Factors determining the adoption of integrated crop-livestock system in South Kivu Province, East of the Democratic Republic of Congo

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1. ABSTRACT

Sub-Saharan African regions are facing the decline in productivity and sustainability of agro pastoral systems. There is therefore the need to reduce the adverse effects of agriculture on the environment with the need to improve agricultural production globally for food security. The study aimed to identify the different factors influencing the adoption of integrated crops-livestock system and to characterize the main types of farms in eastern Democratic Republic of Congo. A survey was conducted among 150 agro-farmers selected in the in the East of the Democratic Republic of Congo. Based on the obtained results, the key variables that significantly affected the adoption of integrated crop-livestock system include age, household size, agricultural experience, membership of a local development association in place, education level, household head, income, access to markets, land ownership, number of fields owned, total area farmed, proportion of hired, access to training, minimization of the use of chemical fuels and total cost of hired labour ($p<0.05$). Results also revealed that the stall breeding system or method of caring livestock in an enclosed space, especially for cattle in a barn or in a limited space (36.70 %) which is useful technic to minimize waste of manure and reduces the cost of its transportation. In view of the obtained results, integrated crop-livestock systems may be a crucial type of ecological intensification required for ensuring long-term environmental sustainability and food security. Therefore, extension services and existing NGOs should organize proper farmers training by bringing them together in cooperatives in order to help them to reduce the cost of purchase inorganic fertilizers.

2. INTRODUCTION

A significant paradigm shift in agricultural systems will be necessary to feed more than 9 billion people by the middle of this century. About 40% of the earth's surface is used for agriculture, which also consumes the majority of the fresh water supply and is responsible for 17% of greenhouse gas emissions. In response, climate change will negatively affect agriculture across a wide range of climatic zones (Chartres *et al*., 2015). This will need to be accomplished by some type of environmentally friendly agricultural intensification given the current demands placed on natural resources. Therefore, the paradigm shift must place "sustainable intensification" at the forefront rather than just agricultural intensification. Additionally, a comprehensive analysis of the situation is required, taking into account population increase, resource-intensive consumption habits, enhanced governance systems, dietary changes, and waste reduction (Lemaire *et al*., 2013). Furthermore, population growth resulting in increased demand for agricultural, food products, and increased pressure on natural resources is one of the greatest challenges facing agriculture in tropical Africa (Pretty *et al*., 2011). In addition to this high population growth, the decline in soil fertility and the decrease in available fodder, lead to problems of productivity and sustainability of agropastoral systems (Poccard-Chapuis *et al*., 2007). In particular, the food situation in South Kivu is more worrying, especially since statistics rank it among the provinces most affected by hunger in the DR. Congo (PAM,2019). This situation would result from the inability of farms to meet the food population needs (Ndjadi *et al*., 2019). This contrasts with the enormous agricultural potential of this Province (Furaha *et al*., 2012). On the other hand, the country's land-to-person ratio of less than 0.05 ha per capita-1 (Huq *et al.* 2013) continues to decline due to rapid population growth resulting in food insecurity for the growing population of South- Kivu (Roy *et al*., 2019). Thus, a wide variety of technological solutions have been developed in order to achieve food self-sufficiency. These include optimizing the use of fertilizers and adopting integrated crop-livestock management. Unfortunately, the use of these modern technologies has not increased enough due to their slow adoption (Karim *et al*., 2017, Faruque *et al*., 2018). Lack of interest from farmers is often cited as the reason for this. According to Mutoko *et al*., (2014); Ruben and Pender (2004), identifying variability within and between farms is the first step in developing interventions that might be useful for the adoption of advanced technologies in a farming community. It is therefore useful to gather evidence on the constraints faced by farming households in the adoption of new agricultural technologies and which could guide future strategies for introducing sustainable development-oriented innovations that increase resilience and improve incomes. Therefore, the determinants of adoption must be studied at the level of each household in a village to develop specific interventions to introduce new agricultural technologies (Rahman et Das, 2019). This study aimed to identify and characterize the types of farms as well as determine the socioeconomic, agronomic and ecological factors likely to influence the adoption of the agriculture-livestock integration system. This study offers important information for policymakers that could stimulate and support the adoption of new technologies in the study region.

