

Landslide hazard and risk management in Rwanda: institutional challenges and the *PanAfGeo+* framework

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Zagrożenie osuwiskami i zarządzanie ryzykiem w Rwandzie: wyzwania instytucjonalne oraz zakres współpracy w ramach projektu *PanAfGeo+*. Prz. Geol., 74: 181–186; doi: 10.7306/2026.15

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Abstract. Rwanda is highly susceptible to landslides due to its steep and dissected terrain, complex geological setting, intense tropical rainfall, and rapid land-use change. Landslides represent one of the most frequent and damaging geohazards in the country, causing loss of life, damage to infrastructure, and degradation of land and water resources, particularly in the Northern and Western provinces. Existing studies and national initiatives have provided valuable insights into landslide processes and spatial patterns; however, landslide information remains fragmented across institutions, datasets, and methodologies, limiting its effective use for hazard assessment, risk reduction, and land-use planning. Within this context, Rwanda's participation in the EU PanAfGeo+ program has a strategic importance for strengthening national capacity in landslide risk management. PanAfGeo+ supports the harmonization of landslide inventory development, susceptibility and hazard assessment, and monitoring and early warning approaches through capacity building and international collaboration. Selected pilot areas near Bugarama, Ndaba, Gatonde and Kazirankara are identified as priority sites for methodological testing and scaling up at the national level. The integration of these approaches is expected to enhance evidence-based decision-making and improve resilience to landslide hazards under current and future climatic conditions.

Abstract. Rwanda jest krajem szczególnie narażonym na osunięcia ziemi ze względu na duże deniwelacje terenu, złożone warunki geologiczne, intensywne opady tropikalne oraz gwałtowne zmiany w użytkowaniu gruntów. Osuwiska stanowią jedno z najczęstszych i najbardziej niszczycielskich zagrożeń geologicznych w kraju, powodując ofiary śmiertelne, zniszczenia infrastruktury oraz degradację zasobów gruntowych i wodnych, szczególnie w prowincjach północnych i zachodnich. Dotychczasowe badania i inicjatywy krajowe dostarczyły cennych informacji na temat procesów osuwiskowych i ich rozkładu przestrzennego; jednakże informacje dotyczące osuwisk pozostają rozproszone między różnymi instytucjami, zbiorami danych i metodologiami, co ogranicza ich skuteczne wykorzystanie do oceny zagrożeń, ograniczania ryzyka oraz planowania zagospodarowania przestrzennego. W tym kontekście udział Rwandy

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w projekcie PanAfGeo+ ma strategiczne znaczenie dla wzmocnienia krajowego potencjału w zakresie zarządzania ryzykiem osuwiskowym. Program PanAfGeo+ wspiera harmonizację działań związanych z tworzeniem wykazów osuwisk, oceną podatności i zagrożeń oraz monitorowaniem i systemami wczesnego ostrzegania poprzez budowanie potencjału i współpracę międzynarodową. Wybrane obszary pilotażowe w pobliżu Bugaramy, Ndaby, Gatonde i Kazirankary zostały uznane za priorytetowe miejsca do testowania metodologii i wdrażania jej na skalę krajową. Oczekuje się, że integracja tych podejść usprawni podejmowanie decyzji opartych na dowodach oraz poprawi odporność na zagrożenia osuwiskowe w obecnych i przyszłych warunkach klimatycznych.

Keywords: areas at threat from mass earth movements, Rwanda, PanAfGeo+ Project, international cooperation

Słowa kluczowe: obszary zagrożone masowymi ruchami ziemi, Rwanda, projekt PanAfGeo+, współpraca międzynarodowa

Rwanda covers an area of approximately 26,000 km² and has a population exceeding 14 million, with an annual growth rate of about 2.3%. This makes Rwanda the most densely populated country in continental Africa, with an average population density of approximately 570 inhabitants per km². The country is characterized by hilly and mountainous terrain of the Karagwe-Ankole Orogenic Belt, commonly referred to as the “Land of Thousand Hills”, and lies within the western branch of the East African Rift System. This geological and geomorphological context, combined with intense tropical rainfall and rapid land-use change, makes Rwanda highly susceptible to climate-related hazards.

