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Global research patterns on earthquake-induced landslides: A bibliometric analysis

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Abstract: Earthquake-induced landslides represent a critical global challenge, contributing significantly to secondary hazards associated with seismic activity. This study presents a comprehensive bibliometric analysis of earthquake-induced landslides research to highlight dominant trends, research interests, and future directions. Literature published between 2000 and 2024 was retrieved from the Web of Science (WOS) database using search terms "earthquake-induced landslides" and "coseismic landslides," yielding 1,090 relevant publications. Bibliometric analysis was conducted using VOSviewer, focusing on co-authorship networks, citations, keyword co-occurrence, and publication sources. The results indicate that the keywords 'landslides and earthquakes' exhibited the highest frequency and total link strength, with strong associations to 'earthquake chain hazards' and 'hazard and risk assessment'. Landslides emerged as the leading journal with 85 publications and ranked second in total citations. Chong Xu was identified as the most prolific author, contributing 70 articles, followed by Qiang Xu and Xuanmei Fan, both with high citation impacts. Institutional analysis highlighted Chengdu University of Technology as the most influential organization with 35 articles. Overall, bibliometric trends reveal a sustained emphasis on susceptibility, hazard, and risk assessment of earthquake-induced landslides and mitigation strategies. Future research is expected to expand rapidly, underscoring the importance of interdisciplinary frameworks and international collaboration to enhance resilience to earthquake-induced geohazards.

Keywords: Earthquake-induced landslides, coseismic landslides, Web of Science, VOSviewer, bibliometric trends

Abstrak: Tanah runtuh akibat gempa bumi merupakan cabaran global yang signifikan dan menyumbang secara langsung kepada pembentukan bahaya sekunder yang berkaitan dengan aktiviti seismik. Kajian ini membentangkan analisis bibliometrik yang komprehensif terhadap penyelidikan tanah runtuh akibat gempa bumi bagi mengenal pasti corak perkembangan, kecenderungan penyelidikan, serta hala tuju masa hadapan dalam bidang ini. Literatur yang diterbitkan antara tahun 2000 hingga 2024 telah diperoleh daripada pangkalan data Web of Science (WOS) menggunakan kata kunci *earthquake-induced landslides* dan *coseismic landslides*, menghasilkan sebanyak 1,090 penerbitan yang relevan. Analisis bibliometrik dilaksanakan menggunakan perisian VOSviewer dengan menumpukan kepada rangkaian kerjasama penulisan, analisis sitasi, kewujudan bersama kata kunci, dan sumber penerbitan. Hasil kajian menunjukkan bahawa kata kunci "*landslides and earthquakes*" mencatatkan kekerapan dan kekuatan hubungan tertinggi, serta mempunyai kaitan rapat dengan "*earthquake chain hazards*" dan "*hazard and risk assessment*". Jurnal Landslides dikenal pasti sebagai jurnal paling dominan dari segi bilangan penerbitan dan jumlah sitasi. Chong Xu muncul sebagai penyumbang paling prolifik, diikuti oleh Qiang Xu dan Xuanmei Fan yang turut menunjukkan impak sitasi yang tinggi. Analisis institusi menonjolkan Chengdu University of Technology sebagai institusi paling berpengaruh dalam bidang ini. Secara keseluruhannya, dapatan bibliometrik memperlihatkan penekanan berterusan terhadap penilaian kerentanan, bahaya dan risiko tanah runtuh akibat gempa bumi, serta pembangunan strategi mitigasi. Penyelidikan masa hadapan dijangka berkembang secara pesat, menekankan keperluan kerangka antara disiplin dan kerjasama antarabangsa bagi meningkatkan daya tahan terhadap bahaya geologi berkaitan gempa bumi.

Kata kunci: Tanah runtuh akibat gempa bumi, *coseismic landslides*, Web of Science, VOSviewer, corak perkembangan bibliometrik

INTRODUCTION

Earthquakes are generated by the sudden release of accumulated stress within the Earth's crust, and strong events can produce widespread ground deformation and slope instability. In mountainous areas, seismic shaking may trigger numerous slope failures, commonly referred to as earthquake-induced landslides (EQILs) (Umar *et al*., 2014; Fan *et al*., 2019). These landslides can inflict

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severe economic losses and cause widespread human casualties through the destruction of buildings, critical infrastructure, and natural environments. In some cases, EQILs also obstruct rivers, forming dammed lakes that pose significant risks of outburst floods and debris flows, threatening downstream communities and properties (Cui *et al*., 2009; Alfaro *et al*., 2012; Mehmood *et al*., 2021). The spatial distribution of EQILs is controlled by several interacting factors, including seismic intensity, terrain morphology, lithology, tectonic setting, and human modification of slopes (Meunier *et al*., 2008; Korup & Stolle, 2014; Fan *et al*., 2018). Because these controls vary considerably from one region to another, predicting post-earthquake landslide-prone areas remains challenging (Korup & Stolle, 2014; Parker *et al*., 2015). In recent decades, numerous models, both physical- and numerical-based, have been developed for assessing landslide susceptibility and identifying potential hazard zones (Romeo, 2000; Mao *et al*., 2019; Song *et al*., 2019; Yiğit, 2020; Mehmood *et al*., 2023). These models seek to enhance our understanding of how factors such as local geology, slope inclination, terrain features, and anthropogenic modifications contribute to the likelihood of slope failures during seismic events.

Historically, EQILs are reported back in 1789 BC in China and 373 BC in Greece, highlighting their centuries-old influence on human settlements and infrastructure (Keefer, 1994). More recent events, including the 1999 Chi-Chi earthquake in Taiwan, the 2005 Kashmir earthquake, the 2008 Wenchuan earthquake in China, the 2010 Haiti earthquake, and the 2023 Kahramanmaraş earthquake, have demonstrated the devastating consequences of EQILs. These events triggered thousands of landslides, causing major loss of life and long-term socio-economic disruption (Weissel & Stark, 2001; Chigira *et al*., 2002; Gorum *et al*., 2011, 2014; Basharat *et al*., 2014; Kazmi *et al*., 2014). For instance, the 2005 Kashmir earthquake saw landslides causing 30% of the total fatalities, while the Wenchuan earthquake-induced landslides resulted in over 20,000 deaths (Dunning *et al*., 2007; Tang *et al*., 2011). Additionally, the Kahramanmaraş earthquake triggered more than 3,000 landslides with numerous casualties, highlighting the persistent nature of these threats (Mehmood *et al*., 2026). The aftermath of EQILs can extend beyond immediate destruction, causing sustained increases in soil erosion, sediment transport, and geomorphological changes in the impacted regions (Kazuo *et al*., 2009; Hovius *et al*., 2011; Tang *et al*., 2011; Parkash, 2013). Such changes can persist for years, altering landscape stability and increasing vulnerability to future hazards (Parker *et al*., 2011). Understanding and predicting the spatial distribution of EQILs is thus critical for effective disaster mitigation and the protection of human life and property (Gorum *et al*., 2011; Parker *et al*., 2015).

Bibliometric analysis has emerged as a prominent quantitative review method that leverages statistical analysis, data mining, and mathematical approaches to reveal evolving trends within specific scientific domains (Donthu *et al*., 2021). This approach is being increasingly adopted across a range of research areas (Tamala *et al*., 2022) and is now regarded as a contemporary means of evaluating scholarly work (Cui *et al*., 2022). By examining publications based on variables such as publication year, keywords, authorship, and country of origin, bibliometric analysis effectively identifies, explains, and classifies research outcomes, thereby aiding in the detection of research gaps and trends in a systematic manner (Zhang *et al*., 2020; Yang *et al*., 2024). The data for such analyses are typically derived from major citation databases like Web of Science and Scopus. Although multidisciplinary research groups have extensively studied earthquake-induced landslides, a comprehensive bibliometric analysis of this topic has yet to be undertaken. Numerous studies have been published on predicting and analyzing earthquake-induced landslides, but no bibliometric analysis is available in the literature. Therefore, bibliometric analysis provides a suitable framework for systematically evaluating the development, contributors, collaboration patterns, and thematic evolution of EQIL research. This quantitative method employs statistical and data mining techniques to identify trends, patterns, and gaps in scientific literature. Bibliometric analysis facilitates a structured understanding of research developments by categorizing publications according to variables such as publication year, keywords, authorship, and geographic origin. Data for such analyses is commonly sourced from established citation databases like Web of Science (WOS) and Scopus.

