UNIVERSITE EVANGELIQUE EN AFRIQUE

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

PROJECT REPORT

RU/2020/GRG/08

FROM NOVEMBER 2020 TO DECEMBER 2022

Improving animal productivity through the valorization of local food resources in South Kivu province, Eastern Democratic Republic of Congo

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GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES

RUFORUM Capacity Building in Agriculture

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ABSTRACT

In South-Kivu province of the eastern DR Congo, the lack of both high-quality and sufficient forages has a negative impact on cattle farming. This situation has worsened recently due to the problems related to the climate change that make the pastures less productive by shortening the period of the rainy season. The Université Evangélique en Afrique/ Faculty of Agricultural Sciences was awarded a two-year project (2020–2022) by the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) and the Global Research Alliance on Agricultural Greenhouse Gases (GRA) with the goal of resolving this issue. The project's vision was to train the current and future generation with the goal of increasing the productivity of livestock in South Kivu, Eastern DRC in the context of climate change. The main objective of this project was to contribute to the evaluation of local feed resources utilization (feed balances) for improved productivity and better accounting of greenhouse gas emissions in ruminants in South Kivu. A household survey was conducted on 692 smallholder farmers from three *territoires* of South Kivu province, including Kabare, Uvira, and Walungu to inventory the livestock feeding practices in order to develop strategies for better livestock feeding. The size of the herd, ruminant eating habits, and primary feed sources that make up the majority of a livestock's diet were the key topics of the survey. The next step was to assess the carrying capacity of the South Kivu pastures by examining their species composition, richness, and nutritional value in connection to the type of soil and the agro-ecological zones (Kabare, Uvira, and Walungu). For pastures floristic diversity, fifteen pastures were chosen. 976 cattle farmers were chosen from five of the province's eight territories, including 179 in Kabare, 344 in Walungu, 207 in Uvira, 182 in Kalehe, and 63 in Mwenga, to characterize how farmers in the South Kivu province perceive and are vulnerable to climate change-related shocks. Participatory interviews with farm managers and a standardized survey questionnaire were conducted on each farm. Primary data on the situation and trends of climate risk, as well as its impact on livestock production (feed, water, disease, productivity), were gathered from the available literature. Secondary data on the situation and trends of climate risk, as well as its impact on livestock production (feed, water, disease, productivity), were also gathered. A total of 4 MSc student from the Department of Animal Production, Faculty of Agriculture and Environmental Sciences at the Université Evangélique en Afrique (UEA). The dissemination of the obtained results consisted in seminar with researchers, students, extension agents and farmers on feeding practices, feed resources management, and methods of improving animal feeding in order to reduce feeding costs and greenhouse gas emissions. Principal results indicate that indicate that current feeding practices for ruminants are insufficient to increase

livestock productivity. It is primarily composed of forage (100%) and crop residues (70.8%), and while nutritional supplements are rarely added (22.7%). The used community pastures are insufficient to meet the nutritional needs of the animals. Animal nutrition must be improved in order to boost animal productivity. In addition, the implemented feeding strategies must ensure adequate nutrition for animals during the dry season and contribute to the mitigation of climate change effects, which could become more severe if greenhouse gas emissions are not significantly reduced, especially in livestock farms, which are also a major source of greenhouse gas emissions. This is especially true given that livestock farms are a major source of greenhouse gas emissions. A total of 169 plant species distributed in 117 genera and 38 plant families. The two plant groups that were most frequently encountered were Fabaceae (33% in the rainy season and 19% in the dry season) and Poaceae (26% in the rainy season and 23% in the dry season). The pasture typology identified three distinct types of pasture: the first type is found in Uvira *territoire* and consist of cluster of *Hyparrhenia rufa* and *Brachiaria ruziziensis*; the second type characterized by a grouping of *Digitaria abyssinica* (A. Rich.) Stapf , *Centella asiatica* (L.) Urb., *Paspalum notatum* Fluegge and *Axonopus sp*. on clayey soil; the third group is characterized by the grouping with *Digitaria abyssinica* (A. Rich.) Stapf and *Paspalum scrobiculatum* L. on a clayey-silt soil. Farmers in Uvira are the most affected by climate change, while those in Kabare, Kalehe, and Mwenga are similarly affected. Farmers from Kalehe are the least susceptible to the effects of climate change, while those from Uvira and Mwenga are the most sensitive, followed by those from Walungu. Moreover, farmers from Uvira are the best at adapting to the consequences of climate change, ahead of farmers from Walungu, Kabare, Kalehe, and Mwenga. The most vulnerable to climate change are the illiterate farmers who do not belong to farmers' associations, have no other source of income except agriculture, have the largest household sizes (10.3), and have the fewest adults. Farmers believe that the causes of climate change and its effects are either divine will (47.5%) or unidentified sources (29.9%). Strategies including income diversification, greater livestock investment, animal stalling or transhumance, crop residue use, increased disease and pest control, and prayer are likely to be implemented in order to deal with these effects.Three men and one woman were selected for MSc studies. The three men have completed their degree in Environmental Resource Management at the Université Evangélique en Afrique (UEA), Faculty of Agriculture and Environmental Sciences while the woman completed her degree in Biostatistics at the University of Abomey-Calavi. A 2-day session on methods for enhancing pastures for better animal nutrition was attended by 56 stakeholders in all, who also got training materials and flyers on the four topics covered throughout the event.

Three key strategies were raised by all stakeholders to improve animal productivity through animal feeding. They include: good pasture management, good management of animal feeding and forage conservation. For the applicability and the implementation of these strategies; keys actors including farmers (individual or farmers' associations), policy makers in livestock sector and in land use management, researchers in livestock sector as well as local, national and international associations or NGOs involved in livestock sector and particularly animal feeding should be working together. A public-private partnership is required for the good management of livestock production sector. In conclusion, South-Kivu's current ruminant feeding practices are insufficient to improve livestock productivity. It primarily consists of fodder and crop remnants, and nutritional supplements are rarely employed. Moreover, the used community pastures are insufficient to meet the animals' nutritional demands. To accomplish this goal, it would be beneficial to adopt strategies based on integrated agro-sylvo-pastoral systems that are completely eco-friendly, practical on small plots of land, and beneficial for both sustainable food production and more productive animal production with low greenhouse gas emissions. Pastures of the 3 *territoires* are rich in plant species but most of them are not grazed by animals as a result of their poor nutritional value and carrying capacity. These pastures should be reinforced with improved forage species with high biomass production and nutritional values for better animal nutrition, especially during the dry season. For better animal nutrition, especially during the dry season, these pastures should be strengthened with enhanced forage species with high biomass production and nutritional value. It would be important to adopt new technologies (breeds and techniques) to improve the resilience of farmers to climate change. A public-private partnership including government services, NGOs, research institutions and farmers is required for the good management of livestock production sector.

Key words: Animal nutrition, Greenhouse gas, Local food resources, MSc students, Pasture management, RUFORUM, South Kivu province, UEA

Chapiter 1: PROJECT OVER VIEW

1.1.About the RU/2020/GRG/08 project

On May, 2020 The Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) and the Global Research Alliance on Agricultural Greenhouse Gases (GRA) invite applications from RUFORUM Member Universities for the first Global Research Alliance Graduate Research Grants (GRA-GRG) call. The Global Research Alliance Graduate Research Grants (GRA-GRG) are aimed at building the capability of graduate and post-graduate level students in Africa to conduct applied research on agricultural greenhouse gases. This specific Call of **US$70,000** intended to extend university activities to work more closely with rural communities through multidisciplinary and multi-institutional partnerships involving key stakeholders such as research, extension and development agencies, policy-makers and the private sector.

In this sense, the Evangelical University in Africa through its Faculty of Agricultural Sciences has coordinated for two years (2020-2022) this project whose vision was to train the current and future generation with the aim of improving the productivity of livestock in South Kivu, Eastern DRC.

Under the research-intensive training program, a multidisciplinary team of Master Students, BSc were trained and worked to improve the productivity of ruminants through the valorization of locales feed resources in South Kivu. This project aimed the evaluation of local feed resources utilization (feed balances) for a better accounting of greenhouse gas emissions and increase productivity in ruminants in South Kivu. This included the inventory and characterization of feed resources for ruminants, the evaluation of the distribution and the spatial-temporal variability of feed resources, the evaluation of the nutritional value of identified feed resources, a suggestion of a scheme to improve the use of these resources according to time and space, the strengthening of the capacities of stakeholders on the identification, management and valorization of feed resources available for ruminants in South Kivu.

1.2.The problem behind the project

Livestock play important economic and socio-cultural roles in both developed and developing countries, such as food supply, income generation, employment provision, livelihoods, transportation, agricultural traction, agricultural diversification and sustainable agriculture (Bettencourt et al., 2015, Moyo et al., 2020). However, despite the importance of livestock in most African countries, its productivity remains insignificant to meet the needs of the population. Several factors, including the breeding system, genetic potential of the animals raised, feed sources, husbandry practices, diseases, etc. are associated with this decline in livestock productivity (Otte and Chilonda, 2000). In the Democratic Republic of Congo (DRC), animal husbandry contributes more than 72% of the household income of rural populations representing more than 75% of the total population. In the Eastern part of the country, livestock play multiple important roles for smallholders; livestock farming is essentially traditional and dominated by species of local breeds of cattle, pigs, goats and chickens and contributing to the source of income of the populations (Mutwedu et al., 2015, Mugumaarhahama et al., 2016, Akilimali et al., 2017, Wasso et al., 2018). The type of feeding, dominated by forages with or without supplement is one of the factors constraining livestock productivity in the region.

At the national level, animal feed and, especially that of ruminants, contribute for more than 10% to the destruction of the environment through the production of greenhouse gases (Steinfeld et al., 2006; Gerber et al., 2013), deforestation for the expansion of arable and grazing land. Thus, good management, improvement of resources and feed quality, and the development of non-methanogenic feed resources (Tisserant, 1990) would be of paramount importance to increase production and reduce greenhouse gas emissions, which is one of the sources of climate change (FAO, 2010).

In the livestock sector in the DRC, there are few strategies and investigations in the framework of improving animal nutrition and productivity. Thus, an inventory, an evaluation of the quality and quantity of food resources (fodder, crop residues, by-products of agri-food industries, etc.), a study of their availability and their distribution in time and space are important for the development of this sector. This would benefit not only livestock farmers but also researchers and policy makers in this field. Given that animal production through its feed has impacts on the environment (Steinfeld et al., 2006) through the production of greenhouse gases; understanding the harmful effects, the management of animal feed, the improvement of its quality and the valorization of other feed sources (crop residues, agro-industrial by-products) (Tisserant, 1990) are important in the conservation of the environment (Gerber et al., 2013; FAO, 2010). This project is therefore part of the framework for improving livestock productivity in South Kivu through the development and improvement of livestock feed resources, proper management of animal nutrition and feeding while preserving the environment and reducing greenhouse gas emissions related to animal production. This project is in line with the objectives of the African Union, since it contributes to the knowledge or the establishment of a feed balance in South Kivu in particular and in DRC, in general. It will help improve the agricultural sector, and will guide decision makers in making decisions on animal production and use of available resources, and pasture management, both at the local and national levels. This project will support policy makers, producers and livestock sector stakeholders to improve animal feeding practices, planning and evaluation of livestock production. It will enable livestock farmers and operators to properly assess the adequacy between the needs of the livestock and the available food resources for a good response in case of lean season.

1.3.Associated projects

This project complemented projects including “Enhancing productivity of smallholder’s farmers on the steep slopes of DRC” supported by USAID hosted by Food for the Hungry (FH) which contributed to the Identification and characterization of crop residues and food by-products used in animal nutrition in the target areas, to set up multi-local fodder trials in order to evaluate their agronomic performance and farmers' appreciation in the respective areas.

Two UEA based project namely: “Valorization of local food resources in chicken and pig feed; Valorization of phytobiotics in the feed of strict monogastrics” have developed a database that served as a reference for the present project.

1.4.Project Objectives

1.4.1. Main objective

Contribute to the evaluation of local feed resources utilization (feed balances) for improved productivity and better accounting of greenhouse gas emissions in ruminants in South Kivu.

1.4.2. Main objective

a) to make the inventory and characterize feed resources for ruminants
b) to evaluate the Pastures floristic diversity and chemical characteristics of forages
c) to evaluate the distribution and the spatial-temporal variability of feed resources
d) to strengthen the capacities of stakeholders on the identification, management and valorization of feed resources available for ruminants in South Kivu
e) to propose a scheme to improve the use of these resources and to evaluate the performances of animals raised on local pastures
f) to perception of small livestock keepers on the effect of climate related risks and household food security: the case of South Kivu province, Eastern DR Congo

1.5.Project's Conceptual Framework

The project involved a multidisciplinary team comprising staff from the "Universite Evangelique en Afrique (UEA)", the "Institut National de Recherche et d'Etude Agronomique (INERA)", local and national organizations and researchers involved in livestock sector, the "Centre de Recherche en Sciences naturelles (CRSN)", "Inspection Provinciale de l'Agriculture, Pêche et Elevage (IPPEL)", and farmers (individual and farmers' associations). All these stakeholders involved in the project had the objective of contributing to the improvement of animal productivity through the improvement of livestock feeding. To achieve this, a methodology based on the different specific objectives was developed as presented in the Project's Conceptual Framework (Figure 1).

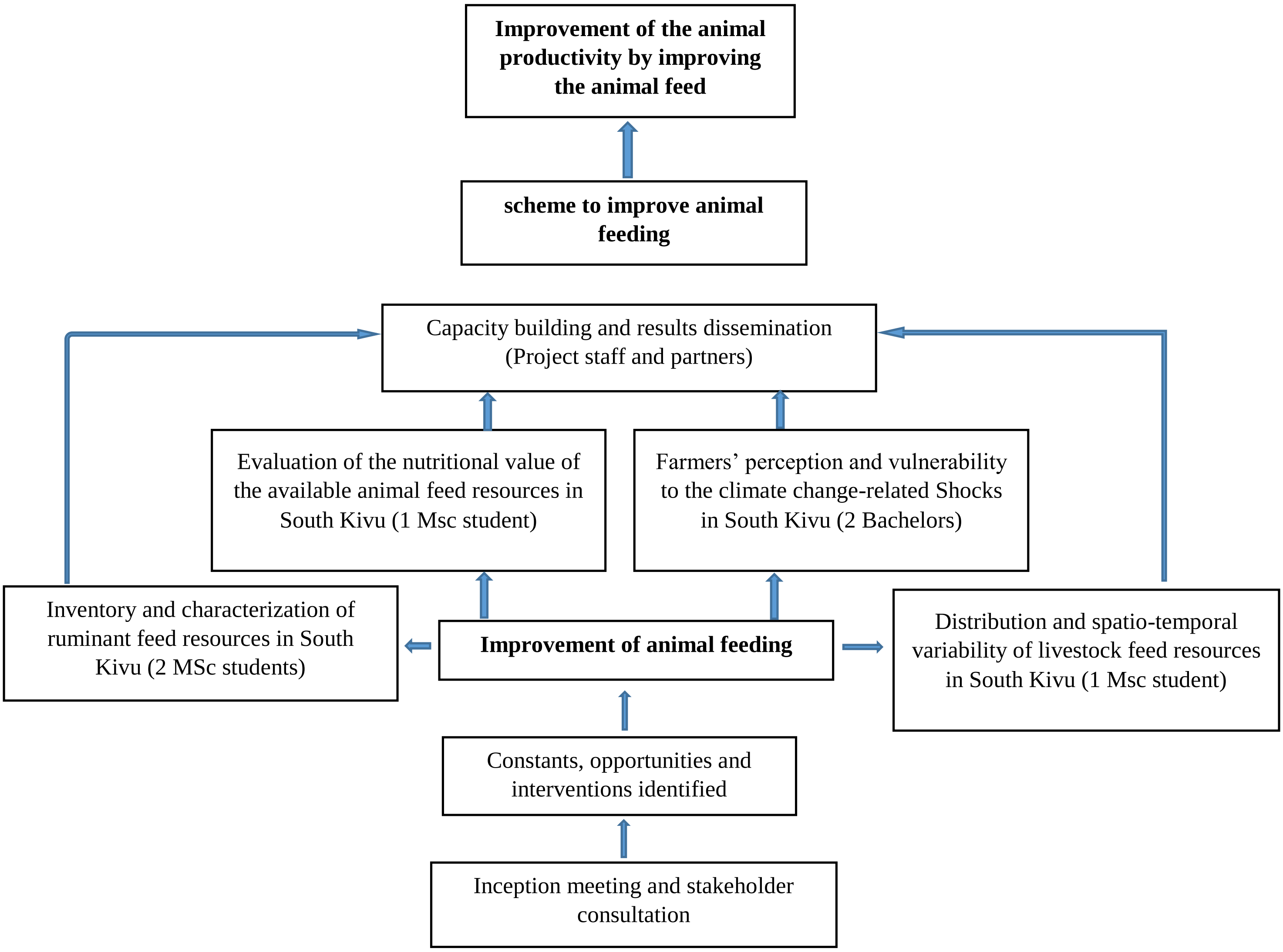

Figure 1 *Conceptual Framework*

1.6.Partners' involvement

The project has being implemented by a consortium of partners and institutions from the public and private sectors as well as farmer groups and community based organizations. the " Université Evangélique en Afrique (UEA)" was the lead institution in partnership with the 'Inspection Provinciale de Pêche et Elevage (IPPEL), the "Institut National de Recherche et d'Etude Agronomique (INERA), the "Centre de Recherche en Sciences naturelles (CRSN) (CRSN). Below is the list of key project partners: The report on partners' involvement, their role on the project and contacts is summarized in Table 1.

***Table 1**. Partners' involvement*

I. Researchers and Supervisors			
No	**Name & Institution**	**contacts**	**Roles**
1	Prof Pascaline CIZA (UEA)	pascalineciza@gmail.com	PI &Student Supervisor: 2 MSc Student
2	Dr Patrick Baenyi(UEA)	baenyipatrick@gmail.com	CO-PI, follow-up of students' activities
3	Dr Valence Mutwedu (UEA)	mutweduvalence@gmail.com	Project Assistant , organization and follow-up of field activities
4	Mr Yannick Mugumaarhahama(UEA)	yanmuguma@gmail.com	Project Assistant , organization and follow-up of field activities, data analysis
5.	Prof Katcho Karume (UEA)	kkatcho@yahoo.com	Mentor & Student supervisor: 1 MSC Student
6	Prof Ayagirwe Basengere (UEA)	raygirwe@gmail.com	Mentor & Student supervisor: 1 MSC Student
II. Students			
7.	Emmanuel Kunde	kundamani2018@gmail.com	MSc. Student working on objective 1 et 2
8.	Mwanga Mwanga Ithe (CRSN)	Ithemm1801@gmail.com	MSc. Student working on objective 1et 2
9.	Furaha Mpuranyi (University of Abomeyi Calavi)	Julianessy82@gmail.com	MSc. Student working on objective 3
10.	Justin Amani	Amanijustin15@gmail.com	Msc Student working on Objective 3 (partially)
III. Others institutions			
11	Provincial Inspectorate of Fisheries and Livestock (IPPEL),	ippelskivu@mail.com	-To facilitate data collection and dissemination of key results of the project, to supervise the farmers activities.

