ESI Preprints **Not Peer-reviewed**

Overview of Community Landslide and Flood Vulnerability in Northwestern Rwanda

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Doi: 10.19044/esipreprint.8.2024.p70

Approved: 05 August 2024
Posted: 08 August 2024

Cite As:
Idukunda, C., Henry, S., Twarabamenye, E., & De Longueville, F. (2024). *Overview of Community Landslide and Flood Vulnerability in Northwestern Rwanda*. ESI Preprints. https://doi.org/10.19044/esipreprint.8.2024.p70

Abstract

Northwestern Rwanda is highly susceptible to landslides and floods. Understanding the community's vulnerability to these hazards is crucial for implementing effective mitigation measures. This study assesses the vulnerability of communities in Northwestern Rwanda through a household survey and interviews with key informants conducted in May-June 2022. A total of 158 households were randomly sampled from the study area to ensure representation across various socio-economic backgrounds and geographic locations. In addition, 22 key informants were randomly selected from among local leaders, including heads of cells and officials responsible for disaster risk reduction and management at district and sector levels. This approach was designed to complement the data collected from the households. The results indicate that landslides and floods are the primary hazards affecting the community in the study area. Agriculture livestock, and small businesses are the main income sources impacted by these hazards, with 88.7% of respondents heavily dependent on agriculture. Dependence on agriculture as the sole source of income (88.7%), low educational attainment

(61.4%), low economic status (56.3%), and proximity to rivers or steep slopes were identified as significant contributors to community vulnerability. To mitigate landslide and flood risks in the study area, several preventative measures are being implemented. These include the relocation of residents from hazardous areas to safer locations, repairing and constructing rainwater drainage systems in flood-prone areas, development of radical terraces on hillsides, building of water channels, and establishment of early warning systems. Despite these efforts, a notable 69.5% of respondents have mentioned insufficient financial resources as a principal barrier to achieving effective implementation. This study provides valuable insights for policymakers, underscoring the imperative for robust policies and programs aimed at mitigating the impacts of landslides and floods. The study recommends (1) increasing financial allocations to local administrative entities to bolster the execution of preventative measures against landslides and floods, and (2) enhancing educational initiatives and economic prospects to diminish community vulnerability. Addressing these areas is crucial for ensuring the well-being of inhabitants in the face of landslides and floods.

Keywords: Vulnerability, Disaster Risk Reduction, Flood, Landslide, Northwestern Rwanda

Introduction

Natural hazards are often unexpected and uncontrollable events that can threaten people (Alexander, 2018; Bokwa, 2013; Flanagan et al., 2011). Floods and landslides are two of the most damaging types of natural hazards (Herho et al., 2018; Najafi et al., 2024; Opperman & Galloway, 2022; Pradeepkumar et al., 2014). These hazards lead to fatalities, injuries, destruction of property, economic and social disruptions, and environmental degradation around the globe (Agrawal, 2018; J. A. F. Ignacio et al., 2016; Lindell & Prater, 2003). The difficulty of addressing the impacts of these hazards is that they can occur with little warning, making it difficult for communities to prepare. Additionally, the factors that contribute to these hazards are often complicated and changeable, making it difficult to accurately predict where and when they will occur (Haddow et al., 2020; Shi, 2019). However, landslide and flood models help to address these challenges (Depicker et al., 2021).

"Vulnerability" is defined as the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, community, assets or systems to the impacts of hazards (UNISDR, 2017). "Community" in this context refers to people inhabiting a common geographical space characterized by its susceptibility to hazards (authors' definition adapted from Aksha et al.(2020); Quarantelli,

(1999). Hazard vulnerability is most often measured in three dimensions: (a) economic vulnerability, which refers to the community's economic assets and its susceptibility like living resources, (b) social vulnerability, which is based on social inequalities such as gender, poverty, health, marginalized people, and affordable housing, and (c) physical/environmental vulnerability, which focuses on human-environment systems (Schwarz and Kuleshov, 2022; Nor Diana et al., 2021).