MATERIAL AND METHODS

3.1 Description of the area study: This study was carried out in three villages namely Lurhala, Kamisimbi and Ikoma located in Walungu territory, South Kivu province, Eastern DR Congo (Figure 1). This territory is located between 2°38' South latitude and 28°40' East longitude. This area is characterized by two seasons: the dry season and the rainy season with temperatures varying between 17°C and 20°C, the daily thermal amplitude can reach 10°C to 12°C, and rainfall oscillating between 900 and 1500mm per year with an annual average of 1300mm. This region is also geographically vulnerable to natural hazards such as rainfall deficiencies, which have led to increased food scarcity (Ndjadi *et al.*, 2019).

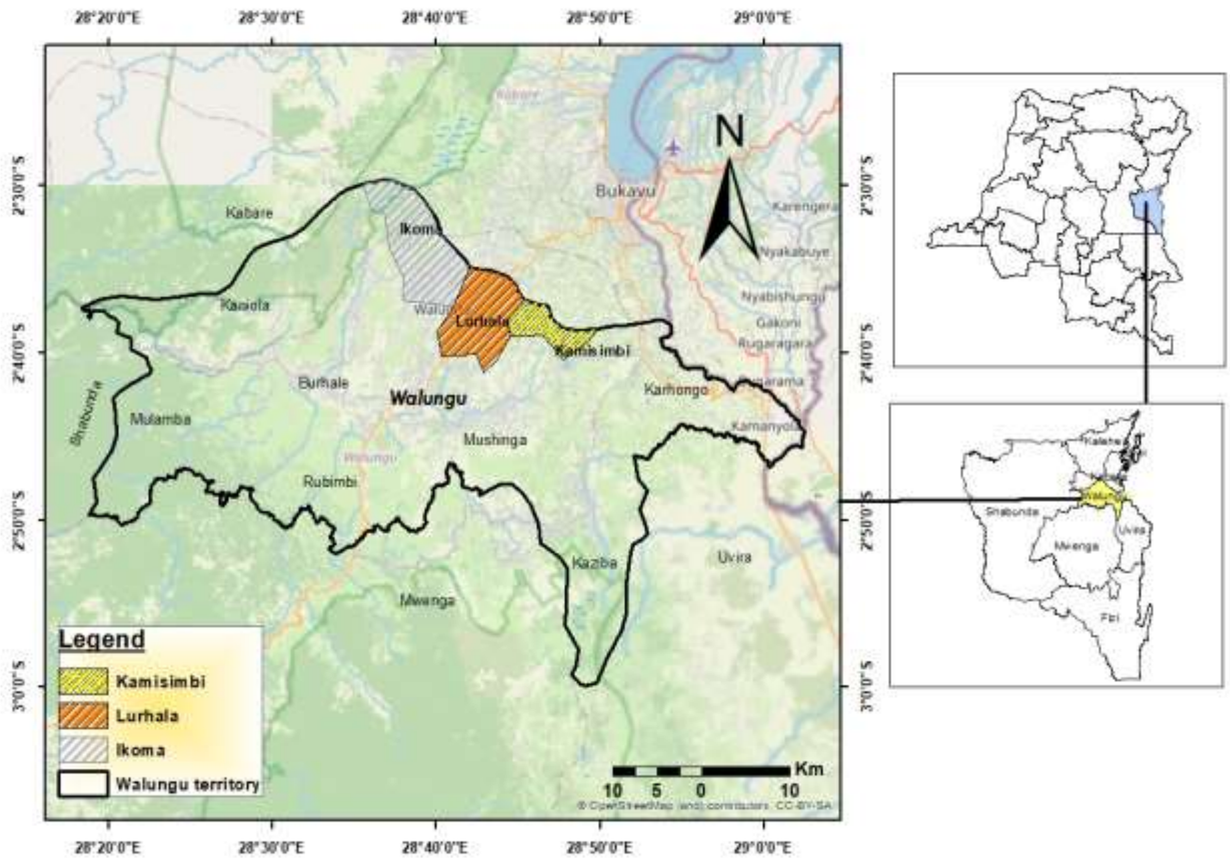

Figure 1: Presentation of the study area Map.