12	National Institute for the Study and Research in Agronomy (INERA)	ineramul@gmail.com	To facilitate data collection and dissemination of key project results
13	Center for Research in Natural Sciences (CRSN)	bbajope@yahoo.fr	To facilitate the collection and analysis of vegetation data from pastures and implement the resulting recommendations.
IV. Extension Officers and Local Community			
14	GASTON/ Coord PAFVD: kabare, Mudaka Village	+243 991200180	Non-academic partners engaged with extension services and coordination of farmers
15	Jean PIERRE/ vet , Miti village	+243 991419972	
16	Munyerenkana Stephanie, Kavumu village	+243 976827581	
17	Ir Francis Kaloko/Bio kivu	+243999488682	
18	Honore Banywesize/ Walungu village	+243 990092139	
20	Mr Kabiona/ Coord HERI KWETU, katana village	+243 997780033	
21	Mr Samy Bacigale , IITA Uvira,	+243 996728594	
22	Mr Thierry Cishesa, ISEAV	+243 990857623	

There was modification to project design, stakeholders, partnerships envisaged support to the implementation process planned for the project. It was initially planned to have two master's students but we ended up with 4 master's students plus 3 bachelors (not mentioned). We also expanded the area of coverage and the network with a focus on farmers' perception and vulnerability to the effects of climate change on livestock production. As the project team members and collaborators have different expertise that fits well with the research objectives, mentorships were provided by the project team members and stakeholders who worked in the area where the project is implemented.

1.7.Students’ Recruitment and research

1.7.1. Students ‘recruitment and enrolment

The project involved 3 master students who worked on the objectives 1,2,3 in the framework of research capacity building, a 4th student was recruited, to complete the objective 2 in order to have an idea on the characterization of the pastures that could be at risk of health for the animals. The training opportunity was announced on the UEA website and information was sent to research institutions, including the project partners, namely CRSN and INERA, IITA. Interested students applied by submitting concept notes of research projects that are aligned with specific research objectives, a CV and proof of enrolment in the master program (as one of the conditions was to have done at least 6 months of master courses) as specified in the call for applications. In order to achieve the research objectives, we initially needed two master's students who should do their program at the local level, but some challenges arose and in order to overcome them we chose students who have finished the master's courses with a research need only.

1.7.2. Students ‘academic and research

The Table 2 summaries the student’s information at the end of the project.

***Table 2**: Student's information*

<table>
<tr><th>Names</th><th colspan="2">Student Details</th><th>Supervisors</th><th>Remarks</th></tr>
<tr><td rowspan="6">1.Emmanuel Kunde</td><td colspan="2">Degree program: MSc in Environment and sustainable management of natural resources
School: Université Evangélique En Afrrique (UEA) Registration date: Nov 2019
Registration number: 22346

Research Title: Evaluation of nutritional value of forage resources used in cattle feeding in South Kivu, DRC
Graduation date/year: November , 2022</td><td>Prof Ayagirwe Basengere
Prof Pascaline Ciza</td><td>1 paper in preparation
1 paper submitted with the project team</td></tr>
<tr><td colspan="4">Presentations &/ conferences</td></tr>
<tr><td colspan="4">-3 orals presentations at school level (UEA)
-Defense of the master's thesis (UEA, March 10th, 2022)
- 1 poster and 1 oral presentation at the 18th RUFORUM Annual General Meeting, Harare, Zimbabwe, 12-16th December 2022</td></tr>
<tr><td colspan="4">Current and Expected Achievements: in terms of</td></tr>
<tr><td>Objectives</td><td>output</td><td>outcome</td><td>Expected impacts</td></tr>
<tr><td>To Contribute to the improvement of feeding and productivity of ruminants in South Kivu.</td><td>-Determine the various pastures in South Kivu based on their agro-ecological zones
- A list of South Kivu's available ruminant feed resources.
- Estimating the South Kivu pastures carrying capacity</td><td>- The various ruminant feed resources in South Kivu are inventoried, along with the various ruminant growing methods.
Inventorying fodder species and</td><td>-Enhancing pastures to ensure proper breeding practices

-Evaluation of the performance of animals fed with various feed sources</td></tr>
</table>

		- Determining the nutritional value of the various species found in the South Kivu pastures.	estimating the carrying capacity of South Kivu's pastures based on the seasons - South Kivu grassland species are evaluated for their nutritional value.	- Enhancing livestock nutrition - Increased production of milk and meat .
2.Mwanga Mwanga Ithe	**Degree program**: MSc in Environment and sustainable management of natural resources **School**: Université Evangélique En Afrique (UEA) **Registration date**: Nov 2019 **Registration number:**22360 **Research Title:** Characterization of natural pastures in South Kivu: Typology, fodder value and physico-chemical analysis of the soil. **Graduation date/year**: November, 2022		Prof Katcho Karume Prof Pascaline Ciza	1 paper in preparation 1 paper submitted with the project team
	Presentation &/ conferences			
	3 orals presentations at school level (UEA) -Defense of the master's thesis (UEA, March 10th , 2022) - 1 poster and 1 oral presentation at the 18th RUFORUM Annual General Meeting, Harare, Zimbabwe, 12-16th December 2022			
	Current and Expected Achievements: in terms of			
	Objectives	**output**	**outcome**	**Expected impacts**
	To contribute to the characterization of pastures in South Kivu with a view to their improvement and sustainable management	-estimation of the area of natural pastures in South Kivu using GIS and remote sensing;	-The area and biomass of several pastures were known, -the relationship between the	- Farmers will feed the animals while taking the variety of the pastures into consideration.

		-determination of the floristic diversity, the specific contribution, and the type of the pasture in South Kivu; -Analysis of soil parameters influencing the distribution of forage species in South Kivu pastures; -Identification of the best season for the ideal production of forage biomass and nutrients;	distribution of fodder and the characteristics of the soil was established. -The floristic diversity and the typology of the south Kivu were also determined.	-When there is a food shortage during the dry season, farmers would save or retain fodder grasses throughout the rainy season. -An improvement in animal performance leading to more milk and lean meat being produced. -It is known which species favor which types of soil. This will enable the selection of appropriate species when improving pastures.
3.Amani Justin	**Degree program:** MSc in Environment and sustainable management of natural resources **School:** Universite Evangélique En Afrique (UEA) **Registration date:** Nov 2018 **Registration number**: **Research Title**: Spatial distribution and modeling of Small ruminants pest in South Kivu **Graduation date/year:** November 10th ,2022		Prof Ahadi Birindwa Prof Pascaline Ciza	This student was only recruited to complete one of our objectives on pasture characterisation, he was working on small ruminant pests but for this project he characterised the different pastures with their level of health risk.
	Presentation &/ conferences			
	-2 orals presentations at school level (UEA) -Defense of the master's thesis (UEA, March 10th , 2022) - 1 oral presentation at the Biennial Africa CSA Stakeholders Conference, 14th September,2022 - abstract presented at All Africa Conference for Animal Agriculture (16 - 19 August, 2022) - poster presentation at seventh Africa higher education week and Ruforum triennial conference, 06 – 10 December 2021			

	Current and Expected Achievements: in terms of			
	Objectives	**output**	**outcome**	**Expected impacts**
	To contribute to the small ruminant's pest (SRP) eradication program by understanding its distribution and setting up a control model in the Democratic Republic of Congo.	- identify risk factors for small ruminant's pest for proper control - identify environmental factors characteristic of SRP - identify and characterize the high risk pastures	determine the spatial distribution of SRP -map pastures at high risk of PPR in the different agro ecological zones (high, medium and low altitudes) -generate and test a maxent model for the control and surveillance of PPR in South Kivu based on epidemiological and environmental factors	-Small ruminant's pest control (SRP) and eradication adopted by at least 700 goat and sheep breeders
	Degree program: Master degree in Biostatistics. **School**: University of Abomey-Calavi **Registration date**: September 2020 **Registration number: 40328021** **Duration remained before completion in (years & months):** 1 month		Prof Glele Kakai Dr Chenangnon Tovissode	

4.Furaha Mpuranyi	(graduation scheduled in March) **Research Title:** performances of models used in dynamics of vegetation cover in pastures **Excepted Graduation date/year**: April 2023			
	Presentations &/ conferences			
	2 orals presentation at school level			
	Current and Expected Achievements: in terms of			
	Objectives	**output**	**Expected impacts**	
	Determine how some models can be used to fit the dynamic of vegetation cover pastures under spatial and temporal fluctuations	-generalized linear mixed models (beta and ordinals models show their performances) are used to fit the dynamic of species -Application of simulation functions to generate data for the abundance-dominance response variable. -Using the diverse models to predict the values of each response variable from the simulated data, and then evaluating the outcomes,	access the performances models in analyzing the dynamics of vegetation. -understand how environmental change could affect vegetation patterns and dynamics. -understand how dynamic models help to evaluates species dynamics and estimate their distributions.	

Chapter 2: Livestock feeding practices in three agro-ecological zones of South-Kivu, eastern DR Congo: Need for strategies for better livestock feeding

Abstract

The majority of Africans reside in rural areas and rely primarily on agriculture and animal husbandry for income. However, their livestock farms are not productive enough to meet the rising demand for agricultural products. Improving livestock feeding methods is essential for increasing farm productivity. This study aimed at assessing feeding practices, the limitations and potential of livestock feeding systems in South-Kivu province, as well as the availability of feed. A household survey was conducted on 692 smallholder farmers from three *territoires*, including Kabare, Uvira, and Walungu. Results indicate that current feeding practices for ruminants are insufficient to increase livestock productivity. It is primarily composed of forage and crop residues, and nutritional supplements are rarely added. The used community pastures are insufficient to meet the nutritional needs of the animals. In order to increase animal output, it is essential to improve animal nutrition. In addition to promoting the use of feed supplementation and fed concentrates, the implemented feeding strategies must ensure adequate nutrition for animals during the dry season and contribute to the mitigation of climate change effects that could become increasingly severe if greenhouse gas emissions are not significantly reduced, particularly in livestock farms, which are also a major source of greenhouse gas emissions. Adopting strategies based on integrated agro-sylvo-pastoral systems that are fully respectful of the environment, applicable on small parcels of land, and advantageous for both sustainable food production and more productive animal production with low greenhouse gas emissions would contribute to the achievement of this goal.

Keywords: Smallholder farming systems, livestock feeding systems, community pastures, livestock feeding, South-Kivu

1. Introduction

The majority of Africans live in rural areas, with 54% of the population working in agriculture and animal husbandry (Kuivanen et al., 2016). Indeed, along with agriculture, livestock husbandry are the primary means of subsistence and income for rural populations in Sub-Saharan Africa (SSA) (Davis et al., 2017). Since smallholders are responsible for growing the majority of Africa's food supply, the rural economy is strongly dependent on them (Wiggins, 2009). Despite increased livestock output globally, particularly in SSA, food security is still a major concern for many countries (Dehoux et al., 2018). Due to the low level of livestock productivity farms and the rapid population growth in SSA, imports of animal products have risen in response to the rising population's demand (Rakotoarisoa et al., 2012). Therefore, livestock production systems must become more productive in order to meet the rising demand for animal-based food and the pressing need to relieve poverty (Oosting et al., 2014).

Livestock farming is among the alternatives for income generation to cope with poverty and food insecurity (Maass et al., 2012). It is expected that, increased livestock productivity would help relieve poverty and food insecurity among smallholder farmers in the Democratic Republic of Congo (DRC) (Cox, 2012). As a matter of fact, livestock farming accounts for up to 9.2% of GDP and is crucial to the economic well-being of rural populations (Baenyi et al., 2021; Mutwedu et al., 2022). However, agriculture and livestock productivity in the South-Kivu region has decreased throughout the past decade of turmoil, resulting in a perpetual cycle of low food production and food shortages (Tollens, 2003; Maass et al., 2012; Mutwedu et al., 2022) . The productivity of current livestock farms must be increased.

One of the main obstacles limiting livestock productivity in Eastern DR Congo is a lack of feed, particularly during the dry season (Maass et al., 2012;Bacigale et al., 2014;; Mutwedu et al., 2022). This situation has resulted in price swings, a lack of feed concentrates and enhanced fodder adapted to marginal circumstances, rendering them uncompetitive with food crops, further complicating the issue with regard to feeding livestock (Bacigale et al., 2014). Adequate livestock feeding is an important means of increasing their productivity in various livestock systems (Imbou-Ngalamou, 2016).

In SSA, livestock feeding mostly rely on the forages grazed on community pastures to satisfy all of their nutritional needs, notably in South-Kivu province (Mugumaarhahama et al., 2021; Underwood & Suttle, 2000). In fact, grazing animals typically do not acquire enough quantities of all critical mineral components from pastures owing to inadequate pasture management

(Underwood & Suttle, 2000). There have been several reports of feed mineral shortages, which might be the primary cause of reduced livestock productivity (Khan et al., 2007). Pastures degradation has resulted in diminishing availability of livestock feed supplies, according to increasing evidence (Imbou-Ngalamou, 2016). In addition, it has been shown that inefficient livestock feeding increases farm greenhouse gas emissions, which in turn contributes to climate change and all of its severe repercussions for livestock farming (Rendon-Huerta et al., 2018). Improved livestock feeding practices are crucial. Increasingly, as the world moves toward sustainable extensive systems for the production of milk and meat from ruminant livestock, it is becoming more and more critical to understand the advantages and limitations of pasture feeding (Knowles & Grace, 2014) in order to propose alternatives for adequate livestock feeding. The aim of this study was to assess feed practices, the limitations and potential in the t livestock feeding systems, as well as the availability of feed in South-Kivu province.

2. Methods

2.1. Study area

This study was conducted in three *territoires* which correspond to three agroecological zones (AEZs) of the South-Kivu province, Eastern DR Congo (Figure 2), namely Kabare, which corresponds to high altitude zones, Walungu, which corresponds to medium altitude zones, and Uvira, which corresponds to low altitude zones. Walungu is located at 2°37'S latitude and 28° 40'E longitude, receives rainfall of approximately 1500 mm per annum and 22 °C mean temperature per annum, and the soil is primarily clay sandy. Kabare is located at 2°17'S latitude and 28°40'E longitude, with 19.2°C as mean temperature per annum, 1608 mm per annum as mean rainfall, and the soil is clayey. Finally, Uvira is located at 3°20’S latitude and 29° 30’E longitude, receives rainfall of about 1600 mm per annum and 25 °C mean temperature per annum and the soil is very sandy, in some places sandy loam, rarely clay and sandy (Bagula et al., 2021; Bagula et al., 2022).

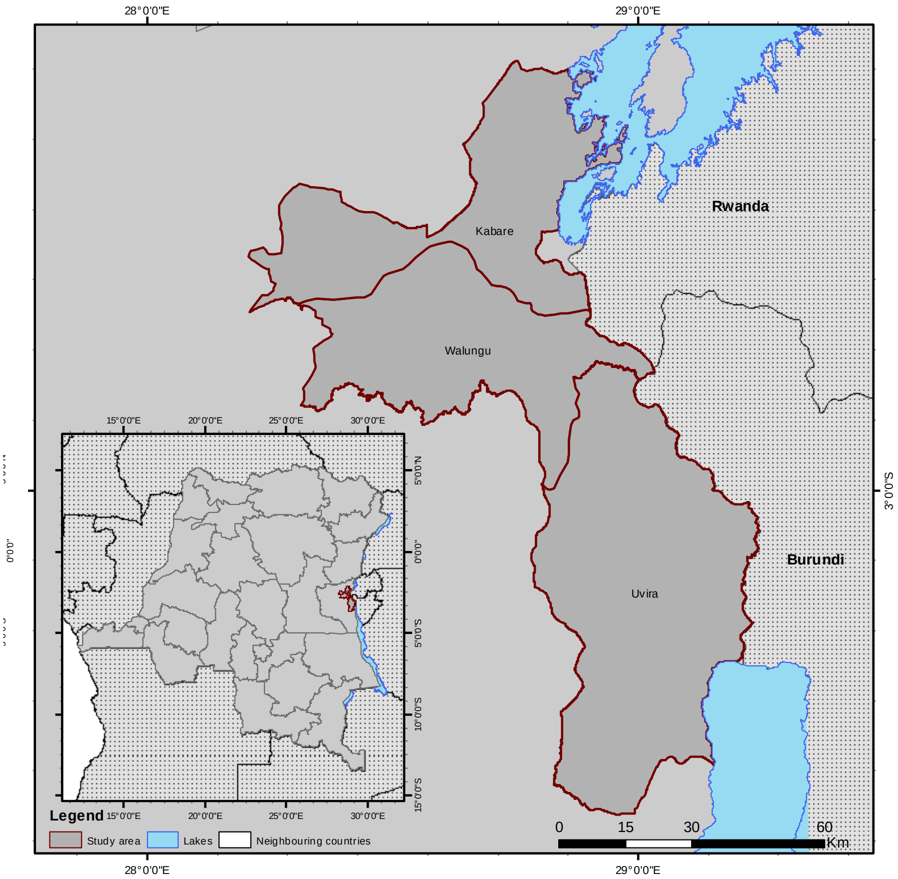

Figure 2. *Map of the study area*

2.2. Data collection

To assess whether feed is one of the primary limiting factors in livestock production and to arrive at possible solutions in a participatory manner, two primary approaches have been utilized. The first method used the Feed Assessment Tool (FEAST) developed by Duncan et al. (2012) at three *territoires* representative of the three AEZs in South-Kivu. This tool consisted of two parts: firstly, focus group discussions (FGD) with 30 to 40 farmers per *territoire*, including different socioeconomics categories, ages, and genders of farmers; and secondly, individual farmer interviews (IFI) to collect specific quantitative data from households at each site. The FEAST tool was translated, and all interactions with respondents were conducted in either Swahili or French. IFIs were conducted with 692 farmers (Kabare; n=175, Uvira; n=239 and Walungu; n=278). From the FGDs and IFIs, key elements of the farming system were characterized focusing on: Land holding by households, livestock holding by households, dominant crops and use of crop residues (CRs) and agroindustrial byproducts (AIBs), main problems relating to crop-livestock production and potential solutions. In addition to FGDs and IFIs, two key informants per *territoire* displayed the forage species typically fed to their animals as part of the second strategy. Before obtaining herbarium specimens for identification, these plants and their biotopes were described morphologically.

