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**Article**

**Keywords:** Cattle productivity, Reproductive technologies, Artificial insemination (AI), Adoption, Socio-economic factors

**Posted Date:** April 23rd, 2026

**DOI:** https://doi.org/10.21203/rs.3.rs-8907373/v1

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**Additional Declarations:** No competing interests reported.

# Revitalizing cattle productivity in Eastern Democratic Republic of the Congo: Analyzing reproductive management, farmer perspectives, and socio-economic drivers of improved breeds adoption

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**Abstract**

Dairy cattle production remains a low-contributing subsector in eastern Democratic Republic of Congo (DRC). Since the 1990s, several interventions, including the introduction of artificial insemination (AI) as a rapid genetic improvement strategy, have been implemented to enhance productivity; however, cattle productivity in South Kivu and Tanganyika provinces remains low. This study assessed the current status of these interventions and examined farmers' potential to adopt genetic improvement innovations, contributing to Sustainable Development Goals 1 and 2 and the African Union Agenda 2063. Data were collected from 369 dairy cattle farmers in selected areas of South Kivu and Tanganyika through a cross-sectional survey, capturing information on socio-economic characteristics, awareness of genetic improvement, knowledge and utilization of artificial insemination (AI), and adoption status of related technologies. Results revealed low adoption rates, with 29% of farmers using general genetic improvement practices and 25% adopting AI, constrained mainly by limited availability of AI services, and financial barriers. While awareness of AI in South Kivu was significantly higher (73.9%) compared to Tanganyika (34.4%), adoption rates were comparable in both provinces, suggesting awareness alone does not drive adoption. Farmers in South Kivu and Tanganyika expressed largely similar perceptions of cattle breeds. Holstein-Friesian and Brown Swiss were valued for high milk production, good body conformation, and high market value, while Ankole cattle were preferred for their affordability, adaptability, disease resistance, and good temperament. However, Ankole cattle were also perceived as having low milk yield and market value, whereas exotic breeds were commonly viewed as disease-prone and demanding in terms of breeding and management. Enhanced availability and accessibility of artificial insemination services, supported by targeted financial mechanisms and farmer capacity building, are critical to increasing the adoption of modern livestock production practices. Such interventions would contribute directly to improved rural livelihoods and progress toward the Sustainable Development Goals. Policy priorities should include the establishment of functional AI centers, training and deployment of local veterinarians and technicians, and the provision of financial incentives to encourage uptake of improved breeding technologies. Integrating farmer education and awareness into agricultural policy frameworks is essential for addressing knowledge gaps that limit adoption. Moreover, expanded use of improved breeds must

be accompanied by strengthened veterinary services and effective vaccination programs to reduce health risks and ensure long-term sustainability.

**Keywords:** *Cattle productivity, Reproductive technologies, Artificial insemination (AI), Adoption, Socio-economic factors*

## 1. Introduction

Africa, which is experiencing tremendous population increase, is a major topic of discussion about the Sustainable Development Goal 2 (SDG2): Achieving zero hunger (Niang et al., 2014; Lee et al., 2016). Achieving SDG2 is undoubtedly one of the most important and challenging tasks facing humanity (Giller, 2020). SDG2 goes beyond ending hunger. It also aims to promote sustainable agriculture to ensure food security and better nutrition. Achieving SDG2 requires sustainable agriculture and livestock. SGD2 and SDG1, which aims to eradicate poverty in all its manifestations, are closely linked, as nearly 70% of households depend on agriculture and livestock for their livelihoods (Lee et al., 2016; Giller, 2020).

More than 450 million smallholder farmers in sub-Saharan Africa (SSA) depend on agricultural and livestock production for their livelihoods (Kuivanen et al., 2016; Davis et al., 2017; Mutenje et al., 2020). Smallholder farmers predominate throughout SSA playing essential role for expanding Africa's food supply and significantly contributing to the rural economy (Dixon et al., 2001; Wiggins, 2009). At least half of the livestock produced in the region is produced by these farmers (Mutenje et al., 2020). However, despite a global rise in livestock production, food security remains a major issue in many countries in SSA (Kiki et al., 2018). According to Otte et al. (2012), 85% of livestock farmers on the continent remain impoverished and live in acute poverty. Most agree that livestock production has remained extremely low, especially in smallholder farming systems with low input costs (Washaya et al., 2019). The rapid population growth, combined with low livestock productivity, has led to rising challenges to satisfy the growing demand (Rakotoarisoa et al., 2012). This highlights the need for more productive livestock farming systems to meet the rising demand and reduce food insecurity and poverty (Oosting et al., 2014).

In the Democratic Republic of Congo (DRC), particularly in the South Kivu and Tanganyika provinces, agriculture and livestock are central to the rural economy, supporting livelihoods, ensuring food security, and strengthening local economies (Davis et al., 2010; Herrero et al., 2013). Despite this importance, the livestock sector faces significant constraints, especially in terms of animal productivity, which undermines the effectiveness and sustainability of local livestock enterprises. For instance, the national cattle herd of approximately 40 million head represents only about 2.3% of the country's estimated herd potential, highlighting the underutilization of livestock resources (SNSA, 2014). In South Kivu, productivity is limited by poor feeding practices, low genetic potential, and minimal investment, contributing to persistently low outputs and food insecurity. Consequently, annual per capita consumption of livestock products remains among the lowest globally, with approximately 5.2 kg of beef and 0.6 kg of milk consumed per person per year (Speedy, 2003). Local production data further illustrate these challenges: adult cattle in South Kivu weigh between 261.5 and 362.3 kg, daily milk production ranges from 1.7 to 4.6 liters, and annual cattle sales per farm average 1.0 to 2.4 head (Mugumaarhahama et al., 2021). A decade of instability has exacerbated these issues, leading to declines in agricultural and livestock productivity and perpetuating cycles of inadequate food production and scarcity (Maass et al., 2012; Mutwedu et al., 2022).

Studies have shown that some livestock species, particularly those reared in SSA rural areas, could help alleviate household food insecurity and reduce poverty by strengthening resilient livelihoods (Maass et al., 2012; Vilakazi, 2018). Improving livestock productivity is expected to help smallholder farmers in the DRC reduce poverty and food insecurity (Cox, 2012). Livestock contributes about 10% to the GDP and is crucial for the financial stability of rural communities (Baenyi et al., 2021; Mutwedu et al., 2022). Despite its importance in South Kivu and Tanganyika

provinces, sustainable smallholder livestock production is largely constrained by inadequate infrastructure, lack of access to markets, lack of information and technology, poor policy and environmental concerns (Tavirimirwa et al., 2013; Mueller et al., 2015; Malebana, 2017), all of which impede productivity and sustainability. Moreover, the primary causes of low performance per animal are limited feed supplies, inadequate husbandry techniques, and the use of inappropriate genetic material (Mwanga et al., 2018).

Improving livestock productivity is a crucial component to consider for ensuring the sustainability of smallholders' livestock production systems (McDermott et al., 2010; Mutenje et al., 2020; Mapiye et al., 2021). It depends heavily on the control of livestock reproduction through the adoption of improved cattle breeds and artificial insemination (Mwanga et al., 2018; Mapiye et al., 2021). In the Democratic Republic of Congo (DRC), as in many other countries in SSA, the adoption of improved technologies depends on a number of socio-economic factors, including the farmers' wealth, the agricultural credit access, their education level, the extent and quality of extension services offered in their respective communities, etc (Oke et al., 2014; Mugisha et al., 2014; Mugumaarhahama et al., 2021a; Gebre et al., 2022; Zemarku et al., 2022). In addition, farmers' perceptions of the attributes of local and improved cattle breeds play an important role in their adoption decisions, considering traits such as milk yield, growth rate, disease resistance, and suitability to local conditions as influencing these perceptions (Bebe et al., 2003; Lukuyu et al., 2019). It is imperative to understand these perspectives and their socio-economic drivers in order to develop strategies that promote the adoption of improved breeds and reproductive technologies.

This study seeks to comprehensively address these issues by (i) examining cattle reproductive management practices, (ii) analyzing the socio-economic factors influencing the adoption of improved cattle breeds and artificial insemination, (iii) assessing farmers' perceptions of the positive and negative traits of local and improved cattle breeds, and (iv) assessing the objectives behind the adoption of improved cattle breeds and artificial insemination as well as the major constraints to the adoption of innovative reproductive technologies. Through this comprehensive approach, the study aims to provide a basis for formulating effective strategies to increase livestock productivity, meet the nutritional needs of a growing population, alleviate poverty and improve the livelihoods of rural communities in eastern DRC and other similar regions.

