Landslide Warning Systems in Low-And Lower-Middle-Income Countries: Future Challenges and Societal Impact

Irasema Alcántara-Ayala and Ricardo J. Garnica-Peña

Abstract

There is a growing body of literature that recognises the importance of warning systems to reduce landslide disaster risk and avoid the occurrence of disasters. Recent developments in landslide disasters around the world have heightened the need for the implementation of Landslide Early Warning Systems (LEWSs) particularly in low-and lower-middle-income countries (LICs and MICs), where levels of vulnerability and exposure are very high. However, no previous study has systematically evaluated the use of LEWSs in LICs and MICs. By means of a systematic review on the scientific literature this chapter explores the ways in which LEWSs have been implemented in LICs and MICs. This research seeks to address the spatial distribution of LEWSs in the world, specifically in LICs and MICs. Special attention is given to reviewing the development of LEWSs in terms of their inclusion in integrated disaster risk reduction (DRR) strategies or as standalone initiatives, and the type of approaches followed, either as top-down or bottom-up. The chapter has three key components: (1) to prepare a search and inclusion criteria strategy for systematic literature review to collect a set of articles on LEWSs using the ISI Web of Science database; (2) to organize the literature review set to extract and analyse quantitative and qualitative data and information on LEWSs in LICs and MICs; and (3) to provide insights on a future LEWSs research agenda concerning critical issues and gaps in the literature and identifying main challenges with high societal impact. A noteworthy remark about this review is that only 12.4% of the total publications that met the specified criteria are from LICs and MICs. These papers address diverse dimensions of LEWSs in different degrees, but despite that, the actual use or implementation of LEWSs was addressed only by five papers. This suggests a potential disadvantage in the development and successful systematic implementation of LEWSs in these countries.

Keywords

Landslide early warning systems • Low-and lower-middle-income countries • Implementation • Community-based approaches • Challenges • Societal impact

1 Introduction

In the international sphere, the establishment of the Sendai Framework for Disaster Risk Reduction 2015–2025 (UNISDR 2015) and the call for science and technology to support its implementation (UNISDR 2019) have helped science-evidence policy making and practice to be visualised as a high priority, but also, have opened up opportunities to improve science and to promote wider interaction among all disaster risk relevant stakeholders. Particularly, in the field of landslide research, initiatives such as the Sendai Landslide Partnerships 2015–2025 (Sassa 2015, 2016) and the Kyoto Landslide Commitment 2020 (KLC 2020) (Alcántara-Ayala and Sassa 2021) have created and set in motion solid and effective projects to promote landslide research in benefit of society, and foster relations between institutions and landslide research networks from different regions of the world. These developments have helped some countries make progress towards informed decision making and practice.

Among other significant actions, the KCL (2020) promotes greater awareness of the importance of people-centred early warning. Therefore, and in order to secure some positive progress in aspects relating to the development of

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people-centred early warning systems, this new initiative calls for an increased precision and reliable prediction technology for landslides in both time and space, especially in a changing climate context (Sassa 2019, 2020).

Landslide early warning systems (LEWSs) is a major area of interest within the field of landslide research and one of the most critical key elements for disaster risk reduction (DRR). In the light of such circumstances, there is increasing concern that some low-and lower-middle-income countries (LICs and MICs), are being disadvantaged in the development and successful systematic implementation of LEWSs. Accounting specifically for the varying experiences these countries have at different scales is unknown.

Recent evidence suggests that owing to their complex and operational landslide forecasting character, LEWSs remain a difficult and uncertain task, which require conceptual developments and technological improvements along with open standards for the design, implementation, management, and verification (Guzzetti et al. 2020). This is of uttermost relevance in LICs and MICs where obstacles for science for action should not be underestimated.

Drawing upon a systematic literature review, this study attempts to provide insights on the development and implementation of LEWSs in LICs and MICs from 2000 to 2021. Especially important is to identify whether those reported cases are included into a comprehensive disaster risk reduction strategy, or they are standalone initiatives. Furthermore, finding out if they follow a top-down or a bottom-up approach will be particularly valuable.

The remaining part of the chapter includes a brief section on Early Warming Systems (EWSs), the methodology, and results. Finally, recommendations derived from this systematic literature review are presented.

2 Early Warning Systems (EWSs)

Building on the work of Smith (1996), Twigg (2002) argued that in addition to the three known inter-related stages of EWSs, which comprised evaluation and forecasting; warning and dissemination; and response, the significance of appropriate communication of timely and accurate hazard warnings, based on the comprehensive understanding of perceptions and needs of communities at risk, is key for the success of an EW system.

Accordingly, in an effort to implement people-centred early warning systems, four elements of effective EWSs were established (Fig. 1), and EWSs defined as "the provision of timely and effective information, through identified institutions, that allow individuals exposed to hazards take action to avoid or reduce their risk and prepare for effective response" (UNISDR 2006). After a decade, its meaning was redefined, but hardly changed in practice, in terms of "an integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events" (UNISDR 2016).

Alcántara-Ayala and Oliver-Smith (2017) claimed that despite the evolution of definitions through time, EWSs are not yet articulated or integrated systems, but segments of the capacity-building process required to achieve DRR through DRM. One of the main reasons for this is a lack of disaster risk understanding as a social construct, which implies that not only hazard occurrence, but the spatial and temporal scales of the dimensions of vulnerability and exposure must be considered.

