https://doi.org/10.5194/egusphere-2025-2112
Preprint. Discussion started: 27 June 2025

Evaluating Disaster Risk Management System: A Case Study of Rwanda's Response to the 2nd-3rd May 2023 disaster event

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Abstract

This study evaluates Rwanda's Disaster Risk Management (DRM) system in response to the severe floods and landslides that struck the Southern, Northern, and Western provinces on May 2–3, 2023. The study uses a mixed-methods approach, including document analysis, semi-structured interviews with 16 government officials and 140 disaster-affected individuals, and field observations. Qualitative data were analysed thematically, while quantitative data were examined using descriptive statistical methods. While institutional frameworks and planning tools exist for disaster risk reduction, challenges remain in both disaster preparedness and response. These include inadequate early warning systems, poor coordination between authorities and communities, inefficient resource allocation, and insufficient local-level information dissemination have exacerbated disaster impacts. The study recommends enhancing community-based early warning systems, involving local communities in DRM efforts, fostering local resilience, conducting hazard-specific research, and adopting regional best practices. These findings offer valuable insights for improving DRM systems in Rwanda and other disaster-prone regions.

Keywords: Disaster, Disaster Risk Management System, Disaster Risk Reduction, Preparedness, Recovery, Response, Rwanda

https://doi.org/10.5194/egusphere-2025-2112
Preprint. Discussion started: 27 June 2025

1. Introduction

Disasters, as defined by the United Nations International Strategy for Disaster Reduction (UNISDR, 2009), are "events that severely disrupt communities or societies, causing widespread losses that overwhelm local resources". Natural hazards, which can lead to such disasters, are typically categorized into long-lasting and sudden events according to their duration, and differing impacts and characteristics (Dickinson et al., 2016; Michellier et al., 2020; Ramli et al., 2020).

Long-lasting hazards, including droughts and environmental degradation, develop slowly over time. Their impacts, while potentially equally devastating, unfold over a long period, leading to prolonged stress on communities (Anenberg et al., 2019; Bly et al., 2020; Staupe-Delgado, 2019). These hazards can result in chronic food and water shortages, long-term health issues, and sustained economic hardship (Conway & Schipper, 2011; Myers & Patz, 2009). The extended duration of these events demands sustained efforts and resources to manage their consequences effectively (Hochrainer-Stigler et al., 2023; Wang et al., 2021).

In contrast, sudden hazards, such as storms, floods, landslides, earthquakes, and volcanic eruptions, occur abruptly and with little to no warning (Accastello et al., 2021; Agrawal, 2018; Bly et al., 2020). These events cause immediate and severe damage, leading to significant loss of life, injuries, destruction of infrastructure, and disruption of essential services. The sudden onset of these hazards often leaves communities with short time to prepare and/or evacuate, exacerbating the immediate impact and complicating emergency response efforts (Schwarz and Kuleshov, 2022; UNISDR, 2017). The rapid and intense nature of these events requires robust disaster risk management systems to respond quickly and effectively (Cumbane & Gidófalvi, 2019; Dora & Kumar, 2022; Kedia et al., 2022).

Reducing the risks posed by these hazards is a complex challenge that requires a multi-actor's approach (Amin et al., 2024; Gill & Malamud, 2016). Policy makers, emergency managers, scientists, community members, and other stakeholders must work collaboratively to develop and implement strategies to mitigate the potential consequences of these events. This involves leveraging environmental observations, hazard analysis, and research on social and behavioural factors to deliver risk information in accessible and actionable forms (Cutter et al., 2013; Hariri-Ardebili, 2020). The ability to manage the consequences of such events depends on a combination of factors, including exposure to the hazard, community vulnerability, and its capacity to respond and recover (Agrawal, 2018). Several studies underline the necessity of inclusive, well-informed, and participatory approaches to address disaster risk management effectively (Baudoin et al., 2016; Das, 2018; Fekete et al., 2021). Specifically, Lindell & Prater (2003) highlighted the role of hazard mitigation, emergency preparedness, and community recovery resources in reducing physical and social impacts. Moreover, Villarino (2023) presents a macroergonomic approach, focusing on hazard adaptation and public engagement to improve perceived preparedness, while Nahayo et al. (2017) underscore the vital role of early warning mechanisms and community engagement in shaping effective Disaster Risk Reduction (DRR) policies.

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The international agenda for disaster risk reduction, as promoted through the Hyogo and the Sendai Frameworks for Action, emphasizes the importance of decentralized platforms for effective disaster risk management (Dewa et al., 2021; Matsuoka & Gonzales, 2021; Sandoval et al., 2023). Maes et al. (2018) critically examined the implications of such network governance in Uganda, revealing that these decentralized platforms often lead to the co-production of unequal risks and concentrated power. This results in a diffusion of responsibility and allows for the shifting of accountability to different levels or actors, undermining effective solutions.

Recognizing the growing challenges posed by disasters, governments across Africa are increasingly adopting proactive strategies to mitigate their impacts. These efforts include implementing DRR policies, establishing comprehensive frameworks, and creating institutional structures to enhance preparedness, response and recovery. By doing so, these countries are aligning their national strategies with the Sendai and the Hyogo Frameworks Action for Disaster Risk Reduction, emphasizing early warning systems, sustainable land management practices, and community resilience (Bang et al., 2019; Saja et al., 2020; Uchiyama et al., 2021).

Typical examples of African countries that have taken steps to strengthen their DRR systems, include Gambia, South Africa, Nigeria, Egypt, and Rwanda. Gambia has adopted various policy frameworks aligned with the Hyogo Framework for Action in the early 2000s, including environmental and disaster management strategies; their National Disaster Management Agency (NDMA) was established in 2008 to coordinate disaster risk management. South Africa has developed comprehensive disaster management guidelines for all government levels, focusing on preparedness; their Disaster Management Act (Act No. 57 of 2002) was already promulgated in 2003, leading to the establishment of the National Disaster Management Centre (NDMC). Nigeria has also developed institutions like the National Emergency Management Agency (NEMA) in 1999, while the Nigeria Meteorological Agency Meteorological Agency (NiMET) was founded in 2000 to support the disaster management (Olowu, 2010). In addition, the COSPAS-SARSAT (Cosmicheskaya Sistyema Poiska Avariynych Sudov – Search and Rescue Satellite-Aided Tracking) system was set up in Nigeria, South Africa, and Egypt in collaboration with international organizations around 2000 to enhance search and rescue operations.