3.2 Sampling and data collection: A survey questionnaire was used to collect data from households covering the study area. Face-to-face household interviews in the sampled villages were scheduled. A total of 150 farm households from three villages (about 50 farms per village) named Lurhala, Kamisimbi, and Ikoma were chosen randomly. The interviews were carried out in the local language (Swahili) with the facilitation of local leaders for four months. Farmers were then interviewed in their residences or farms. This step involved gathering data about the individuals' socio-economic status (family structure, incomes, and expenses), farming management practices (fertilization, vegetable planting, irrigation, and pesticide application), and relationships with other stakeholders, depending on what information was pertinent to various stakeholders. The socioeconomic, agronomic, and ecological factors of the integrated system were the main subjects of the data collection.

3.3 Statistical data analysis: Data collected were analysed using SPSS statistical software package version 22.0 to perform the two samples Khi2 test and T-tests. After homoscedasticity and normality tests, data were submitted to the parametric test of ANOVA (analysis of variance) with 95% confidence interval to determine the significance of the treatments ($p<0.05$). When a significant difference was found, Tukey post-hoc test was performed to compare means that were determined to be significant. Descriptive statistics (frequency distributions) and inference tests were conducted for different variables involved in this study. The probit model was applied for the qualitative variables in order to evaluate the factors determining the adoption of integrated systems (Bua *et al.*, 1999; Adesina *et al.*, 2000). This model included the following variables: size of labour, cost of labour per cropping season, total area cultivated, area number of animals reared, access to agricultural credit, use of fertilizers, origin of fertilizers, farming method, cropping system, gender, age, years of experience, household size, membership of an association, level of study and training in an integrated system.

3.4 Conceptual framework and analytical model (Probit model): The probit model was the most appropriate in the specification of the relationships between determining factors (Ng'ombe *et al.* 2014). This model can be presented by the following equation:

$$\mathbf{E\ (Yi) = P\ (Yi)} = \frac{e^{\propto+\beta xi}}{1+e^{\propto+\beta xi}}$$

Where:

P (Yi) = probability for an individual using the technology;

P (Yi) = 1 if the technology is used and is equal to 0 if the technology is not used.

***e* =** Exponential function

Yi represents the explained variable; the use of technology

Xi = characteristic of individual; i; represents the vector of explanatory variables (age, grouping,)

$\boldsymbol{\beta}$= vector of the parameters to be estimated whose sign allows the interpretation of the results

$\propto$= constant

4 RESULTS

Socioeconomic status of Walungu agro-breeders :he results of table 1 in relation to the socio-economic status of Walungu agro-breeders show that agriculture-livestock integration system is mainly practiced by married men (63.00%) who have mostly attended primary school (44 .00%) followed by those who have reached secondary school (28.00%) and others are illiterate (23.30%). These agro-breeders are mainly Catholic (55.30%) and Protestant (40.70%). They are mainly involved in agriculture combined with livestock (99.30%) which they have been practicing since (18.83±11.64) years and are on average aged of (44.84±14.58) years. The households of these agro-breeders have an average size of (4.99±3.06) of which (3.27±1.98) of these people represents the active part in the households. From this table 1, it should be noted that only (24%) agro- breeders have access to agricultural credit. Most do not have access to agricultural credit, and are therefore content with the family income. The below table 1 shows the characteristics of Walungu agro-breeders.