2.3. Data analysis

The collected data were entered in MS Excel 2019. They were first examined using descriptive statistics, such as cross-tabulation, bar charts and pie charts. To aggregate numbers of individual livestock species into the Tropical Livestock Unit (TLU), conversion factors were used (0.7 for cattle; 0.1 for sheep and goats) (Chianu et al. 2007).

3. Results

3.1. Socio-economic characteristics of farmers

Table 3. *Socio-economic characteristics of farmers*

	Kabare N = 175	**Uvira** N = 239	**Walungu** N = 278	**Total** N = 692
Gender (%)				
Female	9.6	0.0	8.9	6.0
Male	90.4	100.0	91.1	94.0
Marital status (%)				
Single	14.9	14.2	17.6	15.8
Married	80.6	75.0	75.5	77.3
Widower	4.6	8.8	6.8	6.9
Age (years)	39.8 ± 14.8	42.3 ± 13.9	40.6 ± 16.1	41.0 ± 15.0
Time spent in school (years)	5.3 ± 4.8	7.4 ± 4.8	7.1 ± 6.2	6.3 ± 5.0
Seniority in livestock farming (years)	10.4 ± 9.5	16.0 ± 12.7	12.6 ± 12.3	13.2 ± 12.0
Membership in farmers associative movements (%)	20.0	25.5	11.5	18.5
Seniority in the associative movements (years)	3.8 ± 3.3	5.2 ± 5.1	3.7 ± 3.8	4.5 ± 4.4

Table 3 shows the socio-economic characteristics of livestock farmers in South-Kivu. The bulk of the owners of animals raised are household heads (married men, according to local traditions). They have between one and twenty-five years of experience in raising ruminants and are typically between 26 and 56 years old. The majority of them have had at least one year of formal education, granting them the ability to read and write. Very few (18.5%) of them have been involved in associative movements. Those involved in these movements have been there for less than ten years.

3.1.1. Herd composition and load estimates

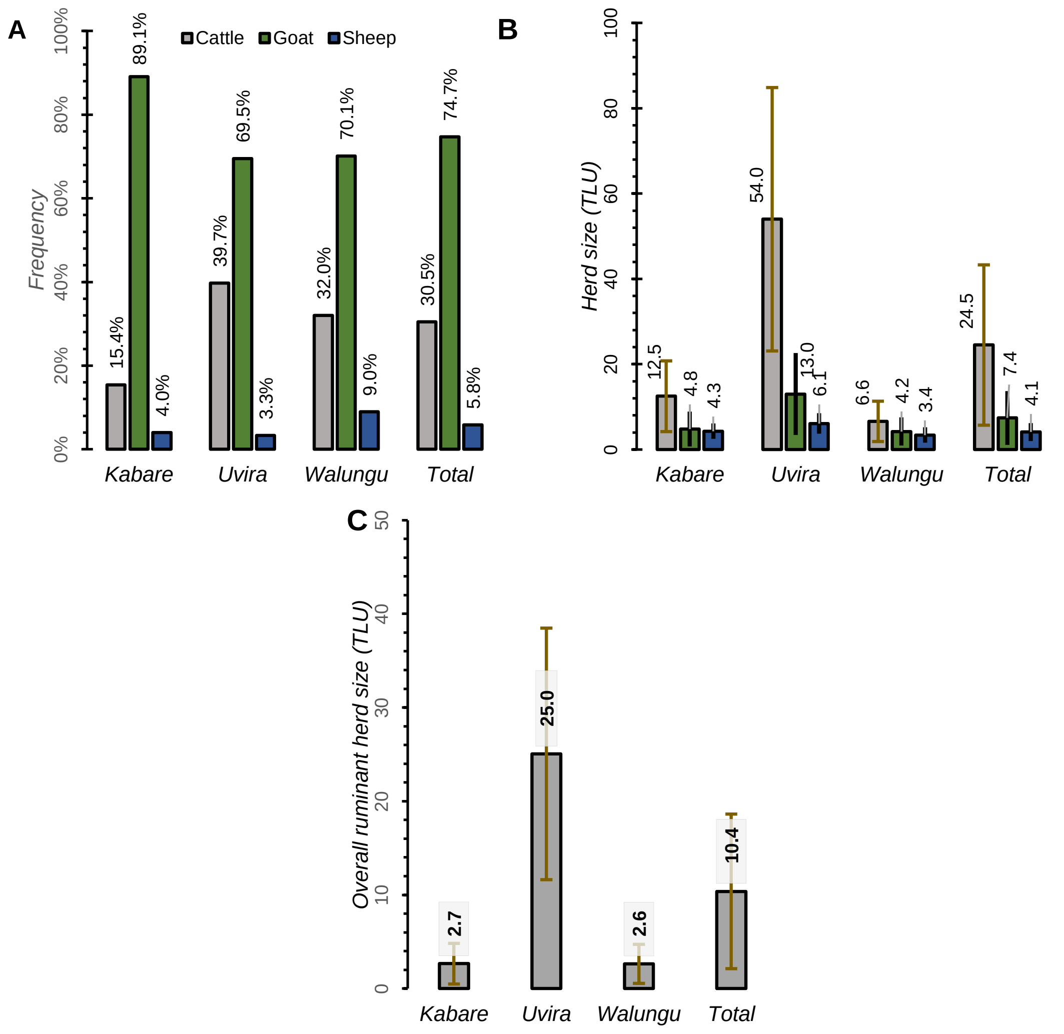

***Figure 3**. Raised ruminants and their load estimates*

The results in Figure 3 show that goat (small ruminant) is the species found in the vast majority (at least 70%) of the farms in Kabare, Uvira and Walungu. However, they are found in small numbers (rarely reaching 5 TLU) on the farms where they are raised. On the other hand, cattle are found on less than half of the farms in each area, but represent the largest feeding load on these farms. Cattle in Walungu average 5.3 ± 3.8 TLU, which is about half the size of cattle in Kabare, where they average 10.0 ± 6.6 TLU. The cattle farms in Uvira have the largest number of animals with an average of 43.2 ± 24.7 TLU. In terms of feed load (see Figure 3C), there is an average of 2.7 ± 2.6 TLU to feed in Kabare, 25.0 ± 15.4 TLU in Uvira and 2.6 ± 2.3 TLU in Walungu. It should also be noted that with these livestock, farmers do not own enough space to be used as grazing lands for their animals.

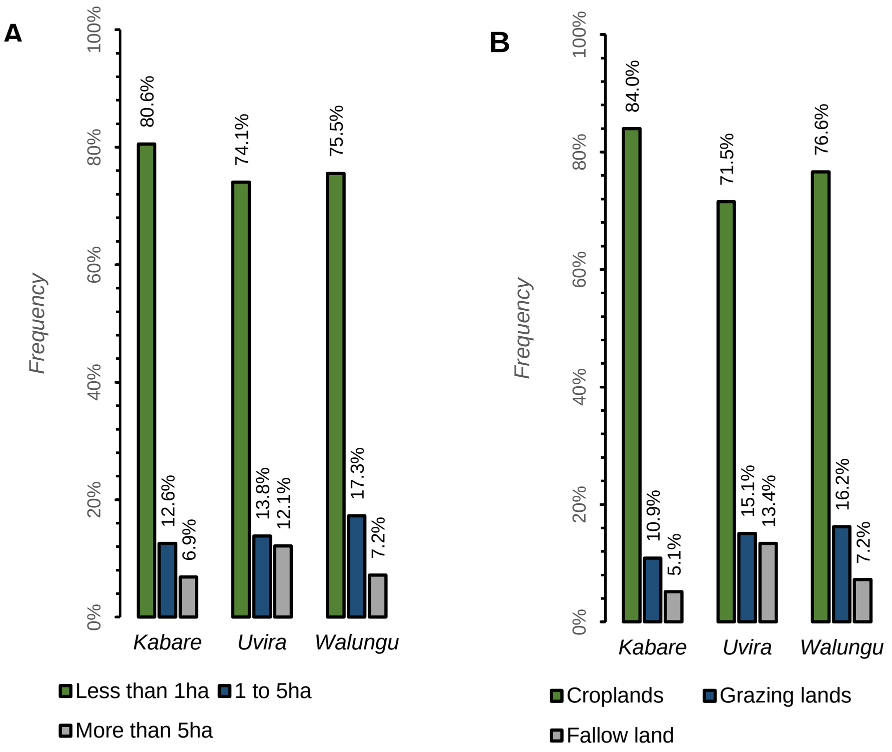

Figure 4*. Size of landholdings and their primary use*

The results in Figure 4**.** show that many ruminant farmers have only small portions of land (less than 1 ha). But the little land they have is mostly used to grow food crops.

3.2. Feeding practices

Table 4*. Characterization of feeding practices*

Parameters	**Kabare** N = 175	**Uvira** N = 239	**Walungu** N = 278	**Total** N = 692
Breeding system (%)				
Extensive	86.9	99.6	93.5	93.9
Intensive	13.1	0.4	6.5	6.1
Grazing system (%)				
Zero grazing	8.6	0.4	6.5	4.9
Herding	90.8	98.3	92.1	93.9
Free range in paddocks	0.6	1.3	1.4	1.2
Used pastures (%)				
Common pastures	90.3	97.9	87.8	91.9
Own pasture	9.7	2.1	12.3	8.0
Grazing type (%)				
Continuous	82.4	100.0	61.8	80.2
Rotational	17.6	0.0	38.2	19.8
Feeds (%)				
Forages	100.0	100.0	100.0	100.0

Nutritional supplements	22.9	22.6	22.7	22.7
Agro-industrial byproducts (AIBs)	33.1	14.2	35.9	27.7
Crop residues (CRs)	78.3	61.2	74.2	70.8
Forage cultivation (%)	33.1	17.3	22.2	23.2
Availability of CRs and AIBs (%)				
Periodical	37.5	24.1	22.2	26.7
Permanent	62.5	75.9	77.8	73.3
Impact of drought on feed availability (%)				
Low	0.0	0.0	0.0	0.0
Medium	37.5	10.4	38.2	28.4
High	62.5	89.6	61.8	71.8
Strategies for coping with drought (%)				
Transhumance	15.0	82.7	9.3	36.1
Breeding of animals in stall	87.0	15.2	46.1	45.8
Silage	9.6	2.1	11.7	8.0
Use of CRs and AIBs	2.2	12.1	35.0	18.9

Results in Table 4 show that in all the three agro-ecological zones, extensive livestock farming (93.9%) in which the animals are fed on community pastures (91.9%) in a continuous manner (80.2%) without any conservation or restoration actions can be noted. The feed ration of animals raised is mainly made up of forages (100%) and crop residues (70.8%). In some farms, feed supplements (22.7%) and/or agro-industrial byproducts (27.7%) are served to the animals in addition to forages and crop residues. For the majority of farmers (73.3%), crop residues and agro-industrial byproducts are permanently available. Since herders have practically no land to allocate to grazing their animals, have no alternative other than grazing their cattle on community pastures. To try to ensure adequate feed for their livestock, only a minority (23.2%) of herders grow forages. In the study area, there is an annual dry season that certainly affects the food resources of the animals. Most farmers (71.8%) find that drought in dry season severely alters the availability of forages, which leads them to resort to certain strategies to cope with this constraint. The strategies undertaken vary from one area to another. In Kabare, farmers resort more to feeding their animals in their stables (87%), while in Uvira, they resort more to transhumance (82.7%); those in Walungu resort mainly to two strategies: feeding their animals in their stables (46.1%) and/or the use of crop residues and/or agro-industrial by-products (35%).

3.3. Main feed resources that comprise the bulk of a livestock's diet

Table 5. *Inventory of livestock feed resources*

Feed resources	Family	Kabare	Uvira	Walungu	Accep-tability	Consumed part
Fodder species						
Chentela asiatica	*Apiaceae*	-	-	+ (1.4)	2.4	Lf,Fr,St
Dracaena phragrans	*Asparagaceae*	+ (1.7)	-	++ (1.5)	2.1	Lf,St
Ageratum conyzoides	*Asteraceae*	-	-	+ (1.6)	2.3	Lf,St
Bidens pilosa	*Asteraceae*	+++ (1.9)	++ (2.4)	+++ (2.2)	2.6	Lf,St
Bothriocline longipes	*Asteraceae*	-	-	+ (1.3)	2.8	Lf
Conyza sumatrensis	*Asteraceae*	++ (2.4)	+++ (2.2)	+++ (2.3)	2.5	Lf,St
Galisonga ciliata	*Asteraceae*	+ (2.3)	+ (2.3)	+ (2.6)	2.8	Lf,St
Parthenium sp	*Asteraceae*	-	++ (2.4)	-	2.0	Lf,Fr,St
Tithonia diversifolia	*Asteraceae*	++ (2.1)	++ (2.6)	++ (2.4)	2.5	Lf,St
Commelina difusa	*Commelinaceae*	++ (2.1)	+ (2.5)	+ (1.9)	2.7	Lf,St
Acasia spinose	*Fabaceae*	-	+ (1.9)	-	2.3	Lf
Crotalaria spinosa	*Fabaceae*	+ +(1.7)	++ (1.6)	++ (1.6)	2.0	Lf,St
Desmodium trifoliom	*Fabaceae*	+ (1.9)	++ (2.2)	+ (2.1)	2.0	Lf,St
Lecaena lecocefala	*Fabaceae*	+ (1.4)	+ (1.0)	-	2.6	Lf,St
Stylosanthes guianensis	*Fabaceae*	-	++ (2.0)	-	2.3	Lf,St
Tephrosia vogeli	*Fabaceae*	-	+ (2.0)	+ (2.1)	2.3	Lf,St
Vigna unguiculata	*Fabaceae*	-	+ (1.5)	-	2.7	Lf,Fr,St
Sida acuta	*Malvaceae*	-	+ (1.4)	-	1.1	Lf
Dissotis senegambiensis	*Melastomataceae*	-	+ (1.4)	-	2.0	Lf
Musa sp	*Musaceae*	+ (1.7)	-	-	2.9	Lf
Axonopus compresus	*Poaceae*	-	+ (1.5)	-	2.6	Lf,Fr,St
Brachiaria ruziziensis	*Poaceae*	++ (2.2)	+++ (2.5)	++ (2.6)	2.6	Lf,St
Cynodon dactylon	*Poaceae*	++ (2.5)	++ (2.5)	++ (2.5)	2.7	Lf,St
Digitaria abyssinica	*Poaceae*	+++ (2.5)	+++ (2.4)	+++ (2.7)	2.7	Lf,St
Eragrostis tenuifolia	*Poaceae*	+ (2.0)	-	+ (2.5)	2.1	Lf
Hyparrhenia rufa	*Poaceae*	+ (2.4)	++ (2.3)	++ (2.3)	2.3	Lf,St
Imperata cylindrica	*Poaceae*	-	-	+ (2.5)	2.2	Lf
Panicum maximum	*Poaceae*	-	++ (1.8)	-	2.6	Lf,St
Paspalum sp	*Poaceae*	++ (2.4)	+ (2.6)	++ (2.5)	2.7	Lf,St
Pennisetum purpureum	*Poaceae*	++ (2.4)	++ (1.8)	++ (2.5)	2.5	Lf
Setaria barbata	*Poaceae*	++ (2.4)	+ (2.2)	+ (2.1)	2.5	Lf,St
Sporobolus pyramidalis	*Poaceae*	+++ (2.6)	+++ (2.8)	+++ (2.7)	2.7	Lf,St
Tripsacum andersonii	*Poaceae*	++ (2.1)	++ (1.8)	++ (2.3)	2.6	Lf,St
Crop residues						

Arachis hypogaea	*Fabaceae*	-	+ (1.5)	-	2.7	Lf,St
Brassica oleracea	*Brassicaceae*	+ (1.2)	-	+ (1.8)	2.9	Lf
Coffea sp	*Rubiaceae*	+ (2.0)	-	-	2.5	Lf
Ipomoea batatas	*Convolvulaceae*	++ (1.7)	++ (1.9)	+++ (1.6)	2.7	Lf,St,Rt(Pl)
Manihot esculenta	*Euphorbiaceae*	+ (1.5)	++ (2.0)	++ (1.7)	2.5	Lf,Rt(Pl)
Musa sp	*Musaceae*	++ (2.0)	+ (1.5)	++ (2.2)	2.7	Lf,Fr(Pl)
Oryza sativa	*Poaceae*	-	+ (1.8)	+ (1.0)	1.8	Lf
Persea americana	*Lauraceae*	++ (2.1)	+ (2.0)	+ (1.9)	2.8	Lf,Fr(Nt)
Phaseolus vulgaris	*Fabaceae*	++ (1.5)	++ (1.7)	++ (1.5)	2.8	Lf,St,Fr(Pd)
Saccharum officinarum	*Poaceae*	+ (1.8)	+ (1.0)	+ (1.8)	2.7	Lf
Sorghum bicolor	*Poaceae*	+ (1.7)	+ (1.5)	+ (1.5)	2.6	Lf,St
Zea mays	*Poaceae*	+++ (1.7)	+++ (1.8)	++ (1.7)	2.6	Lf,St
Agro-industrial byproducts						
Brewery grains		+ (2.5)	-	+ (1.0)	3.0	
Phaseolus vulgaris	*Fabaceae*	+++ (1.6)	+++ (2.0)	++ (1.9)	2.8	*Boiled bean sauce*
Zea mays	*Poaceae*	+ (2.0)	++ (2.0)	+ (2.0)	2.3	Cob, Husk, Stalks
Oryza sativa	*Poaceae*	-	++ (2.1)	-	2.0	Bran, Stove
Glycine max	*Fabaceae*	-	-	+ (2.0)	3.0	Crab
Elaeis guinensis	*Arecaceae*	++ (1.7)	-	+++ (1.6)	2.8	Crab

Utilization frequency: - : *Almost nil ;* **+ :** *Low ;* **++ :** *Moderate ;* **+++ :** *High*

Consumed parts: Lf : *Leafs ;* **St :** *Stems ;* **Fr :** *Fruits ;* **Rt :** *Roots (tubers) ;* **Nt :** *Nuts ;* **Pl :** *Peels ;* **Pd :** *Pods*

Values in brackets are mean scores of availability*:* **1 :** *Low ;* **2 :** *Moderate ;* **3 :** *High*

Scores of acceptability : 0 : *Very low ;* **1 :** *Low ;* **2 :** *Good ;* **3 :** *Very good*

Farmers gather a broad variety of plants for animal feed; in total, nine botanical families and 33 distinct forage species were identified. The most dominating families were *Poaceae*, *Fabaceae*, and *Asteraceae*, and they were essentially devoid of improved forage plants (Table 5). Forage species of family *Poaceae* are the most mentioned, and they seem to be the ones that make up the most of the cattle's diet. The results show that the plant species such as *Digitaria abyssinica*, *Sporobolus pyramidalis*, *Brachiaria ruziziensis*, and *Tripsacum andersonii* are the most used in the *Poaceae* family. In the *Fabaceae* family, the most used forage is *Crotalaria spinosa*. *Bidens pilosa* and *Conyza sumatrensis* are the most used forages for the *Asteraceae* family. The aforementioned species are also among those with high availability and acceptability scores.

