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Impacts of Landslide Disasters on Community Livelihoods in Rutsiro District, Rwanda

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Abstract: Landslides represent chronic geomorphological hazards that systematically compromise human safety, structural integrity, and ecological stability. In the Western Province of Rwanda, specifically within the Rutsiro District, high-frequency landslide events have resulted in significant population displacement and the destabilization of rural livelihoods. This study employed a mixed-methods research design, integrating qualitative thematic analysis with quantitative data derived from 400 household survey respondents, to evaluate the frequency, causality, and socio-economic ramifications of these events. The investigation examined primary geophysical and anthropogenic drivers including steep topographic gradients, high-intensity precipitation, deforestation, and unsustainable land-use practices, alongside their resultant impacts on community health and economic resilience. Findings demonstrate a profound correlation between landslide activity and livelihood instability. Notably, the loss of farmland (72%) serves as a primary driver of food insecurity, while water source contamination (81%) exacerbates regional public health vulnerabilities. While the study recorded a high baseline of perceived community preparedness (98%), the functional efficacy of localized mitigation such as afforestation (63%) and bench terracing (18%) is frequently constrained by technical and maintenance deficiencies. Furthermore, despite a 97% reach in government outreach initiatives, a critical "support gap" persists, with 38% of affected households reporting a total lack of post-disaster assistance. These results underscore an urgent requirement for integrated disaster risk reduction (DRR) frameworks that prioritize sustainable land management, standardized community education, and synchronized institutional response mechanisms. Strengthening these pillars is essential for fostering long-term climate resilience and safeguarding vulnerable populations against escalating environmental threats

1. Introduction

Natural hazards, including landslides, present significant socio-economic and environmental challenges globally, particularly in developing countries. High exposure, acute vulnerability, and limited resilience in these regions increase the likelihood that natural hazard events will escalate into full-scale disasters. As emphasized by the United Nations Office for Disaster Risk Reduction (UNDRR, 2019), there is no such thing as a "natural disaster"; rather, disasters are the result of natural hazards intersecting with vulnerable and exposed human populations. Among these hazards, landslides constitute a major threat, leading to loss of life, destruction of property, and severe environmental degradation.

Rwanda, characterized by steep topography and high annual rainfall, is highly susceptible to landslide hazards, particularly in the Western Province where Rutsiro District is located (MINEMA, 2020). The increasing frequency and severity of these events raise urgent concerns regarding their long-term impacts on community livelihoods and sustainable development. Landslides in this region are triggered by a complex interplay of factors, including intense precipitation, deforestation, and soil erosion, further exacerbated by anthropogenic activities such as poor land-use planning and agricultural expansion on high-incline slopes. In mountainous sectors like Rutsiro, these recurrent hazards are intensified by climate change and unsustainable land management practices (Nsengiyumva *et al.*, 2018).

Recent reports (Macháček, 2022) indicate that extreme weather events, particularly prolonged heavy rains, have increased the occurrence of landslide-induced disasters in Rwanda. These events severely disrupt community livelihoods by halting economic activities, destroying residential and public infrastructure, and displacing vulnerable populations. Agriculture—the primary livelihood pillar for Rutsiro households—is disproportionately affected; landslides strip away fertile topsoil and standing crops, directly triggering food insecurity and catastrophic reductions in household income. Furthermore, the destruction of road networks renders essential services, such as education and healthcare, inaccessible, deepening the socio-economic crisis. Such hazards often lead to forced migration, as families are relocated to safer zones, a process that frequently disrupts social stability and economic continuity (World Bank, 2020).

Beyond socio-economic disruption, landslides drive significant environmental degradation by altering landscapes and compromising biodiversity. The loss of vegetative cover accelerates soil erosion, reducing land productivity and heightening the risk of future hazard events. In Rutsiro, landslides contribute to the sedimentation of river systems and wetlands, detrimental to water quality and aquatic ecosystems. Moreover, these events often undermine reforestation and conservation initiatives spearheaded by government and community bodies. The resulting loss of forest cover diminishes carbon sequestration capacity, contributing to a feedback loop where climate change increases the frequency of the very extreme weather events that trigger landslides (REMA, 2021).

