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Diversity of farming systems integrating fish pond aquaculture in the province of Kinshasa in the Democratic Republic of the Congo

Patrick Mafwila Kinkela [a,f,*], Bienvenu Kambashi Mutiaka [a], Thomas Dogot [b], Denis Dochain [c], Xavier Rollin [d], Roger Ntoto Mvubu [e], Charles Kinkela [e], Jacques Mafwila [a], Jérôme Bindelle [f]

[a] *Animal Science Unit, University of Kinshasa, Kinshasa, Democratic Republic of the Congo*
[b] *Gembloux Agro-Bio Tech, Rural Economics and Development Unit, University of Liège, Gembloux, Belgium*
[c] *Mathematical Engineering Department (INMA), Catholic University of Louvain, Louvain-la-Neuve, Belgium*
[d] *Plateforme technologique et didactique en biologie aquicole Marcel Huet, Life Sciences Institute, Catholic University of Louvain, Louvain-la-Neuve, Belgium*
[e] *Department of Agricultural Economics, University of Kinshasa, Kinshasa, Democratic Republic of the Congo*
[f] *Gembloux Agro-Bio Tech, Precision Livestock and Nutrition Unit, University of Liège, Gembloux, Belgium*

Abstract

Agriculture and aquaculture systems are used by many farmers in various tropical countries of Asia, America and Africa. They have proven their relevancy to increase the productivity of farms by optimising nutrient fluxes and reducing requirements for external fertilisers. This article analysed the current state of fish farming and the way it is integrated with other farm subsystems in the urban/peri-urban and rural areas of Kinshasa, Democratic Republic of Congo. More precisely, it examined the allocation of resources at the farm level, the recovery of helophytes plants, and the fate of fish production choices and it explored the possibility of intensifying these existing integrated farming systems. After a census of ponds in the urban and rural areas of Kinshasa, an on-site survey was conducted on 150 fish pond farms to assess the different activities practiced on farms, the impact of integrating crops and livestock to fish pond aquaculture and the constraints of the system. A total of three thousand and twenty (3020) fish ponds were recorded in the urban and rural areas of Kinshasa. Among these farms integrated aquaculture-agriculture systems exist with a wide diversity of practices (about 79 % of farms combined fish with livestock and/or vegetable production). No striking differences between fish farms according to the allocation of resources, fish production method such as monoculture or polyculture, the recovery of helophytes plants and the fate of fish production choice were found depending on the location. However, fish farms were differently managed when combined with agriculture and/or livestock. Regarding the integration of the different subsystems through nutrient fluxes, 11 different movements of material between subsystems were found in integrated farms. However, not all fluxes are equally used in all farms and therefore improvements cannot be generalised. Improvements to be explored are such as making better use of manure pond mud and helophyte plants. For this purpose, proper training of farmers might be critical. Finally, bringing farmers together in cooperatives could also contribute to reduce the cost of purchase and transportation of fish fry and feed.

Keywords: crops, fish pond, integrated farm, livestock, rural, urban

1 Introduction

Faced with an overall annual population growth of 2.7 %, low soil fertility, and low livestock and aquaculture production (Hishamunda & Ridler, 2006; Subasinghe *et al.*, 2009), smallholder farmers in Sub-Saharan Africa (SSA) are facing a huge challenge of sustainable agricultural intensification to address their food security issues. They rely on low to no external inputs to maintain soil fertility. The sustainability of their production system heavily depends on the efficiency

* Corresponding author
Email: patrickmaf@yahoo.fr Phone: +243 998995916

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by which nutrients are kept and recycled in the farm (Rufino *et al.*, 2006). Integrating several subsystems, such as crops and livestock, within a same farm is one possible way to promote the efficient use of nutrients within a given farm while increasing global productivity (Lemaire *et al.*, 2014) in such a way outputs from one subsystem become inputs of another associated subsystem (Edwards, 1993; Rukera *et al.*, 2012). In several humid tropical countries mainly in South-Eastern Asia and South America, this diversification includes aquaculture as a subsystem of farms, along with crops, livestock, or both to yield integrated agriculture-aquaculture (IAA) systems (Symoens & Micha, 1995; Phong *et al.*, 2011; Preston & Rodriguez, 2014).

Based on the flow of nutrients between subsystems, integrated systems aim to improve the use efficiency of nutrients such as nitrogen and phosphorus to increase soil fertility and reduce external inputs while optimising agricultural resources for income generation and food supply at farm level (Nhan *et al.*, 2007). For example, Poot-López *et al.* (2010) reported that IAA systems involving tilapia production in the Yucatan State of Mexico almost doubled economic returns in poor rural areas compared to plain crop production. The practice of integrated farming enables farm households to increase agricultural production while not depleting their base of natural resources. Tipraqsa *et al.* (2007) compared integrated farming systems (crops, pigs, poultry, trees, and fish) to commercial farming systems in north-eastern Thailand and concluded that the integrated farming system gave a more secure supply of food at the family level, it improved the resource base, created higher economic returns, and better matched the social needs of agriculture as a supplier of materials for food, medicines, local rituals, tools, and shading. In addition, the total output from integrated farms (3480 USD per farm) was significantly higher than of the commercial farms (2006 USD per farm).

