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Typology of smallholder's pig production systems in South Kivu, Democratic Republic of Congo: Challenges and opportunities

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Abstract

Pig farming plays an important role in farmers' livelihoods in many tropical countries. It contributes to food security of the poorest as well as the development of rural economy through multiplier effects. In the South Kivu province, pig farms are almost exclusively owned by smallholders. A few studies have attempted to describe thoroughly pig farming systems in this province. This study was undertaken to characterise pig production systems, in order to better understand their current situation, namely constraints they face and opportunities they offer. Investigation was conducted based on a structured survey questionnaire and participatory interviews with the owners of 989 farms in South-Kivu. Collected data was analysed using Multiple Correspondence Analysis and clustering techniques. Results showed that there are two types of smallholder pig farms differing mainly in the type of husbandry and feeding management. One category includes farms that raise pigs in free-range system consuming forages and scavenge feed (heaps picked-up from garbage and trash on their ways), which are sometimes, combined with crop residues and kitchen leftovers. The second category includes improved pig farms raising tethered pigs or in lairage where feed is mostly based on forages combined with kitchen leftovers, crop residues and concentrate feed. Nevertheless, all these different farm types share many common characteristics, including having pigs of local breeds, small herd sizes, absence of breeding boars and absence of adequate prophylactic measures. It emerged that female farmers together with experienced farmers mainly own pig farms with better characteristics (breed type, management practices, litter size, etc.). Hence, the involvement of women in pig farming can offer better prospects for the improvement of this sector. In addition, access to agricultural credit can also be an alternative to foster investment in livestock in South Kivu. All this can only lead to better results though improved local market access to smallholder producers.

Keywords: Breeding practices, feeding strategies, hierarchical clustering on principal components, multiple correspondence analysis, pig farming systems

1 Introduction

Food insecurity remains a major issue in several countries, especially developing countries despite the growth in global livestock production (Dehoux *et al*., 2018). This situation increases meat importation from other countries to alleviate the observed shortage (Rakotoarisoa *et al*., 2012). To address this problem, livestock development programs focus on the promotion of species with short lifespan such as poultry, pigs, rabbits and non-conventional animals (Dehoux *et al*., 2018). In this context, pig farming has many advantages in tropical countries (Logtene *et al*., 2010). For instance, its breeding constitutes an important saving for producers and a safety net during periods of crisis explaining a rapid growth in production within the sector, especially in societies where there is a major shift from ruminant to monogastric production (FAO, 2011). It is better suited to poverty alleviation because of its multiple advantages compared to

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other livestock in addition to providing income to farmers with low subsistence resources in tropical regions (Logtene & Kabore-Zoungrana, 2010), improving farmer's livelihood and food security (Keoboualapheth & Mikled, 2003; Kumaresan *et al*., 2007; Costard *et al*., 2009).

Pig production, mainly from small family units produces more than 90 % of pork in sub-Saharan Africa (Boutonnet *et al*., 2001). Recent studies have shown a rapid increase in pork production and consumption in some sub-Saharan African countries, including the DR Congo (Nantima *et al*., 2015). However, despite the increase in pig production, demand remains significantly higher than supply (Alexandratos & Bruinsma, 2012). Indeed, the strong demographic growth in developing and emerging countries induces a strong increase in the demand for animal products (Steinfeld *et al*., 2006) and this demand remains strongly superior to the supply on local markets.

Pig production systems in the tropics, and in DR Congo in particular, encompass a variety of production systems including those that are poorly developed and practised mainly by smallholders (Lekule & Kyvsgaard, 2003). In DR Congo, pigs are raised almost exclusively by smallholders in a variety of environments ranging from large cities to rural areas (Akilimali *et al*., 2017). Nowadays, there is an increasing number of small and medium-sized farms engaged in semi-intensive pig production (Kambashi *et al*., 2014) representing more than 5 % of the national flock. Nevertheless, pig farms face various constraints and opportunities depending on their location leading to various needs for developing improvement programs.

In South Kivu province, the pig production sector is subject to several constraints that hinder its development among which health, breed and hygiene are predominant (Akilimali *et al*., 2017). Thus, to satisfy animal protein demand, the province relies on imports from neighbouring countries (Akilimali *et al*., 2017). Furthermore, a few studies have attempted to describe thoroughly pig farming systems in this province. However, they provide little information on pig production. Thus, this study aims to characterise pig production systems in South Kivu Province, DR Congo, in order to better understand their current situation, the constraints they face and the opportunities they offer. In particular, it establishes a typology of these farms that will serve as a basis for future research and development policies.

2 Materials and methods

2.1 Study area

This study was carried out in the province of South Kivu, Eastern DR Congo (Fig.1). This province is located between 1°36' and 5° South latitude and between 26°47' and 29°20' East longitude. It covers an area of 69,130 km^2 and has an average annual temperature of 19 °C, with an altitude ranging from 773 to 3,000 m asl (Mugumaarhahama *et al*., 2016).