In recent years, there have been significant advancements in vulnerability studies particularly regarding social vulnerability to natural hazards (Aksha et al., 2020; Dintwa et al., 2019; Kamarudin et al., 2022). These studies aim to understand how various factors influence a community's susceptibility to harm or losses resulting from natural hazards. One critical aspect of assessing social vulnerability is the need to consider multiple dimensions, including poverty, social inequality, health, access to resources, and resilience mechanisms. Such assessments are complex due to the multifaceted nature of vulnerability (Birkmann, 2006; Cutter et al., 2003; Hinkel, 2011). Researchers have employed data-driven methodologies to quantify social vulnerability, relying on socio-economic data and statistical analyses to create comprehensive vulnerability indices. Dintwa et al. (2019) analysed vulnerability to natural disasters in Botswana; Joseph (2013) focused on flood vulnerability in Assam, India; K.C. (2013) examined factors affecting vulnerability to floods and landslides in Nepalese villages; Siagian et al. (2014) assessed vulnerability in Indonesia using the Social Vulnerability Index (SoVI); and Michellier et al. (2020) investigated volcanic hazard vulnerability in Goma.

Vulnerability has also been studied in data-limited contexts, with some researchers adapting existing methodologies and others developing new approaches to suit their specific environments. For example, For example, in Indonesia, (Siagian et al., 2014), they looked at villages near a volcano called Merapi. In Sao Paulo, Brazil, Maharani et al.,(2016), they focused on areas prone to flooding. In the Mekong Delta in Vietnam, Roncancio & Nardocci, (2016) assessed vulnerability, as well as in the Philippines where coastal risks are a concern (Ignacio & Henry, 2015, 2015; Rossignol et al., 2015). The GeoRisCA project (Michellier et al., 2016) demonstrated an approach to collect socio-economic information and create a social vulnerability index for cities like Goma and Bukavu, addressing the challenges posed by limited data. Although a substantial amount of literature exists on assessing population vulnerability to hazards, few studies have focused on flood and landslide-related risks in Rwanda, despite the country's annual susceptibility to these hazards and their significant impact on communities (Aloys, 2016; Bizimana , 2015; Mugisha et al., 2020).

Rwanda is susceptible to flooding and landslides (Nsengiyumva et al., 2018). Since the 1960s, events of floods and landslides have caused more than one million casualties (deaths, injuries, and displacement), destruction of hundreds of acres of farmland, loss of livestock, and destruction of several infrastructures such as roads, bridges, and homes (MIDIMAR, 2015; 2019). The UNEP report (2011) reveals that around two million people were affected by floods in Rwanda between 1974 and 2008. In 2000, a series of floods and landslides caused 108 deaths, 10,000 homeless people, and destroyed land (MIDIMAR, 2015). The Ministry of Emergency Management (MINEMA) reports (2016-2020) show that, between 2016 and 2020, floods and landslides have led to 485 deaths, 202 injuries, 8,624 damaged houses, and 18,311.54 hectares of damaged crops (MINEMA, 2016, 2017, 2018, 2019 ,2020). The same report highlights Northwestern to be the most affected region in the whole country.

To mitigate the effects of such disasters, the Government of Rwanda (GoR) has implemented several Disaster Risk Reduction (DRR) initiatives. The most significant is the National Strategy for Disaster Risk Reduction (NSDRR), established in 2013. In addition, the GoR has established local institutional frameworks such as the National Disaster Management Committee (NADIMAC) and the National Disaster Management Technical Committee (NADIMATEC) at the national level, the District Disaster Management Committee (DIDIMAC) at the district level, and the Sector Disaster Management Committee (SEDIMAC) at the sector level. There are also national-scale early warning systems in Rwanda, operated by the MINEMA, to alert communities of imminent disasters, such as floods and landslides, especially in high-risk areas like the Northwestern regions. These systems work by monitoring weather patterns and geological activity and disseminating alerts through SMS, radio, and community networks. Additionally, awareness-raising initiatives, land-use planning measures, building codes, and financial assistance for disaster recovery are in place to further enhance community resilience and preparedness (MINEMA, 2022).