The analysed literature shows strong growth in earthquake-induced landslide research, but its geographic distribution remains uneven. Publications are concentrated mainly in China, the USA, Japan, Italy, Taiwan, and selected European countries, whereas several seismically active and landslide-prone regions remain comparatively underrepresented. These include parts of Central Asia, the Hindu Kush-Karakoram-Himalaya region outside the most frequently studied areas, the Middle East, Central and South America, Central and Eastern Africa, Southeast Asia, and Eastern Europe. This imbalance is important because many of these regions experience high seismicity, steep terrain, rapid land-use change, and limited monitoring infrastructure. The keyword and thematic results also suggest that some subtopics remain less developed than susceptibility and hazard assessment, including post-seismic landslide reactivation, earthquake-triggered debris flows, landslide-dammed lake formation and breaching, long-term sediment cascading effects, real-time monitoring and early warning, uncertainty quantification in predictive models, and socio-economic vulnerability assessment.

Addressing these geographic and thematic gaps would improve the global representativeness of earthquake-induced landslide research and strengthen its relevance for disaster-risk reduction. Despite the significant body of work exploring EQILs and their influencing factors, a comprehensive bibliometric analysis on this topic has not been conducted. Such an analysis is essential for summarizing the evolution of research, identifying leading contributors, and guiding future studies. This study presents a bibliometric analysis of publications in from 2000 to 2023 on earthquake-induced landslides using "coseismic landslides" as an additional search term in the Web of Science database. The search focuses on publication trends, author collaborations, geographic distribution, journal impact, and keyword mapping in the WOS database. The findings aim to provide valuable insights for researchers, policymakers, and stakeholders invested in advancing the field of earthquake-triggered landslide studies.

METHODOLOGY

A comprehensive bibliometric analysis was conducted to examine publication growth, leading contributors, dominant journals, and significant authors in earthquake-induced landslide research. In this study, "earthquake-induced landslides" is used as the main term, while "coseismic landslides" is retained as an additional search term because it is commonly used in the literature. Our methodology offers an extensive overview of authorship, country-level contributions, institutional affiliations, prevalent keywords, and collaborative networks, thereby enhancing the global literature in this field (Ahmad *et al*., 2021; Yang *et al*., 2024). To carry out bibliometric analysis, we utilized the WoS Core Collection (https://www.webofscience.com/WOS), a widely respected database that indexes a broad array of sources such as journals, books, reviews, and conference proceedings. This database is renowned for its comprehensive citation records and frequent updates, making it a trusted tool for bibliometric research (Liaqat *et al*., 2023; Rasera *et al*., 2023).

For this research, we searched the WOS database to retrieve documents related to earthquake-induced landslides, using "coseismic landslides" as an additional search term. The search covered the period from January 1, 2000, to January 1, 2024, and was limited to journal articles, books, review papers, and conference proceedings. It was conducted in the "Topic" field using the keywords "earthquake-induced landslides" OR "coseismic landslides," which resulted in 1,090 publications. These records were extracted on July 01, 2024, to ensure consistency and mitigate the effects of ongoing database updates. The data was collected in tab-delimited format for further processing. We employed VOSviewer (version 1.6.20) for data analysis. VOSviewer, developed by Leiden University, is a robust tool for bibliometric visualization and analysis that supports clustering, tagging, and density views (Van Eck & Waltman, 2010). The software's strong text-mining capabilities allow it to extract significant terms and visualize co-occurrence networks, making it popular in bibliometric studies across multiple disciplines (Lv *et al*., 2021; Liaqat *et al*., 2023; Rasera *et al*., 2023).

The analysis began with a basic examination of publication trends directly within the WOS interface. Advanced analyses, including co-authorship patterns, keyword co-occurrences, and co-citation networks, were then performed using VOSviewer. Network maps generated by VOSviewer consist of nodes representing entities such as authors, institutions, countries, and keywords. The node size reflects the frequency of occurrences, while the links indicate relationships between these entities; thicker links denote stronger connections. VOSviewer's visualization capabilities facilitated the identification of high-frequency keywords and the exploration of research clusters, contributing valuable insights into research dynamics and collaboration within the field of earthquake-induced and coseismic landslide studies.

RESULTS

Publication trends

The earliest Web of Science record identified in the broader search was Wachs and Levitte's 1981 article, "Earthquake-Induced Landslides in the Galilee" (Wachs & Levitte, 1981). This publication is recognized as the foundational work in the study of this phenomenon. During the initial years of research, spanning from 1981 to 1999, the literature on this topic was relatively sparse, with only a few documents available. Figure 1 presents the annual number of articles published in this field from 1981 to 1999, illustrating the progression of scholarly activity over time. The quantitative bibliometric analysis in this study was restricted to publications from 2000 to 2024, as stated in the methodology. During the analyzed period, a total of 1,090 publications related to

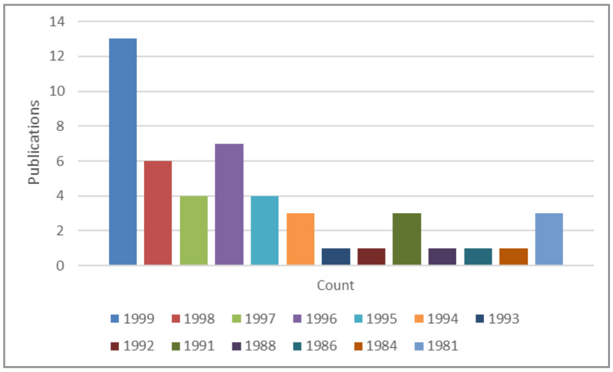

Figure 1: Annual publication trends in earthquake-induced landslide research WOS database (1981-1999).

earthquake-induced landslides were identified in the Web of Science database for the period 2000 to 2024, using "coseismic landslides" as an additional search term. The results show a clear increase in research output during the 21st century, reflecting growing academic interest in earthquake-triggered slope failures, susceptibility assessment, hazard evaluation, and related multi-hazard processes. The annual publication trend from 2000 to 2024 is presented in Figure 2, illustrating the progressive growth of scholarly activity in this field. These publications comprised 875 (80.3%) original research articles, 154 (14.13%) conference papers, 48 (4.4%) book chapters, and 13 review articles. The highest output was recorded in 2023, with 114 publications, closely followed by 113 publications in 2022 (Figure 2). English was the predominant language for these works, accounting for 970 publications (89%), while other languages included Chinese (115), Spanish (5), French (1), and Korean (1). Notably, 330 (28.1%) of the total publications were open-access, with 182 (16%) published under the gold open-access model.