It is beyond the scope of this study to identify and analyse the strengths and serious weaknesses of both EWSs and LEWSs. However, it is important not to forget that despite the fact that, due to uncertainty, determining the occurrence of hazards in space and time is technically challenging, the performance of EWSs is often constrained by a lack of integrated transdisciplinary approaches, sustainability of financial and human resources, sound strategies of risk communication and most importantly, due to disarticulated institutional arrangements and weak disaster risk governance (Alcántara-Ayala 2021). These issues are of great concern to the international community and have important implications for LICs and MICs.

Fig. 1 Four elements of people-centred Early Warning Systems (*Source* adapted from ISDR-PPEW 2005)

3 Methodology

This study employed a systematic review methodology, which involved definition of the review scope, literature search, literature analysis and synthesis, and perspectives on challenges and societal impact of LEWSs. The central area of interest of the review scope was focused in categorising the spatial extent of the research institutions that have been involved in the development of LEWSs and to identify, when possible, whether these have been included into a comprehensive disaster risk reduction strategy, or they were built as standalone initiatives, following either top-down or a bottom-up approaches.

With respect to the literature search, most suitable keywords and search criteria were chosen in order to extract the required set to be analysed from the ISI Web of Science database. The search was conducted between January and February 2022. The system was requested to search the words "landslide", "warning system", and "early warning" in the title and abstract of the articles. In this way, the search results included a total of 1709 papers. Results were sorted by year of publication within 1990–2021 range, to avoid the inclusion of the work in progress in 2022. During the evaluation phase, following filtering to include papers which did not have the full abstract available, search results were reduced to 1691 papers. Additional filtering excluded all works which were not published in English language, and number of papers was reduced to 1669. Additional filtering aimed at eliminating papers which were not suitable for the review scope as well as data papers, retracted publications, editorial material, and letters. The use of these criteria involved the exclusion of 540 papers. Number of papers was cut to 1129. Final filtering involved the classification of papers based on countries of publication. Categories of Low, Lower middle, Upper middle and High income were considered. Final selection was concentrated on Low and Lower middle-income countries. Therefore, number of papers examined for this study was 141 (Fig. 2).

Literature analysis and synthesis involved geographic analysis, time, institutions, areas of research, methodological typology, and approaches. After articles were selected, two researchers review them and further discussed differences to ensure relevance. Data management and analysis were performed using Excel and HistCite. Perspectives on challenges and societal impact of LEWSs in LICs and MICs were building on the relevant experiences included in the analysed set of papers and based on the practical knowledge of the authors.

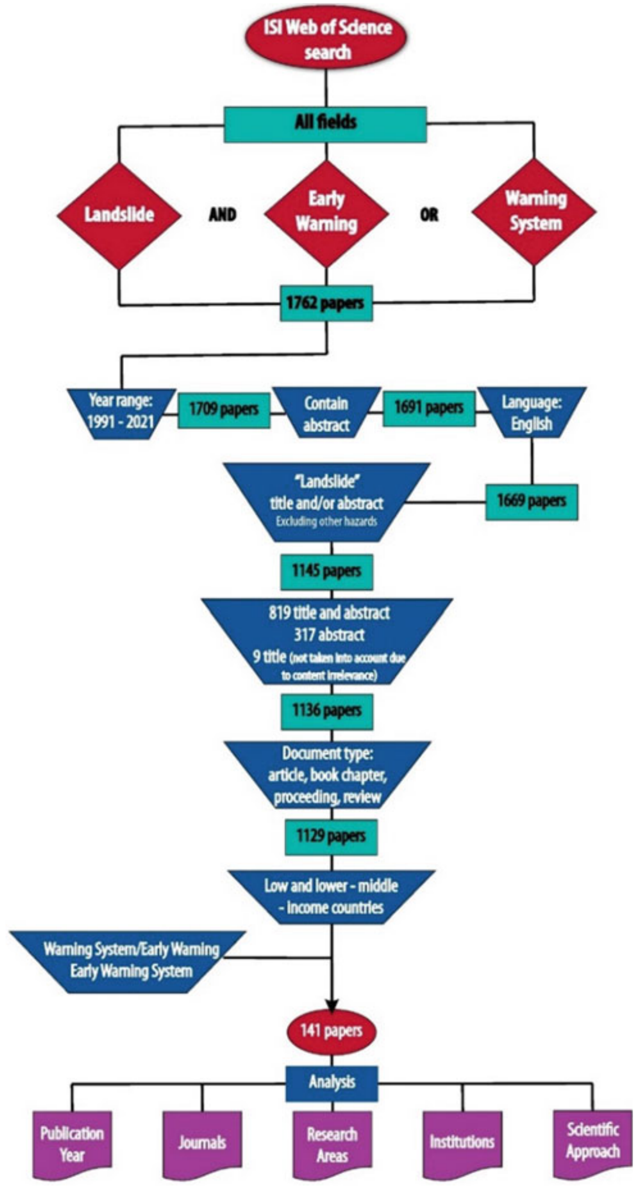

Fig. 2 Search strategy for systematic review

4 Results

A noteworthy remark about this study is that 141 articles, the equivalent of only 12.4% of the total publications that met the specified criteria, were published by researchers working in institutions situated in LICs ($N = 3$) and MICs ($N = 20$). LICs included Malawi, Uganda and Rwanda, whereas MICs involved Bangladesh, Bhutan, Egypt, El Salvador, Ghana, India, Indonesia, Iran, Kenya, Nepal, Nicaragua, Nigeria, Pakistan, Philippines, Sri Lanka, Tanzania, Ukraine, Uzbekistan, Vietnam and Zambia.