## 2. Methods

### 2.1. Study area

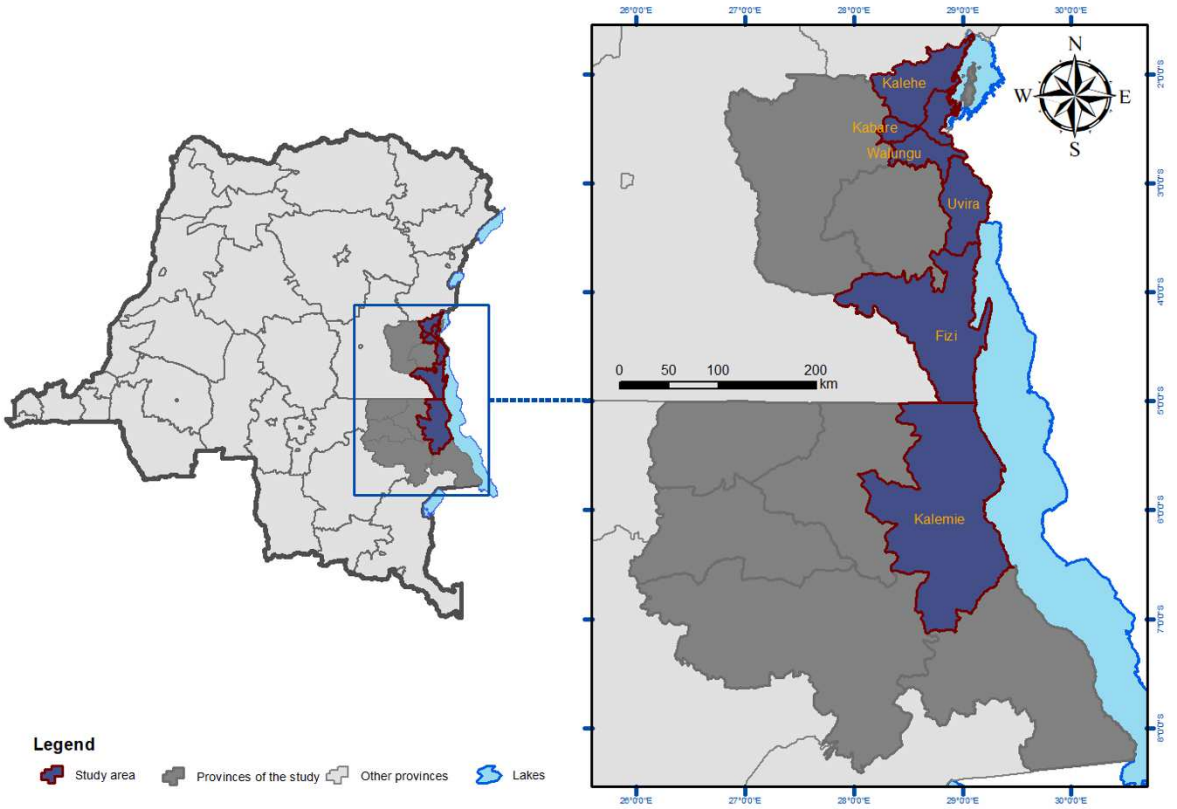



**Figure 1**. Map of the study area

This study was conducted in the provinces of South Kivu and Tanganyika in the eastern Democratic Republic of Congo (DRC) (Figure 1). South Kivu Province, located between 1.36° and 3.00° south latitude and 27.00° and 29.45° east longitude, and Tanganyika Province, located between 4.35° and 7.03° south latitude and 27.00° and 30.00° east longitude, are provinces with very different climatic characteristics. South Kivu has a tropical rainforest and savanna climate, with temperatures ranging from 16°C to 28°C and annual rainfall ranging from 1,400 to over 2,000 mm. In this province, the rainy season lasts from October to May and the dry season from June to September. However, the tropical savanna climate prevails mainly in Tanganyika Province, with some zones experiencing tropical rainforest climate. In this province, temperatures are in the interval of 20°C to 30°C throughout the year, with 1,200 mm to 1,800 mm annual rainfall. In Tanganyika, the rainy season lasts from November to April, followed by the dry season from May to October. The different climatic conditions in South Kivu and Tanganyika have a strong influence on agricultural and livestock practices.

### 2.2. Study design and population

We adopted a cross-sectional design for this study, which was conducted in communities between January and July 2022 in the *territoires* of Kalehe, Kabare, Walungu, Uvira and Fizi in the province of South Kivu, and in the *territoire* of Kalemie in the province of Tanganyika. A team of 15 surveyors participated in this study. They were selected on the basis of their local background and were trained prior to the field work, not only on the data collection tools, but also on understanding the objectives of the study, the methodology and the expected results.

Smallholder cattle farmers from the selected areas with different socio-demographic characteristics constituted the research population. This study includes participants of both sexes, different age groups, different religious and occupational backgrounds, different marital status and different educational backgrounds. Informed consent was obtained from the cattle farmers prior to data collection. They were informed of the voluntary nature of their participation in the study and of the guarantee of anonymity and confidentiality of their data.

In addition to direct, structured observations of farm infrastructure, livestock, and farming practices, the target population was interviewed with specific questions grouped into the five sections: Section I provided information on the socio-economic background of the farmer and his/her household; Section II provided information on herd size and composition, means of animal acquisition and the farming system practiced; Section III provided information on genetic improvement of cattle: breeds known to the cattle farmer and their positive and negative traits and degree of preference; Section IV provided basic information on reproductive practices and management and related objectives; Section V provided information on constraints associated with the adoption of improved reproductive technologies.

Data collection was done by administering the above questionnaire tailored to cattle farm owners and conducting in-depth interviews with them using Kobocollect software and speeking in local languages to facilitate effective communication. The farm owner was chosen as the primary unit of analysis because a significant portion of agricultural and livestock decisions, including production, investment and consumption decisions, are typically made at the farm owner level.

### 2.3. Sampling and data collection

The minimum sample size (n) required for this study was determined assuming a finite population. An updated list of 9217 cattle farmers (4791 farmers in South Kivu and 4426 farmers in Tanganyika) was provided by the provincial divisions of national services in charge of fisheries and livestock. To determine n, the widely used confidence level of 95% was used, which corresponds to Z = 1.96; for the maximum acceptable sampling error (E), as commonly chosen, the largest acceptable difference between the sample estimate and the true population value is E = 5% (0.05); for the estimated proportion of the population with the characteristics of interest (P), since we did not have a credible estimate, we used P = 50% (0.5), as commonly used, to maximize variability, which in turn maximizes the required sample size. The n value was determined using the following equation (Anwar et al., 2023):

$$n = \frac{NZ^2P(1-P)}{E^2(N-1)+Z^2P(1-P)} \quad (1)$$

This resulted in a minimum required sample size of approximately 369 farmers (192 in South Kivu and 177 in Tanganyika). To avoid problems related to the removal of erroneous entries, which are likely to occur during the data cleaning process due to errors in data collection, 37 additional farmers (19 in South Kivu and 18 in Tanganyika), representing 10% of the minimum sample size, were considered, bringing the total number of farmers included in the data collection process to 406 (211 in South Kivu and 195 in Tanganyika).

### 2.4. Data processing and Statistical analysis

#### 2.4.1. Data processing and descriptive statistics

The acquired data underwent the process of data entry and cleaning in MS Excel 2019, a software widely used for such purposes in the field of data management and analysis. After this phase of data cleaning, the refined dataset was used to elucidate different aspects related to the cattle farms studied and associated cattle management practices. In order to summarize the qualitative data, frequency distributions were carried out, which allowed a thorough description of the categorical variables contained therein. Conversely, for the quantitative variables, statistical calculations such as means and standard deviations were accurately calculated, providing insight into the central tendency and dispersion of numerical variables. The results of these analytical processes were competently performed in R v4.0.5 and presented using visual aids such as figures or tables to effectively communicate the research findings.

#### 2.4.2. Word network analysis

In this study, we adopted a word network analysis approach (Kuby et al., 2009) to understand and characterize the main traits of the common cattle breeds raised in South Kivu and Tanganyika Provinces. This methodology is an approach adapted from network analysis, a set of techniques derived from graph (network) theory developed in computer science to study the influence of social networks (Kuby et al., 2009). It is a visualization technique that maps complex relationships between different entities based on the symmetry or asymmetry of their proximity (Smiraglia, 2015).

In this study, word network analysis was essential to understand the association between cattle breeds and their traits as perceived by farmers. In the approach we used, cattle breeds and their characteristic traits were represented by nodes, and the links (edges) connecting them represented, through their thickness and color, the frequency, strength, and rank of these relationships. In this analysis, it is essential to examine the adjacency matrix to assess the existence or strength of an existing relationship between cattle breeds and a given cited trait. For a deeper understanding of the network configuration, this is accompanied by the calculation of parameters such as node degree, which indicates the number of connections to that node, and clustering coefficients, which express the tendency of cattle breeds and traits to form closely related groups. Parameters such as interdependence centrality and eigenvector centrality play an important role in identifying the most influential breeds and traits within the network. These two parameters allow, respectively, to quantify the number of shortest edges between breeds and traits to highlight those that serve as important links, and to assign connection-based rankings to nodes with a large number of connections to identify the most influential breeds and traits within groups of connections (Kuby et al., 2009).

This analysis approach, which integrates graph theory with the analysis of networks formed between cattle breeds and traits, provides a quantitative assessment of the associations between the latter. This study thus provides a solid basis for characterizing the cattle breeds commonly reared in South Kivu and Tanganyika on the basis of traits perceived by breeders, providing valuable information that can inform breeding strategies and trait selection.

#### 2.4.3. Word cloud analysis

In order to collect data on the objectives of breeding improved cattle breeds, the use of artificial insemination and the constraints to the adoption or use of improved reproductive technologies, the farmers interviewed were given the opportunity to share freely and fully their experiences. Their opinions on the three questions were expressed in local languages, recorded, and then translated and transcribed. Word cloud analysis was used to extract the essence of their words. This analytical technique is a form of simplified factorial analysis based on the absolute frequency of keywords, which organizes them in the corpus of textual data. It allows us to highlight the relationship of the most frequent words at its center with other periheric forms, linked to the semantic means of the keywords. Word cloud analysis has allowed us to illustrate and identify the main objectives of breeding improved breeds of cattle, the objectives of using artificial insemination, and the main constraints limiting the adoption of improved reproductive technologies and practices. Through a visual representation built around the most common or important words, this technique makes it possible to highlight the words that are most frequently employed by cattle farmers and to draw out the main message that needs to be conveyed among a large amount of textual data. The size of the characters indicates the frequency or importance of the words. By connecting the most frequent words, we can extract the information from interviews or surveys, which is an advantage of this technique, as well as providing an immediate overview of key aspects without the need for complex data processing and analysis methods (Atenstaedt, 2017).

#### 2.4.4. Assessing the socio-economic determinants of adoption of improved breeds and artificial insemination

**a. Logit Logistic Model**

In this study, we used the logistic logit model to determine the socio-economic factors influencing: (i) the adoption of improved cattle breeds and (ii) the use of artificial insemination. This model is commonly used in cases where the explained variable of interest is binary and likely to be influenced by categorical or quantitative explanatory variables. The variable of interest has only two possible realizations: adoption or non-adoption of improved cattle breeds or artificial insemination. With this model, the variation in the probability of adoption of the insemination technology is evaluated as a function of the variation in the explanatory variables (Hosmer & Lemeshow, 2000; Greene, 2003; Glantz & Kissell, 2014; Gujarati & Porter, 2016).

Mathematically, the logistic model can be represented by the following equations:

$$\text{logit}\big(\text{P}(\mathbf{Y}_\text{i} = 1)\big) = \log\left(\frac{\text{P}(\mathbf{Y}_\text{i} = 1)}{1 - \text{P}(\mathbf{Y}_\text{i} = 1)}\right) \quad (2)$$

$$\text{logit}\big(\text{P}(\mathbf{Y}_\text{i} = 1)\big) = \mathbf{X}_i^T\beta + \varepsilon_\text{i} \quad (3)$$

$$\pi_\text{i} = \text{P}(\mathbf{Y}_\text{i} = 1 \mid \mathbf{X}_\text{i}) = \left(1 + \exp\big(-\mathbf{X}_i^T\beta\big)\right)^{-1} \quad (4)$$

where:

- $\text{P}(\mathbf{Y} = 1)$ is the probability of adoption (e.g., improved cattle breed or artificial insemination),
- $\beta$ is the vector of the coefficients of the explanatory variables $\mathbf{X}$ hypothesized to influence the adoption,
- $\mathbf{X}_\text{i}$ is a vector of realizations of the explanatory variables $\mathbf{X}$ of the i-th farmer,
- $\varepsilon_\text{i}$ is the error term,
- $\pi_\text{i}$ is the probability of adoption.

The log-likelihood function for a sample of size n is given by:

$$\text{L}(\beta) = \sum_{\text{i}=1}^{\text{n}} \left[\mathbf{Y}_\text{i}\mathbf{X}_\text{i}^\text{T}\beta - \log\left(1 + \exp\big(\mathbf{X}_\text{i}^\text{T}\beta\big)\right)\right] \quad (5)$$

This log-likelihood function is maximized with respect to $\beta$ to estimate the parameters of the logit model.