Table 1: Characteristics of Walungu agro- breeders

Variables	Modalities	Villages (%)			Average	Kh2	P-Value
		Ikoma	Kamisimbi	Lurhala			
Gender	Female	38.00	40.00	32.00	36.70	0.753	0.689
	Male	62.00	60.00	68.00	63.30		
Marital status	Single	28.00	28.00	16.00	24.00	4.609	0.822
	Married	58.00	64.00	68.00	63.00		
	Widower	14.00	8.00	16.00	12.70		
Study level	Illiterate	22.00	30.00	18.00	23.30	9.925	0.128
	Primary	36.00	50.00	46.00	44.00		
	Secondary	32.00	20.00	32.00	28.00		
	University	10.00	0.00	4.00	4.70		
Religion	Catholic	56.00	54.00	56.00	55.30	1.299	0.869
	Protestant	40.00	44.00	38.00	40.70		
	Jehovah Witness	4.00	2.00	6.00	4.00		
Main activities	Agro-breeder	100.00	100.00	98.00	99.30	2.211	0.365
	Teacher	0.00	0.00	2.00	0.70	27.193a	0.000
Access to credit	No	80.00	96.00	52.00	76.00		
	Yes	20.00	4.00	48.00	24.00		
Age		44.08±15.17	47.28±15.43	43.16±13	44.84±14.58	1.101	0.335
Household size		5.12±3.38	4.30±2.89	5.56±2.8	4.99±3.06	2.213	0.113
Active households		3.52±2.31	3.10±1.96	3.18±1.6	3.27±1.98	0.63	0.534
Experience (year)		18.42±12.4	18.30±10.41	19.78±12.12	18.83±11.64	0.248	0.781

4.1 Farm management in the integrated crop-livestock system in Walungu : In view of the results obtained on farm management in the integrated crop-livestock system in Walungu (Table 2), it appears that farmers in Walungu integrate livestock and agriculture mainly to meet their mixed needs, i.e. needs for self-consumption, sale and purchase of agricultural products (74.00%). The most practiced cropping system is the association of crops (50.70%) followed by monoculture (49.30%). Most farmers reported low yield (56.00%) before the adoption of the crop-livestock integration system, but the yield increased after adoption (63.30%). Agricultural by-products (vegetable residues) are used in cattle feed and composting (62.70%) in order to produce manure for soil fertilization. Finally, (68.70%) of farmers use only family labour against 31.30% who hire labour; this is a major asset for a better adoption of the system.Table 2 shows how farms are managed in an integrated system in Walungu territory.

Table 2: Farm management in the integrated system

Variables	Modalities	Villages			Average	Kh2	P-value
		Ikoma (%)	Kamisimbi (%)	Lurhala (%)			
Production goals	Self-consumption	14.00	0.00	18.00	10.70	12.168	0.016
	Mixed	74.00	76.00	72.00	74.00		
	Sale	12.00	24.00	10.00	15.30		
Land status	Purchase	4.00	6.00	0.00	3.30	44.925	0.000
	Inheritance	26.00	26.00	0.00	17.30		
	Location	12.00	22.00	6.00	12.70		
	Private	58.00	46.00	94.00	66.00		
Cropping systems	Association	36.00	36.00	80.00	50.70	25.818	0.000
	Monoculture	64.00	64.00	20.00	49.30		
Farm profitability before adoption	Good	42.00	38.00	42.00	40.70	5.974	0.201
	Bad	56.00	62.00	50.00	56.00		
	Very good	2.00	0.00	8.00	3.30		
Farm profitability after adoption	Good	30.00	34.00	16.00	26.70	11.771	0.019
	Excellent	8.00	2.00	20.00	10.00		
	Very good	62.00	64.00	64.00	63.30		
Hired labour	No	54.00	72.00	80.00	68.70	9.954	0.041
	Yes	46.00	28.00	20.00	31.30		

4.2 Livestock management in the integrated crop-livestock system in Walungu: With regard to livestock management in the integrated crop-livestock system in Walungu, the results in table 3 shows that stalling (36.70%) is the most practiced farming method in the study area, followed by those who practice semi-stabling (33.30%). On the other hand, (57.30%) of selected farmers use on-farm livestock waste (excreta) for composting and thereafter apply it once is decomposed for the fertilization of their fields while other spread it directly (29.30%). The below table 3 shows how livestock are managed in an integrated system in Walungu territory.