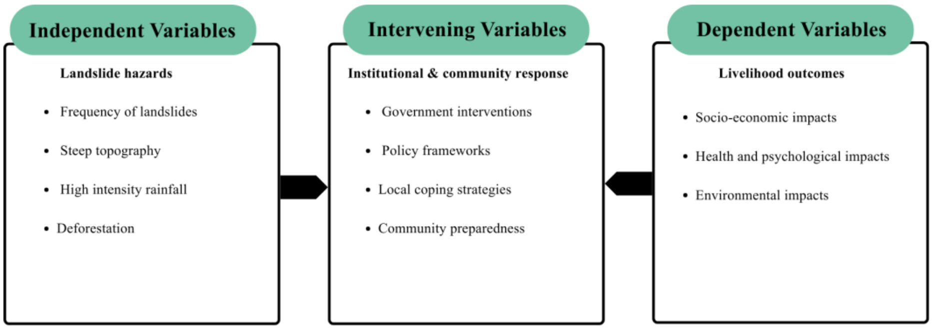

Figure 1. Conceptual framework illustrating the relationship between landslide drivers, mediating factors, and livelihood outcomes in Rutsiro District

Despite the escalating threat, research into the long-term impacts of landslide hazards on community livelihoods in disaster-prone areas like Rutsiro remains limited. Understanding these impacts is critical for developing the mitigation and adaptation strategies necessary to enhance community resilience. This study aligns with Rwanda's Vision 2050, which prioritizes climate-resilient sustainable development (Macháček, 2022). While existing literature has largely focused on the physical mechanisms of landslides in Rwanda, this research seeks to fill the prevailing gap by analyzing the socio-environmental implications and community-driven resilience strategies in Rutsiro District.

2. Methodology

2.1 Study Area

The following case study profile provides a foundational analysis of the geographical, environmental, and socio-economic conditions of the Rutsiro District. Understanding these parameters is critical for assessing the specific mechanisms through which landslide hazards impact community livelihoods.

This research was conducted across three specific sectors within the Rutsiro District: Manihira, Ruhango, and Rusebeya. These sectors were purposively selected due to their high susceptibility to frequent landslide events, driven by a combination of steep topographic gradients, specific soil characteristics, and localized climatic conditions. Situated in the Western Province of Rwanda, the Rutsiro District is defined by a rugged, hilly terrain and high annual precipitation, factors that inherently facilitate soil instability and accelerated erosion. Empirical evidence suggests that landslides in this region are primarily triggered by intense precipitation events, widespread deforestation, and the prevalence of unsustainable agricultural practices, which collectively result in severe environmental degradation and the systemic loss of livelihoods. The selection of Manihira, Ruhango, and Rusebeya is further justified by their documented history of landslide occurrences and their profound socio-economic dependence on agriculture. Agriculture serves as the primary economic pillar of the Rutsiro District, with most of the population relying on subsistence farming for survival. However, the recurring nature of these hazards has led to significant topsoil depletion, the destruction of established farmlands, and the forced displacement of entire communities. Such disruptions exacerbate regional poverty and deepen food insecurity. Previous disaster risk assessments confirm that the impact of landslides in Rutsiro is statistically and socially significant, necessitating targeted research to quantify these effects on community livelihoods and to inform the development of robust mitigation strategies.