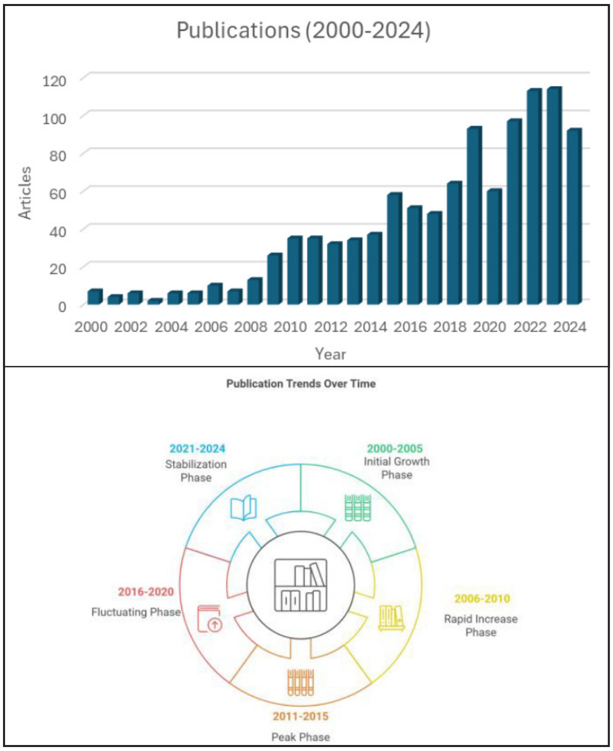

Figure 2: Annual publications trends in earthquake-induced landslides between 2000 and 2024.

Keyword network analysis

Figure 3 presents a visualized network of keywords with a minimum occurrence threshold of eight, generated

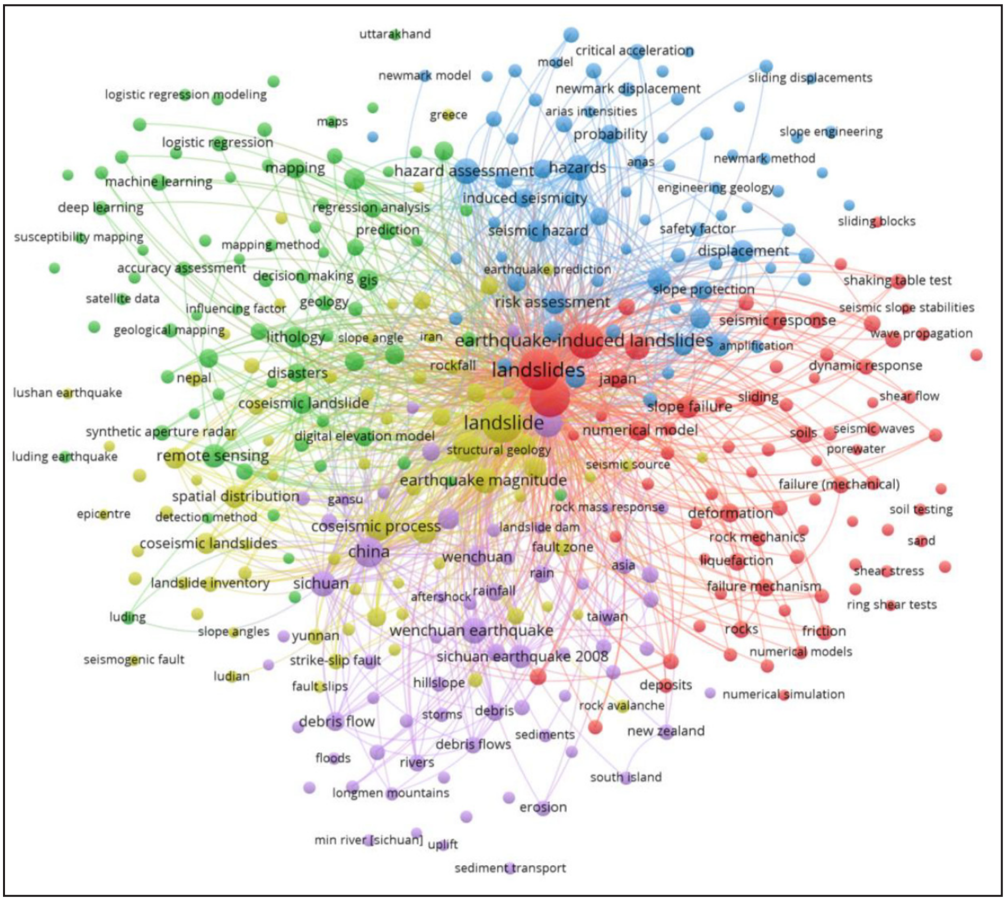

Figure 3: Keyword co-occurrence network for publications on earthquake-induced landslides, with "coseismic landslides" included as a related search term. Node size represents keyword frequency, while links indicate co-occurrence relationships among keywords.

using VOSviewer software. The network comprises five clusters, each represented by a different color, illustrating the thematic focus and interconnections within earthquake-induced landslide studies. The largest cluster, highlighted in red and consisting of 80 items, includes key terms such as Wenchuan earthquake, catastrophic landslide, earthquake-induced landslides, hazard assessment, and coseismic landslides. This cluster emphasizes the strong association between earthquake-induced landslides and hazard assessment. The second major cluster, depicted in yellow, features keywords like accuracy assessment, controlling factors, damage detection, and coseismic landslide, pointing to research themes related to the detection and accuracy of hazard assessments under seismic event conditions.

The most common keywords in the data set were landslides and earthquake-induced landslides, with accumulated connection strengths of 373 and 368, respectively. Other prominent keywords included earthquake events and coseismic processes, which had link strengths of 347 and 333, respectively (Figure 3). This analysis demonstrates central themes and interconnected areas of research, providing insight into the main focus areas and collaborative potential within the field.

Publication and citation overview

Table 1 highlights the thirty of the most cited documents focused on earthquake-induced or coseismic landslides. The majority of these influential publications are original research articles, supplemented by conference papers and book chapters. The average citation count among the top thirty documents was 315.63, indicating their substantial influence within the field. Jibson *et al.* (2000) was the most cited publication, with 659 citations, followed by Fan *et al.* (2019), with 604 citations. Overall, earthquake-induced landslide research was distributed across 132 journals, of which 40 published at least five documents. The top ten journals collectively published 379 articles, representing 34.7% of the total output in the field. The journal 'Landslides' leads this group, with 85 articles published (7.8% of the total publications) and an impressive impact factor of 5.8. Additionally, 'Landslides' is the most frequently cited journal in the field, accumulating 3,755 citations. Following closely is Engineering Geology, which published 75 articles and received a cumulative citation count of 6,106. Geomorphology ranks third, contributing 41 articles and earning 2,736 citations (Figure 4). These leading journals indicate key dissemination channels for earthquake-induced landslide research.

Leading contributors and geographic trends

Table 2 outlines the top ten countries, authors, and institutions contributing to research on earthquake-induced landslides. Xuanmei Fan from the State Key Laboratory of Geohazard Prevention and Geoenvironment Protection (SKLGP) in China, in collaboration with The Faculty of Geo-Information Science and Earth Observation (ITC) at the University of Twente in the Netherlands, has been identified as the most frequently cited author. Fan's work, comprising 28 publications, has been cited 2,683 times. The University of Twente has also made a significant impact, garnering 783 citations across five key articles.

Geographically, China leads in the number of cited articles, with 546 (49.7%) articles that have collectively received 12,410 citations. The USA and Japan follow, each contributing 134 (16.8%) articles with citation counts of 8,320 and 4,570, respectively (Figure 5). This data underscores the central role of China as a dominant force in the field, both in terms of publication volume and citation impact, with significant contributions also from other leading research hubs. The research in this field has received substantial financial support from various organizations in China (Figure 6), further highlighting the country's pivotal role in advancing this area of study.

