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Socioeconomic and Zootechnic Characterization of the Fish Farming in the High and Low Altitude Rural Zones in the South-Kivu (DRC): Which Link with the Fish Farming History?

Akilimali Itongwa Justin[1,*], Hyangya Lwikitcha Béni[2], Masilya Mulungula Pascal[2,3]

[1]Department of Animal Production, Faculty of Agriculture and Environmental Sciences, Université Evangélique en Afrique, PO Box: 3323 Bukavu, DR Congo
[2]Department of Biology, Unité d'Enseignement et de Recherche en Hydrobiologie Appliquée (UERHA), Institut Supérieur Pédagogique (ISP). PO Box 854 Bukavu, DR Congo
[3]Department of Biology, Centre de Recherche en Hydrobiologie (CRH)-Uvira, PO Box. 73, Uvira- RDC
*Corresponding author: justinakilimali2@gmail.com

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Abstract This study aims to identify the current state of fish farming in two rural agroecological zones in the South-Kivu province (Democratic Republic of Congo, DRC): one of Low Altitude (L.A.) and another of High Altitude (H.A) different by their fish farming histories. It was carried out from January to June 2017 using a participatory survey coupled with individual interviews with 263 fish farmers distributed in these two rural agroecological zones. In addition to these interviews, field observations have also been focused on 576 fish ponds. The results obtained revealed that the fish farming is mainly practiced by men (L.A.: 72.0%, H.A.: 84.1%) for subsistence and business (L.A.: 57.0 %, H.A.: 67.5%) in both zones of study, that the fish ponds of these two zones are of the same average length (L.A.: 25.9 m and 25.06 m, H.A.: 25.17 m), have almost all the wooden monk (L.A.: 73.17% and 82.53%, H.A.: 72.64%) and composters (L.A.: 73.17 % and 73.53%, H.A.: 96.96%) where is made fertilization with local ingredients (L.A.: 69.0%, H.A.: 90.8%). However, beyond these similarities, the results reveal several differences between the socioeconomic and zootechnic characteristics of the fish farming of these two zones. These differences can be correlated with the different fish farming histories of the two zones; aspects which are widely discussed in the article.

Keywords: *fish farming practices, ponds, NGO funds, colonial inheritance, agro-ecological zones*

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1. Introduction

In DRC, fish holds a high share of the animal protein consumption [1]. The South-Kivu province, in the East of Democratic Republic of Congo (DRC) possesses an enormous fish farming potentialities and a wide hydrographic system dominated by Lakes Tanganyika and Kivu. Nevertheless, the fish food supply in this province remains deficient [2,3].

Fishing activities in these two lakes are traditional without respect for any regulation, including the unknown number of fishermen as well as the use of prohibited fishing techniques which threatens the fish biodiversity and leads to the risk of overfishing and reduction of fish catching [4,5,6]. As a result, this province relies presently on imported fish from East African countries and Asian countries like China. Unfortunately, the purchasing price of fish remains high and not affordable for the poor population prevailing in this region [7].

In addition, the fish farming is not a very recent activity in South-Kivu province, it dated back to the colonial period. During this period, the province of South Kivu was endowed with the first 25 main breeding ponds. This province was ranked third with 1,444 fish farmers after the Bas Congo province (2156 fish farmers) and the province of Kinshasa (1800 fish farmers) [8]. There are currently several water bodies and wetlands in five of the eight territories of South Kivu province (namely Kabare, Kalehe, Mwenga, Uvira and Shabunda).

However, the fish farmer's practices remain primitive and characterized by low productions which seem to stagnate [8]. Several factors responsible of fish production stagnation were enumerated in the basin of Congo [9]. These are the unstable socio-political situation, multiple unachieved projects, the perception by the fish farmers that fish farming is only intended for subsistence farming but not for generating income and jobs, the absence of financial support and the scarcity of good quality fingerlings. In the other hand, the domestication effort of some local fish species with higher aquaculture interest as well as the knowledge of the fish breeding in ponds remain very poor in the rural conditions. As consequence, fingerlings are still collected in the wild environment further to the isolated and little organized local initiatives. In this context, there is a strong need to promote ecological and productive fish farming in these territories with high potential by disseminating the best fish farming practices.

