	90	82	83	79	81	90	79	84	0.713
	Yes	15	10	18	17	21	19	10	21	16	
Benefits of agro-piscicultural integration	No	92	94	82	89	86	94	95	84	89	0.514
	Yes	8	6	18	11	14	6	5	16	11	
Farmers' organization	No	74	29	73	35	0	69	90	19	43	<0.001 *
	Yes	26	71	27	65	100	31	10	81	57	
Technical supervision	No	86	76	86	74	86	81	95	58	75	0.000 *
	Yes	14	24	14	26	14	19	5	42	25	
Number of farmers by sector		72	62	22	54	14	16	20	90	350	

p value: chi-square test of independence, $\alpha = 0.05$. * Significantly different between areas, N/A: not applicable. N = 350 respondents.

Membership levels to farmer organizations significantly ($p < 0.05$) differed among the surveyed sectors, and 100% of the respondents in the Kwilu-Ngongo sector belonged to a farmer organization, while 90% did not belong to one in Mbanza-Ngungu. Globally, 43% of respondents are not part of any association, and 57% are members of a farmer organization.

A significant proportion of respondents, 75%, did not receive technical support from either government or non-governmental organizations, whereas only 25% benefited from such support. The percentage varied significantly ($p < 0.05$) across Boko, Ntimansi, and the city of Mbanza-Ngungu.

3.5. Constraints and Orientation of Fish Production

A significant ($p < 0.05$) difference was observed among the surveyed sectors regarding the constraints encountered by fish farmers throughout their aquaculture activities (Table 6). In the Lunzadi sector, 31% of respondents had limited access to inputs (feed, fry, material, fertilizer, etc.) compared to those in other sectors where this constraint was less frequently reported. The Boko sector displayed the lowest proportion of respondents (15%) that encountered problems related to feeding, while Ntimansi had the highest proportion of respondents (37%) facing feed-related issues.

Table 6. Challenges and orientation of production.

Variables	Surveyed Areas	Frequency (%)									*p*-Value
		Boko	Gombe Matadi	Gombe Sud	Kivulu	Kwilu Ngongo	Lunzadi	Mbanza-Ngungu	Ntimansi	General Total	
Constraints	Limited access to inputs	13	10	14	5	21	31	15	11	12	<0.001 *
	Fish feeding	15	27	36	35	36	19	15	37	28	
	Formation	33	19	18	30	29	25	35	9	23	
	Workforce	10	7	0	2	0	0	0	0	4	
	Diseases	10	2	0	0	0	0	0	0	2	
	Lack of high-quality seed	7	8	0	4	0	0	15	0	4	
	Financial resources	12	27	32	24	14	25	20	43	27	
Purpose of production	Self-consumption	4	3	9	22	0	6	0	2	6	0.001 *
	More consumption and little sales	0	0	0	2	0	0	0	0	0	
	More sales and less consumption	96	97	91	76	100	94	100	98	94	
Product transformation	No	99	97	91	91	100	100	90	94	95	0.322
	Yes	1	3	9	9	0	0	10	6	5	
Number of farmers by sector		72	62	22	54	14	16	20	90	350	

p value: chi-square test of independence, $\alpha = 0.05$ * Significantly different between areas. N = 350 respondents.

The Mbanza-Ngungu and Boko sectors exhibited a higher proportion (35 and 33%) of farmers facing training constraints, while the Ntimansi sector encountered the lowest training constraints (9%). The need for training was reported by 23% of fish farmers.

A noticeable disparity in the Boko sector was observed concerning constraints linked to the lack of manpower (10%) and the prevalence of diseases (10%). Problems related to seed quality were mainly observed in the city of Mbanza-Ngungu (15%). Overall, 28% of respondents mentioned feeding as a challenge. Among these challenges, limited access to inputs was reported by 12% of respondents.

The Boko sector had the lowest proportion of fish farmers (13%) facing major issues with funding sources, while the Ntimansi sector had the highest proportion (43%) of farmers facing major financial constraints. The lack of financial resources, as reported by 27% of respondents, emerged as a significant challenge, underscoring the importance of access to funding to overcome obstacles.

