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Socio-economic drivers of improved sweet potato varieties adoption among smallholder farmers in South-Kivu Province, DR Congo

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ABSTRACT

Promotion of improved crop varieties is an effective means of increasing farm productivity and alleviating poverty in rural areas. A successful dissemination of such varieties requires a deep understanding of target farmers' attitudes, preferences and socio-economic status. This study aimed at assessing factors linked to smallholder farmers' adoption decision for improved sweet potato varieties (ISPVs) in South-Kivu. A household survey was conducted on 360 smallholder farmers from four South-Kivu territories, in eastern Democratic Republic of Congo (DRC), including Idjwi, Kabare, Kalehe and Walungu, and data were analyzed using a logit regression model. The adoption decision was negatively affected by farmers' age and the field-to-house distance. In contrast, the ISPVs adoption was favored by farmers' education level, reduced farm size, off-farm incomes, high monthly income and use of hired farm labor. Besides, farmers' cooperative membership, access to credit and planting materials, and contacts with extension services were instrumental in adopting improved sweet potato varieties in South-Kivu. This study highlighted the need to strengthen extension services, seed delivery systems, and amending the credit systems for increased impact on improved varieties adoption among South-Kivu sweet potato farmers.

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Introduction

Sweet potato (*Ipomea batatas* L.) is an important food crop in sub-Saharan Africa where it is the second most widely grown root and tuber crop [10]. Both its roots and leaves are consumed as source of energy, essential minerals and vitamin A [22]. Sweet potato allows multiple harvests and thus, ensures food security and income to rural households in lean seasons [18,22]. Besides, it is resilient to drought and less demanding in soil fertility [28]. Its yields in African smallholder farmers' conditions are between 5 and 25 t ha^{-1} and could reach 50-60 t ha^{-1} in South Africa [22]. All these facts show the potential of sweet potato in maintaining food security and alleviating poverty in rural areas of Africa.

The Democratic Republic of Congo (DRC) is a major producer and consumer of sweet potato in Africa [10,22]. Its 2018 overall production was 384,350 tons from 76,809 ha [10]. At country level, sweet potato is the second most important root and tuber crop after cassava and used for human consumption, animal feed and processing. Over 40% of the national sweet potato production originates from the North- and South-Kivu provinces [37]. However, the full potential of this crop is yet to be exploited as the Congolese yields are low (5 t ha^{-1}) compared to the African potential [10]. Besides, there are downward production and cultivated area trends, 19.7 and 19.6%, respectively, from 2015 to 2018 [10]. Shukuru et al. [37] hypothesized that the low production and yields are linked to use of old landraces with low adaptation to climate change, emerging pests and diseases and not meeting expectations of an increasingly urbanized population of eastern DRC. Thus, there is an urgent need to increase sweet potato yields and quality through the use of improved cultural practices and varieties.

The African Union's Agenda 2063 calls for a five-fold increase in agricultural productivity per capita and an increase in food crop production of at least 10% per year by 2030 [7]. To achieve these goals, the development and adoption of more productive crop varieties and the use of good agricultural practices are needed. Efforts are being made by local and international organizations to introduce high yielding sweet potato varieties with resistance to pests and diseases and high nutritional value (mainly high beta-carotene content) in eastern Africa, including eastern DRC [22]. Mondo et al. [27] showed that effective variety dissemination strategy in South-Kivu requires a deep understanding of target farmers' socio-economic characteristics and crop varietal preferences. Most common socio-economic factors influencing sweet potato varieties uptake among the African smallholder farmers include the education status, gender, off-farm incomes, access to credit and planting materials, farm size, farmer association membership, contact with extension agents, farming experience, field-to-market distance, market demand, cropping practices, etc. [1,29,32]. However, there are huge disparities for leading factors among countries and among regions within a country. There is no report on the sweet potato farmers' attitudes toward introduced sweet potato varieties in South-Kivu.

Furthermore, the role of access to extension services in the adoption of agricultural innovations remains poorly documented in the target area. Yet, there is a link between farmers' perceptions and adoption of agricultural innovations. This study, therefore, attempts to fill this gap by providing supporting data to organizations involved in agricultural extension services. Knowledge of farmers' attitudes and associated socio-economic characteristics would be crucial for guiding efforts by sweet potato farmer support structures in the region. Therefore, this study aimed at assessing leading factors driving improved sweet potato varieties adoption by South-Kivu farmers, to guide local and regional farmer support structures priorities. Generated information will enhance the sweet potato value chain through increased rate of innovation adoption.