Table 3: Livestock management in the integration system

Variables	Modalities	Villages (%)			Average	Kh2	P-Value
		Ikoma	Kamisimbi	Lurhala			
Breeding methods	Scavenging system	22.00	26.00	42.00	30.00	14.217	0.007
	Semi-stalling	30.00	28.00	42.00	33.30		
	Stalling	48.00	46.00	16.00	36.70		
Raised animals	goats	3.56± 2.87	5.96±2.87	4.76±3.96	4.76±3.40		
	Pigs	2.16± 2.34	1.92±1.90	1.92±2.76	2.00±2.35		
	Poultry	3.34± 3.85	4.37±6.06	4.94±5.20	4.21±5.12		
	Rabbits	3.98± 3.42	4.26±3.57	3.42±7.27	3.89±5.05		
	Guinea pigs	17.72±13.5	11.04±9.36	10.82±13.74	13.19±12.68		
Livestock waste management	Composting	56.00	50.00	66.00	57.30	17.458	0.008
	Sale	0.00	0.00	4.00	1.30		
	Direct spreading	32.00	26.00	30.00	29.30		
	Composting and Sale	12.00	24.00	0.00	12.00		
Sale of droppings	No	66.00	64.00	70.00	66.70	0.420	0.811
	Yes	34.00	36.00	30.00	33.30		

4.3 Socio-economic factors determining integrated crop-livestock system in Walungu: From the probit regression presented in Table 4, it emerges that the socio-economic factors that influenced the adoption of agriculture-livestock integration system include the age of agro- breeders, seniority in innovation, level of education, household size, the membership of farmers in a local development association, the number of fields in possession; the amount and type of labour used; the land status, the access to training facilities, the presence of organizations and the development of human capital ($p<0.05$). In contrast, the exploited area, the size of the hired workforce, the number of active members in the household, the religion and the sex did not significantly influence the adoption of the integration system. Table 4 describes the socioeconomic determinants of integrated crop-livestock system in Walungu territory.

Table 4: Socioeconomic determinants of integrated crop-livestock system

Variables	Model fit criteria				
	AIC of reduced model	BIC of reduced model	-2 log-likelihood of the reduced model	Chi-square	P-value
Age	306.266	625.394	94.266[b]	7.873	**0.002**
Sex	301.622	620.75	89.622[b]	3.229	0.199
Marital status	292.333	593.397	92.333[b]	5.94	0.654
Religion	296.135	609.241	88.135[b]	1.742	0.783
Education level	293.521	600.605	89.521[b]	3.127	**0.003**
Main activity	302.394	627.542	86.394[a]	0	-
Household size	305.999	625.126	93.999[b]	7.605	**0.001**
Number of working people in the household	303.646	622.774	91.646[b]	5.253	0.072
Experience (years)	305.748	624.875	93.748[b]	7.354	**0.001**
Number of owned fields	308.114	627.241	96.114[b]	9.72	**0.008**
Area exploited	298.952	618.079	86.952[b]	0.558	0.756
Land status	301.641	613.754	97.478[b]	7.451	**0.000**
Quantity of hired labour	307.936	627.063	95.936[b]	9.542	**0.008**
Credit value ($)	298.786	617.913	86.786[b]	0.392	0.822
Access to training facilities	311.427	624.533	103.427[b]	17.033	**0.002**
Member of an association	298.629	617.757	86.629[b]	0.235	**0.001**
Total cost of hired labour	247.732	440.413	119.732[b]	33.338	**0.049**
Access to credit	302.394	627.542	86.394[a]	0	0.001
Credit sources	297.784	610.89	89.784[b]	3.391	0.495

Legend: Small letters compare the likelihood of the reduced model for the different socio-economic determinants of integrated crop-livestock system.