The production orientation significantly ($p < 0.05$) varied across regions, and 94% of respondents reported production targeting commercial purposes, with a relatively low allocation (6%) for self-consumption. The Kivulu sector was the exception with 76% of respondents primarily directing their production towards sales and minimal consumption and 22% applying self-consumption. It is noteworthy that transactions occurred mainly on-site, attracting buyers directly to fish farms. A total of 95% of respondents did not transform their products destined for consumption and/or sale. In most cases, consumption aimed for fresh fish.

4. Discussion

4.1. Socio-Professional Characteristics

The gender distribution in fish farmers from the different studied areas was similar, with a clear male predominance in the whole Mbanza-Ngungu territory. Ref. [12] also obtained similar results in nine counties in western Kenya. Ref. [4] stated that this dominance indicates the leading position of men as heads of households. Another reason could be the nature of fish farming, which involves manual labor and seems to be more accessible to men than to women.

With nearly half of the farmers aged up to 41, fish farming in this region is increasingly becoming an activity for experienced people who have benefited from fish farming support over time. Ref. [13] also obtained similar results in Cameroon. Ref. [1] asserted that fish farming is an activity that is almost abandoned in the Democratic Republic of the Congo. The relatively low proportion of respondents in the youngest age group (20–30 years old) is noticeable, particularly the absence of this age group in the city of Mbanza-Ngungu. This could indicate a need to promote fish farming education and activities among young people to ensure its continuity. The absence of this age group in the city of Mbanza-Ngungu can also be explained by a significant proportion of young people pursuing higher education and being attracted to urban regions that offer more opportunities than rural areas. Ref. [13] reports that this activity is considered by most young people as a profession primarily intended for older individuals. The Kwilu-Ngongo sector displays a high proportion of young people involved in fish farming activities, suggesting a recent introduction of this practice in the region.

The majority of respondents in all sectors are married, which raises questions about the potential impacts of family life on fish farming practices. Most of the visited farms are family-owned. Refs. [1,2] described that the model developed in the country was more based on subsistence fish farming aimed at family consumption. Currently, although fish farming activities remain largely family-based, subsistence aquaculture is increasingly being abandoned in favor of a trend focused more on sales than consumption. This shift is creating new sources of income for families, driven by the growing demand for fish products in urban markets. However, preserving the harvested products in rural areas remains a significant challenge.

The city of Mbanza-Ngungu has the highest proportion of respondents with a higher education certification. Boko, Gombe Matadi, Kwilu-Ngongo, Kivulu, and Ntimansi, which are influenced by major urban centers, have an intermediate level of education (State Diploma). The relatively intermediate level of education across all fish farmers in the territory suggests that this could be a valuable resource for influencing their approach to sustainable fish farming practices. The distribution of fish farmers by sector highlights development disparities between the different regions. It provides insights for the development of public policies aimed at supporting and promoting fish farming in a balanced and sustainable manner.

4.2. Experience, Site Selection, and Fish Farming Activities

Fish farming represents a secondary economic activity in the Mbanza-Ngungu territory, suggesting that most of the respondents consider it as complementary income. However, even though it represents a secondary source of income, it can play an important role in the economic diversification of households [1].

Most of the respondents have been engaged in fish farming for over five years, with a range of six to over 30 years. This demonstrates the longevity of this activity in the region. It also indicates persistent traces of past strategies implemented to promote the development of fish farming in the country, despite their abandonment over time. Pond fish farming has long been practiced by rural communities in many Asian countries and is a common practice in Africa [14]. Ref. [1] reported that fish farming was introduced into the country just after the end of World War II. Furthermore, the distribution of experiences, ranging from several years to more recent beginnings, reflects the dynamics of learning and renewal

within the fish farming community. This is particularly evident in the establishment of certain support structures for fish farmers, such as APEFE (Association for the Promotion of Education and Training Abroad, Belgium) in Boko, Kivulu, and Ntimansi.