Among these hazards, landslides are one of the most frequent and destructive phenomena in Rwanda, causing

loss of life, damage to infrastructure, and degradation of land and water resources. The landslides are triggered by a combination of factors, including steep topography, deeply weathered rocks, intense and prolonged tropical rainfall, deforestation, and intensive agricultural activities on unstable slopes. As population pressure continues to increase, human settlement and land use have progressively expanded into landslide-prone areas, further exacerbating the level of risk.

Landslides in Rwanda have been investigated by several international and national research teams over the past decades. Bizimana and Sönmez (2015) reported that between 2000 and 2010, rainfall-induced landslides caused at least 108 fatalities and displaced approximately 10,000 people (Fig. 1A), particularly in the Northern and Western provin-



Fig. 1. A – ruins of a traditional mud brick house damaged by the Rutabo landslide (Gakenke District); B – landslide on the road, blocking the roadway (Karongi District); C – erosion of agricultural soil on a cultivated slope (Ngororero District); D – Ndaba-Musogoro sub-catchment affected by the Ndaba landslide (Karongi District)

Ryc. 1. A – ruiny tradycyjnego domu z cegły mułowej zniszczonego przez osuwisko w Rutabo (okręg Gakenke); B – osuwisko na drodze blokujące przejazd (okręg Karongi); C – erozja gleby rolniczej na uprawianym zboczu (okręg Ngororero); D – zlewnia Ndaba-Musogoro dotknięta skutkami osuwiska w Ndaba (okręg Karongi)

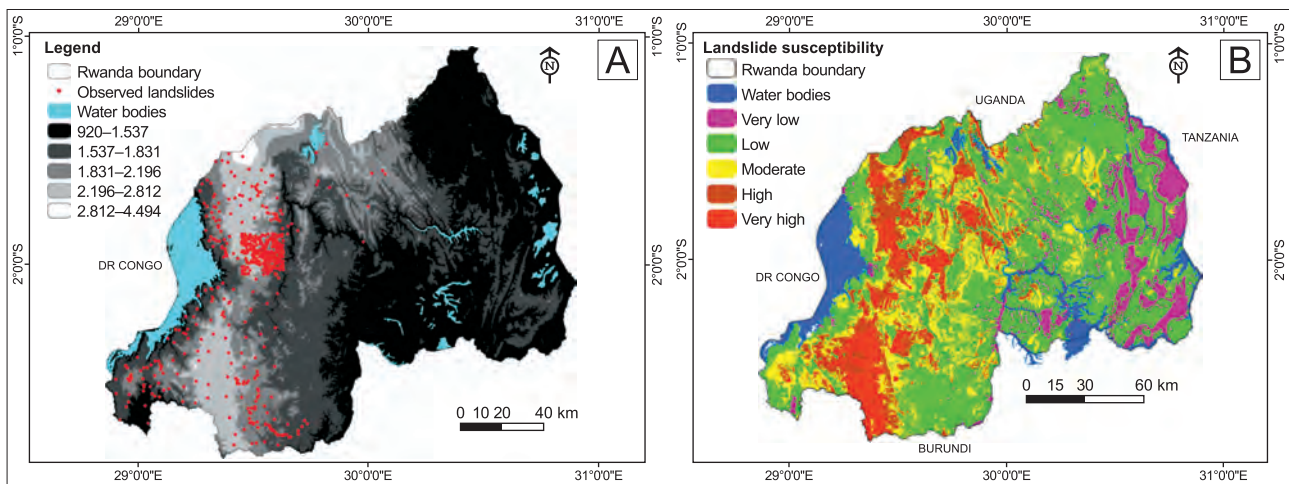


Fig. 2. A – recorded landslides; B – landslide susceptibility zones in Rwanda (MIDIMAR, 2015)

Ryc. 2. A – zarejestrowane osuwiska; B – obszary zagrożone osuwiskami w Rwandzie (MIDIMAR, 2015)

ces. During this period, an estimated 110 million m³ of soil and rock material was mobilized and deposited in rivers, streams, and along both national and local road networks (Fig. 1B). In many cases, landslides obstructed river channels, resulting in the loss of fertile agricultural soil (Fig. 1C) and contamination of water supply systems (Fig. 1D).

The spatial distribution and frequency of landslides in Rwanda (Fig. 2) are closely linked to the country's geological and geomorphological setting. The bedrock geology is dominated by Precambrian basement formations of the Karagwe-Ankole Orogenic Belt, including schists, quartzites, phyllites and granites, as well as volcanic rocks in the Virunga region, north-western Rwanda. These lithological units are commonly deeply weathered, leading to the development of thick regolith (up to 20–60 m) and clay-rich soils with low shear strength. When saturated during periods of intense rainfall, these materials are highly susceptible to failure.