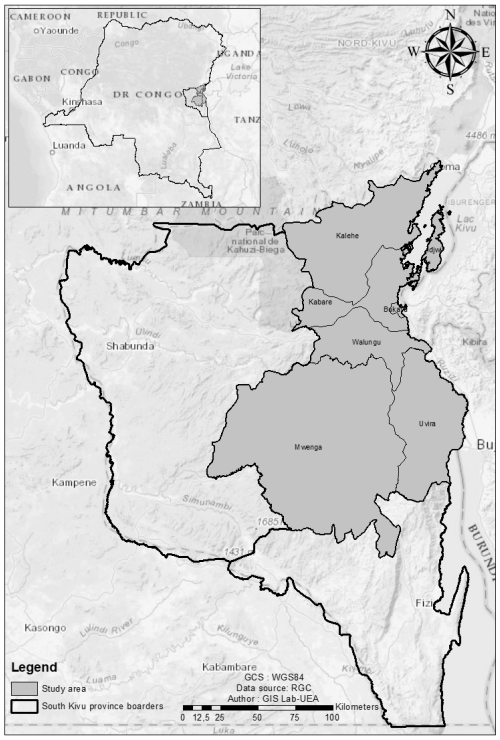

Fig. 1: *Map of study area, South Kivu Province: Map made using shapefiles from the RGC (Référentiel Géographiqe Commun).*

2.2 Sampling and data collection

Sampling was conducted in six of the eight territories of South Kivu province (Kabare, Walungu, Uvira, Kalehe, Mwenga and Idjwi) and Bukavu city on 989 households. The territories were selected based on the prevalence of pigs and in each territory surveyed farms were selected randomly. Our investigation was not extended to Shabunda and Fizi due to limited access to these territories.

Data collection in each farm was carried out using a structured survey questionnaire and participatory interviews with farm managers in local language. The gathered information mainly covered breeder's sociodemographic information, experience in pig farming as well as husbandry and feeding practices (Table 1).

2.3 Data analysis

Multivariate statistical analyses are commonly used to identify explanatory variables that can help grouping indi-

Table 1: *Variables used in Multiple Correspondence Analysis.*

Variables	*Modalities*	*Configuration*
Main activity	Agriculture; Petty trade; Livestock; Odd jobs	Active variable
Sex	Female; Male	Active variable
Education level	Illiterate; Primary school; Secondary school; University	Active variable
Marital status	Single; Married; Widower	Active variable
Experience in pig farming	Less than 10 years; 10 years and more	Active variable
Housing system	Free-range; Tethering; Lairage	Active variable
Cleaning of pig houses	No; Yes	Active variable
Frequency of forage supply	A few times; Regularly*	Supplementary variable
Frequency of adding kitchen leftovers	A few times; Regularly*	Active variable
Frequency of adding crop residues	A few times; Regularly*	Active variable
Daily frequency of feed provision	1 to 2 times; 3 to 4 times; More than 4 times	Active variable
Dietary supplements provision	No; Yes	Active variable
Concentrate feed provision	No; Yes	Active variable
Number of pigs	Less than 5 pigs; 5 pigs and more	Active variable
Possession of a boar	No; Yes	Active variable
Breed of pigs	Crossbred; Local	Active variable
Selection of breeding sows	No; Yes	Supplementary variable
Litter size	Less than 5 piglets; 5 to 8 piglets; 8 to 12 piglets	Active variable
Sanitary bathing	No; Yes	Supplementary variable

*A few times = at most once a week; Regularly = at least thrice a week.

viduals into homogenous groups (Alvarez *et al*., 2018). For this particular case, it primarily helped grouping farms into homogeneous clusters that represent farm types. Multiple Correspondence Analysis (MCA), a data-reduction method was applied on the selected set of variables to derive a smaller set of non-correlated principal components. Although the number of key variables is reduced, the variability of the dataset is largely preserved (Alvarez *et al*., 2018). The core idea common to all principal component methods such as MCA is to describe a data set using a small number of uncorrelated variables while retaining as much information as possible. In MCA, the reduction is achieved by transforming the dataset containing categorical variables into a new set of continuous variables (principal components) (Husson *et al*., 2010). Subsequently, clustering analysis (CA) is applied on these principal components to identify clusters that minimize variability within clusters and maximize differences between clusters. There are two methods of CA commonly used: Non-hierarchical clustering, such as K-means and Hierarchical clustering. At time both clustering methods are used to combine the strengths of the two approaches (see for e.g. Iraizoz *et al*., 2007; Kuivanen *et al*., 2016; Michielsens *et al*., 2002).

In MCA, only the first axes are retained to stabilize the clustering by deleting the noise from the data (Husson *et al*., 2010). To retain as much as possible, the variability in the data, we have chosen to do clustering using the first five components, which account for nearly 75 % of the total inertia of the data. In order to identify the main characteristics of the different clusters, Euclidean distances were calculated between clusters' centroids and all categories considering their principal coordinates on the first five principal components. All the statistical analyses were performed under R, version 3.5.1 (R Development Core Team, 2018).