The Global Facility for Disaster Reduction and Recovery (GFDRR) reported that by 2009, 15 African countries, including Gambia, South Africa, Nigeria, Egypt, Burundi, and Cape Verde, had included DRR into their national development strategies, with risk-reducing policies in key sectors like urban development, water management, and infrastructure (GFDRR, 2009:7). Recognizing the increasing threat disasters pose to human lives and national development, the Government of Rwanda (GoR) adopted its first National Disaster Risk Reduction and Management (DRRM) Policy in 2009, revised it in 2012, and again in 2018 to align with national and international development frameworks. In line with these efforts, the Government also established the Ministry of Disaster Management and Refugee Affairs (MIDIMAR) in 2010, which was restructured and renamed the Ministry in Charge of Emergency Management

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(MINEMA) in 2018, reinforcing institutional leadership in disaster risk management and emergency response (Kuradusenge et al., 2020, 2021; MIDIMAR, 2015; Ntawigenera & Yadufashije, 2019).

Although Rwanda has established a Disaster Risk Management (DRM) framework, a critical gap remains in assessing its effectiveness during actual disaster response events. This study uses the floods and landslides that struck the Southern, Northern, and Western provinces between May 2nd and 3rd, 2023 (hereafter referred to as the May Disaster) as a case study, to assess the performance of Rwanda's DRM system in practice. Specifically, the research examines how the framework addresses disaster prevention, emergency response, and post-disaster recovery in the context of this event. The findings aim to generate evidence-based recommendations to strengthen Rwanda's DRM strategies and contribute to the improvement of the DRR system.

The case study: a compound disaster in northwestern Rwanda

Rwanda is recording every year numerous disasters due to various hazards (Kabalisa, 2021; MIDIMAR, 2015; MINEMA, 2023; Nahayo et al., 2017). Since the 1960s up to 2000, disasters in Rwanda have cumulatively resulted in over 370 deaths, the displacement of approximately 10,000 people, damage to nearly 1,500 hectares of crops, and the destruction of 3,300 houses, along with infrastructure such as roads and bridges (Nsengiyumva et al., 2018; Piller, 2016; Wagesho and Claire, 2016). However, in the much shorter period between 2011 and 2020 alone, Rwanda recorded more than 3,300 disaster events, leading to over 1,200 deaths, the displacement of around 8,000 people, and significant infrastructure damage (MINEMA, 2015), mainly located in the Northern and Western provinces (Nahayo et al., 2019; Nsengiyumva et al., 2018;(Dawson & Martin, 2015)).

During the night of 2nd and 3rd of May 2023, a major compound disaster occurred in Rwanda. A compound disaster is defined as an event that involves the simultaneous or successive occurrence of multiple hazards, which can exacerbate overall impacts on affected communities (Deijns et al., 2022; Leppold et al., 2022; van den Hurk et al., 2023). These hazards may interact in ways that amplify the severity of the disaster, complicate emergency response efforts, and prolong recovery times (Cutter, 2018; Liu & Huang, 2015; UNDRR, 2023). This May Disaster, involved both huge river and flash floods, as well as severe landslides across fourteen districts of the three provinces of the country (MINEMA, 2023). The disaster particularly affected six districts of the Western province (Nyabihu, Rubavu, Rutsiro, Ngororero, Karongi, and Nyamasheke), four districts of the Northern province (Gicumbi, Burera, Gakenke, and Musanze), and four districts of the Southern province (Muhanga, Ruhango, Nyanza, and Nyamagabe) (Fig.1. and Fig.2.).

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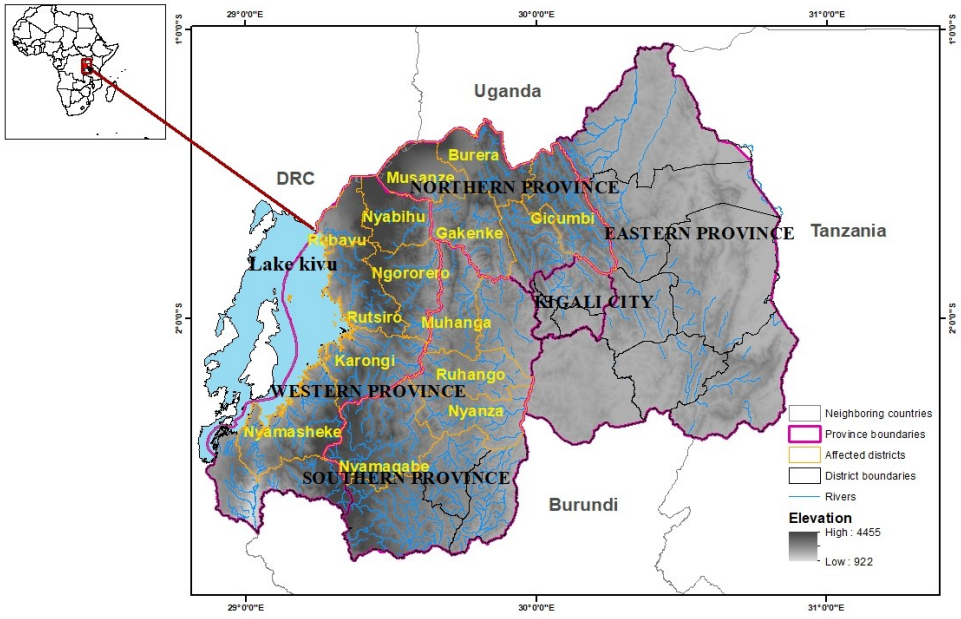

Fig 1. Location of districts affected by the May Disaster in Rwanda (MINEMA, 2023; IFRC,2023); Source: prepared by authors, 2024

Fig 2. Photographs of disaster-affected sites: (a) Landslide impacts on farmland in Nyabihu District; (b) Flood impacts from the Sebeya River on residential areas in Rubavu District. Source: Idukunda C., May 4, 2023.

2. Methodology

The methodological framework employed in this study adopts a mixed-methods approach, integrating both qualitative and quantitative data collection techniques to ensure a comprehensive analysis of the Rwanda's DRM system. It incorporates three primary data collection methods: grey literature review to analyse existing policy and planning instruments; field interviews with affected individuals and key informants to capture experiential insights;

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and field observations to assess on-the-ground conditions and responses mechanisms. This multi-method approach ensures a comprehensive analysis by triangulating data from diverse sources, enhancing the reliability and depth of the findings. The analysis focuses specifically on the May Disaster, examining the DRM system's performance, defined as the effectiveness of strategies and actions implemented to reduce disaster risk, manage disaster response, and enhance resilience. It is evaluated by the integration of DRR into development planning, the availability and accessibility of disaster preparedness resources, the timely and appropriate response to disasters, and the involvement of community stakeholders in decision-making.

