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Impact of Volcanoes National Park conservation on local food security

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ABSTRACT

This study employed mixed methods, including a survey of 400 households, 21 key informants, and 10 focus groups conducted in January-March 2019, to evaluate the contribution of Volcanoes National Park (VNP) conservation to local food security in Rwanda. Data was collected from communities within 0-5 km and 5-10 km park buffers, facilitating distance-based comparisons. Food security status was assessed using the Consolidated Approach to Reporting Indicators of Food Security. Despite government attention to food security, its integration into VNP conservation remains minimal. Shockingly, 71% of local residents experience food insecurity, concentrated within the 0-5 km buffer. Interestingly, while only 38% of households directly benefit from park conservation, 72% of these beneficiaries reside within the 0-5 km zone. This suggests that community conservation and revenue-sharing programs are disproportionately funded at the park's edge, where human pressure on resources is most significant. These findings highlight the need for policy and strategy amendments, as well as revisions to the park management plan, to effectively integrate food security concerns into VNP conservation efforts. Linking a specified percentage of revenue-sharing funds to participation in relevant food security programs, co-managing land for conservation and community needs, weaving food aid into safety nets for vulnerable groups, prompt wildlife damage payouts for secured livelihoods and fostered coexistence, and skill training and microloans for diversifying income and curbing poaching are crucial for enhancing food security among households around the VNP.

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1. Introduction

Loss of biodiversity and food insecurity remain key issues in the twenty-first century (Glamann et al., 2017). For years, rural communities have relied on natural forests for food (FAO, 2014; WWF, 2016). These habits continue in different parts of the globe, where bush meat and wild vegetables, honey, mushrooms, fruits, seeds, and tubers provide diet-rich nutrients for households around protected areas (FAO, 2014). In addition, estimates show that feeding the growing world population will require 70% food production increase by 2050 (FAO et al., 2015). This puts a lot of pressure on both protected areas and arable land (Ganivet, 2020), threatening more species with extinction today than ever before, worldwide (Díaz et al., 2019).

Humans continue to convert natural forests and other landscapes into farms, heavily poach wildlife, and overexploit fish stocks (WWF, 2016). Since the 1900s, native species have started to decline in major biodiversity habitats, with approximately 1 million species worldwide currently facing extinction. This is expected to continue to rise and heavily affect the contribution of ecosystem processes to people's livelihoods (IPBES, 2019; WWF, 2016). In the tropics, where most of biodiversity of global importance is found, 32 million hectares of natural forests were cut down between 2010 and 2015, and indigenous species in major terrestrial habitats have reduced by 20%, with an average of 25% of plant and animal

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species threatened (IPBES, 2019). Concurrently, land degradation has caused a reduction in agricultural productivity in approximately 23% of the global terrestrial areas (IPBES, 2019).

This degradation of natural ecosystems and agricultural land exposes landscapes to climate change effects, leading to crop failure and biodiversity extinction owing to the increased frequency of extreme events (IPBES, 2019; Brussaard et al., 2010), thus leading to increased food insecurity. Biodiversity is very important for sustaining food production, as food security is key to reducing human pressure on biodiversity habitats, which are mainly national parks (Vijay & Armsworth, 2020).

International policy commitments to simultaneously address biodiversity loss and food insecurity have existed for decades and have been reviewed over time. Recent targets include the Convention on Biological Diversity (CBD)'s 20 targets for 2020 (Secretariat of the Convention on Biologival Diversity, 2020) and Sustainable Development Goals (SDGs) (Baldwin-Cantello et al., 2023). In addition, scholars continue to argue that the world should fight for hunger reduction and biodiversity conservation in a more integrated way because there is no way to overlook or neglect one over the other (Brussaard et al., 2010). Sustainable integration requires approaches that treat biodiversity conservation and people as unity because the security of biodiversity depends on the food security of those people, and vice versa (Mandima et al., 2011). Understanding this unity necessitates multidimensional and multisectoral approaches in the broader context of rural development and sustainable livelihoods, including the natural environment, land use, demographics, technology, market, social, and cultural processes (Mandima et al., 2011).

As with many other African countries, Rwanda adopted an international move to consider sustainability in the country's development agenda. This includes the development of a national strategy for climate resilience and green growth (Republic of Rwanda, 2011) and the Rwanda Vision 2050 (Republic of Rwanda, 2014) which are both clear on interlinkages between environmental protection, biodiversity conservation, food security, and economic growth.

Rwanda national parks offer different kinds of benefits and prospects for local livelihoods, national economic growth, and ecosystem service provision. Before the COVID-19 pandemic, tourism was the country's top income earner with USD 489 million in 2019 (Butera, 2020). Despite their importance, national parks remain under human pressure because of rapid population growth. In total, Rwanda lost over 60% of its national parks' land area over the past 40 years, mainly due to agricultural development (Republic of Rwanda, 2013). Since 1950s, Nyungwe Mountain Forest lost 21% of its surface area (from 114,125 hectares to 90,000 hectares in 2005), the Gishwati forest 97% (from 21,000 hectares to 600 hectares in 2002), the Akagera National Park 73% (from 331,000 hectares to 90,000 hectares in 2005), and Volcano National Park (VNP) 57% (from 35,000 hectares to 15,000 hectares in 2000) (Republic of Rwanda, 2014).

In Rwanda, Food insecurity also remains an important issue (Republic of Rwanda, 2010) affecting 19.7% of households (Republic of Rwanda, 2018). People around national parks depend on subsistence agriculture with land owned averaged to less than 0.3 hectares (Republic of Rwanda, 2012b). This land scarcity increases the local dependence on parks' food (Plumptre et al., 2004).

The Food Security Status Report of the Republic of Rwanda (2018) reveals that districts around the VNP are among those with a larger proportion of food insecure households and stunted children. Burera has the greatest number of severely food insecure households (6.5%); it is the 5th district with food insecure households (29.7%) and 4th district with highest chronic malnutrition rate countrywide. Nyabihu District has the 6th highest food insecurity rate, with 25.7% of food insecure households and the 2nd in malnutrition, with 53% of stunt children. Also, the percentage of food insecure households in Rubavu District is above the country average (22%), and it is the 3rd district with highest stunting rate of 50%. Musanze District has better food security, with a percentage below the country average of food insecurity (11.5%). However, the stunting rate (38%) is above the national average (35%).