Murshed-E-Jahan & Pemsl (2011) showed, that fish pond provided additional benefits besides nutrient recycling for an IAA system in Bangladesh, such as higher incomes from fish culture and an increase in water availability. They tested the hypothesis that IAA based on low cost aquaculture techniques led to improved productivity, profitability, efficiency and also human and social capital in Bangladesh. The net income of farmers practicing IAA grew at an average rate of 21.8 % per year compared to the 5.8 % income increase per year of farmers without IAA. Barbier *et al.* (1985) showed similar results in the marshes of Rwanda after the farming system was converted into dyke pond systems combining horticulture and aquaculture.

Despite their advantages depicted above and the possible role that integrated farming systems could play in the food security challenge, few data have been reported for Africa regarding integrated farming systems, especially when it comes to those including aquaculture. The result of the adoption of IAA systems including vegetables, fruits, livestock, irrigation and fish culture as subsystems in Malawi raised the productivity with 11 %. Technical efficiency was increased by 134 %, and total farm income by 60 % (Dey *et al.*, 2010). The results of Rukera *et al.* (2016) in a rabbit-fish-rice system showed clearly that although the productivity of individual subsystems is not always increased, the efficiency of the whole farm is improved. This illustrates the potential of IAA to contribute to poverty reduction and improvements in livelihoods in Malawi, Rwanda and Cameroon, as well as other countries in SSA with similar agro-ecological conditions, where IAA practices have recently been adopted.

In the Democratic Republic of Congo (DRC), fish holds a high share of the animal protein consumption (Brummett & Williams, 2000). Besides, Tollens (2004) showed that vegetable cropping is very important in urban and peri-urban areas with annual volumes consumed of 24.4 kg/capita in 2000 in Kinshasa. Moreover, Kambashi *et al.* (2014) reported that residues such as root and leaves of some vegetable crops such as sweet potato and *Psophocarpus scandens* are commonly used to feed pigs, completing the available feed ingredients such as corn, cassava and potato tubers in urban and peri-urban areas of Kinshasa. In this way, vegetable crops have a great potential to support the development of livestock and fish pond aquaculture if grown in IAA systems by using crop residues to supplement fish and livestock feeds. Nonetheless, very little information is available on the present state of fish farming (Micha, 2015) and the way it is integrated with other farm subsystems in urban/peri urban and rural areas of Kinshasa. The success of an IAA farming system not only depends on its subsystems but, more importantly, on the appropriate combination of the different subsystems and the management of nutrient flows between these subsystems. Therefore, the aim of this research was to quantify the extent of fish pond farming and to understand whether the management of the ponds depends on the integration of other subsystems (e.g. market gardening and livestock) in urban/peri-urban and rural areas of Kinshasa (DRC).

For this purpose, a large scale survey has been conducted to address the following research questions:

- Do IAA systems exist in urban/peri urban and rural areas of Kinshasa in the DRC?
- Are fish ponds differently managed when combined with agriculture or livestock?
- Which subsystems are actually integrated through nutrient fluxes between the components and how these are managed?

2 Materials and methods

2.1 Pond density assessment

Given that no recent data are available in the literature on the number of fish farms in Kinshasa, a preliminary pond census was performed in order to quantify the density of ponds in the urban/peri urban area of Kinshasa and to set-up an appropriate sampling procedure for the following survey. For this purpose, satellite images available from Google Maps were used (Google Maps, viewed on 17/12/2012 map version, DigitalGlobe). The urban territory of the city was divided into 4 areas (North West, North East, South West, South East), in which fish ponds were counted. This work enabled the selection of sites to conduct the survey.

2.2 Survey

A survey was conducted from March to May 2013 in two urban/peri-urban areas with a high density of ponds (N'djili Brasserie and Funa), and one rural area (Mbankana) of Kinshasa (Fig. 1). Both urban/peri-urban areas are located in the city of Kinshasa in the municipality of Mont Ngafula (4° 25′ 35″ S; 15° 17′ 44″ E), where the population density is 727 inhabitants per km^2. Mbankana is located in the eastern part of Kinshasa, 145 km from the capital, on the Batékés' plateau, in the municipality of Maluku (4° 26′ 48.9″ S; 16° 11′ 30.8″ E). The city covers an area of 1,500 km^2, with a population density of 23 inh. per km^2.