Thus, investing in fish farming activities appears to be one of the promising solution to deal with this real problem of fish's proteins deficiency, especially in rural areas [10,11].

Therefore, the aim of this research was to establish the general state of fish farming in these two rural territories of South-Kivu province in order to guide local and regional priorities of breeding programs and extension services. The specific objectives was: i) to draw up the socioeconomics' profile of the rural fish farmers, ii) to describe the fish farming practices and iii) to characterize the types of ponds management and the fish feeding systems.

2. Material and Methods

2.1. Study Area

The present study was carried out in two agro-ecological zones namely high altitude and low altitude zones (Figure 1) in 2017. Three localities namely Mumosho, Mudusa and Katana were selected in the high altitude zone located in the territory of Kabare which is between 28°45' and 28°55' E (longitude), 2°30' and 2°50' S (latitude) and between 1460 and 3000 m above sea level (altitude). In the low altitude, Sange the one selected locality is located in the Ruzizi plain in the territory of Uvira at altitude 773-1000m and between latitude 2°21'-3°32'S and longitude 28°35'- 29°56'E. The choice of Kabare and Uvira for this study was motivated by their different geographical positions and also their different histories in fish farming practices.

Kabare has a high altitude tropical climate falling within the Aw3 type according to Koppen classification with an average annual rainfall of 1411 mm per year and mean daily temperature oscillating around 16.45°C while Sange in the Ruzizi plain has a semi-arid climate of type Aw4 with an average annual rainfall of 978 mm per year and an average mean temperature of 23.95°C [12].