2.1 Document review

The grey literature review involved examining the National Disaster Risk Reduction and Management DRRM policy, National Strategy for Disaster Risk Reduction (NSDRR) (2021–2030), contingency plans for landslides and floods, National Risk Atlas of Rwanda, and published post-disaster reports to establish a contextual framework for the study. These documents were instrumental in providing essential background information on the formal structure of Rwanda's DRM system, including its preparedness measures and overall approach to manage disaster risks. The review facilitated the identification of key components within the DRM framework, which were subsequently analysed in the context of the May Disaster.

Table1 Source and type of documents reviewed and analyzed

Source	Type of documents
MINEMA	Web content, DRRM Policy, NSDRR, contingency plans for landslides and floods, and published post-disaster reports
MIDMAR	National Risk Atlas of Rwanda
International Federation of Red Cross and Red Crescent (IFRC) Rwandan Chapter	Published reports on the May Disaster responses and recovery efforts
Rwanda Meteorology Agency	Web content and weather prediction announcements

The analysis specifically focused on prevention, response, and recovery strategies by systematically extracting relevant information through content analysis. This process involved a comparative examination of the documents to identify consistencies, discrepancies, and gaps in the system' planning and implementation. By assessing alignment between policy, planning instruments, and published post-disaster reports, this approach provided a comprehensive understanding of Rwanda's DRM system and its effectiveness in managing the disaster.

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2.2 Interviews

2.2.1 Field interviews with affected individuals

The field interviews with individuals directly affected by the May Disaster was conducted between May 4th and 13th, 2023. Random sampling was used, selecting a total of 140 individuals across seven districts affected by the disaster in the Northern and Western provinces (20 residents per district). This sample size was chosen to ensure that the affected community was fairly represented while also keeping the data collection and analysis process manageable, given time and resource constraints. While the Southern Province was also affected by the disaster, we focused on the Northern and Western provinces being reported as more severely affected than Southern Province. The interviews provided a community-level perspective on how the DRM system functioned in practice, capturing the experiences of people impacted by the disaster.

Quantitative data from interview with affected individuals, were analysed using descriptive statistic. These findings were synthesized to evaluate the overall performance of the DRM system during the May Disaster. The key indicators of performance retained include (1) preparedness, such as the readiness of communities through early warning systems and evacuation plans; (2) response efficiency, reflecting the speed and adequacy of the disaster response, including resource deployment and emergency services; (3) recovery capability, which measures the ability to restore normalcy and provide support to the affected populations; and (4) coordination and collaboration, assessing the cooperation between government agencies, NGOs, and local communities in managing the disaster.

2.2.2 Key informant interviews

In addition to the field interviews with directly affected individuals, semi-structured interviews were conducted between January and March 2024 with key informants which included two staff members from MINEMA and 14 disaster management officials at the district level (Administrative level 2 in Rwandan administrative structure). A purposive sampling technique was used to select key informants with direct knowledge and experience of the DRM process. These interviews aimed to gather insights into the operational aspects of the DRM system, during the disaster event, including its functionality, effectiveness, and the challenges encountered in disaster prevention, response, and recovery.

Apart from the general information (sex, age, education, position, duration of involvement in the position), the main themes asked to the key informants were focusing on:

1. May Disaster awareness and preparedness
2. Impacts recorded following the May Disaster in their living area
3. Types of disaster response and recovery practices
4. Extent of local communities' participation in May Disaster response and recovery practices
5. Challenges encountered in disaster prevention, response, and recovery

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6. Insights from the May Disaster for strengthening future preparedness and response

Qualitative data from key informants' interviews were analysed using thematic analysis to identify recurring patterns and key themes related to DRM performance, in order to understand risk reduction, focusing on efforts to mitigate future disaster risks through resilient infrastructure and sustainable land use practices.

2.3 Field Observations

Field observations were conducted at firsthand in the affected areas between May 4th and 13th, 2023. These observations focused on the disaster impacts, response efforts, and ongoing recovery activities. The observations took place in several key locations within the affected regions, including Musanze, Nyabihu and Rubavu districts. A sample of the affected areas was purposely selected based on the extent to which the area was reported being affected, and the field visits were carried out both independently and in collaboration with key informants who provided additional insights. The landscape was observed using a reading grid that included factors such as physical damage, responses, and recovery progress. This comprehensive approach allowed for a nuanced understanding of the disaster's impacts, responses and the recovery process.

Table 2 Data collection methods for primary data

Data Source	Method of Collection	Number of Respondents
Affected individuals	Interviews	140
MINEMA Staff	Interviews	2
Disaster Management Officers at district level	Interviews	14
Field	Observation and note taking	Not Applicable (NA)

3. Results

The study's results provide a thorough analysis of the Rwanda's DRM system, focusing on factors that influenced its performance during the May Disaster. This section begins by profiling the interviewed respondents and proceeds to examine critical components of the DRM framework, including the DRRM policy and NSDRR, contingency plans, and coordination mechanisms at both national and sub-national levels. It further summarizes the impacts of the May Disaster, evaluates the DRM system's performance during the event, and highlights key lessons to inform and strengthen future disaster preparedness and response efforts.

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3.1. Profile of interviewed respondents

As mentioned above, approached respondents are classified into two categories: the affected individuals and key informants. Among all the respondents (N=156), more than 70% are male and the majority of them (around 47.5%) are aged between 42 and 52 years old. More than half (50.6%) of the key informants attended secondary school, while this was the case for only 24.9% of the affected individuals (Table 3).

Table 3 Description of the respondents

Variable	Key informants (%) (n=16)	Affected individuals (%) (n=140)	Total (N=156)
Function (cluster)			
Residents	----	100	140
MINEMA staff	12.5	----	2
District Staff	87.5	----	14
Sex			
Male	70.8	71.8	112
Female	29.2	28.2	44
Age			
20-30	13.6	13.4	21
31-41	25.0	25.0	39
42-52	47.4	47.5	74
53 and above	14.0	14.1	22
Education			
Illiterate	5.0	7.2	8
Primary	26.9	50.6	42
Secondary	50.6	24.9	79
University	17.5	17.3	27
Living period in the region			
0-5 years	7.1	7.1	8
6-10 years	11.5	11.6	11.9
Above 10 years	81.4	80.1	80.1

Furthermore, over 80 % of all respondents (N=156) had lived in the study area for more than 10 years. Their long-term residence provides valuable insights into how disasters have shaped community preparedness and risk reduction strategies over the years.