**b. Double Hurdle Model**

In this study, we assessed the intensity of adoption of improved cattle breeds based on their numbers on farms. To do this, we used the double hurdle model for count data. This model has two components, hence the name double hurdle. The first component is related to binomial distribution that models a binary phenomenon: adoption or non-adoption of improved cattle breeds. The second component is related to count distribution (of the Poisson family) corresponding to the intensity of adoption expressed in terms of the number of cattle of improved breeds in the farms.

**Binary Choice Model (First Hurdle)**: At this level, the probability of adopting improved cattle breeds is evaluated as a function of the explanatory variables using a logistic model. The logit model is the one used in this paper. Equations 2 to 5 abovementioned represent the logistic logit model also used at this level.

**Count Model (Second Hurdle)**: For those who have adopted improved cattle breeds, the objective is to evaluate the factors that influence the breeding of a large number of the improved cattle breeds. Given the high variability observed in the farms' herd size, a negative binomial distribution model was chosen for this study. This distribution model is more appropriate in such situations (Payne et al., 2015; Payne et al., 2017).

The negative binomial model is specified as:

$$\log(\mathbf{Y}_\mathrm{i}) = \mathbf{W}_i^T\delta + \varepsilon_\mathrm{i} \quad (6)$$

where:

- $\mathbf{Y}_\mathrm{i}$ is the observed number of cattle of improved breeds owned by the i-th farmer,
- $\delta$ is the vector of coefficients for the explanatory variables $\mathbf{W}$ hypothesized to influence the herd size of cattle of improved breeds,
- $\mathbf{W}_\mathrm{i}$ is a vector of realizations of the explanatory variables $\mathbf{W}$ of the i-th farmer,
- $\varepsilon_\mathrm{i}$ is the error term.

The probability mass function for the negative binomial model is:

$$\mathrm{P}(\mathbf{Y}_\mathrm{i} = \mathrm{k}) = \frac{\Gamma(\mathrm{k} + \theta)}{\Gamma(\theta)\mathrm{k}!}\left(\frac{\theta}{\theta + \lambda_\mathrm{i}}\right)^{\theta}\left(\frac{\lambda_\mathrm{i}}{\theta + \lambda_\mathrm{i}}\right)^{\mathrm{k}} \quad (7)$$

where:

- $\mathrm{k}$ is the observed count.
- $\Gamma$ is the gamma function,
- $\theta$ is the dispersion parameter,
- $\lambda_\mathrm{i} = exp(\mathbf{W}_i^T\delta)$ is the mean parameter for the i-th observation.

The log-likelihood function for a sample of size n is given by:

$$\mathrm{L}(\delta,\theta) = \sum_{\mathrm{i}=1}^{\mathrm{n}}\Big[\log\big(\Gamma(\mathbf{Y}_\mathrm{i} + \theta)\big) - \log\big(\Gamma(\theta)\big) - \log(\mathbf{Y}_i!) + \theta\log(\theta) + \mathbf{Y}_i\mathbf{W}_i^T\delta - (\mathbf{Y}_\mathrm{i} + \theta)\log\big(\theta + exp(\mathbf{W}_i^T\delta)\big)\Big] \quad (8)$$

**Table 1**. Overview of predictors used in the logit and double hurdle models

| Predictor (X / W) | Description | Purpose and hypothesis |
|---|---|---|
| Province | This variable identifies the geographical location of the farms, whether from South Kivu or Tanganyika. | To capture regional differences, which can affect adoption rates, driven by things such as access to resources, infrastructure, and information. |
| Gender | This variable denotes the gender of a farm owner, as male or female. | To understand whether or not gender affects the adoption of improved cattle breeds, as gender may influence access to resources while also affecting decision-making power and work responsibilities. |
| Age | This is a continuous variable showing the age of an individual in years. | To gauge how much age can affect adoption probability; age can be a characteristic correlated with experience, openness to new practices and technology, and the degree of risk aversion. |
| Marital status | This variable categorizes the marital status of the farm owner as single, married, divorced, and widowed. | Assess the impact of marital status on adoption decisions, as marital status may reflect some differences in household responsibilities, economic stability, and social support. |
| Education level | It shows the maximum level of education attained by the farm owner: illiterate, primary education, secondary education, or university education. | Assess the impact of educational attainment on adoption, with a priori expectation of increased awareness and capability to undertake the implementation of and adopting improved technologies at higher levels of education. |
| Income source | This variable identifies where the farm owner household derives its main source of income: agriculture/livestock, small trade, NGO work, or public service. | How adoption is affected by different sources of income, since the stability and type of income will affect investment capacity and risk-taking behavior. |
| Access to agricultural credit | This is a binary variable on whether the farm owner has access to agricultural credit or not. | It was supposed to test the effect of access to credit on adoption, since more credit availability can affect the financial capacity to invest in improved technologies. |
| Membership in associations | It is a binary variable capturing whether the farm owner is a member of any agricultural or community associations or not. | The role social networks and collective support play in adoption was assessed, since membership can provide informational, resource, and peer support benefits. |
| Herd Size | This is a discrete variable on the number of cattle a farmer owns. | This will help in understanding the effect of the existing herd size on the likelihood of adopting improved cattle. The hypothesis is that larger herd sizes may correlate with greater capacity and willingness to adopt improved breeds and other improved technologies. |
| Farming system | This is a categorical variable on the kind of farming system the farmer uses in his production. The farming | How different farming systems influence the likelihood of adopting improved cattle. The farming system reflects management practices and resource availability on the farm, which |

| | | |
|---|---|---|
| | system may be herding, semi-stalling, or zero-grazing | could have a considerable impact on the feasibility and attractiveness of adopting improved breeds. |

## 3. Results

### 3.1. Characteristics of cattle farmers

**Table 2**. Socio-economic characteristics of cattle farmers

| Variables | South Kivu | Tanganyika | Total |
|---|---|---|---|
| **Gender (%)** | | | |
| Female | 6.2 | 4.3 | 5.3 |
| Male | 93.8 | 95.7 | 94.7 |
| **Age (years)** | 53.8 ± 12.9 | 44.6 ± 13.3 | 49.4 ± 13.9 |
| **Marital status (%)** | | | |
| Single | 1.9 | 10.2 | 5.8 |
| Married | 74.8 | 76.3 | 75.5 |
| Divorced | 11.4 | 8.6 | 10.1 |
| Widowed | 11.9 | 4.8 | 8.6 |
| **Education level (%)** | | | |
| Illiterate | 19.5 | 21.0 | 20.2 |
| Primary | 43.8 | 29.0 | 36.9 |
| Secondary | 31.9 | 37.6 | 34.6 |
| University | 4.8 | 12.4 | 8.3 |
| **Main source of income (%)** | | | |
| Agriculture - Livestock | 70.5 | 68.3 | 69.4 |
| Small trade | 17.6 | 12.9 | 15.4 |
| NGO work | 2.9 | 4.3 | 3.5 |
| Public service | 9.0 | 14.5 | 11.6 |
| **Access to agricultural credit (%)** | 36.2 | 44.1 | 39.9 |
| **Membership in farmers' associations** | 27.6 | 25.8 | 26.8 |
| **Experience in livestock farming (years)** | 24.2 ± 13.2 | 16.1 ± 13.2 | 20.4 ± 13.8 |
| **Experience in cattle farming (years)** | 18.7 ± 13.5 | 13.0 ± 11.9 | 16.0 ± 13.1 |

Results presented in **Table 2** show that the demographic and socioeconomic characteristics of cattle farmers from South Kivu and Tanganyika disclose a good number of striking differences and similarities between the two provinces. Overall, these results exhibit demographic differences between the regions, education levels, income sources, and agricultural experience. South Kivu has an older population with more experience in agriculture and livestock raising, whereas Tanganyika's population is younger, more educated, and has slightly more diversified sources of income. It, therefore, implies that policy formulation and implementation concerning the improvement of agricultural and livestock practices in these provinces might differ.

On gender grounds, both provinces are overwhelmingly male, with male farmers making up 93.8% in South Kivu and 95.7% in Tanganyika. This is such a huge percentage, pointing to male farmer representation dominating activities in cattle farming.

Comparing the average age of cattle farmers, it is higher in South Kivu: 53.8 ± 12.9 years, compared to their counterparts in Tanganyika at 44.6 ± 13.3 years. It therefore shows an older population involved in cattle farming

activities in South Kivu. Altogether, the average age of cattle farmers in both provinces is 49.4 ± 13.9 years. This disparity may be indicative of different social structures or economic opportunities that draw in younger cattle farmers to Tanganyika. Moreover, years of experience in livestock farming are far higher in South Kivu at 24.2 years, on average, than in Tanganyika at 16.1 years. Similarly, the experience in cattle farming is higher in South Kivu Province, 18.7 ± 13.5 years, in comparison with the Tanganyika Province with 13.0 ± 11.9 years, which implies that the farming population of South Kivu is older.

Marital status varies greatly from one province to another. In Tanganyika, the percentage of single cattle farmers is very high, 10.2%, in comparison with South Kivu, which stood at 1.9%. In turn, South Kivu has more widowed cattle farmers, 11.9%, than Tanganyika, which had 4.8%. Married farmers dominate in both provinces: 74.8% in South Kivu and 76.3% in Tanganyika, thus showing strong family structures.

Educational levels also vary: A higher percentage of cattle farmers in Tanganyika have university education compared to South Kivu, indicating better access to higher levels of education or other priorities in education. However, in both provinces, the majority has primary or secondary education, while a fair proportion is illiterate.

Agriculture and livestock remain for both provinces the major sources of income for the majority: 70.5% in South Kivu and 68.3% in Tanganyika. Other sources of income, like small trade, work in NGOs, and public service, are less common; public service is more important in Tanganyika (14.5%) than in South Kivu (9.0%).

While agricultural credit is still out of reach, it is more so in Tanganyika than in South Kivu. Membership of farmers' associations is relatively well balanced between the provinces, and again, it is slightly higher in South Kivu, where 27.6 percent is seen against 25.8 percent in Tanganyika.

### 3.2. Characterization of farms and farming practices

**Table 3**. Characterization of cattle farms

| Variables | South Kivu | Tanganyika | Total |
|---|---|---|---|
| **Farming system (%)** | | | |
| Grazing | 85.7 | 86.6 | 86.1 |
| Semi-zero-grazing | 10.0 | 10.2 | 10.1 |
| Zero-grazing | 4.3 | 3.2 | 3.8 |
| **Diet composition (%)** | | | |
| Forages + supplements | 17.1 | 6.2 | 11.8 |
| Forages only | 82.9 | 93.8 | 88.2 |
| **Reared breeds (%)** | | | |
| Local (indigenous) breeds only | 71.9 | 69.9 | 71.0 |
| Local and Improved (or hybrid) breeds | 28.1 | 30.1 | 29.0 |

According to results in **Table 3**, grazing is the common rearing system practiced by most farmers in both provinces, 85.7% in South Kivu and 86.6% in Tanganyika. Semi-zero-grazing and zero-grazing systems are less common and are present with almost the same low percentage in both provinces; thus, 10.1% are involved in semi-zero-grazing and about 4% in zero-grazing.

