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CONTRIBUTION OF FENCING STRATEGY TO BIODIVERSITY CONSERVATION AND SOCIO-ECONOMIC DEVELOPMENT AROUND VOLCANO NATIONAL PARK, NORTHERN PROVINCE RWANDA

A thesis submitted in partial fulfillment of the requirements for the degree of Master in Biodiversity Conservation and Natural Resources Management

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Kigali, August 2025

DECLARATION

I Alice MUJAWIMANA, declare that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Rwanda or any other institution.

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APPROVAL

I certify that this research project entitled **" CONTRIBUTION OF FENCING STRATEGY TO BIODIVERSITY CONSERVATION AND SOCIO-ECONOMIC DEVELOPMENT AROUND VOLCANO NATIONAL PARK, NORTHERN PROVINCE RWANDA "** was done under my supervision and has been submitted for examination with my approval**.**

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DEDICATION

I dedicate this work to the Infinite-Powerful God, who is the root of all knowledge, insight, and wisdom as well as my mentor and steadfast support system. Throughout my research, He has been my greatest source of inspiration, and I have only been successful when I have followed His guidance. My husband, Théoneste HABUMUREMYI, is also honored in this endeavor for his constant support, which has allowed me to remain focused and complete the duties I have begun. To my entire family, who have been affected in every way by this search.

I respect each and every one of you more than you can possibly know.

Respectively

Stay blessed

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ABBREVIATIONS AND ACRONYMS

%: Percent

Avg: Average

Df: Degree of freedom

eg: Example

FAO: Food Agriculture Organization

IUCN: International Union for Conservation of Nature

NGOs: Non-Government Organizations

ORTPN: Rwandan Office of Tourism and National Parks

RDB: Rwanda Development Board

Reg. Number: Registration Number

SPSS: Statistical Package for the Social Sciences

TBPA: Transboundary Protected Area

UR: University of Rwanda

VNP: Volcanoes National Park

ABSTRACT

The Northern Rwandan Volcanoes National Park (VNP) is a globally recognized biodiversity hotspot. It is under growing threat from conflicts between people and wildlife as well as pressure from land use change that degrades habitat. Fencing was chosen as one of the methods of conservation to protect its biodiversity and lessen wildlife conflicts with nearby residents. Less is known, though, about the ways in which this approach influenced the socioeconomic and ecological growth of the neighborhoods surrounding the park. The purpose of this project is to investigate how fencing strategy and/or intervention pray a role to balance socioeconomic development and biodiversity conservation in the regions surrounding Volcanoes National Park in the northern province of Rwanda. In addition to supporting a wide variety of species, like as the endangered mountain gorilla, the park has previously faced problems with resource degradation, expansion, and conflict between people and wildlife. In order to assess how the park's fencing design contributes to lowering human-wildlife conflict, protecting habitats, and enhancing the standard of living for nearby populations, the study employed a mixed-methods approach that included questionnaires, interviews, and field observations. According to my research, fences have improved food security and economic stability for those living close to the VNP while also somewhat lowering the frequency of crop raiding and animal predation. Additionally, by decreasing illegal access and enhancing biological integrity within the protected area, the method enhanced conservation results. Nonetheless, the study also highlights the significance of inclusive management techniques and community concerns around access to traditional resources. The results highlight how important it is to combine ecological preservation with local development objectives in order to reap the long-term advantages of conservation. Additionally, the study identifies the wildlife species that are most and least impacted by the technique, as well as the function that fencing plays in preserving endangered wildlife species and the effects that the strategy has on local customs and cultural values.

Key words: Fence ecology, human-wildlife conflict, community livelihoods, Volcanoes National Park (VNP), Northern Province, Rwanda.

CHAPTER 1: INTRODUCTION

1.1. Background and problem statement

One of Africa's most important conservation areas is Volcanoes National Park, which is situated in Rwanda's Northern Province and is well-known for its endangered mountain gorilla population as well as its contributions to ecotourism and biodiversity preservation (Munanura, Backman, & Sabuhoro, 2013). The oldest national park in Africa, it was created in 1925 and provides vital habitat for a variety of different wildlife and plant species, including golden monkeys and mountain gorillas (Plumptre et al., 2017). The Park is essential to Rwanda's tourism and conservation industries, bringing in large sums of money for the nation and its residents through gorilla-driven ecotourism (Spenceley & Snyman, 2017).

Despite the park's significance, human-wildlife conflicts nevertheless happen frequently. According to McInturff, Xu, Wilkinson, Dejid, and Brashares (2020), human-wildlife conflict arises when the fundamental demands of animals collide with those of humans, leading to detrimental outcomes for both communities and wildlife. Conflict arises when the needs of humans and nature collide, having negative consequences for both parties (Bowen-Jones, 2012). Accordingly, human-wildlife conflict occurs when wildlife abilities and needs encroach on human populations and have a detrimental impact on life (Packer et al., 2013). Crop raiding, livestock predation, or direct attacks on people are examples of this type of conflict, which can lead to monetary losses, injuries, and wildlife murders in return (Nyhus, 2016).

One of the solutions adopted to avoid human-wildlife conflicts include fencing. Fencing is defined as a physical barrier designed to control the movement of animals or people across landscapes (McInturff, Xu, Wilkinson, Dejid, & Brashares, 2020). Fencing involves building visible barriers such as electrical wires, or natural fences to delineate boundaries and manage animal movements. Fencing protected areas is increasingly recognized across Africa for its effectiveness in reducing illegal encroachment and poaching (Hayward & Kerley, 2009). Fencing is frequently used in conservation contexts to shield fragile species from outside hazards and to stop wildlife from invading agricultural or human areas (Guinness, 2015). Fences thus serve as a non-lethal method for regulating interactions between humans and potentially dangerous wildlife. It does not only support conservation objectives but also enhances local livelihoods by reducing risks associated with wildlife (Kioko, Muruthi, Omondi, & Chiyo, 2008).

In Rwanda, human wildlife conflicts have been reported as a persistent challenge affecting both conservation efforts and local livelihoods (Sun, Bariyanga, & Wronski, 2025). Considering the volcanoes national park, it is a refugee to endangered mountain gorillas and other wildlife species that frequently venture into nearby communities, leading to crop raiding, property damage, and occasional threats to human safety (Guinness, 2015). These conflicts are primarily driven by the proximity between human settlements and the park (Munanura et al., 2013).

Fencing consists of a 76-kilometer dry-stone wall commonly known as "buffalo wall", which was designed to prevent buffaloes and mountain gorillas from straying into farmland and damaging crops (Guinness, 2015). Despite these perceived benefits, the contribution of fencing to both animals inside the park and socioeconomic development of communities around the park remains understudied. This study aims to evaluate the impact of fencing techniques on the preservation of biodiversity and the socioeconomic advancement of the local people surrounding VNP.

1.2 Problem statement

One of the most important issues facing contemporary civilizations is biodiversity conservation. Studies have revealed that human activities have caused a 70% reduction in the geographic range of terrestrial animals in Africa, Australia, Europe, and Southeast Asia (Ceballos & Ehrlich, 2002). Fencing strategies have been increasingly adopted in conservation areas to mitigate human wildlife conflicts (Durant et al., 2015). Despite the purposes of fencing, there is a need to empirically examine the importance of fencing strategies to socioeconomic development including income generation, community security, and conservation awareness (Mbaiwa, 2006).

The Volcanoes National Park (VNP) in Rwanda's Northern Province is a critical biodiversity hotspot that protects endangered species like the mountain gorilla (*Gorilla beringei beringei*) (Uwayo et al., 2020). However, rising human populations, agricultural expansion, and human-wildlife conflicts have all threatened biodiversity conservation in and around the park (Uwayo et al., 2020). Wildlife frequently strays onto nearby farmlands, causing crop damage and jeopardizing local livelihoods, and retaliatory acts by local communities can impact wildlife populations (Kalpers et al., 2003).