3.2 Components of DRM system in Rwanda

The section below presents the components of the DRM system framework, including policy and legal frameworks and planning instruments, as well as institutional arrangements.

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3.2.1. Policy and Legal Frameworks and Planning Instruments

Rwanda's DRM system is grounded in the DRRM policy, which provides a comprehensive framework for effective disaster management, emphasizing prevention and preparedness to enable timely response, efficient recovery, and long-term resilience to future disasters. The policy is designed within the broader development context of national (e.g. Rwanda Vision 2050, National Strategy for Transformation; NST-1), regional (East African Community Vision 2050), continental (African Union Agenda 2063), and global frameworks such as the Sustainable development goals (SDGs 2015-2030), the Sendai Framework for Disaster Risk Reduction (2015-2030), and the Paris agreement. Its overarching vision is to build a nation that is resilient to disaster risks and capable of managing emergencies effectively (MINEMA, 2018b). Building on this foundation, the NSDRR operationalizes the policy by providing strategic priorities and actionable measures, focusing on strengthening institutional capacities, risk assessments, early warning systems, and multi-sectoral coordination (MINEMA, 2018b). Complementing this core document are various sectoral policies and legal instruments from environment, land use, and climate change to health and infrastructure which contribute to mainstreaming disaster risk reduction across development sectors, promoting risk-sensitive planning, and enhancing adaptive capacity at all levels of governance (MINEMA, 2023).

In addition, the review of documents indicates that there are hazard-specific contingency plans such as for floods and landslides (MINEMA, 2018a), national preparedness and response plans such as construction guidelines for emergency shelters in disaster-prone areas (MININFRA, 2012), and assistance to vulnerable groups as well as risk-sensitive district development plans (MINEMA, 2022). These planning instruments aim to enhance preparedness, response, and recovery efforts, highlighting the list of actions that are needed, and identifying the lead institution, as well as other institutions in charge for each activity. Furthermore, MINEMA web content reports the establishment of risk assessment and information system such as National Risk Atlas of Rwanda, early warning systems, disaster databases, and monitoring tools (MINEMA, 2023).

3.2.2 Institutional arrangements at the national scale

From the existing document review analysis, it can be highlighted that Rwanda's DRM system operates as a multi-stakeholder framework, bringing together government bodies, UN agencies, NGOs, private sector entities, and civil society. At the national level, MINEMA leads the coordination and development of DRRM policy and NSDRR, ensuring integration with national development plans (https://www.minema.gov.rw/disaster-management).

As shown in figure 3, the National Disaster Management Committee (NADIMAC) is the highest disaster management organ. This organ is chaired by the Minister of MINEMA and the Minister of Ministry of Defence (MOD), as the vice-chairperson. Members of NADIMAC include Ministry of Environment (MOE), Ministry of Agriculture and Animal Resources (MINAGRI), Ministry of Health (MoH), Ministry of Finance and Economic Planning (MINECOFIN), Ministry of Infrastructure (MININFRA), Ministry of Local Government

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(MINALOC), Ministry of Foreign Affairs and International Cooperation (MINAFFET), and the Rwanda National Police. NADIMAC is responsible for coordinating all aspects of disaster management, from prevention to recovery. Supporting NADIMAC is the National Disaster Management Technical Committee (NADIMATEC), which includes directors of units from the ministries mentioned above, as well as representatives from the Rwanda Meteorology Agency (Meteo Rwanda). NADIMATEC, chaired by MINEMA's Director in charge of Risk Reduction and Preparedness unit, focuses on assessing disaster risks and providing technical advice to NADIMAC.

To support the implementation of the DRM system frameworks, the National Platform for Disaster Management (NPDM) was established. It serves as a collaborative forum that brings together a wide range of stakeholders, including representatives from NADIMATEC, the private sector, United Nations agencies, various non-governmental organizations (NGOs), and faith-based organizations. The NPDM plays a key role in coordinating and operationalizing disaster risk management efforts by providing essential support to the entire institutional framework (see Fig. 3).

3.2.3 Coordination mechanisms at the sub-national levels

At the sub-national level, the DRM system is primarily coordinated at the district and sector levels, which represent the second and third tiers of Rwanda's administrative structure. At the district level, the District Disaster Management Committee (DIDIMAC), chaired by the District Mayor, brings together a diverse group of stakeholders, including local government representatives, non-governmental organizations (NGOs), and civil society members. Key members include , the Vice Mayor responsible for Social Affairs, the Executive Secretary of the District, the District Officer in Charge of Disaster Management (Secretary), the Director of Development, the Director of Infrastructure, the Director of the District Hospital, the Coordinator of the District Administration Security Support Organ (DASSO), the representative of the Reserve Forces, the Senior Military Commandant (Vice-Chairperson), the District Police Commandant, and the representative from the Rwanda Red Cross at the district level. DIDIMAC maintains direct reporting lines to MINEMA, facilitating effective coordination and communication between national and local entities.

At sector level, further decentralization is achieved through the Sector Disaster Management Committee (SEDIMAC), which mirrors DIDIMAC's composition and engages local community representatives. This structure promotes direct engagement with residents at both sector and cell levels (4^{th} tier), thereby enhancing the effectiveness of disaster management from national policy formulation to local execution (Fig. 3.).

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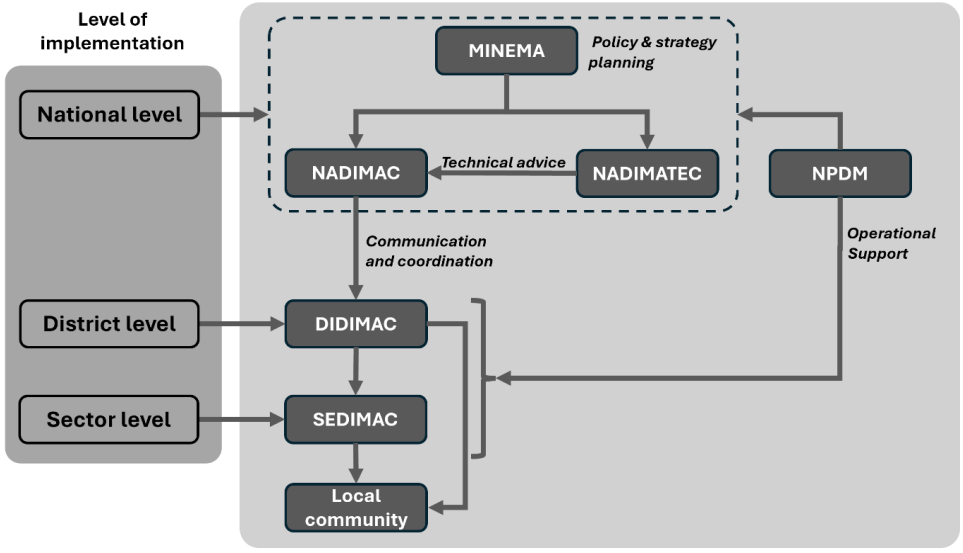