The Mbanza-Ngungu territory offers a favorable environment for fish farming, with rivers and relief being among the most cited reasons for choosing a particular site. Ref. [14] reports that pond fish farming can be divided into two types based on their water supply: dike ponds and watershed ponds (or depressions). During this field study, these two types were encountered in different regions, depending on the topography of the area The importance of continuous water availability is the primary reason for selecting the fish farming site that is based on criteria, such as water permanence, accessibility, and relief, underscoring the importance of environmental conditions for the success of the activity. This also emphasizes the need to consider these factors in planning new installations. Ref. [2] indicated that the ecological conditions of the Democratic Republic of Congo are suitable for fish farming. Furthermore, water permanence, favorable soil, and topography for pond construction are essential. The water supply, whether from surface or groundwater sources, significantly influences water availability and quality. These parameters are crucial for the well-being of fish, as well as for the profitability of aquaculture activities. Our results underscore the importance of understanding local variations in the water supply for the effective and sustainable management of fish ponds in this region. This also illustrates the capacity of the Mbanza-Ngungu territory to exploit its hydrographic resources for fish farming. The average pond surface highlights the diversity of fish farm dimensions. Natural ponds in the Boko (Nkolo axis) and Kwilu Ngongo areas contribute to the total area, displaying a higher surface. While these ponds do not meet the majority of artificial fish pond requirements, fish farmers in this area still stock these natural ponds.

The number of ponds per fish farmer varies considerably across sectors. Ref. [15] reports that the majority of small-scale fish farmers in Kenya own at least one pond and up to a maximum of forty ponds. Fish farmers grouped within associations hold a higher number of ponds than their counterparts working independently. This difference can be attributed to the increased availability of labor when managed collectively compared to an individual approach. Indeed, collaboration within a team offers advantages in terms of operational efficiency and the sharing of responsibilities, which can lead to the more extensive and successful management of a larger number of ponds. This trend highlights the importance of considering organizational dynamics and collaboration strategies in the fish farming sector for the optimal management of aquatic resources. On the other hand, it is observed that Mbanza-Ngungu city has a higher proportion of fish farmers with only one pond and less affiliated with professional organizations. This reinforces the affirmation that fish farming activity in urban areas of the territory is less developed than in rural areas due to the availability of a wider range of opportunities.

The extensive farming system is the most prevalent in the Mbanza-Ngungu territory, reflecting a trend towards low productivity, lower production costs, or a lack of training in new production techniques to increase productivity and optimize outputs. These results also testify to the production model established in the country, which favors an approach focused on subsistence rather than large-scale intensive production [1]. In extensive systems, inputs are primarily provided by natural foods, such as plankton, mollusks, and insect adults and larvae, while in semi-extensive systems, natural or supplementary feeds are used [16]. Extensive systems use basic management levels, as they do not use inputs for production; organisms grow on their own, and productivity is limited by the natural conditions of the water. The stocking density is low, resulting in production not exceeding 500 kg/ha [17]. The marked preference for the monoculture of Nile tilapia indicates an interest in this region for this species. Ref. [18] stated that Nile tilapia is one of the most cultivated species in aquaculture in the sub-Saharan region. However, the relatively low percentage of fish farmers rearing African catfish (*Clarias gariepinus*) may be attributed to the difficulty of natural reproduction in captivity. Ref. [19] also encountered both aforementioned species during their study in the Borgou department in northern Benin. Limited