Materials and methods

Study area

This study was conducted from January to March 2020 in South-Kivu Province, eastern DRC. It covered four territories including Idjwi, Kabare, Kalehe and Walungu (Fig. 1). These regions are characterized by grassy savannah with a large number of streams and a mountainous tropical climate, moderate temperature (~19 °C); a bimodal rainfall regime (1300-1800 mm); a depleted and eroded clay soil [27,34]. Except Walungu, the three other territories are bordered by Lake Kivu. The Kahuzi National Park extends to Kabare, Walungu and Kalehe. Thus, the lake and the forest are regulators of rainfall and temperatures despite climate variability which has been reported in the study area [30]. Populations depend mainly on agriculture, livestock farming and fishing for income. Major subsistence crops include cassava, maize, sweet potato, sorghum, banana, and beans while coffee, tea and sugar cane are the major cash crops. These regions are direct food suppliers to the Bukavu City which constitutes their primary market [27]. The four territories covered by this study are densely populated (>300 persons km^2) and inhabited by ~1.4 million people, from two main ethnic groups: Bashi and Bahavu. For these two ethnic groups, sweet potato is not only a food and cash crop but also an integral part of social and cultural belief systems. For instance, sweet potato is part of all major festive ceremonies such as wedding in which it is consumed with fermented cow milk.

Sampling and data collection

This study was conducted in four territories of the South-Kivu Province, eastern DRC. These included Kalehe, Idjwi, Kabare, and Walungu. The choice of these areas was dictated by the nutritional, economic and socio-cultural importance of sweet potato for these areas' populations. It is noteworthy that these areas possess agro-ecological characteristics conducive to sweet potato cultivation and host major local, national (INERA-Mulungu, CRSN-Lwiro) and international agricul-

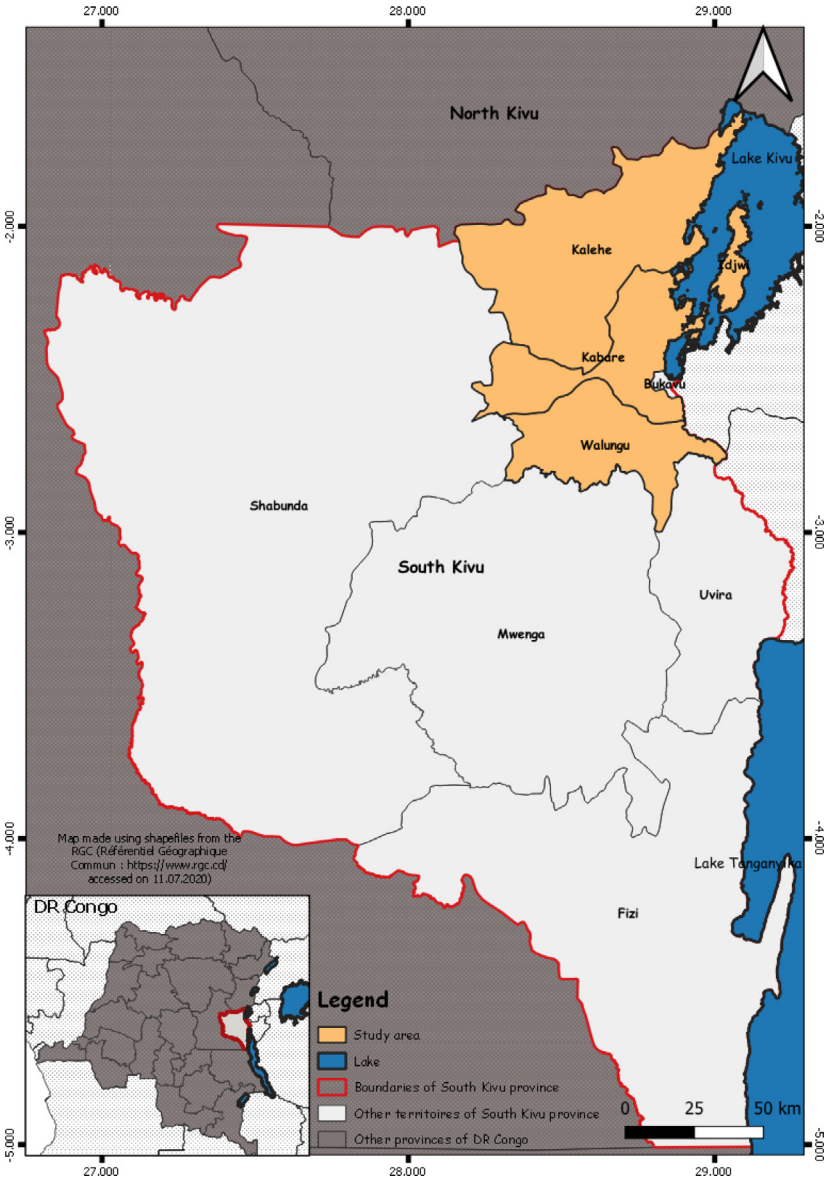

Fig. 1. Map of the study area, South Kivu Province, DR Congo.

tural research centers (IITA, CIAT-HarvestPlus) which promote improved crop varieties, including sweet potato. Thus, farmers of these regions are the major beneficiaries of these organizations' activities and support. Besides, their proximity to Bukavu City, the largest city in the South-Kivu Province, provides to them a unique market opportunity for their agricultural productions.

Data collection was preceded by pre-surveys in each of the territories to get information on the number of sweet potato farmers and an exhaustive list of farmers benefiting from improved sweet potato dissemination programs. With the help of key informants (resource persons such as leaders of farmers' associations, local authorities, extension agents, religious leaders and representatives of farmers' support structures), we identified 2,234 farmers growing and marketing sweet potatoes in the study area. In each territory, three villages were randomly sampled as sweet potato is equally grown in all villages of the study area. In each village, 30 smallholder farmers were randomly selected. A total of 90 farmers were thus selected in each territory, making a total sample size of 360 respondents for the entire study. The equal sample size across communities is due to a relatively equal importance of the crop in the study area.

