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Sustainability Nexus AID: landslides and land subsidence

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Abstract
Landslides and land subsidence pose significant threats that are both existing and growing in nature. These complex phenomena should not be considered in isolation but rather as interconnected challenges. To effectively understand and mitigate them, a data-driven nexus approach is necessary. Recognizing the importance of addressing this issue comprehensively, the United Nations University has launched the Sustainability Nexus Analytics, Informatics and Data Programme, a comprehensive initiative that intends to enable the nexus approach to problem solving in coupled human–environment systems. This paper provides a detailed background on the Programme's "Landslides and Land Subsidence Module", underscoring the crucial need for a nexus approach. Additionally, it highlights some of the tools and strategies that can be employed to tackle the challenges at hand. The success of this initiative hinges on active participation from various stakeholders. By embracing a holistic approach and fostering collaboration, we can strive towards better preparedness and long-term resilience against landslides and land subsidence.

Keywords Analytics · Informatics · Data · Landslide · Land subsidence · Remoting sensing · Artificial intelligence · Sustainable development

1 Why landslides and land subsidence matters

Landslides and land subsidence are among geological hazards that can have devastating effects on infrastructure, human lives, the environment, and the sustainability of resources (Alimohammadlou et al. 2013; Garg et al. 2022; Haque et al. 2019; Mallick et al. 2021). Landslides are natural hazards that involve the movement of rock, soil, or debris down a slope under the influence of either gravity or external factors such as intense rainfall and/or earthquakes. They can occur in various forms, such as rockfalls, debris flows, mudslides, or avalanches, resulting in thousands of fatalities worldwide each year (Gariano & Guzzetti 2016). Land subsidence, referring to the gradual sinking of the Earth's surface, occurs when the support beneath the surface decreases or is removed, leading to the collapse of overlying layers and soil compaction (Gambolati et al. 1996). It can be caused by varied reasons including withdrawal of groundwater, oil, gas, and geothermal fluids, mining activities, tunneling, consolidation of certain types of soil, development of sinkholes in the karstic environment, or certain tectonic processes (Geertsma 1973; Karanam et al. 2021; Karanam

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& Lu 2023; Krishna & Lokhande 2022; Motagh et al. 2008, 2017; Oliver-Cabrera et al. 2022; Yu et al. 2021).

The issue of land subsidence and landslides is emerging as a critical global challenge, necessitating urgent attention and action (Bagheri-Gavkosh et al. 2021; Stanley et al. 2021). These geohazards, driven by a combination of natural processes and human activities, have widespread implications for communities, economies, and the environment (Fig. 1). Globally, land subsidence and landslide instances have been reported in numerous countries, impacting millions of people (Froude & Petley 2018; Herrera-García et al. 2021a). Economic losses attributed to these phenomena often amount to billions of dollars annually (Schuster 1996; Grima et al. 2020; Dinar et al. 2021). They pose a direct threat to buildings, bridges, transport networks, and other built structures on the ground, and to the underground infrastructure such as water pipes, sewage and drainage (Cigna & Tapete 2021; Bott et al. 2021; Kadiyan et al. 2021; Lyu et al. 2020; Haghshenas et al. 2019; Sundell et al. 2019). In terms of social and environmental consequences, land subsidence and landslides lead to the loss of arable land and disruption of ecosystems (Göransson et al. 2018), and displacement of communities (Kato and Lee 2022).

Projecting into the future, the circumstances seem increasingly challenging. Studies indicate that the frequency and severity of these geohazards are likely to escalate due to the increased frequency of extreme weather events, urbanization, and increasing resource demand (Ozturk et al. 2022). This trend points to an increased risk of global land movement making it an issue of immediate and pressing concern.

The relevance of addressing land subsidence and landslides extends to several United Nations Sustainable Development Goals (SDGs). It aligns closely with SDG 11 (Sustainable Cities and Communities), which focuses on making cities and human settlements inclusive, safe, resilient, and sustainable. The implications of these issues also intersect with other SDGs, such as SDG 13 (Climate Action), SDG 6 (Clean Water and Sanitation), SDG 15 (Life on Land), and SDG 9 (Industry, Innovation, and Infrastructure). This intersectionality underscores the complexity of the problem and the necessity for integrated and comprehensive solutions to minimize the risks posed by landslides and land subsidence to communities and infrastructure.