Fig. 3. Institutional arrangements and coordination mechanisms of Rwanda's Disaster Risk Management system; Source: Adapted and modified from MIDIMAR, 2015

3.3 The May Disaster impacts

The information gathered through key informant interviews, confirmed by published post-disaster reports on the May Disaster, allows for the identification and description of the impacts generated by the event. In the **Western Province**, 6 districts were affected (See fig.1.). A total of 8,225 houses were directly impacted, with 4,933 destroyed, while 3,292 others were identified being at risk, which means houses that were likely to experience significant impacts if mitigating measures are not taken or if similar disasters occur in the future. Moreover, in this province, the May Disaster affected 46,430 people including 19,946 males and 21,179 females, as well as 5,305 children under 5 years old, who are counted separately as a vulnerable group in disaster impact assessments (IFRC, 2014; UNICEF, 2016). In the **Northern Province**, a total of 1,919 houses were affected by the disaster, with 507 destroyed and 1,412 left at risk. The affected population comprised 10,795 individuals, including 4,654 males, 4,941 females, and 1,200 children under the age of 5 (Disaster effects situation, 2023). Gakenke District experienced the most significant impact, followed by Burera, Musanze, and Gicumbi DistrictsIn addition, the published post-disaster report mentioned that in the **Southern Province**, there were 237 affected houses, with 32 destroyed, and 205 others left at risk (Disaster effects situation, 2023). The same document stated that 1,338 individuals were affected with 574 males, 611 females, and 153 children under 5 years old.

Furthermore, 8 national and 9 district roads, 13 bridges, 6 water treatment plants, 12 power stations, 2 health posts, 4 health centers, 1 hospital, and approximately 3,116 hectares of croplands were damaged (Disaster effects situation, 2023). Key informants highlighted that the impacts of this disaster were the highest recorded over the past three to five years in Rwanda with significant loss of lives reported across districts, as this disaster made in total 136 dead and 112 injuries (MINEMA, 2023; IFRC, 2023).

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Table 4 Summary of impact of the May Disaster on population by district.

Province	District	Number of Deaths	Number of injuries	Number of Residential houses destroyed	Number of Residential houses critically in high-risk zones to be relocated
Western	Rubavu	28	50	1,621	1,629
	Nyabihu	21	9	193	489
	Ngororero	23	4	197	694
	Karongi	16	12	133	238
	Rutsiro	29	23	223	223
	Nyamasheke	0	0	11	0
Northern	Gakenke	2	3	77	1,211
	Burera	8	3	47	210
	Musanze	6	8	123	0
	Gicumbi	3	0	56	117
Southern	Nyamagabe	2	0	3	205
	Muhanga	0	0	22	0
	Ruhango	0	0	6	0
	Nyanza	0	0	1	0
Total		**136**	**112**	**2,713**	**5,016**

Source: Report on Disaster effects situation (MINEMA,2023; IFRC, 2023).

3.4 The DRM system around the May Disaster event

As reported by the affected individuals in the surveys, 70% of respondents were aware of the heavy rainfall forecast that contributed to the May Disaster, which was exacerbated by significant landslides and flooding. The majority (90%) reported receiving warning messages about the May Disaster via Radio Rwanda, while a smaller portion (10%) indicated they received warnings through local community announcements made by local government authorities during community meetings. However, 60% of respondents felt the warnings were insufficient, particularly regarding the scale and specifics of the risks. They claimed the warnings, issued one to three weeks prior to the event, forecasted heavy rainfall but did not clearly specify the risks of landslides and flooding, which ultimately caused substantial devastation. The study further revealed that only 15% of respondents believed they had received adequate information to take preventive action. Additionally, 40% of respondents from areas not initially identified as high-risk zones reported significant property damage due to flooding and landslides.

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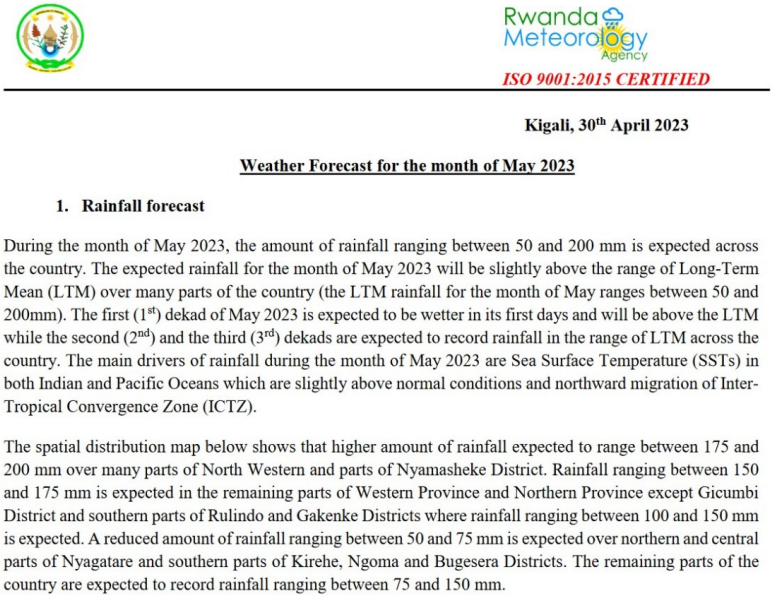
Moreover, the study findings indicate that the recorded floods and landslides resulted from a predicted high intensity rainfall. Meteo Rwanda (2023) shows that the maximum rainfall usually recorded before May 2023 varied between 35.6 mm and 60.9 mm. However, during the period of the May Disaster, it reports a high rainfall intensity of 182.6 mm. It is noteworthy that Meteo Rwanda issued a rainfall forecast message on April 30th (see fig.4).