3 Results

3.1 Overall description of local pig farms

Table 2 summarizes characteristics of pig farms in the surveyed territories of South Kivu Province.

Overall, local pig farmers are married men with at least primary education and mainly engaged in agricultural activities. Their herd size is on average less than five local pigs, raised either in free-range system or in lairage system. Most of pig farmers in this region exhibit an experience in pigs farming of less than 10 years on average. The basic feed ration consists of heaps (scavenge feed picked-up from garbage and trash), forages, kitchen leftovers and crop residues served once or twice a day. Concentrate feed and/or dietary feed supplements are also served to pigs in respectively 49.8 % and 58.1 % of pig farms in addition to the

Table 2: *Overall description of pig farms (N=989)*

Variables	*Modalities*	*Overall (%)*
Main activity	Agriculture	47.0
	Petty trade	17.7
	Livestock	11.3
	Odd jobs	24.0
Sex	Female	28.8
	Male	71.2
Education level	Illiterate	25.5
	Primary school	26.2
	Secondary school	43.3
	University	5.1
Marital status	Single	20.0
	Married	74.4
	Widow	5.6
Experience in pig farming	Less than 10 years	85.3
	10 years and more	14.7
Housing system	Free-range	41.1
	Tethering	17.4
	Lairage	41.6
Cleaning of pig houses	No	42.3
	Yes	57.7
Frequency of forage supply	A few times	5.7
	Regularly	94.3
Frequency of adding kitchen leftovers	A few times	29.8
	Regularly	70.2
Frequency of adding crop residues	A few times	44.6
	Regularly	55.4
Daily frequency of feed provision	1 to 2 times	74.1
	3 to 4 times	15.2
	More than 4 times	10.7
Dietary supplements provision	No	42.0
	Yes	58.0
Concentrate feed provision	No	50.3
	Yes	49.7
Number of pigs	Less than 5	82.7
	5 pigs et more	17.3
Possession of a boar	No	72.9
	Yes	27.1
Breed of pigs	Crossbred	18.8
	Local	81.2
Selection of breeders	No	4.9
	Yes	95.2
Litter size	Less than 5	13.7
	5 to 8	76.6
	8 to 12	9.7
Sanitary bathing	No	5.3
	Yes	94.7

basic ration. In the majority of pig farms, there are no breeding boars. The litter size comprises between 5 and 8 piglets. To prevent disease within farms, pig houses are cleaned and the pigs are subjected to sanitary baths.

3.2 Multiple Correspondence Analysis results

Table 3 presents the principal coordinates of all modalities on the first five principal components derived from the multiple correspondence analysis (MCA).

In total, 16 qualitative variables (40 modalities) were included in the multiple correspondence analysis from which 5 principal components were derived. The 5 principal components represent more than 74 % of the total variance of the entire data set, with the first two components representing more than 62 % of the total inertia. A quick glance of the results presented in Table 1, shows that it is possible to define each component according to the modalities it is strongly associated with.

The first axis (PC1) for instance separates two categories of pig farms. On the one hand, there are farms owned by single women who attended university and whose main activities involved small businesses and livestock. In most of these farms, pigs are raised in lairage and feed, which mainly consisted of kitchen leftovers, crop residues, feed concentrates and dietary supplements, was served more than 4 times feed concentrate. Results also revealed that most of pigs raised in his category of farms are essentially crossbreds with litters' size ranging from 8 to 12 piglets. Results indicate that boars are often found within these farms. Information on prophylactic measures indicate that frequent cleaning of pigs' houses is dominant. On the other hand, the second category of pig farms is constituted by free-range pig farms held mainly by illiterate widowed men with agriculture as their main activity. In these farms, the raised animals are of local breed giving litters of less than 5 piglets. Mainly dominated by a free-range raising system, farms falling under this category are characterised by a ration consisting of heaps (scavenge feed picked-up from garbage and trash) and forages, and sometimes kitchen leftovers and crop residues served once or twice a day. No prophylactic measures had been reported among these farms except sanitary bathing of pigs; the same can be observed for selection of breeding stock that is quasi-inexistent under this category; besides boars were not found in most of the farms belonging to this category.