Most households around the VNP are poor, with many members, substandard housing, low levels of education, very small landholdings, food shortages with no surplus in the market, and a lack of access to basic infrastructure such as water and markets (Plumptre et al., 2004). According to different studies (Bush et al., 2010; Guinness, 2014; Munanura, 2013; Plumptre et al., 2004), a high level of poverty causes local people to become more dependent on VNP resources for their livelihood. Thus, despite strong law enforcement, locals, including men, women, and children, enter VNP in search of bush meat, bamboo,

wild honey, fuelwood, water, and medicinal plants (Munanura, 2013; Republic of Rwanda, 2015). This challenges the view that the tourism of mountain gorillas has made a substantial contribution to addressing direct conservation threats (Bush et al., 2010; Munanura, 2013).

Previous studies at the VNP focused on the consequences of conflicts between humans and wildlife on the conservation of biodiversity and development (Guinness, 2014); household poverty and forest dependence (Munanura, 2013); impacts from community conservation interventions (Bush et al., 2010); the role of ecotourism in conservation (Sabuhoro, 2006), the socio-economic status of communities at the VNP (Plumptre et al., 2004) and the socio-ecological issues in conservation of this park (Weber, 1987). Although these studies recommend addressing food insecurity to reduce human pressure on park resources, none have focused on the relationship between biodiversity conservation and food security in local communities.

While it is widely recognized that addressing the link between biodiversity conservation and food security is necessary to reduce human dependence on parks' resources, related studies are also limited, making it difficult for decision makers to clearly understand the impact of policy and interventions (Glamann et al., 2017). The current study identified this research gap at VNP, where previous studies examined the link between local people and VNP conservation from a wider perspective of poverty by aggregating indicators. Recent studies suggest disaggregating poverty and food security indicators if precise and useful recommendations must be drawn (Barrett, 2010). They argued that aggregating indicators narrows measurements, and that the resulting generalization does not allow for the elaboration of effective interventions because it masks considerable heterogeneity among and within areas and households. This study examines food security around the VNP, disaggregated from poverty indicators. The overall objective was to evaluate the implications of biodiversity conservation on food security in the vicinity of the Volcanoes National Park.

2. Data and methodology

2.1. Study area, sample size and sampling procedure

This research was conducted within a 10-kilometer radius of the VNP's edge. The VNP is a 160 km^2 mountainous natural forest. This park was created in 1925 to protect mountain gorillas. It lies in the Albertine Rift Valley (1°21'–1°35 s and 29°22–29°44'E), which separates the Nile and Congo River basins (Republic of Rwanda, 2004). The VNP ranges in altitude from 2,300 m to 4,500 m, and it is in the northwestern corner of Rwanda, bordering the Virunga National Park in the Democratic Republic of Congo and the Mgahinga Gorilla National Park in Uganda. The study area was spatially delimited using the shape files of the boundaries for the VNP and Rwanda administrative entities in ArcGIS. Two zones were defined in the study area: one from the VNP boundary to 5 km (0–5 km buffer) and another from 5.1 km to 10 km (5 km–10 km buffer).

Together, these three contingent parks form the Virunga massif (Weber, 1987). It is rich in biodiversity of global importance, including mountain gorillas, golden monkeys, elephants, buffalos, bushbucks, duikers (Nyiratuza, 2016; Owiunji et al., 2005; Plumptre et al., 2007), bird species, amphibians, reptiles, insects (Plumptre et al., 2007), and 624 plant species (Gray et al., 2010; Owiunji et al., 2005). At the park's edge, there are exotic plants, such as black wattle (*Acacia mearnsii*), eucalyptus (*Eucalyptus spp.*), cypress (*Cupressus spp.*), and pine (*Pinus spp.*) (Owiunji et al., 2005).

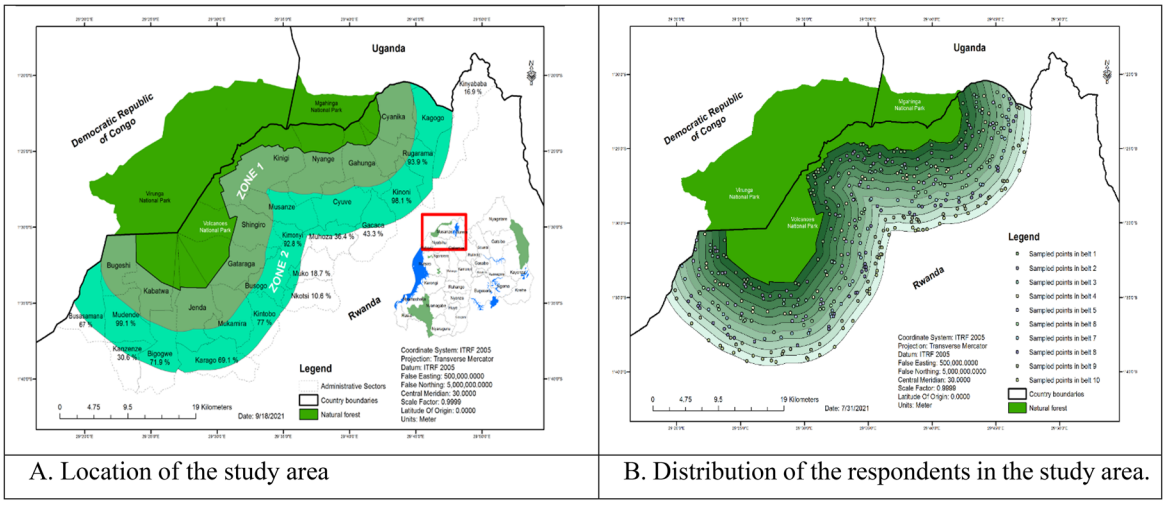
Livelihoods around the VNP rely on rain-fed subsistence agriculture, which employs 90% of the labor force and provides most of the population's food and income. Potatoes, beans, wheat, pyrethrum, sorghum, green peas, maize, bananas, and fruits are the principal crops, but their ability to grow vegetables is severely limited. The park's immediate surroundings are dominated by potatoes and pyrethra (Republic of Rwanda, 2012a).