Rwanda Meteorology Agency
ISO 9001:2015 CERTIFIED

Kigali, 30th April 2023

Weather Forecast for the month of May 2023

1. Rainfall forecast

During the month of May 2023, the amount of rainfall ranging between 50 and 200 mm is expected across the country. The expected rainfall for the month of May 2023 will be slightly above the range of Long-Term Mean (LTM) over many parts of the country (the LTM rainfall for the month of May ranges between 50 and 200mm). The first (1st) dekad of May 2023 is expected to be wetter in its first days and will be above the LTM while the second (2nd) and the third (3rd) dekads are expected to record rainfall in the range of LTM across the country. The main drivers of rainfall during the month of May 2023 are Sea Surface Temperature (SSTs) in both Indian and Pacific Oceans which are slightly above normal conditions and northward migration of Inter-Tropical Convergence Zone (ICTZ).

The spatial distribution map below shows that higher amount of rainfall expected to range between 175 and 200 mm over many parts of North Western and parts of Nyamasheke District. Rainfall ranging between 150 and 175 mm is expected in the remaining parts of Western Province and Northern Province except Gicumbi District and southern parts of Rulindo and Gakenke Districts where rainfall ranging between 100 and 150 mm is expected. A reduced amount of rainfall ranging between 50 and 75 mm is expected over northern and central parts of Nyagatare and southern parts of Kirehe, Ngoma and Bugesera Districts. The remaining parts of the country are expected to record rainfall ranging between 75 and 150 mm.

Fig. 4. Heavy Rainfall Alert Message; Source: ©Meteo Rwanda, 2023

This high intensity rainfall caused the Mukungwa and Sebeya rivers to overflow, resulting in flash floods in the volcanic mountains (MINEMA, 2023; IFRC, 2023). These findings suggest that, despite the efforts of Meteo Rwanda in issuing the warnings and MINEMA in disseminating them, there were significant gaps in the early warning system. The lack of clarity regarding the specific risks, such as landslides and flooding, and the insufficiency of information about the scale of the disaster, contributed to inadequate preparedness, particularly in areas not initially identified as high-risk zones.

Field observations indicated that several factors significantly exacerbated the impacts of the May Disaster. These include unplanned settlements and structurally weak houses lacking essential features such as rainwater harvesting systems. Inappropriate farming practices in high-risk areas, coupled with inadequate slope stabilization measures, such as limited vegetation cover, contributed to increased landslide impact on hillsides. Similarly, insufficient riverbank protection and irregular maintenance of stormwater drainage systems, particularly along roadsides, intensified flooding (see Figure 2a and 2b).

With regard to disaster response, key informants emphasized that all institutions from community to national levels of the DRM system collaborated closely to address the impacts of the May Disaster. However, due to the magnitude of the disaster, most response measures

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were coordinated at the national level, with close collaboration of SEDIMAC and DIDIMAC at the sub-national levels. Key informants reported that the majority of response efforts (approximately 90%) focused on rescue operations, evacuation, and the setup of emergency shelters for vulnerable groups, including children under five, the elderly, pregnant women, and single women. Following these efforts, emergency medical assistance constituted around 10% of the overall response actions. As reported also by the key informants, the government of Rwanda organized funeral services for the victims, with each affected household receiving financial aid of Rwf 100,000 (approximately 100 USDs by then).

In addition to that, affected individuals specified that they were provided with essential assistance like food, clothing, hygiene items, and blankets, with the support of NGOs led by the IFCR Rwandan chapter. The IFRC published post-disaster report indicated that it distributed school kits to 1,600 children to facilitate the children's ability to resume their education.

Moreover, key informants indicated that evacuees were initially accommodated in schools, facilities of faith-based organizations, and government buildings. In response to the scale of displacement, 95 temporary camps were established across the affected districts through coordinated humanitarian efforts. These camps housed an average of approximately 800 individuals each, with an estimated total of around 8,000 people in need of shelter. Individuals residing in high-risk areas were also encouraged to relocate to these camps for their safety. While not all displaced individuals were accommodated in formal camps, many sought refuge in temporary structures such as community centres, or with host families. However, as highlighted by the affected individuals who lived in the camps, these arrangements, while providing necessary safety and support, led to feelings of discomfort among residents who had to adjust to limited personal space and a lack of autonomy. There was an expression of contentment with their living conditions, particularly in terms of the lack of privacy and freedom due to the communal living arrangements in a shared hall. Moreover, the cramped living conditions contributed to challenges such as noise, overcrowding, and limited opportunities for personal interaction, all of which negatively impacted the overall well-being and mental health of the affected individuals, according to their statements. Key informants noted that many had been living under these conditions for over a month.

The recovery measures, as identified through key informant interviews and field observations, involved multiple stakeholders. Local government authorities, representatives of private sectors, and local communities played a primary role in clearing debris from affected areas, ensuring accessibility and safety. Infrastructure rehabilitation was primarily managed by government agencies and contracted construction companies, while community volunteers contributed to minor repairs of residential structures.

These recovery efforts reflect the implementation of Policy Objective 14, particularly in strengthening multi-stakeholder coordination, and promoting socio-economic recovery. They also align with the policy's emphasis on building back better by addressing infrastructure, thus enhancing community resilience.

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According to MINEMA web content, an official relief channel was established to support recovery efforts following the disaster event. Through this mechanism, approximately 613 million Rwandan Francs (≈ 600,000 USD by then) was received via bank transfers, while 35 million Rwandan Francs (≈ 35,000 USD by then) was contributed through mobile money transactions. These funds were sourced from individuals, private companies, local NGOs, and the Rwandan diaspora. In addition to financial contributions, various forms of in-kind assistance including food, clothing, and building materials, were provided by the same donors. Furthermore, key informants highlighted that the government, through the National Land Authority (NLA), planned to construct 2,763 housing units in designated safe areas to relocate communities from high-risk zones.

These findings address the gap in the policy objective 14 and NSDRR, particularly the actions aimed at increasing contingency stock, supporting socio-economic recovery, and facilitating sustainable resettlement through safe housing construction. The coordinated provision of in-kind assistance and planned relocation efforts also support the policy's goal of building back better and enhancing long-term resilience in disaster-affected communities.

3.5 Insights from the May Disaster: Strengthening Future Preparedness and Response

The analysis identified key challenges encountered during the event, including ineffective early warning systems which were reported by 50% and resource shortages which were reported by 28.57% of respondents. Inconsistent coordination between local authorities and community was reported by 21.43%. Additionally, the study findings underscored the importance of enhancing early warning systems, identified by 29% of respondents, relocating people from hazard-prone areas to safer locations (23%), and strengthening infrastructure resilience (24%). Another 24% of respondents emphasized the need for regular community meetings and the supervision of master plan compliance.