Despite efforts to mitigate the disaster impact, including the implementation of early warning systems, relocation of communities from hazard-prone areas to safer locations, and awareness programs, Rwanda continues to face significant challenges from landslides and floods exacerbated by climate change and these hazards disproportionately affect the Northwestern regions of the country (Bagstad et al., 2020; Benineza et al., 2019; Nahayo et al., 2019). However, there remains a research gap concerning comprehensive analyses of community vulnerability and its drivers at the local level in these areas.

Therefore, this study aims to fill this crucial gap by providing an overview of community vulnerability to landslides and floods in

northwestern Rwanda. By doing so, the study seeks to provide insights into hazard community vulnerability in the study area and in the similar contexts. It focuses on: (1) investigating the major hazards affecting communities and their impacts, (2) assessing the socio-economic factors contributing to vulnerability, and (3) identifying the risk prevention measures used in northwestern Rwanda.

2. Materials and Methods

2.1 Description of Study area

This study focuses on the northwestern part of Rwanda, which is the region of the country most prone to landslides and floods. The area is hilly and mountainous with an average elevation of 1,500 meters. The climate is tropical with temperatures ranging from 18-27 degrees Celsius. There are two rainy seasons during the year, from February to May and September to December. The geology of the region comprises various rock types and soils, the most common being metamorphic and sedimentary rocks, and these tend to be highly erodible due to the high rainfall (MIDIMAR, 2015).

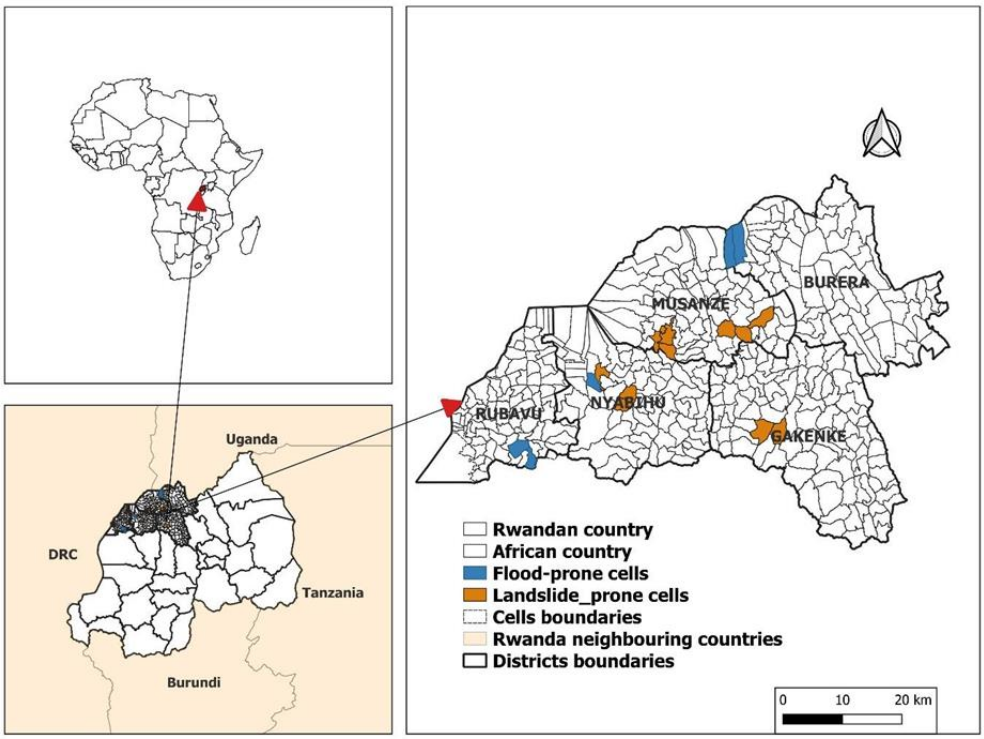


Fig.1: Location of the study area**:** Northwestern Rwanda

The authors' attention was drawn to the significant impact of landslides and floods on the local community. Recognizing that collaborating

with the community at a local level could enhance hazard awareness and adaptation, they ensured that vulnerability assessment to both landslides and floods was conducted at the local level, specifically through cell-level analysis, being the lowest administrative level of the country's policies implementation.