The most common landslide processes observed in Rwanda include shallow soil slides, debris flows, and localized rockfalls, following the classification given in Highland and Bobrowsky (2008), typically occurring on steep slopes where surface runoff and subsurface groundwater converge. The presence of low-permeability clay layers further contributes to slope instability by impeding drainage, increasing pore-water pressure, and promoting translational sliding along weak horizons. Slopes with northwest- and west-facing aspects have been identified as particularly vulnerable, which is consistent with spatial patterns of higher rainfall intensity. A notable cluster of shallow landslides recorded in May 2018 (Byiringiro *et al.*, 2024) further illustrates the recurrent and spatially concentrated nature of landslide activity in the country. More recent landslide disastrous events occurred on 2–3 May 2023 affecting Ngororero, Rubavu, Nyabihu and Karongi in Rwanda's Western Province, and resulting in 95 fatalities (Nwazelibe *et al.*, 2023).

Landslide susceptibility assessment in Rwanda has progressively evolved from largely inventory-based mapping to more advanced GIS-supported and quantitative approaches. In the early 2010s, national-scale maps of high-risk zones for floods and landslides were produced, delineating areas of elevated hazard primarily in the north-western part of the country, including Burera, Musanze,

Nyabihu, Ngororero, Rubavu, Rulindo and adjacent districts (Nsengiyumva, 2012). These early efforts were mainly cartographic and descriptive in nature, relying on topography, rainfall patterns, and historical event statistics, but lacked detailed engineering-geological and geophysical analyses. A subsequent milestone was the *National Risk Atlas of Rwanda* (MIDIMAR, 2015), which presented a national landslide susceptibility map based on multiple conditioning factors such as relief, precipitation, soils, and land use, identifying zones of very high to high susceptibility across the western highlands, parts of the Northern and Southern provinces, as well as localized areas within the Eastern Province and Kigali. Further methodological advancement was achieved through the application of Spatial Multi-Criteria Evaluation within a GIS framework (SMCE-GIS), resulting in a country-wide landslide susceptibility map that confirmed elevated risk levels in the western, southern and northern regions of Rwanda, while explicitly recommending a transition toward more quantitative approaches (Nsengiyumva *et al.*, 2018). Most recently, Panelli *et al.* (2024) published an updated national landslide susceptibility map based on higher-resolution datasets and modern GIS modelling techniques, substantially improving the representation of terrain controls on landslide occurrence and highlighting the continuing need for harmonized national datasets and standardized methodologies.

From an institutional perspective, the mandate for monitoring geohazards and advising the Government of Rwanda on geological risks is defined by Presidential Law No. 028/01 of 18/05/2023, which assigns these responsibilities to the Rwanda Mines, Petroleum and Gas Board (RMB). In line with this mandate, RMB conducts geological and geophysical investigations to identify landslide-prone areas, assess triggering mechanisms, and support risk mitigation strategies. In recent years, RMB has undertaken detailed investigations of the Ndaba landslide and adjacent slopes, assessed landslide impacts in Gakenke District, and carried out integrated geological and geophysical surveys at the Bugarama and Kazirankara landslide sites.

Despite the increasing societal and economic impacts of landslides in Rwanda, information related to landslide occurrence, mechanisms and impacts remains fragmented across scientific publications, technical reports, and institutional databases. National institutions, including RMB, the

Ministry in Charge of Emergency Management (MINEMA), and the Rwanda Space Agency, have developed landslide inventories to support their respective mandates. However, these initiatives are largely sector-specific and insufficiently coordinated. Rwanda is currently developing a national policy framework for landslide risk management that aims to systematically integrate landslide inventory mapping, hazard and risk assessment, monitoring and early warning systems, land-use planning, and mitigation measures. Such an integrated approach is essential to support evidence-based decision-making and enhance resilience to landslide hazards under current and future climatic conditions. In this context, Rwanda's engagement in the *PanAfGeo+* program provides an important framework for strengthening institutional coordination, harmonizing methodologies, and promoting standardized approaches to landslide inventory development, hazard and risk assessment, and monitoring.