Data collection through individual interviews was carried out using semi-structured survey questionnaires and concerned the following major aspects: (1) the socio-demographic characteristics of the farmers' household; (2) ownership of agricultural assets; (3) location, land tenure, household ownership; (4) farm size; cropping system; management and decision

Table 1
Variables used in principal component analysis (PCA).

Variables	Definition/measurement
Sex	Dummy variable : 1 if the farmer is male; 0 otherwise
Age	Age of the farmer in years
Experience in sweet potato farming	Number of years in sweet potato cultivation by the household head
Off-farm income	Dummy variable : 1 if farmer gains some off-farm income; 0 otherwise
Time spent at school	Number of years spent at formal education
Household size	Number of persons in the household
Landholding size	Total land owned by the farmer in are
Monthly income	Monthly household income in US$
Land ownership	Dummy variable : 1 if the farmer owns the cultivated land; 0 otherwise
Cooperative membership	Dummy variable : 1 if the farmer is member of a certain group; 0 otherwise
Cropping system	Dummy variable : 1 if sweet potato is grown in pure cropping; 0 otherwise
Use of hired labor	Dummy variable : 1 if use of extra household persons for farming; 0 otherwise
Access to credit	Dummy variable : 1 if farmer has access to credit; 0 otherwise
Access to planting material	Dummy variable : 1 if farmer has access to vines of ISPVs; 0 otherwise
Field to market distance	Dummy variable : 1 if the field is far from local market; 0 otherwise
Field to house distance	Dummy variable : 1 if the field is far from farmer residence; 0 otherwise
Contact with extension service	Dummy variable : 1 if farm records at least one visit per year from extension services; 0 otherwise
Disease constraint status*	Disease score ranging from 1 to 3
Pest constraint status*	Pest score ranging from 1 to 3
Soil fertility status**	Soil fertility score ranging from 1 to 3

*and ** are based on farmers appreciation.
*Score ranging from 1 to 3: 1 = Weak; 2 = Medium; 3 = High.
**Score ranging from 1 to 3: 1 = Low; 2 = Medium; 3 = High.

making; access to markets and membership in farmers' organizations; type of varieties cultivated; sources of varieties as well as contacts with extension services (Table 1).

Methods of data analysis

Principal component analysis (PCA)

PCA was run to characterize the relationships between the farmers' socio-economic variables and their attitudes vis-à-vis introduced sweet potato varieties. Data-reduction method by Husson et al. [17] was applied on the selected set of variables to derive a smaller set of non-correlated principal components. In fact, Alvarez et al. [5] showed that reducing the number of key variables does not affect the variability of the dataset. To retain as much variability as possible in the data set, we interpreted the first four principal components, which accounted for nearly 52.74% of the total inertia of the dataset. The number of principal components (PC) retained was decided on the basis of Kaiser's criterion: all PCs exceeding an eigenvalue of 1 were retained [21]. The appropriateness of PCA analysis was based on Kaiser–Meyer–Olkin measure of sampling adequacy and Bartlett's test of sphericity: a value equal to or superior to 0.60 and p-value < 0.05 indicated the PCA adequacy, respectively [38,41].

Logistic regression model

Farmers' decision to adopt a new variety was captured as a binary choice: 1 if the farmer adopted and 0 otherwise. Empirical evidences support that a farmer adopts new technology if the utility gained from adopting it is greater than the utility from not adopting ($U_i^* = U_{iA} - U_{iN} > 0$) [11]. However, since the utility is unobservable, it was expressed as a function of observable variables in the following equation:

$$U_i^* = X_i'\gamma + \varepsilon_i$$
$$\text{With } U_i = \begin{cases} 1 \; if \;\; U_i^* > 0 \\ 0 \; otherwise \end{cases}$$

where, U_i^* is the latent variable, representing the farmer adoption likelihood: 1 if the farmer adopts and 0 otherwise. The term X_i' represented explanatory variables associated to adoption decision, γ is a vector of estimated parameters, and ε_i is the error term (assuming it was independent and normally distributed as $\varepsilon_i \sim \text{N}(0,\ 1)$).

From the econometric literature, identifying factors affecting adoption decision is modelled through a binary model such as logit or probit, with little consideration on the choice between the two models [15,23,42]. To identify factors affecting adoption decisions of ISPVs in South-Kivu, we fitted a logit model [15]. The fitted logistic distribution function was specified as by Greene [13]:

$$P_i = \frac{1}{1 + \exp\left(-U_i^*\right)}$$

where Pi is the i^{th} farmer's uptake probability, it ranges from 0 to 1. The Chi-square independence test or the Fisher exact test (in case of the presence of an absolute frequency lower or equal to 5 in the frequency distribution table) were used to test the independence between adoption and the other categorical variables.