Although the first publication addressing LEWSs worldwide was issued in 1991, only from 2000 LICs and MICs countries researchers started publishing their work on this topic. Therefore, the range of years analysed was established as 2000–2021 (Fig. 3).

During the first seven years, only one publication was produced annually. The largest percentage of publications (52.4%) was concentrated in 2019, 2017 and 2020, with 29, 25 and 20 publications, respectively. During the last two years of the analysis, a clear decrease in number of publications was identified.

Types of documents in which research on LEWSs was published comprised articles (*N* = 81), conference proceedings (*N* = 56), book chapters (*N* = 2) and reviews (*N* = 2). These were included in publications from a wide and diverse range of research fields in the many subject areas relevant to landslides. However, a major concentration of publications, equivalent to 43% of the total, was identified in the fields of engineering, engineering geology and geology (Fig. 4). Only one publication was issued in a social science journal. This indeed mirrors the predominance of technical approaches.

Articles on these themes were published, to a major extent, in the Landslides Journal (*N* = 14), followed by Natural Hazards (*N* = 6) and Water (*N* = 6) journals. Additional publications were included in Advancing Culture of Living with Landslides, Vol 3 (*N* = 4), Geomatics, Natural Hazards & Risk (*N* = 4), Journal of Mountain Science (*N* = 3), International Journal of Disaster Risk Reduction (*N* = 3) and the International Journal of Geomate (*N* = 3) (Fig. 5).

Researchers from 179 institutions, from LICs, MICs and other income countries participated as contributors in the analysed publications. Top institutions in terms of participation in highest number of publications included Amrita Vishwa Vidyapeetham University (*N* = 15), the Indian Institute of Technology Indore (*N* = 14), the Indian Institute of Technology Roorkee (*N* = 12), and the University of Technology Sydney (*N* = 11). They were followed by Sejong University (*N* = 7), the University of Tokyo (*N* = 7) and the Chinese Academy of Sciences (*N* = 6) (Fig. 6).

The review suggested that research associated with LEWSs in LICs, and MICs is built around three main lines of work, the first focused on studies of hazard analysis for LEWSs (*N* = 53, 37.5%), the second, on technological developments for potential LEWSs (*N* = 49, 34.7%), and the third, concerning the design, development, calibration and validation of models and prototypes for LEWSs (*N* = 21, 14.8%) (Fig. 7).

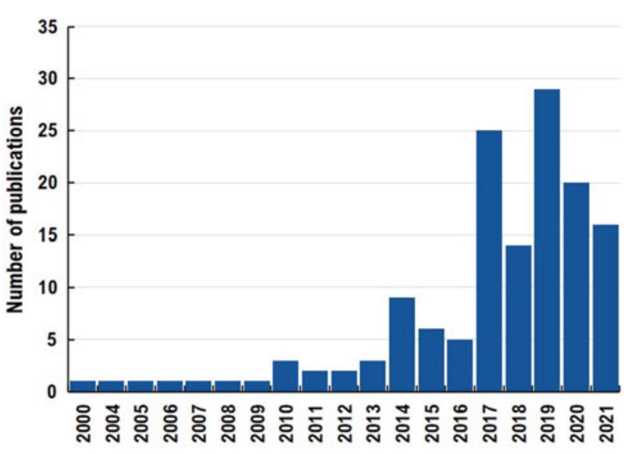

Fig. 3 Time analysis: number of publications analysed concerning LEWSs in LICs and MICs

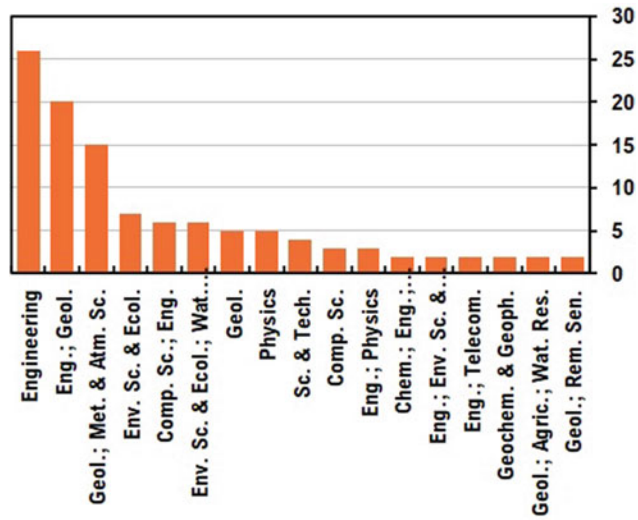

Fig. 4 Research areas concerning the publications analysed on LEWSs in LICs and MICs