Based on the list of farms obtained from farming organisations operating in the areas of the selected sites (Figure 1), farms holding at least one active pond were randomly selected, after on fields verification. For this purpose, Bernoulli's equation (Ancelle, 2008) was used to determine the lowest number of farms per sites required for representativeness, homogeneity and sample accuracy for a confidence level of 95 %. In total, 150 farms with at least one pond were surveyed in the three selected sites: 51 in Funa (Urban 1), 45 in N'djili Brasserie (Urban 2), and 54 in Mbankana (Rural).

The survey comprised six main sections: one per farm subsystem (livestock, fish, and crops), one for farm management, another focused on the characteristics of the farms (farm area, land type and so on), and the last section comprised socio-economic questions to characterise the farm manager. In the "fish" section, questions were directed towards the characterisation of ponds, feeding practices, fish species, method of manure and fertilisation in ponds. In the "livestock" and "crops" sections, key information was collected on animal and vegetable species, animal housing systems, livestock and vegetable management, manure and vegetable waste flows, as well as methods used for soil fertilisation. In few cases, farmers reported to own some fields far from the ponds where some staple crops such as cassava were cultivated. Since those crops were not managed in integration with the other components, they were considered an external component of the farm. The survey was completed after a draft version of the questionnaire had been tested on some farms in the urban area.

The questionnaire was handled in a single pass during an interview with the farm manager. The technique for data collection consisted of questions followed by a discussion when needed for clarity. The interviews were conducted in Lingala or French. Measurements of the total area of the farm were undertaken when necessary; pond area, mean depth, width of the dike, and cultivated area were measured at the end of the interviews. As the survey was conducted in areas known for endemic epizooties such as the African Swine Fever, pigsties were measured by the farmers to avoid contamination between farms; the interviewers did not touch any animal and a quarantine period was observed before going from one survey site to the other.

Farms were divided into four types according to the encountered subsystems on the visited piece of land: fish farming solely (F), fish and livestock farming (FL), fish and vegetable farming (FV), and fish, livestock and vegetable farming (FLV).

The mixed procedure of SAS was used to compare mean values of quantitative data between farm types after testing distributions for normality. The chi-square test was applied to analyse the dependence of frequency variables on the farm types. Association between farm types (F, FL, FV or FLV), farm location (urban/peri-urban or rural), the different farm characteristics measured and quantitative variables in the survey was assessed by using the Pearson correlation procedure in SAS.