The second axis (PC2) distinguishes two categories of farms. The first category includes farms whose owners are married men, with a demonstrated experience of more than 10 years in pig farming, venturing into agriculture as their main activity but who attended at least high school. These

Table 3: *Loadings of modalities on the five principal components resulting from the multiple correspondence analysis (MCA).*

Variables	*Modalities*	*PC1*	*PC2*	*PC3*	*PC4*	*PC5*
Main activity	Agriculture	0.418*	−0.192*	0.077*	0.233*	0.286*
	Petty trade	−0.775*	−0.124	0.338*	0.583*	−0.472*
	Livestock	−0.374*	0.907*	−1.075*	0.070*	0.622*
	Odd jobs	−0.061	0.021	0.123	−0.888*	−0.500*
Sex	Female	−0.318*	0.317*	−0.200*	0.722*	−0.395*
	Male	0.126*	−0.126*	0.079*	−0.286*	0.156*
Education level	Illiterate	0.232*	0.531*	−0.628*	0.444*	0.405*
	Primary school	−0.199*	−0.121	0.661*	0.355*	−0.058*
	Secondary school	0.036	−0.249*	−0.027	−0.331*	−0.163*
	University	−0.448*	0.149	−0.010	−1.096*	−0.290
Marital status	Single	−0.208*	0.513*	0.087	−0.267*	0.234*
	Married	0.029	−0.165*	−0.015	−0.039	−0.003
	Widower	0.387*	0.311*	−0.126	1.523*	−0.823*
Experience in pig farming	Less than 10 years	−0.037	0.205*	0.191*	0.059*	0.093*
	10 years and more	0.216	−1.190*	−1.109*	−0.342*	−0.537*
Housing system	Free-range	0.680*	0.458*	0.302*	0.182*	0.212*
	Tethering	−0.267*	−0.054	0.234*	−0.364*	0.530*
	Lairage	−0.529*	−0.407*	−0.378*	−0.022*	−0.415*
Cleaning of pig houses	No	0.828*	−0.361*	−0.067	−0.029	−0.002
	Yes	−0.629*	0.274*	0.051	0.022	0.002
Frequency of forage supply	A few times	−0.104	0.377	−0.527*	−0.826	2.512*
	Regularly	0.005	−0.020	0.028*	0.043	−0.131*
Frequency of adding kitchen leftovers	A few times	0.654	−0.993	−0.240	0.028	0.355
	Regularly	−0.277	0.420	0.102	−0.012	−0.150
Frequency of adding crop residues	A few times	0.804*	−0.532*	0.153*	0.023	−0.101*
	Regularly	−0.635*	0.420*	−0.121*	−0.018	0.080*
Daily frequency of feed provision	1 to 2 times	0.208*	−0.001	0.030*	0.306*	−0.116*
	3 to 4 times	−0.017	0.263*	−1.182*	−1.061*	0.148*
	More than 4 times	−1.328*	−0.363*	1.480*	−0.489*	0.544*
Dietary supplements provision	No	0.576*	0.591*	0.305*	−0.134*	−0.172*
	Yes	−0.410*	−0.421*	−0.217*	0.096*	0.122*
Concentrate feed provision	No	0.444*	0.380*	0.010	−0.243*	−0.018*
	Yes	−0.451*	−0.386*	−0.011	0.247*	0.018*
Number of pigs	Less than 5	0.009	−0.128*	0.162*	−0.066*	−0.162*
	5 pigs et more	−0.046	0.670*	−0.844*	0.343*	0.846*
Possession of a boar	No	0.138*	0.231*	0.182*	−0.009	0.051*
	Yes	−0.358*	−0.600*	−0.471*	0.023	−0.133*
Breed of pigs	Crossbred	−0.691*	−0.717*	0.888*	−0.224*	0.517*
	Local	0.157*	0.163*	−0.202*	0.051*	−0.118*
Selection of breeders	No	0.871*	1.371*	0.287	−1.022*	−1.821*
	Yes	−0.046*	−0.072*	−0.015	0.054*	0.095*
Litter size	Less than 5	0.184*	0.973*	−0.267*	−0.481*	−0.460*
	5 to 8	−0.001	−0.178*	0.104*	−0.051*	0.099*
	8 to 12	−0.253*	0.035	−0.442*	1.075*	−0.133*
Sanitary bathing	No	1.662*	0.142	0.662*	0.771*	0.627*
	Yes	−0.097*	−0.008	−0.039*	−0.045*	−0.037*
Adjusted inertia		0.01	0.006	0.002	0.001	0.001
Adjusted inertia (%)		37.900	24.667	6.477	3.483	2.369
% cumulative		37.900	62.567	69.044	72.527	74.897

PC1, PC2, PC3, PC4 and PC5: Five first principal components. * Coordinates for which the modality is significantly correlated (square cosine > 0.50 and p-value < 0.05) with the corresponding principal component and which (if considered as active variable) contribution is greater than 1/n (where n is the total number of modalities).