2 The need for a nexus approach

Land subsidence and landslides are not just physical phenomena; they are deeply intertwined with human activities such as urban development, groundwater extraction, and land use changes (Haghshenas et al. 2024a; Mishra & Jain 2022). This interconnection means that solutions must consider not only geological and hydrological factors but also socio-economic, political, and environmental aspects. Climate change, deforestation, increased urbanization, and anthropogenic activities in mountainous

Fig. 1 **a** Seafront of Pluit district in Jakarta (Indonesia), situated a few meters below mean sea level and protected from seawater by a concrete wall that needs to be raised every few years to counteract a land subsidence of 10–20 cm/year due to unsustainable groundwater withdrawal (photo by Pietro Teatini, September 20, 2019). **b** Damage to buildings and road caused by the March 2019 landslide at Hoseynabad-e Kalpush village in Iran (photo by Mahdi Motagh, July 30, 2019). **c** An example of a surface fissure due to groundwater extraction in Hormozgan province of southern Iran (photo credit: Mahdi Motagh, June 15, 2017). **d** A rockslide in the Mandakini Catchment in the Indian Himalayas along the National Highway (photo credit: Alok Bhardwaj, May 11, 2023)

regions have significant implications for triggering landslides. The impact of catastrophic slope failures can be magnified when they coincide or are in close proximity to other disastrous events, such as dam failures. An example is that in 1963, when a massive mass slid into the newly built Vajont reservoir in northern Italy, creating a huge wave that broke through the dam and killed approximately 2,000 people (Genevois and Ghirotti 2005). Moreover, landslides have profound effects on ecosystems, as they can lead to habitat loss, species extinction, soil erosion, changes in natural drainage system and loss of biodiversity (Li et al. 2022; Kato and Lee 2022). Land subsidence due to excessive pumping of groundwater can similarly affect ecosystems in a variety of ways including reduction in agricultural productivity and aquifer-system storage capacity, loss of wetlands, and facilitating saltwater intrusion into coastal freshwater aquifers. Changes in land elevation in urban areas damages buildings and civil infrastructure, and increase flood susceptibility and risk in coastal regions (Erban et al. 2014).

Policies on land use and water management have direct implications for the stability of land and can either mitigate or exacerbate the risk of landslides and subsidence (Vassileva et al. 2021, 2023; Xia et al. 2022). Furthermore, these geohazards present significant trade-offs and synergies that need careful consideration. Measures to prevent land subsidence, such as reducing groundwater extraction, can have economic implications for communities dependent on water resources. Similarly, efforts to control landslides through reforestation or land-use planning must balance ecological benefits against potential socio-economic impacts.

Instead of a siloed approach, a collaborative, interdisciplinary nexus approach enables specialists from various fields to pool their expertise. Geologists, hydrologists, and geomorphologists can analyse the physical and environmental factors contributing to landslides and subsidence. Engineers and urban planners can assess the implications on infrastructure and propose resilient designs. Earth observation experts and geospatial analysts can utilize advanced technologies to monitor and predict these hazards over time (Bally, 2012). Furthermore, a nexus approach recognizes the social and economic dimensions intertwined with landslides and land subsidence. Economists, social scientists, and environmental scientists can evaluate the impact of these hazards on communities, including economic and justice implications, displacement risks, and effects on local economies. This holistic view ensures that strategies not only address geological risks but also consider human welfare and livelihoods.

By incorporating geological, environmental, social, economic, and governance perspectives, the nexus approach facilitates a comprehensive understanding of landslides and land subsidence. It ensures the development of well-rounded, sustainable strategies, balancing the need for risk mitigation with environmental conservation and community resilience. This multidisciplinary collaboration and the resulting comprehensive perspective based on the nexus approach (Brouwer et al. 2023) can pave the way for hazard managers and policymakers to increase resilience against landslides and land subsidence.