Diet composition of cattle indicates that a large proportion rely on forages solely, 82.9% in South Kivu and 93.8% in Tanganyika. A smaller proportion of farmers in South Kivu use 17.1% forages supplemented with other feed, as opposed to Tanganyika with 6.2%.

On the breeds of cattle kept, most farmers in both provinces keep only local (indigenous) breeds: 71.9% in South Kivu and 69.9% in Tanganyika. A good number of farmers also keep a mix of local and improved or hybrid breeds: 28.1% in South Kivu and 30.1% in Tanganyika.

These findings in **Table 3** give a better understanding of farming practices in these provinces, which is highly dependent on traditional herding systems with local breeds and limited adoption of supplementary feeding and mixed breed rearing. This information is critical in shaping interventions that might enhance livestock productivity and sustainability in South Kivu and Tanganyika.

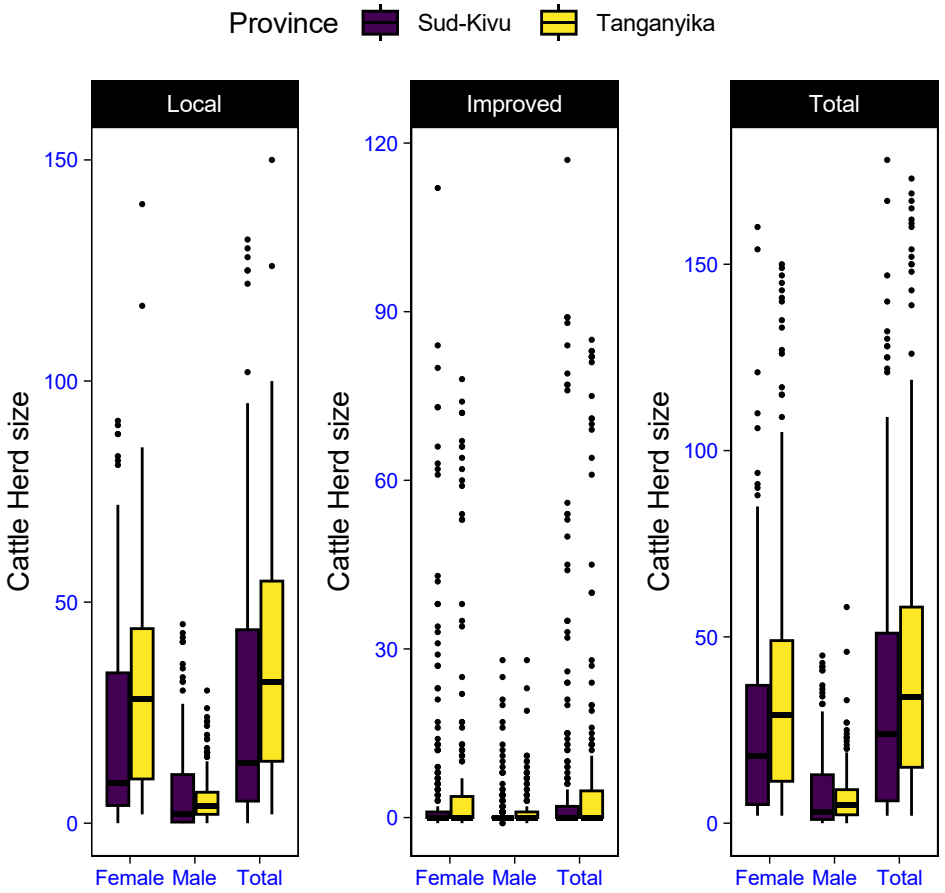



**Figure 2**. Herd size and composition

**Local Breeds**: The herd size of local breeds is usually bigger in Tanganyika than in South Kivu, particularly for males. Tanganyika has a very small to very big size of the herd of local breeds, with some outliers beyond 150 cattle. South Kivu has a much more even, equally weighted distribution, with less-zero presence of outliers. For both male and female cattle, the median herd size is higher in Tanganyika than in South Kivu. This thus implies that farmers in Tanganyika have larger herds of local breeds compared to South Kivu (first panel of **Figure 2**).

**Improved Breeds**: In the second panel of **Figure 2**, improved cattle breeds, are generally of smaller herd sizes than those recorded for the local breeds in both provinces. Tanganyika again has larger herd sizes of improved breeds when compared to South Kivu, with more variability and outliers. Indeed, for improved breeds, median herd sizes were low in both provinces and could indicate that improved breeds are not very common or are simply kept in small numbers. It thus shows a low rate of adoption or capacity to maintain larger herds of improved breeds in both provinces.

**Total Herd Size**: In the third panel of **Figure 2**, when considering the total herd sizes, replicates the overall trend, that Tanganyika reported larger herd sizes than South Kivu did, as observed for local and improved breeds

previously. This signature of dominance by the local breed is inherited in the combined sizes since the Tanganyika's herds are larger in size. The range of the data suggests a greater degree of variability in herd sizes in Tanganyika, with a few large outliers indicating particularly big herds in some cases.

Overall, results in **Figure 2** show that Tanganyika has larger and more variable herd sizes than those of South Kivu for both local and improved breeds. Local breeds dominate in both provinces, although there is a remarkable presence of improved breeds present, even if in small numbers. Data suggests there are regional differences in practices and capacities related to herd management; Tanganyika demonstrates a better disposition toward larger herd sizes.

**Table 4**. Improved cattle breeds' acquisition method

| Means of acquisition (%) | South Kivu | Tanganyika | Total |
|---|---|---|---|
| Heritage | 6.3 | 14.3 | 8.2 |
| Donation | 9.4 | 4.8 | 8.2 |
| Purchase of a bull/cow | 81.3 | 76.2 | 80.0 |
| Artificial insemination | 3.1 | 4.8 | 3.5 |

According to results in **Table 4**, purchase is the way in which most cattle of improved breeds have been acquired in both provinces: 81.3% in South Kivu and 76.2% in Tanganyika. This puts the strategy to build herds as market-based in both provinces. More cattle are acquired through heritage in Tanganyika, 14.3%, in comparison with South Kivu with 6.3%. Traditional inheritance is therefore of more importance in Tanganyika. Moreover, the share of donations to acquire cattle is more significant in South Kivu at 9.4% compared to Tanganyika at 4.8%. Consequently, South Kivu holds more influential structures for communal or family support in livestock acquisition. However, only a very small percentage of cattle of improved breeds are acquired through artificial insemination: the levels of use are marginally higher in the Tanganyika Province at 4.8% than in South Kivu at 3.1%. This depicts very low but existing adoption of modern breeding techniques in both provinces.

### 3.3. Awareness, adoption and willingness to use improved reproduction practices and technologies

**Table 5**. Use and willingness to the use of artificial insemination and improved reproductive management practices.

| | South Kivu | Tanganyika | Total |
|---|---|---|---|
| **Artificial insemination** | | | |
| Awareness (%) | 73.9 | 34.4 | 55.2 |
| Adoption (%) | 25.2 | 24.7 | 25.0 |
| Willingness to use or continue using (%) | 62.7 | 70.3 | 65.0 |
| Availability (%) | 13.7 | 6.3 | 11.5 |
| Willingness to pay (%) | 52.3 | 65.6 | 56.2 |
| **Other improved reproductive practices** | | | |
| Practicing heat control (%) | 51.7 | 60.2 | 55.7 |
| Practicing heat return control (%) | 29.0 | 47.8 | 37.9 |
| Practicing heat synchronization (%) | 5.3 | 5.4 | 5.3 |
| Doing pregnancy diagnosis (%) | 41.5 | 24.2 | 33.3 |

**Artificial Insemination (AI)**: Results in **Table 5** show that the awareness of AI differs significantly between South Kivu (73.9%) and Tanganyika (34.4%). Thus, probably, either educational or outreach programs for AI have been more effective or frequent in South Kivu. Yet, the adoption rate remains very similar: 25.2% in South Kivu and 24.7% in Tanganyika. Interestingly, the willingness of cattle farmers in Tanganyika to adopt or continue using AI is higher (70.3%) compared to South Kivu (62.7%), indicating a more positive attitude toward the practice in

Tanganyika, probably because of perceived benefits or future potential. One outstanding factor is the availability of AI services, standing at 13.7 % in South Kivu and 6.3 % in Tanganyika, hence limiting any interested cattle farmer from adopting artificial insemination. Moreover, willingness to pay for AI services is higher in Tanganyika at 65.6 % as compared to South Kivu at 52.3 %. In fact, this readiness to invest demonstrates the value of AI in improving livestock productivity within Tanganyika.

**Other Improved Reproductive Practices**: Tanganyika leads in a number of improved reproductive management practices. The practice of heat control stands at 60.2% for cattle farmers in Tanganyika, compared to 51.7% in South Kivu, and 47.8% in Tanganyika practice heat return control compared to 29.0% in South Kivu. These practices are very important in optimizing the breeding time for improving reproductive efficiency and hence better reproductive management practices in Tanganyika. However, in both provinces, the practice of heat synchronization is low: 5.3% in South Kivu and 5.4% in Tanganyika. This means that the advanced reproductive technique of heat synchronization is much less adopted, possibly due to a lack of knowledge or means (**Table 5**). However, the percentage of cattle farmers performing pregnancy diagnosis was higher in South Kivu (41.5%) as compared to Tanganyika (24.2%). This practice is essential for managing breeding schedules and for successful pregnancies; hence, farmers in South Kivu give more attention to monitoring and managing the reproductive status of their cattle.

Overall, results on AI and other improved reproductive practices presented in **Table 5** bring the following key messages: South Kivu presents higher awareness with similar adoption rates of AI as in Tanganyika, where there is a willingness to use, and to pay more for, these services. Both provinces report difficulties with availability, which limits AI services and broader adoption. Generally, Tanganyika performs best for heat control and heat return control. On the other hand, South Kivu is the best in pregnancy diagnoses. Evidence points to a requirement for regionally targeted interventions through which to increase awareness, availability, and uptake of AI and other reproductive practices in a manner that addresses local conditions and needs of each province.