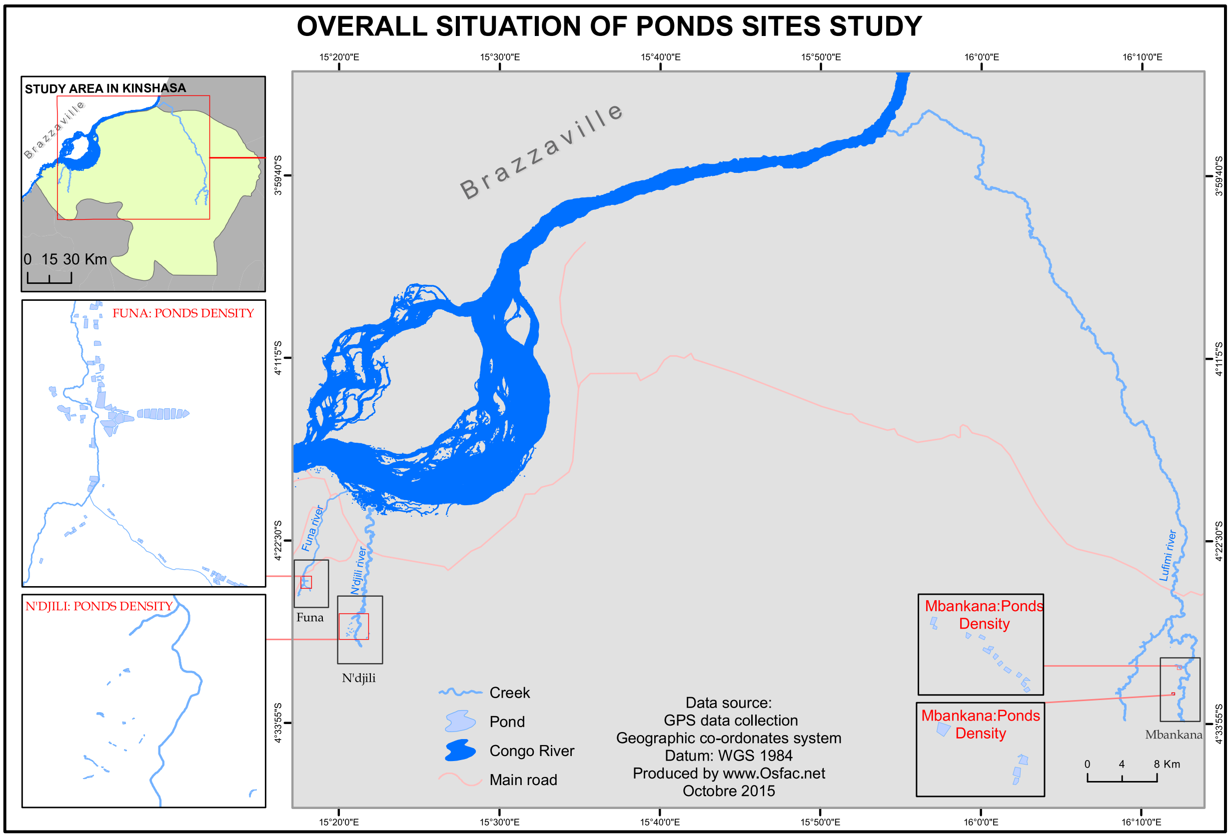

Fig. 1: *Map of Kinshasa (upper left) showing the location of study sites. The "ponds density" squares display enlargements of the three areas were the survey was conducted: N'djili and Funa are urban/peri urban areas and Mbankana is a rural area. Data source: GPS data collection geographic coordinates system. Datum: WGS 1984. Directed by www.osfac.net. October 2015.*

3 Results

3.1 Pond density in Kinshasa

Three thousand and twenty (3020) fish ponds were spotted on the urban/peri urban territory of Kinshasa. This number largely exceeds the latest statistics which mentioned only 769 fish ponds in Kinshasa (Kombozi, 2006). The highest number of fish ponds was found in the South-West area (1427 fish ponds) concentrated along rivers, specifically the Funa and N'djili rivers. Therefore, this area was selected for the urban/peri-urban survey. The South East area accounted for 922 fish ponds while 602 ponds were counted in the North West area and 69 in the North East area. The latter had fish ponds which were mainly located close to the international airport of N'djili, in the alluvial plain of the Congo River.

3.2 Farm activities according to location

Results of the on-farm survey showed that association of fish ponds with agriculture is commonly practiced by pond holders. The combination of fish and vegetables (FV) is largely used (35 %). Fish, vegetable and livestock (FVL) are also quite common (30 %). Fewer pond holders associate fish with livestock (FL) (14 %). Finally, only 21 % of the pond owners do not practice any association with fish farming (F).

Analyses showed that there is no striking difference in farm characteristics between the locations (Table 1). Although some differences were observed between the two urban sites, farms share the same general characteristics, whether they were located in urban or rural sites for their production cycle, the type of ponds, the choice of fish species the use of manure, and the fate of fish production. One notable exception has been observed, however, which concerns the habit of feeding the fish. In rural areas, only 50 % of the farmers feed their fish, while this percentage was as high as 80 to 90 % in urban areas. Moreover, more farmers who feed their fish use purchased feed ingredients in urban areas than in rural areas (Table 1). Finally, in urban areas, the recovery of sludge and helophytes vegetation (e.g. *Nymphaea alba*, *Eichhornia crassipes*) are also more practiced ($P < 0.01$).

Table 1: *Pond characteristics and management according to location.*

	Urban 1	*Urban 2*	*Rural*
n (numbers of farms by site)	51	45	54
Total farm area (are)	4.7 ± 3.5 [†]	7 ± 7.4	6.3 ± 7.1
Operational ponds (N)	1.9 ± 1.1 ^{b}	3.0 ± 1.7 ^{a}	1.8 ± 1.2 ^{b}
Non-operational ponds (N)	0.3 ± 0.8	0.9 ± 1.9	0.7 ± 1.2
production cycle (month)	9.4 ± 6.8	8.9 ± 4.0	8.0 ± 2.7
Average age of fish farm (years)	12.7 ± 11.9	10.1 ± 8.6	14.3 ± 9.1
Types of ponds on the farms (% [‡]) (χ^2, P = 0.58 [§])			
Growth	100	98	100
Pre-growth	0	2	0
Nursery	2	4	0
Storage	10	2	0
Spawning	2	0	2
Fish production method (%) (χ^2, $P < 0.01$)			
Monoculture	67	64	89
Polyculture	33	36	11
Fish species (%) (χ^2, P = 0.05)			
Oreochromis niloticus	96	100	98
Clarias gariepinus	35	38	11
Heterotis niloticus	2	9	2
Parachanna obscura	8	4	2
Practice of fish feeding (%)	94 ^{a}	84 ^{a}	48 ^{b}
Using on-farm resources (%)	6 ^{c}	20 ^{b}	39 ^{a}
Using purchased ingredients (%)	94 ^{a}	78 ^{b}	31 ^{c}
Fate of fish production (%) (χ^2, P = 0.09)			
Quantities sold	74	56	44
Quantities consumed	26	42	56
Recovery of sludge (%)	90 ^{a}	64 ^{b}	50 ^{b}
Recovery of helophytes vegetation (%)	76 ^{a}	56 ^{b}	44 ^{b}
Farm subsystems (%) (χ^2, P = 0.09)			
Fish only (F)	6	29	29
Fish and livestock (FL)	10	16	17
Fish and vegetables (FV)	51	22	30
Fish and livestock and vegetables (FLV)	33	33	24
Ponds water supply (%) (χ^2, $P < 0.01$)			
River	6	38	54
Groundwater	76	29	22
Water source	18	36	24
Sex control (%)	0 ^{b}	2 ^{b}	22 ^{a}
Use of manure (%)	67 ^{a}	49 ^{b}	39 ^{c}