To address these issues, fencing strategies have been implemented to reduce human-wildlife conflicts, protect agricultural land, and promote biodiversity conservation (Uwayo et al., 2020). The effectiveness of the fencing method in striking a balance between the socioeconomic demands

of the park's nearby people and biodiversity conservation aims has not been well-documented, despite these measures (Sun et al., 2025). There are still questions about whether fencing helps to decrease wildlife invasion, improve local incomes by lowering crop losses, and create favourable conservation attitudes (O'Neill, Durant, Strebel, & Woodroffe, 2022). It is challenging for policymakers and conservation managers to make evidence-based decisions regarding whether fencing is a long-term strategy for the development of communities and biodiversity conservation in the context of VNP because of this knowledge gap (Munanura, Backman, Sabuhoro, Powell, & Hallo, 2018).

1.3 Objectives, questions, and hypotheses

1.3.1 Main objective

The main objective of this research is to assess the contribution of fencing strategies to ecological and socioeconomic development around Volcanoes National Park, Northern Province, Rwanda.

1.3.2 Specific objectives

The specific objectives of this study are:

- To evaluate the socio-economic advantages that the fence strategy offers the local community;
- To examine community opinions and attitudes concerning the fence strategy and its effectiveness, and
- To assess how the stone wall fence method affects the preservation of wildlife in and around Volcanoes National Park.

1.4 Research question

These are the related research questions, which are based on the specific objectives mentioned above:

- What are the socio-economic benefits of the fencing strategy to the local populations that surround the park?
- What are the community's perspectives and attitudes concerning the fencing strategy and its effectiveness?

- What is the contribution of the stone wall fence technique to the conservation of biodiversity in and around Volcanoes National Park?

1.5 Hypothesis

The hypotheses of this research are:

- The socio-economic development of the community adjacent to VNP is significantly correlated with stone wall fence constructed;
- Community close to VNP benefit greatly from stone wall fence because it lowers human-wildlife conflict including crop invading, and livestock loss;
- The fence strategy contributes significantly to biodiversity conservation around Volcanoes National Park.

CHAPTER 2: LITERATURE REVIEW

2.1 Fauna of the Virunga Volcanoes Region

Plumptre et al. (2003) state that 34 of the 86-animal species found in Volcanoes National Park are large mammals. Eighteen mammal species are endemic, three are near-endemic, six are threatened, and sixteen are listed by the IUCN (Owiunji et al., 2015). The bigger mammals are the mountain gorilla (*Gorilla beringei beringei*), buffalo (*Syncerus caffer*), bushbuck (*Tragelaphus scriptus*), black-fronted duiker (*Cephalophus nigrifrons*), and elephant (*Loxondata africana*), four species are threatened (Owiunji et al., 2015). The VNP also is a refugia the endangered golden monkey (*Cercophithecus kandti*), which is exclusively found in the Volcanoes, as well as the blue monkey (*Cercopithecus mitis*), also the area previously holds 258 bird species documented in Volcanoes, with 20 species native to the Albertine Rift and four threatened (Owiunji et al., 2015).

2.2 Impact of fencing to biodiversity conservation in protected areas

Fencing in protected areas is increasingly being employed as a biodiversity conservation approach, especially in places with high human-wildlife conflict and land-use pressure (Pekor et al., 2019). Fenced protected areas are intended to physically demarcate conservation boundaries, reduce wildlife encroachment into human settlements, and deter illegal activities like poaching, logging, and encroachment (Mensuro, 2009). Fencing in protected areas can help to improve biodiversity conservation by protecting ecosystems and minimizing human demand (Ringma, Wintle, Fuller, Fisher, & Bode, 2017). However, its long-term success is dependent on balancing ecological integrity with socioeconomic considerations, assuring community engagement, and incorporating other conservation measures including ecological corridors and community-based conservation (Tyrrell et al., 2022).

Nowadays, fencing has become an increasingly popular strategy in biodiversity conservation, especially in areas prone to human-wildlife conflicts (Banamwana, Dukuziyaturemye, & Rwanyiziri, 2021). Empirical evidence from other African Protected areas, for example Kenya's Nairobi National Park, shows that well-implemented fencing reduces wildlife incursions into farms, thereby decreasing economic losses and enhancing local support for conservation (Sun et al., 2025). Fencing is primarily aimed at limiting animal movement into human settlements and vice versa, thereby preserving wildlife and minimizing conflict (Kioko et al., 2008). In the context

of Africa, fencing has been implemented to reduce habitat fragmentation, protect endangered species, and create clear boundaries for conservation zones (Hayward & Kerley, 2009).

2.2. Fencing and human-wildlife coexistence

Globally, fencing has been a widely used strategy in protected area management to mitigate human-wildlife conflict and preserve biodiversity (King et al., 2017). It has been applied in countries like South Africa, Australia, and the United States, using electric and physical fences which have significantly reduced wildlife incursions into farmlands, thereby reducing crop damage and retaliatory killings (Hayward & Kerley, 2009). In Kenya and Tanzania, fences have protected key habitats like the Nairobi National Park (Nyaligu & Weeks, 2013).

In Botswana, studies have shown that veterinary fences designed to control livestock diseases have disrupted migratory routes for species such as wildebeests (Mbaiwa, 2006). In Rwanda, Volcanoes National Park covers 3 Districts (Musanze, Burera and Nyabihu), where 12 sectors are adjacent to the VNP and is one such example where fencing strategies have been introduced to preserve endangered species like the mountain gorilla and reduce tensions with surrounding communities (Bush & Gray, 2010). The integration of fencing into Rwanda's conservation policy aligns with broader regional efforts in the Albertine Rift, where biodiversity conservation is a high priority due to the region's ecological richness and anthropogenic pressures (Plumptre et al., 2017).

Further, fencing plays a critical role in maintaining ecological integrity by protecting biodiversity and sensitive ecosystems from human encroachment and degradation (McInturff et al., 2020). Stone wall fences act as physical barriers in protected areas including Volcanoes National park, preventing illegal logging, and unlawful access and poaching, thereby reducing pressure on wildlife and their habitats, the presence of a well-maintained fence allows for the regeneration of native vegetation and this keeps ecological process like pollination , seeds distribution, , and predator-prey relationship stable (Bernhard, Smith, Sabuhoro, Nyandwi, & , and Munanura, 2021).Fencing acts as a barrier that reduces habitat fragmentation and promotes ecological stability by preserving the natural composition and structure of ecosystems (Somers & Hayward, 2012).

2.3 Socio-economic benefits of fencing

Beyond ecological benefits, fencing has an influence on socioeconomic wellbeing of surrounding communities. Research by (Tumusiime & Vedeld, 2012) in Uganda revealed that households

living near well-managed parks with clear boundaries had higher income than those near poorly managed ones. In Rwanda, community-based conservation models have increasingly emphasized the inclusion of local people through benefit-sharing schemes such as eco-tourism revenues sharing, employment, and infrastructure development (RDB, 2024). Considering the VNP, fence serves as clear demarcation lines between community land and conservation zones, reducing disputes and crop loss due to wildlife invasions (Snyman et al., 2023). However, nothing is known about how this stability encourages agricultural investment and increases productivity, thereby improving food security and household income (Spenceley & Snyman, 2017). Based on above different literature review, the fencing strategies has great potential but its contribution in volcano national park to neighborhood socioeconomic development, ecological integrity, reduces human-wildlife conflicts, protects habitats have been under documented (Munanura et al., 2018).

2.4 Fencing-induced changes in biodiversity conservation efforts

Fencing in protected areas is beneficial to biodiversity conservation because it reduces human-wildlife conflicts, protects endangered species, and keeps habitats free of human intrusion (Nguyen, Phan, Ferdin, & Lee, 2021). However, it may have negative repercussions such as habitat fragmentation, limited wildlife movement, decreased genetic diversity, reduced genetic diversity and disruption of natural process including migration and interactions between predator-pray (Tyrrell et al., 2022). Socio-economically, it may limit local residents' access to natural resources, causing conflict between conservation authorities and nearby populations (Watson, Dudley, Segan, and, & Hockings, 2014). As a result, while fence helps greatly to biodiversity conservation, its design and administration must strike a balance between ecological integrity and community interests using adaptive tactics such as wildlife corridors, ecological monitoring, and community-based conservation methods (Snyman et al., 2023).

Furthermore, fencing can cause overpopulation of particular species within enclosed areas, habitat degradation due to overgrazing, and injuries or deaths to animals attempting to jump fences (Creel et al., 2013). Over time, this ecological pressure can limit plant diversity, disrupt native species regeneration, and degrade habitats, endangering the survival of some species that rely on these resources (Somers & Hayward, 2012). Furthermore, a lack of natural dispersal and migration can exacerbate competition for food and water, hastening resource depletion and potentially resulting in the local extinction of vulnerable plant and animal species (Munanura et al., 2013).