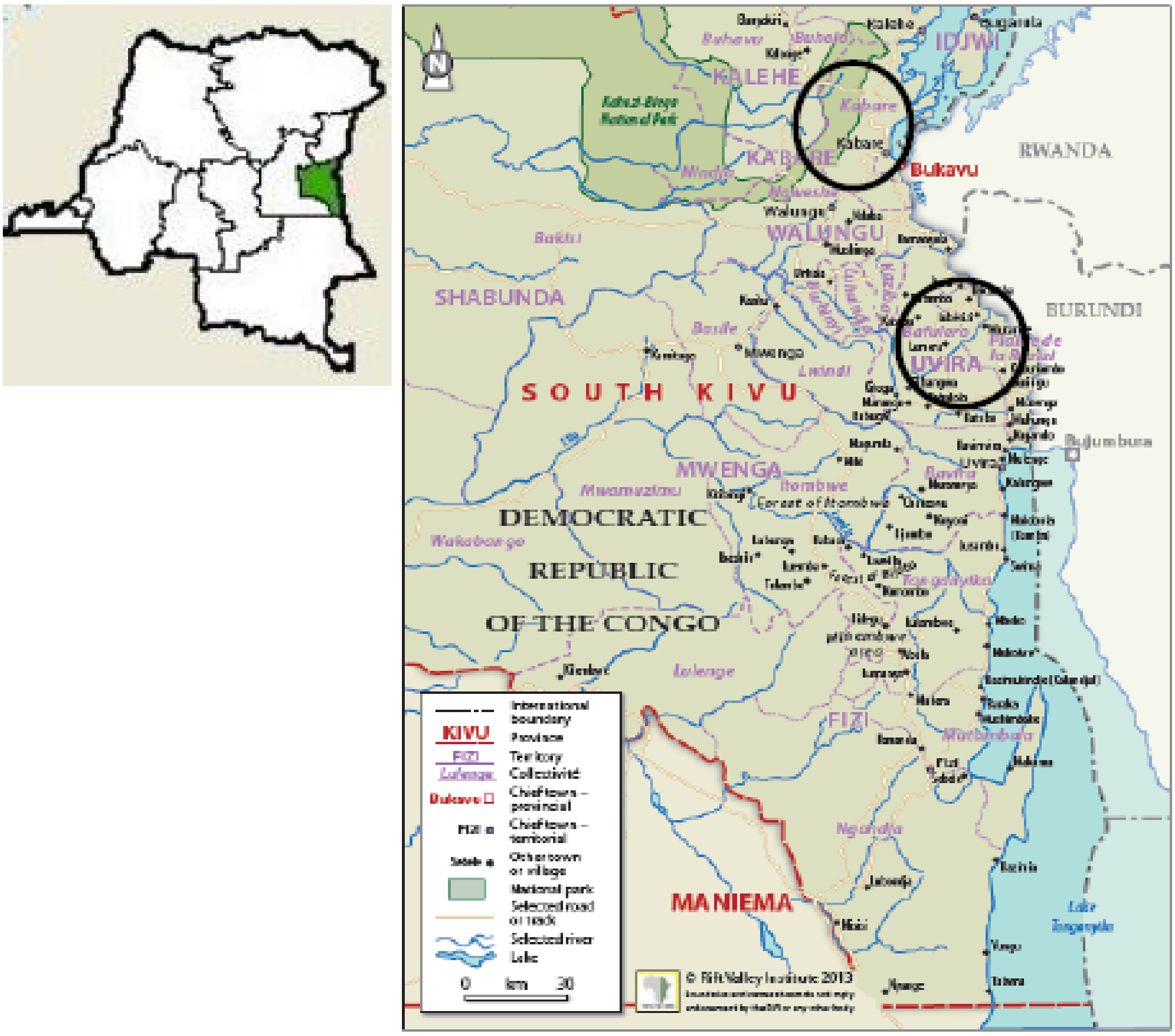

Figure 1. South Kivu administrative map, showing its territories, collectivities and main towns (Study areas are marked with black circle; from [13])

2.2. Sampling and Data Collection

A random sample of 263 fish smallholder farmers was involved in a survey conducted from January to June 2017. Among these fish farmers, 100 and 163 come from the low (three villages: Mataba, Rusabagi and Siazi) and high (eight villages: Cirhindja, Mandwe, Kavumba, Lushasha, Rusheke, Muku, Lwiro and Maziba) altitude zones respectively.

Individual interviews with fish farmers were organized and information on their socio-economic characteristics, aquaculture production practices, and the fish feeding system as well as access to technical and financial information was collected through a well-structured questionnaire. In addition, direct ponds measures and observations were made at the same moment of data collection. Globally, 576 ponds were observed and measured among which 280 ponds in the low altitude zone and 296 others in the high altitude zone. At each pond, the measures were focused on the length, the width, the depth, the surface and the distance between the pond and its water supply source. The direct observations allowed us to note the shape of ponds and the presence or not of monk in each pond.

2.3. Statistical Analysis

Statistical analysis was done with Statistica 6.1. (Licence: AXXF307C020802FA). Chi 2 test was used to compare different distributions of qualitative variables. For quantitative variables, ANOVA or Student t test were used to compare the means of some variables between the low and the high altitude zone. In all comparisons where the Brown-Forsyth test of variances homogeneity revealed the absence of homogeneity, the nonparametric Kruskal-Wallis, Mann-Whitney or Wilcoxon tests were used.

3. Results

3.1. Socio-economic Characteristics of Fish Farmers

Two hundred sixty three (263) fish farmers were selected on the Highest and lowest zones of South Kivu Province. The highest number was found in the highest area (163) concentrated along rivers, specifically the Ruzizi river while 100 fish farmers were counted in the lowest area.

In low and high altitude zones, the fish farming is mainly practiced for subsistence and business farming (57.0 % *vs* 67.5%) by men than by women (72.0% *vs* 28.0% and 84.1% *vs* 15.9%)(χ^2 test, d*f*=1, *p* =0.019) (Table 1). Most of these fish farmers do not have exceeded the level of secondary education. The results presented in Table 1 show that the high altitude zone fish farmers are oldest and have a higher experience in fish farming than the fish farmers from the low altitude area (Mean age =49.6±8.4 *vs* 35.6±7.8. Student t test, *p*< 0.001; mean length of service =10.5±6.3 *vs*9.5±6.6. Student t test, *p* = 0.001).