4. Conclusion

This research demonstrates that South-Kivu's current ruminant feeding practices are insufficient to improve livestock productivity. It consists mostly of forage and crop residues, and nutritional supplements are seldom used. The used community pastures do not cover the nutritional needs of the animals on their own. In order to increase animal output, it is consequently crucial to enhance animal feeding. In addition to promoting the use of feed supplementation and fed concentrates, the feeding strategies to be implemented must ensure adequate nutrition for animals during the dry season and contribute to the mitigation of climate change effects that could become increasingly severe if greenhouse gas emissions are not significantly reduced, particularly in livestock farms, which constitute also a major source of greenhouse gas emission. Adopting strategies based on the integrated agro-sylvo-pastoral systems that are fully respectful of the environment and applicable on small tracts of land, and which are advantageous for both sustainable food production and more productive animal production with low greenhouse gas emissions, would contribute to achieving this objective.

Chapter 3: Evaluation of pasture productivity and nutritional composition in South Kivu province, Eastern DR Congo

Abstract

In south Kivu province, eastern of Democratic Republic of the Congo, cattle are mainly feed with poor grazing fodder in community pastures, fallow lands and roadside grasses where animals are fed without considering the carrying capacity. In this study we investigated the South Kivu plant species composition, richness and nutritional value in relation with the type of soil and the agro-ecological zones where the animals are raised in order to determine their carrying capacity. This study was conducted in *Kabare*, *Walungu* and *Uvira territoires* of the South Kivu province in the rainy and dry seasons. In each *territoire*, 5 pastures were selected and in each pasture 3 transects measuring 20m*20m were installed. In each transect, all plant species were listed and grouped in different botanical families. Three plots 1m^2 were installed in each transect where herbaceous biomass was cut for evaluation of dry biomass and bromatological parameters such as Carbone, Protein, Magnesium, Calcium, Phosphorus, total nitrogenous matter, fat content, energy content. The carrying capacity was evaluated to estimate the number of animals to graze the pasture. The results revealed that 169 plant species distributed in 117 genera and 38 plant families. *Fabaceae* (33% in the rainy season and 19% in the dry season) and *Poaceae* (26% in the rainy season and 23% in the dry season) were the most encountered plant families. The pasture typology indicated 3 types of pasture; the first type is from Uvira *territoire* and is a cluster of *Hyparrhenia rufa* and *Brachiaria ruziziensis*; the second type is the grouping with *Digitaria abyssinica* (A. Rich.) Stapf and *Centella asiatica* (L.) Urb. on one side and that of *Paspalum notatum* Fluegge and *Axonopus sp*. on the other side, on clayey soil; the third group is characterized by the grouping with *Digitaria abyssinica* (A. Rich.) Stapf and *Paspalum scrobiculatum* L. on a clayey-silt soil. Pasture yield, digestibility of dry matter, proteins, the digestible energy and the carrying capacity were elevated in the dry season while the dry matter was elevated in the dry season. From these results, it can be concluded that pastures of the 3 *territoires* are rich in plant species but most of them are not grazed by animals as a result of their poor nutritional value and carrying capacity. These pastures should be reinforced with improved forage species with high biomass production and nutritional values for better animal nutrition, especially during the dry season.

Keywords: Carrying capacity, Nutritional value, Pasture, Plant species, South Kivu province

1. Introduction

Africa is predominantly rural, with 54% of the population engaged in agriculture (Kuivanen et al., 2016). Farming remains the most predominant livelihood activity and source of income of sub-Saharan African (SSA) rural households (Davis et al., 2017). Most food production comes largely from small, fragmented plots of land owned by smallholders, making their production a key player in the continent's rural economy (Wiggins 2009). Furthermore, livestock is valuable in sustainable agriculture by providing meat, milk, manure, skin, hair for increased productivity and therefore enhancing the well-being and increased income of farmers in SSA.

In Democratic Republic of Congo (DRC), livestock contributes up to 9.2% of the gross domestic product and plays an important function in the income and livelihood of the rural population (Mugumaarhahama et al., 2020). Cattle, which is the most reared livestock and the most consumed in the country, contributes to more than 50% of the total meat consumption. However, the current national cattle herd estimated at 40 million head remains far below the country's potential (2.3% of the 1.75 billion head production potential) (SNSA ,2014). As a result, DRC livestock sector is largely undeveloped with majority of farmers focus on small livestock such as poultry, swine, cavies and rabbits (Mutwedu et al., 2015). This situation has been aggravated for about three decades when repeated political unrest in the eastern part of DR Congo have significantly affected the socio-economic situation of the rural population (Tollens, 2003). This situation has created a massive movement of the population with their livestock to the most secured villages, leading to demographic pressure (Battistin, 2013) and scarcity of collectable forages, as well as a restriction to reaching faraway grazing lands due to existing militia and armed groups (Tollens, 2003). This situation has led to the scarcity of livestock feed resources, making them uncompetitive with food crops, which further aggravates the livestock feeding situation (Mutwedu et al., 2022). Livestock feeding remains therefore the most constraint of sub-Saharan animal production (Bacigale et al., 2014; Mutwedu et al., 2020).

In South Kivu province, Eastern DR Congo, cattle are mainly feed with grazing fodder in community pastures, fallow lands and roadside grasses (Mugumaarhahama et al., 2020), followed by crop residues and agro industrial by products (Mutwedu et al., 2022). However, South Kivu community pastures have been reported to be very poor, mostly composed by weeds and non-suitable species for animal feeding such as *Digitaria abyssinica*, *Cynodon dactylon*, *Chloris gayana*, *Sporobolis pyramidalis*, *Hyparhenia rufa*, *Commelina diffusa*, *Bidens Pilosa*, *Conyza sumatrensis*, *Galinsoga ciliata* (Bacigale et al., 2014). In addition, South Kivu's landscapes are naturally formed, maintained and traditionally managed by grazing

(Maass et al., 2013). Grazing can have numerous impacts on landscape structure. For savanna and steppe ecosystems, grazing by large herbivores is a key factor shaping the composition and structure of the vegetation and nutrient availabilities (Gilhaus et al., 2013): the plant species diversity may significantly decline if pasturing is abandoned (Enyedi et al., 2008). Veen et al. (2009) showed a changing plant composition under grazing exclusion in savanna landscapes and even deduced a co-evolutionary adaption of these ecosystems and herds of grazers. However, also underlying soil conditions may determine plant community composition, vegetation structure and biomass ingredients and thus influence grazing intensity (Veblen, 2012). It is, therefore, important to explore the South Kivu plant species composition, richness and nutritional value in relation with the type of soil and the agro-ecological zones where the animals are raised in order to determine their effective carrying capacity. However, in South Kivu province, studies on the combined effects of grazing and soil conditions on vegetation structure development are rare. It is in that line that this study was initiated to determine the South Kivu's pasture floristic composition, nutritional value and carrying capacity depending of soil composition and season.

2. Material and methods

2.1. Study area

This study was conducted in three *territoires* of the South Kivu province, Eastern DR Congo (Figure 2) namely: Kabare which is the northern part corresponds to the high altitude, Walungu in which we covered the zones corresponding to the medium altitude and Uvira which corresponds to the low altitude zones. Walungu is located within 2°37'S latitude and 28° 40'E longitude, receives rainfall of about 1500mm per annum and 22 °C mean temperature per annum. The soil is mainly clayey sandy.

Kabare is located within 2°17'S latitude and 28°40'E longitude, with 19.2°C as mean temperature and 1608mm per annum as mean rainfall while and the soil is clayey.

Uvira is located within 3°20'S latitude and 29° 30'E longitude, receives rainfall of about 1600 mm and 25 °C mean temperature per annum and the soil is very sandy, in some places sandy loam, rarely clay and sandy (Bagula et al., 2021; Bagula et al., 2022).

2.2. Data collection

Pastures floristic diversity

Fifteen pastures were selected consisting in five pastures per agro-ecological zone, meaning one pasture in each village for two seasons (rainy and dry seasons). These pastures were chosen for their regular use by cattle. In each pasture, three phytosociological cross sections measuring 20m*20m were installed. Within each cross section an inventory of all plant species was made; abundant, companion and rare species were identified; plant species abundance-dominance and sociability were determined using the method described by Brown Blanquet (1954). The forage species were identified *in situ*. However, non-identified species were coded and placed in an herbarium for later identification at the CRSN/Lwiro herbarium. The identified forage species were grouped according to their botanical families and the frequency of their presence on pasture was evaluated to determine which plant species is prevalent in the studied pastures. Within each phytosociological cross section, three small plots of $1m^2$ were installed (**figure 5a**). In each small plot, the herbaceous biomass was cut at ground level, wrapped in a bag and weighed directly using a precision balance of 5kg capacity and 1kg of precision.

Figure 5. *Installation of plots of $1m^2$ for forage biomass evaluation (**left**) and harvesting forage in the installed plot (**right**)*

Forage nutritive value

The forage has been harvested (figure 5b) and composite samples were then taken to the chemical laboratory of the Université Evangélique en Afrique for oven drying at 105°C for 24 h to determine the dry weight. Thereafter, samples were ground in a grinder and the obtained powder was used for the analysis of bromatological parameters such as organic matter (Carbone and Protein), mineral matter (Magnesium, Calcium and Phosphorus), total nitrogenous matter, fat content (fatty acids or lipids), energy content (crude and digestible) and the digestibility rate of the organic matter following methods developed by Alhassane et al. (2018), Idrissa et al. (2020) and Diatta et al. (2020) (Figure 6)


Figure 6*. Forages nutritive values laboratory analysis*

Soil characterization

Composite soil samples of each plot were collected along the diagonal using a soil auger of 20 cm at depths of 0-20, 20-40, and 40-60 cm before sowing. Soil pH, soil organic carbon, total nitrogen, phosphorus and texture were analyzed. Soil pH was determined by a digital pH-meter at 1:5 (solute: solution) ratio. Soil organic carbon (SOC) was determined by the combustion method using the Walkley and Black method (Estephan et al., 2013). Total nitrogen was determined by the Kjeldahl method after the soil mineralization (Okalebo et al., 2002). The available phosphorus was determined using the modified Olsen method (Okalebo et al., 2002), and the soil texture by the hydrometer method (Estephan et al., 2013). The study area soil characteristics are presented in Table 6.

Table 6*. Soil properties of the experimental pastures along the selected territoires*

Variable	Walungu	Kabare	Uvira
pH	5.7 (4.8 -6.1)	5.8 (5.4-6.4)	7.14 (5.91-7.94)
Clay (%)	52 (44-59)	42 (38-44)	21 (8-40)
Silt (%)	32 (29-36)	30 (26-35)	17 (2-60)
Sand (%)	20 (10-22)	23 (20-27)	62 (17-89)
Soil texture	Clay (Clay Loam)	Clay (Silty Clay loam)	Sandy Clay Loam (Sandy loam)
Soil Organic Carbon (%)	2.95 (2.9-3.1)	2.53 (2.48-2.59)	3.31 (0.14-6.94)
Nitrogen (%)	0.63 (0.58-0.71)	0.71 (0.66-0.0.77)	0.82 (0.79-0.86)
C/N	4.63 (4.56-4.71)	3.5 (3.1-3.9)	4.03 (3.96-4.45)
Phosphorus (ppm)	11.8 (10.7-12.9)	10.4 (10.2-10.7)	33.6 (12.8-207.5)

The soil analysis results (table 6) show that the Walungu and Kabare soils are predominantly clayey soil textural. However, in Kabare, soils have less clay content (42%) compared to Walungu (52%). Walungu is developed on ancient volcanic soil compared to Kabare Nord. In Uvira pasture soils, the soil texture is dominated by sandy loam-related textures. The average sand content is 62% and the clay content of 21%. Bulk density (BD) varies from 1.21 to 1.28 g.cm3 in Kabare and Walungu soils. For Uvira, on the other hand, we have a higher bulk density (1.4 to 1.5 g/cm3). These high values of BD in Uvira soils are acceptable for sandy soils as they do not reach critical values (1.6 g/cm3) of BD for plant growth at which root penetration is likely to be severely restricted. These BD values for the three sampling sites predict good root development and a loose soil indicator due to the organic matter content. From a soil chemical aspect, the pH remains slightly acidic, with averages of 5.7-5.8 for Kabare and Walungu. On the other hand, the pH is neutral for the Uvira soils (7.18). The soils of Uvira are often known for their low pH in the whole region, thus favouring good soil fertility. The carbon contents of Kabare and Walungu soils were 2.58-2.95%, indicating a pasture soil with an acceptable recommended organic carbon level (1.8-3%). The Uvira pastures showed the highest soil organic carbon (SOC) content (3.31%). It indicates that the three soils of our study area have good structural conditions and high structural stability, pH buffering capacity, soil nutrient levels (especially nitrogen), and water-holding capacity. The average nitrogen level of 0.63-0.81% is acceptable compared to the recommended level in most soils (>0.5%). The C/N ratio is very low (below 5), indicating an unstable and labile organic matter which leads to mineralization over humification. Phosphorus values are very high in Uvira soils, with averages of 33.6 ppm exceeding the recommended norm in sandy soils (> 15ppm). On the other hand, the soils of Walungu and Kabare record low phosphorus levels (10-11.8ppm) compared to the norm (> 30 ppm for clayed soils).

Carrying capacity

Carrying capacity is defined as the capacity of an ecosystem which could maintain its productivity, adaptability and capability of renewal. In this study, the number of livestock that land resources in the study area can support has been considered as the carrying capacity, which was determined using the following formula:

$$\boldsymbol{CC\left({}^{TLU}/_{ha}\right) = \frac{K_i \; X \; TB}{6{,}25 \; Kg \; {}^{DM}\big/_{{}^{TLU}/_{J}} \; X \; UP}}$$

where CC is the livestock carrying capacity of land resources in TLU/ha/year; Ki represents the pasture utilization coefficient; TB (total biomass) representing the productivity of the pasture measured in Kg of dry matter per hectare; 6.25 expressed in kg DM/day represents the daily ration for a 250 kg TLU; UP refers to the period of use of the pasture (number of days).

2.3. Statistical analysis

The collected data were entered in MS Excel 2013. For the data collected on the inventory of forage species, a descriptive analysis was used and all the forage species were grouped according to their botanical families for which the frequencies for each family were determined. Analysis of variance was conducted to determine the nutritive value of the composite forage samples and the pasture carrying capacity. The treatments effects were compared by computing the least mean squares and standard errors of difference (SED); at a p-value threshold of 0.05. The Tukey HSD test was used for mean separation at the significance level of 5%. To find explanatory factors that can aid in classifying individuals into homogeneous groups, multivariate statistical analysis are frequently utilized. The main benefit of the analysis in our study was the homogeneous clustering of pastures. A smaller set of non-correlated principal components was obtained by using the Factorial Analysis of Mixed data (FAMD) on a chosen set of categorical and quantitative variables. The coordinates of the farms on obtained axes were then used as input in clustering algorithms. Although there are fewer important variables, the dataset's variability is essentially maintained (Alvarez et al., 2018). In FAMD, the dataset is converted into a new collection of continuous variables (principal components) to achieve the reduction (Husson et al., 2010). The FAMD output in the form of a reduced dataset based on the retained principal components was subjected to clustering analysis (CA) in order to find clusters that maximize differences between clusters while minimizing variability within clusters. Agglomerative hierarchical clustering and non-hierarchical clustering (partitioning around medoids), such as k-means, were used as the first stage. The HCPC proceduree found in the FactomineR package of R software was used to combine the strengths of the two clustering methods at the time (Michielsens et al., 2002; Iraizoz et al., 2007; Kuivanen et al., 2016). To characterize the final set of clusters, they were examined in terms of their inherent structure (i.e. descriptive statistics of each variable for each cluster). Statistical analysis was performed using R version 3.5.3.

3. Results

3.1. Floristic richness of South Kivu pastures

Floristic investigations conducted throughout the natural pastures of South Kivu province, more specifically in the territories of Kabare, Walungu and Uvira, have allowed to identify a list of 169 species during the rainy and dry seasons, distributed in 117 genera and 38 plant families. The families most frequently identified were *Fabaceae* (33% in the rainy season and 19% in the dry season), *Poaceae* (26% in the rainy season and 23% in the dry season), *Asteraceae* (23% in the rainy season and 20% in the dry season), *Malvaceae* (13% in the rainy season and 10% in the dry season), *Rubiaceae* (10% in the rainy season and 8% in the dry season), *Malvaceae* (11% in the rainy season and 9% in the dry season), *Lamiaceae* (9% in the rainy season and 6% in the dry season) and Cyperaceae (6% in the rainy season and 5% in the dry season) (figure7). Other identified families are *Acanthaceae, Convolvulaceae, Asparagaceae, Solanaceae, Amaranthaceae, Anacardiaceae, Apiaceae, Apocynaceae, Aspleniaceae, Bignoniaceae, Boraginaceae, Celastraceae, Clusiaceae, Combretaceae, Commelinaceae, Cucurbitaceae, Dennstaedtiaceae, Scrophulariaceae, Melastomataceae, Menispermaceae, Myrthaceae, Onagraceae, Oxalidaceae, Phyllanthaceae, Plantaginaceae, Rosaceae, Theaceae, Verbanaceae, Xanthorrhoeaceae, Combretaceae, Juncaceae* and *Proteaceae*. The results show that the plant species *Digitaria abyssinica* (3.1%) and *Sporobolus pyramidalis* (1.5%) are the most represented in the family *Poaceae*. In the family *Fabaceae*, the most frequent species are *Crotalaria spinosa* (1.28%), *Glycine wightii* (1.12%), *Mimosa pudica* (1.1%), *Trifolium pratense* (1.1%) and *Trifolum purseglovei* (0.9%). These results show that the most dominant species in the family *Asteraceae* are *Conyza sumatrensis* (2.5%), *Crassocephalum vitellimum* (1.79%), *Agerantumum conyzoides* (1.53%). For the family *Malvaceae*, the species *Sida acuta* and *Triumfetta rhomboidea* are the most frequent, with frequencies of 2.55% and 1.53% respectively. On the other hand, the species *Spermacoce princeae* (0.7%) is the most frequent in the family *Rubiaceae* while the species *Dyschoriste radicans* present (0.6%) a high frequency in the family *Acanthaceae*. The species *Platostoma montanum* (0.77%) and *Hoslundia opposita* (0.51%) showed high frequencies in the family *Lamiaceae*. *Centella asiatica* is the most frequent plant in the family *Apiaceae* (2.04%) while *Lantana camara* is more frequent (2.02%) in the family *Verbenaceae*. In respect to the different morphological types of these species, it is observed that herbaceous species dominate the South Kivu pastures (62.7%) compared to woody species (37.28%). These pastures are largely dominated with perennial herbaceous plants (32.54%) followed by woody plants where shrubs are mostly represented (15.38%), then sub-shrubs (12.43%), arborescent plants (6.49%) and lianascent plants (4.73%).