The study covers 9 cells prone to landslides, and 5 cells prone to floods. The cells are situated within the districts of Musanze, Nyabihu, Rubavu, Gakenke, and Burera (Fig. 1). The region is predominantly rural, characterized by underdeveloped infrastructure compared to other urban and suburban areas in Rwanda, along with fragile hazard control systems.

2.2 Data collection and analysis

For this study, fourteen cells were sampled based on their annual frequency of landslides or floods. This frequency information was gathered from the MINEMA, which compiled hazard-related information from across the country from 2016 to 2020 and validated by key informants in the study area.

Regarding primary data collection, households living close to hazardous sites (within 50 meters of flooded areas, high steep slopes, and downslopes) were randomly sampled to be surveyed in each cell. A total sample of 158 households in the fourteen sampled cells was considered, with 8 to 12 households per cell. A structured questionnaire together with interview guide questions facilitated the collection of both quantitative and qualitative data.

The major questions asked to respondents included: (1) demographic characteristics (age, sex, marital status, literacy and occupation), (2) major hazards experienced in the study area and their impact on livelihoods, such as damage to house properties and croplands, and loss of employment, (3) key drivers of landslide and flood vulnerability, such as socioeconomic status represented by Ubudehe categories (i.e. categories corresponding to a social stratification program in Rwanda based on household income), with categories ranging from A (highest income) to E (most vulnerable), (4) income sources affected by hazard occurrence, (5) current disaster risk reduction mechanisms practiced in the study area (Niringiye, 2012).

Regarding the effectiveness of preventive measures against risk of landslides and floods, the study targeted key informants through a guided interview process, generating qualitative data. A total of 22 key informants, including heads of cells and officials responsible for disaster risk reduction and management at district and sector levels, was included in the interview. To ensure the reliability and validity of the collected data, researchers employed consistent procedures and trained enumerators any bias that could arise from the interviewer' personal opinions or behaviours. Pre-testing of

the questionnaire was conducted to refine questions and ensure clarity. Additionally, triangulation was used by cross-referencing data from different sources (household surveys, key informant interviews, and secondary data) to enhance data reliability.

The collected data were analysed using the Statistical Package for Social Science (SPSS), version 21. Specific analytical methods included descriptive statistics to summarize demographic characteristics and key vulnerability indicators, and cross-tabulations to examine relationships between variables of source of income and affected households. The choice of these statistical methods was justified by their appropriateness for handling the types of data collected and the study's objectives (Jerjawi, 2012; Niroumand et al., 2013). For the qualitative data from key informant interviews, thematic analysis was employed. This involved coding the interview transcripts to identify recurring themes and patterns related to vulnerability and disaster risk reduction measures. To ensure the reliability and validity of the qualitative data, multiple coders were used, and intercoder reliability was assessed. Detailed field notes were also maintained to support the analysis process.

3. Results

3.1 Demographic description of the respondents

The results in Table 1 provide critical insights into the demographic, educational, and occupational characteristics of the sampled population, which are essential for understanding their vulnerability. The gender distribution indicates a slight majority of female respondents (51.9%). Also, the Table 1 shows that the majority of respondents (65.1%) fall within the working-age population (18-49 years) and the older population (above 60 years) is smaller (13.9%). The same table shows that 61.4% of respondents have primary school as their highest level of education, and a significant 86.7% rely on agriculture for their occupation, with other occupations represented in small percentages.

Table 1: Description of the respondents

Characteristics (N=158)	Categories	Value (%)
Male respondents		**48.1**
Female respondents		**51.9**
Age	18-38	**37.3**
	39-49	**27.8**
	50-60	**20.9**
	Above 60	**13.9**
Literacy rate	Illiterate	**26.6**
	Primary school	**61.4**

	High school	**9.5**
	College/trainings	**0.6**
	University or above	**1.9**
Occupation	Agriculture	**86.7**
	Livestock	**0.6**
	Small business	**10.1**
	Office employment	**1.3**
	External support	**1.3**

Source: Household survey, in Northwestern Rwanda, 2022

3.2 Major hazards affecting the community and their impacts

The types of hazards affecting the community include landslides, floods, windstorms, and combinations of landslides and windstorms. Landslides have impacted a significant number of households, with 86 respondents reporting they were affected. This significant number indicates a high impact of landslides within the study area, suggesting that landslide risk is a major concern for the community. On another side, 57 households reported to be affected by floods, making it the second most prevalent hazard in the area. The substantial number of households affected by floods highlights the area's susceptibility to flooding events and the need for flood risk management. Windstorms alone have affected 4 households.