Table 1. Socio-economic characteristics of fish Farmers of the low and high altitude zones (*For the same parameter, the groups sharing the same letter are not significantly different*)

Parameters	Modalities	High altitude zone	Low altitude zone	Total	Khi2	p-value
Gender (%)	Women	15.9	28.0	20.5	5.52	*0.019*
	Men	84.1	72.0	79.5		
Profession (%)	Fish farmer	39.6	69.0	33.8	95.2	*<0.001*
	Merchant	22.7	1.0	14.5		
	Cattle-breeder	34.4	0.0	21.3		
	Teacher	14.7	16.0	15.2		
	State employee	0.0	1.0	0.4		
	Builder	0.6	0.0	0.4		
Level of education (%)	No schooling	26.4	40.0	31.6	5.5	*0.141*
	Primary school	35.0	27.0	31.9		
	Secondary school	35.6	30.0	33.5		
	University level	3.1	3.0	3.0		
Access to extension services (%)	Yes	68.1	91.0	76.8	18,2	*<0,001*
	No	31.9	9.0	23.2		
Fish farming purpose (%)	Subsistence	28.2	17.0	24.0	27.6	*<0.001*
	Business	4.3	26.0	12.5		
	Subsistance and business	67.5	57.0	63.5		
Average age of fish farmer (years)	(Mean ±SD)	49.6±8.4a	35.6±7.8b	44.3±10.7		
Number of ponds	(Mean ±SD)	2.8±2.7a	1.8±1.1b	2.2±1.9		
Farming experience (years)	(Mean ±SD)	10.5±6.3a	7.9±6,7b	9.5±6.6		
Distance between ponds and households (m)	(Mean ±SD)	869.9±81.0	115.7±3.4	583.2±55.3		
Ponds Types (%)	Embankment pond	0.0	7.0	2.7	55.6	*<0.001*
	Diversion Pond	99.4	93.0	96.9		
	Both types	0.6	0.0	0.4		
Fish farmer status (%)	Active	83.4	70.0	78.3	6.6	*0.01*
	Inactive	16.6	30.0	21.7		
Land tenure accommodating the ponds (%)	Purchase	8.0	0.0	4.9	53.1	*<0.001*
	Donation	2.5	0.0	1.5		
	Inheritance	19.6	0.0	12.2		
	Rent	32.5	21.0	28.1		
	Private	37.4	79.0	53.2		

In low and high altitude zones, the fish farming is mainly practiced for subsistence and business farming (57.0 % *vs* 67.5%) by men than by women (72.0% *vs* 28.0% and 84.1% *vs* 15.9%) (χ^2 test, d*f*=1, *p* =0.019) (Table 1). Most of these fish farmers do not have exceeded the level of secondary education. The results presented in Table 1 show that fish farmers from the high altitude zone are oldest and have a higher experience in fish farming than the fish farmers from the low altitude area (Mean age =49.6±8.4 *vs* 35.6±7.8. Student t test, *p*< 0.001; mean length of service =10.5±6.3 *vs*9.5±6.6. Student t test, *p* = 0.001).

Regarding the implication of fish farmers in their activity, the results highlight the higher proportion of inactive fish farmers in low altitude zone compare to the high altitude zone (30.0% *vs* 16.6%; χ^2 test, d*f*=1, *p* =0.010) (Table 1). Indeed, in the low altitude zone, more than half (59.0%) of fish farmers are first farmers among whom very few of them haven't received a fish farming training contrary to those of high altitude zone (9.0% *vs* 31.9%; χ^2 test, d*f*=1, *p* <0.001) (Table 1).

Finally, most of the low altitude zone fish farmers, even if they have very few ponds/fish farmer compared to those of high altitude zone (1.8±1.1 *vs* 2.8±2.7; Mann-Whitney test, *p* = 0.003), are landowners of their ponds (79.0% *vs* 37.4%; χ^2 test, d*f*=4, *p* <0.010) while those of high altitude zone inherited their ponds (19.6%) or rent them (32.5%). This situation forces them to have their ponds located very far from their living houses contrary to those from low altitude zone (869.9±81.0 m *vs* 115.7±3.4 m; Mann-Whitney test, *p*< 0.001).

No farmer ever raised the issue of preservation or transformation of agricultural products during the survey, meaning that fish was sold as fresh one.

3.2. Fish Farming Typology according to Location

All 296 observed and measured ponds in the high latitude zone were diversion ponds while in the low latitude zone, 12.14% (i.e 34 ponds) among 173 ponds and 87.85% (i.e. 246 ponds) of the 280 observed and measured ponds were embankment and diversion ponds respectively (Table 2). Ponds are typically different in depth, length, width and size according to different types of ponds.