For this study, a total sample of 400 households was randomly selected from a population of 28 sectors, with 10 belts in the 10 km boundary runs parallel to the VNP edge. Fractions were used to determine the number of households per sector, with boundaries going beyond the 10 km belt. To systematically analyze the variations in diverse characteristics from the forest edge to 10 km away, the area was divided into 10 belts, each 1 km long. Subsequently, 45 points were randomly generated for each of the 10 belts using the NOAA Biogeography Branch's Sampling Design Tool for ArcGIS (Buja &

Menza, 2013). The location of the study area and the distribution of the respondents in the area are shown in Figure 1.

For expert-driven understanding of the interplay between VNP conservation and local food security, 21 key informants were carefully chosen through random purposive sampling from a list of 42 resource people on VNP conservation and local food security included staff of the Volcanoes National Park Management, Agronomists of the 12 sectors in which cooperatives that benefit from revenue sharing and community conservation are located, representatives of NGOs supporting community conservation and local development, representatives of the private sector companies involved in tourism and the nutritionist of Musanze hospital. One VNP community conservation warden, the RDB head of community conservation, all agronomists of the 12 sectors, four representatives of conservation NGOs (Karisoke Research Centre (KRC), International Gorilla Conservation Programme (IGCP), Mountain Gorilla Veterinary Project (MGVP), Conservation Turambe), two representatives of private sector actors (Iby'Iwacu Cultural Village and Sabyinyo Community Livelihood Association (SACOLA)) and one nutritionist for the local hospital were selected for interviews. Each informant was chosen based on their deep involvement in at least two of the following areas: community conservation efforts, food security promotion initiatives, and revenue-sharing mechanisms implemented by Volcanoes National Park (VNP). This strategic selection of key informants ensured access to a rich tapestry of knowledge and experience, providing valuable insights into the multifaceted relationship between park conservation and local food security.

To glean detailed insights into the perceived relationship between VNP benefits and local food security, ten focus group discussions were conducted. These focus groups were organized to get details about the relationship between the benefits from the park and the status of local food security. Focus group discussions were created using purposive random sampling. A list of 34 cooperatives supported by community conservation and revenue sharing was shared by VNP management. These cooperatives were distributed in 12 sectors around the park. The cooperatives were then grouped in one focus group per Sector (administrative unit) and each cooperative was represented by two members. Women were encouraged to participate by selecting one man and one woman per cooperative. However, some women could not attend and were replaced by men in the end. Employing purposive random sampling within this pool, a total 68 people (34 men and 34 women) were sampled to participate in 10 focus groups' discussion. Jenda and Mukamira had only one cooperative each and Bigogwe had two cooperatives. All of them were put in one focus group that had 8 members. According to the nature of their profit-based activity, 5 cooperatives multiply Irish potato seeds and sell them locally, 9 plant improved Irish potatoes, 3 do beekeeping, 2 produce and sell agroforestry trees, 3 multiply bamboo, 2 rear sheep and pigs, 2 rear sheep, 2 are porters of tourists luggages, 3 make handcrafts and sell them, 2 plant and sell vegetables. These focused discussions enabled a dynamic and interactive exploration of how park-derived benefits,



A. Location of the study area

B. Distribution of the respondents in the study area.

Figure 1. Study area and sampled random points.
Source: GIS data (2017); Republic of Rwanda (2012b).

such as income generation and resource access, translate into food security experiences within the local communities.

2.2. Data collection procedures

Data on local food security and household benefits from the park were collected from 400 households using a structured questionnaire administered from January to March 2019. The head of the household was interviewed, and where the head of the household was the husband, the wife was asked to contribute, particularly to questions about food security and crop raiding, because women spend more time in the field and are more involved in food preparation, harvesting, selling, and buying agricultural products. Before distributing the questionnaire to the interviewees, it was tested on ten households in the village that were not sampled (Angelsen et al., 2011). GPS units were used to georeference surveyed households. As stated above under section 2.1 'Study Area, Sample Size and Sampling Procedure', 10 focus group discussions with 68 participants and 21 key informant interviews were conducted to collect qualitative data to gather nuanced and contextually rich understanding of the perceived linkages between benefits stemming from the VNP and local food security. For triangulation and a better understanding of the outcomes and relationships between factors, key informants and focus group discussions were guided using a semi-structured questionnaire.

2.3. Data analysis procedure

All data from the household survey were analyzed using Stata software. To understand how the values of different variables were distributed throughout the sample, simple methods, such as frequency and percentage histograms, were used. A Chi-Square test was performed to determine if there was a link between the households' food security and the park's benefits. This study followed the Consolidated Approach to Reporting Indicators of Food Security (CARI) Guidelines of the World Food Programme (WFP, 2015) for food security analysis that categorized households into four descriptive groups: food secure, marginally food secure, moderately food insecure, and severely food insecure. In this study, three indicators of food security were computed to estimate the overall food security index for households near the VNP. These are food consumption, economic vulnerability, and asset depletion indicators.

In addition, following the recommendation of Morgan (1988), this study used content analysis to analyze qualitative data from key informants' interviews and focus group discussions that were subsequently converted into quantitative data through a 'three-element coding framework' (Charmaz, 2006). It is important to mention that descriptive statistics (mainly percentages) were computed while analyzing qualitative data.

3. Results and Discussion

3.1. Status of food security around Volcanoes National Park

To obtain data on the food security status of each of the 400 interviewed households, questions about their livelihood activities, household income, household assets, productive assets, farm production, household expenditures, food sources and consumption, coping strategies, food chocks, external assistance, and distance to socio-economic services (market, health center, and roads) were asked. Table 1 summarizes detailed information on the food security index among the surveyed households.

Results on food security index show that, around VNP, 27% of households were food secure, 2% were marginally food secure, 16% were moderately food insecure, and 55% were severely food insecure. In total, 29% of the households around the VNP are food secure, while 71% are food insecure. This observation is supported by Munanura (2013), who found that a substantial percentage of people living near the VNP live in poverty with food insecurity. According to this survey, food insecurity around VNP is three times higher than the national average of 19% (Republic of Rwanda, 2018).

This study showed that most farmers plant beans (41%), followed by Irish potatoes (29%), maize (12%), sorghum (3%), wheat (2%), sweet potatoes (1%), and pyrethrum (1%). Opposed to other parts of

Table 1. Overall status of food security around VNP.