4.4 Agronomic factors determining integrated crop-livestock system in Walungu: From the regression results presented in Table 5, it can be observed that the total exploited area ($p=0.009$) has a very significant influence on the adoption of the system. We also noticed that the increase in yield is very highly significant ($p<0.001$) for adopters of the system compared to those who have not adopted it. The below table 5 describes the agronomic determinants of the integrated crop-livestock system in Walungu.

Table 5: Agronomic determinants of the integrated crop-livestock system

Variables	Model fit criteria				
	AIC of reduced model	**BIC of reduced model**	**-2 log-likelihood of the reduced model**	**Chi-square**	**P-value**
Number of working people in the household	193.946	470.925	9.946[b]	0.004	0.998
Number of fields	193.943	470.921	9.943[b]	0.452	0.174
Total harvested area	**193.945**	**470.923**	**9.945[b]**	**0.003**	**0,009**
Management of livestock waste (manure)	193.943	470.921	9.943[b]	0	0.511
Purpose of agricultural by-products	189.944	460.901	9.944[b]	0.002	0.651
Production target	189.976	460.933	9.976[b]	0.033	0.221
Yield increase	**193.942**	**470.921**	**9.942[b]**	**29.781**	**<0.001**
Land status	212.21	465.103	44.210[b]	34.268	**0.001**
Operating system	193.951	470.93	9.951[b]	0.009	**0.005**
Breeding method	189.943	460.9	9.943[b]	0.001	0.421

4.5 Ecological factors determining integrated crop-livestock system in Walungu: In relation to the ecological factors determining the adoption of the integrated crop-livestock system, results from the below table 6 show that the level of soil fertility, the conservation and improvement of the soil and the origin of fertilizers had a very strong influence on the adoption of the system ($p<0.05$). The reduction in the use of chemical fuels ($p<0.05$) also significantly influences the adoption of the system. Table 6 shows the ecological determinants of integrated systems in Walungu territory.

Table 6: Ecological determinants of integration system

Variables	Model fit criteria				
	AIC of reduced model	**BIC of reduced model**	**-2 log- likelihood of the reduced model**	**Chi-square**	**P-value**
Operating system	250.308	436.968	126.308[b]	10.203	0.006
Breeding method	245.551	426.189	125.551[b]	9.445	0.049
Soil fertility level	**274.71**	**449.327**	**158.71**	**42.604**	**<0.001**
Use of fertilizers	240.106	426.766	116.106[b]	0	0.231
Type of fertilizers	**245.887**	**432.546**	**121.887[b]**	**5.781**	**0.050**
Origin of fertilizers	**253.73**	**440.39**	**129.730[b]**	**13.624**	**0.001**
Soil conservation	**244.106**	**436.786**	**116.106[a]**	**0**	**<0.001**
Yield increase	240.128	426.787	116.128[b]	0.022	0.989
Minimization of the use of chemical fuels	**248.845**	**435.504**	**124.845[b]**	**8.739**	**0.013**