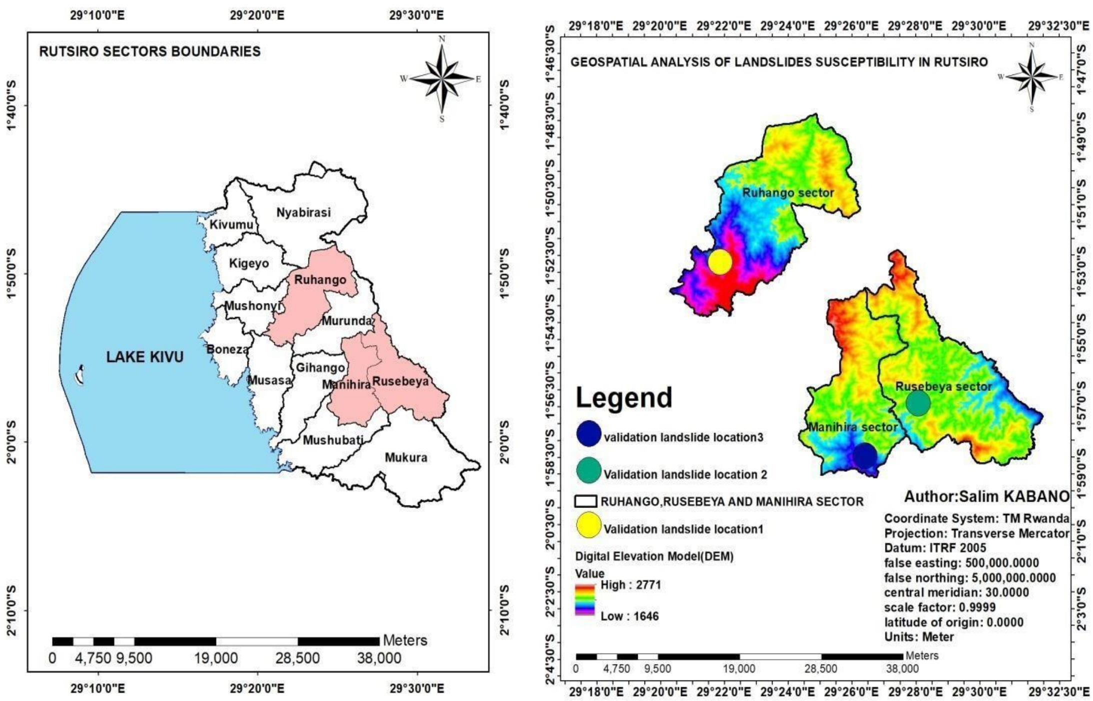

Figure 2. Landslides study areas in three sectors of Rutsiro district.

Geographical Location

Rutsiro District is located in the Western Province of Rwanda, bordering Lake Kivu to the west. It is characterized by a hilly and mountainous terrain, which makes it prone to landslides, especially during the rainy seasons. The district covers an area of approximately 1,159 square kilometers and consists of several sectors, cells, and villages that are affected by landslides.

Climate and Weather Patterns

The climate of Rutsiro District is predominantly tropical highland, with two main rainy seasons: March to May and September to December. The region experiences high rainfall intensity, which contributes to frequent landslides. The average annual precipitation ranges between 1,000–1,500 millimeters, and the temperature varies between 18°C and 20°C. These climatic conditions, combined with the district's steep slopes, significantly influence landslide occurrences.

Topography and Soil Characteristics

Rutsiro District features steep slopes (Nahayo, 2018), ranging from moderate to highly elevated terrains. The soil composition includes clay and sandy loams, which are susceptible to erosion and slope instability. The presence of weathered volcanic rocks also exacerbates soil vulnerability to landslides. Deforestation and agricultural practices on steep slopes have further contributed to soil degradation, increasing the likelihood of landslides.

Socioeconomic Aspects

The district's economy largely depends on subsistence farming, with key crops including beans, maize, potatoes, and bananas. Livestock farming is also common. However, landslides pose a threat to agricultural productivity by destroying crops, eroding fertile soils, and displacing farming communities. Additionally, the district has small-scale mining activities that may contribute to land degradation and increased landslide risk (Macháček, 2022).

Demographics and Settlement Patterns

Rutsiro District has a population of approximately 369,180 people (Rutsiro, 2015), with most residents living in rural settlements. The population density varies across sectors, with some areas experiencing high concentration due to limited arable land. Many houses are built on slopes, making them vulnerable to landslide damage. The displacement of people due to landslides has led to temporary resettlements and loss of property.

Infrastructure and Disaster Management Capacity

The district possesses a network of roads that serve as vital economic arteries; however, these are frequently compromised by landslides, which severely disrupt transportation and regional trade. Critical infrastructure, including health centers, schools, and markets, remains highly vulnerable to slope instability (MINEMA, 2020). In response, the local government, in collaboration with national agencies such as the Ministry in Charge of Emergency Management (MINEMA), has implemented mitigation strategies including afforestation, radical terracing, and the deployment of early warning systems. Despite these efforts, the effectiveness of such interventions is often constrained by limited financial and technical resources (Bizimana and Sonmez, 2015).

Historical Landslide Incidences

Rutsiro District has a well-documented history of landslide occurrences, particularly coinciding with the peak of heavy rainfall seasons. Past events have led to tragic loss of life, the total destruction of residential housing, and the large-scale displacement of communities (Ndayisaba *et al.*, 2017). Historical records and recent longitudinal data suggest that landslide frequency is increasing, driven by a combination of environmental degradation and shifting climatic patterns in the high-altitude regions of Western Rwanda (Nsengiyumva *et al.*, 2018). These trends underscore the urgent necessity for more robust, data-driven mitigation and community adaptation measures.