***PanAfGeo+* FRAMEWORK AND RELEVANCE TO RWANDA**

PanAfGeo+ is the 3rd phase of the European Union's flagship Pan-African Geology and Geoscience Program, running from 2025 to 2029 and building on the achievements of *PanAfGeo-1* and *PanAfGeo-2*. The program is jointly implemented by EuroGeoSurveys (EGS) and the Organization of African Geological Surveys (OAGS), with the overarching objective of strengthening geoscientific capacity within African national geological institutions. *PanAfGeo+* focuses on applied geoscience themes that are directly relevant to sustainable development, disaster risk reduction, climate resilience, and responsible management of geo-resources.

In the context of Rwanda, where landslides constitute a persistent and growing threat to human lives, infrastructure and livelihoods, *PanAfGeo+* provides a timely and structured framework for addressing critical gaps in landslide risk management. As outlined above, landslide-related data, expertise, and operational responsibilities in Rwanda are currently distributed across multiple institutions, with limited harmonization of methodologies and standards. Through its capacity-building and knowledge-exchange activities,

PanAfGeo+ supports the harmonization of approaches to landslide inventory mapping, susceptibility and risk assessment, monitoring techniques, and the application of geoscientific data for policy and planning.

The participation in *PanAfGeo+* offers Rwanda an opportunity to strengthen institutional coordination between RMB and its national and international partners including the Polish Geological Institute – National Research Institute (PGI-NRI) and Geological Survey of Slovenia (GeoZS). By fostering collaboration between African geological surveys and European counterparts, the program enhances the capacity of national institutions to generate reliable, comparable and policy-relevant geoscientific information. This, in turn, supports the integration of geological and geomorphological data into national disaster risk reduction strategies and promotes evidence-based decision-making aimed at reducing landslide impacts under current and projected climate conditions.

Within the framework of collaboration between RMB and PGI-NRI and GeoZS, Rwanda's participation in *PanAfGeo+* is structured around thematic areas that directly address national priorities related to geohazard monitoring, landslide assessment, and disaster risk reduction. These thematic areas (Fig. 3) are designed to strengthen institutional capacity, standardize methodologies, and enhance the effective use of geoscientific information in planning and decision-making processes.

The first thematic area focuses on landslide inventory development and management. Training activities emphasize standardized field mapping techniques, interpretation of remote sensing data, and systematic documentation of landslide characteristics using relational database structures consistent with international best practices. This approach supports the development of a consistent, updatable national landslide inventory that serves as a foundation for subsequent hazard and risk assessments.

The second thematic area addresses landslide susceptibility, hazard, and risk assessment. RMB staff are trained in the integrated use of geomorphological, geological, hydrological, land-use and climatic data to identify landslide-prone areas. Particular attention is given to the role of lithology, slope geometry, land-use practices, and rainfall

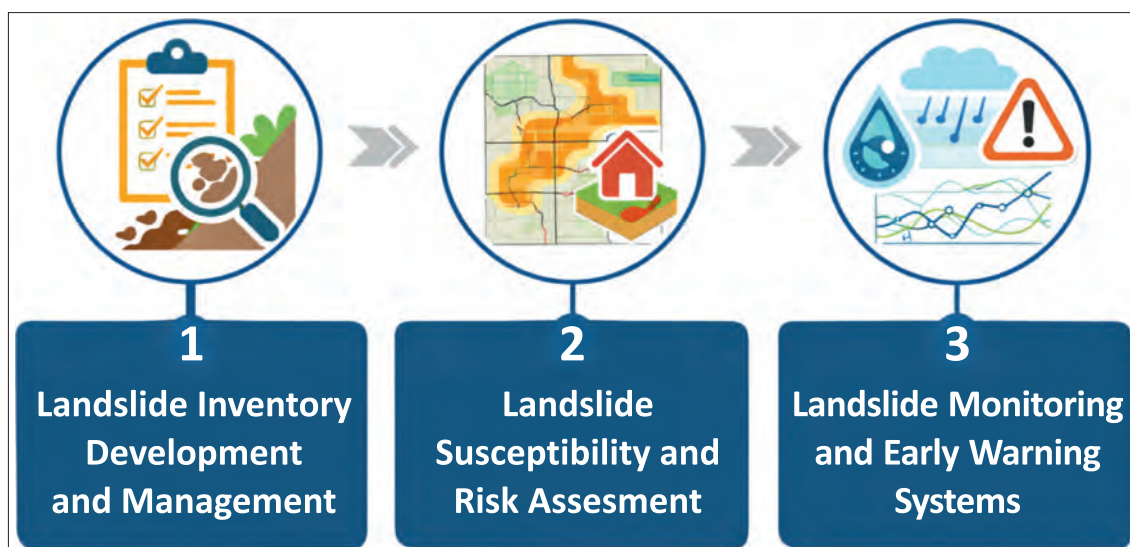


Fig. 3. Thematic areas within the framework of collaboration between RMB and PGI-NRI