Table 5 Measures for strengthening future preparedness and response

Measures for strengthening future preparedness and response (N=156)	**Frequency**	**%**
Enhancing early warning systems	45	29
Relocating people from hazard-prone areas to safer locations	36	23
Strengthening infrastructure resilience	37	24
Regular community meetings and supervision of master plan compliance	37	24

Other critical measures mentioned included allocating dedicated budgets for DRR, expanding psychological support services for affected populations, and incorporating psychological and mental health support into recovery plans.

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4. Discussion

Rwanda's **DRM system** is notable by its comprehensive framework, which effectively integrates policy, institutional structures, and operational tools to reduce disaster risks and enhance resilience. The system is multi-actor, with a well-defined institutional arrangement that delineates specific roles and responsibilities at the national, sub-national (district, sector), and community levels. This structure has proven effective in coordinating disaster response efforts, as evidenced during the May Disaster, where the rapid mobilization of emergency services and the coordinated deployment of relief aid were achieved. Multiple stakeholders, including government agencies, private sector, international and local NGOs, and community volunteers, played active roles in the response. In comparison to the neighbouring countries, Rwanda's DRM system has a well-structured framework and clearly defined roles across all levels of governance (Michellier et al., 2016). However, challenges remain, particularly in the effective implementation of disaster response measures at the local level. Limited budget, insufficient emergency resources, inconsistent coordination between local authorities and community, inefficient resource allocation, and gaps in information dissemination all contribute to delays in decision-making during disaster responses (Mind'je et al., 2020; Nahayo et al., 2019).

The impacts of the May Disaster in Rwanda were exacerbated by the **compound nature of the event**, which involved intense rainfall triggering both floods and landslides. Such compound disasters are inherently more destructive as they expose people and infrastructure in multiple systems simultaneously (Deijns et al., 2024; Sulfikkar Ahamed et al., 2023; van den Hurk et al., 2023). Similar catastrophic events occurred simultaneously in neighbouring countries, underscoring that disasters do not stop at borders (Hagenlocher et al., 2023; Yamori & Goltz, 2021). In the DRC, the floods in the villages of Bushushu and Nyamukubi in South Kivu (along the shore of lake Kivu, mirroring Rwanda's Western Province) caused up to more than 400 deaths, over 2,500 missing, almost 200 injured, 1,200 houses destroyed, 3,000 homes affected, and other economically significant infrastructure damaged (Maki Mateso et al., 2023; Leaity et al., 2023). In the northern part of the North Kivu province, two separate landslides caused significant casualties, including ten deaths in Lubero and at least six in the Songambele mine, with dozens of miners reported missing. In the south-western Uganda, the period between April 24th and May 3rd, 23 fatalities were recorded, and 16 individuals were injured due to landslides and floods, with widespread damage to homes, as it was reported on May 17th by the Uganda's National Environment Management Authority (European Commission, 2024). In 2020, Kenya experienced a comparable disaster, characterized by intense flooding, significant loss of life, widespread displacement, and destruction of infrastructure (Bwambale et al., 2020; Kalantari et al., 2018; Njogu, 2021; IFRC, 2021). The widespread devastation across the region calls for urgent, coordinated action to strengthen disaster risk management efforts both nationally and regionally. It emphasizes the importance of fostering cross-border collaboration, including the exchange of best practices and joint initiatives, to enhance resilience and effectively manage shared risks. Additionally, it underscores the critical need for integrated risk assessments that simultaneously address multiple hazards (Maki Mateso et al., 2023).

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The **high population density and settlements** in disaster-prone areas, particularly in the Western Province of Rwanda, further exacerbated the impacts, suggesting a need for stricter land-use planning and enforcement (Benineza et al., 2019; Kuradusenge et al., 2021; Zimmerman, 2012). In the affected areas, population densities range from 441 to 1,614 inhabitants per square kilometer across districts. Rubavu and Musanze, in particular, exhibit higher densities, 1,614 and 1,157 inhabitants per square kilometer, respectively, largely due to their roles as secondary urban centers supporting Kigali (NISR, 2022). Given the population's heavy reliance on agriculture, the high population density places considerable pressure on land resources. This pressure contributes to the expansion of cultivation into ecologically sensitive areas, such as steep slopes and valleys, and accelerates deforestation (REMA, 2021). Furthermore, in the region, human activities, particularly the construction of houses, urbanization, and road development in disaster-prone areas have exacerbated the impacts of disasters (Depicker et al., 2021; Maki Mateso et al., 2023).

Despite the existence of the **early warning systems**, its effectiveness during the May Disaster was limited. Warning messages were not alarmist enough to the occurrence of landslides and floods of the magnitude that ultimately transpired. Additionally, the warning messages lacked specificity regarding the scale and severity of the expected landslides and floods, which limited the community's ability to fully understand the risk and take appropriate preparedness actions. Rwanda should learn from Uganda and Kenya, where DRM systems emphasize early warning dissemination and community engagement (Maes et al., 2018; Masaba et al., 2017). In both countries, local communities play a key role in disaster preparedness and response, often through volunteer networks, local committees, and grassroots initiatives. Additionally, their early warning systems integrate meteorological forecasts, mobile alerts, and community-based risk communication to enhance preparedness. Moreover, Rwanda could benefit from Kenya's integration of technology-driven solutions, such as mobile-based warning alerts, to enhance its preparedness and response mechanisms (Nyandiko, 2020). Furthermore, lessons can be drawn from countries like Mozambique, where localized communication channels and community-based disaster preparedness programs have improved early warning effectiveness (Hakaloba et al., 2016; Johnson et al., 2014; Perera et al., 2020). While the extent and efficiency of these mechanisms may vary, the emphasis on proactive risk reduction and local participation appear to be crucial. Strengthening anticipatory action to better address the needs of vulnerable populations during displacement (policy objective 13), enhancing disaster preparedness and ensuring effective, and dignified response (policy objective 14) are among the key priorities outlined in DRRM policy. By addressing these gaps, Rwanda would enhance the reach and impact of its early warning systems, particularly for rural and vulnerable populations (Mugisha et al., 2020; Nahayo et al., 2017).

One of the **immediate responses** to the May Disaster included rehousing those whom their residential houses were destroyed and relocating those whom their houses were not destroyed but they were settled in the affected areas. All of these people were temporary rehoused in faith-based organization facilities, government buildings, and newly set up temporary camps. While these efforts were critical, they also exposed significant challenges. Many relocated people were placed in areas with insufficient essential services such as clean water, sanitation,

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and food, leading to secondary risks. This issue is not unique to Rwanda; similar challenges have been observed in Haiti following the 2010 earthquake, where poorly planned relocation efforts created long-term vulnerabilities (Jourdan et al., 2024). Additionally, the lack of land for cultivation for the relocated individuals, further exacerbated their vulnerability, mirroring the challenges faced in the DRC following the same event (Maki Mateso et al., 2023).