		Food security status			
Domain	Indicator	Food secure	Marginally food secure	Moderately food insecure	Severely food insecure
Food consumption	Food consumption group/ score	Acceptable 29.00%	NA	Borderline 29.00%	Poor 42.00%
Economic vulnerability	Food expenditure share	19.25%	6.5%	2.00%	72.25%
Assets depletion	Livelihood coping strategy categories	31.50%	2.50%	4.75%	61.25%
Food security index		27.19%	2.25%	16.19%	54.38%

Source: Field Survey (April 2019).

Table 2. Variation of food security from 1 km belt to 10 km belt outside the VNP.

Belts	Number of food insecure households	% of Food insecure households	Number of food secure households	% of food secure households
1	33	82.5	7	17.5
2	36	90	4	10
3	29	72.5	11	27.5
4	29	72.5	11	27.5
5	28	70	12	30
Total 0-5 km buffer	155	77.5	45	22.5
6	29	72.5	11	27.5
7	28	70	12	30
8	30	75	10	25
9	18	45	22	55
10	24	60	16	40
Total 5-10 km buffer	129	64.5	71	35.5

Source: Field Survey (April 2019).

the country, the households around VNP rely on Irish potatoes and beans for subsistence, with 75% of potato producers that do not grow beans. The total average stock duration for the crops in households around the VNP is 2.2, 1.8, and 1 month for seasons A, B, and 1.4 months for season C. Qualitative data gleaned from focus group discussions among local households revealed a salient challenge within the community: the inability to store Irish potatoes for longer than two months due to rapid spoilage. This finding suggests potential limitations in food security and highlights the need for further investigation into post-harvest storage solutions and practices adopted by local communities. Therefore, they sell most of the harvested beans and purchase beans for storage. Farmers pointed out that they do not benefit from growing Irish potatoes because the fixed prices for their produce are low compared to the high costs of the fertilizers and pesticides they input. The findings of this study also revealed that 84% of crops produced are consumed within a household with limited source of cash to meet food and other household needs.

The study results show that the number of food insecure households reduces, moving from belt 1 at the park edge to belt 10 outside. Belt 2 (1 km -2 km) has the greatest percentage of food insecure households (90% of 40 interviewed households), followed by belt 1 (0 km -1 km) with 82.5% of 40 interviewed households. Belt 9 had the lowest number of food insecure households (40%) while Belt 10 is the second with 60%). It was observed that in the interior belts (between 3 and 8), the rate of food insecure households ranged from 70 to 75%. This study's findings demonstrate that those households in the 0 km - 5 km buffer are more food insecure (77.5%) than those in the 5.1 km -10 km buffer (64.5%). These findings corroborate those of Munanura (2013), Bush et al. (2010), and Plumptre et al. (2004), who revealed that most of the poorest households live near the VNP boundary, whereas wealthier households are found near or in the village centers. Table 2 describes the distribution of households surveyed by belts and food security status.

The results of the household survey show that the average owned-land per household around the VNP is 0.3 ha, and 98% of households rely on subsistence agriculture, with an average household size of five individuals. This landholding is insufficient for growing crops, which would ensure the food security of such large families. The problem is exacerbated by the growing built environment, which gradually encroaches on already-scarce arable land, forests, and woodlots, lowering crop productivity and increasing landlessness.

3.2. Benefits from the interplay between Volcanoes National Park and local food security

While the VNP Management Plan emphasizes the importance of linking VNP conservation with improving local livelihoods to reduce human pressure on park resources, the review of this document revealed that it lacks clear concepts for how this should be done and makes no mention of improving local food security. Consequently, as revealed by the findings of household interviews, local households do not benefit from VNP conservation. Only 152 out of 400 households surveyed (38%) said that they benefited from the park. The livelihoods of the remaining 62% are primarily based on small-scale agriculture that households practice on tiny plots of 0.3 hectares on average, with a minor percentage working as civil servants (0.8%), artisans (0.8%), or own small businesses (1.3%). Approximately 3.8% of households interviewed stated that they were landless and had no stable source of income. The 0 km -5 km boundary is home to 72% of households that claim to benefit from the park. Two of the 400 households surveyed–one in Belt 3 and the other in Belt 6–stated that their members earned money from tourism jobs. The same household in Belt 6 is the only one of the 400 to claim that its members make money from local tourism businesses and sell agricultural produce to tourism businesses. In addition, another household in Belt 3 said that its members make money from park activities, such as local tenders for the *Kwita Izina* (naming) event.

Only two respondents (one in Belt 1 and the other in Belt 6) stated that their household member(s) benefited from educational help, while only four (two in Belt 2 and two in Belt 6) claimed they profited from their membership in a community development group. Only two respondents in Belt 2 stated that the construction of modern houses benefited them. The survey results also show that tourism money has benefitted three households (2 in Belt 1 and 1 in Belt 2). This indicates that there is still a small percentage (1%) of households in the VNP's vicinity who benefit from the income sharing system. Most respondents in the park's neighborhood said that members of their families were involved in park management (3 in Belt1, 2 in Belt 2, 2 in 3, 1 in 4, 2 in 6, and 1 in 7). Porters and other individuals who benefit from revenue sharing are among those who participate in stone wall restoration and chase away wild animals that escape the park and destroy crops. Only two respondents from belts 7 and 10 said that their household members had earned collective income from community ventures. These are members of handcraft cooperatives founded by VNP management to help local households improve their livelihoods. It is mainly people from Musanze town who operate these cooperatives because they are more open to seizing opportunities. None of the 400 surveyed households claimed that their members benefited from their cattle assets. Among the 400 households, 16 households (6 in Belt 1, 7 in Belt 2, and 3 in Belt 3) reported receiving support for access to water tanks. A similar situation was observed in the household survey.

Rainwater harvesting systems are provided by the VNP administration and stakeholders to households in the park's vicinity to limit the number of people who enter the park in search of water. Although it is still a small percentage of the population (4%), it is encouraging to observe that all the beneficiaries are within a 3 km radius of the park's boundary. Out of 400 households surveyed, 49 (12%) said their family members were encouraged to enrol in community-based health insurance (*Mutuelle de Santé*). Given the equal distribution of respondents throughout the ten belts and the efforts of local governments to assist households in accessing health services, it would be challenging to link these benefits to park support.