Wilcoxon test was carried out to compare the medians of the adopters and non-adopters for the quantitative variables. This made it possible to determine, in particular, the variables to be included in the adoption full model. The variables that showed a certain relationship with the improved varieties adoption (p-value lower than 0.1) were used in the full logistic regression model and the stepwise model selection was carried out in order to retain in the final model only the explanatory variables with greater significance. Stepwise logistic regression is widely used for model-building. It involves selection and stopping criteria, and in which variables are selected either for inclusion or exclusion from the model in a sequential fashion [16,40]. All the statistical analyses were performed under R version 3.5.1 [35].

Results

Socio-economic characteristics of South-Kivu sweet potato farmers

Table 2 presents the socio-economic characteristics of adopters and non-adopters of improved sweet potato varieties in South-Kivu. Adopters and non-adopters are distinguished by their age, main income-generating activity, income level, access to land, membership of associations, access to credit, labor used, contact with extension services and access to disseminated improved varieties. For both adopters and non-adopters, sweet potato growing remains an activity mainly practiced by married women. They are mothers of families in households with an average family size of seven members and have more than 25 years of experience in growing sweet potatoes. Potato farmers majorly practice the intercropping system on plots of nearly 45 ares with medium to high soil fertility levels, but facing many more constraints related to diseases and pests. Broadly speaking, most of these women farmers feel that their fields are far away from local markets, which limits their access to these markets to sell potato tubers, the main products targeted on their farms. Unlike non-adopters, those who adopt improved sweet potato varieties are relatively younger with higher education level, cultivating relatively smaller plots of land and engaging most in off-farm activities to secure high household income. Farming is a secondary activity for them and a means of diversifying their income. This diversification gives them the advantage of obtaining relatively higher monthly incomes than non-adopters, and increases the possibility of hiring some extra workforce to take care of their agricultural activities while engaged in off-farm activities. Adopters also represent the category with more access to agricultural credit and are the most open to membership in farmers' organizations and, therefore, more likely to be exposed to agricultural innovations. Adopters also have more access to agricultural innovations through contact with farmer-support organizations and extension agents. Despite all the opportunities that adopters may obtain from new varieties, they still face a major constraint: access to land. In most cases, they do not own the piece of land they are farming; they either rent the land or obtain it through sharecropping.

South-Kivu farmers' attitudes vis-à-vis ISPVs

The results in Table 3 show that the dataset was appropriate for PCA (KMO = 0.721 and significance of the Bartlett's sphericity test: p-value$<$0.001). The first principal component (PC1) retained more than 21% of the total inertia of the dataset. It shows that the older the farmer, the more experienced they become in growing sweet potato, and which they cultivate on larger areas of land that they own. On the other hand, older farmers are less educated, have less off-farm incomes, tend not to join farmers' associations and have less exposure to agricultural extension services, and have limited access to improved varieties. The second principal component (PC2) captures almost 16% of the total variance, and shows that access to agricultural credit is directly proportional to household income. The higher the income, the higher the access to agricultural credit and the more farmers use paid labor for farming. Farmers in this situation appear to be more open to membership in smallholder farmer associations and have more access to planting materials of improved varieties as they access the extension services. The third principal component (PC3) captures 8.27% of the total inertia and shows that the more fertile the fields, the more farmers tend to grow sweet potato in pure cropping system and the less constrained they are by plant diseases. Finally, the fourth principal component (PC4) captures only about 6.95% of the total variance and provides little information on the behavior of sweet potato farmers. This component is strongly linked to constraints stemming from sweet potato pests. This axis reveals that pest constraints are more pronounced on larger plots.

Fig. 2 shows that it is easier to distinguish between adopters and non-adopters on the first two principal components (PC1 and PC2). They tend to be confounded on the last two principal components (PC3 and PC4). Non-adopters take a wide range of values on the four principal components. They take negative values as well as positive values on all axes. On contrary, adopters take negative values on the first principal component (PC1) and positive values on the second principal component (PC2). Based on these results (Table 3 and Fig. 2), adopters are mostly those who have spent much time at school and have the high non-farm income, which gives them the advantage of having the best monthly income and easy access to credits. They mostly make use of hired labor, participate most in smallholder farmers' cooperatives, and have regular contacts with extension services.

Table 2
Socio-economic characteristics of sweet potato farmers in South-Kivu Province.