### 3.4. Characterization of raised cattle breeds based on the positive and negative traits

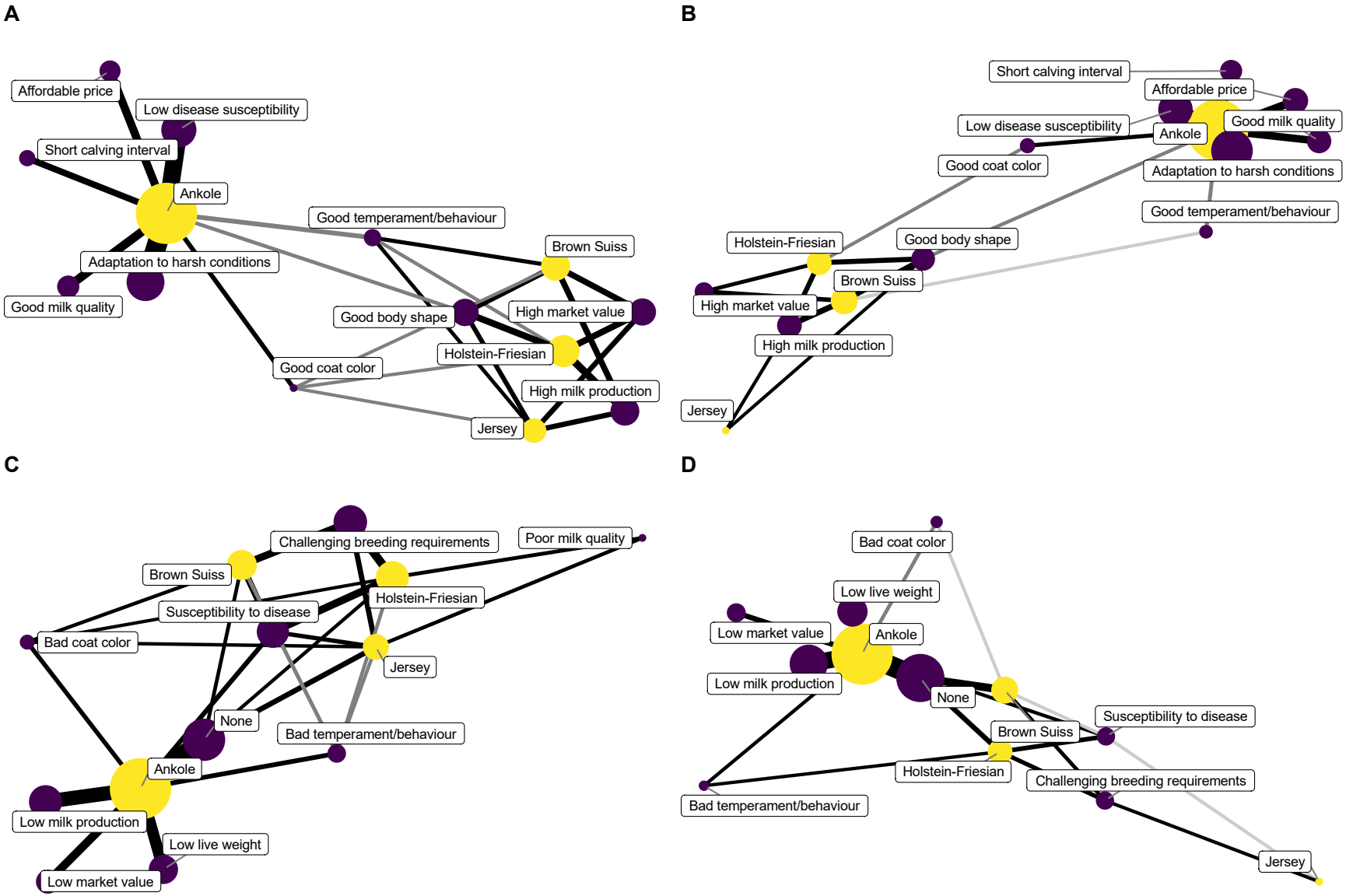



**Figure 3**. Preferred traits and Negative traits

The word network maps in **Figure 3** bring out various perceived positive and negative traits for different cattle breeds as observed by farmers in both South Kivu and Tanganyika. The yellow nodes are the cattle breeds, and the purple nodes represent various traits.

**Perceived positive traits**

In both provinces, the most dominant positive traits include high market value, good body shape, good milk quality, and adaptability to harsh conditions. In South Kivu (Figure 3A), the Ankole breed is highly valued for low cost, low disease susceptibility, short calving interval, good milk quality, adaptation to harsh conditions, good temperament, body shape, and coat color, with affordability and disease resistance being the most frequently cited. Holstein-Friesian cattle are recognized primarily for high milk production, good body shape, and market value, while Brown Swiss and Jersey cattle are appreciated mainly for body shape and market value. Similar trends are observed in Tanganyika (Figure 3B), where Ankole's affordability and adaptability dominate, and Holstein-Friesian and Brown Swiss are valued for high milk production, good body shape, and market value.

**Perceived negative traits**

The most frequently reported negative traits across both provinces include low milk production, low live weight, susceptibility to disease, challenging breeding requirements, bad temperament, and poor coat color. In South Kivu (Figure 3C), Ankole cattle were mainly criticized for low milk production, low live weight, and low market value, while Holstein-Friesians were noted for disease susceptibility and demanding breeding requirements. Brown Swiss were associated with disease susceptibility and poor coat color, and Jerseys with bad temperament and breeding difficulties. Tanganyika (Figure 3D) shows comparable patterns, highlighting the same undesirable traits for these breeds.

Overall, the maps emphasize that both provinces share similar perceptions of cattle breeds. Ankole is favored for cost-effectiveness and adaptability, Holstein-Friesian and Brown Swiss for productivity and market value, while general concerns about low productivity, poor physical traits, and demanding breeding conditions influence farmers' preferences.

### 3.5. Assessment of the socioeconomic determinants of adoption of improved breeds and artificial insemination

**Table 6**: Double hurdle model of adoption and herd size of improved cattle breeds

| Determinants | Logit Model | | | | Negative binomial Model | | | |
|---|---|---|---|---|---|---|---|---|
| | β | SE | z | p | δ | SE | z | p |
| Intercept | -1.141 | 0.980 | -1.164 | 0.244 | 1.944 | 0.411 | 4.733 | 0.000*** |
| Province – South Kivu | | | | | | | | |
| Province - Tanganyika | -0.813 | 0.312 | -2.602 | 0.009* | -0.604 | 0.145 | -4.178 | 0.000* |
| Sex – Female | | | | | | | | |
| Sex - Male | 0.308 | 0.681 | 0.452 | 0.651 | -0.130 | 0.232 | -0.562 | 0.574 |
| Age | -0.037 | 0.013 | -2.877 | 0.004* | 0.005 | 0.005 | 1.005 | 0.315 |
| Marital status – Single | | | | | | | | |
| Marital status - Divorced | 0.039 | 0.718 | 0.055 | 0.956 | 0.083 | 0.272 | 0.307 | 0.759 |
| Marital status - Married | 0.134 | 0.609 | 0.220 | 0.826 | 0.017 | 0.247 | 0.069 | 0.945 |
| Marital status - Widowed | -2.129 | 1.070 | -1.989 | 0.047* | -0.550 | 0.620 | -0.887 | 0.375 |
| Education – Illiterate | | | | | | | | |
| Education - Primary | 0.210 | 0.483 | 0.435 | 0.664 | -0.103 | 0.250 | -0.414 | 0.679 |
| Education - Secondary | 1.403 | 0.491 | 2.858 | 0.004* | -0.332 | 0.247 | -1.341 | 0.180 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Education - University | 3.348 | 0.701 | 4.779 | 0.000* | -0.291 | 0.275 | -1.057 | 0.290 |
| Income source – Agriculture / livestock | | | | | | | | |
| Income source - Small trade | 0.022 | 0.544 | 0.041 | 0.967 | -0.109 | 0.231 | -0.472 | 0.637 |
| Income source - NGO work | -0.857 | 0.772 | -1.109 | 0.267 | -0.007 | 0.263 | -0.025 | 0.980 |
| Income source - Public service | -0.494 | 0.538 | -0.917 | 0.359 | 0.125 | 0.191 | 0.652 | 0.514 |
| Access to agricultural credit – No | | | | | | | | |
| Access to agricultural credit – Yes | 0.141 | 0.460 | 0.308 | 0.758 | 0.193 | 0.183 | 1.060 | 0.289 |
| Membership in associations – No | | | | | | | | |
| Membership in associations – Yes | 1.426 | 0.295 | 4.834 | 0.000* | 0.058 | 0.116 | 0.501 | 0.617 |
| Herd Size | 0.014 | 0.004 | 3.697 | 0.000* | 0.021 | 0.001 | 14.849 | 0.000* |
| Farming system – Herding | | | | | | | | |
| Farming system - Semi-stalling | 0.346 | 0.483 | 0.716 | 0.474 | 0.050 | 0.268 | 0.187 | 0.852 |
| Farm system - Zero-grazing | 1.382 | 0.711 | 1.943 | 0.052 | -0.428 | 0.369 | -1.161 | 0.246 |
| | | | log(θ) | | 1.427 | 0.183 | 7.789 | 0.000* |

In **Table 6**, the logistic logit model was run to assess the probability of adopting improved cattle, and several factors were significantly influential: (i) Cattle farmers in Tanganyika are much less likely to adopt improved cattle compared to their peers in South Kivu (β = -0.813, SE = 0.312, z = -2.602, p = 0.009). This regional difference may point out that geographical factors, perhaps involving access to resources and information, are very important for adoption decisions; (ii) Elderly cattle farmers are less likely to adopt improved cattle breeds (β = −0.037, SE = 0.013, z = −2.877, p = 0.004). This negative relationship may indicate that age shows a resistant-to-change or a low exposure to improved livestock practices and technologies; (iii) Widowed cattle farmers are less likely to adopt in comparison to single cattle farmers (β = -2.129, SE = 1.070, z = -1.989, p = 0.047). That could mean that the economic or social problems confronting the widowed cattle farmers are more than what their adoption of improved cattle breeds is; (iv) Higher education level is positively associated with adoption. Cattle farmers with secondary (β = 1.403, SE = 0.491, z = 2.858, p = 0.004), and university education (β = 3.348, SE = 0.701, z = 4.779, p = 0.000) have significantly higher chances of adopting improved cattle than the illiterate cattle farmers. It shows that education raises awareness and the capacity to adopt improved practices and technologies; (v) Membership of associations greatly increases the probability of adoption (β = 1.426, SE = 0.295, z = 4.834, p = 0.000). This finding implies that social networks and collective support are major facilitators of adoption; (vi) Larger herd sizes raise the likelihood of adopting improved cattle (β = 0.014, SE = 0.004, z = 3.697, p = 0.000). This indicates that those with larger herds are more likely to adopt improved breeds and other improved technologies.