Belt 7 had the lowest percentage of households that benefited from the park (3%), followed by Belt 8 (5%), and Belt 9 (9%). The park has benefited the highest number of households in belts 1 and 2 at the rates of 22% and 21%, respectively. About 30% of the 400 households polled (120 respondents) said they benefited from improved roads. Among them, 71% were within 5 km of the park edge, while 45% were within 2 km belt from the park edge. Furthermore, 20% of respondents said they benefitted from the construction of health services, and 49% of them lived within a 2 km radius of the park edge. In the same vein, 16% reported that they benefitted from a new or enhanced market for local goods, with 34% living within a 2 km radius of the park's boundary. Finally, 7% said that the construction of the schools had benefited their family members, with 55% of those schools being within a 2 km radius of the park's edge.

The number of households that confirmed receiving indirect park benefits was five times higher than the number of households that reported having received direct benefits. Corroborating data from focus

group discussions solidified the notion of adequate school proximity within the VNP. A resounding 91% of participants acknowledged sufficient school accessibility, with an average of one school present in each designated cell. This finding suggests that geographical distribution of educational facilities may not be a significant barrier to access within the VNP. However, further research is warranted to delve deeper into factors beyond mere proximity that may influence school enrollment and attendance within this specific context.

As previously stated, belts 1 and 2 have the highest number of park beneficiaries, yet they are also the most food-insecure. This is because very few households obtain direct advantages from the park and the indirect benefits they receive from the park do not immediately assist them in improving their livelihoods. Despite the small number of households that benefited from the park (38%), seeing that 72% of them were within the 0 km - 5 km boundary is encouraging. This implies that community conservation and revenue-sharing schemes are invested more in the VNP's influence zone than elsewhere. This finding is in line with the land use analysis data that have shown that reforestation efforts are greater in the 0 – 5 km belt than in the 5–10 km belt.

Despite that the park and its partners are addressing the issue of water scarcity by installing rainwater harvesting tanks as 16% of respondents confirmed they have access to rainwater harvesting system), local people highlighted, during focus group sessions, the need to expand this support and enhance it by linking villages to piped clean water systems. Ten respondents to household interviews said that locals still go to the park to collect water, while only one said that locals go there to hunt, gather bamboo, collect bean poles, honey, materials for handicrafts, get fodder, or graze their animals. This suggests that a major problem with water scarcity exists among households close to parks.

While the National Water Supply Policy recommends that water collectors walk no more than 500 m to acquire water (Republic of Rwanda, 2016), household members around the VNP walk several kilometers inside the park to get water. Adults do not have sufficient time to work on farms or undertake other activities to generate income to buy food and non-food items. Consequently, the time spent collecting water has a negative impact on food security. Water scarcity has an impact on children's school enrollment and attendance as well as dropouts, rights to education, and other related issues.

3.3. Disbenefits from the interplay between Volcanoes National Park and local food security

No policy document reviewed, including the Law on Compensation for Damages Caused by Wild Animals and Related Ministerial Orders, adequately describes how wildlife damage should be valued. Of 20% of the respondents who reported that wild animals had destroyed their crops, only 40 households (10%) said they had filed a claim for compensation, and only one person said he was compensated. The reason given by the 39 households that did not receive compensation was that the documentation, statements, and approvals needed to justify the damage were difficult to obtain, that the process was cumbersome, and that people did not receive reasonable compensation.

The quantitative data obtained through the household survey is enriched and contextualized by the qualitative insights gleaned from both focus group discussions and key informant interviews. This triangulation of data collection methods serves to strengthen the research findings by providing a multi-faceted understanding of the phenomenon under investigation. Despite widespread crop damage attributed to wild animals (reported by 70% of focus groups), a significant disincentive to seeking compensation emerged in the research. Participants perceived the cost of pursuing compensation, encompassing travel, communication expenses, and potential underestimation of losses, to outweigh the actual benefits received. The time-consuming appraisal process, corroborated by all key informants and focus groups, served as a significant barrier. Furthermore, the perceived subjectivity of damage assessment adds another layer of complexity, as claims are reportedly reimbursed solely for buffalo and gorilla damage due to their ease of identification – gorillas through bark stripping on eucalyptus trees (compensated at RWF 1000 per tree) and buffaloes through uprooting potatoes, compared to cows simply eating leaves. These findings suggest a need to streamline the compensation process, ensure fair and consistent damage assessment, and potentially expand eligible species to address concerns of inequity and discouragement among affected communities.

Focus group discussions revealed a critical gap in the wildlife damage compensation scheme, with two groups highlighting the exclusion of prevalent species like monkeys, duikers, bushbucks, and porcupines. This exclusion stems from legal challenges in differentiating their crop damage from that caused by small ruminants like goats and sheep. Further underscoring this limitation, a Rugarama sector potato farmer reported a devastating buffalo attack on his 50 m x 50 m plot. Despite planting 500 kg of potatoes, his losses, including RWF 30,000 in transportation costs for follow-up trips and exceeding the RWF 50,000 compensation he received, highlight the inadequacy of the current system. These cases exemplify the need for legal revisions and broader species coverage under the compensation program to address inequities and encourage affected communities to seek reparations.

In a similar way, 90% of the respondents said they would rather not seek compensation and accept their losses. During the survey, 24 of the 40 respondents (60%) who said their crops were damaged by wild animals explained that the process was complicated because of the method for calculating and awarding compensation; 12 (30%) said it took too long to get compensation; and 4 (10%) said it was expensive. Usually, park officials and local government representatives examine the damage to the plot where animals destroy crops, and the compensation value in Rwandan francs is computed in the presence of the farmer. According to the respondents, the authorities undervalued the damage and, consequently, did not receive adequate compensation. Members of the two focus groups also noted that because their crops are for subsistence and they own small plots, it is challenging for them to grow crops that are not edible to wild animals.

Nine focus groups advocated that the compensation fund should be decentralized to the sector level in order to address the disputes/issues related to lengthy waiting periods for compensation, travel expenses related to trips to Kigali, and timely evaluation of the damages (when it delays, the signs are no longer there, and the fund never pays once it does not find signs in place). Five mentioned that the RDB should provide the real value of the damage, and four suggested that the RDB should accept photos as proof of the damage.