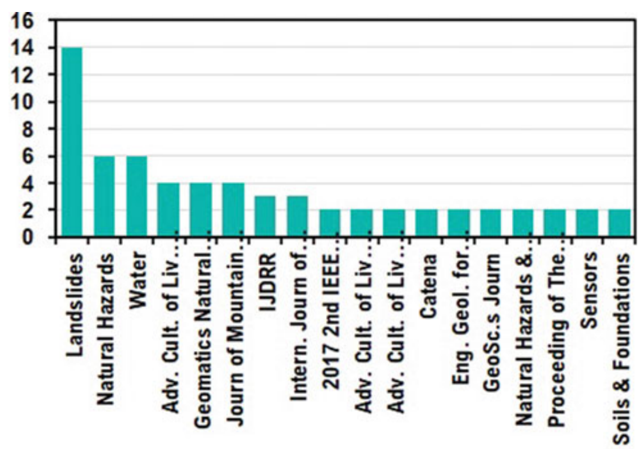

Fig. 5 Journals of publications regarding LEWSs in LICs and MICs

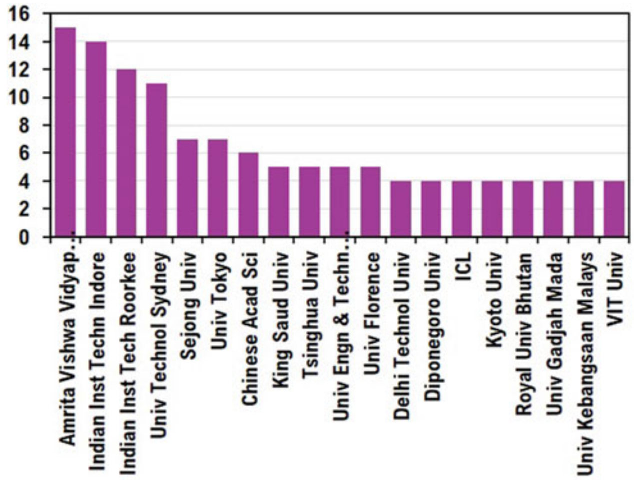

Fig. 6 Research and academic institutions to which the authors of the analysed publications are affiliated

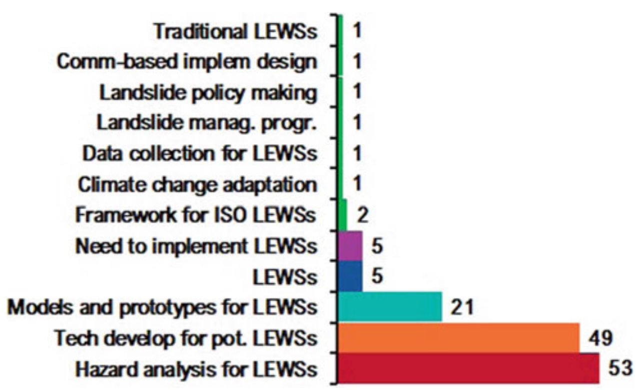

Fig. 7 Thematic lines of research associated with LEWSs in LICs and MICs, based on the systematic literature review

Regardless of the information provided in the title and abstract, out of the total number of papers analysed produced in LICs and MICs (Fig. 8) and represented through a series of study cases (Fig. 9), only five publications included the implementation of an actual LEWS (5, 3.5%) as a main development in the text. Other publications were focused on different aspects to stress the need of implementing LEWSs in different countries (5, 3.5%) (see Fig. 7).

In a lower proportion, other articles focused on various areas, from the proposal of a standard for community-based landslide early warning systems (Fathani et al. 2016, 2017) (2, 1.4%), to addressing the significance of indigenous knowledge for climate change adaptation and warning systems as communities are experiencing the consequences of climate change through the occurrence of landslides and other hazards (Nelson et al. 2019) (1, 0.7%) (see Fig. 7).

In the reviewed publications, other topics of interest from a technical approach, included the establishment of a national system for data collection (1, 0.7%) (Devoli et al. 2007) (see Fig. 7).

From a social science perspective, a publication emphasised and exemplified the architecture of landslide management programmes, which should include social vulnerability ($N = 1$, 0.7%) (Karnawati et al. 2009). Likewise, based on a survey, an assessment on the extent to which landslide disaster risk reduction policy measures have been implemented in Uganda was carried out (1, 0.7%) (Masaba et al. 2017). By means of stakeholder mapping, focus group discussions and key informant interviews, insights derived from the assessment of capacities and vulnerabilities of communities were provided for the design of community-based early warning system for deep-seated landslides ($N = 1$, 0.7%) (Gumiran et al. 2019). Furthermore, a traditional notion of LEWSs was developed by introducing the concept of non-structural mitigation measures through mitigation mapping; this described in terms of the definition of the landslide high-risk area and community evacuation plan based on place-cantered mapping in order to promote community participation ($N = 1$, 0.7%) (Hidayati and Noviana 2018) (see Fig. 7).