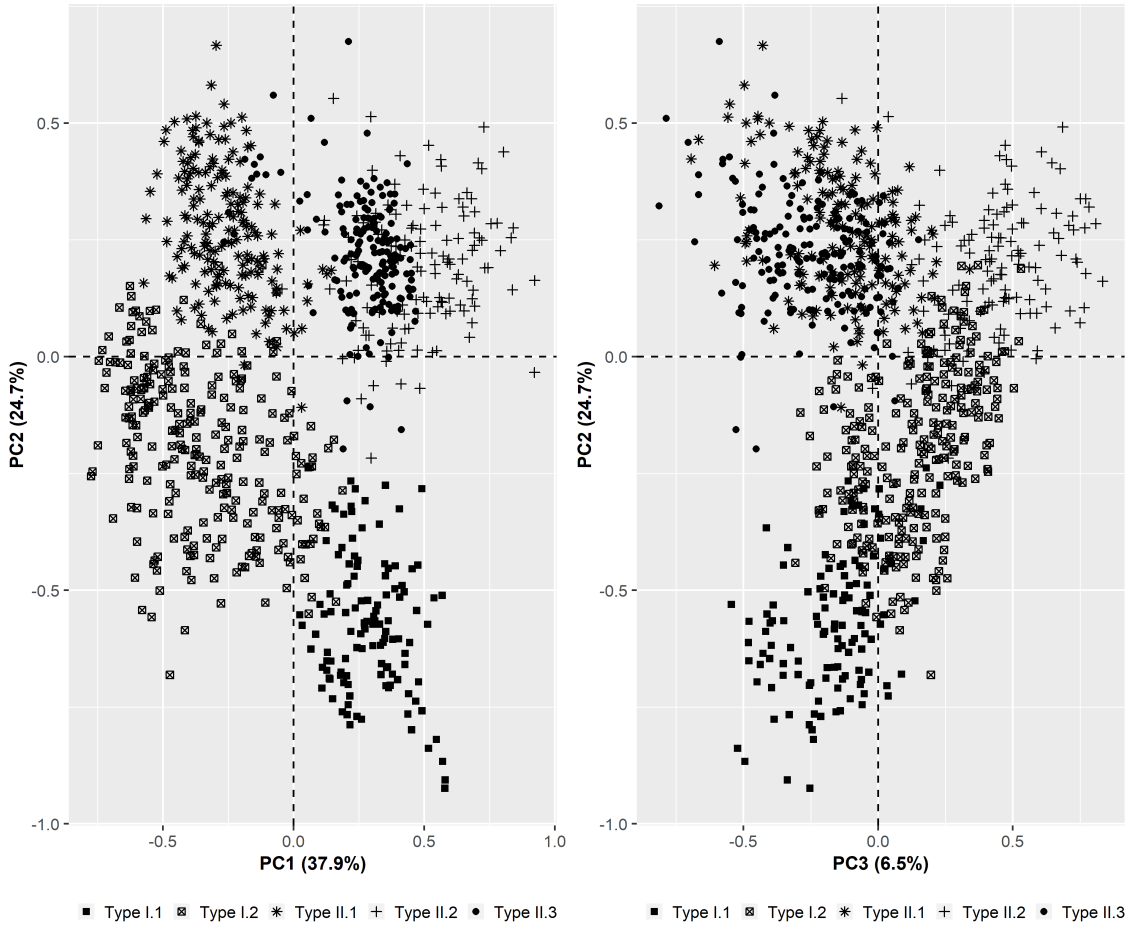

Fig. 2: *Representation of (sub)clusters resulting from the Multiple Correspondence Analysis on the first three principal components. Left: Plan resulting from principal components PC1 (Horizontal) and PC2 (vertical); Right: Plan resulting from principal components PC3 (Horizontal) and PC2 (vertical). Type I.1 – II.2 represent the different identified pig farms' types.*

are small farms with less than 5 crossbred pigs raised in lairage and fed with forage, sometimes combined with kitchen leftovers and crop residues. In addition to this basic ration, farmers give concentrate feed (often rice or maize bran + palm crabs + brewery grains) and feed supplements (mineral salts). Boars are usually encountered in these farms and are used to mate sows selected based on their performance. Sows give litters of about 5 to 8 piglets. The second category includes small farms of less than 5 pigs on average, mainly dominated by local breeds, and belong in most cases to married or widowed women exhibiting low level of education and experience in pig farming. Under this category, livestock is the main source of income. Besides, most of farms falling under this group rarely have a breeding boar. Pigs are just raised in a free-range system, no selection of breeding animals is made, and litters are often less than 5 piglets. The animals' ration is made up of scavenge feed they pick-up from garbage and trash on their ways, forages, kitchen leftovers and crop residues only.

3.3 Cluster analysis results

Fig. 2 shows the point clouds of the two types of pig farms according to the plans constituted from the top three principal components. The two first components, as depicted in this figure, help to clearly distinguish among the two classes as well as their characteristics. As for the main planes presented in Fig. 2, the latter show that the point clouds are too close to the centres, implying a strong similarity between the characteristics of different classes.

The two main types of pig farms identified differ mainly in their breeding and feeding practices.