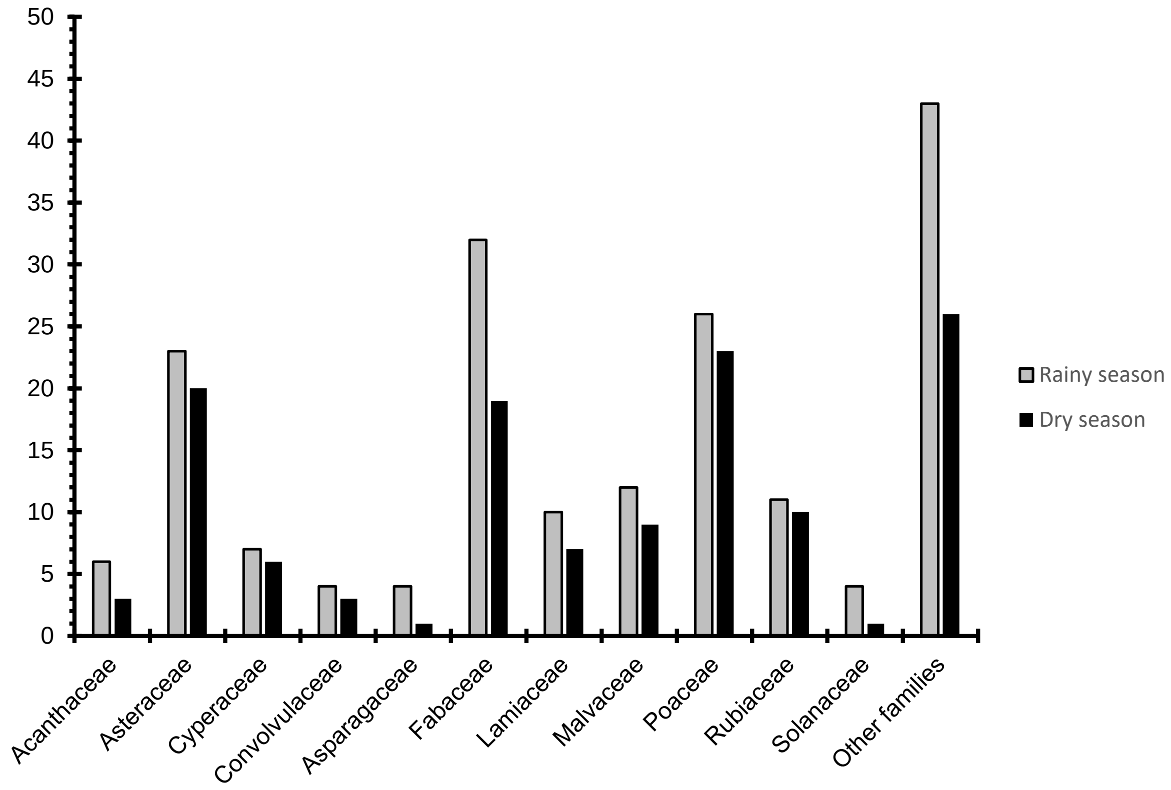

Figure 7. *Presentation of plant families identified in the South Kivu pastures*

3.2. Pastures typology

Based on the data collected in the field, 3 types of pastures were classified at the site level (Figure 8). The types were formed according to whether they were highland or lowland species. These groups are as follows:

The first type (Type 1) is made up of 5 pastures and characterizes the pastures of the Ruzizi plain (Uvira *territoire*). This type forms a single type of plant formation growing on a silty-sandy soil. This is the cluster of *Hyparrhenia rufa* and *Brachiaria ruziziensis*. It is an herbaceous structure adapted to wetlands regions and sandy soil. This formation gathers several hydrophilic species (*Ludwigia abyssinica* A. Rich., *Cyperus angolensis* Böck., *Hygrophyla auriculata* (Schumach.) and forms two strates; one herbaceous and the other shrubby. Physiognomically, these pastures are dominated in the herbaceous stratum by *Hyparrhenia rufa* (Nees) Stapf, *Brachiaria ruziziensis*, *Paspalum glumaceum* Clayton, *Sporobolus pyramidalis* P. Beauv., *Conyza neglecta* R. E. Fries, *Sida acuta* Burm f. and *Mimosa pudica* L. The number of species varies from 22 to 30 plant species per transect. The maximum height of plant species in this stratum varies between 1 and 2 m. The shrub strata up to 3 m high is dominated by *Acacia spinosa*, *Acacia sp.*, *Piliostigma thonningii* and *Senna siamea L.* with an average coverage of 65-80%.

The second type (Type 2) formed by eight (8) pastures is constituted with two (2) types of grazed plant formation. It is the grouping with *Digitaria abyssinica* (A. Rich.) Stapf and *Centella asiatica* (L.) Urb. on one side and that of *Paspalum notatum* Fluegge and *Axonopus sp*. on the other side. The grouping with Digitaria abyssinica (A. Rich.) Stapf and Centella asiatica (L.) Urb. is formed by the 5 pastures, and is an herbaceous fallow growing on clayey soil. It develops much more on dryland but sometimes in hydromorphic soil. This type is constituted by poor species with an herbaceous stratum dominated by *Digitaria abyssinica* accompanied by *Centella asiatic*a (L.) Urb. and sometimes with *Dyschoriste radicans* (Hochst. ex A. Rich.) Nees. The grouping with *Paspalum notatum* Fluegge and *Axonopus* sp. is characteristic of post-cultivation fallows in high altitude areas (1400 and 2000 m). It is formed by 3 pastures that develop on a clayey-silt soil and two strata. The herbaceous stratum is dominated by *Paspalum notatum* Fluegge, *Axonopus sp*, *Paspalum scrobiculatum* and *Paspalum conjugatum*. The shrub stratum, frequently subjected to anthropic actions following the search for firewood in the area, is dominated by *Bothriocline longipes*, *Lantana camara* L. and *Hoslundia opposita* Vahl.

The third type (Type 3) consists of a single type of plant formation. This type of formation characterizes the grassy savanna of high altitude formations. This type is formed by 2 pastures located between 1600 and 1700 m of altitude and is characterized by the grouping with *Digitaria abyssinica* (A. Rich.) Stapf and *Paspalum scrobiculatum* L. This grouping is typical of grassy savanna of slightly cold zones developing on a clayey to clayey-silt soil presents two strata. The herbaceous stratum, rarely exceeding the height of 30 cm, is dominated by *Digitaria abyssinica* (A. Rich.) Stapf, *Paspalum scrobiculatum* L., *Cynodon dactylon* (L.) Pers. and *Rungia grandis* T. whereas the shrub stratum is dominated by sub-shrubby species including *Lantana camara* L., *Triumphetta rhomboidea* Jacq. and *Tephrosia vogelii.*

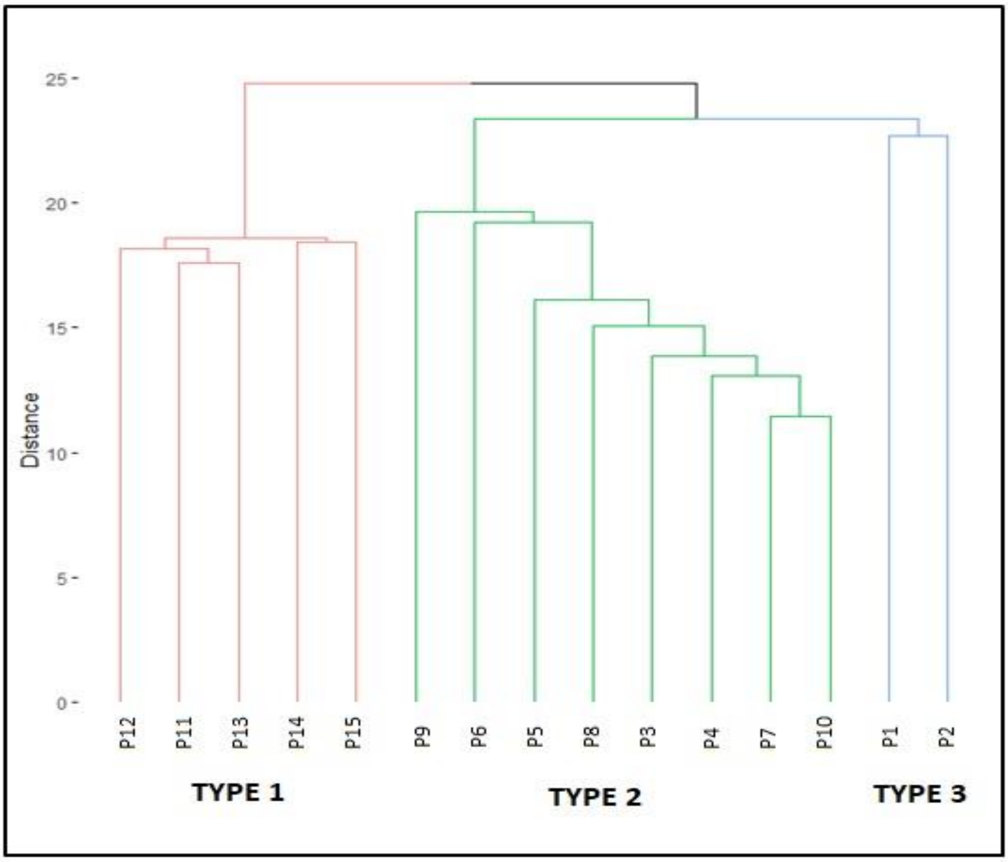

***Figure 8**. Dendrogram illustrating range of cluster solutions resulting from Hierarchical Clustering on Principal Components from forage species abundance-dominance and soil characteristics*

From the results in Figure 9, it can be seen that the pastures in the three agro-ecological zones of South Kivu give relatively the same yields. Although in the rainy season the pastures in Uvira appear to give lower yields, they are not statistically different from those in Kabare and Walungu. However, yields decrease significantly (by approximately yield loss of 75%) in the dry season. Overall, in the rainy season, estimates show average forage yields of 8.5 ± 2.6 tons of dry matter per hectare and 2.1 ± 0.5 tons of dry matter per hectare in the dry season (Figure 9A). The dry matter content of the forages produced in these pastures does not vary form one agro-ecological zone to another, but rather varies from one season to another. The dry matter content of the forages averaged 18.5 ± 10.8 % in the rainy season and increased to an average of 61.7 ± 13.4 % in the dry season (Figure 9B). The organic matter content is more or less constant regardless of the agro-ecological zone or season. It is estimated around 62.2 ± 14.7 % (Figure 9C). We can also see in these results that the digestibility of dry matter from forages from the studied pastures does not vary from one agro-ecological zone to another, it varies slightly from one season to another. The digestibility of dry matter was estimated at 58.7 ± 7.7 % in the rainy season and decreased slightly (not significantly) to 52.8 ± 5.7 % in the dry season

(Figure 9D). The results of the pasture carrying capacity estimates show that, although the Uvira pastures appear to have the lower carrying capacity in the wet season (0.9 ± 0.4 TLU/ha), it is not statistically different from that of the Kabare and Walungu pastures. Overall, the pastures have an estimated carrying capacity of around 1.1 ± 0.3 TLU/ha in the rainy season. In the dry season, the carrying capacity of pastures does not vary from one agro-ecological zone to another. In all agro-ecological zones, in the dry season, the carrying capacity of pastures decreases significantly to an average of 0.6 ± 0.1 TLU/ha, which is about half the carrying capacity in the wet season (Figure 9E).

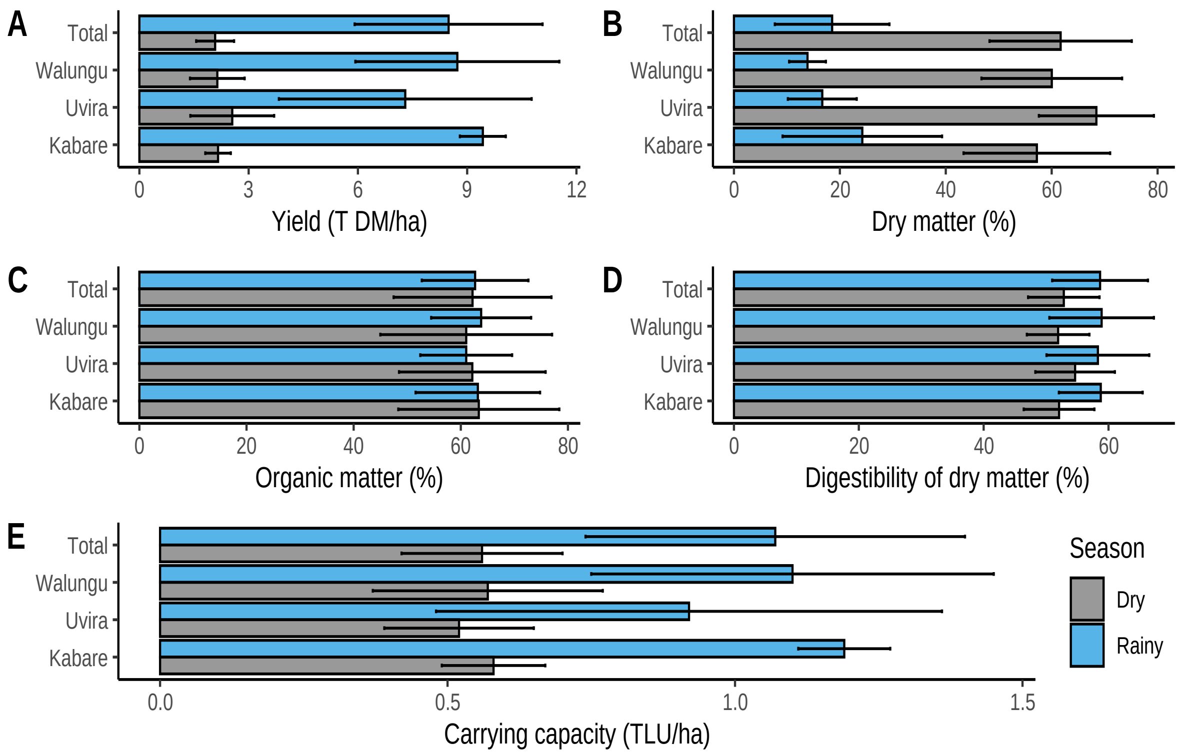

Figure 9. *Pasture yields and carrying capacity estimates*

3.3. Pastures nutritive value

With regard to the nutritional value of the forages that the animals graze on these different pastures, the results in Figure 10 show that there are no differences between the different agro-ecological zones. Rather, there are some differences between seasons. The most remarkable differences are observed in the effects of drought on protein content. In the rainy season, the protein content of the forages averages 7.2 ± 2.1% and decreases in the dry season to 5.1 ± 1.2%. Although in the dry season there was also a decrease in other nutritional parameters, the differences from the rainy season were statistically insignificant. Overall, forages from different pastures in South Kivu contained 37.8 ± 14.7% crude ash, 3.3 ± 0.5% Carbon, 11.2 ± 1.7 ppm Phosphorus, 187.2 ± 53.2 meq Calcium and 314.0 ± 107.1 meq Magnesium in 100g of forage. 1kg of dry matter of these forages contains 4597.9 ± 352.0 Kcal of gross energy and 2531.2 ± 373.7 Kcal of digestible energy.