Sustainable management measures, such as regulated population management and the creation of wildlife corridors, are therefore required to counteract these detrimental effects (Sun et al., 2025). Studies have reported that protected areas with physical boundaries experience fewer disturbances compared to unfenced parks (Tumusiime & Vedeld, 2012). In relation to the Volcanoes National Park, fencing was expected to mitigate threats to biodiversity posed by agricultural expansion, livestock grazing, and wood harvesting from local communities (RDB, 2024). Moreover, physical barriers have helped reduce mortality rates of wildlife due to road accidents and retaliatory killings, particularly in buffer zones surrounding the park (McInturff et al., 2020). For species like the mountain gorilla that require specific habitat conditions, fencing ensures the continuity and protection of their home ranges (Kalpers et al., 2003).

CHAPTER 3: METHODS

3.1 Description of study area

Volcanoes National Park (VNP) shelters an area of 160 km^2 it is positioned on the border of Rwanda, the Democratic Republic of the Congo, and Uganda, is home that range in elevation from 1,850 to 4,507 meters above sea level (Munanura et al., 2013). It was established in 1925 as part of Parc National Albert to protect mountain gorilla populations, but its size and sovereignty have changed since then, the park which is currently part of the Virunga Massif TBPA, encompasses both the Democratic Republic of the Congo and Uganda (Bernhard et al., 2021). It was extended in 1927 and then separated into Virunga National Park in the Democratic Republic of Congo and Volcanoes National Park in Rwanda in 1960 (Guinness, 2015). After Rwanda gained independence, the Forestry Department took over management of VNP (Bernhard et al., 2021).

The Rwandan Office of Tourism and National Parks (ORTPN) was founded in 1974 to oversee national parks, ORTPN merged with other government organizations in 2008 to form the Rwanda Development Board (RDB), which promotes tourism and biodiversity conservation as part of Rwanda's economic development strategy (Munanura, 2013). The zone adjacent to the park, which consists of four districts (Musanze, Nyabihu, Burera, Rubavu), has the peak population density in the country, extending from 500 to 1,041 inhabitants each square kilometre (Bush & Maryke, 2010).

However, the town has little options to diversify into non-farm sources and participate in the tourist and cultural industries, eengaging farmers in park management and cultural tourism could open up new possibilities in Rwanda (Bernhard et al., 2021). Post-independence management has had no positive impact on locals or the park, and there is no conflict resolution mechanism (Harerimana, 2018). The Park contributes up to 90% of Rwandan tourism revenue, with mountain gorilla tourism ranking third, earning around $200 million per year since 2007 (RDB, 2024)

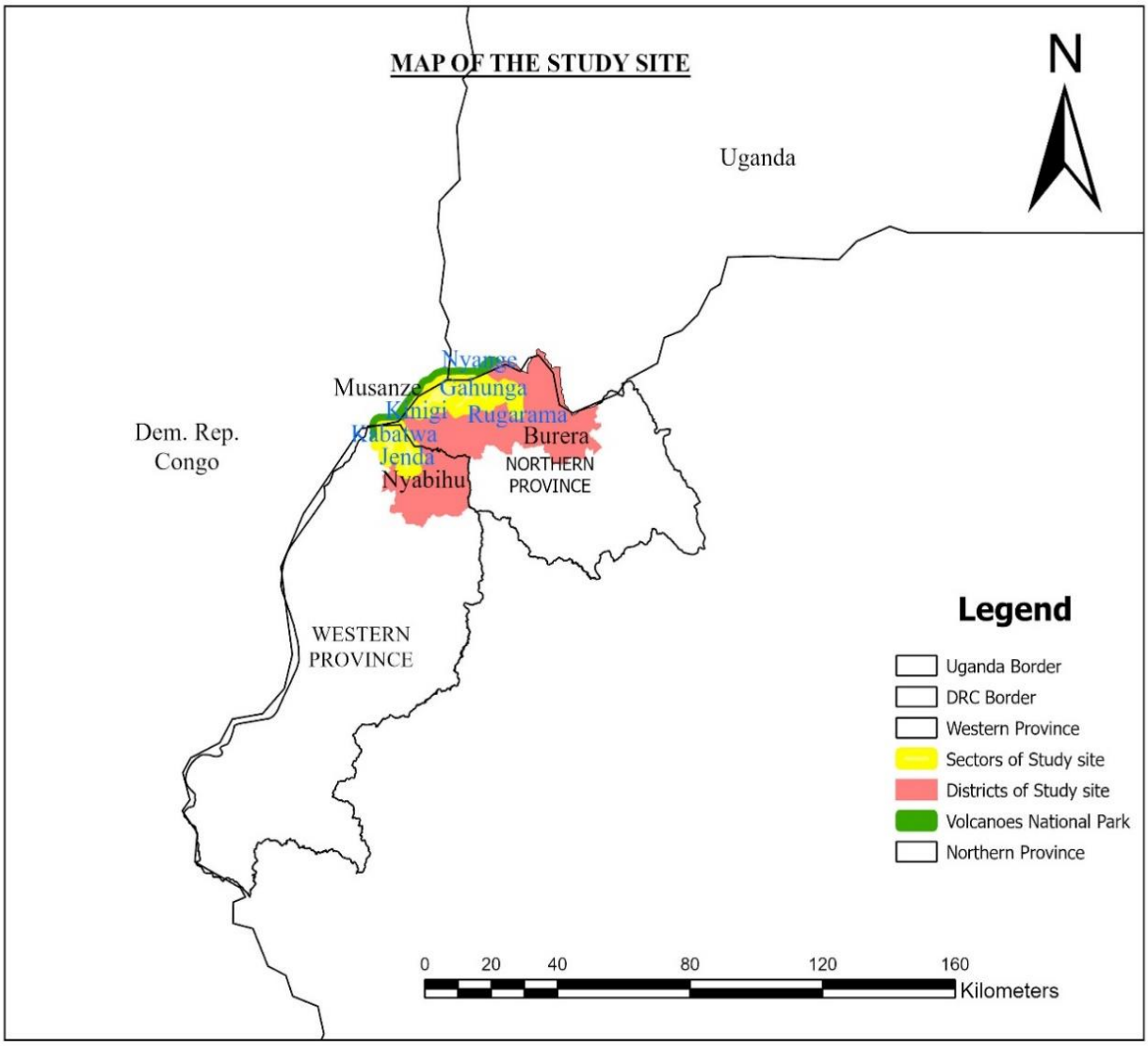

Figure 1: Location of the study area along VNP, Rwanda

3.2 The study design

In order to thoroughly evaluate how stone wall fence strategy supported the ecological integrity of the park's animals and helped to socioeconomic development, this research employed a mixed-methods, a research methodology that combined qualitative and quantitative approaches. Quantitative data has been collected through semi-structured questionnaire (Williamson, 2018) where interviews has been made of open-ended questions and which have been administered to local households and park authorities to evaluate changes in human-wildlife conflict, focusing on agricultural productivity, income generation levels, and employment opportunities before and after fencing interventions. Qualitative data are collected through interviews and focus group discussions (Lanshima & Abdulkarim, 2021) with community leaders, conservation experts, and local government officials in the area where fencing was established to capture perceptions, experiences, and socio-economic impacts of fencing on local communities. In these methods the consent forms have been signed by the respondents prior to the start of the research. Questionnaires have been self-administered and it comprised both closed-ended and open-ended questions to ensure clarity. Both primary and secondary sources of data were used in this research. Residents and park staff provided primary data, while a survey of web and library resources yielded the secondary data (Sarfo, Debrah, Gbordzoe, And, & Obeng, 2022).

Open and closed-ended questions were used during the interview and focus groups discussions. To make sure that every participant's response is carefully maintained in its original form, audio recordings of interviews and conversations were verbatim transcribed. Thematic analysis has been used to carry out the coding process. This involves looking over the transcribed data to find recurrent themes, categories, and patterns that are related to the study's objectives. Text passages that highlight the contribution of fencing strategy to biodiversity conservation and socio-economic development of local people living nearby volcanoes national park have been given initial codes. A quota sampling technique (Sarfo et al., 2022) was used in this research as a non-probability sampling technique in which the population was divided into mutually exclusive sub-groups based on specific characteristics such as age, gender, occupation, or location, and then select participants non-randomly (Sarfo et al., 2022) from each group to ensure representation (Sharma, 2017). Quota sampling was enabled to ensure that key stakeholder groups such as local community members, park staff, local leaders, and key informants are proportionally represented in the data collection.