Variables/Modalities	Adopters ($n_1 = 111$)	Non-adopters ($n_2 = 249$)	Total ($N = 360$)	p-value[a]
Gender				
Female	62.7	59.4	61.0	0.846
Male	37.3	40.6	39.0	
Age (years)	42.8±7.3	48.4±18.2	45.7±14.3	0.030*
Experience (years)	23.9±8.5	28.8±19.2	26.5±15.2	0.446
Main activity				
Crop and livestock production	17.0	42.8	30.3	0.006**
Off-farm activities	83.0	57.2	69.7	
Marital status				
Single	0.0	7.8	4.1	0.011*
Divorced	1.7	4.7	3.3	
Married	88.1	65.6	76.4	
Widow(er)	10.2	21.9	16.3	
Household size	6.8±1.8	7.8±4.2	7.3±3.3	0.279
Time spent to school (years)	6.8±4.8	5.8±5.1	6.3±5.0	0.072.
Landholding size (are)	39.7±30.7	51.2±41.0	45.7±36.8	0.107
Cultivated area (are)	38.6±30.5	50.6±41.0	44.8±36.7	0.092.
Household income/month (US$)	202.1±81.1	117.2±86.0	157.9±93.6	0.000***
Land tenure status				
Ownership	30.5	71.8	52.0	0.000***
Rental	69.5	28.2	48.0	
Cooperative membership				
No	3.4	67.2	36.6	0.000***
Yes	96.6	32.8	63.4	
Cropping system				
Intercropping	64.4	54.7	59.3	0.361
Pure cropping	35.6	45.3	40.7	
Target plant organ				
Leaves	1.7	0.0	0.8	0.824
Tubers	84.7	85.9	85.4	
Tubers and leaves	13.6	14.1	13.8	
Use of hired labor				
No	1.7	32.8	17.9	0.000***
Yes	98.3	67.2	82.1	
Access to credit				
No	6.8	62.5	35.8	0.000***
Yes	93.2	37.5	64.2	
Access to cuttings of improved varieties				
No	1.7	44.4	23.8	0.000***
Yes	98.3	55.6	76.2	
Field to house distance				
Far	80.4	54.7	66.7	0.006**
Near	19.6	45.3	33.3	
Field to market distance				
Far	86.4	78.1	82.1	0.334
Near	13.6	21.9	17.9	
Contact with extension service				
No	5.1	79.7	43.9	0.000***
Yes	94.9	20.3	56.1	
Disease constraint status				
Low	15.3	14.1	14.6	0.001**
Medium	69.4	40.6	54.5	
High	15.3	45.3	30.9	
Pest constraint status				
Low	3.4	7.8	5.7	0.126
Medium	54.2	34.4	43.9	
High	42.4	57.8	50.4	
Soil fertility status				
Low	10.2	14.1	12.2	0.244
Medium	52.5	37.5	44.7	
High	37.3	48.4	43.1	

Quantitative variables : Mean ± standard deviation

[a] For qualitative variables : p-value obtained with χ^2 test or Fisher Exact Test; For quantitative variables : p-value obtained with Wilcoxon test p-value*, **, ***: significant at alpha = 0.1; 0.05; 0.01 and 0.001, respectively.

Table 3
Summary of the PCA and loadings of variables on the four principal components.

Variables	KMO[a] sampling precision	PC1	PC2	PC3	PC4
Eigen value		4.320	3.185	1.655	1.389
Variability (%)		21.598	15.926	8.274	6.945
Cumulative variability (%)		21.598	37.524	45.798	52.743
Sex	0.481	-0.041	-0.083	-0.437	0.138
Age	0.724	**0.711**	0.470	-0.066	-0.125
Experience in farming	0.733	**0.697**	0.502	0.001	-0.142
Off-farm income	0.844	**-0.600**	-0.133	0.084	0.209
Time spent to school	0.742	**-0.517**	-0.423	0.009	0.331
Household size	0.817	**0.591**	0.413	-0.122	-0.040
Landholding size	0.722	**0.534**	0.387	0.082	0.437
Income level	0.711	-0.265	**0.628**	-0.030	0.221
Land tenure status	0.823	**0.645**	-0.019	-0.271	0.326
Cooperative membership	0.816	**-0.667**	0.412	0.089	-0.033
Cropping system	0.338	0.001	-0.067	**-0.593**	-0.123
Use of hired labor	0.728	-0.194	**0.623**	0.034	0.113
Access to credit	0.748	-0.487	**0.590**	0.125	0.176
Access to seeds of improved varieties	0.701	-0.415	0.411	-0.267	0.043
Field to market distance	0.639	-0.188	-0.338	-0.062	0.435
Field to house distance	0.735	0.158	-0.475	-0.227	0.062
Contact with extension service	0.764	**-0.603**	0.568	0.039	-0.095
Disease constraint score	0.566	0.414	-0.183	**0.686**	0.081
Pest constraint score	0.535	0.299	0.094	0.114	**0.735**
Soil fertility score	0.401	-0.041	0.092	**-0.606**	0.154
	KMO[a] = 0.721 *Bartlett Sphericity Test* Observed χ^2 = 883.233 Critical χ^2 = 223.160 DDL = 190 *p*-value = 0.000***				

The values in bold character correspond to each variable of the principal component (PC) for which the cosine square is greater than 0.25 and the contribution greater than 1/n (with n: number of active variables).
[a] KMO = Kaiser-Meyer-Olkin***: significant at alpha = 0.001

Socio-economic factors driving ISPV adoption in South-Kivu

The results of the estimated logit model are presented in Table 4, which represents the propensity to adopt ISPVs by smallholder farmer households. Almost all the variables retained in the final model had significant effects on the probability of adopting ISPVs. Our results showed that the propensity to adopt ISPVs by farmer households increase with off-farm income, high monthly income, group membership, hired labor, easy access to ISPV vines and regular contacts with extension agents. The obtained results suggest that when farmers are engaged in off-farm activities, the resulting income is more likely to foster adoption of improved sweet potato varieties. As for group membership, belonging to a certain organization increases the likelihood of adopting new sweet potato varieties. The positive estimated sign on monthly income suggests as well that the higher the income, the more the likelihood of adopting improved sweet potato varieties. The same applies on the use of hired labor whose positive and significant estimates indicate that the use of extra workforce within the farm increases the propensity to go for improved sweet potato varieties. Easy access to ISPV vines and regular contacts with extension services also increase the odds of adopting sweet potato varieties. However, the farther the field is from their residence, the less likely farmers are to adopt ISPVs.