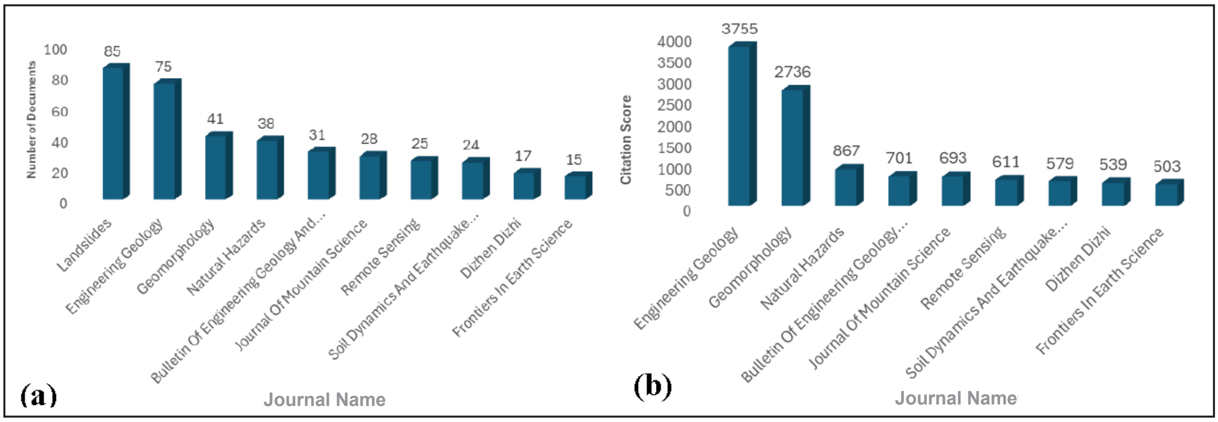

Figure 4: (a) Leading journals in earthquake-induced landslide research: (a) journals with the highest number of publications and (b) journals with the highest citation counts.

Table 1: Thirty most cited publications on earthquake-induced landslide research identified from the WOS database.

Rank	Article Title	Authors	Journal	Affiliated Country	Citations Score	Publishing Year
1	A method for producing digital probabilistic seismic landslide hazard maps	(Jibson *et al*., 2000)	Engineering Geology	United States	659	2000
2	Earthquake-induced chains of geologic hazards: Patterns, mechanisms, and impacts	(Fan *et al*., 2019)	Reviews of Geophysics	China	604	2019
3	Investigating landslides caused by earthquakes - A historical review	Keefer D.K., 2002	Surveys in Geophysics	United States	600	2002
4	Regression models for estimating coseismic landslide displacement	Jibson R.W., 2007	Engineering Geology	United States	556	2007
5	Distribution pattern of earthquake-induced landslides triggered by the 12 May 2008 Wenchuan earthquake	(Gorum *et al*., 2011)	Geomorphology	Netherlands	537	2011
6	Earthquake-triggered increase in sediment delivery from an active mountain belt	(Dadson *et al*., 2004)	Geology	Taiwan	464	2004
7	Mass wasting triggered by the 2008 Wenchuan earthquake is greater than orogenic growth	(Parker *et al*., 2011)	Nature Geoscience	United Kingdom	450	2011
8	Topographic site effects and the location of earthquake induced landslides	(Meunier *et al*., 2008)	Earth and Planetary Science Letters	United Kingdom	410	2008
9	Statistical analysis of an earthquake-induced landslide distribution - The 1989 Loma Prieta, California event	Keefer D.K., 2000	Engineering Geology	United States	369	2000
10	The 12 May Wenchuan earthquake-induced landslide lakes: Distribution and preliminary risk evaluation	(Cui *et al*., 2009)	Landslides	China	360	2009
11	The size, distribution, and mobility of landslides caused by the 2015 Mw7.8 Gorkha earthquake, Nepal	(Roback *et al*., 2018)	Geomorphology	United States	319	2018
12	Earthquake induced landslide susceptibility mapping using an integrated ensemble frequency ratio and logistic regression models in West Sumatera Province, Indonesia	(Umar *et al*., 2014)	Catena	Malaysia	289	2014
13	Seismic slope behavior in a large-scale shaking table model test	Lin M.-L.; Wang K.-L., 2006	Engineering Geology	Taiwan	285	2006
14	Evaluation of factors controlling earthquake-induced landslides caused by Chi-Chi earthquake and comparison with the Northridge and Loma Prieta events	Khazai B.; Sitar N., 2004	Engineering Geology	United States	273	2004
15	Impacts of the Chi-Chi earthquake on subsequent rainfall-induced landslides in central Taiwan	(Lin *et al*., 2006)	Engineering Geology	Taiwan	267	2006
16	Undrained dynamic-loading ring-shear apparatus and its application to landslide dynamics	(Sassa *et al*., 2004)	Landslides	Japan	266	2004

Table 1: Continued.

Rank	Article Title	Authors	Journal	Affiliated Country	Citations Score	Publishing Year
17	Coseismic landslides triggered by the 8th August 2017 M s 7.0 Jiuzhaigou earthquake (Sichuan, China): factors controlling their spatial distribution and implications for the seismogenic blind fault identification	(Fan *et al*., 2018)	Landslides	China	225	2018
18	A systematic review of landslide probability mapping using logistic regression	(Budimir *et al*., 2015)	Landslides	United Kingdom	221	2015
19	Seismically induced landslide displacements: A predictive model	Romeo R., 2000	Engineering Geology	Italy	220	2000
20	The characteristics and failure mechanism of the largest landslide triggered by the Wenchuan earthquake, May 12, 2008, China	(Huang *et al*., 2012)	Landslides	China	219	2012
21	Surface rupture of the 2005 Kashmir, Pakistan, earthquake and its active tectonic implications	(Kaneda *et al*., 2008)	Bulletin of the Seismological Society of America	Japan	216	2008
22	Landslides induced by the Wenchuan earthquake and the subsequent strong rainfall event: A case study in the Beichuan area of China	(Tang *et al*., 2011)	Engineering Geology	China	209	2011
23	Natural and human-induced landsliding in the Garhwal Himalaya of Northern India	(Barnard *et al*., 2001)	Geomorphology	United States	208	2001
24	Statistical approach to earthquake-induced landslide susceptibility	(Lee *et al*., 2008)	Engineering Geology	Taiwan	203	2008
25	Earthquake-induced landslides in Central America	(Bommer; Rodríguez, 2002)	Engineering Geology	United Kingdom	185	2002
26	Presentation and analysis of a worldwide database of earthquake-induced landslide inventories	(Tanyaş *et al*., 2017)	Journal of Geophysical Research: Earth Surface	Netherlands	182	2017
27	Database and spatial distribution of landslides triggered by the Lushan, China Mw 6.6 earthquake of 20 April 2013	(Xu *et al*., 2015)	Geomorphology	China	180	2015
28	Effects of near-fault seismic loadings on run-out of large-scale landslide: A case study	(Zhang *et al*., 2013)	Engineering Geology	Japan	170	2013
29	Modeling typhoon- and earthquake-induced landslides in a mountainous watershed using logistic regression	(Chang *et al*., 2007)	Geomorphology	Taiwan	164	2007
30	Toward the next generation of research on earthquake-induced landslides: Current issues and future challenges	(Wasowski *et al*., 2011)	Engineering Geology	Italy	159	2011

Table 2: A compilation of countries, international organizations, and authors contributing to publications on earthquake-induced and coseismic landslides.