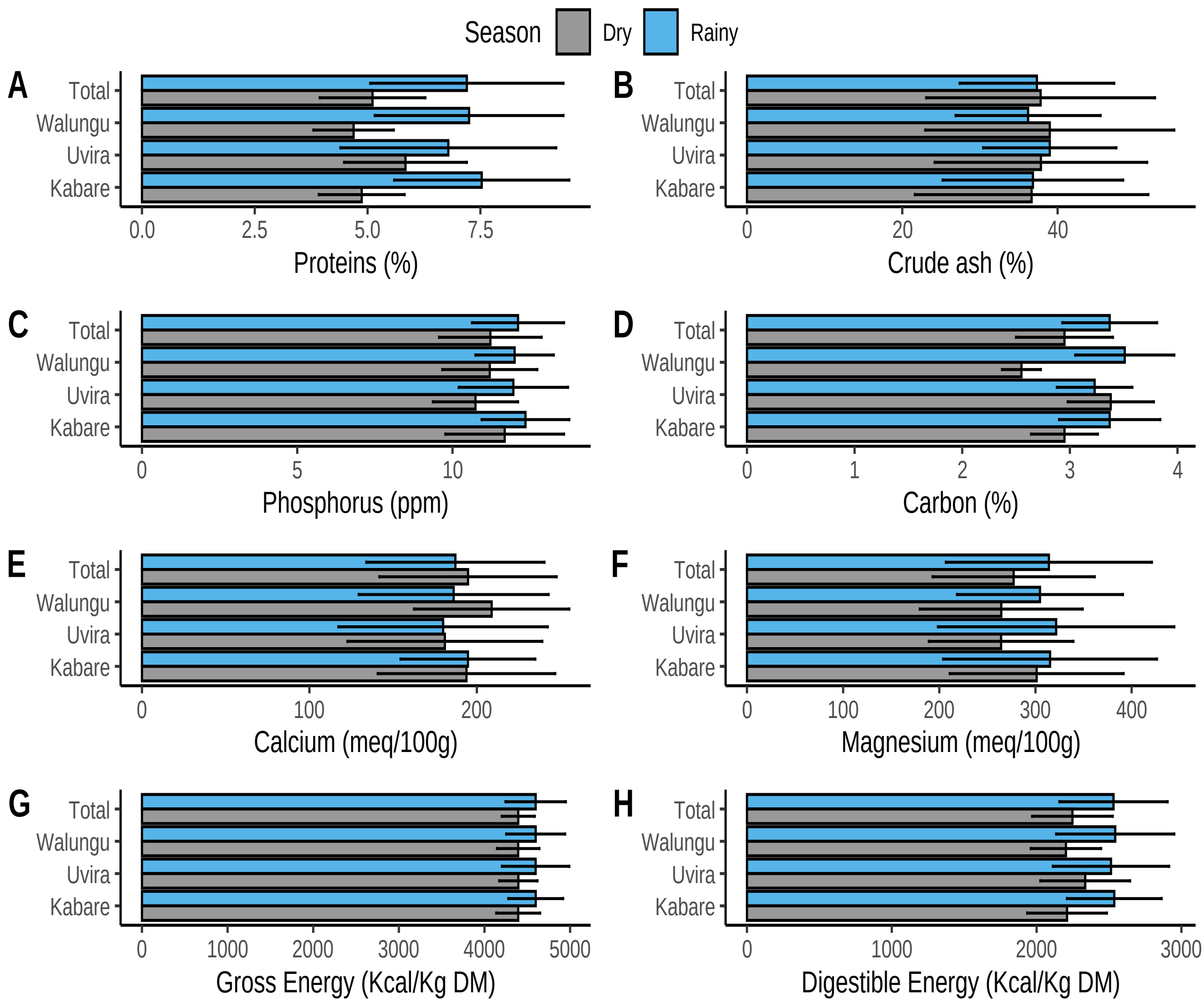

Figure 10. *Nutritional values of grazed forages*

Chapter 4: Farmers' perception and vulnerability to the climate change-related shocks: the case of South Kivu province, Eastern DR Congo

Abstract

Climate change is one of the greatest threats facing the agricultural and livestock sectors. There is no doubt that livestock farmers, especially those with cattle, are vulnerable to the effects of climate change. However, their level of vulnerability would vary according to the agro-ecological zones and their socio-economic situation. This study was conducted to assess farmers' perceptions of climate shocks and to determine the level and determinants of their vulnerability to these shocks in South Kivu. A survey was conducted among 976 cattle farms corresponding to 179 in Kabare, 344 in Walungu, 207 in Uvira, 182 in Kalehe and 63 in Mwenga. In each farm, a structured survey questionnaire and participatory interviews were carried out with farm managers. The results showed that Uvira farmers are the most vulnerable to climate change, followed by Walungu farmers. Kabare, Kalehe and Mwenga farmers are similarly exposed. Uvira farmers have the greatest capacity to adapt to climate change, followed by Walungu, Kabare and Kalehe. Mwenga farmers have the least adaptive capacity. According to the climate change vulnerability index, Uvira and Walungu farmers are the most vulnerable. Kalehe farmers are the most secure. It is evident that Walungu and Uvira territoires have the highest proportions of most vulnerable farmers. Most farmers believe that the observed effects of climate change and their impacts are due to divine will (47.5%) or to other causes unknown to them (29.9%). This reflects a poor understanding of climate change by the farmers. Thus, being aware of the effects of climate change that make farmers vulnerable, the relevance of the strategy implemented should be highlighted.

Keywords: Exposure, Sensitivity, Smallholder farmer, Adaptive capacity, Climate change

1. Introduction

Climate change, a long-term imbalance of customary weather conditions such as temperature, radiation, wind and rainfall characteristics of a particular region, is likely to be one of the main challenges of the present century for mankind (Ganaie et al., 2013). It is a serious threat to food production worldwide (IPCC, 2014). Climate variability has attracted much attention in recent decades, not only because of the globally unparalleled persistence of anomalously low rainfall, but also because of the low capacity of society and economical systems to cope with climate change related risks. As a result of this low capacity, extreme climate variability, such as drought, is frequently accompanied by ecological decline, decimation of livestock herds, widespread food scarcity, mass migration and great loss of human life (Tarhule and Lamb, 2003).

Climate change with expected long term changes in rainfall patterns and shifting temperature zones are expected to have negative effects on agriculture (Charles and Rashid, 2007). Rural Africa is by far the most vulnerable due to its farmers' heavy dependence on rain-fed agriculture, low adaptive capacity, and insufficient investment in mitigation and resilience-building systems (Teshome et al., 2008).

In DR Congo, it was reported an acute vulnerability situation considering that more than 70% of the population are agricultural dependent and rural inhabitants (Dove et al., 2021). However, climate change is one of the major constraints to poverty reduction and food security improvement in the DR Congo (Hassan et al., 2018). Climate change is expected to increase current vulnerabilities within the Democratic Republic of the Congo (DRC). While there will be significant biophysical impact, particularly in the northeast, with increasing temperatures and changing rainfall patterns, due to its widespread poverty, high population density, and the country's conflict situation, DRC's high vulnerability is primarily related to socioeconomic factors. Food security will be affected due to crop losses and failures, increased livestock mortality, negative impacts on fisheries, and damage to infrastructure (Bele et al., 2010).

In DR Congo, smallholder farming systems are diverse, mostly with livestock as an integral part of the system (Cox 2012). Livestock contributes up to 9.2% of the gross domestic product and plays a crucial role in the livelihood of the local population. Cattle, which is the most reared livestock and the most consumed in the country, contributes to more than 50% of the total meat consumption (Mugumaarhahama et al., 2021). However, it is observed in DRC and other African countries a decrease in cattle herd size due to several factors such as inadequate nutrition, low biosecurity practices, diseases, poor management, little or no veterinary attention, low genetic potential of native livestock, lack of concrete national policies, low quality feeds insecurity in rural regions and climate change (Bisimwa et al., 2018; Mutwedu et al., 2021).

Among the livestock sector, cattle production is one of the most susceptible sectors for the devastating effects of climate change (Angel et al., 2018). Several physiological parameters including lowered milk production, reduced reproduction, increased metabolic disorders and poor immune function have been reported to be impaired as a consequence of climate change (Wheelock et al., 2010). Climate change has also adverse effects on pastures and forages production including the changes in growth and development of pastures, changes in the constituents of pastures like changes in the ratio of grasses to legumes, changes in quality of forage due to change in the concentrations of water-soluble carbohydrates and nitrogen, change in dry matter yield (Akshit et al., 2020).

Empirical evidence has revealed that farmers can effectively manage the negative impact of climate change by adapting their farming practices (Füssel 2007; Arunrat et al. 2017). Such adaptation will soften the impact of climate change, help protect farmers' livelihoods, and lead to other potential advantages (Gandure et al. 2013). Research on adaptation in agriculture is therefore crucial (World Bank 2006) to providing farmers with the knowledge and information on how they can adapt to climate change. Like other countries in the sub-Saharan Africa region, DRC is seeking for effective alternatives for countering adverse effects of climate change that are undermining the livelihoods of communities (Katcho et al., 2022). However, before policymakers and researchers attempt to educate farmers about adaptation measures, they need to understand the farmers' perspectives and attitudes towards climate change. Such understanding will, in turn, help to see how such pre-existing perceptions can be changed in order to encourage adaptation behavior (Bryan et al. 2013).

In DR Congo, data related to farmers’ perception to climate change exist, but those referring to the small livestock keepers on the effect of climate related risks and household food security remain rare. It is in that line that this study was initiated with the aim to evaluate the small livestock keepers’ ongoing adaptation measures, and to identify factors that influence their choice of adaptation methods in cattle production in the South Kivu province, eastern DR Congo.

2. Material and methods

2.1. Study area

This study was conducted from May to October 2022 in 5 *territoires* of South Kivu province, Eastern DR Congo (Figure 11) corresponding to the low altitude (Uvira *territoire*), medium altitude (Kabare *territoire*) and high altitude (Walungu, Kalehe and Mwenga *territoires*). The South Kivu province is located between1° 36′ and 5° south latitude and between 26° 47′ and 29°20′ east longitude. It covers an area of 69,130 km^2 and has an average annual temperature of 19 °C, with an altitude ranging from 773 to 3000 m a.s.l. The selected *territoires* 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 (Mondo et al., 2019; Ndjadi et al., 2020). Kalehe, Kabare and Kalehe *territoires* are bordered by Lake Kivu while Uvira is bordered by Ruzizi river. The Kahuzi National Park extends to Kabare, Walungu and Kalehe. Thus, the lake, the river and the forest are regulators of rainfall and temperatures despite climate variability which has been reported in the study area. Populations depend mainly on agriculture, livestock farming and fishing for income. Major subsistence livestock include cattle, goat and chicken. These regions are direct food suppliers to the Bukavu City which constitutes their primary market (Mondo et al., 2019). The five *territoires* covered by this study are densely populated (>300persons km^2) and inhabited by ~1.4 million people, from three main ethnic groups: Bashi, Bahavu and Bafuliru. For these three ethnic groups, cattle is not only a food and cash livestock but also an integral part of social and cultural belief systems. For instance, cattle is part of all major festive ceremonies such as wedding in which it is given as a dowry and provides white cheese as a result of fermentation of cowmilk which is very appreciated by the local population.

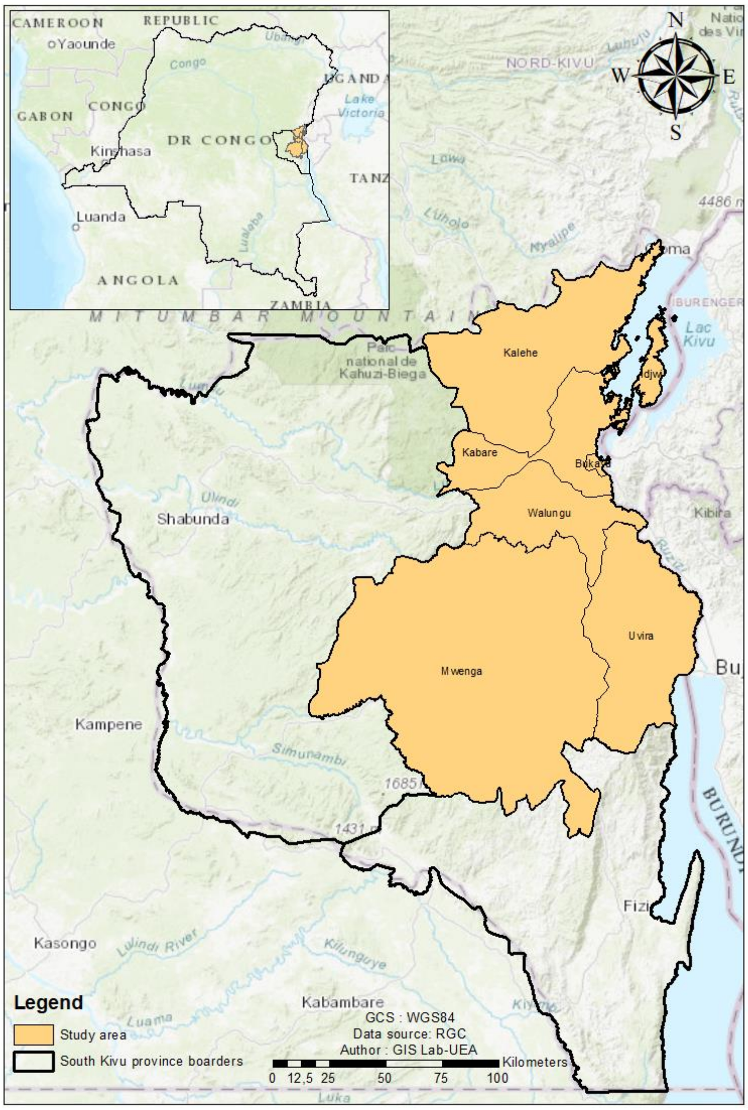

Figure 11. *Map of the study area*

2.2.Sampling and data collection

Sampling was conducted in five of the eight *territoires* of South-Kivu province (Kabare, Walungu, Uvira, Kalehe and Mwenga *territoires*) and data collected from 976 cattle farms corresponding to 179 in Kabare, 344 in Walungu, 207 in Uvira, 182 in Kalehe and 63 in Mwenga. In each farm, a structured survey questionnaire and participatory interviews were carried out with farm managers. The questionnaire was administered in the local language through face-to-face interviews. The households were the units of analysis, as the household level tends to be where decisions about household production, investment, and consumption are made in most agrarian societies, particularly under long-lasting drought conditions. The gathered information mainly covered farmer's socio-demographic information, exposure of livestock keepers to the climate changes' effects, livestock keeper's sensitivity to climatic shocks and livestock keepers' adaptation measures to climate change. Whereas, secondary data on the situation and trends of climate risk, its impact on livestock production (feed, water, disease, productivity, etc) was collected from available literature.

2.3.Empirical approach of vulnerability assessment

Vulnerability of farm-based livelihoods to climatic shocks is their tendency or predisposition to be negatively impacted (adapted from IPCC, 2014). Vulnerability of farm-based livelihood systems encompasses a variety of concepts and factors, such as sensitivity or susceptibility to climate shocks and lack of capacity to cope and adapt (adapted from IPCC, 2014). It is dependent upon exposure, sensitivity, and adaptability. Exposure has an external dimension in the IPCC paradigm, whereas sensitivity and adaptation capacity have internal dimensions (Füssel, 2007). To assess the vulnerability of farm-based livelihood systems to climate shocks, it is vital to comprehend each of the three vulnerability components. In the context of this research, exposure refers to the presence of farm-based livelihood systems in locations and contexts that could be negatively impacted (adapted from IPCC, 2014). Indicators of exposure characterize the frequency of extreme occurrences, the magnitude of land degradation and sea-level rise, and variations in temperature and precipitation (Islam et al., 2014). This research defines sensitivity as the degree to which a farm-based livelihood system is negatively or positively impacted by climate shocks (adapted from IPCC, 2014). Sensitivity encompasses both negative and positive effects, as the occurrence of climate shocks may be advantageous to some farm-based livelihood systems. Adaptive capacity is the capacity of a farm-based livelihood system to adjust to climate shocks, seize opportunities, or respond to consequences (adapted from IPCC, 2014). In the IPCC framework, adaptive capability and vulnerability are inversely connected. In this approach, a higher adaptive capacity equates to a lower vulnerability to climate shocks. However, it is not always the case that a greater adaptive capacity correlates with lower susceptibility. A livelihood system based on agriculture may have a high adaptation capability yet be highly vulnerable to climate shocks as a result. In addition, a low adaptive capability can reduce susceptibility. Due to the fact that sensitivity includes a positive effect of climate shocks, certain farmers can gain from these events.

2.4. Calculation of the vulnerability index

To assess the vulnerability of farm-based livelihood systems to climate shocks, it is vital to comprehend each of the three vulnerability components (exposure, sensitivity, and adaptive capacity). The indicator approach is commonly used for this purpose. It includes assigning a weight to each indicator as one of its features. Therefore, two options are available: either to give them equal weight or to assign different weights, to avoid the uncertainty associated with equal weighting due to the variety of indicators used (Deressa et al., 2008). Principal Component Analysis (PCA) and Factor Analysis (FA) are the dimension reduction techniques that have been proposed and used to assign weights (Lokonon, 2017). This is the one adopted in this study.

As vulnerability is a multidimensional concept (Vincent & Cull, 2014), the sub-indices are computed using all the extracted components from PCA and FA. Each PCA and FA component is weighted by its percentage of variance explained.

$$Y_i^* = \frac{Var_j}{\sum_{j=1}^{p} Var_j} \times Factor_{ji} \times X_i$$

where Var_j is the percentage of explained variance of the component j, Factor ji is the j^{th} factor score relative to the i^{th} indicator, and X_i is the i^{th} indicator.

Vulnerability index is computed for each farm household using the following equation:

$$\hat{v}_h = \sum_{i=1}^{na}\sum_{j=1}^{p}\frac{Var_j}{\sum_{j=1}^{p} Var_j} * Factor_{ji} * X_{ai} - \left(\sum_{i=1}^{ne}\sum_{j=1}^{p}\frac{Var_j}{\sum_{j=1}^{p} Var_j} * Factor_{ji} * X_{ei} + \sum_{i=1}^{ns}\sum_{j=1}^{p}\frac{Var_j}{\sum_{j=1}^{p} Var_j} * Factor_{ji} * X_{si}\right)$$

Where $\hat{v}_h$ is the vulnerability Index, X_{ai}, X_{ei} and X_{si} are respectively the variables of the adaptive capacity, the exposure, and the susceptibility of farmer i. n_a, n_e and n_s: are respectively the number of variables determining the adaptive capacity, the exposure, and the susceptibility.

Table 7. *Variables used in the calculation of the household vulnerability index*

Component	Variables
Exposure	*Change in rainfall*
	Change in rainfall intensity
	Change in rainfall regularity
	Change in spatial distribution of rainfall
	Occurrence of pockets of drought
	Change in temperature
	Occurrence of flooding
	Occurrence of high winds
	Occurrence of erosion
Sensitivity	*Household size*
	Proportion of children in the household
	Proportion of illiterates in the household
	Extent of land ownership
	Losses due to flooding

	Losses due to drought
	Losses due to high winds
	Loss of land due to erosion
	Losses of animals due to erosion
	Decline in pasture productivity
	Loss of forage species
	Appearance of invasive species
	Decrease in crop yields
	Proliferation of parasites
	Proliferation of diseases
	Appearance of new animal diseases
	Decrease in milk production
	Decrease in live weight of animals
	Loss of male fertility
	Loss of male fertility
	Increase in the frequency of abortions
	Decrease in herd size
	Herd size (TLU)
Adaptative capacity	*Proportion of adults in the household*
	Proportion of educated people in the household
	Livestock experience
	Level of education
	Number of telephones in the household
	Possession of off-farm income
	Membership in livestock associations
	Use of family labor
	Use of paid labor
	Solidarity with other herders in conducting herding activities
	Ability to save
	Access to agricultural credit
	Financial assistance from a third party
	Number of contacts with extension workers
	Access to electricity
	Access to drinking water
	Distance from farmer's home to market
	Distance from farmer's home to road
	Number of family members living in the same area
	Number of friends living in the same community
	Number of people who can lend money
	Trust in neighbors
	Participation in community activities
	Participation of community members in achieving common development goals

3. Results

Figure 12 summarizes the indices of exposition, sensitivity, adaptive capacity and potential impact of territoires of South Kivu province.