3.3.1 Type I: Traditional local pigs farms (43.07 %)

This category is dominated by farms raising pigs of local breeds. Sows are raised in free-range system whereas boars

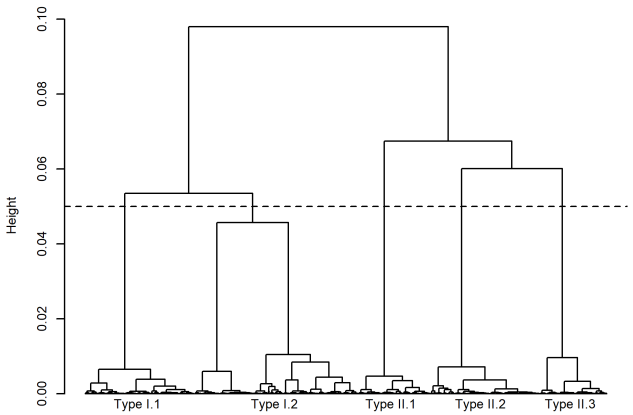

Fig. 3: *Dendrogram illustrating range of cluster solutions resulting from Hierarchical Clustering on Principal Components. Dashed line shows selected cut-off points; Type I.1 – II.2 represent the different identified pig farms' subclusters.*

are raised in lairage. In this category of farm, farmers live mainly from agriculture. These farms are subdivided into two subclusters:

Type I.1: Free-ranging local farms (29.63 %)

This is the category held mainly by male farmers who depend on agriculture as their main subsistence activity, have less than 10 years' experience in pig farming and have herds of less than 5 local breeds of pigs, raised in free-range system. In these farms, pig breeding stock is not selected because sows are raised in free-range system hence they mate with stray boars of local breeds. The basic feed ration of pigs consists only of scavenge feed (heaps) with no provision, feed concentrates nor feed supplements. In addition to the scavenge feed picked-up from garbage and trash, fodder is regularly served to pigs sometimes associated with crop residues. Pigs' houses are almost never cleaned. Sows raised under these conditions have very low reproductive performance giving litters of less than 5 piglets.

Type I.2: Farms providing natural mating services (13.44 %)

This farming system is dominated by pig farmers, mainly married men with a secondary level of education, exhibiting more than 10-years experience in pig farming and having agriculture as their main activity. In these farms, herds of less than 5 pigs are raised in lairage receiving sometimes kitchen leftovers and crop residues to supplement their feed ration consisting of forage, in addition to which dietary supplements and feed concentrates are provided. In these farms, there are breeding boars whose mating services are hired out to other pig farmers who do not keep breeding boars. The only prophylactic measure applied is the practice of sanitary baths (no cleaning of pigs' houses).

3.3.2 Type II: Peri-urban pig farms (56.9 %)

These farms are essentially dominated by local or crossbred pigs basically fed forages regularly combined with kitchen leftovers and crop residues. In addition to this feed ration, dietary supplements and feed concentrates are served to the pigs. This category has three sub-types:

Type II.1: Tethered pig farms (21.2 %)

This raising category held mainly by farmers having less than 10-years experience in pig farming and have herds of less than 5 local breeds of pigs raised in tethering system receiving regularly forage combined with kitchen leftovers and crop. Dietary supplements and feed concentrates are not provided in most of farms of this category. The female breeding stock is not selected because in most of these farms, there are no breeding boars. Sows raised under these conditions produce on average 5 to 8 piglets.

Type II.2: Crossbred pig farms (14.4 %)

These farms are held by farmers who attended primary or secondary schools, exhibit less than 10-years' experience in pig farming and raising pigs in lairage with herds of less than 5 crossbred pigs. The feed is served more than 4 times to the pigs and consists of forages given regularly and combined with kitchen leftovers and crop residues. This diet is usually enriched with feed supplements and feed concentrates. In this type of farms, animals admitted in reproduction are selected based on their weight performance and the litter size is on average 5 to 8 piglets.

Type II.3: Improved local breed pig farms (21.4 %)

This category represents farms held by married female farmers, with less than 10 years of experience in pig farming and having both petty trades and livestock as their main activities. The herd comprises around 5 pigs mainly of local breed raised in lairage and farmers have full control of their reproduction. Sows raised in this type of housing system are able to produce litters ranging from 5 to 8 piglets. Their feed ration is served 1 or 2 times a day and consists mainly of forage combined with kitchen leftovers and crop residues. Dietary supplements and feed concentrates are also provided. The prophylactic measures applied are the cleaning of pigs' houses and sanitary baths.