The negative binomial model (**Table 6**) focuses on the number of improved cattle raised by adopters. Results of this model show that: (i) The number of improved cattle raised is significantly lower in Tanganyika compared to South Kivu (δ = -0.604, SE = 0.145, z = -4.178, p = 0.000). This goes on to confirm the regional difference in terms of adoption levels, whereby Tanganyika had the lowest level of adoption; (ii) A positive coefficient on herd size (δ = 0.021, SE = 0.001, z = 14.849, p = 0.000) suggests that cattle farmers with large herds are not only more likely to adopt but also to adopt a greater number of improved cattle; (iii) Age does not have significant effects on the number of improved cattle kept (δ = 0.005, SE = 0.005, z = 1.005, p = 0.315). While older cattle farmers are less likely to adopt, their age does not influence the quantity of improved cattle raised once they decide to adopt; (iv) Marital status as widowed does not significantly influence the number of improved cattle raised (δ = -0.550, SE = 0.620, z = -0.887, p = 0.375) among adopters; (v) Education levels cause no significant effect on the number of improved cattle raised. The attaining secondary (δ = -0.332, SE = 0.247, z = -1.341, p = 0.180) and university education (δ = -0.291, SE = 0.275, z = -1.057, p = 0.290) have no significant influence over the number of improved cattle raised. This means that although education has an influence on adoption likelihood it does not significantly affect the number; (vi) Membership of associations has no significant influence over the number of improved cattle

kept ($\delta$ = 0.058, SE = 0.116, z = 0.501, p = 0.617). Although affecting the likelihood of their adoption, it does not have any significant effect on the extent of their adoption.

**Table 7**: Logit model of adoption of artificial insemination

| Determinants | β | SE | z | p |
|---|---|---|---|---|
| Intercept | -1.430 | 0.918 | -1.557 | 0.119 |
| Province – South Kivu | | | | |
| Province - Tanganyika | -0.633 | 0.289 | -2.189 | 0.029* |
| Sex – Female | | | | |
| Sex - Male | 0.758 | 0.639 | 1.187 | 0.235 |
| Age | -0.018 | 0.012 | -1.540 | 0.123 |
| Marital status – Single | | | | |
| Marital status - Divorced | -0.008 | 0.669 | -0.012 | 0.991 |
| Marital status - Married | -0.286 | 0.575 | -0.497 | 0.619 |
| Marital status - Widowed | -2.162 | 0.998 | -2.166 | 0.030* |
| Education – Illiterate | | | | |
| Education - Primary | -0.095 | 0.437 | -0.218 | 0.828 |
| Education - Secondary | 0.778 | 0.442 | 1.760 | 0.078. |
| Education - University | 1.971 | 0.598 | 3.294 | 0.001* |
| Income source – Agriculture / livestock | | | | |
| Income source - Small trade | -0.204 | 0.519 | -0.393 | 0.694 |
| Income source - NGO work | -0.935 | 0.720 | -1.298 | 0.194 |
| Income source - Public service | -0.064 | 0.496 | -0.128 | 0.898 |
| Access to agricultural credit – No | | | | |
| Access to agricultural credit – Yes | 0.221 | 0.433 | 0.511 | 0.609 |
| Membership in associations – No | | | | |
| Membership in associations – Yes | 0.787 | 0.274 | 2.870 | 0.004* |
| Herd Size | 0.006 | 0.003 | 1.757 | 0.079. |
| Farming system – Herding | | | | |
| Farming system - Semi-stalling | 0.493 | 0.433 | 1.138 | 0.255 |
| Farm system - Zero-grazing | 1.069 | 0.658 | 1.625 | 0.104 |

In **Table 7**, the logistic regression analysis identifies that several important determinants are associated with the adoption of AI. Noteworthy, cattle farmers who reside in Tanganyika are significantly less likely to adopt AI compared to those found in South Kivu (β = -0.633, SE = 0.289, z = -2.189, p-value = 0.029). This suggests that the regional effect in the adoption of AI already implies potential regional differences for factors affecting the use of this improved reproduction technique.

Marital status too was very significant, in such a way that widowed cattle farmers are significantly less likely to adopt the AI compared to single and married cattle farmers (β = -2.162, SE = 0.998, z = -2.166, p = 0.030).

It is a critical determinant, whereby university-educated cattle farmers are significantly more likely to adopt AI as opposed to the illiterate cattle farmers (β = 1.971, SE = 0.598, z = 3.294, p = 0.001). Further, there is a marginal significance for secondary education (β = 0.778, SE = 0.442, z = 1.760, p= 0.078). This indicates the direction of a positive association between higher educational levels and the likelihood that the adoption of AI is related to educational attainment. This gives cause to the educational variable being influential in this study.

Membership in associations is another significant predictor, with members being significantly more likely to adopt the artificial insemination than non-members (β = 0.787, SE = 0.274, z = 2.870, p = 0.004). It shows a clear role of social networks and collective actions, probably through shared resources and information, in the process of adopting the AI technology.

Despite of the fringes of significance, herd size (β = 0.006, SE = 0.003, z = 1.757, p = 0.079) is positively associated with the likelihood of adoption of AI, this positive coefficient suggests that cattle farmers with large herds seem to be more likely to adopt AI.

### 3.6. Objectives of raising improved breeds and adoption of artificial insemination




**Figure 4**. Purpose of adopting improved cattle breeds

The word cloud presented in **Figure 4** indicates the major reasons for adopting improved cattle breeds; the size of the words informs their frequency or relative importance in the response. Far and away, the most dominant purpose is increasing milk production, as evident from the clearly visible repetition of the words “milk”, “production”, “increase”, and “improve”. This means there is a serious attempt at the level of farmers to increase dairy production and productivity by adopting breeds known for their higher milk yields.

Another major motive indicated here is genetic improvement, expressed by words such as “genetic”, “improvement”, and “breed”. The farmers appear to be aware of the benefits of superior genes. From this interest in genetic improvement, the impression of a more prospective approach to raising stock is gained.

Words like “diversify”, “productive”, and “more” insinuate goals of diversification and increased overall farm productivity. The adoption of improved breeds could also make farming systems more resilient and productive. Interest in breed variety is also expressed by the words “breeds” and “improved”, which indicate a desire to include cattle with superior performance traits so as to ensure a robust and adaptable herd. The theme on economic benefits is, however, slightly more subdued. Increased milk production and an improvement in productivity clearly mean increased income and improved economic stability for farmers.

It is wordy to emphasize that the main reasons towards the adoption of improved cattle breeds are oriented towards milk production improvement and genetic gain. Better productivity and diversification of cattle herds are motives luring farmers. This information should be a reminder to make available to farmers the quality of genetic resources and backstopping services in a bid to maximize the gains from adoption of improved cattle breeds.




**Figure 5**. Purpose of adopting artificial insemination

The word cloud in **Figure 5** overview allows for a look at the main purposes of using AI in cattle farming and gives some key themes. “Breed” is obviously the most highlighted word, reflecting that a major goal of AI is dealing with improving breeds of cattle. This includes the selection of desired traits and making sure they are passed on into subsequent generations.

Another major theme is “improvement”, putting emphasis on the role AI can play in improving different aspects of cattle farming, mostly genetically and in terms of productivity. The term very much interlinks with “improvement” in the sense that it brings about connotations of genetic improvement. By using AI, farmers can introduce and maintain advantageous genetic qualities into their herds so that overall, there may be better quality livestock.

Prominent consideration is given to the term “milk”, which thereupon suggests that one of the foremost objectives of AI has to do with increasing milk production. Of course, terms like “increase” and “productive” are strongly associated with the goal of AI to bring a better level of efficiency and productivity to cattle farming operations. This is achieved by higher milk yield and general productivity through better genetics and controlled breeding, made possible by AI.

Moreover, the term “exotic” refers to a strategy of introducing characteristics from exotic breeds into the herd in order to obtain new attributes of utility. It is the overall “quality” of the herd that matters—using AI to produce cattle that will be healthier, more productive, and have more desirable traits.

The very term “controlled” also implies that AI presents an opportunity for the ultimate management of breeding, where desirable traits are no doubt passed on to subsequent generations. The control of this technology is helping to bring about the general improvement of the “livestock”, while cattle farming is becoming easier and more effective.

**Figure 5** shows that breed improvement, genetic enhancement, and milk increase, in short, improvement in productivity and quality are the main aims of AI in cattle farming. Through AI, farmers have been enabled to carry out controlled breeding, introduce desired traits into the herds, and ensure progressive improvement in their herds.

### 3.7. Constraints for adoption of improved reproductive practices and technologies




**Figure 6**. Constraints of adoption of improved breeding practices

**Figure 6** depicts the limitation and challenges in adopting improved breeding technologies in cattle farming. Various key terms in this explain major barriers faced by farmers.

A very prominent word is that of “availability”, indicating that a big limiting factor is the availability of resources required. This is therefore supported by a high usage of words like “not”, “lack”, “none”, “no”, and “unavailable”. These words show clearly that something is drastically wrong with the availability of materials needed or services, such as semen for artificial insemination.

Another critical theme is “cost”, with words like “high” and “cost” showing that it is the financial burden associated with these technologies. This has been a major barrier. The “high cost” involved in implementing improved breeding techniques can deter farmers, especially those who are low in the financial resources end.

The term “failure” also crops up, which indicates a perceived or actual risk of failure with the technologies' use. This can dissuade its adoption since farmers may not be willing to invest in methods likely to fail to produce expected successful outcomes. Associated with this is the term “success”, which has a connotation meaning that to be successful with these technologies is not guaranteed, and it can turn out to be a worry for farmers.

The next terms are “knowledge” and “lack" of knowledge or even expertise in using improved breeding technologies, thus, a major constraint. Lack of education and training might be the reason for which farmers can't use these technologies.

The term “access” again adds problems of not having access to resources and services as a major constraint. Without access, farmers are not able to use improved breeding technologies.

The word cloud in **Figure 6** thus implies that the main constraints to the uptake of improved breeding technologies in cattle farming are limited resources, high costs, risk of failure, lack of knowledge, and restricted access to necessary services. All these factors, if combined, become the most prominent barriers to full-scale adoption of improved breeding technologies.