4.1 Description of Operational LEWSs from Publications

Colleagues from Amrita Vishwa Vidyapeetham University designed and developed an integrated wireless sensor network system for real-time monitoring and early warning of landslides, which includes three levels of warning. Results obtained from the deployment of the LEWS in Western Ghats and North-Eastern Himalayas in India were satisfactory. This beneficial contribution increased the emphasis on the necessity of implementing LEWSs nationwide. Therefore, the Government of India considered its adoption, and a starting step of the strategy was a second LEWS deployment to the North-eastern Himalayas (Ramesh et al. 2017).

Along the side of the installation of a LEWS in Ledoksari Village in Indonesia, Karnawati et al. (2011) reinforced the preparedness of the communities at risk. A partnership between the University and the key person from the Village, under the coordination of the local regency authority was sought as a main mechanism of interaction for the effective implementation of the developed LEWS. Inputs for hazard mapping included landslide susceptibility derived from the assessment of conditions of slope inclination, types and engineering properties of existing lithologies and soil, along with the incorporation of land-use types.

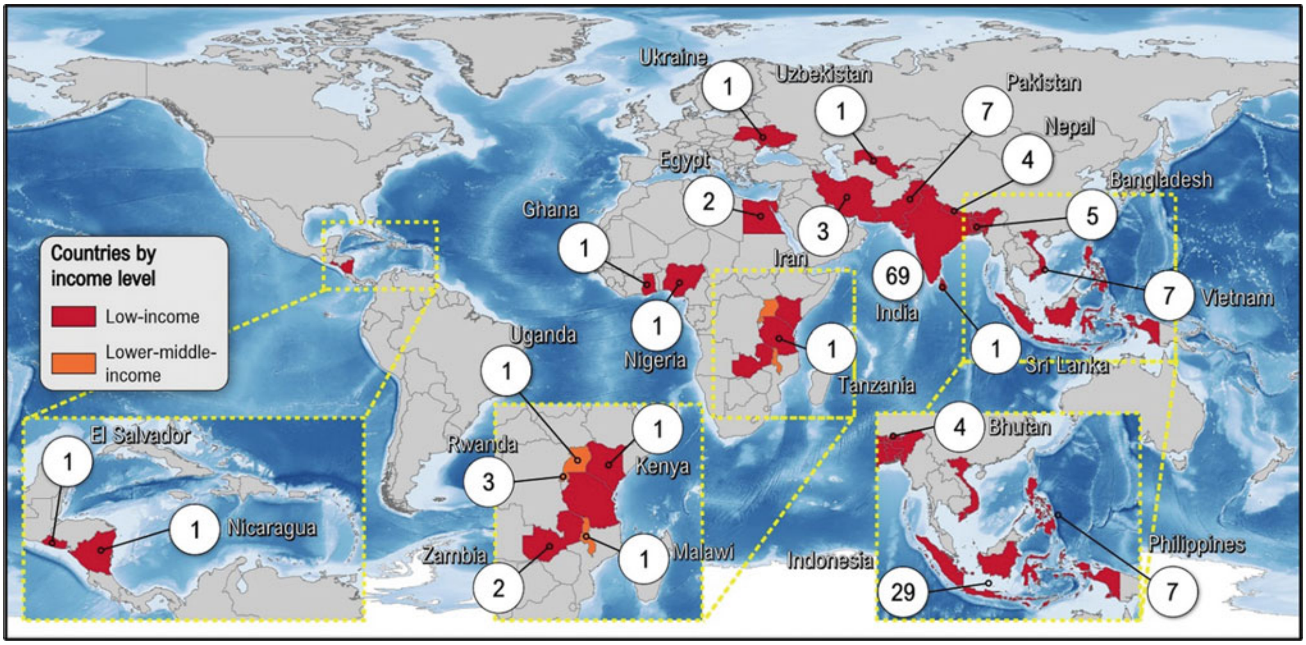

Fig. 8 Countries of the research and academic institutions to which the authors of the analysed publications are affiliated. The number inside the circle represents the number of publications per country