3 The aid of the AID

Addressing the complex challenges of land subsidence and landslides requires more than just an understanding of the physical phenomena involved. It also necessitates the use of tools that enable informed decision-making, promote transparency, and enhance literacy. To this aim, analytics, informatics, and data (AID) tools play a crucial role in managing these geohazards. One of the significant contributions of AID tools is their ability to support informed decision-making. By providing access to comprehensive data sets, advanced analytical tools, and state-of-the-art computational techniques, these tools empower scientists, policymakers, and local communities to develop a better understanding of the causes and potential impacts of land subsidence and landslides. This understanding is paramount in formulating targeted strategies for mitigation and adaptation. For example, an open database containing historical data on landslides and land subsidence can offer crucial insights for research (Herrera, et al. 2018; Wu et al. 2022; Haghshenas et al. 2024a, b). This data, combined with environmental factors like rainfall, topography, land cover, and geology with socio-economic data, such as population density and income levels, can help identify areas prone to high risk of subsidence and landslide hazard, and understand their potential impact on communities. Informatics tools can be used to simulate the effects of land-use changes on subsidence patterns, providing valuable insights for urban planners, mitigation strategists, and environmental managers.

Transparency is another critical aspect enhanced by the AID tools. By making complex data and analyses accessible and understandable using interactive data visualization tools, these tools help to create a bridge between science and policy by building trust among stakeholders, including local communities, government bodies, and international organizations (Pezanowski et al. 2008; Maceda et al. 2009; Dransh et al., 2010). This transparency is essential for collaborative efforts and for gaining public support for necessary but potentially disruptive measures, such as relocation or changes in land use. The tools might also help in disseminating relevant knowledge and skills to a wider audience, including regions and communities that might otherwise lack access to such information. This is critical for empowering local stakeholders to participate actively in decision-making processes and for fostering community-led initiatives especially for management of risk and recovery from landslide disasters.

4 Sustainability Nexus AID programme: landslides and land subsidence

In 2023, the United Nations University (UNU) initiated a pioneering collaborative programme in AID, dedicated to enabling the nexus approach in integrated resource management and sustainable development. This programme aims to develop an international collaboration network concentrating on the identification, development, and promotion of data, computational techniques, and analytical tools that are essential for the sustainable management of critical resources like water, soil, waste, energy, and geo-resources, guided by the principles of nexus thinking. The UNU Sustainability Nexus AID Programme (https://www.sustainabilityaid.net/) is tailored to support and involve an international network of AID scientists and professionals. This network operates at the intersection of science, policy, and society, aiming to facilitate regional and global collaborative efforts that are aligned with achieving the UN 2030 SDGs.

The UNU Sustainability Nexus AID Programme has three pillars. The first pillar, Data, is aimed at facilitating data exchange and filling gaps in analyzing the resource nexus within human–environment systems. It involves collection of new in-situ geospatial data, cataloging existing data and identifying missing information, aiding governments, businesses, and societies in tackling environmental challenges. The second pillar, Informatics, focuses on enhancing the capacity for computing and processing this nexus data. This involves the development and promotion of state-of-the-art tools and practices for data management in complex human–environment systems. The third pillar, Analytics, is centered on extracting meaningful information from data to aid in decision-making. This includes the development and promotion of advanced analytical tools and frameworks for analyzing the resource nexus.

Delving into the specifics of the Landslides and Land Subsidence Module, we find a history of commitment to understanding and mitigating the impacts of land subsidence and landslides. The objectives of this module are closely aligned with the broader goals of the AID Programme, focusing on bridging the gap between science and policy and building capacities to better manage these geohazards. The module brings together a network of experts, researchers, and practitioners dedicated to developing innovative solutions and strategies. The activities of this module are diverse and impactful. They range from conducting in-depth research and analysis to developing tools and frameworks for better decision-making. By facilitating an international network of scientists and professionals, the module enhances collaborative efforts to address the challenges posed by land subsidence and landslides, both regionally and globally.

An integral part of the module's mission is to strengthen the science-policy connection. This aspect is crucial in ensuring that the findings and solutions developed through research are effectively translated into practical policies and actions. Additionally, the module places a strong emphasis on capacity building, recognizing the importance of empowering local communities, policymakers, and other stakeholders with the knowledge and tools to effectively address these geohazards. For those interested in exploring the Landslides and Land Subsidence Module further, a wealth of information is available online at https://www.sustainabilityaid.net/landslidesandlandsubsidence (Fig. 2).