### 3.8. SWOT analysis of current reproductive management practices in cattle farms and strategies for improvement

**Table 8**. SWOT Analysis of current cattle farming and reproductive practices

| Strengths | Weaknesses |
|---|---|
| **High involvement in agriculture and livestock**: About 70% of the total farmers rely on agriculture and livestock as the main source of income, hence high involvement and commitment to its improvement.<br><br>**Experience in livestock farming**: Most farmers in South Kivu and Tanganyika have been raising livestock for several years, with average experience expressed in years at 24.2 and 16.1, respectively, indicating a strong knowledge base.<br><br>**Adoption of improved breeds**: About 29% of farmers in both provinces raise a mixture of local and improved breeds.<br><br>**Positive perception of upgraded breeds**: Improved breeds, such as Holstein-Friesian and Brown Swiss, are liked because they produce a lot of milk, have good body conformation, and are highly valued in the market.<br><br>**Willingness to adopt improved reproductive technologies and practices**: Significant proportion of farmers showing willingness in the use of artificial insemination and other improved reproductive practices. | **Low adoption rate of improved technologies and practices**: This is despite awareness of the same, for instance, improved breeds, artificial insemination and other reproductive technologies.<br><br>**Low availability and access to AI services**: This was depicted by only 11.5% of the farmers having easy access to AI services, hence hindering its large-scale adoption.<br><br>**Educational barriers**: A huge percentage of the farmers are illiterate, and therefore, probably about 20% will have an impact on the uptake of improved technologies and practices.<br><br>**Forage dependence**: Most farmers depend solely on natural forages for cattle feeding, hence limiting the nutrients intake and subsequent productivity.<br><br>**Negative perception of local breeds**: The local breeds are said to have low milk production, low live weight, and a low market price. |
| **Opportunities** | **Threats** |
| **Information/educational programs**: Higher awareness of AI presupposes that educational and outreach programs can be quite effective. There is room for greater awareness programs on improved reproductive practices and AI, coupled with training, to improve the adoption rate.<br><br>**Government and NGO support**: Another difficulty is the ease of access to agricultural credit combined with | **Socio-economic barriers**: Inadequate financial resources, coupled with limited access to agricultural credit, can substantially retard the adoption of improved breeds and practices.<br><br>**Cultural resistance**: Traditional farming practices coupled with resistance to change may lead to slow rates of diffusion of improved technologies and practices. |

the support from NGOs in increasing the adoption of technologies.

**Improved AI service availability**: The improved availability and accessibility of the AI service could enhance, very dramatically, reproductive efficiency and cattle productivity.

**Market potential for improved breeds**: There is, therefore, the potential for economic gain with a shift in breed type to those of improved breeds.

**Improved reproductive practices**: Improved practices are already in place, such as heat control at 55.7% and pregnancy diagnosis at 33.3%.

**Higher willingness to use AI**: There is a high willingness of use or continuing of artificial insemination (65%) and paying for it (56.2%), thereby indicating a potential for increased adoption if the services were to be made available.

**Undesirable traits of improved breeds**: The perceived susceptibility of breeds like Holstein-Friesian and Jersey cattle to diseases, breeding conditions, and bad temperaments very much discourage adoption.

**Disease susceptibility**: The improved breeds could be more susceptible to local diseases, and this can threaten herd health.

**Environmental challenges**: Cattle health and productivity are impacted by harsh local conditions, particularly in breeds not adapted to the local environment.

**Poor infrastructure**: Poor infrastructure constrains the ability to deliver effective AI services or any of the other improved reproductive technologies.

**Gender disparities**: The overwhelming male dominance in cattle farming, at 94.7%, may not harness the full potential of the labor force if women are not equally involved or supported.

## 4. Discussion

The results of this study shade light on different aspects of cattle farming and reproductive practices in the provinces of South Kivu and Tanganyika, eastern Democratic Republic of Congo. These results have broad implications for the productivity of cattle farming in sub-Saharan Africa and for alleviating poverty, given that livestock is central to most livelihoods in rural communities.

### 4.1. Strong attachment to traditional practices versus adoption of improved technologies

As reported in Benin (Babatounde et al., 2012; Assani et al., 2015) and Gambia (Ejlertsen et al., 2012), cattle herds in South Kivu and Tanganyika heavily rely on traditional farming practices and local breeds. Farmers in these regions demonstrate extensive experience in livestock farming, reflecting a deep-seated knowledge and cultural connection to traditional practices. Studies have shown that the adoption of improved technologies correlates with farmers' experience and age (Karanja-Lumumba et al., 2015; Wordofa et al., 2021; Rahman et al., 2023). However, despite their experience, there is a significant gap in the adoption of improved breeds and artificial insemination. Most farmers adhere to traditional practices, with 85.7% in South Kivu and 86.6% in Tanganyika raising cattle using limited supplementary feeding and improved breeds. This dependence on traditional practices suggests many farmers are unable to adopt improved breeds and artificial insemination. Only 29% of farmers raised both local and improved breeds, and just 25% adopted artificial insemination. Factors such as limited availability of AI services, financial barriers, poor performance of improved breeds under harsh conditions, high nutritional requirements, and susceptibility to diseases contribute to low adoption rates (Mugumaarhahama et al., 2021a). Addressing these issues through targeted interventions can improve productivity by promoting the adoption of improved practices and technologies.

### 4.2. Higher awareness and higher willingness to adopt improved technologies are not enough

Despite cattle farmers' strong attachment to traditional practices, which leads to low productivity, significant opportunities for improvement exist in South Kivu and Tanganyika through the adoption of improved breeds, artificial insemination (AI), and modern practices. One of the most notable findings in this study is the stark difference in AI awareness and adoption between the provinces: AI awareness in South Kivu is 73.9%, compared to just 34.4% in Tanganyika. However, awareness alone cannot drive adoption (Janssen-Tapken et al., 2006; Dickson et al., 2018). For instance, AI requires specialized equipment and highly skilled personnel (Rathod et al., 2016), leading to the low availability of AI services which in turn significantly limits farmers' exposure to AI—13.7% in South Kivu and 6.3% in Tanganyika. Yigezu et al. (2018) emphasized that farmers' adoption of improved technologies increases with both, exposure and awareness. Consequently, despite the higher awareness in South Kivu, due to low exposure, the adoption rate remains around 25% in both provinces. This study revealed a strong readiness among farmers to apply AI, with 65% expressing willingness to adopt it and 56.2% willing to pay for the services, driven by the perceived benefits in genetic quality and productivity. Establishing AI centers and training local veterinarians could significantly increase adoption rates and farms' productivity. Current reproductive practices can serve as a foundation for further improvement.

### 4.3. Challenges associated with grazing improved breeds on community pastures

Productivity in cattle farming also depends on healthcare and general management practices. Diet is a very important component of success in cattle farming. Despite improved breeds being much more productive, they have difficulty adapting to the rural harsh conditions of South Kivu and Tanganyika, which is reflected in their high susceptibility to disease in harsh farming conditions, which can lower their productivity. Moreover, farmers criticize these breeds for being too demanding in terms of rearing conditions to express their full productive potential. The poor quality and degradation of community pastures, along with the associated health problems, limit the adoption of improved breeds (Mugumaarhahama et al., 2021a). Community pastures are often linked to a higher risk of parasites and diseases carried by ticks (Pearson and Krecek, 2006; Katongole et al., 2012). Yet in these provinces, cattle feeding is based almost exclusively on communal grazing lands, which are not very productive due to their degradation (Mugumaarhahama et al., 2021a). Poor nutritional management in communal grazing lands has been identified as a major cause of the poor performance of improved livestock breeds (Ngongoni et al., 2007; Tavirimirwa et al., 2013). As stated by Rahman et al., (2023), with limited financial resources, famers do not have ways to provide appropriate diet to their cattle. As depicted in the study, 88.2% of farmers depend on forage alone in feeding their cattle. This kind of dependence restricts its optimum nutritional and productive potential. Although, supplementary feeding practices must be highly encouraged and supported as complementary activities to forage, the financial constraints faced by livestock farmers make it difficult for them to obtain concentrated feed to make up for the deficit in pasture feed. According to Maass et al. (2012), one of the main feeding constraints in livestock production in South Kivu province is the high cost of concentrates and by-products. The same challenge was reported in Bangladesh (Sarma et al. 2014; Rahman et al., 2023).

### 4.4. Younger and educated farmers are more flexible to adopt improved breeds and AI

Socioeconomic characteristics of cattle farmers further deliver important insights. Among the key challenges that have been singled out, the educational background of the farmers is relevant. The level of education features as a significant determinant of adoption of improved reproductive practices. Farmers with university education are more likely to adopt improved breeds and AI compared to illiterate farmers, thus the importance of educational attainment in influencing adoption of improved reproductive practices. The positive relationship between educational attainment and adoption of agricultural innovations is strongly supported by empirical data (Katungi & Akankwasa, 2010; Mwangi & Kariuki, 2015; Dontsop-Nguezet et al., 2016; Ramos-Sandoval et al., 2016; Omondi et al., 2017; Mondo et al., 2019; Mutenje et al., 2020; Mugumaarhahama et al., 2021b; Okello et al., 2021). The majority of farmers are either illiterate or have only primary education, which adversely affects the accessing and understanding of new technologies and improved farming practices. In fact, the farmers with these lower education levels are also the oldest and include the highest number of widowers. These two characteristics are also associated with the low rate of adoption of improved breeds and AI. Results of this study show that since farmers are young, they could therefore be more open to adopting new technologies and thus may be more willing to consider adopting improved breeds and using AI. These results are in line with previous research, which indicate that age is an important factor influencing technology adoption (Mignouna et al., 2011; Li & Sicular, 2013; Hamilton et al., 2015; Mondo et al., 2019; Sharma et al., 2020; Mugumaarhahama et al., 2021b). According to these findings, younger farmers who take risks tend to be more accepting of new technologies than older farmers. Despite the fact that the average age of farmers is higher in South Kivu than in Tanganyika (53.8 years compared to 44.6 years old in Tanganyika), which may mean higher adoption of improved breeds and AI in Tanganyika that in South Kivu, the contrary is observed. Although there is space for younger farmers to become more involved in cattle farming in Tanganyika, the adoption rate of improved breeds and AI is still lower than in South Kivu. This could be explained by problems of availability and accessibility of improved breeds and AI as well as cultural and financial barriers being more pronounced in Tanganyika.

### 4.5. Challenges associated with financial barriers and low access to agricultural credits

Given the high cost of cattle of improved breeds and the limited availability of AI (particularly the semen), limited financial resources of farmers is a key challenge is related to their adoption. Livestock farmers whose only income-generating activities are agriculture or livestock farming find it extremely difficult to obtain the financial resources needed to acquire improved breeds of cattle, which are very demanding in terms of rearing conditions, making them very difficult to raise in farming environments characterized by very harsh conditions characteristics by low inputs. The other critical element that warrants attention is the financial support mechanisms given to farmers. One of the major constraints to investing in improved breeds and technologies is the low access to agricultural credit, at 39.9%. The majority of cattle farms in South Kivu are classified by Mugumaarhahama et al. (2021a) as Type 1 farms, characterized by small herds of six cattle of local breeds (on average). As the size of herd in pastoral communities is a good indicator of farmers' financial status (Omollo et al., 2018), the majority of farmers in Soth Kivu and Tanganyika are considered to be in a poor financial position, limiting their ability to adequately adopt improved technologies. Results of this study show that the likelihood of adopting improved technologies increased with herds' size, indicating that farmers with larger herds had higher financial status and were more likely to adopt improved breeds and AI. Pprevious researches have indicated that the adoption of improved technologies is promoted by farmers' higher financial status (Gedikoglu et al., 2011; Rahman et al., 2023). Consistently with previous researches (Rathod et al., 2016; Jelinski et al., 2020; Rahman et al., 2023), the poor financial status of the majority of farmers in South Kivu and Tanganyika could explain the low adoption of improved technologies. Moreover, the low productivity of livestock farms and local cattle breeds leads farmers being unable to generate significant profits (Rahman et al., 2023) to increase their investment capacity and credibility vis-à-vis microfinance institutions likely to give them access to agricultural credit. According to Mondo et al. (2019), because the majority of farms in South Kivu follow a subsistence model, these smallholder farmers are unable to repay previous loans from microfinance institutions. This keeps them in a vicious circle of poverty and inability to improve their livestock and livelihoods. However, the results of this study show that they are willing to improve the productivity of their livestock by showing willingness to adopt and continue to use improved technologies that enable them to increase farm productivity, which translates into improved livelihoods and poverty reduction by providing farmers with better financial status (Cunguara & Darnhofer, 2011; Teklewold et al., 2013; Hailu et al., 2014; Habtemariam et al., 2019; Wordofa et al., 2021). By easing financial barriers and increasing the household's ability to absorb risk, the availability of agricultural credit encourages farmers to adopt improved technologies (Mohamed & Temu, 2008). The development of microfinance schemes and collaboration with the financial institutions in creating of and offering financial packages tailored to farmers with limited resources (Muzari et al., 2012) are need to empower farmers to invest in improved breeds and technologies. Subsidies or incentives can therefore enhance farmers' motivation and defray the cost of using improved reproductive practices and breeds.