Furthermore, the areas where people were relocated may not have been fully assessed for flood and landslide risks, as there were no maps to indicate these vulnerabilities. Similar to the situation in the DRC, this lack of risk mapping increases the potential for future disasters. Scientific work aimed at producing detailed maps of high-risk zones could significantly improve disaster response efforts by guiding safer relocation decisions and enhancing long-term disaster management, ultimately saving lives in a more sustainable manner (Maki Mateso et al., 2023). In the case of Rwanda that is a hilly and mountainous country, detailed maps of suitable sites for relocation of households affected by disasters at cell level (4^{th} tier in the present administration structure) are needed.

To address these challenges, Rwanda must integrate DRR into its broader development planning, ensuring that adequate resources are set aside for prevention and preparedness efforts. This includes the need for the Government of Rwanda to allocate a budget for DRR initiatives, which is currently lacking. Rwanda's approach to DRM currently prioritizes response and recovery efforts rather than proactive DRR. This approach is largely due to budgetary constraints and competing national priorities, which result in limited allocation of funds for DRR at both national and district levels. As one key interviewee noted, preventive measures and disaster planning are often funded through projects by international NGOs and other external stakeholders, rather than through domestic budgeting. The DRRM policy outlines a financial framework for DRM activities, indicating a required financial provision of approximately $40.26 million (RWF 40.26 billion) over seven years, with an average annual allocation of $5.75 million (RWF 5.75 billion) (MINEMA, 2023). In addition, enhanced coordination among institutions and greater involvement of community organizations in response planning could further improve the effectiveness of disaster responses (Abenir et al., 2022; Bwambale et al., 2020; Dewa et al., 2021). This need became evident during the May Disaster, where gaps in institutional coordination and limited engagement of community organizations were reported as key challenges in the response efforts.

The May Disaster provides important lessons for future disaster preparedness in Rwanda. Firstly, early warning systems must be enhanced to ensure timely, localized, and actionable communication, particularly in high-risk areas. Secondly, risk management efforts should account for the compounding nature of hazards, as these events tend to have far greater impacts than isolated hazards. In this regard, risk assessment should be emphasized as a crucial recommendation for scientists, in collaboration with local communities and decision-makers, to ensure informed and effective interventions. Thirdly, relocation efforts must prioritize long-term sustainability by addressing both immediate needs and future risks.

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5. Conclusion

The present study evaluates the performance of the Rwanda's DRM system using the disaster event that occurred in Rwanda during the night of 2nd and 3rd, May 2023, as a case study. Data were collected from various published documents, semi- structed interviews key with informants and affected individuals, alongside with the field observations. The results demonstrate the presence and operational aspects of Rwanda's DRM system, including its policy and legal frameworks, planning tools, and institutional structures. For the May Disaster event, the study reveals collaboration between the institutions, which facilitated the coordination of the disaster response. However, it highlights inconsistent coordination between local authorities and community, inefficient resource allocation, and gaps in information dissemination at local level. In addition to that, inadequate early warning messages, as it was reported by the respondents (50%) and resource shortages by 28.57% significantly exacerbated the disaster impacts.

Despite significant efforts in disaster response and recovery such as relocating people from disaster-prone areas to more safe sites, clearing debris, and repairing infrastructure, the study findings show that there was a need for Rwanda's DRM system to learn from other countries that face the same disasters, in terms of disaster risk reduction, specifically in improving early warning systems and other disaster process. To enhance disaster risk management, the study recommends (i) strengthening locally-based early warning systems, led by the Meteo Rwanda and MINEMA; (ii) ensuring adequate budget allocation for DRM activities, managed by government finance institutions; (iii) enhancing community resilience through context-specific interventions let by SEDIMAC and DIDIMAC; (iv) promoting active community engagement in DRM implementation, coordinated by local authorities, civil society organizations, and community-based structures; (v) supporting in-depth research on hazard causes, risk-prone areas, and context-appropriate adaptation strategies, carried out by academic institutions, research centres, and technical government bodies such as NADIMAC; and (vi) facilitating knowledge exchange and adoption of best practices from countries with similar disaster profiles, led by national NPDRM in collaboration with international organizations and regional networks.

Data availability

The data supporting the findings of this study are available upon reasonable request from the corresponding author. The datasets generated and analyzed during this study are not publicly available due to privacy concerns but can be accessed through specific requests for academic or research purposes.

Author contribution

All authors contributed substantially to the development of this manuscript. Each author was involved in multiple stages of the research process, including the design, data collection, analysis, and writing.

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C.I.: Contributed to the conceptualization and methodology of the study. Led the data analysis and interpretation of results. Drafted the manuscript's introduction, discussion, and conclusion.

S. H.: Assisted in the methodology design and reviewed the manuscript drafts.

E.T.: Provided critical revisions during manuscript writing.

F. DL.: Reviewed and edited manuscript sections, particularly the methodology and results.

C.M.: Assisted in the methodology design, manuscript revision, particularly in reviewing literature, and provided insights into the discussion, conclusion sections and final manuscript review.

Interactive computing environment

In this study, we have used an Interactive Computing Environment (ICE) to enhance reproducibility and transparency by integrating and adapting publicly available data and visualizations from previous research. Although we did not generate original datasets or graphs, the adapted data and visualizations are embedded within the ICE, allowing readers to interact with and explore them. The code underlying the analysis is fully reproducible, enabling readers to modify parameters and recreate the results. All external sources are properly credited, ensuring that readers can engage with the data and visualizations in the context of our study.

Competing interests

The authors declare that they have no conflict of interest.

Acknowledgements

The authors express gratitude to MINEMA staff, Disaster Management officers at district level, residents for their time and information provided during the conduct of this study as well as. Authors also acknowledge the *Académie de Recherche et d'Enseignement Supérieur* (ARES)/PRD for funding the project "Landslide and Flood Hazards and Vulnerability in Northwestern Rwanda" (LAFHAZAV) (2020-2025), ID: 2022008859, in collaboration with the University of Liège (ULiège), the Royal Museum for Central Africa (RMCA), the University of Namur (UNamur), the University of Rwanda (UR), and the *Institut d'Enseignement Supérieur de Ruhengeri* (INES-Ruhengeri). Thanks are extended to Dr Maki Mateso Jean-Claude and his team for sharing their valuable insights, which contributed significantly to this research. Additionally, we acknowledge the use of an AI tool to assist in reviewing and refining the language of this article.

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