Country Name	Publications	Citations
China	542	12410
USA	183	8320
Japan	174	4570
Italy	137	3710
Taiwan	80	3141
England	72	3050
Greece	53	2032
India	53	1590
France	49	1285
New Zealand	44	1220
Organization		
SKLGP, China	35	763
National Institute of Natural Hazards, China	32	318
Key Laboratory of Compound and Chained Natural Hazards, Beijing, China	24	231
University of Chinese Academy of Sciences, Beijing, China	23	542
Key Laboratory of Active Tectonics and Volcano, China Earthquake Administration	22	763
Institute of Geology, China Earthquake Administration	15	71
Institute of mountain hazards and environments, CAS, China	13	258
Southeast Jiaotong University, China	12	185
Institute of Crustal Dynamics, China	12	312
Chinese Academy of Geological Sciences, China	10	155
Key Laboratory of Seismic and Volcanic hazards, China Earthquake Administration	10	145
Author		
Chong Xu	70	2234
Qiang Xu	29	2582
Xuanmei Fan	28	2683
Runqiu Huang	23	2165
Guangqi Chen	21	465
Yingbin Zhang	19	474
Xiwei Xu	17	667
Xiaoyi Shao	17	238
Siyuan Ma	16	342
Xiangjun Pei	15	1269

Co-authorship network analysis

Co-authorship analysis helps illuminate the collaborative networks within a research domain by evaluating the number of publications co-authored by different researchers. In the field of earthquake-induced landslide research, 3,224 authors have contributed to the body of literature. Among these, Chong Xu stands out as the most prolific author, with 70 publications that have amassed 2,234 citations. Jiang Xu follows closely with 29 articles and 2,582 citations, while Xuanmei Fan has authored 28 documents that garnered 2,683 citations. The total link strength, which represents the cumulative strength of an author's co-authorship connections, was recorded at 135 for Chong Xu, 88 for Jiang Xu, and 83 for Xuanmei Fan. This metric underscores the degree of collaboration each researcher has established within the scientific community as shown in Figure 7a.

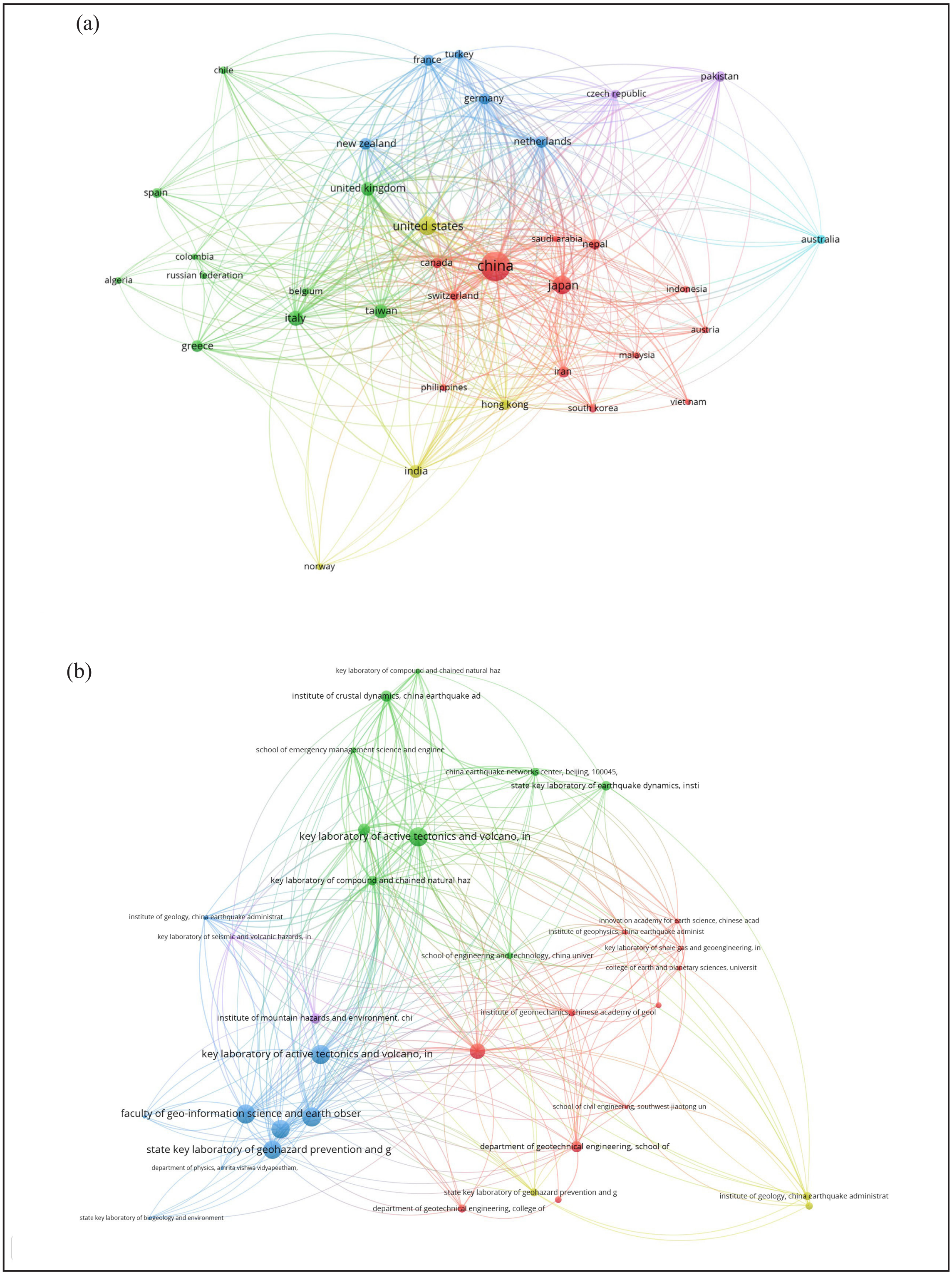

Figure 5: Citations analysis (a) Countries citations; China receives the highest number of citations (12410) presented in green. (b) Organization citations. The University of Twente received a maximum citation (783) presented in the blue cluster. Circle size represents citation score and colors indicate different grouping.

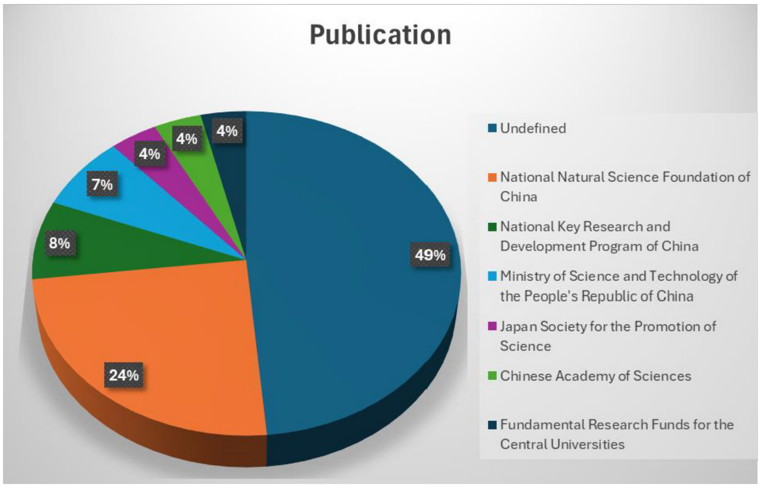

Figure 6: Leading research sponsorship organization in earthquake-induced landslides research.

The analysis extends to organizational involvement, revealing that 2,292 organizations have contributed to publications on the subject. Of these, 34 institutions have published at least five documents each. The State Key Laboratory of Geohazard Prevention and Geoenvironment Protection in China leads with 35 articles and 763 citations. It is followed by the National Institute of Natural Hazards in China, which has published 32 documents and received 318 citations. The collaborative strength, indicated by the total number of co-authors and their link strength, was notable for these institutions. The State Key Laboratory reported four collaborators and a total link strength of 5, while the National Institute of Natural Hazards had 13 collaborators with a total link strength of 59 (Figure 7b). In terms of international collaboration, China has partnered with 27 other entities, achieving a total link strength of 227, whereas the USA has also collaborated with 27 partners but with a lower total link strength of 130 (Figure 7c). This data highlights the extensive research network centered in China and indicates a strong collaborative framework contributing to advancements in the field.