Ryc. 3. Obszary tematyczne w ramach współpracy pomiędzy RMB a PIB-PIB

thresholds in controlling landslide occurrence, enabling the production of scientifically robust and policy-relevant susceptibility and hazard maps.

The development of landslide monitoring and early warning systems constitutes a third key thematic area. Capacity-building activities introduce low-cost, scalable monitoring approaches suitable for the Rwandan context, including rainfall-based threshold analysis, systematic ground observations, and selected instrumental techniques. These efforts aim to support national early warning, emergency preparedness, and rapid response mechanisms, particularly in high-risk regions such as the Northern and Western provinces.

PILOT LANDSLIDE INVENTORY WITHIN *PanAfGeo+* OBJECTIVES

A core objective of *PanAfGeo+* is to strengthen national capacities for systematic landslide assessment and risk reduction through the development of standardized landslide inventories. In Rwanda, the proposed national landslide inventory will build on established European expe-

riences (Herrera *et al.*, 2017) that emphasize consistency, interoperability, and long-term usability of landslide data. Such characteristics are essential for both scientific analysis and effective policy support.

In particular, the design of the Rwandan landslide inventory will draw on the principles of the Polish Landslide Counteracting System (LCS), which was developed as a relational database composed of two interconnected schemas: one dedicated to spatial data and another to descriptive and analytical attributes (Mrozek *et al.*, 2014). This structure enables systematic storage, updating and querying of landslide information, including location, type of movement, triggering factors, material properties, activity state, and associated impacts.

Adoption of a similar database structure, supported by expertise from PGI-NRI, will facilitate the integration of multi-source data in Rwanda, including field surveys, remote sensing products, historical records, and technical reports generated by RMB staff. A standardized national landslide inventory will support the production of reliable landslide susceptibility and hazard maps, enable temporal analyses of landslide activity, and improve information sharing among