Only seven of 400 respondents (2%) in the household survey confirmed their household benefits from the control of problem animals, such as the stone wall that divides the park from agricultural plots, ranger patrols, and so on. Responses to the question of whether households benefited from extension services yielded the same proportion. When asked if any household member had received training on nutrition, 29% of respondents reported that at least one member had received it, while 76% said that their village (*Umudugudu*) had a community-based nutrition program. These figures suggest that nutrition promotion efforts have been successful in this area.

Qualitative data from both key informant interviews and focus group discussions overwhelmingly pointed to poverty, landlessness, and small plot sizes as the primary drivers of food insecurity in the VNP region. This finding emerged consistently across all 21 interviews and 10 focus groups, highlighting the limitations of attributing food insecurity solely to low sanitation and dietary awareness. Notably, participants expressed skepticism about the ecological viability of the VNP's conservation efforts in the face of widespread food shortages and minimal local benefits accruing from the park. The qualitative data paints a stark picture of disconnect between the park's objectives and the lived realities of surrounding communities. This raises concerns about the long-term sustainability of conservation efforts implemented without meaningfully addressing the pressing food security challenges faced by local residents.

Therefore, the study underscores the urgent need for strategies that actively engage local communities in park management. This could involve granting them access and resource use rights, fostering improved collaboration, establishing co-management agreements, and ensuring equitable distribution of benefits derived from resource utilization within the park. Such measures, informed by the insights gleaned from qualitative analysis, hold the potential to create a more inclusive and sustainable approach to conservation, one that addresses the critical needs of local communities while safeguarding the VNP's ecological integrity.

While this study's findings warn that people in the VNP's vicinity are food insecure and have limited access to potable water and cooking energy, 67.04% of tourism revenue sharing is allocated to public infrastructure rather than to addressing direct household needs, which are more closely linked to human pressure on park resources. As a result, unless clear regulations are in place to assist local food security, households in the vicinity of the VNP will continue to use park resources illegally to obtain food.

The state of food security among households in VNP surroundings is determined by how institutions and stakeholders design, view, and implement policies to integrate food security and conservation, as well as how households are affected by land-use changes, household income, asset ownership, harvests, markets, seasonality, and how they benefit from VNP conservation. This also implies that long-term conservation of VNP is contingent on local households' food security. People use park resources illegally because they are hungry. Therefore, the VNP protection and local food security must be integrated.

3.4. Relationship between the food security status of the households and the benefits from the park

This section focuses on testing the relationship between the household's food security status and park benefits. Food consumption group (FCG) was used as a measure of food security. Tourism employment and/or income from tourism employment, collective income, health center construction, cooperative membership, education support, improved market, improved roads, income from park events, part of the park management team, health insurance, sales of farm produce, school construction, water tanks, and tourism revenue are all benefits of the park. Given that all these variables are either categorical or discrete, the chi-square test was used to test for dependence, and the findings are shown in Table 3.

The Chi-square analysis results reveal a positive and significant relationship between collective income, benefits from the setting of health centers, benefits from improved access to the market, and advantages from involvement in park management in the neighbourhood of VNP. While the number of households that gain from VNP is still small, the positive relationship between collective income and food security suggests that these households can improve their food security situation. This indicates that as income rises, so does the level of food security. In terms of the positive impact of the benefits from the construction of health centers on food security, this implies that people living around the VNP who work in economic activities funded through revenue sharing from tourism or who are directly hired by park management are likely to be food secure. The more employed people are, the more money they earn and the more goods and services they can purchase to maintain and improve their standard of living.

Another aspect that has a positive impact on food security is the benefits of access to the market. This indicates that people living around VNP who have a market for their agricultural produce and handicrafts (hotels, restaurants, sales to park administration workers, and sales to tourists) are likely to be food secure. They earn money in this way, which they spend while buying food and non-food items to improve their living conditions or investing in farming and/or other income-generating activities. For the benefits of being a part of VNP management, one household reported having a member employed by park management: his wage is part of the household income and is spent on improving household welfare (food, clothes, shelter, school fees, health care, etc.). The salary permanently received contributes to the social sustainability of the household, and, as such, the food security status becomes resilient.

Table 3. Test for dependence of household's food security status on the benefits from VNP.

	Dependence of FCG on VNP benefits	
Benefits from VNP	Chi^2	$Prob > chi^2$
Tourism employment	0.919	0.632
Income from tourism employment	1.384	0.50
Collective income	4.921*	0.085
Construction of health centre	9.290***	0.010
Cooperative membership	2.242	0.326
Education support	9.919	0.632
Improved market	8.016**	0.018
Improved road	4.478	0.107
Income from park events	0.919	0.632
Part in park management	6.809**	0.033
Community based health insurance	3.614	0.164
Sales of farm produce	1.384	0.50
School construction	2.804	0.246
Water tank	1.031	0.597
Tourism revenue	4.174	0.124

Note. The dependence test is considered significant if the $Prob > chi^2$ is at most equal to 10% or 0.10.
*, **, and ***indicate significance level at 1 per cent, 5 per cent, and 10 per levels, respectively. FCG: food consumption group.
Source: Field Survey (March 2019).

This analysis shows that the more direct the benefits local households receive from the park, the more food secure they are. This confirms Brown's (2002) assertion that it is critical to integrate protected areas into local, national, and regional economic and social settings to achieve success in their conservation. According to Mulongoy and Chape (2004), national parks must go well beyond doing no harm to contribute significantly to poverty reduction. As for Brown (2002), the success of conservation is becoming increasingly linked to the level of local support it receives and the nature of the appropriate benefits it offers to surrounding communities as the global human population grows, particularly on the sidelines of national parks. Mulongoy and Chape (2004) indicated that the major problems facing national parks need to be addressed by institutions with appropriate roles at the appropriate scale if sustainable benefits are to be provided to local communities.