3.3 Sample size and sampling procedures

The research was carried out across six local administrative sectors including (Rugarama & Gahunga) in Burera District, (Kinigi &Nyange) in Musanze District and (Jenda &Kabatwa) in Nyabihu District of twelve (12) sectors in three Districts that cover Volcanos the National Park namely Burera, Musanze and Nyabihu, where dry-stone wall fencing was installed to protect park wildlife conflict with the surrounding communities (Figure 2).

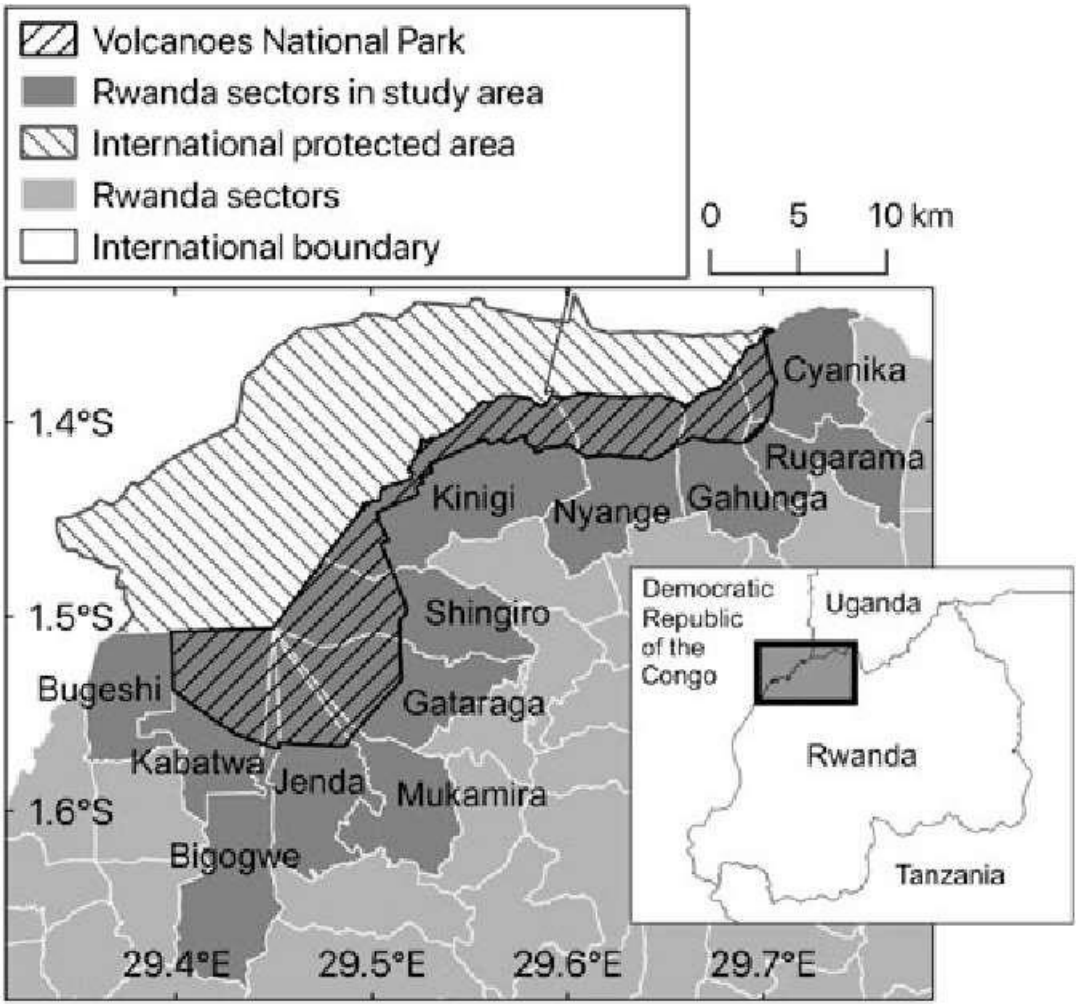

Figure 2: Location of 12 sectors adjacent to VNP

In each sector two cells were sampled in fenced zone and two cells in the control site in each cell 30 residents were sampled respecting 50% male and 50% females.

Questionnaire has been provided to 360 respondents comprising representatives from key informants' local community members (342), park staff (6) and local leaders (12) from the area where the fence was established (Figure 3).

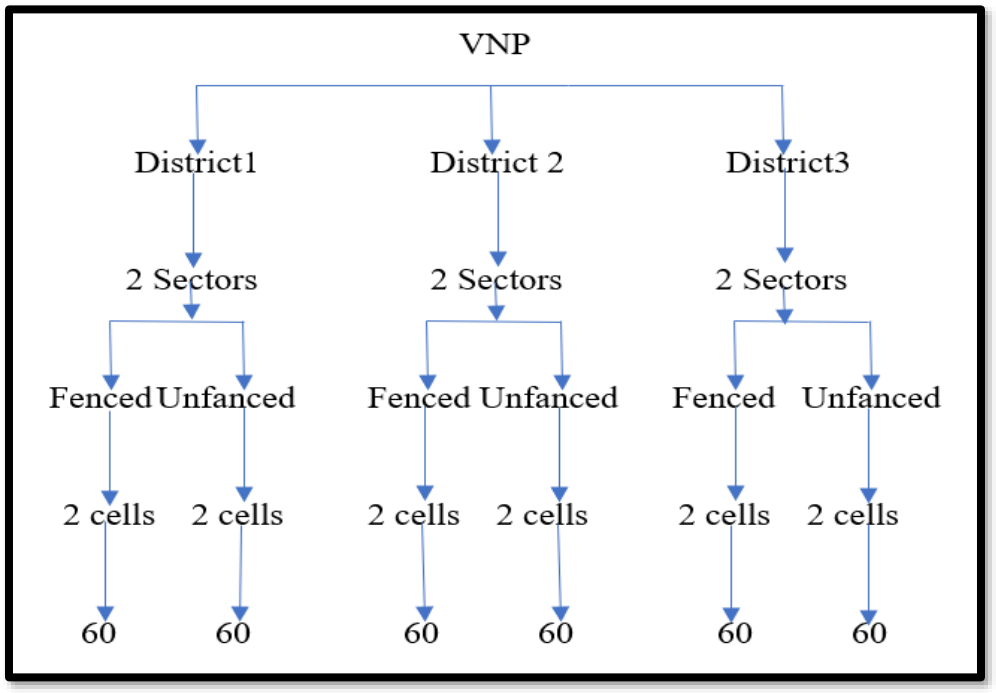

Figure 3: Stratified sample size

Participant with different age categories have been involved in this research to explore different views and experiences. The interview and focus group discussion (Williamson, 2018) were conducted in Kinyarwanda to enable better understanding of questions among participants and later has been translated in English. Key informant interviews and focus groups discussion with, park management staffs, local leaders, and local communities have been conducted to supplement the ecological data. These stakeholders provided relevant qualitative information about wildlife movements both before and after the fence placement because they have extensive, long-term knowledge of the park's ecosystems.

The integration of expert opinion with empirical data allowed me for a comprehensive interpretation of ecological changes and the influence of fencing on biodiversity. The community living nearby the volcanoes national park also provided information about the movements of animals from the park and detect any fence damage. A well-monitored fence strategy can effectively assist biodiversity conservation and ensure that ecological integrity is preserved while fitting with regional socioeconomic and environmental goals due to the development of community ownership and engagement.

3.3 Data analysis

Both quantitative and qualitative techniques were used in the data analysis to assess how stone wall fence intervention influenced the preservation of biodiversity and the socioeconomic advancement of the VNP surrounding populations. For statistical analysis, SPSS software (Rahman & Muktadir, 2021) has been used, and for qualitative data, thematic methodologies were employed. Quantitative data from structured questionnaires have been analyzed using chi-square tests (Krishna Pasupuleti, 2024) to ascertain whether categorical factors such as the existence of stone wall fence and observed improvement in local livelihoods, biodiversity, and human-wildlife conflict are significantly correlated (Nyiratuza, Maniriho, Ming'ate, & Mireri, 2024).