5 Landslides and land subsidence AID tools

In addressing the multifaceted challenge of ground instability, the Landslides and Land Subsidence Module emphasizes the integration of diverse resources and tools, as well as the importance of making complex data accessible to a broad audience. Central to this endeavor is the systematic presentation of key resources, software tools, and interactive platforms, each serving a distinct but interconnected role in understanding and managing ground instability issues. Moreover, we also require collaboration of expertise from diverse disciplines. However, for effective cross-disciplinary collaboration, it's crucial to have tools, data, and resources that are interpretable across different domains and not overly specialized. Recognizing this necessity, we have compiled information into tables that provides a comprehensive overview of the tools, data, and resources available.

Table 1 presents a collection of inventories and susceptibility maps, information on historical landslides and land subsidence records, offering foundational data essential for initial risk assessment and understanding the geographical distribution of instability. This information is crucial for learning from historical events and helping us to improve predictions. Software tools, used for technical analysis of landslides and land subsidence are detailed in Table 2. There are sophisticated geological and geotechnical analysis software as well as advanced earth observation technologies, to better understand the causes and dynamics of ground movements. Their application ranges from analyzing past landslide events to real-time monitoring of subsidence, crucial for proactive management and mitigation efforts.

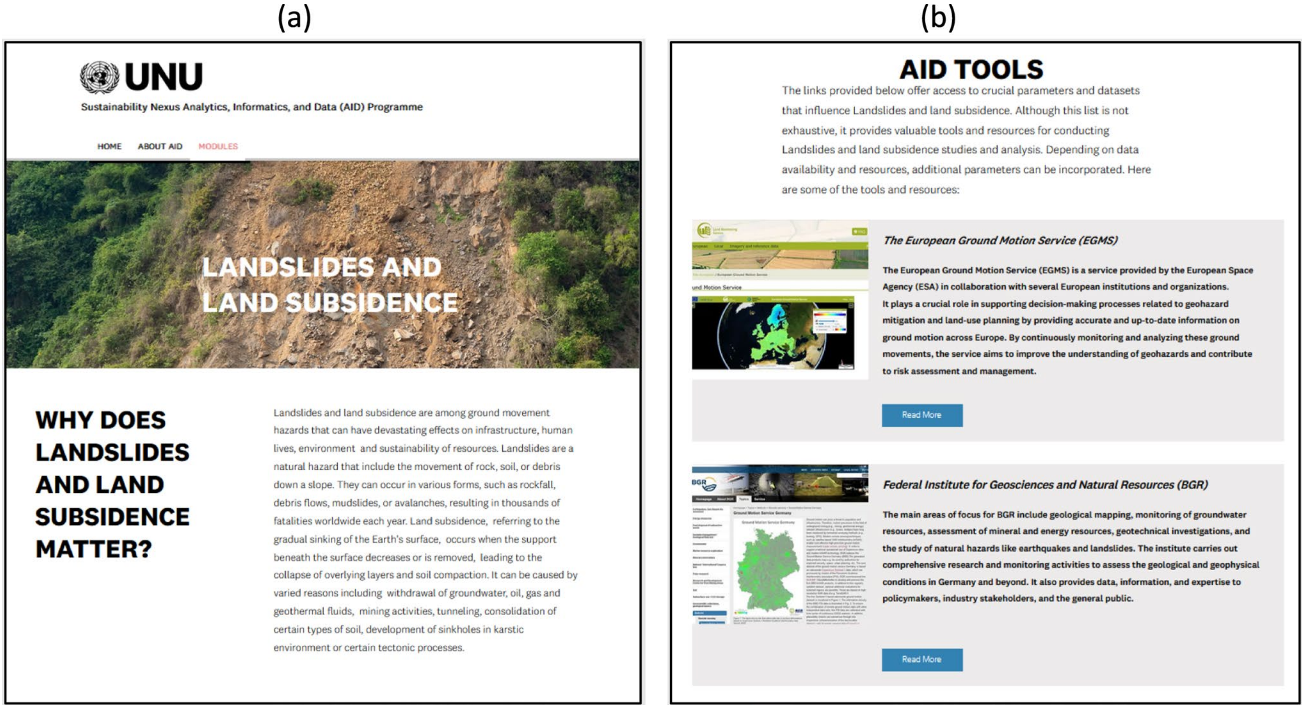

Fig. 2 The Landslides and Land Subsidence Module webpage on the UNU Sustainability Nexus AID website, enabling access to **a** general information on the geological processes and **b** available AID tools