[†] Means ± standard deviation; [‡] Percentage of farms for a given location;
[§] P-value: Chi-square tests, probability between sites;
$^{a\,b\,c}$: means in a same row followed by different superscript letters differ at a significance level of 0.05

3.3 Farm organisation according to subsystem

Most farms relied on unpaid family labour with some engagement of paid workers but with no significant differences between farm types (Table 2). Very few integrated farms used a paid workforce only and many farmers had complementary activities to generate income. FLV farms provided more work to family members than all other types of farms and displayed the longest experience in agriculture in general (13.4 years); however the difference is not statistically significant. On FL and FLV farms, managers had the highest education levels ($P < 0.01$).

On IAA farms, vegetables or livestock, in this sequence, contributed more to farm income than fish. Aquaculture was always considered a secondary contributor to income. Vegetable production was generally the first farming subsystem, as famers practising this have around 12 years of experience. On IAA farms, the fish farming and livestock subsystems followed later (Table 2). However, the integration with other subsystems did not influence the purpose of fish production, i.e. self-consumption or selling. In all types of farms, about half of the production is sold and half is consumed by the farmers' families. No farmer ever raised the issue of preservation or transformation of agricultural products during the interviews, meaning that everything that was sold was sold fresh.

3.4 Farm subsystems and management

Ponds are typically small in size and cover most of the areas of the farms, with an average of 2.5 are per fish pond and a total pond area of 4 to 7 are per farm (Table 3). No effect of farm type was found related to pond area. Livestock species were present on 44 % of the farms. Tropical Livestock Unit (TLU) densities varied from 2.5 to 5.3. Although no significant differences were found whether vegetables were present or not in the integrated system due to high variability FL farms had twice as many more animals (in TLU) as FLV farms. On the farms rearing livestock, reared animals species were pigs (95.3 %), chicken (6.1 %), goats (3 %), ducks (1.5 %) and rabbits (1.5 %). Activities on the farm are very often associated with vegetable crops (65 %). The average area dedicated to cropping is 96 m^2 and 67 m^2 for FLV and FV, which represents approximately 10 and 7 vegetable beds per farm. No effect of integration was found according to vegetable area. Amaranth (*Amaranthus hybridus*) (40 %), potato leaves (*Ipomoea batatas*) (38 %), roselle (*Hibiscus sabdariffa*) (25 %), and eggplant (*Solanum melongena*) (17 %) were the most cultivated species. Other vegetables such as cabbage, onion, bean, spinach, cucumber, tomato, pepper were less represented.

Almost all farms had growth ponds with sometimes other types of specialised ponds, for example nursery or storage ponds, existing on fewer farms. Most farms were growing *Oreochromis niloticus* in monoculture (64 to 81 %) regardless of the farm type. Farms with fish only (F) tended ($P = 0.10$) to declare longer fish growing periods than farms associating fish production with livestock and/or vegetables, as they did not practice intermediate harvests. F farms seemed to rely more than the other types on the natural productivity of the ponds and on freely available feed such as plants harvested outside the farm or leftovers from family meals (31 % vs. 19 to 29 %) and less on purchased ingredients (53 % vs. 62 to 75 %; $P < 0.01$). Reported on-farm feeds included *Manihot esculenta* leaves and peelings, *Elaeis guineensis* nuts, and leaves of *Ipomoea batatas*, *Moringa oleifera*, *Chromolaena odorata* and *Eichhornia crassipes* while commercial feeds ingredients included mainly brewer's grains followed by wheat bran, fish meal, blood meal, and rice bran. Collected manure was mainly used as fertiliser for the pond on farms associating livestock to fish ponds (67 to 73 %), followed by FV farms (42 %) and F farms (25 %). Farmers who did not have livestock declared that manure was purchased. Recovery of pond sludge was higher in farms with vegetables, with 79 and 84 % for FV and FLV, respectively, than in FL and F farms, with 52 and 38 % respectively ($P < 0.01$). Pond sludge was mostly used by farmers for fertilising and/or compacting pond dikes. Helophytes plants were used for feed animals and piled in the compost. They were also recovered for no actual intended use, except to avoid the cluttering of fish ponds.