2.2 Research Design

This study adopted a descriptive, cross-sectional research design using a concurrent mixed-methods approach. The integration of both qualitative and quantitative methods was essential for methodological triangulation, ensuring that findings were both statistically significant and contextually deep.

- **Role of the Quantitative Approach:** Used to establish the magnitude and frequency of the problem. By surveying 400 households, the study provided objective, generalizable data on the extent of farmland loss (72%) and the prevalence of water contamination (81%).
- **Role of the Qualitative Approach:** While the survey provided breadth, qualitative methods (key informant interviews, field observations) captured the nuances of human perception, psychological burdens of displacement, and institutional barriers.

The research architecture mapping objective to tools is detailed in **Table 1.**

Table 1. Mapping Research Objectives to Data Collection Tools and Data Types.

Research Objective	Data Collection Tool	Data Type
Assess frequency and causes of landslides	Household Questionnaire / Field Observations	Quantitative / Qualitative
Analyze socio-economic impacts	Household Questionnaire	Quantitative
Evaluate local coping strategies	Key Informant Interviews / Questionnaires	Qualitative / Quantitative
Assess health and psychological impacts	Household Questionnaire	Quantitative

Sampling Design

This study employed a multi-stage sampling design to collect representative data:

1. **Quantitative Sampling (Probability-Based):** Three sectors (Ruhango, Rusebeya, and Manihira) were purposively selected based on high vulnerability. Cells were stratified by altitude and slope steepness, selecting 400 households randomly using village registers.
2. **Qualitative Sampling (Non-Probability-Based):** Purposive selection was applied for local authorities and experts ($n = 12$), while snowball sampling tracked displaced victims relocated outside their villages.

Sample Size Determination

Using the Yamane (1967) formula:

$$n = \frac{N}{1 + N(e)^2}$$

Where $N = 369{,}180$ and $e = 0.05$:

$$n = \frac{369{,}180}{1 + 369{,}180(0.05)^2} \approx 399$$

This value was rounded up to 400 households to ensure robust cross-sector allocation (approx. 133 questionnaires per sector) to balance comparisons without population-size skews.

2.3 Sources of Data

Primary fieldwork ran over a four-month period (September–December 2024), disaggregated as follows:

Table 2. Summary of Primary Data Collection Methods and Participant Profiles.

Method	**Sector**	**Household survey respondents (n)**	**Participant Profile**	**Rationale for Inclusion**
Household Questionnaire	Ruhango, Rusebeya, Manihira	400 (134 Ruhango, 133 Rusebeya, 133 Manihira)	Heads of households (48% Female, 52% Male)	To quantify direct livelihood losses (land, income, assets) at the family level.
Key Informant Interviews (KII)	District-wide	12	Local Leaders (4), MINEMA (2), Environmental Officers (3), Health Workers (3)	To obtain expert perspective on policy execution.
Focus Group Discussions (FGD)	1 per sector	24 total (8 per group)	Community Elders, Farmers, Women Reps (50% Female)	To capture collective memory and socio-cultural impacts.

2.4 Data Analysis and Processing

Quantitative database cleaning and descriptive/inferential processing were managed through IBM SPSS Statistics version 26.0. Min-Max scaling was applied to transform and normalize binary and 5-

point Likert scale indicators into a standardized composite *Overall Livelihood Impact Score* falling along a standard continuous range:

$$\text{Normalized Value} = \frac{x - x_{\min}}{x_{\max} - x_{\min}}$$

Inferential patterns were extracted via cross-tabulations, Chi-square (χ^2) association tests, and one-way ANOVA tests across structural configurations. Qualitative transcripts from KIIs and FGDs were hand-coded using continuous two-cycle thematic framing to isolate idiomatic cultural variables and micro-level traditional adaptations.

3. Results and Discussion

3.1 Demographic and Socio-economic Profiling

The working labor force (ages 31–60) represented the dominant baseline block, signifying that environmental disruptions trigger localized shocks directly into regional asset productivity.