5 DISCUSSION

5.1 Socio-economic determinants of adoption integrated crop-livestock system:

The results show that among the socio-economic factors, the age of farmers, seniority in the activity, level of study, household size, membership of a development association, number of fields in possession, quantity and the type of labour used, the land status, the access to training facilities and the cost of this labour affect significantly the adoption of integration system in Walungu. Indeed, most literature on agriculture technology adoption considers that the decision to adopt technologies is affected by the characteristics of the farm household head and the household at large (Kassie *et al.,* 2012; Nyanga 2012). For instance, households that are large in size are more likely to adopt innovative technologies because integrated crops-livestock system is documented to be labour intensive (Marenya et Barett, 2007; Kassie *et al.,* 2008). As the household size continues to increase, the likelihood of adoption is expected to be high. Household heads are the final decision makers who may decide on adoption of new technologies at a farm. They also noted that quality of human capital could also make a huge difference in adopting CF practices in addition to the amount of labour available in the household. The age of the household head is likely to influence adoption of the system. Indeed, older farmers may not be enthusiastic to adopt new farming technologies as compared to younger farmers who are expected to be more willing to try new technologies. Additionally, as farmers grow older, there is an increase in risk aversion and a decreased interest in long-term investment in the farm (Mauceri *et al.,* 2005; Udibal *et al.,* 2017). Seniority is also an important factor that affects the adoption of the technology because the longer someone is in the system, the more he/she masters it, the more he/she understands its advantages, disadvantages and risks to better prevent them. On the other hand, the surface area used, the size of the hired labour, the number of working people in the household, religion, sex and marital status significantly influenced the adoption of the crops-livestock integrated system in the territory of Walungu. The obtained results regarding the influence of the farm size on the adoption are dissimilar to the findings by Udibal *et al.,* (2017) who reported that the farm size has a positive relation with the adoption of the integration; this means technology should target farmers with large farms since they have the potential of adopting the technology. According to them, farmers with large farm size are likely to adopt a new technology as they can afford to devote part of their land to try new technology which when successful would cause them to adopt the technology fully, unlike those with less farm size. It is therefore, argued that farmers with large farms are wealthier than small-scale farmers, and can afford inputs that go with the technology adoption.These results obtained in this study seem similar to those reported by Dedehouanou *et al.,* (2014); Vall (2009) and Bakary *et al.,* (2014), Mounirou (2015). According to the latter, adoption and dissemination of new agricultural technical innovations are simultaneously inhibited by socio-demographic, economic and environmental factors. Indeed, Dedehouanou *et al.,* (2014) report that the adoption of a new technology is generally influenced by the level of training and literacy of the adopters, the membership of a peasant organization and available monetary value agricultural and household equipment. Kassie *et al.,* (2012) also found that household's participation in at least one rural institution or group and extension support from skilled civil servants is significant in adoption of CF practices because of increased chance of interaction and access to quality knowledge among farmers. According to these authors, the more the producer's level of training increases, the more the farmer understands the importance of innovation and the more he uses it to improve his performance. Training allows producers to be better informed and to easily understand the technological packages of extension agents, and thus, the producer better perceives the advantages linked to the implementation of the new technology (Vall, 2009). On the other hand, Bakary *et al.,* (2014), prove that producers who are able to read and write in local languages have facilities to exchange with other actors in the agricultural sector and thus gain experience in order to achieve production targets. According to them, literacy is a factor that favours the orientation of the producer towards the adoption of the new system. The large majority of those surveyed (88.70%) observed an increase in their family income thanks to agriculture-livestock integration. These results are not far from those reported by Sempore *et al.,* (2012). These authors believe that the improvement in the income of agro- breeders is observed following the diversification of sources by the introduction of sheep and cattle fattening in the holdings. This is therefore reflected in the reduction of crop production costs, the increase in productivity and, in turn, and the increase in the financial margin resulting from the sale of these products. The results obtained by Silva and Broekel (2016) corroborate the ones reported in this study. They found that economic barriers, poor educational competency, inadequate resources and incompatibility of new technologies with prevailing conditions are the four main constraints for the adoption of new technologies by farmers.