4 Discussion

This study was carried out with the aim of understanding the diversity that exists within pig farms in South Kivu. Through our findings, we were able to identify that the rural pig farms in South Kivu have heterogeneous characteristics despite some similarities. Generally, pig farmers have little experience in pig farming and limited access to resources to develop their activities at larger scale (Akilimali *et al*., 2018). Pig farms, based on the obtained results can also be described as subsistence farms that make use of cheap and locally available resources and provide smallholder pig farmers with additional revenues to improve their livelihoods. Considering the gender aspect, women seem less involved in pig farming in the surveyed territories. This could be due to cultural beliefs, which recognizes ownership of large animals to men, but also to the low level of women emancipation in rural areas as stated by Nantima *et al*. (2015). Indeed, in rural areas of South Kivu province, pig farms are often owned by households, which often implies that they are owned by households' heads, who are men from a cultural point of view. This is why livestock are often reported to be owned by male households' heads. It is thus difficult to give an accurate picture of the level of women's involvement in pig farming due to gender disparities or inequalities on livestock ownership (Njuki & Sanginga, 2013). The situation of women in pig farming in South Kivu is similar to that of their counterparts in the western provinces of DR Congo (Kambashi *et al*., 2014), Liberia (Karnuah *et al*., 2018) and Botswana (Nsoso *et al*., 2006) but slightly different from the gender situation in pig farming in Kenya and Uganda where women seem to play an important role in pig farming (Kagira *et al*., 2010; Nantima *et al*., 2015).

In the western provinces of DR Congo, pig herds are approximately 18 individuals on average (Kambashi *et al*., 2014), relatively higher than herd size in South Kivu, currently estimated at less than 5 individuals; but relatively higher as compared to herds in rural areas of some other developing countries. In fact, in most rural areas in developing countries, pig herds are small, approximately 4 individuals in Kenya (Kagira *et al*., 2010), 6 individuals in Vietnam (Lemke *et al*., 2006) and 3 individuals in Nigeria (Ajala *et al*., 2007). In addition to small herd sizes, local pig farmers raise local and low-producing breeds under marginal conditions that inhibit their full productive potential and impede good disease control. As explained by Kambashi *et al*. (2014), the proximity of pig farms to large populated areas is one of major factors that can influence pig herds' size reduction. One of the biggest challenges of smallholder farmers in South Kivu remains the deficient state of roads connecting major production centres, usually located in remote and rural areas, and mass consumption centres in urban areas. This increases the transaction costs of agricultural and meat products in particular and thus competitiveness of local produces vis-à-vis products imported from neighbouring countries is seriously compromised. For instance, much of the pig meat consumed in Bukavu, the main city in South Kivu province, comes from neighbouring countries. Market prices of imported products are relatively low as compared to local products, leading to discouragement of local producers who incur severe losses while engaged in transactions. This negatively affects the development of local pig farming as well. Local breeds of pigs are hardy but have very low productive potential (Halimani *et al*., 2010, 2020). Their average carcase weight is estimated at 30-35 kg (FAO, 2012). With low incomes from subsistence farming and high risk of loss from investment associated with local pig farming, farmers' propensity to invest in pig farming improvement declines (FAO, 2017). Apart from the low level of farmers' incomes, another factor that could explain the small pig herds sizes within study areas may be the increasingly limited access to land. Indeed, with increasing demographic growth, land is becoming scarcer and a highly coveted resource. The increasing pressure from farming activities, especially food crops, on available land and pastures has led to continuous decline in owned livestock herd sizes as well as less land dedicated to livestock farming and forage growing (Katongole *et al*., 2012). The more access to land the pig farmers have, the more possibilities they have to produce forages and/or crop residues to feed their pigs. It can be expected that the more land they have, the more likely they are to be able to raise large herd sizes of pigs, since they have the ability to produce the feed resources with which to feed them. On the other hand, the less access to land they have, the less opportunity they have to raise large herd sizes of pigs since they are unable to obtain sufficient feed resources to feed them and have no choice but to let them feed on the scavenge feed and the few kitchen leftovers they can find.

Results also showed that the basic feed ration for pig consists of forage and scavenge feed picked-up from garbage and trash. As for farmers who give concentrate feed and dietary feed supplements to their pigs, study findings reveal that such feed combination is done by farmers themselves, regardless of the nutrients they may contain and animals' nutritional needs . It can therefore be inferred that pig's ration is not balanced and adapted to their nutritional needs (Kambashi *et al*., 2014). Similar practices have been reported in the western provinces of DR Congo (Kambashi *et al*., 2014). The distribution of unbalanced diets to pigs is known for causing a decrease in animal performance (Kumaresan *et al*., 2009). As for livestock farms in western DR Congo, the

choice of forages as feed for pigs in South Kivu farms was not motivated by their palatability or nutritional value, but rather by their availability (Kambashi *et al*., 2014).

Since the main prophylactic measures in pig farming are cleaning of the housing and sanitary baths, pigs are more likely to be exposed to disease. It is known that one of the main challenges in pig farming are endemic diseases (Mbuthia *et al*., 2014) such as African swine fever (ASF), the most devastating disease (Costard *et al*., 2009; Praet *et al*., 2010; Fasina *et al*., 2012a; Fasina *et al*., 2012b). Patrick *et al*. (2019) have recently demonstrated the evidence for the presence of ASF Virus in South Kivu province. Limited access to good and high quality veterinary services and products, as well as the lack of information and training on vaccination and adequate prophylactic measures explain the poor health and hygiene practices observed in pig farms. Besides, the low-income level of rural households constitutes another often-mentioned impediment to providing adequate care to animals raised (Patrick *et al*., 2019). The high cost of veterinary services and drugs remains one of the most recurrent challenges in pig farming in rural areas (Karnuah *et al*., 2018).