3.5. Discussion of the main research findings

This study paints a bleak picture of food insecurity around Volcanoes National Park (VNP). The landholdings are critically small, averaging a mere 0.3 hectares for families of five, making subsistence agriculture an insufficient path to food security. Exacerbating this vulnerability is the encroachment of urbanization on vital arable land, forests, and woodlots, further diminishing crop yields and driving landlessness. These findings align with previous research, which casts doubt on the ability of gorilla tourism, revenue-sharing initiatives, and community conservation efforts to substantively improve local livelihoods (Bush et al., 2010; Sabuhoro, 2006). Studies by Guinness (2014), Bush et al. (2010), and Brown (2002) further corroborate this notion, highlighting the persistent shortcomings of similar conservation programs in Rwanda and across Africa, often failing to reach the intended beneficiaries or adequately address the needs of local communities. This confluence of insufficient land, environmental degradation, and ineffective support mechanisms paints a concerning picture of food insecurity for communities surrounding VNP.

Building upon Mandima et al. (2011) call for conservation projects to prioritize local livelihoods through appropriate governance, incentives, and compensation mechanisms, this study's investigation into both food security and policy gaps surrounding Volcanoes National Park (VNP) reveals critical shortcomings in current management practices. The findings demonstrate that, despite the pressing need to address food insecurity as a means to mitigate resource pressure on the park, VNP management and its partners have fallen short in providing adequate support to the surrounding communities. This failure to prioritize the very communities most likely to impact the park's long-term biodiversity protection underscores the urgent need for a reevaluation of current approaches and the implementation of more effective community-centered conservation strategies.

Besides, the finding that only 38% of households directly benefit from the park, with benefits concentrated near the park boundary, aligns with broader critiques of protected area management. Brockington et al. (2012) argue that top-down conservation approaches often fail to consider the needs and aspirations of local communities, leading to uneven distribution of benefits and increased pressure on park resources. This research underscores this concern, suggesting that the VNP's current strategies may not be effectively addressing the needs of the communities most impacted by its existence.

While direct benefits like tourism income remain limited, the research indicates that improved infrastructure and access to social services play a role in enhancing livelihoods. This finding resonates with arguments by Brown (2002) and Mulongoy & Chape (2004) who emphasize the need for protected areas to move beyond simply doing no harm and actively contribute to poverty reduction and local development. Investments in infrastructure and social services, while not directly addressing immediate food and water needs, can create enabling conditions for livelihood diversification and improved well-being in the long term. However, it is crucial to ensure that such investments are aligned with community needs and priorities to avoid reproducing top-down development models (Agrawal & Ribot, 1999; Ribot, 1999; Ribot et al., 2006).

The research highlights the significant challenge of food insecurity among households surrounding the VNP. This finding aligns with broader concerns about the links between conservation and food security in Africa (Fisher et al., 2012; Musavengane & Leonard, 2022). The reliance on small-scale agriculture and limited income sources underscores the vulnerability of these communities and the potential for conservation efforts to exacerbate food insecurity if not carefully designed. As noted by

the research, the time spent collecting water due to scarcity further compounds these challenges, highlighting the need for integrated approaches that address both conservation and basic human needs. The current study also presents a seemingly contradictory finding to that of Naidoo et al. (2019). While Naidoo et al. observed decreased poverty and increased wealth near protected areas with tourism, the present study finds a gradient of decreasing food insecurity with increasing distance from the park edge, suggesting households furthest from the park experience greater food security. This divergence in findings warrants further investigation to reconcile the apparently contrasting impacts of proximity to protected areas and tourism on household food security and economic well-being.

The research reveals the significant problem of wildlife damage to crops and the inadequacy of the existing compensation system. This finding aligns with studies by Frank et al. (2019) and Bhatia et al. (2020) who highlight the challenges of human-wildlife conflict and the importance of fair and effective compensation mechanisms to mitigate negative impacts on local communities. The flaws identified in the VNP's system, such as lengthy processes, underestimation of losses, and high transaction costs, discourage claims and exacerbate feelings of injustice among affected communities. Addressing these issues is crucial for building trust and cooperation between park authorities and local residents, ultimately contributing to more sustainable conservation outcomes.

The research provides valuable recommendations for improving the VNP's conservation approach. The call for increased access and resource use rights for local communities aligns with growing recognition of the importance of participatory conservation models (Hoffmann, 2022). Similarly, the emphasis on co-management agreements and equitable benefit distribution resonates with calls for more collaborative and inclusive approaches to protected area governance (Islam et al., 2018; Kimengsi et al., 2019). Addressing water scarcity and integrating food security efforts into conservation planning are also crucial steps towards achieving long-term sustainability.

However, the main contributor to food insecurity in the region is poverty, which is connected to landlessness and the small size of owned plots, compared to low levels of awareness about sanitation and the preparation of a balanced diet. This was emphasized by all 21 key informants and 10 focus group discussions. The results of this study match previous findings that crop raiding is still a significant problem in the vicinity of the VNP and that human-wildlife conflicts reduce local farmers' support for conservation and tourism projects (Guinness, 2014; Plumptre et al., 2004).

With few local benefits from the park and widespread food shortages in the vicinity of the VNP, it is unclear whether the park's conservation efforts will be ecologically viable. As the data herein suggest, there is no significant contribution from VNP benefits to local food security at the household level. This is supported by the findings of Guinness (2014), Bush et al. (2010), and Brown (2002), who found that despite the widespread deployment of ICDPs, they failed to produce either long-term protection of the focus resources or improvements to local livelihoods, even though tourism was the country's first source of revenue (USD 489 in 2019) (Butera, 2020).

While the National Water Supply Policy recommends that water collectors walk no more than 500 m to acquire water (Republic of Rwanda, 2016), household members around the VNP walk several kilometers inside the park to get water. Adults do not have sufficient time to work on farms or undertake other activities to generate income to buy food and non-food items. Consequently, the time spent collecting water has a negative impact on food security. Water scarcity has an impact on children's school enrollment and attendance as well as dropouts, rights to education, and other related issues. These findings support those of Guinness (2014), Munanura (2013), Bush et al. (2010), Sabuhoro (2006), and Plumptre et al. (2004), who showed that a large percentage of households around the VNP are poor, with low income, water scarcity, and food insecurity.