The results of the Table 2 show that in almost all point of view, except for the length of ponds (ANOVA, F2; 578 = 0.45, p =0.64), the ponds of low altitude zone differ from those of high altitude zone. Indeed, ponds from the high altitude zone are more squared than rectangular (χ^2 test, d*f*=2, *p* =0.0201), shallower (Kruskal-Wallis test, H2 ;581 = 495.45, *p*<0.001), less wide (Kruskal-Wallis test, H2 ;581= 87.54, *p*< 0.001) and consequently with small area (Kruskal-Wallis test, H2 ;581 = 25.39, *p*< 0.001) but situated farther of their water supply sources (Kruskal-Wallis test, H2 ;581 = 364.99, *p*< 0.001) compared to those located in the low altitude zone. All the ponds observed, regardless of area or type, have mainly a wooden monk (test ², df = 4, p = 0.24) and among them, the proportion of those who which a composter is much higher than those with no composter (χ^2 test, d*f*=2, *p*<0.001).

3.3. Fish Farming Practices

The fish farming practices results are presented in the Table 3.

Results from Table 3 show that the monoculture fish farming with *Oreochromis niloticus* is the dominant fish farming practiced in both the high (100.0%) and low altitude zones (57.0%). Although if monoculture is the only practice in the high altitude area, there is a mixed fish farm with *O. niloticus* and *Clarias gariepinus* (37.0%) or with *Tilapia melanoptera* and *C. gariepinus* (6.0%) in low altitude zone.

These species are chosen according their growth performance (100.0% and 73.0%) rather than their rusticity (24.0%) or their ability to reproduce in captivity (3.0%) whatever the considered zone. Some fish farmers from high altitude zone (55.8%) obtain fingerlings from NGOs to stock their ponds, and others (35.0%) get back them from their own ponds. However, many fish farmers (47.0%) in low altitude zone buy the fingerlings to stock their ponds even if NGOs provide it to farmers. This activity is realized without any preliminary sex control in the two zones (Table 3).

Table 2. Fish farming typology in both zones of study (For the same parameter, the groups sharing the same letter are not significantly different)

		High altitude zone		Low altitude zone	
		Diversion ponds	Embankment ponds	Diversion ponds	Embankment ponds
Parameters and their modalities	Number	296	-	246	34
	Depth (m)	2.75 ± 1.17^a	-	3.27 ± 0.43^b	3.37 ± 0.23^b
	Length (m)	25.17 ± 8.51^a	-	25.90 ± 9.91^a	25.06 ± 12.24^a
	Width (m)	13.28 ± 5.73^a	-	17.97 ± 6.46^b	18.38 ± 7.13^b
	Area (m^2)	353.65 ± 218.07^a	-	498.81 ± 329.19^b	490.79 ± 437.08^b
	Distance with the water supply sources (m)	713.22 ± 832.22^a	-	113.23 ± 37.05^b	537.00 ± 416.61^b
Monk types	Concrete (%)	11.49	-	8.54	0.00
	Brick (%)	15.88	-	18.29	17.65
	Wooden (%)	72.64	-	73.17	82.35
Presence of sedimentation basin	Yes (%)	41.55	-	22.76	97.06
	No (%)	58.45	-	77.24	2.94
Presence of composter	Yes (%)	96.96	-	73.17	73.53
	No (%)	3.04	-	26.83	26.47
Ponds form	Square (%)	52.70	-	40.24	26.47
	Rectangular (%)	47.30	-	59.76	73.53

Table 3. Fish farming practices in both zones of study (For the same parameter, the groups sharing the same letter are not significantly different)