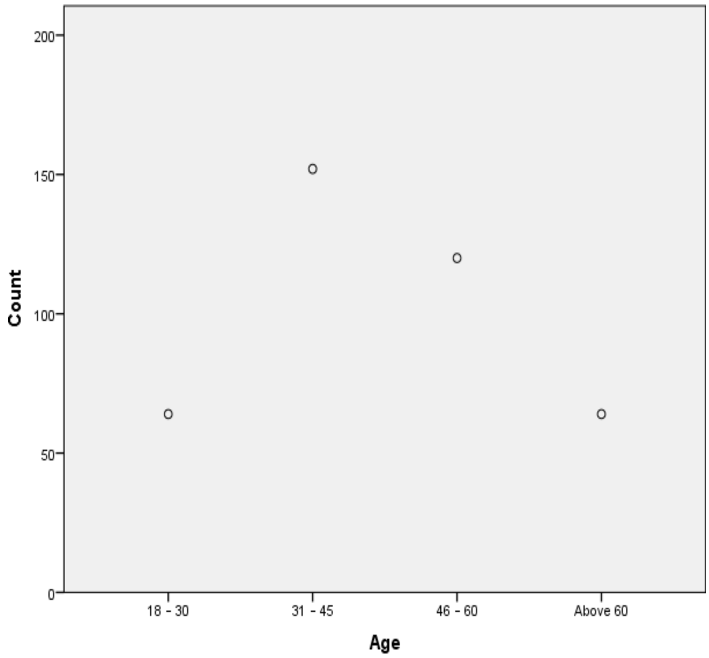

Figure 3: Age Distribution of Household survey respondents

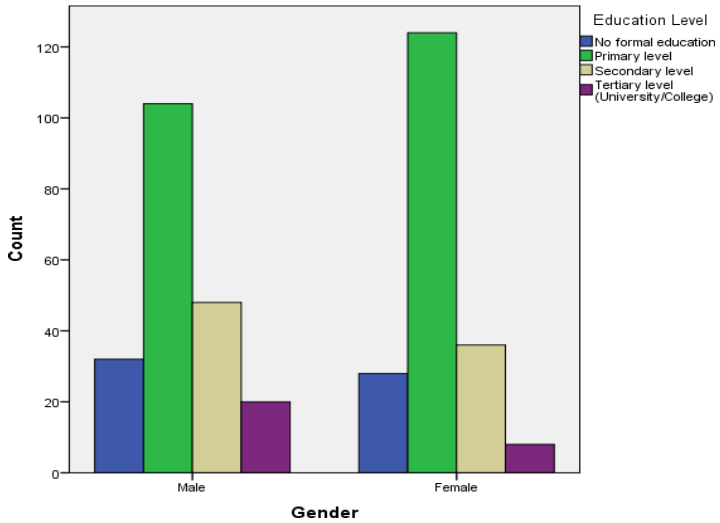

Figure 4: Gender and Educational Profile of Household Survey Respondents (n=400)

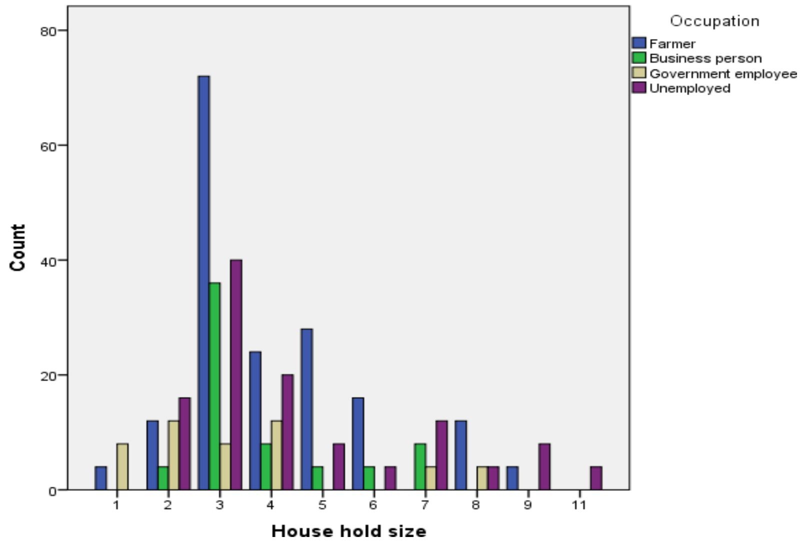

Figure 5: Household Size and Primary Occupation of Household Survey Respondents (n=400)

Educational cross-sections showed heavy clustering at primary levels. This dynamic highlights the need to avoid overly technical administrative jargon during risk communication. Instead, programs should focus on translating mitigation directives into accessible, hands-on strategies.