Additionally, a combination of landslides and windstorms has also affected 4 households. Although these numbers are relatively small compared to landslides and floods, they still represent important impact that should not be overlooked, particularly considering the potential for combined hazard impacts. Only 7 households reported being not affected by any of the listed hazards. This low number of unaffected households underscores the widespread impact of natural hazards in the study area, emphasizing the importance of hazard preparedness and mitigation strategies.

To understand how landslides and floods affect people’s livelihoods, the authors asked respondents to rank the primary livelihood sources affected by the hazards in their neighbourhood. As shown in Table 2, a total of 117 (97.5%) respondents said that agriculture and livestock were the main livelihood sources affected by the occurrence of landslides and floods. Most small business owners are also affected (19 out of 20). Households relying on income-generating buildings (likely income-generating properties or rental properties) also show high levels of being affected (11 out of 12). Landslides and floods directly damage buildings, including office equipment and supplies, thereby making this income source highly vulnerable. This suggests a significant impact on property, including office materials, due to landslides and floods in the study area. Fewer households are engaged in this

category (4 out of 6 affected). This implies that office materials or jobs related to this field might have less direct exposure to the hazards. However, the affected households still represent a considerable proportion, indicating some level of vulnerability.

Table 2: Major sources of income affected by landslide and flood occurrence

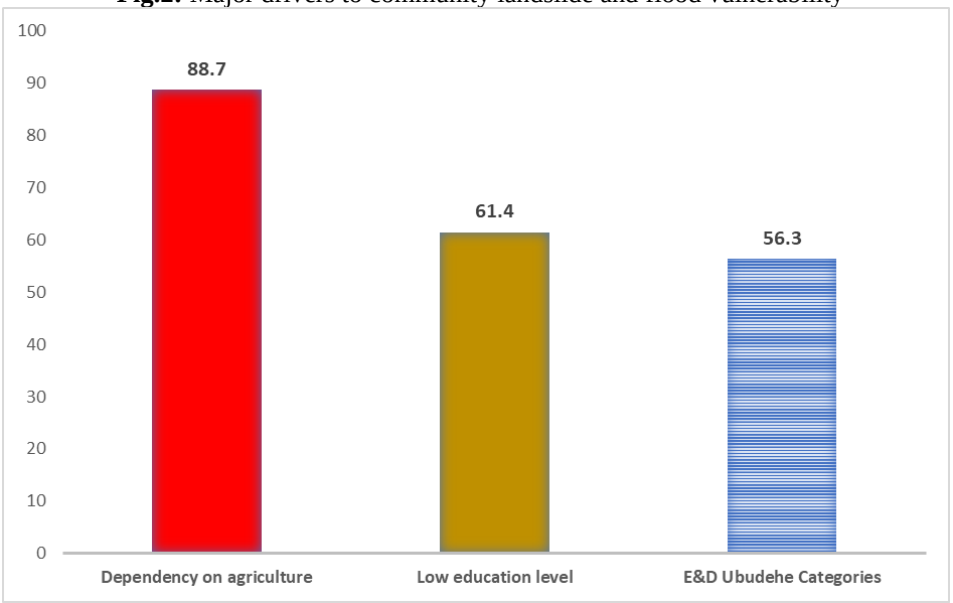
Income sources	**Households affected**	
	Yes	**No**
Agriculture and livestock	117	3
Small business	19	1
Income-generating properties	11	1
Office materials	4	2
Total	**151**	**7**

Source: Household survey conducted by authors in Northwestern Rwanda, 2022

3.3 Hazards vulnerability drivers

The study results indicate the factors contributing to vulnerability in the study area. As depicted in Figure 2, heavy dependence on agriculture for livelihoods (88.7%) emerges as a primary driver of community vulnerability to landslides and floods. The low education level was also revealed as the vulnerability contributor as primary education is the highly scored level (61.4%). The other driver of landslide and flood vulnerability is the Ubudehe categories, with 56.3% of the respondents felt into the last Social-Economic (E&D) categories.