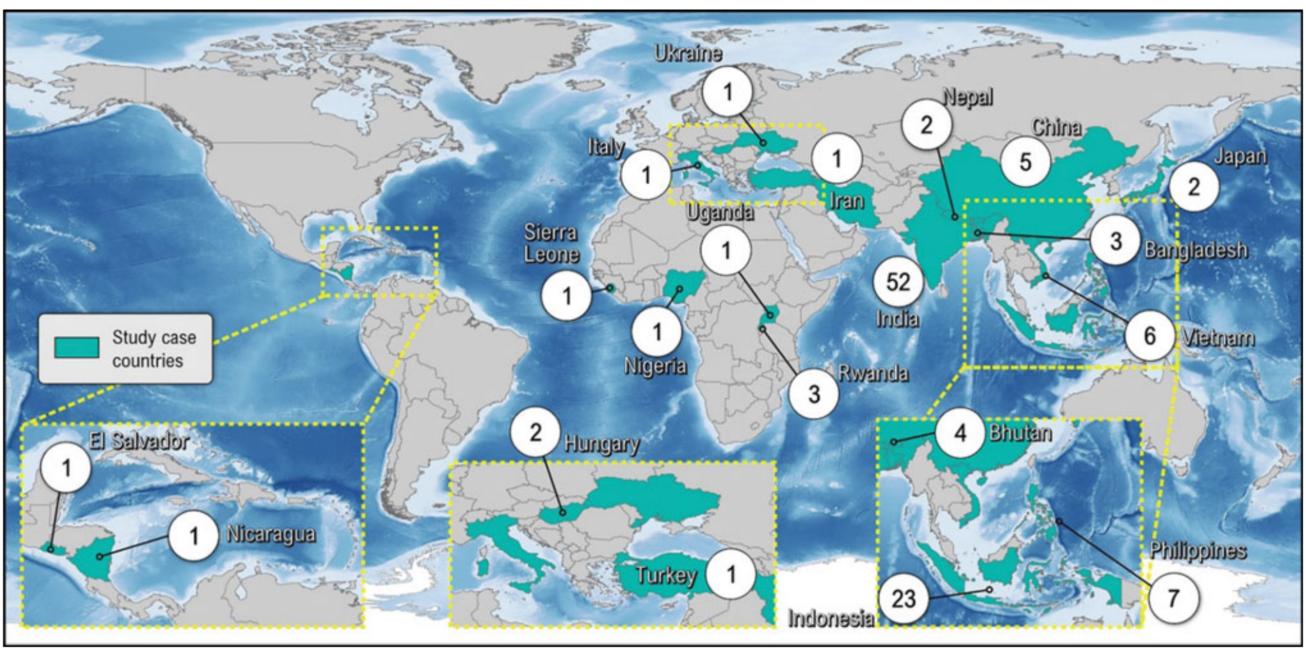

Fig. 9 Study case countries reported in the analysed publications. The number inside the circle represents the number of study cases per country, including those which are not categorised as LICs and MICs

In a comprehensive study, Thapa and Adhikari (2019) led to the development of a LEWS in the central Nepal Himalaya region. This comprised extensometers, soil moisture sensors, rain gauge stations, and solar panels. The protocol involves transmission of data generated through a Global System for Mobile Communications (GSM) network to responsible organizations in real-time to issue the warning to local residents. Successful experiences with the implementation of the LEWS included saving 495 people from 117 households in August 2018. However, they also found out that landslide monitoring, and dissemination of warnings remains a complex process where a convergence of technical and communications skills is required to guarantee successful practise.

In the context of the Development and Deployment of Early Warning System for deployment of the monitoring system in ten different sites across the Philippine Deep-Seated Catastrophic Landslides and Slope Failures (DEWS-L) program of the University of the Philippines and the Philippines Institute of Volcanology and Seismology (PHIVOLCS), Marciano and colleagues (2014) set up a series of enhancements in the design of an alternative instrumentation for monitoring deep-seated landslides using tilt and soil moisture sensors.

Experiences derived from the deployment of the LEWS in ten different sites across the Philippines highlighted the need to creating awareness in the community and fostering active community involvement in understanding the risks of landslides. For this reason, engaging the community and other stakeholders was identified as one of the main challenges of effective community and technology based LEWSs. Training members of communities at risk was conducted to establish a Local Landslide Monitoring Committee (LLMC). Integrated by volunteers, the LLMC acquired basic knowledge and skills to accurately monitor, map and survey the visual indicators of ground movement, and to maintain the continuous operation of the sensor columns (Marciano et al. 2014).

The SATREPS project is an example of a regional cooperation project between Japanese and Vietnamese researchers which was developed in a way that can be considered as key stepping stone towards disaster prevention and reduction in Vietnam in the future. Major contributions included development of human resources, research equipment and development of a standard system of landslide investigation, monitoring, forecast and LEWS, which was implemented based on real-time landslide monitoring in the Hai Van Station landslide (Tien et al. 2017).

4.2 Hazard Analysis for LEWSs

Examining the content of the analysed publications, it emerged that although the title and abstract reference LEWSs, 53% of the publications focused on diverse perspectives of hazard analysis that were considered significant for posterior development of warning systems. This category included papers regarding the following topics: landslide field monitoring, laboratory strength tests and experiments, determination of landslide rainfall thresholds, development of landslide susceptibility maps, numerical simulations, modelling, geological and geomorphological approaches, characterization of exposed buildings, artificial neural networks, and neuro-fuzzy approaches for prediction of landslides. Additional strategies involved the use of slope mass rating, hydrological-geotechnical and factor of safety modelling, satellite-based rainfall estimation, soil moisture changes and deformations in slope surface by means of elastic wave propagation in soil, high resolution SPOT panchromatic and airborne images for landslide recognition and digital terrain modelling in GIS platforms.

4.3 Technical Developments for Potential LEWSs

To summarize the evidence emerging from the literature review about the reported technical developments for the potential developments of LEWSs, the following insights can be listed: learning adaptive neuro-fuzzy inference systems, application of sliding force remote monitoring systems as a diagnostic tool for a rapid assessment of open pit slope stability and prediction of landslides, electrical resistivity techniques, cellular mobile infrastructure for using geo-spatial data, monitoring based on micro-electro-mechanical systems, landslide detection system based on flat coil and coil sensors, coupling of landslide simulation models and a hydrological models, and very importantly, utilisation of hazard and risk information for spatial planning and zoning, indicating areas where landslide hazard is too high for planning future developments.