To reduce the collaboration gap between well-funded and less-funded regions, future research should promote more inclusive international partnerships. Researchers from less-funded but hazard-prone regions can strengthen collaboration by developing open-access earthquake-induced landslide inventories, sharing field observations and local geological data, and co-designing case studies with institutions that have advanced remote-sensing, seismic, and computational facilities. Joint supervision of graduate students, short-term research exchanges, regional training workshops, and participation in international networks such as engineering geology, landslide, and disaster-risk-reduction consortia can also improve visibility and technical capacity. Collaborative projects should prioritize equitable authorship, shared data ownership, and capacity building rather than treating low-resource regions only as study sites. Such partnerships would help bridge funding and infrastructure gaps while improving the global representativeness of earthquake-induced landslide research.

Coupling and co-citation patterns in literature

Bibliographic coupling occurs when two separate works cite the same source, while co-citation refers to two publications cited by a third. Figures 8a and 8b illustrate the bibliographic coupling maps for documents and sources, respectively. Out of the 1,090 documents analyzed, 675 met the threshold of at least 10 citations, resulting in the identification of eight clusters. Jibson *et al.* (2000) recorded the highest citation count, with 659 citations and a total link strength of 433. Fan *et al.* (2019) followed with 603 citations and a total link strength of 545, indicating strong connectivity within the research network. Among the 321 analysed sources, 44 met the threshold of at least five documents. The journal 'Landslides' emerged as the leading source with 85 documents, followed by 'Engineering Geology' journal with 75 documents and 'Geomorphology' journal with 41. The total link strengths for these sources were recorded as 35,933 for Landslides, 36,070 for Engineering Geology, and 26,307 for Geomorphology. The most highly cited source was Engineering Geology, which amassed 6,106 citations, while Landslides and Geomorphology followed with 3,755 and 2,637 citations, respectively.

In the co-citation analysis, a total of five clusters of cited sources were identified. The two largest clusters comprised 15 and 14 items, showcasing key groups of highly interconnected and frequently co-cited literature within the domain (Figure 8C). This analysis underlines the significant influence of core publications and sources that shape the research landscape of earthquake-induced

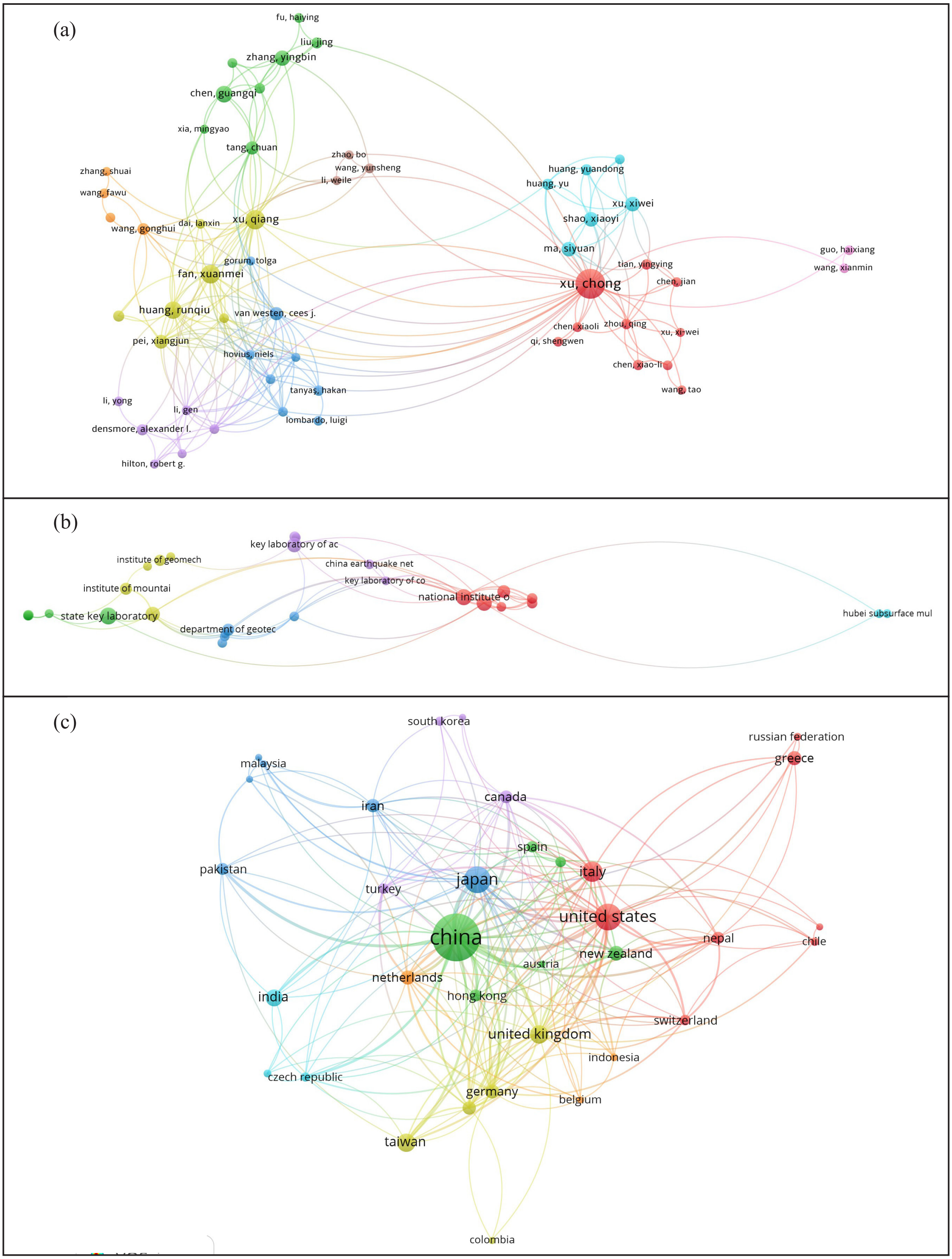

Figure 7: Co-authorship networks in earthquake-induced landslide research: (a) author-level collaboration, (b) organizational collaboration, and (c) country-level collaboration. Node size represents publication volume, and link width indicates collaboration strength.