Parameters	Modalities	High altitude zone	Low altitude zone	Total	Khi2 (or t-test)	P-value
Fish farming types (%)	*Monoculture*	100.0	76.0	90.9	43.05	*<0.0001*
	Polyculture	0.0	24.0	9.1		
Fish species (%)	*Clarias, Tilapia melanoptera.*	0.0	6.0	2.3	83.79	*<0.0001*
	Tilapia nilotica	100.0	57.0	83.7		
	Tilapia nilotica, clarias	0.0	37.0	14.1		
Criteria of species choice (%)	Fast growth	100.0	73.0	89.7	49.01	*<0.0001*
	Rustic character	0.0	24.0	9.1		
	Reproduction in captivity	0.0	3.0	1.1		
Production cycle(months)	*Mean±SD*	10.1±0.14a	7.04±0.18b	8.9±2.3	178.6	*<0.0001*
Origins of fingerlings (%)	Purchase at the neighbour	9.2	47.0	23.6	51.19	*<0.0001*
	NGO donation	55.8	26.0	44.5		
	Own pond	35.0	27.0	31.9		
Time of emptying the ponds (months)	*Mean±SD*	10.38±0.18a	9.58±0.23b	10.1±2.29	7.72	*0.006*
Main challenges (%)	Difficulty of fry supply	35.6	9.0	25.5	48.87	*<0.0001*
	High input cost	15.3	11.0	13.7		
	Lack of land	4.3	31.0	14.4		
	Lack of capital	44.8	49.0	46.4		
Time between emptying and filling the ponds (days)	*Mean ± SD*	7.7±0.31a	6.41±0.39b	7.21±3.96	6.625	*0.011*
Water quality control (%)	*No*	38.0	59.0	46.0	10.96	*0.001*
	Yes	62.0	41.0	54.0		
Sex control (%)	*No*	100.0	97.0	98.9	4.95	*0.026*
	Yes	0.0	3.0	1.1		

The average time of grow-out stage of fish is higher in fish farming practices in high latitude zone (10.11 months) compare to low altitude zone (7.04 months) ($p< 0.001$). In this latter zone, the results show, in one hand, that the average time of emptying the ponds (9.58 months) is higher than the average time of pond production (7.04months) (Wilcoxon test, $p<0.001$) contrary to high latitude zone where the two average times are in the same range (10.38 months *vs* 10.11 months; Student paired t test, $p = 0.23$). In another hand, after their emptying, ponds are quickly put back under water in low altitude zone.

3.4. Characterization of Fish Feeding System

Table 4. Characterization of the fish feeding system in both agro ecological zones

Parameters	**Modalities**	**High altitude zone**	**Low altitude Zone**	**Total**	**Khi2**	**P-value**
Feed source (%)	Exogenous	84.7	13.0	57.4	130.18	*<0.0001*
	Natural food	15.3	87.0	42.6		
Feed supplementation (%)	No	63.2	34.0	52.1	154.5	*<0.0001*
	Yes	36.8	66.0	47.9		
Types of fish feeds (%)	Kitchen wastes and palm kernel cake	3.1	0.0	1.9	42.69	*<0.0001*
	Kitchen wastes	0.0	11.0	4.2		
	Agriculture by-products	63.2	34.0	52.1		
	Palm kernel cake	27.6	35.0	30.4		
	Kitchen wastes and palm kernel cake	6.1	20.0	11.4		
Pond Fertilization (%)	No	0.0	28.0	10.6	51.08	*<0.0001*
	Yes	100.0	72.0	89.4		
Type of fertilizers (%)	Poultry manure	3.1	12.0	4.6	179.21	*<0.0001*
	Cow manure, cassava retting and chickens dung	48.5	0.0	30.0		
	Pig manure	27.0	5.0	16.7		
	Goat manure	21.5	34.0	26.2		
	N/A	0.0	28.0	10.6		
	Cassava rustling	0.0	21.0	8.0		
Association fish farming-livestock (%)	*No*	100.0	83.0	93.5	29.63	*<0.0001*
	Yes	0.0	17.0	6.5		
Presence composters (%)	No	0.0	39.0	14.8	74.64	*<0.0001*
	Yes	100.0	61.0	85.2		

Finally, the results of Table 4 concerning the fish feeding system did not indicate any direct association between agriculture and fish farming or livestock in high altitude zone while in low altitude zone, 17.0% of fish farmers associate livestock and fish farming. All fish farmers mainly use manure and/or hens droppings to fertilize their ponds. In both zones, fish are mainly feed with agricultural by-products but in low latitude zone fish farmers use also palm kernel cake and kitchen wastes to complete these mainly foods. Moreover, more farmers who feed their fish use purchased feed ingredients. Fish farms in the low altitude zone seemed to rely more on the natural pond productivity and on freely available ingredients.

Reported on-farm feeds included kitchen wastes and palm kernel cake, kitchen wastes, agriculture by-products, palm kernel cake, kitchen wastes and palm kernel cake without using commercial feeds ingredients. Collected manure was mainly used as fertiliser for the pond on farms associating livestock to fish ponds and farmers who did not have livestock used to purchase manure.