access of fish farmers to *clarias* fingerlings could explain this relatively low proportion. It would be important to establish hatchery centers in areas proximate to major urban centers and readily accessible, such as the Boko and Gombe Matadi sectors, to facilitate the acquisition of *Clarias gariepinus* fingerlings by fish farmers. Moreover, it would be advantageous for administrative or non-governmental organizations to devise training programs based on the artificial reproduction of this species in rural areas, thereby enabling fish farmers to diversify the species they rear. The prevalence of monoculture indicates a simplification of fish pond management in this territory. According to the observations of [20], rural fish farmers resort to exchanging fingerlings among themselves, a practice that could lead to a decrease in genetic diversity within their ponds. Furthermore, it is generally recognized that polyculture, characterized by the simultaneous farming of different species, is considered more productive than monoculture. In Bangladesh, China, Taiwan, Thailand, and Vietnam, the majority of tilapia farmers who use pond-based systems practice polyculture. In contrast, tilapia farming in the Philippines predominantly follows a monoculture approach. The cultivation methods employed in these regions vary according to the type of farmland and the farmers' ability to invest. Tilapia pond culture in these countries involves the use of diverse inputs, including agricultural by-products (such as bran, oilcake, vegetation, and manures), inorganic fertilizers, and specialized feeds. In monoculture tilapia systems, animal manures are used to provide nutrients that promote the growth of protein-rich phytoplankton, which is then consumed by filter-feeding Nile tilapia [18]. Moreover, Ref. [15] highlights that the low adoption of polyculture can also be attributed to a lack of knowledge among fish farmers. Regarding the understanding of fish density and the average weight at stocking, its comprehension is important for optimizing fish production. The fact that the majority of respondents do not take these factors into account (or are not aware of these concepts) suggests opportunities for improving technical knowledge to optimize productivity. Similarly, the utilization of self-sufficient restocking to maintain the fish population in ponds may be a contributing factor to the low production observed in this region, as some stocks are already degenerating. Ref. [1] emphasized that production is also dependent on the quality of grown progenies. The uncontrolled breeding of tilapia in ponds, which led to excessive recruitment, stunting, and a low percentage of marketable-sized fish, could hurt production [18]. This underscores the pivotal role of hatcheries, indicating their reliance on them, which contrasts the findings of [19] in the department of Borgou in northern Benin, where 70% of respondents indicated their reliance on hatcheries. The presence of hatcheries could ensure the availability of quality fingerlings in this region. Two hatcheries are operational in the region, one located in Mansende/Mawunzi (Kivulu), overseen by APEFE (Association for the Promotion of Education and Training Abroad), and the other in Boko sector, overseen by a local fry producer. However, the current number of hatcheries in the region is insufficient to meet the needs of fish farmers across the entire Mbanza-Ngungu territory. Therefore, it is necessary to increase the number of hatcheries in the region and implement strategies to train fish farmers in the production of fingerlings for the main species raised in tropical regions.

4.3. Feeding, Pond Management, and Rearing Cycle

The predominant use of by-products from agricultural activities as a source of fish feed is encouraging. Ref. [20] observed the same trend in rural areas in the Kinshasa region. This reflects the utilization of local resources and the valorization of by-products, thereby reducing production costs. Additionally, it presents a potential benefit for agro-fish farming integration perspectives. Nevertheless, it is crucial to guarantee that the feed input from agricultural activities meets the nutritional requirements of the cultured species [20]. Diversifying farm activities is a crucial strategy for smallholder farmers seeking to broaden their income sources, manage risks, stabilize their production, and enhance resource efficiency. Integrated Agriculture-Aquaculture (IAA) connects aquaculture with crop or livestock farming through two main approaches: direct on-farm integration and indirect integration, which involves using by-products from other farm activities as inputs for aquaculture. IAA

is frequently applied in extensive and semi-intensive farming systems. This approach can yield impressive results, with semi-intensive systems potentially producing up to 10 tonnes of fish per hectare [21].

The fact that the majority of farmers do not use pond fertilization may indicate a lack of information on fish pond management or the inadequate monitoring of fish pond management. However, the use of compost to promote the growth of aquatic organisms is a positive practice contributing to improving pond productivity through the proliferation of primary production [22]. The regular maintenance of ponds indicates an awareness of the importance of maintaining the quality of the aquatic environment, thereby contributing to the productivity of fish ponds. Nevertheless, most fish farmers need to improve their maintenance procedures. Ref. [23] has underscored the significance of physico-chemical water parameters in aquaculture. Water quality is the most important limiting factor in fish farming and directly affects the feed efficiency, growth rate, health, and survival of the fish [15]. It would be important to disseminate information among these fish farmers about the significance of water quality monitoring and to encourage the implementation of appropriate practices.