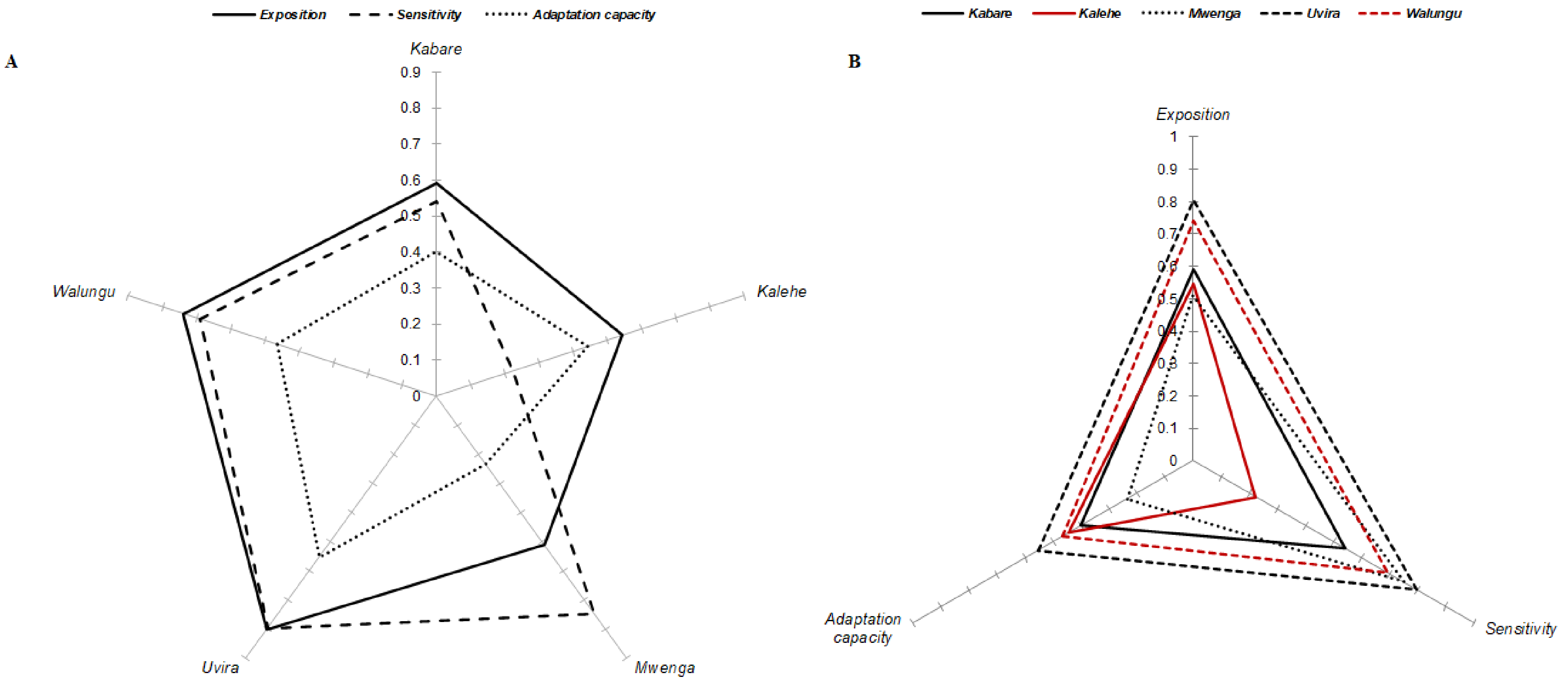

Figure 12*. Vulnerability of livestock farmers in the territoires of South Kivu province*

Figure 12 demonstrates that Uvira farmers are the most exposed to the effects of climate change, followed by Walungu farmers. Farmers in Kabare, Kalehe, and Mwenga are exposed to comparable levels. In terms of sensitivity, the farmers in Uvira and Mwenga are the most sensitive. Those in Walungu are ranked second. The farmers in Kalehe stand out as the least vulnerable to the effects of climate change. It shows that farmers in Uviri and Walungu are more likely to be severely impacted by climate change shocks. These impacts are significantly less severe for farmers in Kalehe. As long as adaptive capacity is concerned, It appears that the farmers in Uvira have the greatest capacity to adapt to the effects of climate change, followed by those in Walungu, Kabare, and Kalehe. The farmers in Mwenga had the lowest adaptative capacity. Overall, the farmers in Uvira and Walungu are the most vulnerable to climate change, according to the results of the vulnerability index of farmers to climate change. The farmers in Kalehe are the least vulnerable.

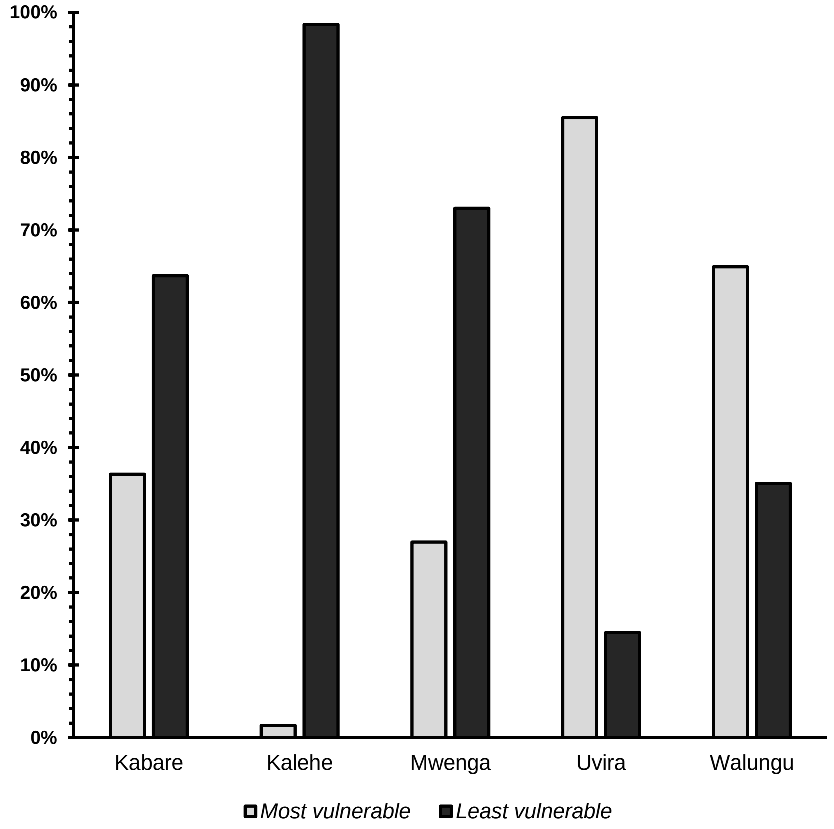

Figure 13*. Vulnerability of farmers in the territoires of South Kivu province*

Figure 13 shows the spatial distribution of vulnerable farmers in the province of South Kivu. It is evident that Walungu and Uvira *territoires* have the highest proportions of most vulnerable farmers. The majority of vulnerable farmers in Walungu reside in Kamanyola, the northern portion of the Ruzizi plain. In comparison, there are almost no vulnerable farmers in Kalehe.

This indicates that farmers living in arid climates in South Kivu are the most exposed to climate change shocks.

***Table 8**. Profile of household heads*

	Most vulnerable	Least vulnerable	Total	Probability
Sex				
Female	14.1	15.6	14.8	0.522
Male	85.9	84.4	85.2	
Age				
Less than 20 years old	2.3	1.5	1.9	0.052
20 - 30 years old	8.1	8.8	8.5	
30 - 40 years old	19.5	12.8	16.2	
40 - 50 years old	26.8	26.9	26.9	
50 - 60 years old	26.3	34.5	30.4	
Over 60 years old	17.0	15.4	16.2	
Experience				
Less than 5 years	14.3	10.7	12.5	0.250
5 - 10 years	18.9	17.9	18.4	
10 - 15 years	20.7	22.5	21.6	
15 - 20 years	19.9	24.4	22.2	
More than 20 years	26.1	24.4	25.3	
Marital status				
Single	9.3	7.8	8.6	0.000*
Divorced	3.5	10.7	7.1	
Married	71.8	60.4	66.1	
Widowed	15.4	21.1	18.2	
Level of education of head of household				
None	46.3	33.3	39.8	0.000*
Primary	27.4	18.9	23.2	
Secondary	21.6	32.6	27.1	
Higher-University	4.8	15.2	9.9	
Main source of income				
Agriculture-Livestock	77.4	52.8	65.2	0.000*
Small business	9.5	11.8	10.7	
Private business	1.2	4.8	3.0	
Public service	2.5	10.7	6.6	
Small trade	8.5	14.5	11.5	
NGO work	0.8	5.3	3.0	
Time allocated to herding				
None	3.5	12.8	8.2	0.000*
Partial	30.9	30.1	30.5	
Full	65.6	57.1	61.3	

Membership in associations	15.1	45.3	30.1	0.000*
Possession of off-farm income	29.0	60.8	44.8	0.000*
Ability to save	21.0	53.1	36.9	0.000*
Possession of a bank account /COOPEC	7.3	41.3	24.1	0.000*
Access to agricultural credit	4.4	25.3	14.7	0.000*
Financial assistance from a third party	2.7	30.1	16.3	0.000*
Assistance from other farmers in raising livestock	35.9	62.5	49.1	0.000*
Annual contact with extension workers	1.3 ± 2.0^{b}	2.7 ± 2.5^{a}	2.0 ± 2.4	0.000*

The results of table 8 show that the vulnerable farmers encountered in South Kivu are those among whom there is a high proportion of illiterates and a low proportion of those who have completed higher education - university. This highlights the role of schooling for rural populations in reducing their level of vulnerability, as most of them make their living from agriculture and livestock. The fact that herders do not belong to farmers' associations also seems to be another important factor in increasing farmers' vulnerability. The possession of off-farm income in addition to agricultural income seems to give farmers a major advantage in coping with the effects of climate change. This income seems to give farmers a strong capacity to save and, in addition, the possibility of having an account in a bank or microfinance structure such as the COOPEC and thus a certain credibility to benefit more easily from agricultural credit.

***Table 9**. Characteristics of households*

	Most vulnerable	**Least vulnerable**	**Total**	**Probability**
Type of housing				
Sustainable	22.2	23.2	22.7	0.067
Semi-sustainable	37.1	43.2	40.1	
Non-sustainable	40.7	33.7	37.2	
Household size	10.3 ± 4.1^{a}	9.6 ± 4.0^{b}	9.9 ± 4.1	0.008*
Adult males	2.5 ± 1.3^{b}	3.1 ± 1.8^{a}	2.8 ± 1.6	0.000*
Female adults	2.3 ± 1.4^{b}	2.7 ± 1.8^{a}	2.5 ± 1.6	0.000*
Children	4.4 ± 3.2^{a}	3.7 ± 3.0^{b}	4.1 ± 3.1	0.000*
Persons with primary education	2.7 ± 2.2	2.8 ± 2.5	2.8 ± 2.4	0.588
Persons with secondary education	2.3 ± 2.0^{b}	3.1 ± 2.1^{a}	2.7 ± 2.1	0.000*
Persons with higher education	0.6 ± 1.0^{b}	1.5 ± 9.3^{a}	1.0 ± 6.6	0.000*
Telephones in the household	1.8 ± 1.3^{b}	2.2 ± 1.7^{a}	2.0 ± 1.5	0.000*
Access to electricity	25.1	37.7	31.3	0.000*
Access to drinking water	56.2	56.0	56.1	0.944
Use of family labor	54.8	43.6	49.2	0.001*

Use of paid labor	56.8	64.2	60.5	0.000*
Amount of land owned				
None	44.2	53.7	48.9	0.000*
Less than 1 ha	36.9	14.7	25.9	
1-5 ha	11.8	19.2	15.5	
6-10 ha	5.6	11.4	8.5	
More than 10 ha	1.5	1.1	1.3	
Amount of land used				
None	21.6	14.3	18	0.000*
Less than 1 ha	47.9	32.0	40	
1-5 ha	22.4	33.5	27.9	
6-10 ha	7.1	17.9	12.4	
More than 10 ha	1.0	2.3	1.7	
Distance from the nearest market				
Less than 1km	29.9	27.4	28.6	0.008*
Between 1 and 5km	63.1	59.6	61.3	
More than 5km	7.1	13.1	10.0	
Distance from the nearest roads				
Less than 1km	49.4	41.7	45.6	0.037
Between 1 and 5km	45.2	50.5	47.9	
More than 5km	5.4	7.8	6.6	
Family members living in the same locality				
None	13.9	11.8	12.9	0.488
Few	41.5	44.6	43.1	
Very many	44.6	43.6	44.1	
Friends living in the same area				
None	9.3	8.8	9.1	0.159
Few	42.9	49.1	46.0	
Very many	47.7	42.1	44.9	
People who can lend money				
None	46.9	42.3	44.6	0.017*
Few	45.2	44.2	44.7	
Very many	7.9	13.5	10.7	
Trust in household neighbors				
None	3.1	6.1	4.6	0.004*
Low	51.2	41.9	46.6	
High	45.6	52.0	48.8	
Participation in community activities				
No	34.0	14.3	24.2	0.000*
Yes	66.0	85.7	75.8	
Involvement of community members in development objectives				

Majority	73.4	85.3	79.3	0.000*
Minority	26.6	14.7	20.7	

The largest household size (10.3 4.1) and the greatest number of children (4.4 3.2) belong to vulnerable livestock keepers (Table 9). The fewest adults and those with a sufficient level of education reside in these houses as well. Table 9 demonstrates that vulnerable livestock keepers have poor access to land resources.

***Table 10**. Herd composition*

	Most vulnerable	Least vulnerable	Total	Probability
Cattle	7.0 ± 12.2[b]	22.7 ± 34.3[a]	14.8 ± 26.8	0.000*
Goats	8.4 ± 9.3[b]	9.4 ± 10.2[a]	8.9 ± 9.8	0.033*
Sheep	1.8 ± 3.5[b]	3.5 ± 5.2[a]	2.6 ± 4.5	0.000*
Pigs	2.7 ± 4.1[b]	4.7 ± 6.8[a]	3.7 ± 5.7	0.000*
Poultry	7.8 ± 24.9[b]	12.1 ± 33.9[a]	9.9 ± 29.8	0.001*
Guinea pigs	8.0 ± 24.1[a]	6.9 ± 18.4[b]	7.5 ± 21.5	0.001*
Rabbits	3.4 ± 16.5[a]	2.7 ± 6.8[b]	3.0 ± 12.6	0.000*
TLU	7.9 ± 10.6[b]	21.4 ± 28.6[a]	14.6 ± 22.6	0.000*
Number of species	4.0 ± 1.7[b]	4.3 ± 1.4[a]	4.2 ± 1.6	0.000*

It should be noted that herd size is not a factor that increases the vulnerability of livestock farmers to the effects of climate change. The most vulnerable households are those with the smallest herd sizes (7.9 ± 10.6 TLU) with less diversity compared to the herds of the least vulnerable farmers (Table 10)

***Table 11**. Perceived exposure to climate change hazards*

	Most vulnerable	Least vulnerable	Total	Probability
Change in rainfall	95.8	73.9	84.7	0.000*
Change in rainfall intensity	94.5	47.3	70.7	0.000*
Change in the start of the rainy season	94.1	66.8	80.4	0.000*
Change in the end of the rainy season	81.1	47.3	64.1	0.000*
Change in rainfall regularity	90.1	59.1	74.5	0.000*
Change in spatial distribution of rainfall	82.7	51.2	66.9	0.000*
More regular occurrence of pockets of drought	80.4	20.5	50.3	0.000*
Lengthening of the dry season	93.1	27.6	60.1	0.000*

Change in temperature	90.7	51.5	71.0	0.000*
Change in temperature in rainy season	81.9	44.4	63.0	0.000*
Temperature change in dry season	88.6	29.0	58.6	0.000*
Change in daytime temperature	76.8	22.0	49.2	0.000*
Change in temperature at night	61.7	38.4	49.9	0.000*
Regular occurrence of floods	87.4	26.1	56.5	0.000*
Occurrence of high winds	84.4	40.7	62.4	0.000*
Occurrence of unusual heat	83.8	33.8	58.6	0.000*
Occurrence of intense rainfall	81.5	40.7	60.9	0.000*

The results in Table 11 show that vulnerable livestock producers are the most exposed to the effects of climate change. Vulnerable herders report exposure to most indicators of exposure to climate change impacts. In contrast, there is strong heterogeneity in the indicators to which the least vulnerable herders are exposed. For the latter, they are more likely to observe changes in rainfall, the regularity and spatial distribution of rainfall, and increases in temperature. Table 12 provides information on what the farmers think are the causes of climate change.

Table 12. *Causes of climate change*

	Most vulnerable	**Least vulnerable**	**Total**	**Probability**
Divine Will	49.0	46.1	47.5	0.376
End of time	7.1	13.9	10.4	0.001*
Deforestation	17.0	49.3	33.0	0.000*
Desertification	2.1	12.0	7.0	0.000*
Non-respect of customs and traditions	7.3	20.8	14.0	0.000*
Degradation of the soil	7.3	25.9	16.5	0.000*
Intense cultivation without fallow	6.0	31.8	18.8	0.000*
Emission of greenhouse gases	5.6	29.1	17.2	0.000*
Poor feeding of animals	4.8	38.3	21.4	0.000*
Other unknown causes	38.4	21.3	29.9	0.000*

Most farmers believe that the observed effects of climate change and their impacts are due to divine will (47.5%) or to other causes unknown to them (29.9%). A high proportion (49.3%) of the least vulnerable farmers consider deforestation to be one of the major causes of climate change. Some of the farmers in this category (the least vulnerable) believe that among the causes of climate change identified are poor animal feed (38.3%), intense exploitation of land without fallowing (31.8%) and greenhouse gas emissions (29.1%), among others, as can be seen in Table 12. With regard to the impacts of the observed changes, Table 13 presents the related results.

Table 13. *Perceived impacts of exposure to climate change hazards*

	Most vulnerable	Least vulnerable	Total	Probability
Losses due to flooding	64.2	27.8	45.9	0.000*
Losses due to high winds	63.4	34.2	48.7	0.000*
Drying up of rivers	86.9	38.0	62.3	0.000*
Occurrence of erosion	68.0	27.0	47.3	0.000*
Loss of land due to erosion	83.2	55.4	69.2	0.000*
Loss of animals due to erosion	77.3	39.6	58.3	0.000*
Occurrence of famine	90.7	58.3	74.4	0.000*
Change of date for planting	89.1	47.9	68.3	0.000*
Loss of forage biomass	88.2	47.5	67.7	0.000*
Disappearance of certain forage species	87.6	36.7	62.0	0.000*
Appearance of invasive species	66.1	51.7	58.8	0.000*
Decrease in crop yields	87.4	46.3	66.7	0.000*
Proliferation of parasites	85.3	41.9	63.4	0.000*
Proliferation of animal diseases	87.6	48.8	68.0	0.000*
Occurrence of new diseases	84.0	44.2	63.9	0.000*
Decrease in milk production	84.4	44.0	64.1	0.000*
Loss of animal weight	84.8	46.1	65.3	0.000*
Increase in the frequency of abortions	66.9	14.9	40.8	0.000*
Decrease in the size of the herd	76.0	34.2	55.0	0.000*
Progressive abandonment of livestock farming	71.2	26.3	48.6	0.000*
Increase in the frequency of bush fires	72.4	30.1	51.1	0.000*

As with exposure, the most vulnerable farmers report experiencing most of the identified climate change-related impacts. On the other hand, the least vulnerable farmers report experiencing fewer climate change-related impacts. To cope with these impacts, strategies are likely to be put in place. Table 14 summarizes the main strategies that farmers think would be appropriate for coping with the effects of climate change.