3.5 Fluxes inventory between subsystems

Possible fluxes of material (dotted boxes) between subsystems (full boxes) of the farming system due to management actions are shown in Figure 2. Farmers with all subsystems on their farms (fish, livestock and vegetables) showed the highest percentage of flux use between subsystems, whatever the material that could be transferred between subsystems (Table 4). One exception lays in the use of pond water to water the vegetables during the dry season. Due to a lack of space or soil characteristics, some farmers have relocated one activity further away from the farm land. This is the case for FL systems which use manure for composting and vegetable farming. In some farms, benefits from fluxes between these activities are negatively impacted by the costs of moving manure towards remote subsystems that are not actually present on the same farm site.

Table 2: *Farm characteristics according to the diversity of subsystems.*

	Subsystems				*P-value* †
	F	*FL*	*FV*	*FLV*	
n (number of farms)	32	21	52	45	
Household size	7.3 ± 3.5 ‡	5.3 ± 2.9	6.5 ± 3.8	7.1 ± 3.6	0.22
Family members work (FTE)	1.4 ± 0.9	1.0 ± 0.9	1.9 ± 2.0	2.1 ± 2.0	0.07
Average age of farm (years)	10.7 ± 9.4	10.9 ± 8.5	13.5 ± 11.5	13.4 ± 9.4	0.52
Years of experience in farming system (years)					
Fish pond	10.7 ± 9.4	8.8 ± 8.0	11.5 ± 10.9	11.4 ± 9.0	0.73
Livestock	–	6.8 ± 6.8	–	9.1 ± 9.6	0.32
Vegetables crops	–	–	12.4 ± 11.7	11.7 ± 9.7	0.77
Workforce (%)					χ^2, 0.17
Unpaid family labour	38	24	46	22	
Paid workers only	16	29	14	29	
Combination of paid and unpaid	47	47	40	49	
Off-farm activities	44	76	52	62	χ^2, 0.09
Level of education (%)					χ^2, <0.01
No education	0	5	4	2	
Elementary school	34	5	25	16	
High school	56	38	54	38	
Post-secondary education	9	52	17	44	
Share of farm income (%)					χ^2, <0.01
Livestock	–	57	–	37	
Fishes	100	43	35.5	24	
Vegetables	–	–	64.5	39	
Fate of fish production (%)					χ^2, 0.79
Quantities sold	47	58	67	56	
Quantities consumed	53	42	33	44	

† *P*-value: ANOVA test, Chi-square tests, probability between subsystems. ‡ Means ± standard deviation
F: Fish farming solely, *FL*: fish and livestock farming, *FV*: fish and vegetable farming, *FLV*: fish, livestock and vegetable farming.

Table 3: *Size or area allocated to each subsystem in the different types of farms (Means ± standard deviation).*

	Subsystems				*P-value* †
	F	*FL*	*FV*	*FLV*	
n (number of farms)	32	21	52	45	
Total farm area (are)	6.6 ± 8.0	7 ± 6.9	4.7 ± 3.9	6.4 ± 6.7	0.35
Pond area (%)	100 ± 0	94 ± 98	86 ± 94	86 ± 95	0.19
Vegetable area (%)	N/A ‡	N/A	14 ± 34	15 ± 31	0.42
Operational ponds (N)	2.4 ± 1.9	2.5 ± 1.9	1.8 ± 1.0	2.4 ± 1.3	0.13
Non-operational ponds (N)	0.7 ± 1.6	1.0 ± 2.1	0.5 ± 1.2	0.6 ± 1.2	0.73
Livestock density (TLU)	N/A	5.3 ± 16	N/A	2.6 ± 2.8	0.26

† *P*-value: ANOVA test, probability between subsystems; ‡ N/A: not applicable
F: Fish farming solely, *FL*: fish and livestock farming, *FV*: fish and vegetable farming, *FLV*: fish, livestock and vegetable farming.