4.4 Models and Prototypes for LEWSs

Indeed, from the systematic literature review concerning LEWSs, it was observed that the spread of models and prototypes in LICs and MICs have some shared features. These included the efforts to develop cheap LEWS, applications for smartphone devices, dynamic web-based alert systems, machine learning algorithms for wireless sensor networks, the use of Wireless Sensor Networks, electrical resistivity tomography techniques, field monitoring data and risk evaluation model using fibre-optic based transducers, tools for improving connectivity. Additionally, great significance was given to the promotion of proven and innovatory techniques and technologies of early warning systems based on monitoring ground surface deformation using Synthetic Aperture Radar, artificial neural networks based on rainfall forecasting models, simple monitoring systems and using micro electromechanical systems concerning tilt and volumetric water content sensors. What is more, the extensive use of social media users as potential contributors to landslide hazard monitoring and as providers of additional support for landslide prediction and decision making was also considered.

4.5 Implementation of LEWSs: An Urgent Task

The need to implement LEWSs has been regarded as an urgent endeavour. To this regard, five of the examined publications were concerned with diverse perspectives on this matter. In Bangladesh, for instance, interviews on the methods local-level institutions follow to mitigate landslide hazards in terms of structural and non-structural measures were sought. Since structural measures are insufficient due to the financial constraints, mechanisms of sustainable hillslope management and LEWSs were suggested (Sultana and Tan 2021). Likewise, based on a quantitative estimation of elements at risk to landslides, the implementation of LEWSs in India was put forward (Sajinkumar et al. 2014). Similarly in Indonesia, a series of interviews were focused on analysing awareness and preparedness of primary stakeholders (i.e., government and non-departmental government institutions) to mitigate landslide disaster risk and disasters (Susanto et al. 2018). In a similar manner, in Japan, attention has been given to LEWSs as the major non-structural measures which are based on judgment and action of local people. The latter being highly influenced by information provided by mass media (Fujita and Shaw 2014).

4.6 Scientific Collaborations

It can be said that there needs to be more integrated action leading to successful practice concerning the implementation of the Sendai framework, which includes "to promote and improve dialogue and cooperation among scientific and technological communities, other relevant stakeholders and policymakers in order to facilitate a science policy interface for effective decision-making in disaster risk management" and "to enhance the scientific and technical work on disaster risk reduction and its mobilization through the coordination of existing networks and scientific research institutions at all levels and in all regions" (UNISDR 2015).

In the same spirit, through the systematic review of literature it was possible to identify that international scientific cooperation enabled numerous collaborations between LICs and MICs and other countries to understand and manage landslide disaster risk, and most importantly to advance the research on LEWSs and their potential implementation (Fig. 10). Such collaborative efforts can build trust and facilitate progress in landslide disaster risk reduction.

Therefore, indicators of future progress on landslide disaster research, should include number of LICs and MICs with implemented LEWSs, number of long-term scientific collaborations, and number of people at risk who benefited from their use.

5 Discussion

The analysed publications provided an overview of the existing literature on the different dimensions of LEWSs in LICs and MICs. This was useful to highlight the key gaps in the published studies and allowed the possibility to offer suggestions for future research.

In the international arena, scientific cooperation has enabled numerous collaborations in different fields among LICs and MICs and other countries. One of the thirteen guiding principles of the Sendai Framework for DRR has pointed out that (the so-called) "developing countries, in particular the least developed countries, small island developing States, landlocked developing countries and African countries, as well as middle-income and other countries facing specific disaster risk challenges, need adequate, sustainable and timely provision of support, including through finance, technology transfer and capacity building from developed countries and partners tailored to their needs and priorities, as identified by them" (UNISDR 2015). However, in the area of LEWSs, attempts have not been largely focussed yet on such endeavour.

The majority of efforts continue to be centred in hazard perspectives. This was clearly demonstrated by the large number of publications on hazard analysis, technical developments and models and prototypes for the potential implementation of LEWSs. Contrastingly, only five articles reported the actual successful implementation of LEWSs in LICs and MICs, and very few considered the diverse dimensions of community participation as a key element.

Consequently, as one of the main challenges ahead argued here is that LEWSs should not focus on people's response to purely technical systems in terms of hazards, but rather rely on the participation of communities as a fundamental component of Early Warning Articulated Systems (EWAS). This of course requires an understanding of landslide disaster risk by the communities themselves and by the other relevant DRR stakeholders. A more substantial approach to the significance of EWAS can be found in Alcántara-Ayala and Oliver-Smith (2017, 2019).

A full discussion of the existing obstacles for the establishment and operationalisation of LEWSs in LICs and MICs at different scales lies beyond the scope of this study. However, it would be a vital consideration in any future regional and/or international comprehensive strategies or frameworks, to consider difficulties such as high prices of most devices; loss of property, and loss of valuable data derived from vandalism and insecurity conditions; inaccessibility of remote mountain sites; frequent power interruptions; absence of interest of local authorities to collaborate with the scientific community; bureaucratic procedures to