Table 14. Adaptation strategies

	Most vulnerable	Least vulnerable	Total	Probability
Income diversification	63.6	51.7	57.6	0.000*
Increase in funds allocated to livestock	64.4	56.6	60.5	0.014*
Increase in the amount of land used for grazing	74.9	22.4	48.5	0.000*
Adoption of improved forages	80.6	31.7	56.0	0.000*
Fertilization of pastures	75.2	16.2	45.5	0.000*
Irrigation of pastures	75.8	13.9	44.6	0.000*
Intensification of erosion control	76.0	42.1	58.9	0.000*
Stabling of animals	77.7	63.7	70.6	0.000*
Practice of integrated farming systems	84.0	46.7	65.2	0.000*
Transhumance	78.3	59.8	69.0	0.000*
Contribution of food supplements	66.9	34.2	50.5	0.000*
Contribution of food supplements	60.0	28.2	44.0	0.000*
Concentrated feed intake	56.4	19.5	37.8	0.000*
Silage	52.4	18.7	35.4	0.000*
Use of crop residues	80.6	65.1	72.8	0.000*
Use of agro-industrial by-products	70.5	13.5	41.8	0.000*
Adoption of improved animal breeds	62.5	20.3	41.3	0.000*
Breeding of short-cycle animals	73.1	30.5	51.6	0.000*
Fodder crops	77.3	20.3	48.6	0.000*
Reforestation	78.5	35.7	56.9	0.000*
Genetic selection of animals	79.6	33.2	56.2	0.000*
Disease control	88.4	55.8	72.0	0.000*
Control of parasites	86.9	56.8	71.8	0.000*
Intensification of pasture irrigation	76.8	13.7	45.0	0.000*
Control of bush fires	70.9	28.8	49.7	0.000*
Traditional rites	60.0	13.9	36.8	0.000*
Prayer	79.6	63.1	71.3	0.000*

The results in Table 14 show that almost all of the strategies identified for coping with the effects of climate change seem to be of interest to the most vulnerable farmers. Most of them believe that these strategies would allow them to cope with the effects of climate change. The most vulnerable herders seem to be more open to the implementation of most of these strategies to cope with the effects of climate change. However, opinions are very divided among the least vulnerable group of farmers. For these farmers, the strategies that are most important to them are diversification of income, increased investment in livestock, stabling or transhumance of animals, utilization of crop residues, intensification of disease and pest control, and prayer.

The results of this table show that indicate that the main variables influencing the susceptibility of livestock households to the effects of change are the proportion of adults who are female and have higher education in the household, the presence of off-farm income, membership in livestock associations, the use of family labor, assistance from other livestock keepers, the household's ability to save, the availability of financial support from a third party, and the frequency of annual contacts with external parties. Less vulnerability exists in households with more educated and adult females. When a lot of a household's relatives reside in the same area, vulnerability is also reduced (village). On the other hand, vulnerability increases when households have less contact with extension workers.

4. Conclusion

This research examines how farmers in South Kivu Province in the eastern Democratic Republic of Congo perceive and are affected by the impacts of climate change in three different agro-ecological zones within the province. The results show that farmers in arid zones such as Uvira have a high vulnerability index. As one moves from more arid to less arid zones, the level of vulnerability decreases. Farmers in Kabare, Kalehe and Mwenga have the same level of vulnerability. Farmers in Uvira have the greatest potential to adapt to climate change, followed by those in Walungu, Kabare and Kalehe. The farmers in Mwenga have the lowest adaptive capacity. In terms of farmers' sensitivity index, farmers in Uvira and Walungu are the most sensitive. Farmers in Kalehe have the most secure livelihoods. It is clear that Walungu and Uvira have the highest number of the most vulnerable farmers. The majority of farmers believe that the observed effects of climate change and its consequences are due to the will of a divine being or other unknown factors. This shows how fundamentally farmers misunderstand climate change. Therefore, awareness of the impacts of climate change that make farmers vulnerable should highlight the relevance of the strategy being implemented.

Chapter 5: Stakeholders capacity building

Abstract

The purpose of this specific objective was to reinforce the capacity of different stakeholders involved in the livestock production sector (especially those who are involved in the food aspect) in South Kivu in order to propose a scheme for the improvement and the use of available animal feed resources for the improvement of livestock productivity in South Kivu.

The method used to achieve this objective was based on the discussion with these stakeholders (farmers, policymakers, researchers, local and national NGOs, and master's students funded by the project) involved in the livestock productivity value chain in South Kivu.

In fact, those actors focused on the results obtained on (i) the identification, description, geographic distribution, and seasonal dynamic of available forage and other animal feeding resources; (ii) livestock feeding practice (Chapter 2); (iii) the evaluation of pasture chemical composition and productivity (Chapter 3); and (iv) farmers' perception and vulnerability to climate change-related shocks (Chapter 4) in the four different agro-ecological zones covered in this study to conceive the scheme. Three key strategies were raised by all stakeholders to improve animal productivity through animal feeding. These are: good pasture management, good management of animal feeding and forage conservation. For the applicability and the implementation of these strategies; keys actors including farmers (individual or farmers' associations), policy makers in livestock sector and in land use management, researchers in livestock sector as well as local, national and international associations or NGOs involved in livestock sector and particularly animal feeding should be working together. A public-private partnership is required for the good management of livestock production sector.

Keywords: Livestock, productivity, stakeholders, improvement scheme, South Kivu

1. Introduction

One of RUFORUM's main objectives is to strengthen the capacity of actors at all levels (farmers, researchers, local, national, and international organizations, policymakers, etc.) involved in the agriculture and livestock sectors to improve agricultural productivity and fight against food insecurity in African's countries.

In this perspective, research initiatives are supported by RUFORUM with the primary goal of creating strategies and models to increase agricultural productivity along the entire agriculture and livestock value chain in African nations. It is within this framework that this project was conducted with the objective of contributing to the improvement of animal productivity through improved animal feeding in the province of South Kivu in the Democratic Republic of the Congo. For the applicability of the recommendations resulting from this study, the implementation of its results, and the long-term impact of its results on the improvement of animal productivity in South Kivu, a capacity-building activity involving the different actors involved in the value chain of animal production was necessary with the purpose of proposing a scheme for the improvement and the use of available animal feed resources for the improvement of livestock productivity in South Kivu.

This activity was organized with farmers, researchers involved in livestock sector, policy makers in the livestock land use management sectors, local, national and international organizations involved in livestock sector.

2. Material and methods

To achieve this objective and to define a feeding scheme for the improvement of animal productivity in the province of South Kivu, the results of the research carried out within the framework of the project (summarized in chapters 2, 3, and 4) were presented to the different actors involved in animal production in South Kivu (Training schedule presented in table 16). A total of 56people from each category of stakeholders (livestock keepers, researchers in the livestock production sector, policymakers in the livestock production sector, and local, national, and international organizations involved in livestock production) were considered for this purpose (Figure 14).

These actors were selected based on their level of involvement in livestock production activities, their locality, and their history in the livestock production sector.

Based on the results of this project and the personal experiences of the participants, focus groups (figure 15) were organized with the objective of answering two questions.

1. What are the important factors to consider in animal feeding and how should they be managed to improve animal productivity in South Kivu?

2. Who should be interested in feeding and improving animal nutrition in the South Kivu livestock system?

***Table 15**. Training schedule*

Time	Activity	Topic	Speaker	Institution
08 :30-08 :45 AM	Welcome and opening remarks	-----------------------------------	Prof. Ayagirwe BASENGERE Rodrigue, Dean of the Faculty	UEA
08 :45-08 :55 AM	Project presentation	----------------------------------	Prof. Pascaline CIZA	UEA
08 :55-09 :25 AM	First presentation	Physical characteristics and dynamics of pastures in the province of South Kivu; case of the territory of Walungu, Kabare and Uvira	Mr MUGUMAARHAHAMA Yannick MSc. AMANIBASENGERE Justin	UEA
09 :25-09 :45	Discussion	Questions and answers	Participants	
09 :45-10 :30	Second presentation	Nutritional value of forage resources and animal needs according to species, age, physiological condition, and type of production (GENERAL CONTEXT)	Prof CIZA PASCALINE MSc. MWANGA MWANGA ITHE	UEA
10 :30-10 :45	Discussion	Questions and answers	Participants	
10 :45-11 :15	Coffee			
11 :15-12 :00	Third presentation	Nutritional value of pasture fodder in South Kivu and animal nutrition: advantages, limitations, and ways of improvement for better animal productivity	Dr. MUTWEDU BWANA Valence MSc. AMANI KUNDE	UEA
12 :00-12 :15	Discussion	Questions et réponses	Participants	
12 :15-13 :00	Group work	Proposition of appropriate animal feeding models for increasing livestock productivity according to the environment and the animals' needs	Participants et facilitators	
13 :00-14 :00	Lunch			
14 :00-14 :25	Forth presentation	The role of policy and research in the management, improvement, and valuing of available food resources in South Kivu to improve livestock productivity	Dr. Patrick BAENYI Simon	UEA
14 :25-14 :40	Discussion	Questions and answers	Participants	
14 :40-14 :55		Recommandations	Participants	
14 :55-15 :00	Closing words		Prof. Ayagirwe BASENGERE Rodrigue, Dean of the faculty	UEA

Note: The same training schedule was followed for the capacity building of all of the stakeholders.

Figure 14. *Workshop participants*

Figure 15. *Focus groups with different stakeholders in order to define scheme for the improvement and the use of available animal feed resources for the improvement of livestock productivity in South Kivu*

3. Results

Three key concepts were raised by all stakeholders to improve animal productivity through animal feeding. These are: good pasture management**,** good management of animal feeding and forage conservation.

3.1. Good pasture management

The following measures should be considered and incorporated into the model at various levels of stakeholders:

- respect the load capacities by developing a grazing schedule;
- introduce new drought-resistant forage species with high feeding value;
- regroup the farmers in an association for the management and the exploitation of their pastures;
- respect the carrying capacity;
- select pastures over time;
- harvest fodder during the abundance of fodder/rainy season;
- prohibit bush fires;
- adopt for the stable farming system;
- introduce the rotation model in the use of pastures;
- raising awareness on pasture maintenance;
- integrate new species of forage;
- amend the soil/ increase soil fertility;
- integrate and improve the technique of mowing forages;
- establish and develop paddocks in pastures;
- improve the pastures through the introduction of new forage species resistant to drought and of good nutritional value;
- introduce the concept of pasture rotation and fallow practice in some areas;
- introduce and adopt fodder conservation techniques

3.2. Good management of animal feeding

The following measures should be considered and incorporated into the model at various levels of stakeholders:

- explore and use the available forage resources;
- valorise agricultural residues (integration of agriculture and livestock);
- introduce and popularize food supplements;
- combine pastures with supplements and food supplements;
    - Some animal feed supplements:
        - Crop residues;
        - Industrial by-products;
        - Conserved fodder;
        - Kitchen residues;
        - Water.
    - Some food supplements for animals
        - Licking block;
        - Salt;
        - Vitamins;
        - Rock salt.
- introduce fodder species with high nutritional value, highly animal palatability and adapted to the environment: *Pennicetum*, *Brachiaria*, *Cetaria*, *Desmodium*, etc**.**
- balance the feeding;
- improve the technique of mowing/cutting forage at the right time (according to the phrenological cycle);
- identify and conserve the fodder most desired by the animals;
- calculate the ration and distribute it to the animals according to their age and physiological condition

3.3. Fodder conservation

The following measures should be considered and incorporated into the model at various levels of stakeholders:

- disseminate different techniques of fodder conservation adapted to the local context;
- install processing units for agricultural products in order to valorize the results of the research;

- making silage and tedding of forages that will be used for the animal feeding during the dry season.

Table 16. *SWOT analysis for the improvement of animal productivity through animal feeding improvement in South Kivu Province, DRC*

Strengths	Weaknesses	Opportunities	Threats
• Availability of ruminant farmers; • Adaptability of livestock to the local environment; • Presence of communities' pastures; • Availability of local and improved forages as well as other animal feeding resources (crops residues, concentrates) • Availability of farmers organisations and associations; • Favourable environment (climate conditions) for farmers, animals and forages;	• Lack of appropriate infrastructure for livestock; • Non respect of the texts and laws governing the breeding; • Small-scale livestock system characterized by the absence of inputs; • Land conflicts between herders and farmers due to the lack of specific pasture for grazing animals; • Absence of financial institutions that can enable to ensure credit between farmers 'associations;	• Presence of research institution that can enable to provide training to farmers on livestock feeding; • Presence of markets for livestock products; • Favourable environmental conditions for livestock production and for growth and production of forage; • Existence of national policy and regulation that support livestock activities; • Availability of extension officers at territories and villages levels that can advise and support farmers activities and that can also be farmer	• Insecurity due to the increase of armed groups; • Land conflicts due to the lack of space for grazing • Lack of enough space for agriculture and forage cultivation

Source: Focus groups with the stakeholders involved in livestock production in South Kivu/ This project

Chapiter 6: Financial management of the project

1. Award of Grant

The Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) and the Global Research Alliance on Agricultural Greenhouse Gases (GRA) awarded the Université Evangélique en Afrique (UEA) with Grant ID #RU/2020/GRG/08 amounted to USD $70,040.00 for project "*Amélioration de la productivité animale par la valorisation des ressources alimentaires locales au Sud-Kivu*". The amounted grant was disbursed in two instalments: the first instalment (46% of the total grant amount) was received after receipt of the signed Grant award letter and a request for funds while the second instalment (54% of the total amount) was conditional on the timely submission of six-monthly progress reports, 6, 12 months narrative report and audited financial statements and a request for funds. Table 18 presents the summary of completion of the financial report.

Table 17. *Summary of the report completion and submission status*

Disbursement date and amount (in USD)	**Project time (Months)**	**Narrative report**	**Accountability report: Narrative financial Audit report**			**Detailed report**	**Submission date**
28 January 2021 $30,445.00	6	YES	**6 months narrative report** Starting: 16 November 2020 End: 16 May 2021	Narrative reporting total amount Narrative report of expenditure Cumulative expenditure Balance brought forward to 12 months	$30,445.00 $15,250.00 $15,250.00 $15,195.00	YES	4 June 2021
	12	YES	**12 months narrative report** Starting: 16 May 2021 End: 16 November 2021	Starting balance from 6 months Narrative report of expenditure Cumulative expenditure Balance brought forward to 18 months	$15,195.00 $15,290.00 $30,540.00 $-95.00	YES	17 February 2022

10 March 2022 $32,595.00	18	YES	**18 months narrative report** Starting: 17 November 2021 End: 17 May 2022	Starting balance from 12 months: Cash receipt Total amount of expenditure Cumulative expenditure Balance brought forward to 24 months	$-95.00 $32,595.00 $15,662.00 $46,202.00 $16,838.00	YES	31 May 2022
	24	YES	**24 months narrative report** Starting: 17 May 2022 End: 17 November 2022	Starting balance from 18 months Narrative report of expenditure Cumulative expenditure Balance	$16,838.00 $16,838.00 $63,040.00 $0.00	YES	9 January 2022
Total received amount		**$63,040.00**					
Retained amount by RUFORUM							
Year 1 (28 January 2021)		**$2,000.00**					
Year 2 (10 March 2022)		**$5,000.00**					
Total retained amount		**$7,000.00**					
Total amount of the project		**$70,040.00**					

2. Disbursement and Expenditure of Project Funds

a) Total Project Budget

The RUFORUM grant approved amount was $70,040 being sum of year 1 ($30,445.00), year 2 ($32,595.00) and administration costs of $70,040.00 (which is 10% of grant budget).

b) Disbursed Funds

The RUFORUM grant received a total of $63,040 during the two years of project duration and all were made in two disbursements as follows:

- ✓ 1st disbursement: $30,445.00 dated 28th January 2021
- ✓ 2nd disbursement: $32,595.00 dated 10th March 2022

Bank Statements were used as evidence to support the disbursements.

c) Accounted Funds

The received amount $63,040 has been accounted for without reminders by the Principal Investigator as evidenced in the Audit/ Accountability Report submitted. All Audit / Accountability Reports have been resubmitted before completion of technical reports.

d) The Outstanding balance from $70,040.00

The difference from our disbursement and expenditure records is only $7,000.00 (Total Grant of $70,040.00 minus the amount that was actually disbursed to UEA of $63,040.00). The project team observes from its analysis that there is a possibility for the mentioned difference to be originated from the components of retained costs related to: PI Orientation and other RUFORUM Convening Events for Research team and Travel (Local and International costs for RUFORUM Conferences).

Chapter 7: Conclusion and recommendations

1. Conclusion

(i) The project managed to implement all of set objectives

(ii) Involvement of the Government authorities such as those in charge with agriculture and livestock provided trust to the ongoing project works.

(iii) We have been able to produce three Master holders and 4 Bsc holders in the project.

(iv) Pasture characterization has been established and farmers have learned to manage their pastures on the basis of the available forage

(v) Farmers were informed about the impacts of climate change on livestock production and shared their resilience practices to face climate change

(vi) We have been able to establish the innovation platform, which will unite the smallholders' farmers around the Uvira, Walungu and Kabare provinces.

(vii) Networking and capacity building has been the key aspect for this community action research project.

2. Recommendations

(i) Engagement of smallholder cattle farmers and community at large is very important for guaranteed uptake of any outputs

(ii) An involvement of the beneficiaries since the early stages of the research is quite important.

(iii) Community action research provides a suitable model for engaging smallholder farmers and therefore need to be practiced and maintained for sustainability of the projects initiated activities.

(iv) Improve extension services to livestock smallholder farmers

(v) RUFORUM Secretariat need to improve communication among all project implementers within the Secretariat and external implementers as far as fund disbursement, reporting, accountability and publications is concerned.

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