5.2 Agronomic determinants of adoption integrated crop-livestock system: The results have shown that the increase in crop yield as well as the livestock numbers is the most decisive agronomic factors pushing agro- breeders to integrate livestock farming into their farms in the study area. These results corroborate those obtained by Blanchard *et al.,* (2011); according to whom, integrating crop-livestock improves agronomic performance regardless of the type of farm. According to these authors, the increase in production by the addition of organic manure impresses agro- breeders in the adoption of agriculture-livestock integration system. The use of organic manure had an effect on soil fertility because it reduces expenditure for the purchase of fertilizers although the quantities provided per farm are generally low (Lhoste *et al.,* 2013; Blanchard, 2010). In line with agronomic facilities required for the integration, Udibal *et al.,* (2017) reported that the ownership of tractor shows a positive influence on the adoption of new agricultural technologies. They further showed that farmer's access to inputs such as fertilizers through Credit influence on farmer's adoption of new technologies. In Walungu territory, including Lurhala, Kamisimbi and Ikoma villages very few farmers have access to agricultural extension services. This observation is different from what was reported by Acheampong *et al.,* (2021) in Ghana where access to agricultural extension services (0.71) has strong correlation with both adoption (0.52) and intensity of adoption of agricultural practices (0.44). Agricultural extension agents in Ghana educate farmers on best farming practices such as how to use land, modern inputs, sustain soil fertility, control pests and diseases, and increase crops yields. However, the extension agents are not able to reach all farming communities due to limited resources and poor road infrastructure in remote areas (Acheampong *et al.,* 2018). The findings of this study revealed that the land status affected significantly the adoption. Similar results have been reported by Besley (1995) as well as Bambio and Bouavad-Agha (2018). According to Besley (1995), land tenure security has been considered as the first attribute that drives modern technology adoption. For Bambio and Bouavad Agha (2018), it is defined as the right to use, control, and transfer land and in adoption studies, the degree of land rights matters for investments and can heterogeneously varies across other attributes such as gender and immigration status amongst others.

5.3 Ecological determinants of adoption integrated crop-livestock systems: The results obtained show that the level of soil fertility, the conservation and improvement of the soil as well as the origin of the fertilizers influenced significantly the adoption of the integration system. In fact, the reduction in the use of chemical fuels, the farming system as well as the farming method influence the adoption of integration system because these factors improve the ecological conditions of the soil as reported by discovered Kanté (2001). In line with this, Hendrickson *et al.,* (2008) and Ryschawy *et al.,* (2017) showed that integrated crop-livestock systems promote ecological interactions over space and time between system components (e.g., crops, grasslands, and animals) and allow farmers to limit the use of inputs through development of 1) organic fertilization from livestock waste and 2) diversified crop-grassland rotations to feed animals. When well suited to local conditions, such integration improves nutrient cycling by re-coupling nitrogen and carbon cycles (Martin *et al.,* 2016). On the other hand, Agbo *et al.,* (2012) demonstrate that application of organic manure is increasingly recommended for sustainable agriculture (intensification of agriculture) insofar as animal manure reinforces fertility through the contribution of microorganisms which create a more suitable environment for the harmonious development of crops by maintaining soil moisture in the current context of climate change. According to Kanté (2001), the application of organic manure makes it possible to improve the physico-chemical and biological conditions of the soil and thereby increase crop yield. Organic manure can also restore marginal land and return nutrients lost through erosion to the soil under conditions of land degradation and loss of nutrients. On their side Gupta *et al.,* (2012) showed that, the crop-livestock integration system is important, considering that this system can reduce production costs, especially in providing forage and the use of manure as organic fertilizer to increase soil fertility, which in turn has a positive impact on increasing crop yields. According to them, in detail, the benefits of crop livestock integration system include: (1) reducing erosion, (2) increasing crop yields, soil biological activity and nutrient recycling, (3) intensifying land use, (4) increasing profits and helping reduce poverty.

6 CONCLUSION

This study concluded that an integrated crop-livestock system needs to be developed and popularized in different agro-ecological regions in South Kivu province in particular and East of the Democratic Republic of Congo in general. Additionally, the merging of cutting-edge management techniques such as indoor vertical farming, precision agriculture technology, digital technology and agriculture drones can pave the way for an exciting and sustainable future for both producers and consumers. Therefore, in order to meet the challenge of ensuring food security for a growing human population, previous agricultural systems must be improve on. At the same time maintain or improve the environmental quality associated with agricultural production and adjust farming systems to the risks and uncertainties posed by climate change and fluctuations in commodity prices.

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DISCLOSURES

The authors certify that there is no conflict of interest regarding the materials discussed in this manuscript.

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