Fig.2: Major drivers to community landslide and flood vulnerability



Source: Household survey, in Northwestern Rwanda, 2022

In addition to the above-mentioned vulnerability drivers, respondents highlighted limited financial capacity to afford a safe location as the main reason for settling near hazardous areas. This observation was also confirmed during the field visits, where it was found that 100% of the households visited are located in close proximity (within 50 m or on the same site) to the river and/or in areas with steep slopes prone to landslides (Fig.3).

The challenge of building unsafe houses and their poor location was explained by respondents where most households (97.5%) stated that they reside in underdeveloped houses primarily constructed using mud as the main material.

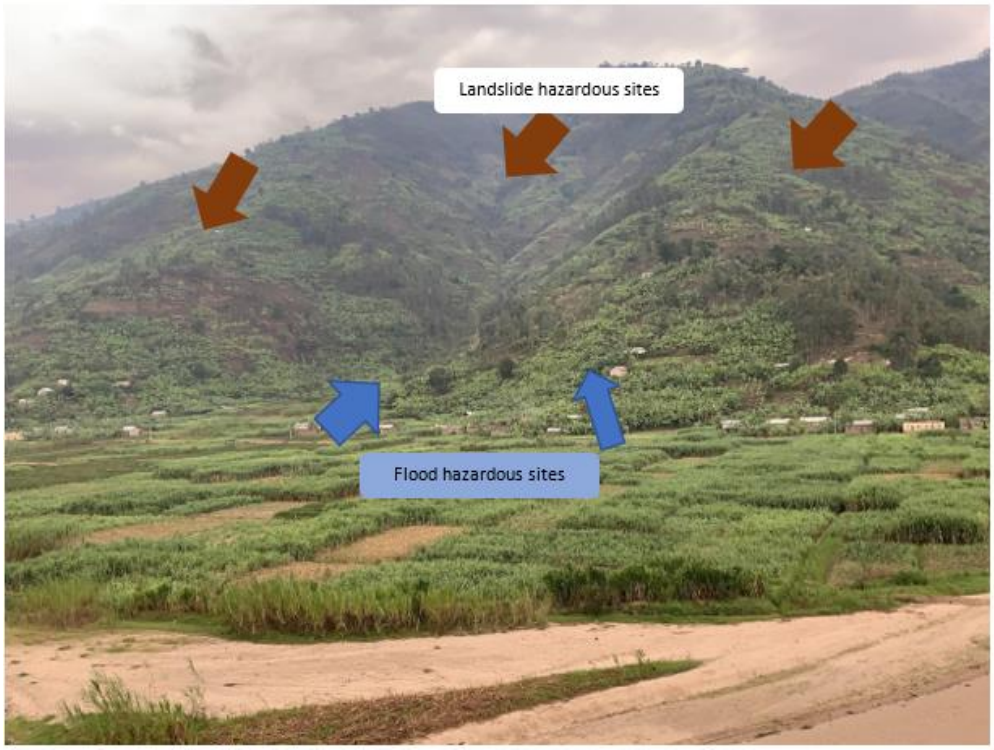


Fig.3: Residence in adjacent to flood (Blue arrows) and Landslide (Brown arrows) hazardous sites in Kavumu cell, Busogo Sector, Musanze District, Northern Province of Rwanda
Source: Authors' capture, May 2022

3.4 Landslide and Flood risk prevention measures

As it was reported by the respondents and observed from the field, prevention measures are being implemented to mitigate the risks of landslides and floods in the study area. These measures include: (a) relocation of residents from hazardous areas to safer locations; (b) building containment walls and repairing and constructing rainwater drainage systems

in flood-prone areas; (c) constructing radical terraces on hillsides; (d) construction of water channels. Additionally, emphasis was placed on (e) early warning systems to enhance disaster awareness and preparedness within the community.