Post-estimation analysis showed through the pseudo R-squared (0.76) that the model is useful in predicting adoption of improved sweet potato varieties. As for the likelihood ratio statistic, it can be seen that all the retained variables contribute significantly in predicting the adoption.

Discussion and policy implications

Young and educated farmers are more inclined to ISPVs adoption in South-Kivu

The results from this study showed that older farmers with a strong sweet potato farming experience participate less in farmer cooperatives' activities and have less contacts with extension services. Consequently, their access to agricultural innovations such as improved varieties is limited. Previous studies supported that the farmer age is an important technology adoption determinant [24,27]. From these studies, older farmers tend to be skeptical to new technology in opposition to younger ones who take risks.

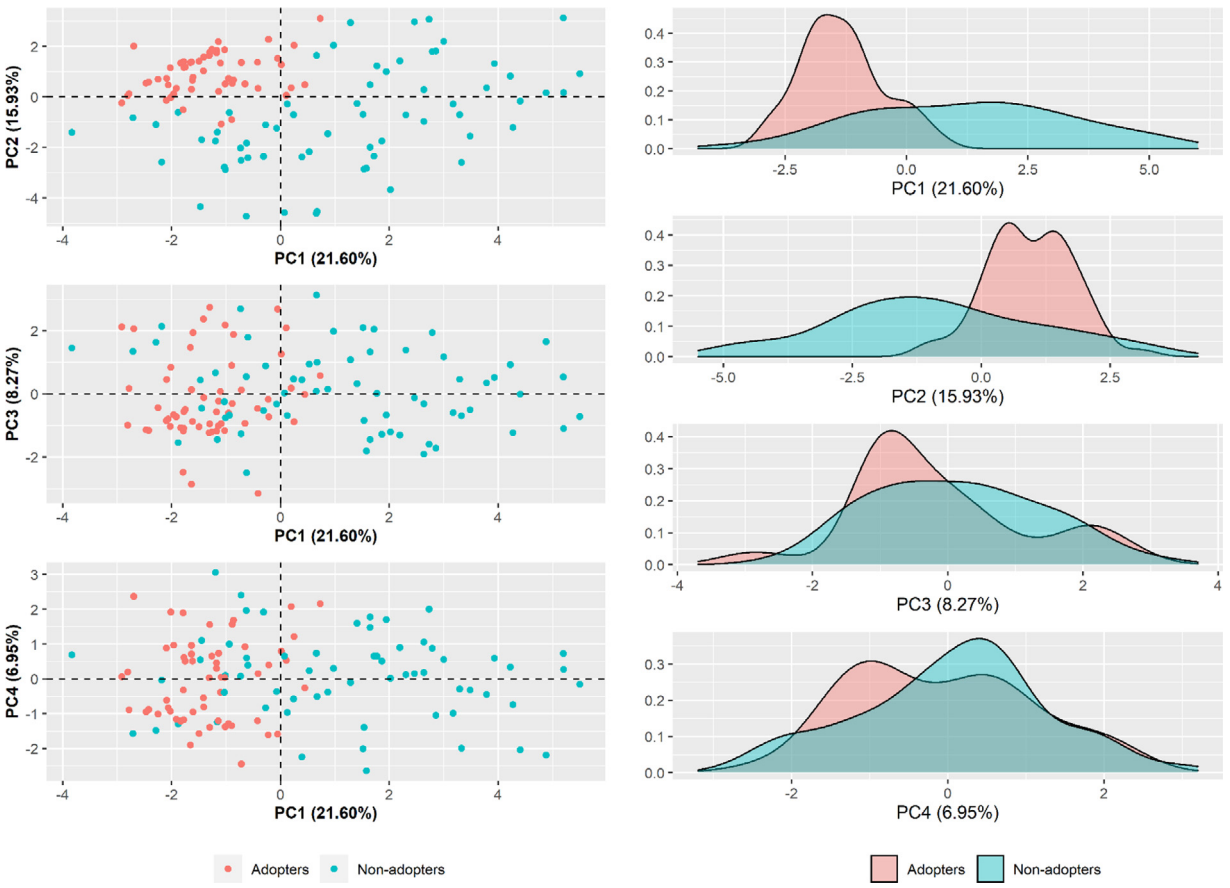

Fig. 2. Characterization of adopters and non-adopters based on the principal components results.