Interactive platforms for landslides and land subsidence tracking, listed in Table 3, play a crucial role in making complex data accessible and interpretable to a wider audience. These platforms not only facilitate data visualization and user interaction but also promote community involvement and awareness. They serve as a bridge between technical data and its practical, on-the-ground applications, making information readily available for better understanding, decision-making, education, and outreach. Additionally, the resources highlighted in Table 4 are curated to serve as an introductory to advanced information gateway for researchers venturing into the field of landslides and subsidence from different domains. The goal is to provide a comprehensive knowledge base that spans basic understanding to more complex, specialized insights. Please note that the resources and tools listed in Tables 1, 2, 3 and 4 represent only a subset of widely used tools in this domain and do not include all available options. Moreover, the website is also dynamic, and the list of AID tools is constantly updated and expanded. The goal of this initiative is to bring together experts from different fields, encouraging them to share and apply tools that are well-known in one area but not in others. We invite professionals to join us in enhancing these tools, analyses, and data. This effort is crucial for building a stronger, more informed response to the challenges of landslides and subsidence.

6 The way forward

Landslides and land subsidence are currently significant and escalating issues, particularly in the context of worsening climate change impacts. Recognizing and quantifying the risks associated with these geohazards is critical, but it is only a part of the solution. The focus needs to shift towards making informed decisions to enhance the resilience of our people and infrastructure against these challenges. This calls for a collaborative effort involving various stakeholders, including scientists, policymakers, community leaders, and industry experts, to develop and implement effective strategies.

A nexus approach is vital in this scenario. It results in an integrated and holistic perspective, combining expertise and insights from different fields to address the complexities of landslides and subsidence. By embracing the collaborative approach, we can go beyond mere risk identification to formulate comprehensive solutions that consider environmental, social, and economic factors. The UNU Sustainability Nexus AID Programme stands out as an exemplary initiative in this direction. It underscores the importance of interdisciplinary collaboration and the merging of scientific research with policymaking. Recognizing the disproportionate impact of landslides and land subsidence on the Global South (Petley 2012), the UNU Sustainability Nexus AID Programme prioritizes the

Table 1 Landslides and land subsidence inventories and data featured by the UNU Sustainability Nexus AID Programme as of August 2024

Inventory/Data	Description	Link
European Landslide Susceptibility Map (ELSUS V2)	A map highlighting landslide susceptibility across Europe, providing critical data for risk assessment and planning	(Wilde et al. 2018)
Global Landslide Hazard Distribution (GDLND)	A worldwide assessment of landslide susceptibility based on factors such as slope, lithology, soil moisture, precipitation, seismicity, and vegetation cover	(Nadim et al. 2006)
Nepal 2015 Earthquake: Landslide Maps	Detailed landslide maps created following the 2015 Nepal earthquake, are crucial for understanding seismic landslide risks	(Durham Landslide Maps 2024; Kincey et al. 2021)
U.S. Landslide Inventory (USGS)	An extensive database of landslide occurrences in the United States, offering a comprehensive national overview	(U.S. Landslide Inventory 2024)
Atlas of Landslide (NRSC, India)	A collection of landslide atlases providing detailed information on landslide zones in India	(NRSC, ISRO)
NASA's Global Landslide Catalog	A global database collecting information on rainfall-induced landslides, instrumental for global analysis and research	COOLR 2024
Global Landslide Hazard Map (World Bank)	The World Bank's Global Landslide Hazard Map provides an extensive database of landslide susceptibilities around the world, aiding in risk assessment and mitigation planning on a global scale	(Global Landslide Hazard Map Data Catalog 2024)
Landslide Inventory of Kyrgyzstan	An extensive database maintained by the GFZ German Research Centre for Geosciences, focusing on landslide events in Kyrgyzstan	(Behling et al. 2014, 2016)
New Zealand's National Landslide Database (GNS)	A comprehensive database of landslides in New Zealand, maintained by GNS Science	(GNS Science—Landslide Database 2024)
Italian Landslide Inventory	The Italian web platform on landslides and floods	IdroGEO 2024
Swiss Flood and Landslide Damage Database	Swiss database managed by Swiss Federal Institute for Forest, Snow and Landscape Research (WSL)	WSL 2024
Japanese Landslide Inventory	Japan database as part of Japan Seismic Hazard Information Station (J.SHIS)	J.SHIS 2024
Global Land Subsidence Mapping	A global land subsidence dataset created by employing remote sensing data, and advanced geospatial and modeling techniques	(Hasan et al. 2023)
China's Sinking Cities	Land Subsidence database for 82 major cities in China	(Ao et al. 2024)
Land Subsidence Database of Iran	Distribution and extent of land subsidence areas across Iran derived Sentinel-1 satellite survey between 2014 and 2020	(Haghshenas Haghighi and Motagh 2024b)
Subsidence in Coastal Cities	Subsidence in coastal cities throughout the world observed by InSAR observations between 2014 and 2021	(Wu et al. 2022)