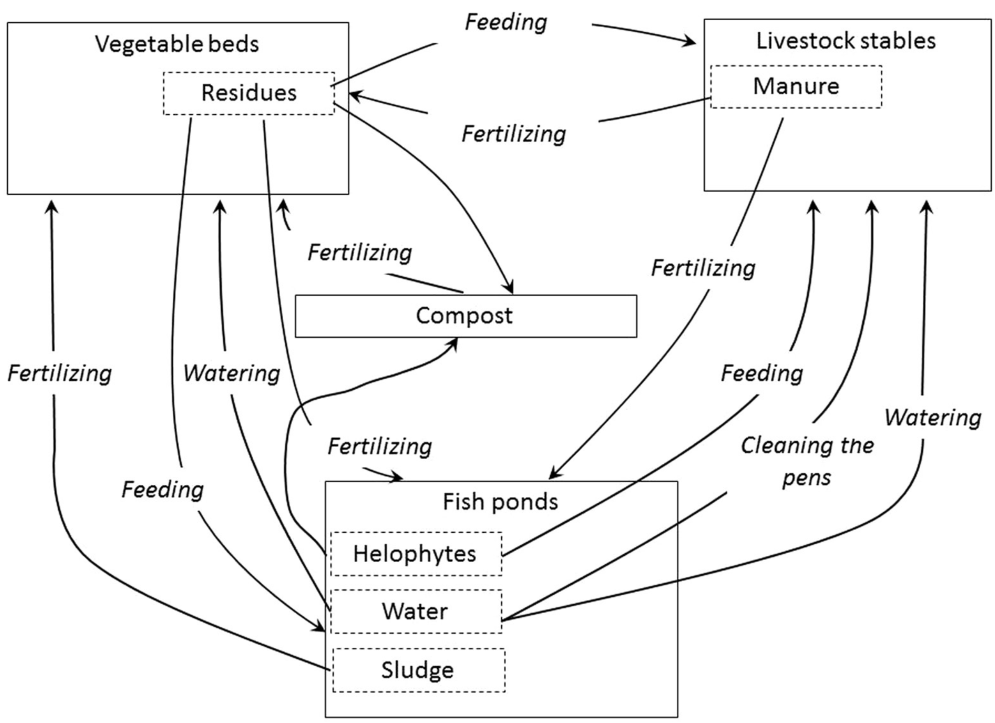

Fig. 2: *Description of the fluxes between subsystems mentioned by the farmers. Arrows represent the movement of the fluxes between subsystems.*

Table 4: *Inventory of fluxes between subsystems mentioned by the farmers according to the farm type (% of farms in the category using the fluxes).*

	Subsystems			*P-value* †
	FL	*FV*	*FLV*	
n (number of farms)	20	52	45	
Pond used for				
Fertilising vegetables with sludge	N/A ‡	10	20	χ^2, <0.01
Composting of helophytes plants	N/A	21	22	χ^2, 0.89
Feeding helophytes plants to livestock	14	N/A	16	χ^2, 0.74
Watering animals	10	N/A	31	χ^2, <0.01
Cleaning pigsties	10	N/A	18	χ^2, <0.01
Watering plants	N/A	64	49	χ^2, <0.01
Manure used for				
Pond fertilisation	57	N/A	64	χ^2, <0.01
Vegetable farming	19	N/A	80	χ^2, <0.01
Composting	5	N/A	4	χ^2, 0.11
Vegetable wastes used as				
Animal feed (pig, fish)	N/A	6	33	χ^2, <0.01
Pond fertiliser	N/A	2	4	χ^2, <0.01

† *P*-value: Chi-square tests, probability between subsystems; ‡ N/A: not applicable
FL: fish and livestock farming, *FV*: fish and vegetable farming, *FLV*: fish, livestock and vegetable farming.