Besides, low adoption among older South-Kivu farmers could be associated with their predominantly low education level. Katungi and Akankwasa [20] found that educated and younger Ugandan farmers adopt most new innovations than less educated and older farmers. Barrera et al. [6] established a negative relationship between the farmer's age, risk taking and a long-term investment. Furthermore, farmers' education level increases the ability to obtain, process and use information relevant to a new profitable technology [24,26,33]. This agrees with findings from this study as a positive relationship was established between education and improved sweet potato varieties adoption. Much empirical evidence support the positive relationship between education status and agricultural innovation uptake [9,14,27,33,36].

Since sweet potato is associated with female farmers (Table 2), the attitudes of old farmers toward ISPVs as discussed in this study could stem from the relationship formerly established between gender and crop choice, between gender and resource ownership and between gender and education level in the study area [26,27]. In rural South-Kivu, women practice mostly subsistence crops in contrast to their male counterparts who are mostly interested in cash crops. Also, women have generally less land and financial resources than men, and thus, unable to access credit and agricultural innovations such as improved varieties. Besides, women are less educated than men as a result of long gender discrimination experience of past cultural beliefs. In the context of a household inability to educate all family members, boys were favored at the expense of girls who had to do household and field works. Therefore, rural South-Kivu women understanding and access to novel technologies is limited.

Membership in associations and regular contacts with extension agents increase farmers' awareness and thus favor ISPVs adoption in South-Kivu

Findings from this study showed that membership in farmers' cooperatives increases likelihood of ISPVs adoption. This could be attributed to regular contacts of cooperative members with farmer support structures and the extension services and, thus, they gain knowledge on new profitable technologies [2,43]. Also, planting materials and credit are most easily granted to groups than individuals. Studies support that membership in a social group improves the social capital and allows trust, idea and information exchange among group members [24,33,39].

Table 4
Estimation of logit model for determinants of adoption of improved sweet potato varieties in South-Kivu.

	Model coefficients					Marginal effects				
Source	β	SE	z value	Pr(>|z|)		dy/dx	SE	z value	Pr(>|z|)	
Constant	-13.179	3.953	-3.334	0.001	***					
Age	-0.064	0.041	-1.561	0.119		-0.007	0.005	-1.526	0.127	
Off-farm income	2.775	1.204	2.305	0.021	*	0.233	0.105	2.224	0.026	*
Monthly income	0.012	0.005	2.363	0.018	*	0.001	0.001	2.122	0.034	*
Cooperative membership	4.374	1.367	3.200	0.001	**	0.413	0.130	3.178	0.001	**
Use of hired labor	3.520	1.545	2.279	0.023	*	0.209	0.092	2.260	0.024	*
Access to ISPV seeds	4.756	1.571	3.027	0.002	**	0.316	0.107	2.945	0.003	**
Field to house distance	-2.279	1.082	-2.107	0.035	*	-0.209	0.096	-2.170	0.030	*
Contact with extension service	3.167	0.979	3.237	0.001	**	0.348	0.134	2.597	0.009	**
	LR χ^2 (8) = 130.010 Prob > χ^2 = 0.000*** Log likelihood = -20.153 Pseudo R^2 = 0.763 AIC = 58.305 AUC = 0.984									

*, **, ***: significant at alpha = 0.05, 0.01 and 0.001, respectively
ISPV: Improved sweet potato variety.

This study also ascertained the positive impact of regular contacts with extension officers on the ISPVs adoption in South-Kivu. Access to extension services has long been associated with high technology adoption rates [3,19,24,33,39]. It has been demonstrated that information received through the extension agents dissipate the uncertainty about improved varieties performance, and thus, helps to make a positive change in the individual's decision on adoption [2,27,39]. Some authors showed that the influence of extension agents compensates lack of formal education in technology adoption decisions [3,33]. The implication of this finding is that extension service should really be intensified to promote the adoption of improved sweet potato varieties in South-Kivu. On the other hand, farmers' associations should be encouraged and supported in rural South-Kivu for their potential in boosting adoption of introduced technologies among smallholder farmers. Incentives should also be promoted to attract more farmers to these associations.

Off-farm income increases household incomes, eligibility to credit and ISPVs adoption in South-Kivu

This study showed a relationship between off-farm income, monthly income, ease of access to credit and technology adoption. In fact, microfinance organizations tend to favor high income farmers than low-income farmers in granting agricultural credits in South-Kivu. In rural South-Kivu, very few smallholder farmers access financial credit as a result of the scarcity of microfinance institutions in rural areas and eligibility requirements which discriminate among farmers. On the other hand, Mondo et al. [27] showed that South-Kivu smallholder farmers fail to refund previous loans from microfinance organizations as most farms are run on the subsistence model. There is also absence of subsidies from government agencies for farm inputs and risk management. It is noteworthy that when these farmers access credit, they hardly allocate it to farming activities, fearing agriculture-associated risks. Therefore, access to credit is mainly observed among farmers with alternative off-farm income generating activities. This work suggests that agricultural credit systems should be amended to reach more farmers, especially those relying exclusively on agriculture for income. This requires establishing credit packages that fit resource-poor farmers [31]. Nevertheless, access to credit stimulates innovation uptake by farmers through relaxation of the liquidity constraint and the boost of household's-risk bearing ability [25]. Wossen et al. [43] argued that there is a significantly stronger impact of extension services in reducing poverty and increased technology uptake when smallholder farmers access the credit. Besides, access to credit increases the farmers' access to quality seed, which is considered as a limiting factor in improved variety farming. In response to this, most farmers' support structures in South-Kivu provide planting materials or other farm inputs in forms of rotating credits [27]. Rotating credits using improved crop seeds positively stimulates new variety uptake. It plays similar roles as the traditional credit by making factors of production ac-

cessible to farmers and consequently affecting their livelihoods [4]. This study supports, therefore, findings by Kaguongo et al. [18] who reported a link between access to planting materials and variety adoption in Kenya.