While internal VNP factors influence local food insecurity, a comprehensive understanding demands exploration of the broader socio-economic and environmental context. Pervasive poverty, evident in landlessness and small plot sizes (Nilsson, 2019; Nsabimana et al., 2021), suggests structural inequalities impacting food access. Analyzing regional wage disparities (Combes et al., 2009), land ownership patterns (Leonard et al., 2020), and market access (Usman & Haile, 2022) could illuminate these dynamics. Only through such a holistic approach can the complex drivers of VNP-region food insecurity be fully grasped.

Climate change poses a growing threat to VNP region food security due to its impact on rainfall patterns and agricultural productivity. Researching historical and projected rainfall variability, crop yields, and water availability (Parmesan et al., 2022; Pörtner et al., 2022) can inform adaptation strategies. Moreover, unsustainable land practices and climate change exacerbate soil degradation and erosion, necessitating investigations and promotion of sustainable agriculture (Abdullahi et al., 2023; Rao et al., 2023). The increasing frequency and intensity of extreme weather events like floods and landslides further threaten agricultural production and supply chains. Analyzing regional vulnerability and developing risk management strategies (Parmesan et al., 2022; Pörtner et al., 2022) are crucial for long-term food security.

As for national agricultural policies, their effectiveness in supporting VNP-area smallholders warrants scrutiny, encompassing access to subsidies, extension services, and market opportunities (Musafili et al., 2019). Inequitable land-use policies and fragmentation necessitate examination, as they may contribute to food insecurity (Knippenberg et al., 2020). Striking a balance between wildlife conservation and local food security is crucial. Assessing existing policies' effectiveness in mitigating human-wildlife conflict and providing adequate crop damage compensation is vital (Ravenelle & Nyhus, 2017).

This study aligns with several SDGs by critically examining the complex interplay between Volcano National Park conservation and local food security. Directly addressing SDG 2 (Zero Hunger), it sheds light on the geographic distribution and prevalence of food insecurity, informing policies that reconcile conservation and food security objectives. Recognizing the crucial role of clean water for food security, the research connects with SDG 6 (Clean Water and Sanitation). Furthermore, by revealing the disproportional burden of food insecurity borne by households closest to the park, it suggests potential inequalities in resource access and conservation benefits, aligning with SDG 10 (Reduced Inequalities) and informing more equitable conservation practices.

Building upon its contribution to SDG 2, the research further aligns with SDG 15 (Life on Land) by focusing on the vital role of VNP conservation in protecting biodiversity and ecosystems. Recognizing the intricate link between conservation and local well-being, as underscored by this study, is crucial for achieving sustainable and inclusive conservation practices. Finally, the research champions SDG 17 (Partnerships for the Goals) by emphasizing the need for collaborative efforts between park management, local communities, and government institutions to bolster food security around VNP. By providing evidence for such partnerships and outlining concrete actions for different stakeholders, the study paves the way for a more holistic and effective approach to achieving the SDGs in the VNP region.

4. Conclusion and recommendations

This study revealed that there is a need to integrate food security into the conservation of VNP if the human pressure on park resources must be reduced. This demonstrates that people around the VNP are food insecure, mainly due to land scarcity, high dependence on subsistence agriculture, large household size, dependence on potato crops, and limited alternative livelihoods. This study found that the revenue-sharing scheme for the local community is relatively low and focuses more on public infrastructure than on direct threats to VNP resources. Actors in VNP conservation and community conservation are dominated by NGOs that also provide very limited support to communities with more focus on gorilla research. In addition, few Private Sector actors, such as hotels, provide limited support for local food security, including jobs and buying agricultural produce. This leads to a minimal benefit-stream for local communities. These findings are in line with previous studies at VNP, which showed that little from revenue sharing goes directly to activities that support local food security, but rather to public needs such as constructing roads, health facilities, and markets.

Despite current limitations of park support for rainwater harvesting tanks, primarily accessible to households within the 0-5 km buffer zone, the initiative represents a positive step. Enhanced collaboration among diverse stakeholders holds promise for expanding access to similar interventions in other areas surrounding the park. Furthermore, multiple opportunities exist for mainstreaming food security into the VNP conservation agenda. Wildlife and biodiversity policies recognizing the need for alternative livelihoods to mitigate resource pressure within the park provide one such entry point. Additionally, the

involvement of a broad range of stakeholders in VNP conservation efforts presents another avenue for advancing food security initiatives. By strategically leveraging these points of entry and fostering closer collaboration, effective integration of food security goals into the broader conservation framework for VNP becomes achievable.

For enhanced integration of food security with VNP conservation, this study recommends (1) a linkage of a portion of revenue-sharing to participation in food security interventions, such as agricultural training, adoption of sustainable practices, or access to microfinance for income diversification; (2) facilitation of land leasing or co-management arrangements between park authorities and landless communities for sustainable and diversified food production; (3) an integration of food security support with existing social safety programs for vulnerable groups; (4) establishing a dedicated fund to ensure timely and fair compensation for crop losses or livestock depredation caused by wildlife; and (5) offering skill development training and microfinance support for income-generating activities beyond agriculture, reducing dependence on poaching during dry seasons.

Authors' contributions

Madeleine Nyiratuza, Caleb Mireri, and Aristide Maniriho contributed to the study conception and design. Material preparation, data collection and analysis were performed by Madeleine Nyiratuza and Aristide Maniriho. The first draft of the manuscript was written by Madeleine Nyiratuza. Aristide Maniriho, Caleb Mireri, and Felix L. M. Ming'ate commented on the draft versions of the manuscript, and they have read and approved the final manuscript.

Consent statement of the participants

Prior to the commencement of the interview, all potential participants were informed of the voluntary nature of their participation and the anonymous utilization of their data for research purposes. This information was conveyed verbally to ensure clear understanding. Subsequently, the first question posed to everyone was a binary option: 'Do you agree to participate in this interview?' Only those who responded affirmatively to this initial inquiry proceeded with the interview. This approach ensured that all participants entered the study with full autonomy and awareness of the research objectives and data utilization.

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Dr. Madeleine Nyiratuza is a seasoned environmental leader with over 15 years of experience in conservation and sustainable development. Her career spans roles with renowned organizations like the Wildlife Conservation Society (WCS) and the United Nations Development Programme (UNDP) in Rwanda. Currently, she works with the UN in Addis Ababa, Ethiopia, leveraging her expertise at a regional level.

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Data availability statement

No data were generated along this study.

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