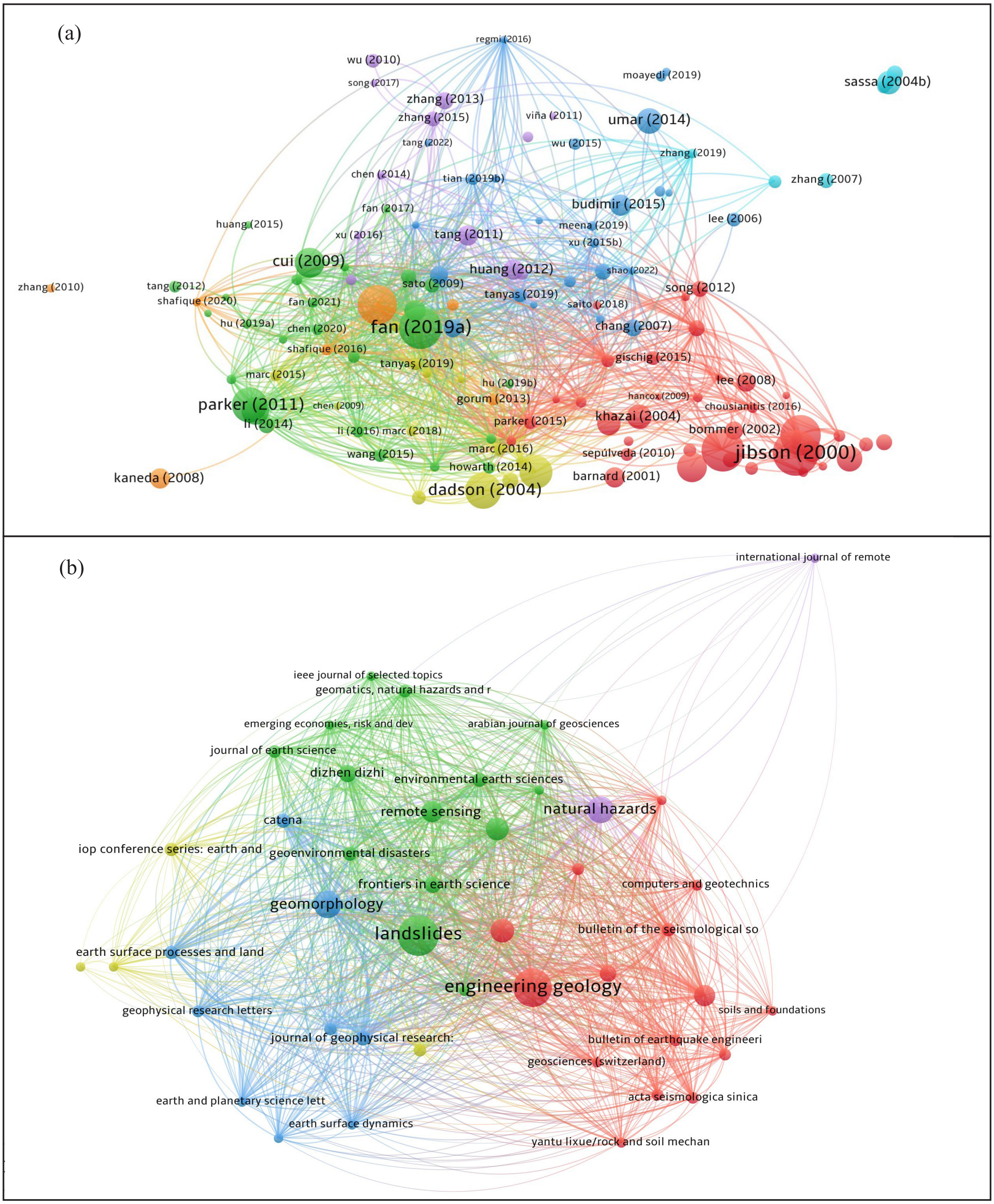

Figure 8: Bibliographic coupling and co-citation networks: (a) document coupling, (b) source coupling, and (c) source co-citation. Node size represents citation or co-citation frequency, and link distance indicates the strength of relationship.

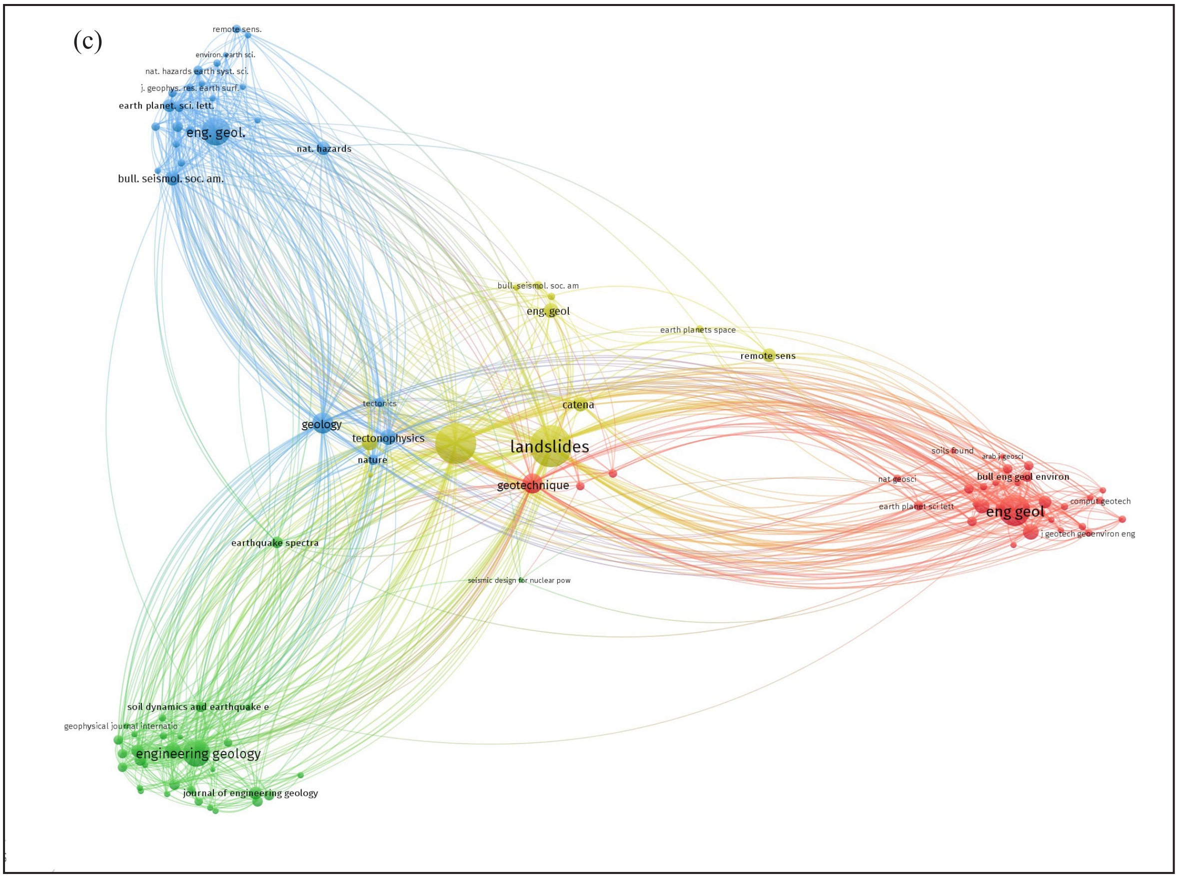

Figure 8: Continued.

landslides, demonstrating how foundational studies continue to inform and connect with newer research efforts.

Bibliometric analysis of keywords co-occurrence

The co-occurrence analysis of keywords revealed eight distinct clusters, each representing thematic areas within earthquake-induced landslide research. The largest cluster, shown in purple, encompasses 72 items, followed by the red cluster with 61 items. The yellow, green, and blue clusters include 56, 55, and 54 entries, respectively (Figure 9a). Figure 8b illustrates a trend network map that visualizes how research themes have evolved over time based on keyword usage. The purple cluster indicates topics that were the focus of earlier studies, highlighting foundational research areas. In contrast, the yellow and green clusters represent more recent areas of exploration, suggesting emerging trends and modern research directions.

Keywords such as earthquake events, coseismic process, remote sensing, machine learning, landslide inventory, landslide forecasting, and seismic response appear within the green and yellow clusters. Their presence underscores their prominence in contemporary studies and indicates a shift towards incorporating advanced technological and analytical methods in the field (Figure 9b). This co-occurrence analysis reflects the progression and broadening of research, emphasizing the integration of innovative approaches like machine learning and remote sensing in recent investigations. The recent growth in modelling approaches is most strongly associated with data-driven and hybrid techniques for susceptibility, hazard, and inventory mapping. In particular, machine-learning models such as random forest, support vector machine, artificial neural networks, decision-tree-based algorithms, gradient boosting, and ensemble approaches combining frequency ratio, logistic regression, and other statistical classifiers have become increasingly prominent. Deep-learning techniques, especially convolutional neural networks applied to remote-sensing imagery and landslide inventory extraction, also represent an emerging direction. At the same time, physically based and probabilistic approaches, including Newmark displacement modelling, seismic slope displacement estimation, and runout simulation, continue to be used, but recent keyword trends indicate a stronger shift toward machine learning, remote sensing, and hybrid modelling frameworks. This trend reflects the increasing availability of satellite imagery, digital elevation models, open landslide inventories, and computational tools for large-scale earthquake-induced landslide assessment.