The qualitative information received from respondents via interviews and focus group discussions has been manually categorized and transcribed to find recurring trends like wildlife conflict, community benefits, and livelihood support to ensure the biodiversity conservation of volcanoes national park. In thematic analysis, thematic coding has been used to identify themes and patterns across interviews. Data were organized in tables for comparison across various participant groups namely park staff, local leaders, and community members to enable manual coding. This systematic approach (Krishna Pasupuleti, 2024) ensures that the analysis remains transparent, rigorous, and grounded in participants' perspectives.

CHAPTER 4: RESULTS

4.1 Demographic Characteristics of respondents

To improve gender balance, we collected data from an equal number of men and women (Table1).

Table 1: Age and sex of respondent

Sex	Frequency (n)	Percentage (%)
Male	180	50
Female	180	50
Total	**360**	**100**

Out of 360 responders, the sample was evenly split (50%) between males and females. The majority of responders (33.6%) were between the ages of 31 and 40, followed by those aged 41 to 50 (24.2%), 18 to 30 (21.9%), and beyond 50 (20.3%). This suggests that the sample population was dominated by people aged 31 to 50, means economically active population was well represented (Figure 4).

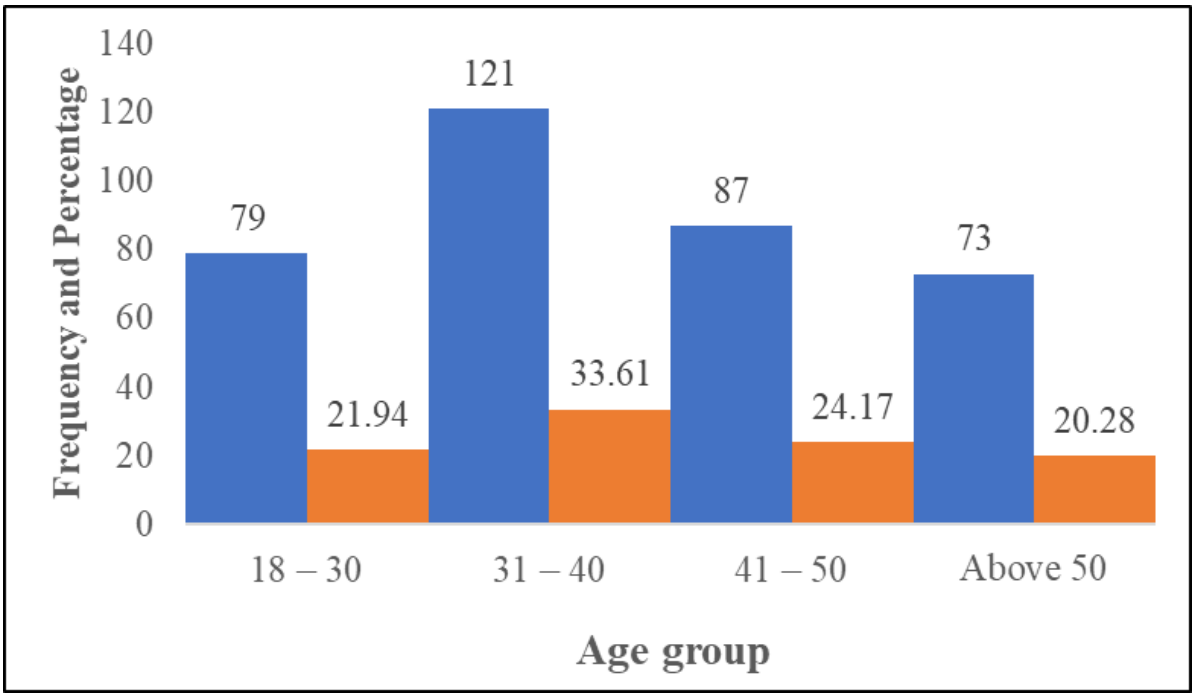

Figure 4: Age distribution of respondents

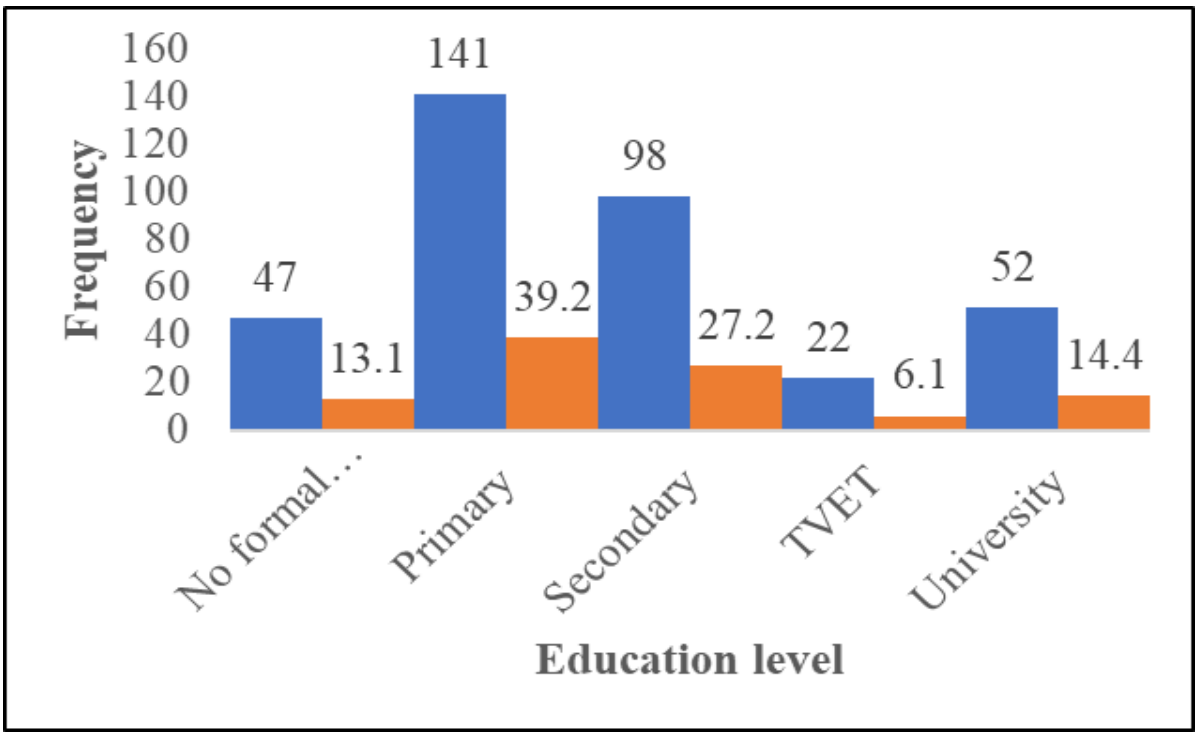

Figure 5: Education level of respondents

A significant proportion of respondents (39.2%) completed primary school, whereas only 14.4% completed higher education. Farming was the most common occupation (69.7%), confirming the study area's agrarian nature (Figure 6).