3.2 Spatial-Temporal Patterns and Asset Destabilization

A total of 53% of respondents reported experiencing landslides annually, locking communities into a continuous cycle of recovery. Quantified structural damages show that farmland loss is the primary driver of vulnerability (72%). Meanwhile, public post-disaster aid displays a critical structural mismatch. Relief is heavily weighted toward agricultural inputs (56%), leaving urgent cash assistance (1%) and food gaps (5%) largely unaddressed. Furthermore, a substantial 38% support gap remains, leaving a large portion of the population entirely unaided.

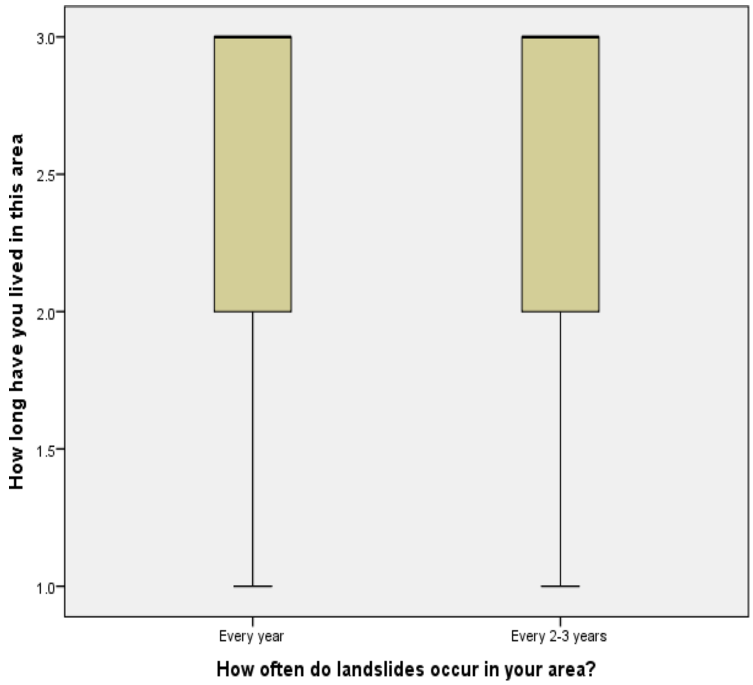

Figure 6: Reported Frequency of Landslides by Household Survey Respondents (n=400)

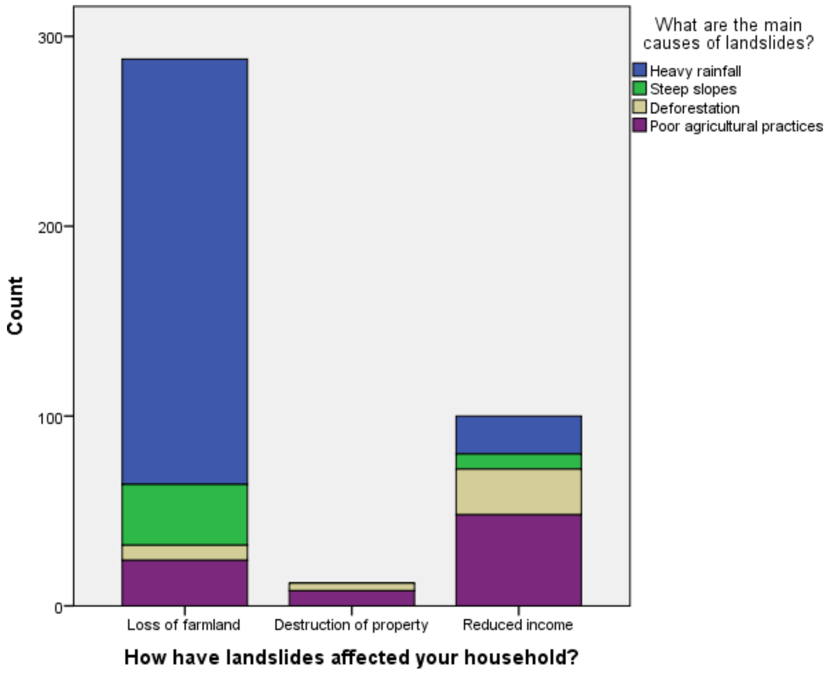

Figure 7: Impact of Landslides on Household Livelihoods (n=400)