Despite the measures in place, 69.5% of the respondents declared that these measures were lacking in their respective areas. They mentioned lack of financial resources as a limitation to implement these measures. Conversely, 30.5% of the households reported to have taken preventive measures at the level of their households such as constructing water channels and digging pits to control water flow on their farms.

Discussion

The present study is conducted as an overview of community to landslide and flood vulnerability in Northwestern Rwanda, an area that largely records the occurrence of both hazards with immense impacts on the community.

The study findings indicate that landslides, floods, windstorms, and combinations of landslides and windstorms are the primary hazards affecting the community. Landslides affect the highest number of households, followed by floods. The high number of households affected by landslides and floods confirms the occurrence of the mentioned hazards in the area and that the area has geographical and geological characteristics conducive to both hazards, including steep slopes, unstable soil, and significant rainfall (Nahayo et al., 2019; Nsengiyumva et al., 2018; Uwihirwe et al., 2020) . There is a need for increased monitoring, early warning systems, and community education about the hazards risk. Infrastructure improvements, such as retaining walls or better drainage systems, could be necessary to mitigate the hazards risks.

In addition, the findings of the study reveal that the agriculture sector is the main income source affected by the occurrence of both landslides and floods (see Table 2). This high impact is due to the exposure of agricultural lands and livestock to landslides and floods, which damage crops, soil, and livestock infrastructure. The high dependence on agricultural and livestock makes these households particularly vulnerable to adverse weather conditions. (Mind'je et al., 2020; Mugisha et al., 2020; Nahayo et al., 2019). The study results also show that small business owners are also affected. Small businesses are affected by disruptions in infrastructure, supply chains, and customer access due to landslides and floods. This indicates that small businesses, while less directly tied to the natural environment than agriculture, still face significant impact of these hazards raising community vulnerability. Income from office employment and external support, present a lower affected ratio compared to other income sources. This imply that

office materials and jobs related to this field might have less direct exposure to the hazards.

Furthermore, the results in Figure 2 confirmed the fact that dependence on agriculture, low education level, and E&D Ubudehe categories are the major drivers of landslide and flood vulnerability in Northwestern Rwanda. This was previously reported that unemployment, poverty, low education level, and family size are among the factors raising people's hazard vulnerability (Michellier et al., 2016; Cutter and Corendea, 2013; Mavhura and Manyangadze, 2021; Donner and Rodríguez, 2008). The dependence on agriculture as the single economic source reduces the community's ability to cope with the impact of hazards once their source of income is not stable (Oluwatayo and Ojo, 2016). The occurrence of hazards leaves impacts mostly by washing away crops and cultivated land, leading to food insecurity in the community, which has no other means of survival (Nahalomo et al., 2022). In addition, this dependence on agriculture has a direct influence on the yearly and decade-long incomes as well as the sustainability of the available resources. Consequently, the population is ill-equipped to handle the repercussions of hazards once their source of income becomes unstable. This low socio-economic status leads to poor housing quality, difficulty in finding safe land for settlement, and a weak ability to recover from hazards such as rebuilding damaged houses (Hejazi et al., 2022; K.C., 2013; Mavhura et al., 2017). Diversifying income sources through promoting small businesses, vocational training, and other non-agricultural employment opportunities can reduce this vulnerability.

A study conducted in Nigeria by Akinsemolu and Olukoya (2020) reported that education plays a crucial role in reducing vulnerability by raising awareness about various measures to prevent the impacts of landslides and floods. Similarly, this study's findings indicate that respondents completed primary education more frequently than other educational levels. While this suggests that individuals in the study area have basic literacy skills in the local language, it is noted that they struggle to understand formal written communications, such as early warnings or disaster risk reduction information. This difficulty in interpretation increase vulnerability and hinder effective preparedness and recovery efforts. Education can enhance community awareness and preparedness for disasters, promote better farming practices, and encourage diversification of livelihoods (Asio, 2021; Hoffmann & Blecha, 2020; Hoffmann & Muttarak, 2017; McNeill et al., 2018).