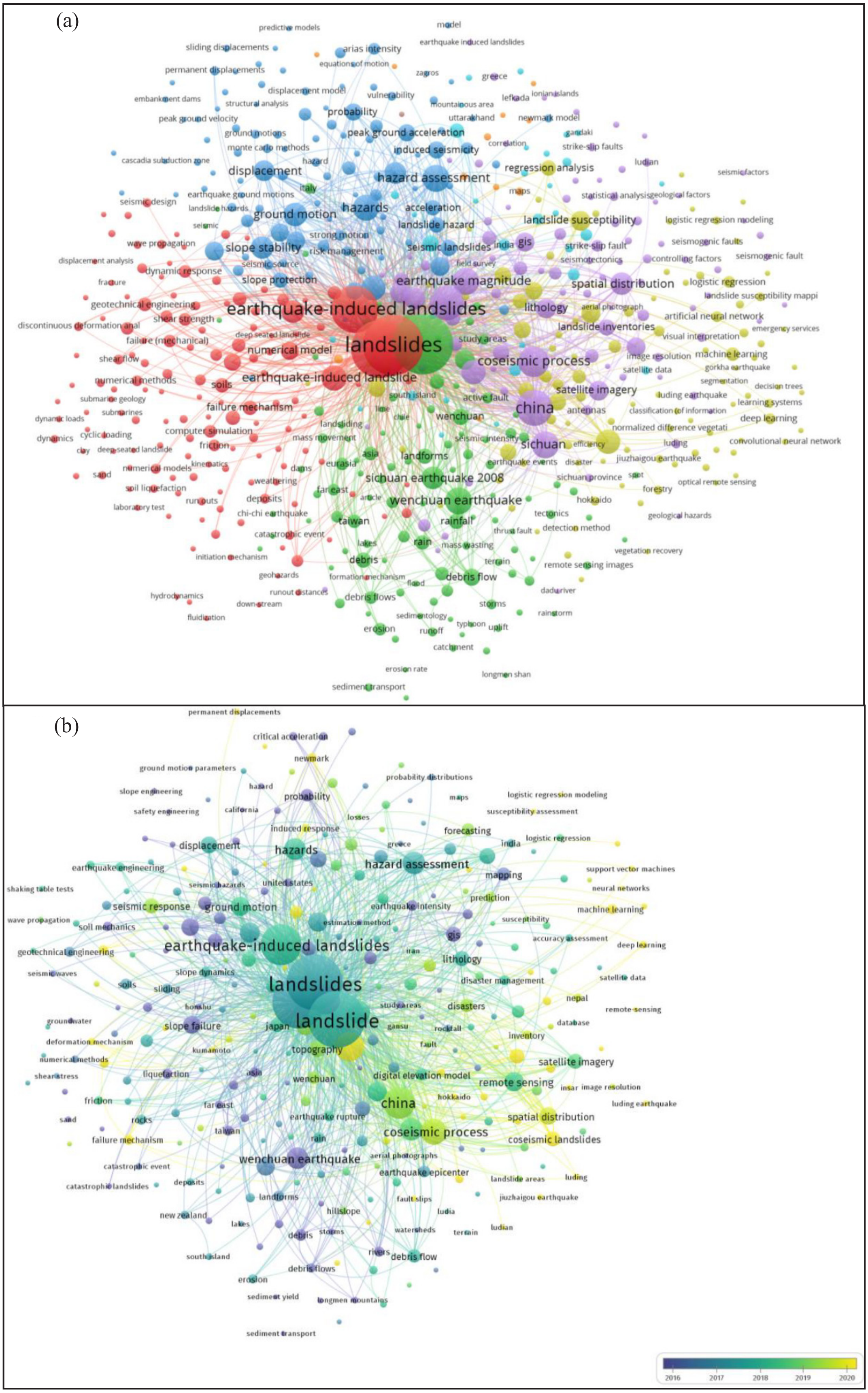

Figure 9: Keyword analysis of earthquake-induced landslide research: (a) keyword co-occurrence network and (b) temporal trend map of research themes.

DISCUSSION

The bibliometric results show that earthquake-induced landslide research has expanded substantially during the past two decades, with a particularly clear increase after the 2008 Wenchuan earthquake. The analysis identifies China, the USA, Japan, Italy, Taiwan, and selected European countries as the main contributors to the field, while several seismically active and landslide-prone regions remain comparatively underrepresented. The results also show that research has been concentrated mainly on susceptibility, hazard, and risk assessment, with increasing attention to remote sensing, machine learning, landslide inventories, and earthquake-induced chain hazards. These patterns indicate that earthquake-induced landslides have become an important research theme within geohazard science because of their severe socio-economic impacts and their role in cascading disaster processes. The strong growth in publications after major seismic events suggests that research activity is closely linked to destructive earthquakes, especially those that generate large landslide inventories and long-term geomorphic impacts. The uneven geographic distribution of publications also points to differences in funding, technical capacity, monitoring infrastructure, and international collaboration among regions.

The dominance of a limited number of countries and institutions also indicates an imbalance in global research capacity. Although leading research centres have contributed substantially to methodological development and citation impact, earthquake-induced landslide studies would benefit from stronger participation by less-funded but highly exposed regions. Future work should therefore promote equitable international collaboration through shared landslide inventories, open-access remote-sensing data, joint field campaigns, co-supervised postgraduate research, regional training workshops, and open-source modelling workflows. Such mechanisms can help improve technical capacity in underrepresented regions while producing more globally representative assessments of earthquake-induced landslide hazards. Based on the recent research activities the emerging trends and future directions can be summarized as follows:

Research in EQILs is becoming increasingly interdisciplinary, intersecting with fields such as geology, remote sensing, environmental science, and hydrology. This multidisciplinary approach supports comprehensive analyses and innovative solutions, signalling a progressive shift towards collaborative and integrated research methods. Keyword clustering over time illustrates the transition from empirical and theoretical models to data-driven, technology-enhanced paradigms, with future research likely focusing on the application of intelligent methods to boost precision and efficiency in early warning and disaster mitigation. Key areas for future research include:

- Continued exploration of how climate change impacts the triggering mechanisms of EQIL, which will be critical as global weather patterns evolve.
- Investigating earthquake-induced chain geological hazards, including secondary effects like debris flows and collapses, especially in complex geological settings.
- Technological Advancements in Hazard Identification: The application of cutting-edge remote sensing, monitoring systems, machine learning techniques, and artificial intelligence for more effective identification, prediction, and early warning.
- Enhancing the precision of probability models to predict the timing and spatial occurrence of EQIL.
- Develop real-time monitoring and integrated risk assessment frameworks to enhance disaster preparedness and response strategies in earthquake and landslide prone areas.

CONCLUSION

This study analysed 1,090 Web of Science publications on earthquake-induced landslides and coseismic landslides from 2000 to 2024. The results show a clear increase in research activity after major seismic events, particularly the 2008 Wenchuan earthquake, reflecting growing scientific attention to EQIL mechanisms, susceptibility assessment, hazard evaluation, and risk mitigation. The bibliometric patterns also show that publication output is concentrated in a relatively small number of countries and institutions, whereas several hazard-prone regions remain underrepresented. Keyword trends further show a shift from conventional susceptibility and hazard assessment toward remote sensing, machine learning, landslide inventory development, and integrated risk assessment. Future research should strengthen international collaboration, improve data sharing, and include less-funded but highly exposed regions through equitable research partnerships. These efforts will improve the global representativeness of EQIL research and support more effective disaster-risk reduction strategies.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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