### 4.6. Farmers' networking is needed for effective improvement actions

The role of social networks and collective support is also patent, with membership in associations increasing significantly the likelihood of adoption of improved technologies. The results of this study indicate that farmers' membership in associations is low (27.6% in South Kivu and 25.8% in Tanganyika), resulting in poor social networking. This could undermine the effectiveness of actions and policies aimed at improving mass adoption of improved technologies. This may be explained by association members' frequent interaction with farmers' support organizations and extension services, which helps them learn about improved technologies (Ainembabazi et al., 2016; Wossen et al., 2017). In addition, associations are more likely to receive materials of improved technologies and funding than individuals. Research shows that belonging to a social group increases social capital and facilitates the sharing of trust, ideas, and information among association members (Uaiene, 2008; Mignouna et al., 2011; Mwangi & Kariuki, 2015). This shows that community-based approaches and cooperative models could be an effective means to facilitate the adoption of improved practices and technologies. By working through these

existing social structures, extension services and development programs can better reach out to people and make a greater impact.

### 4.7. Disparities in gender

In terms of gender, women are underrepresented in livestock production. A potential area where the actualization of this labor force potential can be improved is the gender imbalance in cattle farming, with a strong male dominance of 94.7%. The fact that most farmers are men in both provinces—93.8% of them in South Kivu and 95.7% of them in Tanganyika provide evidence of gender disparities in cattle farming. This may be due to the low level of emancipation of women in rural areas and cultural attitudes that recognize men as the owners of large animals like cattle. In fact, livestock farms are often family-owned, which suggests that, from a cultural perspective, the heads of households - who are usually men - own the farms (Mugumaarhahama et al., 2021a). For this reason, it's common knowledge that male heads of households keep animals. Because of these gender differences or inequalities in livestock ownership, it is difficult to get an accurate picture of the extent of women's involvement in livestock production (Njuki and Sanginga 2013). The women's livestock situation in South Kivu and Tanganyika is similar to that in Ethiopia and Nigeria, where most women are rarely involved in livestock production. In the agricultural sector, women are more likely to work at home, taking care of children, preparing meals, and transporting fuel and water (Yisehak 2008; Ayoade et al. 2009).

### 4.8. Implications of current low adoption of improved technologies for SDG1, SDG2, and African Union's Agenda 2063 attainment

SDG1 aims at reducing poverty in all its dimensions everywhere. In this respect, increased adoption of improved agricultural technologies such as improved breeds and AI is critical to improving farm productivity and increasing farmers' incomes. This sets an economic growth limit to farming communities, who often apply traditional farming practices that lead to lower productivity. Low adoption of improved technologies limits the ability of farming communities to get out of the poverty trap. Clearly, low productivity means less marketable surplus. This limits the farmers from investing in further improvement, education, and healthcare. Hence, poverty becomes widespread in these areas. Therefore, SDG1 cannot be achieved.

The aim of SDG2 is to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture. Low adoption rates for improved breeds and AI will directly encroach on food production. Traditional farming practices usually result in low production that cannot sustain the ever-increasing human population. This deficit may promote food insecurity, leading to a myriad of malnutrition, especially in susceptible groups of people. Low adoption of improved reproductive technologies also retards the genetic improvement of animals so that more resilient and productive ones can be bred. Not adopting these technologies therefore puts a constraint on the achievement of food security and sustainable agriculture key messages of SDG2.

The African Union Agenda 2063: Envisions a Prosperous Africa Based on Inclusive Growth and Sustainable Development. This is underpinned by transformation of the agricultural sector to achieve food security, job creation and poverty reduction. Low diffusion of improved agricultural technologies in South Kivu and Tanganyika exemplifies a lost opportunity for such transformation. Without the infusion of modern technologies, farming remains labor-intensive and of lower productivity, hence making it less potent in creating job opportunities to spur economic growth. This stagnation of agricultural productivity and innovation undermine the goals expressed in the Agenda 2063 of the African Union, which builds on modernized agriculture as a cornerstone for sustainable development.

### 4.9. Strategies for improvement

**Awareness and training:** Periodic workshops and trainings regarding the benefits and methods of AI and improved reproductive management practices should be organized. Moreover, build up extension services with extension workers in the field who can guide and assist farmers in the villages.

**Improve access to AI services:** Strengthen the infrastructure related to AI services by establishing AI centers and mobile units in the rural areas; offer AI services at a reduced price through the use of subsidies or any other form of financial incentives on the farmers; train local vets and technicians to increase the availability of AI services.

**Promote improved breeds:** Develop cattle breeds that combine the hardiness of local breeds and the productivity of improved breeds through selective breeding. In addition, incentivize farmers' adoption and continued use of improved breeds through financial support or better market access.

**Enhance feeding management:** Educate farmers on how to complement poor nutrient forages with rich nutrient feeds to attain enhanced cattle health and productivity. In addition, encourage the cultivation of high-nutritional forage crops so that the cattle will receive adequate supplies of quality feeds continuously.

**Enhance disease management:** Extensive vaccination programs should be undertaken to save the improved breeds from endemic diseases. Furthermore, extension of better veterinary services to ensure timely treatment and preventive care to cattle.

**Supportive policies and credit facilities:** Steps should be taken to promote agricultural credit by linking with financial institutions in extending low-interest loans to farmers. Moreover, support policies that promote improved breeds/reproductive practices through financial incentives such as subsidies and grants.

**Redress Gender Imbalance:** Initiate programs for women farmers by making available credit facilities, training, and other resources. Furthermore, engendering gender equity in farming practice—sensitization programs and community outreach.

## 5. Conclusion and policy implications

This study shade lights on challenges in the adoption of improved cattle breeds and artificial insemination in South Kivu and Tanganyika. Even though farmers have long experience and are culturally attached to traditional practices, the use of improved breeds and artificial insemination clearly has a gap, with 29% and 25%, respectively, in terms of adoption rate. This low adoption is influenced by several factors, including limited AI service availability, financial constraints, and harsh rearing conditions affecting the performance of improved breeds. Exactly, results show stark differences in AI awareness between South Kivu and Tanganyika, yet having similar adoption rates, hence implying that awareness alone is necessary but not sufficient to drive adoption. These findings call for more targeted interventions to improve the uptake of modern agricultural technologies. Addressing these challenges will hence be important in improving farm productivity and attaining broader development objectives. The potential to increase livestock productivity and hence economic growth, which are sources of poverty reduction required by the SDGs 1 (No Poverty) and 2 (Zero Hunger), and the African Union Agenda 2063, is constrained by low adoption of improved technologies. Improved breeds and reproductive technologies have huge potential for improvement of food security, nutrition, and income for farming communities, hence sustainable agricultural development. Preliminary results offer promising ground for future interventions that seek to transform cattle farming practices in South Kivu and Tanganyika, particularly with regard to farmers' readiness to adopt AI and their willingness to invest in these technologies.

The findings of this study underline a number of key policy implications critical for the wide-scale diffusion of improved agricultural technologies and practices in South Kivu and Tanganyika. First and foremost, policies should be implemented, facilitating the availability and accessibility of AI services and improved breeds. To this end, AI centers could be established, local veterinarians could be trained, and there could be subsidies or financial incentives toward the technologies for farmers. In this respect, infrastructure investments and capacity building shall be priorities among policymakers to make sure that farmers have the resources and required support to adopt improved farming practices and technologies. The second measure in bridging the knowledge gap and building farmers' preparedness in adopting new technologies should be through integration of educational and awareness programs into agricultural policy frameworks. This can be done through workshops, seminars, and on-the-job trainings, whereby the problems of improved breeds and reproductive technologies are explained, together with the benefits accruable from adoption, and practical advice on application and management. In addition, policies have to consider the development in veterinary services and vaccination programs to minimize health risks from improved breeds to be productive and sustainable. Such policies would enable an environment in which innovation can be fostered, agricultural productivity enhanced, and poverty reduction, food security, and sustainable development efforts advanced in line with the broader goals spelled out in SDG1, SDG2, and the African Union Agenda 2063.

## Declaration

### Ethics approval and consent to participate

All methods were carried out in accordance with relevant institutional guidelines and regulations. The study protocol was reviewed and approved by the Social Sciences Research Ethics Committee of Université Evangélique en Afrique (Ref: SSREC/1214/018S). All participants provided written informed consent prior to their inclusion in the study. Data were fully anonymized before analysis.

### Clinical trial number

Not applicable

### Consent for publication

All authors gave their consent for publication

### Availability of data and material

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

### Competing interests

The authors declare no competing interests.


### Funding

This study was supported by the World Bank Group through the Integrated Project for Agriculture Growth in the Great Lakes Region (PICAGL - P143307) implemented by the International Institute of Tropical Agriculture (IITA) in eastern Democratic Republic of of the Congo


### Authors contribution

RA, YM, VM and SB contributed to conceptualization and methodology,
RA, VM, YM, DW and SB collected and curated the data,
RA, YM, VM and SB performed formal analysis,
RA, YM, VB, SB and DW wrote the main manuscript text
All authors validated the study, reviewed and edited the manuscript, and read and approved the final manuscript.

**Acknowledgements**

This research was funded by the World Bank through the Integrated Project for Agriculture Growth in the Great Lakes Region (PICAGL) implemented by the International Institute of Tropical Agriculture (IITA) in South-Kivu and Tanganyika provinces. Unreserved information provided by cattle farmers and key informants from both provinces is recognized by the authors. Enumerators and other researchers from the Université Evangélique en Afrique (UEA) and IITA are thanked for their engagement and contribution in data collection.

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