The diversity of breeding cycles observed among fish farmers reflects their individual preferences and lack of information, and it may be influenced by factors, such as fish feeding and local market demand. The feeding methods used may not be optimal, mainly due to the feed quality, increasing the time required to reach the commercial size. Ref. [20] indicated that some operators extend the pond draining period based on the availability of an increased number of customers willing to purchase their products. They therefore adjust the breeding duration according to market demand. The literature recommends a breeding cycle of six months [24,25], emphasizing the importance of proper feeding and effective management practices to optimize fish growth. Extending breeding cycles results in a decrease in productivity and fry recruitment for restocking [24]. A pond harvested every six months typically yields a higher annual return than a pond harvested every twelve months. Improved approaches for feeding and pond management could be explored to align breeding cycles with profitable best practices. These approaches may include pond fertilization, appropriate feeding based on the needs of the species being raised, better water quality management, the use of high-quality seeds, and regular pond maintenance.

4.4. General Knowledge

The results indicated significant gaps in the knowledge of fish farmers in the Mbanza-Ngungu region regarding various aspects of fish farming, including production, aquaculture effluent management, and other techniques, such as agro-fish farming integration. While [20] identified eleven nutrient flows within integrated farms located in the Kinshasa area, presenting various levels of intensification, this study highlighted limited knowledge of these flows and their management in the region. A significant proportion of farmers were unaware of the effluent volume released by their farms. Furthermore, 100% lacked knowledge of sustainable effluent management from the ponds, which could compromise the sustainability of aquaculture in this territory. Valorization of these effluents represents an important avenue for ensuring the sustainable management of fish farms in this region by reducing environmental impacts and increasing productivity. Awareness and training are necessary, particularly in the context of agro-fish farming integration. The majority of respondents utilize by-products from agricultural activities as a source of feed for fish farming, which could be considered as a form of "integration" for which they claim to lack full knowledge. Ref. [26] indicates that vegetable waste can be used as fish feed, thereby reducing the need for small-scale farmers to purchase costly, specially formulated feed. The dike-pond system represents a common form of local agro-fish farming integration. In this system, fish are reared in ponds, while vegetables are cultivated on the dikes (or in areas adjacent to the ponds). In some instances, the vegetables are irrigated with pond water and, in others, fertilized with pond sludge [4]. In this approach, fish pond water is utilized to water vegetables, hence reducing the farmer's need to buy chemical fertilizers [26].

The multiple uses of water in Integrated Agriculture-Aquaculture Systems (IAASs) are effective in enhancing farm and water productivity, improving the water quality of fish ponds, and reducing the environmental impact of nutrient-rich water discharges, as well as lowering the cost of water and the amount of chemical fertilizers needed for crops [27]. The agro-fishery integration is emerging as a potential solution to diversify food sources and reduce environmental impacts [26]. Experts in livestock and fish farming argue that integrated farming, by optimizing resource use, can minimize environmental degradation [28,29]. This method is designed for small-scale deployment, allowing farmers to recycle the majority of agricultural and home wastes inside the system using materials and equipment already on the farm [30]. At the end of each fish growth cycle, pond muck is scraped and used to fertilize vegetable fields and fruit trees; animal excrement is utilized to fertilize plants. This method is common in Vietnam and is practiced in both uplands and lowlands [30]. The application of agro-fish farming techniques represents a pivotal aspect of global food security and the long-term viability of agricultural systems across a multitude of geographical regions.

Participation in farmer associations is encouraging, but there is still a need for improvement in associative initiatives, even in urban or peri-urban areas. Furthermore, equity in learning opportunities is important, as only a few of the respondents have received technical guidance. Ref. [31] asserts that frequent contact with aquaculture and/or agricultural extension agents positively influences the adoption behavior of aquaculture in a community. This was observed in a study conducted in the Ivory Coast, where the abandonment rate among fish farmers was 46% due to a lack of follow-up through extension agents. It may be necessary to implement targeted interventions, such as training sessions and capacity-building, to enhance knowledge and practices, particularly in the domains of pond management and agro-fish farming integration concepts.