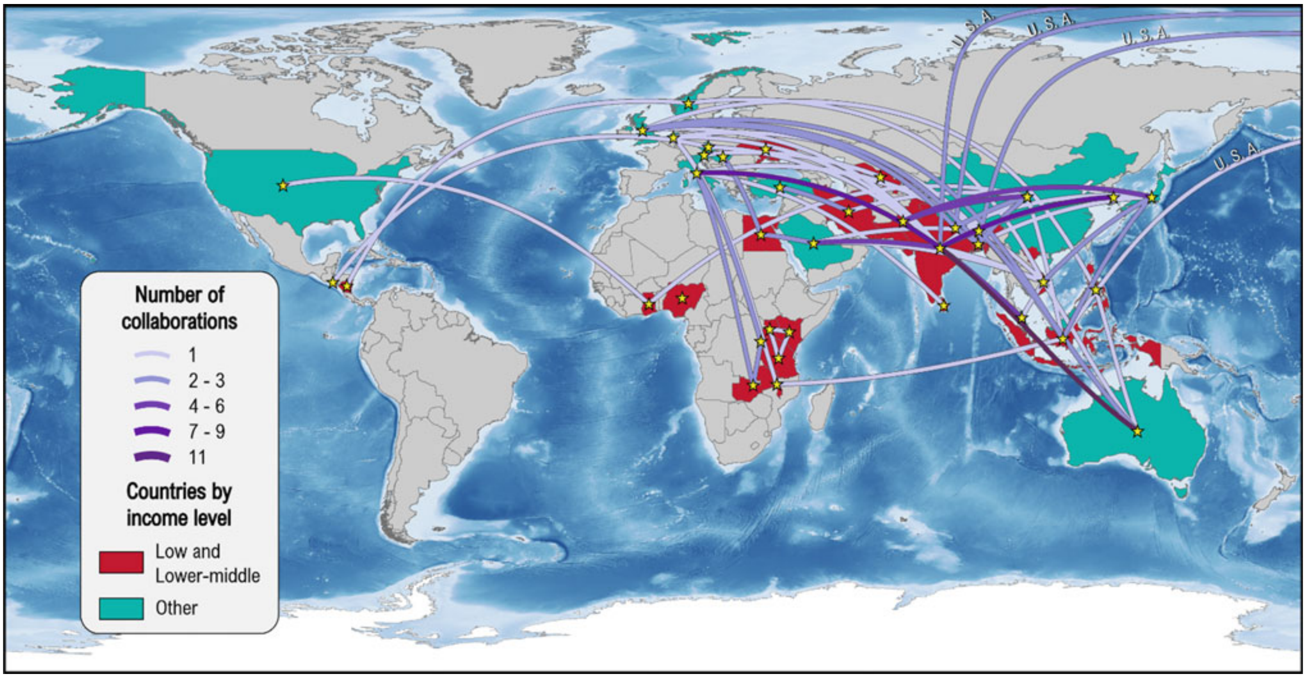

Fig. 10 Regional and international collaborations among LICs and MICs and other countries

obtain permits; lack of information databases regarding hazards, vulnerability and exposure; limited or non-existent technical capacities at national and local scales; lack of sustained financial resources for the design, development, implementation and maintenance of LEWSs; lack of political will and sustained political support; and high expectations and failure to provide the required means.

Certainly, lack of human and financial resources poses special challenges to science, DRR and particularly to the implementation of LEWSs in LICs and MICs. Tackling these challenges effectively requires modern, innovative, and integrated approaches based on sharing financial resources in the best possible way to bridge the gap between science, policy making and practice.

Last, but not least, the setting up of LEWSs aimed at reducing disaster risk in LICs and MICs requires actions from the entire society to support the development of adequate strategies of disaster risk communication, a challenge that should provide some orientations to design appropriate and effective integrated measures in favour of the communities at risk.

6 Concluding Remarks

Derived from the impact of large disasters, especially after the tsunami of Southeast Asia in 2004, particular attention has been given to the establishment and/or evaluation of EWS at international and national levels.

Since 1991, a considerable amount of literature has been published on LEWSs, and although studies have recognised the significance of LEWSs around the world (Guzzetti et al. 2020), these studies have been concentrated to a major extent on Upper middle-and High-income countries.

This systematic literature analysis provided an important opportunity to advance the understanding of the use of LEWSs in LICs and MICs and it is also hoped that the findings could make an important contribution to the field of policy formulation and practice on landslide disaster risk reduction.

The literature to date provides interesting insights into the way that research on LEWSs has been gradually evolved through time from engineered perspectives into more community-based approaches that can be used for solving pressing societal issues. However, such advancement in LICs and MICs has either taken place at a very slow rate or has not properly been reflected in peer reviewed literature. Beyond analytical lenses, what is clear is that landslide disasters continue to occur around the globe and consequences are of greater adverse impact in countries of lower income.

Up to now, the use of LEWSs in LICs and MICs has been limited due to diverse restraints. Prominent among these is the high costs of equipment, their limited usability in the long-term associated with vandalism and insecurity, and lack of sustained financial and human resources. The absence of human resources also suggests that there are no structured strategies for capacity building in the medium and long terms.

Over and above all, the role of communities at risk has been often neglected in the implementation of LEWSs. This aspect is not less important than technical challenges, but a core ingredient in the design and implementation of efficient LEWSs.

The demand for effective regional and international collaborations with the DRR scientific community in terms of LEWSs advancement is out there, and it is growing. Certainly, this is a critical time to focus on the implementation of LEWSs in LICs and MICs.

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