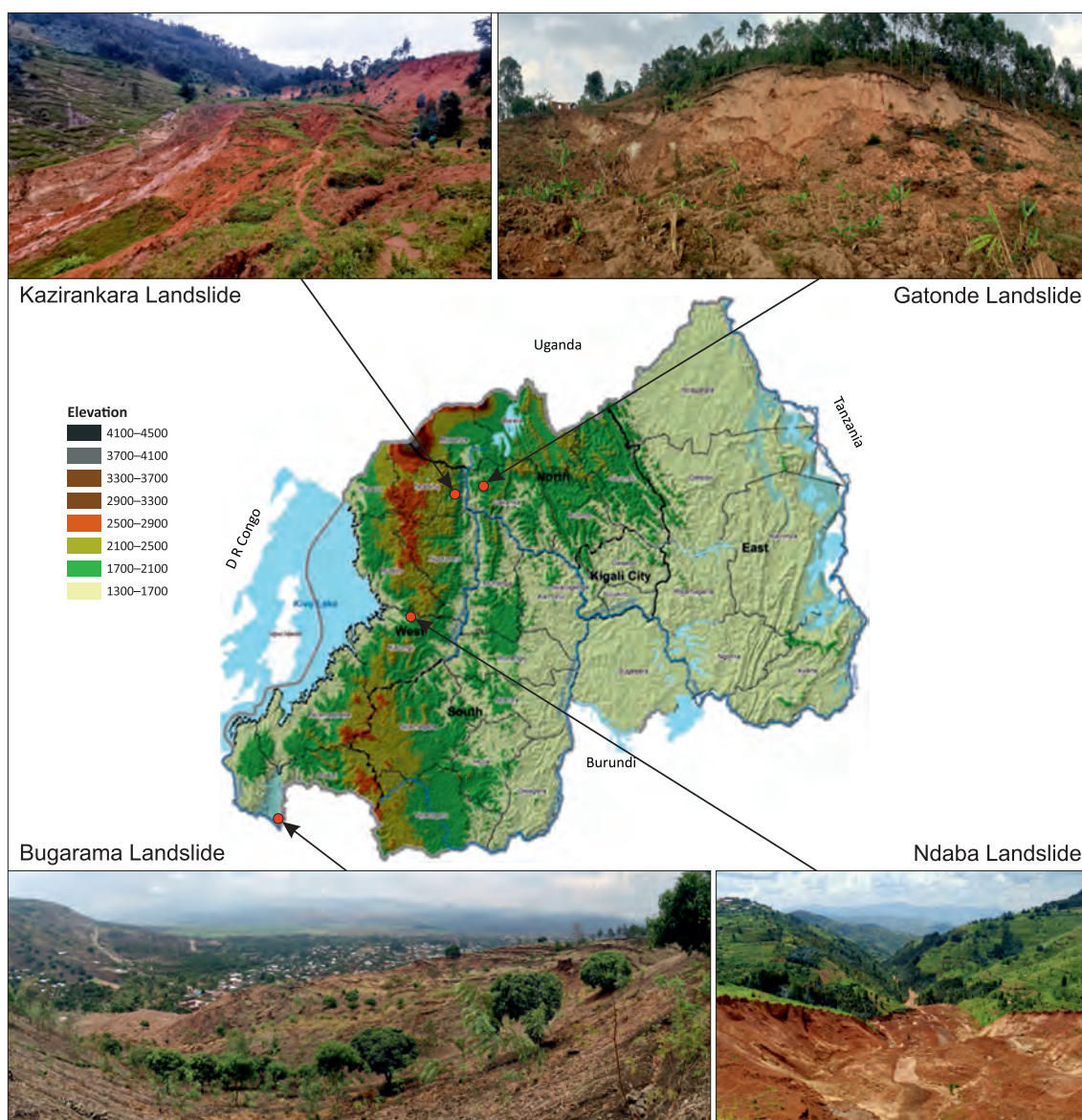


Fig. 4. Location of four landslide sites identified as the pilots

Ryc. 4. Lokalizacja czterech miejsc osuwiskowych wybranych jako projekty pilotażowe

stakeholders. From a policy perspective, the inventory will provide a robust evidence base for land-use planning, infrastructure development, and disaster risk reduction, in line with RMB's mandate to monitor geohazards and advise the Government of Rwanda.

At the initial stage of implementation, four landslide sites (Fig. 4) have been identified as priority areas for detailed monitoring and methodological testing within the *PanAfGeo+* framework:

- ❑ Bugarama landslide, representing a complex and active slope instability affecting infrastructure and settlements;
- ❑ Ndaba landslide, characterized by recurrent movement and well-documented geological and hydrological controls;
- ❑ Gatonde landslide, which illustrates the interaction between lithology, land use and rainfall in a high-risk setting;
- ❑ Kazirankara landslide, characterized by recurrent movement and well-documented geological and hydrological controls potentially affecting a school and a hospital.

These sites provide representative case studies for testing inventory methodologies, monitoring approaches, and risk assessment workflows, and will serve as pilot areas for scaling up landslide risk management practices at the national level.

CONCLUSIONS

Rwanda's geological and geomorphological setting, combined with intense tropical rainfall, rapid land-use change, and high population pressure, creates a persistent and increasing susceptibility to landslides, particularly in the Northern and Western provinces. While significant progress has been made in understanding landslide processes and spatial patterns, landslide-related information in Rwanda remains fragmented across institutions, datasets, and methodological approaches.

Previous national and regional efforts have provided valuable inventories and susceptibility assessments, but their sector-specific nature and limited harmonization constrain their effectiveness for comprehensive hazard and risk management. The ongoing development of a national policy framework for landslide risk management therefore represents a critical opportunity to integrate landslide inventory mapping, susceptibility and risk assessment, monitoring, early warning systems, and land-use planning within a coherent and standardized national system.

In this context, Rwanda's participation in the *PanAfGeo+* program offers a robust and timely framework for strengthening institutional capacity, improving coordination among national stakeholders, and aligning national practices with internationally recognized standards. Through

targeted capacity-building, methodological harmonization, and knowledge exchange with European geological surveys, *PanAfGeo+* supports the development of standardized landslide inventories, scientifically robust susceptibility and hazard assessments, and context-appropriate monitoring and early warning approaches. The adoption of relational database structures inspired by established European systems further enhances the long-term usability, interoperability, and policy relevance of landslide data.

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