4. Discussion

The results of this study highlight two totally different types of fish farming, influenced by the history of these two zones (colonial fish history influence *vs* NGO influences) in one hand and traditional practices (attached to land *vs* agriculture habits) in another hand. Nevertheless, some similarities concerning the main fish farming objective, the person involved in this activity, the type of fish farming applied and the fish species which is used to stock the ponds. Indeed, in both zones, the fish farming activity is practiced for subsistence and business exist between socioeconomic and zootechnic characteristics of the fish farming in these two zones. This can be explained by the fact that fish farming in these two zones create jobs especially for young people. According to this study, men are more involved in fish farming activities than women. Indeed, even if men are ponds landowners, most of activities such as transportation of fertilizers, regular maintenance of ponds and sale of pond products are executed only by women Therefore, there is a strong necessity to provide training for these women for the development and sustain ability of fish farming in these two zones [14]. The training is particularly important because the majority of investigated fish farmers did not exceed the primary and secondary school and they did not receive technical guidance.[15] mentioned the lack of training as the main reason of lack of professionalism by the African fish farmers. This situation can explain the dominance of the monoculture fish farming with *O. niloticus* in both these two zones. According to [16] and [17], the domestication of new fish species requires a high technical experience level and a big interest in fish farming activities.

In low altitude zone, farmers have an easier access to fingerlings from the Ruzizi River and commercial fingerlings producers, allowing poly culture instead of monoculture more easily as fish production method. Conversely, rural farmers from High altitude zone rely on the exchange of fingerlings between farmers by donations, lowering the diversity of fish species when stocking ponds.

Concerning the differences, the high altitude zone fish farmers are oldest and have a higher experience in fish farming than the low altitude zone fish farmers. The fish farming histories of these zones can be the reason of these differences. Indeed, the high altitude zone took advantage of having the CAP since 1954 during the colonial period [9] while fish farming in low altitude zone is a recent activity disseminated by NGO after the war of 1996.

So, the old men of this high altitude zone possessing a fish farming tradition are more interest by this activity by the fact that they agree to buy ponds (80.0%) or to rent them (32.5%) despite their poverty level, while the young people are the more interest with fish farming activities in low altitude zone.

Endemic malnutrition in high altitude zone can be another raison influencing peasants to adopt fish farming contrary to low altitude zone where many agro-fish farming potentialities exist such as rice farming which is traditional in this zone [18,19,20]. Another difference is related to the fish farmer's traditional habits and concerns their ponds typology as well as their location with regard to the fish farmer dwelling-houses. Indeed, ponds from the high altitude zone are shallower, less wide but located very far from their living houses compared to the low altitude zone's ones. Ponds are typically small in size in both zones, probably due to the lack of appropriate construction materials and construction costs.

The pond's depth in the high altitude zone (2.75m *vs* 3.3m), fairly close to the average depth of diversion ponds (~ 2m, [21]), can be interpreted as a behaviour of imitation of the model of the ponds of CAP constructed and left by the Belgian colons in their zone contrary to low altitude zone fish farmers without model to be imitated. On the other hand, the small distance between the ponds and the fish farmer dwelling-houses in the low altitude zone compared with the high altitude zone must be link with the main activity of fish farmers in the low altitude zone. The latter are mainly rice farmers, agriculture type which requires to maintain a basic services [22]. This situation imposing the fish farmers to build houses around these wetland zones. This small distance between the ponds and the fish farmer dwelling-houses is an enormous advantage to be valued for the sustainability of the rice-fish farming in this zone if others constraints to this activity like are filled and if NGO adopt strategies to educate the beneficiaries of their funds in more independence towards the allocated funds [23].

The last difference between the fish farming practices in these two zones is in accordance with the average time of emptying the ponds which is higher than the average time of pond production in low altitude zone contrary to high latitude zone where the two average times are in the same range. In another hand, ponds are quickly put back under water after emptying in low altitude zone than in high altitude zone. These results can be correlated with the traditional empirical knowledges. In high altitude zone, fish farmers try to respect the normal production duration of *O. niloticus* [24] by avoiding making partial harvests despite their higher poverty than in low altitude zone [12].

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