Results of this study revealed that most of the farmers prefer to keep female than male pigs. These results are in accordance with findings from the Philippines (Lañada *et al*., 2005) and among Kikuyu smallholder farmers in central Kenya (Wabacha *et al*., 2004). The absence of breeding boars was also reported in most surveyed farms in South Kivu pushing farmers to let all their sows reproduce without taking into account their performance. Keeping boars was considered uneconomical for many farmers due to the small number of sows within their farms. This is due to extra funds required to take care of them which are deemed to be greater than what is required for hiring service either with cash or through in-kind payment (Nantima *et al*., 2015). Thus, some pig farmers relied on hired boars of crossbred or exotic breeds for mating their sows. Others preferred leaving their sows to be serviced by free-range boars of local breeds. Given the scarcity of farms that own boars, breeders in the same area tend to rent the services of a very small number of boars, which increases the risk of inbreeding. In addition, the habit of sharing boars for breeding purposes increased the risk of spreading ASF (Fasina *et al*., 2012a). The small litter size reported in this study can be attributed to poor diets and inbreeding. In fact, inbreeding has been previously reported to negatively affect litter size (Toro *et al*., 1988), birth weight (Brandt & Möllers, 1999), daily gain and final weight (Fernández *et al*., 2002). Most pig raisers in the present study did not seek for extension information on pig farming and this might explain the poor pig-management practices observed (Wabacha *et al*., 2004).

The typology has made it possible to identify clusters of pig farms that differ essentially in the systems in which pigs are raised, the way they are fed and managed. Nevertheless, we recognize that it is difficult to fully capture the diversity of pig production systems (Kuivanen *et al*., 2016) and we are aware of the limitations of the typology in this regard. The free-range farming of sows makes them less productive. Although local breed pigs are hardy, the risk of mortality is high, thus reducing the probability of launching some pig production with very low investment. In light of the aforementioned investment situation, we were brought to believe that these farms face several constraints and their production is extremely low. In farms providing natural mating service, considering the fact that boars are of local breed, production and breeding performance is somehow limited, and thus reducing the likelihood of obtaining sufficient earnings. Nevertheless, these farms have the advantage of controlling the feeding and reproduction of their pigs, which is of critical importance in improving pig production (Guy *et al*., 2012). We suspect that the limited financial resources from agriculture available to farmers limit their practice of more efficient pig breeding systems. Raising of tethered pigs represents an improvement compared with the free-range farming of sows. It has the advantage of allowing the control of feeding and reproduction but does not allow a more adequate control of hygiene. Thus, since these are local breed pig farms and farmers do not have enough resources to invest more in them, they are also likely to be less productive. Tethering appears to improve litter size somewhat but may not necessarily result in reduced mortality. However, the farming of pigs in lairage represents the best alternative of improving pig farming. Our findings demonstrated the extent to which the level of education of farmers and the involvement of women represent opportunities for pig farming. In these farms, the feeding, hygiene and reproduction conditions are more or less controlled. Educated farmers and women seem to be the two categories of farmers who invest more in pig farming although both do not have significant financial resources to invest. However, in most of these farms, there are no breeding boars, making it difficult to improve the genetic quality of their pigs, given that most farms rear breeding boars are local breeds. Education is very crucial in decision making and most importantly provides farmers with the ability to perceive and process information in a relatively changing environment and constitutes one of the key drivers of technology mix, resource allocation and technology adoption (Davis *et al*., 2012). In addition, it has been argued that improving access to resources for rural women to the same extent as

men would increase agricultural production (Quisumbing *et al*., 2014). Therefore innovations such as improvement of animal husbandry and adoption of disease control strategies would make a more significant impact if women are involved (Nantima *et al*., 2015).

5 Conclusion

Typology conducted in this study allowed to identify 2 types of pig farms with respectively 2 and 3 subtypes for the first and the second type. These pig farms differ mainly in their housing and feeding practices. Nevertheless, all these different types share many common characteristics, such as the type of breeds that are in majority local, small herd sizes, lack of breeding boars, and inadequate prophylactic measures. The main constraints to pig farming in South Kivu are rearing low productive potential pigs, small herd sizes, poor health and feeding practices. Nevertheless, there are some opportunities in these farms that can be used to improve them. Farms with better characteristics are mainly owned by female and/or experienced farmers. Hence, women involvement in pig farming can offer better prospects for the development of the sector. The valorisation of kitchen leftovers and crop residues as sources of pigs' feed can also help reduce the cost of feeding pigs. However, farmers must take care to pre-treat these feeds before feeding pigs to prevent infestations, but they must also feed their pigs according to their feed requirements so that they are fed with balanced rations. The lairage system is also recommended, for better control of animal reproduction and health management.

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Conflict of interest

The authors state they have no conflict of interest.

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