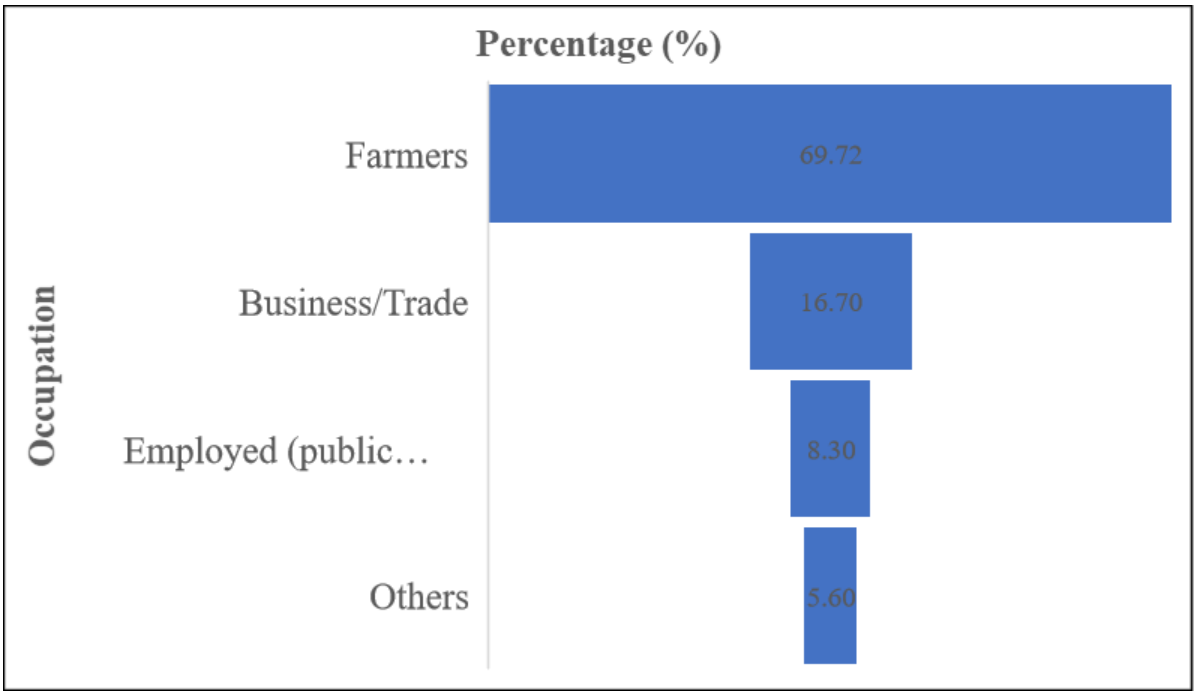

Figure 6: Occupation status of respondents

4.2 Socioeconomic benefits of stone wall fence strategy to the community living around VNP

4.2.1 Employment creation

The table 2 displays the percentage of people from three stakeholder groups Park staff, local leaders, and local community who acknowledged getting specific job creation benefits from the park or conservation program. The research revealed obvious patterns of unequal benefit distribution (Table 2).

Table 2: Impact of fencing on employment opportunities

Contribution	% of Respondents Agreeing
Park fence maintenance works	48%
Increased tourism jobs	37%
Indirect labour opportunities (e.g., transport, vendors)	29%

4.2.2 Perception on human-wildlife conflict trend

The results indicate a moderate reduction in human-wildlife conflict, which resulted to a 30% decrease in crop raiding incidents, and a 27% decrease in livestock predation. Additionally, the community's perception of the strategy on safety improved at 50%. The fencing strategy showed positive but not complete effectiveness in reducing human-wildlife conflict (Figure7).

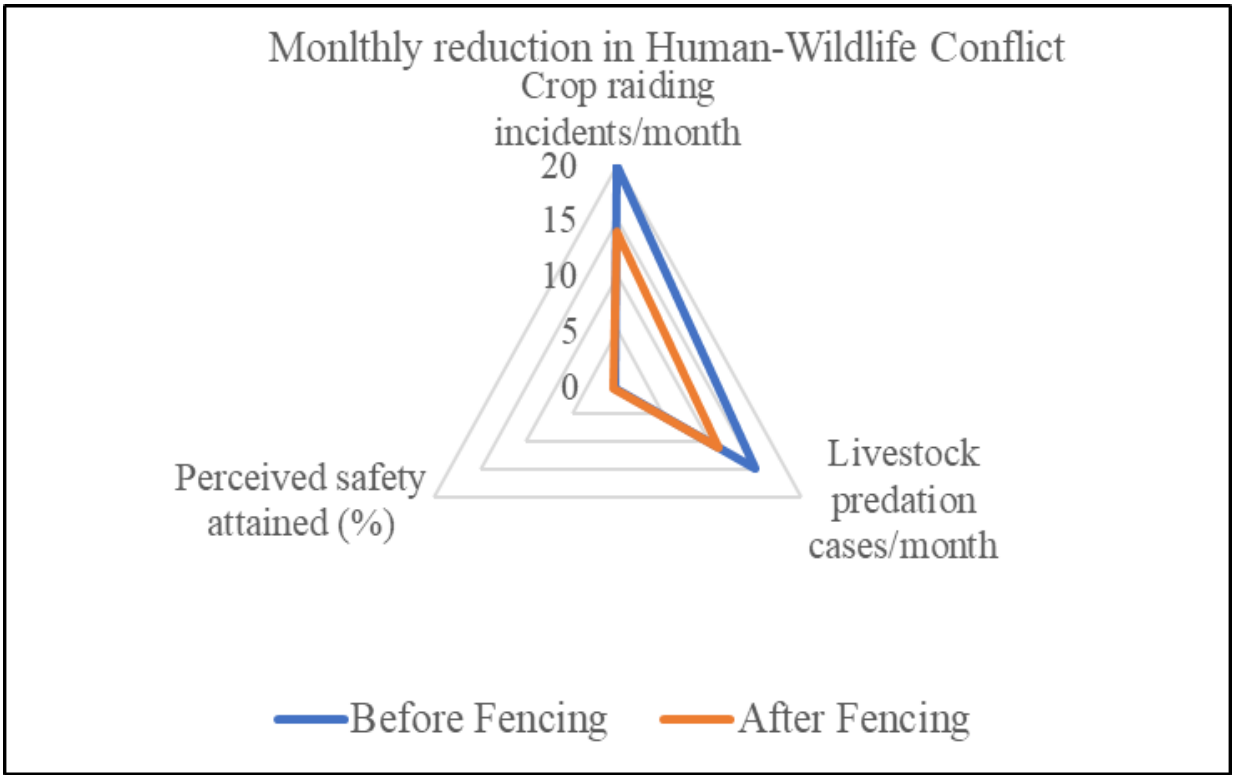

Figure 7: Perception on human-wildlife conflict trend

4.2.3 Economic improvement at Household level

The table compares major economic metrics before and after fencing was installed around Volcanoes National Park. The data clearly reveals good socioeconomic improvements in local areas (Table 3).

Table 3: Economic improvement of households adjacent to fenced VNP

Economic development indicator	Pre-Fencing (Avg.)	Post-Fencing (Avg.)
Monthly household income	100,000	200,000
% Engaging in small business	27%	47%
Increased revenue from eco-tourism (%)	16%	27%

4.2.4 Relationship between social economic benefits from the park

There is a significant difference in how respondents perceive the park-related benefits (χ^2=16.42, Df=4 and P value=0.03, Table 4).

Table 4: Relationship between social economic benefits from the park

Socio economic benefits	Park Staff (n=6)	Local Leaders (n=12)	Community Members (n=342)
Employment Opportunities (%)	87.4%	62.6%	33.7%
Increased revenue from Tourism (%)	76.3%	81.4%	45.1%
Reduced crop raiding (%)	61.8%	51.9%	23.4%
Improved food Security and income (%)	94.1%	86.2%	68.8%

4.3 Local community opinions and attitudes towards fence strategy and its effectiveness

4.3.1 Concerns of local community on dry-stone wall fencing

There no statistical significance between variables under study since the (χ^2=3.99, Df=2 and P value=0.136, Table 5).

Table 5: Perception of respondents on fence strategy and its effectiveness

Statement / Question	Park staff (n=6)	Local leaders (n=12)	Local community (n=342)
Fencing improves wildlife protection especially Gorillas (%)	92%	85%	68%
Fencing limits access to natural resources (%)	88%	58%	14%
Fencing leads to human-wildlife conflict	90%	72%	55%
Support continuation of fencing strategy (%)	95%	77%	49%
Lack of consultation before fence construction reduction (%)	91%	75.8%	32.6%

4.3.2 Community tradition and cultural values affected by fencing activity in the VNP

There no statistical significance between fencing strategy, traditional and cultural values under study since the (χ^2=0.598, Df=2 and P value=0.741, Table 6).