Regardless of other social, economic, and environmental drivers of landslide and flood vulnerability, in most cases, as reported by the National Atlas of Rwanda (MIDIMAR, 2015), people's vulnerability increases due to their proximity to hazardous locations (See Fig.3.). Several studies (Pham et

al., 2020; Kjekstad and Highland, 2009) have highlighted the increasing landslide and flood vulnerability rate mainly due to poor land management, climate change, and other anthropogenic activities. Despite the entire area being at risk of hazards, residing near hazardous locations significantly increases the community's impacts to these risks. The challenge of residing in poor location and in underdeveloped houses primarily constructed using mud as the main material, was also highlighted by the respondents. Consequently, when faced with hazardous events, the community experience inadequate protection, higher material losses, and potentially greater harm or destruction to their houses.

In section 3.4, key informants confirmed that measures such as relocation from hazard-prone areas, building water retention walls, constructing water channels, building bench terraces, and implementing early warning systems are in place as landslide and flood risk mitigation strategies in the study area. However, the level of implementation remains low in some areas, highlighting the necessity for additional efforts to enhance the safety of communities, the environment, and the economy in Northwestern Rwanda. Despite these challenges, communities acknowledge that these measures have somewhat reduced vulnerability, although specific quantification is lacking.

This was starkly highlighted by the recent highly destructive compound disaster that struck the country on the night of May 2nd to 3rd, 2023. Triggered by continuous torrential rainfall, the disaster resulted in massive river and flash floods, as well as severe landslides, predominantly affecting the Western, Northern, and Southern provinces. According to the Ministry in Charge of Emergency Management (MINEMA, 2023) and the International Federation of Red Cross and Red Crescent Societies (IFRC, 2023), this event caused 135 fatalities, 110 injuries, the destruction of nearly 5,500 houses, and affected over 51,900 people.

The occurrence of this compound disaster underscores the relevance and urgency of our study on the community's vulnerability to landslides and floods in Northwestern Rwanda. The findings from our 2022 survey, which highlighted significant vulnerability factors among the 158 households studied, are now even more pertinent given the recent catastrophic events. This disaster validates our earlier assessments and emphasizes the critical need for robust disaster preparedness and mitigation strategies.

This study offers an important overview of community landslide and flood vulnerability in Northwestern Rwanda. However, the limitations related a few self-reported data, to limited sample size, and biases related to data collection instruments, underscore the need for deep research, to address these limitations by employing more robust data type, expanding sample sizes, and accounting for the biases to provide a more comprehensive

understanding of community landslide and flood vulnerability and inform more effective risk reduction strategies.

Conclusion

This present study provides an overview on community vulnerability to landslides and floods in Northwestern. The study collected data from a sample of 158 households and 22 key informants from the study area. The findings reveal that landslides and floods are the predominant hazards and affected 86 households and 57 households respectively. These hazards primarily impact those reliant on agriculture sector, with 117 out of 120 agricultural households reporting significant effects. The high dependence on agriculture, coupled with low education levels, and low economic status, exacerbates the community's vulnerability. Relocation of at-risk populations, construction of rainwater drainage systems, development of radical terraces on hillsides, building of water channels, and establishment of early warning systems are being implemented to mitigate landslide and flood risks in the study area.

In order to reduce community vulnerability, the study recommends increasing community awareness about hazard preparedness and improving early warning systems, encouraging households to develop alternative livelihoods that can reduce the economic impact of agricultural losses due to hazards, and providing financial allocations to local administrative bodies to boost the execution of preventative measures against landslides and floods. This study's findings highlight the urgent need for targeted interventions to reduce the vulnerability of Northwestern Rwanda's communities to landslides and floods.

Acknowledgments: The authors are grateful to the Ministry in Charge of Emergency Management (MINEMA), the local communities, and key informants for their time and data provided which led to the completion of this study. The authors also extend special appreciation to the Académie de Recherche et d'Enseignement Supérieur/Projets de Recherche pour le Développement (ARES/PRD) for the scholarship that enabled the doctoral studies from which this study stems.

Conflict of Interest: The authors reported no conflict of interest.

Data Availability: All data are included in the content of the paper.

Funding Statement: The authors did not obtain any funding for this research.

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