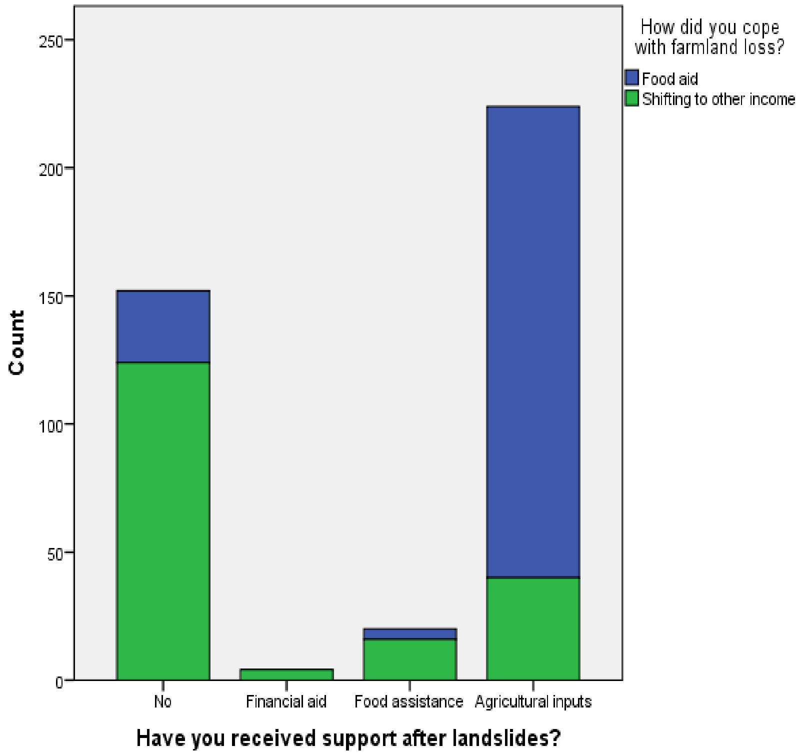

Figure 8: Types of Support Received by Household Survey Respondents (n=400)

3.3 Mitigation Paradigms, Perception, and Interface Dynamics

Community-led measures center around vegetative cover, basic terrace structures, and makeshift drainage channels. However, a major disconnect persists regarding institutional framework integration.

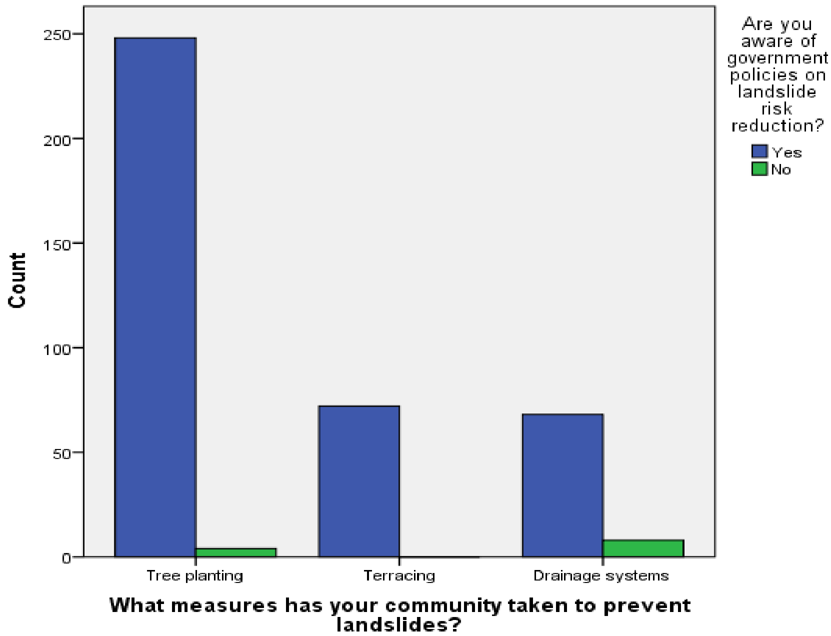

Figure 9: Community-Driven Mitigation Strategies and Reported Policy Awareness (n=400)