Table 6: Community tradition and cultural values affected by fencing activity in the VNP

Main indicators	Park Staff (n=6)	Local Leaders (n=12)	Community Members (n=342)
Collection of medicinal plants and other resources	19.8%	30.4%	33.8%
Limited access to sacred ancestral sites	41%	55.7%	58.2%
Limited access to young generations to significant stories and areas	65%	68.1%	77.4%
Weakened Human–Wildlife Cultural Symbolism	57.9	62%	69.1%

4.3.3 Alternatives to dry-stone wall fence for reducing human-wildlife conflict mitigation

Only "Noise and light deterrents" had a statistically significant difference (p = 0.030), demonstrating varying levels of support across the three categories. Community members expressed significantly lower support (8.3%) than Park staff (33%) and local leaders (16.7%). This could indicate uncertainty about the method's applicability or effectiveness at the community level. All other methods (e.g. beehive fences, trenches, monitoring teams) showed no significant differences, suggesting broad agreement among stakeholders on their usefulness (Table7).

Table 7: Alternative methods to mitigate human-wildlife conflict in the VNP

Alternative Method to mitigate human-wildlife conflict	χ^2 (Chi-Square)	Df	p-value
Beehive fences	0.773	2	0.68
Buffer zones (non-palatable crops)	0.821	2	0.663
Live hedges/natural barriers	0.227	2	0.893
Trenches and electric	0.499	2	0.779
Noise and light deterrents	7.03	2	**0.03**
Community-based monitoring teams	0.471	2	0.79

4.4 Impact of fence on Biodiversity Conservation

4.4.1 Impact of fence on wildlife species in the VNP

Certain forest-dwelling or less mobile species tend to gain from the fence method, including mountain gorillas, which may face fewer dangers from human activities due to reduced encroachment, bushbuck, and birds, which are anticipated to benefit from improved habitat security. Large or wide-ranging species like elephants and buffalo are badly impacted, most likely due to: restricted migration paths, increased stress or conflict due to confinement, while Chimpanzees had little discernible influence, presumably because of their adaptability to habitat changes and mixed use of forest and edge regions (Table 8).

Table 8: Impact of fence on wildlife species in the VNP

Impact	Number of Species	Species
Positively Affected	3	Mountain Gorilla, Bushbuck, Bird species
Negatively Affected	3	Elephant, Buffalo, Duiker
No Significant Impact	1	Chimpanzee

4.4.2 Impact of fence on protection of endangered species in the VNP

The Figure 8 depicts how various groups perceived the usefulness of fencing in safeguarding endangered species such as mountain gorillas in VNP, Rwanda.

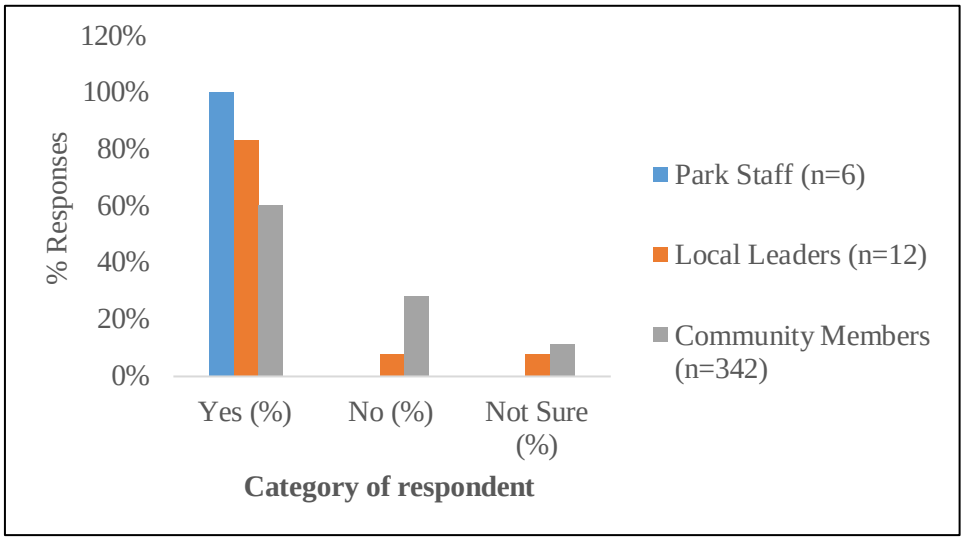

Figure 8: Perception on effectiveness of fence in protecting endangered species

CHAPTER 5: DISCUSSION

The finding of the present study illustrates how various groups perceived the usefulness of fencing in safeguarding endangered species such as mountain gorillas in the VNP, Rwanda, and highlights that Certain forest-dwelling or less mobile animals benefit from the fence strategy, such as mountain gorillas, which may face fewer threats from human activities due to reduced encroachment, bushbuck, and birds, who are expected to benefit from better habitat security. Elephants and buffalo are negatively impacted by limited migration paths, stress, and conflict due to confinement. Chimpanzees have little impact due to their adaptability to habitat changes and mixed use of forest and edge regions.

The results obtained match with the results obtained from research done by (Ringma et al., 2017) where his research conducted on fences a tool to minimize species extinctions, found that conservation fences are a popular management tool, especially for species threatened by invading predators. Fence networks are spreading randomly, often in response to local financing possibilities or threats, unlike other conservation measures. The exclusion fence network provided inconsistent protection, leaving 67% of predator-sensitive species unrepresented. The results found also agree with the findings of (O'Neill et al., 2022), he found out that fences are an important intervention activity in conservation. The interventions are sometimes employed to avoid human-wildlife conflict such as poaching, considering their harmful influence on habitat connectivity and the patterns and dynamic of wildlife. Wide-ranging animals, like the African wild dog (*Lycaon pictus)*, require extensive continuous habitat to meet their resource needs.

A study also conducted in south African savanna revealed that fences create obstacles for large mammals, as they impact wildlife dynamic (Somers & Hayward, 2012). They fail to adjust for seasonal migrations of migratory species, wet season range expansion, or the dispersal of adolescent animals from their native regions. Given that wildlife species occasionally inhabit small regions, they may lose their genetic potential, and when the area's carrying capacity is exceeded, animal disease can be propagated. Additionally, the species composition may shift, and nomadic individuals may disappear.

The results of my study also demonstrated that dry-stone wall fences are not more effective in controlling wildlife conflicts, there is a slightly decrease (30%) in crop raiding, and a 27% decrease in livestock predation in the VNP. Furthermore, fences have been seen able to protect wildlife inside the park, although not entirely. The results of the study tie with a study conducted in Kenya,

where highlighted that the number of crop raiding reduced up to 1 or 2 individuals, and revealed that Unfanced zones, received a higher frequency of elephant crop raiding that farm inside Kimana fenced zones. After the stone wall fence were put in place, the amount of elephant damages on their fields decreased in just four years (Kioko et al., 2008).

The results also tie with those found from research led by (Pekor et al., 2019) where he found out that fences are more effective in controlling large mammals (*Ceratotherium simum* and *Diceros bicornis*) and least in controlling leopards (*Panthera pardus*) and digging species like warthogs (*Phacochoerus africanus*). (O'Neill et al., 2022) also revealed that fences are not effective in controlling wild dogs. Furthermore, (Durant et al., 2015) showed that fencing is used globally to protect wildlife inhabitants from excessive hunting, poaching, and invasive species, as well as reduce conflict and encroachment by humans. He came to the conclusion that fencing was an economical conservation method for lions' control after evaluating populations trends before and after fence installation. Furthermore, he learned how fences can help reduce conflicts between humans and wildlife, including harvesting, persecution disturbance, and environmental degradation (Chedup, Dendup, Dorji, Tshering, & Maya Tamang, 2023). Physical barriers as management techniques aren't always economical. They frequently ask populations and their families to put in extra work and never provide full protection (FAO, 2008). This failure can be explained by the behaviour of various animal species the buffalo's strength is considerably higher than those tiny and those easily to breach the wall. Moreover, it was felt that the stone wall was insufficiently substantial to totally block the migration of elephants and Buffalo (Guinness, 2015). As noted by Hoare (1992), animals with high strength, animal able to jump breakup the fencing strategy, other species that burrow break down barriers and provide access to other species (FAO, 2008). These results agree with the findings of (Chedup et al., 2023) who found that there was a gradual reduction in damages caused before and after the fence was built in Dungmin geog, Pemagatshel, Bhutan.