4.5. Constraints and Orientation of Production

Our results revealed several significant challenges faced by fish farmers, which have implications for the management of their activities. Among these challenges, feed quality and supply were identified. Ref. [32] also reports the same results in two districts of Zambia. It indicates the necessity for innovative approaches in this region, such as agro-fish farming integration, to ensure adequate feeding for farmed fish. Another significant challenge is the lack of financial resources. This emphasizes the need to improve access to financing to overcome financial obstacles hindering the development of aquaculture in this area. Limited access to inputs is mentioned, highlighting the need to enhance the availability of necessary resources for aquaculture. The need for training indicates a clear demand for capacity building to improve practices and increase productivity. Labor and a lack of seedlings (fingerlings) are less frequent concerns. However, these aspects must be taken into account to ensure the holistic and sustainable management of fish farms. Despite the low occurrence of fish diseases, the importance of maintaining rigorous sanitary practices cannot be overstated. These practices may include the disinfection of equipment and disinfection of ponds [22]. Such measures are necessary to prevent any risk of an epidemic that would compromise fish production in this region. Ref. [22] affirmed that environmental stressors (e.g., poor water quality, loads of sedimented waste that produce toxic gases), and the presence of opportunistic or infectious pathogens (e.g., viruses, bacteria, parasites, and fungi) and non-infectious (nutritional, genetic) defects can all lead to sick fish.

The constraints listed by respondents regarding fish farming operations and development in the Democratic Republic of the Congo were corroborated by [1,2,14]. Furthermore, other factors were identified as animal predation problems, such as otters, snakes, and frogs, as well as fish poaching.

The majority of respondents mainly direct their production towards sales (with little self-consumption), highlighting the significant commitment of fish farmers to local markets. This underscores an economic and commercial perspective in their activities, highlighting the importance of supporting this orientation to stimulate local economic development and

promote local fish consumption. Sales occur directly on the farm, as observed by [19]. The lack of product transformation for consumption and/or sale indicates an opportunity for development in the valorization of aquaculture products in the market. The few farmers who transform their products, mainly through salting and, to a lesser extent, smoking, demonstrate a positive initiative that could be encouraged and expanded upon. Ref. [33] emphasized that fish, as a food, is highly susceptible to deterioration following capture, becoming unfit for consumption and potentially hazardous due to microbial, chemical, and enzymatic issues. Therefore, rigorous management is essential to ensure the quality and safety of aquaculture products. The preservation of fish quality necessitates the utilization of a multitude of preservation and processing techniques, including refrigeration, freezing, drying, smoking, frying, cooking, and fermentation. Ref. [22] also recommends specific strategies to ensure better quality for fish intended for sale: stop feeding the fish at least one day before harvesting, kill the fish quickly before gutting or filleting them, use clean water and appropriate containers while avoiding placing the fish directly on the ground, and if the fish are to be sold fresh, the best way to guarantee their freshness is to sell them alive or on ice. These techniques vary according to geographical regions and dietary habits. In this region, fish are typically consumed fresh. Processing these fish could add value to the value chain, providing an additional source of income for the respondents.

5. Conclusions

The study assessed the fish farming situation in the Mbanza-Ngungu territory in the Democratic Republic of the Congo (DRC). It evaluated practices, fish farmer profiles, and challenges and proposed recommendations to enhance the sustainability of this activity in the region.

The results indicated that the fish farming situation across these various sectors exhibits similar trends and differences regarding the profiles of fish farmers, practices employed, the general level of knowledge, and challenges encountered. Fish farming is predominantly practiced in rural areas rather than in urban centers. The region under study presents diverse opportunities for enhancing this activity while encountering limitations that impede its development.

The challenges encountered include financial issues, limited access to inputs, the need for training, and the necessity to improve farm management knowledge. The primary focus on sales highlights the economic importance of fish farming in the region. It is necessary to implement awareness programs, training initiatives, improved access to financing, and efforts to promote more integrated and sustainable farm management practices to strengthen the sustainability of fish farming in the Mbanza-Ngungu region. The integration of techniques in agro-fish farming has the potential to contribute to fulfilling the population's food needs for vegetables and fish, socio-economic development, the reduction of negative environmental impacts, and the rational management of resources.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of "Ecole de Santé Publique/Comité d'Ethique" (protocol code: ESP/CE/210/2024 and date of approval: 23 July 2024).

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