Off-farm income positively impacts improved varieties adoption. It enables farmers to overcome credit constraints experienced in rural areas where credit markets are either missing or dysfunctional [8,33]. Farmers owning off-farm incomes easily purchase productivity-enhancing inputs such as quality seed of improved variety, pesticides and fertilizers [8]. However, cases of negative relationships between off-farm income and labor-intensive technology adoption have been reported as well [12].

Extensive ISPVs adoption in South-Kivu is constrained by a faulty seed delivery system

This study showed that the distance between farmer's residence and the field is negatively associated with improved varieties adoption. A similar observation was made by Mondo et al. [27] for improved cassava variety adoption in the study area. They showed that improved crop seeds are scarce or absent in rural South-Kivu local markets, encouraging tuber and cutting thefts when fields are far from farmer's residence. Mondo et al. [27] showed also that scarcity of seeds discourages cultivation of larger plots. Smaller fields are, therefore, established in the vicinity of farmer residence for household consumption and easy access.

The above-described seed scarcity context could also explain our finding that adopters tended to have smaller and rented fields. Consequently, to make these plots profitable, these smallholder farmers opt for new technologies. Mwangi and Kariuki [33] argued that small plot size provides a technology adoption incentive especially for input-intensive innovations such as a labor-intensive or land-saving technology. However, most studies on agricultural innovation adoption report a positive relationship between farm size and the technology uptake likelihood [24,26,39]. Some authors hypothesized that large farm size provides an option of devoting part of it in testing new technologies unlike those with smaller farms who cannot bear the risk associated with trying new things [39]. Other authors showed that larger farm size often qualifies the households for credit which in turn enables them to access capital-intensive technologies such as improved variety seeds, fertilizer, pesticides and mechanization [19,26].

The policy implications of this study are therefore clear. Agricultural extension services in the country should focus on training farmers through capacity building programs on new sweet potato agronomic practices, not just for increased productivity but also high adoption rates. This would also require recurrent contacts with producers in major sweet potato growing areas. The implementation of land tenure policies in favor of women would also constitute one of the means of removing constraints to sweet potato production. As a food security crop, sweet potato is perceived as a women's crop, who, in turn, are also considered as prime responsible for households' food security. The results of the study also showed a relationship between participation in off-farm activities, access to credit and adoption of improved sweet potato varieties. These results suggest that reinvesting income from non-farm activities in agricultural innovations would reduce the risks associated with agricultural innovations as well as the amount of labor for agriculture. Thus, various actors involved in agricultural development programs are expected to promote off-farm activities in addition to purely agricultural technologies. As for microfinance institutions, the establishment of small agricultural loans' system would guarantee access to credit for smallholder farmers and would provide them enough funds to venture into off-farm activities, and increase their production. Lastly, results showed that for the South-Kivu province, the access to planting materials is limiting extensive adoption of improved varieties among sweet potato farmers who can only produce on small plots. A seed delivery system is, therefore, necessary to ensure that farmers can access at any time, desired amount of quality seeds in their vicinity.

Conclusion

This study highlights the need to strengthen and empower organizations involved in agricultural extension. It is one of the few studies that address the role played by farmers' attitudes and perceptions in the adoption of agricultural innovations in eastern DRC. This aspect has long been neglected by agricultural economic studies in the region, even though it may be one of the main reasons for the rejection of agricultural innovations. The results of this study are in line with the African Union's Agenda 2063, in particular the objectives of increasing agricultural production and productivity, as well as the preservation and sustainable use of biodiversity to address food security issues. It has been shown that sweet potatoes play an important role in maintaining food security and reducing poverty in rural Africa. There is, therefore, a need to increase yields and quality of sweet potato through the use of improved cultural practices and varieties. Indeed, the adoption of highly productive ISPVs and better agricultural practices will improve the sweet potato value chain and thus contribute to improved livelihoods and food security. A better understanding of farmers' attitudes and perceptions as well as the socio-economic factors determining the adoption of ISPVs is, therefore, considered a prerequisite for an effective dissemination strategy in South-Kivu in order to achieve the objectives of the African Union's Agenda 2063. ISPVs adoption has been found to be associated with household, socio-economic and institutional factors. A positive relationship between income, off-farm activity, access to credit, education, cooperative membership, contacts with extension agents and improved varieties adoption in rural South-Kivu was observed. In contrast, age, farm size and field to house distance discourage ISPVs adoption.

This study recommends the need to strengthen extension services and seed delivery systems and amending the credit systems for increased impact on improved varieties adoption among South-Kivu sweet potato farmers.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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