engagement of experts from these regions. Their firsthand experience in tackling these challenges provides invaluable insights for understanding and addressing the complexities of geohazards, aligning with the growing recognition of the importance of local and indigenous knowledge in disaster risk reduction (Kelman et al. 2012; Gaillard & Mercer 2013).

We acknowledge that universal policies are often ineffective in diverse geographical and socio-economic contexts (Blaikie et al., 2003). Therefore, the integration of local knowledge and expertise is crucial for developing context-specific strategies. To this end, we are initiating international collaborations through workshops, virtual conferences, and exchange programs to facilitate knowledge sharing across

Table 2 Landslides and land subsidence software and analysis tools featured by the UNU Sustainability Nexus AID Programme as of August 2024

Software	Description	Official Website
SLIDE2	Advanced, user-friendly 2D slope stability analysis software	(Slide2 Rocscience 2024)
SEEQUENT	Comprehensive software for slope stability, deformation, heat transfer and groundwater flow analysis in soil and rock	(Seequent 2024)
PLAXIS	Geotechnical finite element analysis software	(PLAXIS 2D 2024)
SNAP (Sentinel Application Platform)	Common architecture for Sentinel Toolboxes, supports high-resolution satellite data exploitation, suitable for radar and optical data	(ESA STEP 2024)
PyLandslide	A Python tool for landslide susceptibility mapping and uncertainty analysis	(Basheer and Oommen 2024)
GMTSAR (Generic Mapping Tools Synthetic Aperture Radar)	Open-source software for SAR data processing in geophysics, focusing on InSAR techniques	(Sandwell et al. 2011)
ISCE (InSAR Scientific Computing Environment)	Flexible software for automated SAR data processing, used in earthquake monitoring and surface studies	(*GitHub—Isce-Framework/Isce2: InSAR Scientific Computing Environment Version 2*, n.d. 2024)
Mintpy (Miami INsar Time-series software in Python)	Python-based package for InSAR time series data analysis, applicable in geophysics and geology for ground deformation studies	(Yunjun et al. 2019)
STEP_TRAMM	Simulate rainfall induced landslides	(Lehmann and Or 2012)
TRIGRS	Rainfall-induced shallow landslides	(Baum et al. 2008)
D-Claw	Debris flow model	(Iverson and George 2014)
Anura 3D	Numerical modelling of large deformations and soil–water–structure interaction	(Anura3D MPM Research Community 2024)
SUB	Subsidence and Aquifer-System Compaction Package	(Hoffmann et al. 2003)
POEL	Code for simulating the diffusion and deformation process induced by pump tests in a layered poroelastic half-space	(Wang and Kümpel 2003)
r.avaflow	a GIS-supported open source software tool for the simulation of complex, cascading mass flows	(Mergili et al. 2017)
r.randomwalk	a conceptual tool for backward- and forward-analyses of mass movement propagation	(Mergili et al. 2015)
r.slope.stability	Open-source code for physically-based slope stability analysis	(Mergili et al. 2014)

diverse settings. This approach aims to bridge the gap between scientific and local knowledge, employing a system thinking approach to capture the interconnected nature of geohazard risks and their societal impacts. Simultaneously, we are developing targeted capacity-building initiatives to ensure that stakeholders at all levels—from local government officials to community leaders—are equipped to effectively utilize advanced tools for risk assessment and management. This people-centered approach (Scolobig et al. 2015) aims to empower local communities and decision-makers, enhancing their ability to contribute to and implement effective disaster risk reduction strategies.