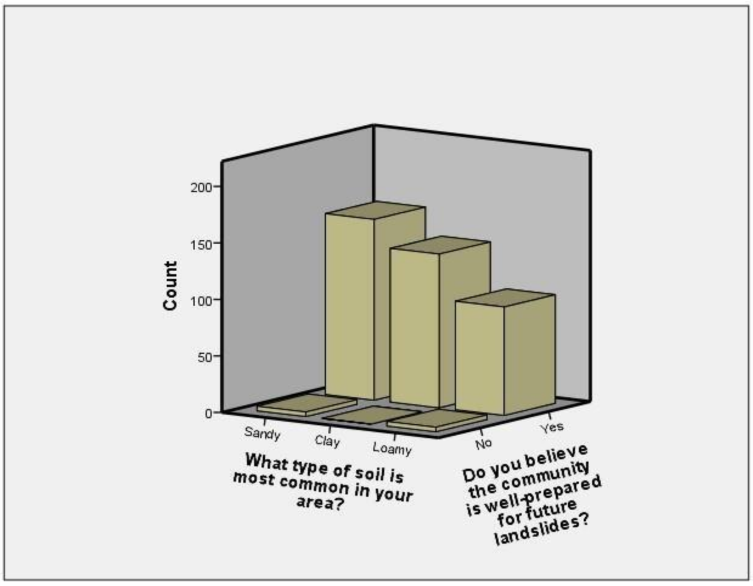

Figure 10: Perceived Soil Stability Across Soil Types (n=400)

Perceptions of soil safety show a downward trend across all soil profiles. Sandy soils are identified as highly vulnerable to severe runoff erosion, while clay terrains present a higher risk of deep slope failure when saturated.

3.4 Infrastructure Correlation Analysis

The relationship between private livelihood asset degradation and public infrastructure failure was evaluated using Pearson's statistical correlation (Table 3). The tracking confirmation ($r = 0.148$, $p = 0.003$) reveals a statistically significant positive correlation. This demonstrates that residential impacts are coupled with wider water infrastructure damage. Landslides trigger a double burden, combining property damage with severe water contamination from soil debris.

Table 3. Pearson Correlation Between Household Impact and Water Source Impact.

Parameter	How have landslides affected your household?	How have landslides affected water sources?
How have landslides affected your household? Pearson Correlation Sig. (2-tailed) *N*	1 400	**0.148**** 0.003 400
How have landslides affected water sources? Pearson Correlation Sig. (2-tailed) *N*	**0.148**** 0.003 400	1 400

. *Correlation is significant at the 0.01 level (2-tailed).*

3.5 Comparative Discussion

The high reliance on agriculture means that farmland degradation severely impacts the local economy, matching reports by the Food and Agriculture Organization (FAO, 2023) on hazard-driven agrifood supply chain disruptions.

Regarding bio-engineering fixes, planting native species like *Alnus acuminata* and *Grevillea robusta* offers substantial root-binding benefits. This approach aligns with successful outcomes observed in the Himalayas (Gerrard and Gardner, 2002). However, as highlighted by MINEMA (2021), terraces can inadvertently collect water and accelerate failures if structural drainage points are neglected (Sidle and Ochiai, 2006). Additionally, the 38% aid gap observed in Rutsiro closely mirrors structural tracking delays seen after the 2015 Nepal earthquake (WFP, 2015). This underscores the clear need to transition away from centralized, reactive relief systems.

4. Conclusion and Recommendations

Landslides in Rutsiro District have evolved from localized physical hazards into chronic socio-economic disasters. To break this cycle of vulnerability, the study proposes the following targeted policy actions:

- Regenerative Land Management: Scale up agroforestry programs using deep-rooted native tree species, backed by stronger enforcement of local land-use zoning laws.
- Infrastructure Hardening: Upgrade to landslide-resilient water piping materials and integrate engineered drainage networks alongside terrace steps.
- Enhanced Community Preparedness: Implement localized, bilingual Early Warning Systems (EWS) and integrate basic risk education directly into farming cooperatives.
- Equitable Recovery Mechanisms: Address the 38% aid gap through decentralized microfinance options, crop insurance programs, and immediate cash relief.

Declarations

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

Ethics Approval and Consent to Participate: This study involved human participants and was conducted in accordance with institutional ethical standards. Ethical approval was obtained from the relevant academic authority at the University of Lay Adventists Kigali (UNILAK). Informed consent was freely obtained from all participants prior to data collection.

Data Availability: Data will be made available on reasonable request.

Funding Information: No funding was received for this study.

Consent to Publish: The authors give full consent for the publication of this manuscript.

Author Contributions Statement: S. Kabano and T. F. Ediagbonya designed and conceptualized the study, developed the methodology, and interpreted the data. S. Kabano conducted fieldwork and data processing. S. Kabano carried out the literature review. T. F. Ediagbonya and C. Mupenzi reviewed the article, provided critical feedback, and edited the final draft.

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