My results revealed a significant difference in how respondent's groups perceive the park-related benefits, there is an improvement in economical standards at household level, while also demonstrated an improved food security and income and job creation and increased tourism revenues. These results agree with the findings of (Dawa, Dorji, & Dorji, 2021), stone wall fence has been shown to be economically and socially beneficial to families and communities in terms of social security, and safety. This study demonstrated that fencing in Bhutan has resulted in

numerous positive effects on social and family's well-being, as over 90% of survey participants gave high ratings to social impacts like lowering family and community conflicts, saving time when protecting their children, crops, and livestock, and other economic activities reduced psychological and physical stress, and fostering positive sentiments towards wildlife due to less interactions and damages to crops. The results also agree with the findings from reduced the overall crop guarding by 70%, whilst elephants and deer required uppermost crop safeguarding efforts before fence was constructed, and also demonstrated an increase in annual net benefit of rural households (Feuerbacher, Lippert, Kuenzang, & Subedi, 2021). Reduced crop raiding boost economical standards of rural community adjacent to fenced areas (Xu & Huntsinger, 2022).

The study revealed that no significance difference observed on community tradition and culture values resulting from stone wall fencing intervention. A study conducted in China showed that fences have an impact on human movement, land practices, economic, social, and human-nature linkages in a given system (Xu & Huntsinger, 2022). Fencing in the western China, created division among community members thus, led to a drop in social gatherings, such as groups singing, dancing, as well as reciprocal relationships of friends, and shared memory such fencing resulted in violent territorial conflicts (Xu & Huntsinger, 2022). In addition, societal implications challenged traditional human-nature connections. Fencing in Southern and Eastern Africa separated communities from nature, limiting movement and affecting traditional practices and beliefs (Xu & Huntsinger, 2022).

My results found out that there is no significance difference observed on the effectiveness of stones wall according to the respondent's surveyed majority of local community still cross the dry-stone wall within the park to search for resources. The results are similar to those highlighted by Guinness, 2015 during his survey, respondents individually mentioned that the stone wall as one of the methods used to reduce crop raiding nonetheless, the majority of them expressed dissatisfaction with its usefulness saying "we requested to the RDB to plan a dry-stone wall but the wall constructed is not serving" (Guinness, 2015).

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The fence system established in the Volcanoes National Park has made significant contributions to biodiversity protection and socioeconomic development in Rwanda's Northern Province. Most importantly, the fence has helped to safeguard endangered wildlife species, such as the famed mountain gorilla (*Gorilla beringei beringei*) and other large mammals, by minimizing human encroachment, habitat degradation, and poaching. The barrier improves the security of these crucial habitats by establishing a physical border, allowing species to survive and contributing to global conservation goals.

Furthermore, the technique has slightly decreased human-wildlife conflicts, including crop raiding and livestock loss, which had previously threatened local livelihoods. This has increased food security and lowered unfavorable attitudes toward wildlife in neighboring region. Furthermore, the fencing program has boosted socioeconomic development by creating jobs in conservation activities, increasing revenue from tourism, and improving neighborhood income and safety.

However, the study acknowledges that the fence has not significantly created societal issues, notably in terms of traditional behaviors and cultural values. Hence, local communities, still cross the stones wall for collecting and access to sacred sites, medicinal plants, and other resources. This need and emphasizes the significance of incorporating indigenous knowledge and cultural values into conservation planning, along with encouraging open interface between park administrators and the residents living in this area. In terms of biological implications, the fence has helped to shape wildlife species assemblages in the park especially for endangered species mountain gorilla (*Gorilla beringei beringei)*. While it provides shelter, it may disrupt normal migratory patterns, particularly for wide-ranging species, thereby influencing ecosystem dynamics. Continuous ecological follow up is thus essential to measure the long-term effects on species distribution, diversity, and interspecies interactions.

In conclusion, while the fencing technique has resulted in major benefits for species protection, habitat conservation, and community development, its effectiveness is dependent on adaptive management approaches that are culturally sensitive, environmentally informed, and socially inclusive. Sustainable protection of Volcanoes National Park will necessitate continual coordination among partners to guarantee that nature and people coexist in harmony.

6.2 RECOMMENDATIONS

The results of the study on the contribution of fencing strategy to biodiversity conservation and socio-economic development around Volcanoes National Park, Northern Province, Rwanda, allow for the development of recommendations that would optimize the park's ecological and socio-economic benefits. This includes the following:

To Park Management (RDB):

- Promote inclusive conservation policies by integrating community participation into planning and decision-making process, particularly in areas with cultural values and traditional practices;
- Enhance benefit-increased mechanisms from tourism and conservation revenues to ensure that adjacent communities experiences tangible economic benefits which build sustainability in management of these infrastructures;
- Straightening community outreach programs aiming at improving understanding of importance of fence while addressing community concerns;
- Develop wildlife corridors to mitigate potential overexploitation and isolation of migratory wildlife species inside the park.

To local leaders:

- Facilitate communication between communities and park officials to ensure that local opinions and concerns are included in conservation planning;
- Encourage community conservation projects, such as village patrols or collaborative wildlife monitoring, to increase local ownership of conservation efforts.

To researchers and academic institutions:

- Investigate the cultural aspects of conservation, particularly how fencing influence's identity, spiritual values, and traditional ecological knowledge.

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Appendix A

UNIVERSITY OF RWANDA, COLLEGE OF SCIENCE AND TECHNOLOGY QUESTIONNAIRE

Dear Respondent,

I am conducting academic research entitled "The Contribution of fencing strategy to Biodiversity conservation and Socio-economic development of local communities living around volcanoes national park." You have been identified as a resourceful person for this study and hereby requested to spare your resourceful time and fill in this questionnaire. The information you provide will be kept strictly confidential. It will be greatly appreciated if you would complete the questionnaire, as your opinion can help to improve the conservation of volcanoes national park. In case you are interested in the outcome of the study, kindly provide your contact address. Thank you for your time and effort.

Yours faithfully,

Mrs, MUJAWIMANA Alice

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SECTION A:

CHARACTERISTICS OF RESPONDENTS (PLEASE TICK THE MOST APPROPRIATE OPTION)

1. What is your age group?

Age (years):

- ☐ 18-30
- ☐ 31-40
- ☐ 41-50
- ☐ 51 and above

2. What is your gender?

- ☐ Male
- ☐ Female

3. What is your marital status?

- ☐ Single
- ☐ Married
- ☐ Divorced
- ☐ Widowed

4. What is your education level?

- ☐ University
- ☐ Secondary
- ☐ Primary
- ☐ Vocational training
- ☐ None

SECTION B

QUESTIONNAIRE

Questions Related to Biodiversity Conservation

1. Do you think that an electric fence would affect wildlife management and habitat use inside the park?

   Yes No

   If yes, what are these effects?

   .....

   .....

2. Have you observed wildlife entering farms or communities from the park?

   Yes No

   If yes, how frequent and damaging is it?

   .....

   .....

3. Do you think that fencing would reduce human wildlife conflict in your area?

   Yes No

   If yes, why fencing would reduce human wildlife conflicts in your area?

   .....

   .....

4. Which species do you think would be most affected by the installation of a fence?

   .....

   .....

5. Do you think that a fence would help to protect endangered species like the mountain gorilla?

   Yes No

If yes, why a fence would help to protect endangered species like the mountain gorilla?

.....

.....

Questions related to Socio-economic development

6. Do you think that installing a fence would reduce crop and livestock losses due to wildlife?

   Yes No

If yes, why installing a fence would reduce crop and livestock losses due to wildlife?

.....

.....

7. How could reduce conflict with wildlife impact your family's income or food security?

.....

.....

8. Would fencing the park encourage or discourage tourism in the area?

   Yes No

If yes, why fencing the park would encourage or discourage tourism in the area?

.....

.....

9. In what ways could the fence affect employment or business opportunities linked to the park?

.....

.....

10. Do you think that fencing would change the way your community interacts with the park? (e.g. access to resources or participation in ecotourism)?

 Yes No

If yes, why fencing would change the way your community interacts with the park?

.....

.....

Questions related to community involvement and perception

11. What concerns do you have about fencing the park with electric wire?

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12. Would you be open to participating in the planning and monitoring of the fence project?

 Yes No

If yes, why? If no, why?

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.....

13. How do you think community members should be compensated or involved if they lose access to park resources?

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14. Are they any traditional or cultural values associated with the park that might be affected by fencing?

 Yes No

If yes, what are these traditional or cultural values associated with the park that might be affected by fencing?

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15. What alternatives to stone wall fence would you suggest to reduce human wildlife conflict while still protecting biodiversity?

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