4 Discussion

Results of the present study showed that Integrated Aquaculture-Agriculture systems exist in different forms, combining fish ponds with vegetables (FV), livestock (FL) or both subsystems (FLV) within farms in urban/peri urban and rural areas of Kinshasa. Compared to the very diverse systems developed in tropical Asia where the system is usually built around a paddy field with rice as the main crop associated with fish and livestock (Symoens & Micha, 1995; Edwards, 1998; Ahmad, 2001; Micha, 2005), emphasis in Kinshasa is given to vegetable crops such as amaranth, sweet potato leaves, roselle, and eggplant, and to raising small livestock such as pigs, chickens, ducks, and goats associated with fish. Crops such as cassava, peanut, corn and soybeans can be found in few farms and are generally grown in rural areas. Because of their requirement for space (flat and wide land), soil characteristics (less clay) and water, these crops are often located outside of the farm and managed without integration with ponds. Under these conditions, even when it is practiced by the same farmer, those crops have little influence on the pond farming because flows are never really exchanged with components outside the immediate vicinity of the pond due to factors such as transportation issues and a lack of manpower to carry the manure, for example. Integration with ponds is therefore basically related to vegetables in Kinshasa like in the Vuon-Ao-Chuong system (VAC, literally meaning "garden/pond/livestock pen" in Vietnamese), which is practiced by a large number of small-scale farmers in Vietnam (Chung *et al.*, 1995; Long *et al.*, 2002; Micha, 2005) or systems associating fruit and vegetable farming on fish pond dikes in India (Tripathi & Sharma, 2001). Practices in fish farming in Kinshasa are different between rural and urban areas only for some aspects. For example, the short distance that separates farms and the city centre of Kinshasa in urban areas offers some advantages. Farmers close to the city centre use more commercial feed ingredients to feed the fishes and other animals. They have better access to markets and can therefore more easily support high TLU densities on small areas by purchasing feed ingredients for their livestock and mixing with on-farm resources, as shown by Kambashi *et al.* (2014) in the same area. This practice is also noticeable for the management of the ponds. Regarding fish feeds, the high proportion of farmers reporting the use of purchased fish feeds in urban areas hides the fact that very few of them actually used commercial well-balanced feeds. They purchased any kind of agro-industrial wastes such as wheat bran or brewers' grains and throw them in their ponds thinking that they feed the fishes. Moreover, they don't do it regularly, but only when these ingredients are available. Such feed ingredients have little values for fishes and are rather acting as fertilisers for the ponds and also possibly supplying some maggots from flies that lay eggs on the brewers' grains during storage. Urban farmers have an easier access to purchased fingerlings from the Congo River and commercial fingerlings producers, allowing polyculture instead of monoculture more easily as fish production method (35 % urban vs. 11 % rural). Conversely, rural farmers rely on the exchange of fingerlings between farmers by donations or purchase, lowering the diversity of fish species when stocking ponds. Having more than one species of fish together in the same pond (polyculture) has generally been regarded as more productive than raising individual species separately (monoculture) (Edwards, 1998; Long *et al.*, 2002). Over half of the fish produced is sold. Customers are predominantly resellers who carry the products to the markets. The farmers therefore wait to have sufficient customers before making the decision to sell the production by emptying the ponds. This situation has an influence on the production cycle, which varies greatly from one farm to another in urban area (high variability of SD table 1). This situation is very similar to that observed by Efole Ewoukem *et al.* (2012), where the duration of production cycles varied from 9 to 18 months. In contrast, fish production in rural area is more oriented towards self-consumption (Table 1), with a higher use of on-farm resources to feed the animals. The decision to sell the production is taken by farmers when thinking it's ready for consumption. Since over 60 % of farmers live on or near their farms, they are very much present on the farm to care of and expect result from the farm. Considering the growing demand for fish, there is an opportunity for smallholder farms to evolve towards partly or completely commercial systems in the future. Major use of purchased ingredients by urban famers hides the fact that brewer's grains are the main purchased ingredients provided by two breweries located in Kinshasa. For rural farmers the cost of transportation is very high and exceeds the cost of acquisition of brewer's grain. This also hides a strong dependence of the urban farms on the breweries.

Regarding the impact of integration, farmers practicing integrated farming generally have more experience in agriculture and have the highest level of education. These farms require high monitoring, involving the highest workforce who are usually family members in Kinshasa. Generally, increased subsystem diversity for more nutrient linkage requires additional labour (Prein, 2002). The paid workforce is normally used for operations that require abundant labour such as harvesting, preparing flowerbeds and transporting farm production if necessary. In this study, an exception lies in FL farms because livestock require more paid labour. FL farms are bigger and contain twice as many animals (in TLU) as FLV; some farmers made big investments and intensive use of the purchased ingredients. The use of paid workforce allows also some farmers to make off-farm activities. Although they are considered a secondary activity contributing only secondarily to the income, ponds play an important role in integrated farms. Ponds are typically small in size, probably due to construction costs, and the lack of appropriate construction materials. The size of the ponds on the farms is correlated with the total area of farm ($P < 0.01$, $r = 0.97$) and tends to be correlated with the length of the production cycle ($P = 0.14$, $r = 0.06$). Also, the larger the ponds, the more they display economic importance since pond area is negatively correlated with the contribution of vegetables to the income ($P = 0.01$, $r = -0.20$). Results showed that the total amount of harvested fish tends to be correlated with TLU ($P = 0.14$, $r = 0.07$) and total cost of materials ($P = 0.11$, $r = 0.14$). Therefore, it seems that the productivity of the animal subsystems is linked with the production of the ponds, possibly due to nutrient transfer through the manure that sustains pond productivity.

The degree of integration and intensification in IAA systems varies with the variation in the pattern of bio-resource flows among various enterprises (Pant *et al.*, 2005). In urban/peri-urban and rural areas of Kinshasa, 11 fluxes were identified within integrated farms with different degrees of intensification. Integrated farms showed a greater use of manure and sludge for fertilising ponds and vegetables. Manure is directly used in ponds or vegetable farming. Table 4 also shows that only a few integrated farms make full use of the entire range of possible fluxes and require further guidance on the benefits of, for example, a moderate eutrophication of ponds or the use of helophytes in combination with manure to produce compost; this intensifies the positive flows between subsystems, without any deterioration of environmental conditions, in order to derive more profit, as reported by Murshed-E-Jahan & Pemsl (2011) in Bangladesh.

In addition to the fact that this study shows that integrated system exists in rural and urban areas in DRC, it also reveals the fact that the management of the fish pond is not the same when it is alone or associated with other sub-systems in the farm; also there is a tendency for greater efficiency following the management of a greater number of flows for farms with multiple subsystems. However, to confirm this last statement, a proper technical economic analysis or a life cycle assessment would be necessary to show which combination of subsystems provides high economic return and improves the farmers' socioeconomic conditions.

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