The AID Programme also recognizes the complex governance challenges in disaster risk reduction (Djalante & Lassa 2019) and the need to consider climate change

Table 3 Interactive landslides and land subsidence platforms featured by the UNU Sustainability Nexus AID Programme as of August 2024

Platform	Description	Link
NASA Landslide Reporter	A crowdsourcing tool for landslide data, part of the Cooperative Open Online Landslide Repository (COOLR)	(NASA Landslide Reporter 2024)
NASA Landslide Viewer	A web portal to open global landslide data from NASA	(NASA Landslide Viewer 2024)
European Ground Motion Service (EGMS)	Operated by ESA, provides information on ground motion across Europe, supporting geohazard mitigation and land-use planning	(Costantini et al. 2021)
Norwegian Ground Motion Service	A nationwide, freely accessible and web-based map service for InSAR-based ground deformation data in Norway	(InSAR Norway)
Federal Institute for Geosciences and Natural Resources (BGR)	Offers geological mapping, monitoring groundwater resources, and studying natural hazards like landslides. Provides comprehensive research and monitoring	(BGR Geoportal 2024)
IGME Global Subsidence Information System	Visualizes and provides information on global subsidence data, crucial for assessing ground stability and risks	(Herrera-García et al. 2021b)
Harris Subsidence Map	Showcases subsidence rates in Harris, Galveston, and surrounding counties, Texas, USA. It details the annual rate of change in ellipsoidal height from GPS data (2018–2022), with period of record plots for each station	(Harris-Galveston Subsidence District 2023)
Interactive Map of Land Subsidence in Iran	Interactive map of land subsidence in Iran based on Sentinel-1 SAR data (2014-2020)	Subsmap-Iran
COMET Subsidence Portal	Land Subsidence Portal presenting 99 subsiding regions in Iran with InSAR time-series data	(COMET-LiCS Land Subsidence Portal)

Table 4 Landslides and land subsidence educational and capacity building resources featured by the UNU Sustainability Nexus AID Programme as of August 2024

Resource	Description	Link
USGS Landslide Hazards Program	Comprehensive resource for learning about landslides, including educational materials, interactive maps, and research tools	(Landslide Hazards Program 2024)
American Geosciences Institute—Landslide Basics	A guide on understanding landslides, including mitigation techniques, and resources for educators	(Landslide Basics, AGI 2024)
The Landslide Blog—AGU	Up-to-date commentary on global landslide events and research, ideal for staying current in the field	(The Landslide Blog 2024)
NASA Earthdata	Offers data toolkits, webinars, tutorials, and articles for Earth scientists, including resources on land subsidence	(Earthdata 2024)
Earth Observation Center Geoservice (EOC)	Offers rich geospatial datasets provided by the Earth Observation Center (EOC) of the German Aerospace Center (DLR)	(EOC Geoservice 2024)
USGS Groundwater Information	A fact sheet providing insights into the causes and effects of land subsidence in the United States, focusing on groundwater withdrawal	(USGS Groundwater Information 2024)
Land Subsidence on the Virginia Coastal Plain	Detailed resource on the measurement and causes of subsidence in coastal regions	(USGS—Virginia And West Virginia Science Center 2024)
UNESCO Land Subsidence International Initiative (LaSII)	The UNESCO Land Subsidence International Initiative (LaSII) enhances the scientific understanding and technical knowledge required to identify and characterize hazards related to natural and anthropogenic land-level lowering	LaSII

impacts on geohazard risks (Birkmann et al. 2022). By fostering collaboration between experts from the Global South and international partners, we aim to develop more robust, locally relevant, and sustainable approaches to managing landslide and land subsidence risks. The future of managing landslides and land subsidence effectively lies in fostering these kinds of multi-disciplinary partnerships and knowledge exchanges, which are essential for crafting resilient and sustainable solutions in an era of changing climate.

The path forward is challenging, but with the combined power of the Fourth Industrial Revolution (Industry 4.0) and a collaborative, multi-disciplinary approach, we can build a more resilient future. This is an invitation to all stakeholders to contribute their expertise and resources towards mitigating the impacts of landslides and land subsidence and adapting our communities and infrastructure for a changing climate and technological landscape. Through united efforts and a multidisciplinary approach, it is possible to forge a future that is resilient in the face of changing climatic conditions and technological advancements.

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