JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Systematic Literature Review and Bibliometric Analysis of Landslide Risk Assessment Research: Insights from the Dimensions Database

INDRAJIT PODDAR[1], RANJAN ROY[2]

[1]Research scholar, Department of Geography & Applied Geography, University of North Bengal, P.O.- NBU, Dist.- Darjeeling - 734013, India, indrajit.poddar.cob@gmail.com. ORCID: 0000-0002-3758-5888, Contact No. - +916296950946

[2]Professor, Department of Geography & Applied Geography, University of North Bengal, P.O.- NBU, Dist.- Darjeeling - 734013, India, royranjangeo@gmail.com. ORCID: 0000-0002-3700-051X, Contact No. - +917384108845

*Corresponding author.

e-mail addresses: indrajit.poddar.cob@gmail.com, rs_indrajit@nbu.ac.in (I. Poddar)

Abstract

This study presents a systematic literature review and bibliometric analysis of landslide risk assessment research, utilizing the Dimensions database to map the scientific landscape from the early 1990s to 2025. The study was conducted using the Bibliometrix R-package to evaluate annual scientific production, citation impact, and thematic evolution. The results reveal a significant paradigm shift in the field, characterized by a dramatic surge in publication volume starting in 2010, primarily driven by the integration of emerging technologies. While early research focused on general hazard mapping and basic susceptibility, contemporary studies are dominated by "motor themes" such as artificial intelligence (AI), machine learning (ML), deep learning, and remote sensing. Geographically, the study identifies China as the leading contributor in both scientific production and international collaboration, followed by Italy, India, and the USA. Analysis using Bradford's Law identifies Remote Sensing, Landslides, and Applied Sciences as the core journals disseminating this research. Furthermore, Lotka's Law analysis highlights a high concentration of productivity among a small group of prolific authors, such as Wang Y and Zhang Y. The thematic evolution analysis confirms that the field has transitioned from qualitative descriptions to data-driven, predictive modeling, with "Explainable AI" emerging as a significant niche theme. This study provides a comprehensive overview of global research trends, offering valuable insights for future directions in landslide hazard mitigation and technological applications.

Keywords: Landslide Risk Assessment; Bibliometric Analysis; Dimensions Database; Artificial Intelligence (AI); Machine Learning (ML); Remote Sensing; Landslide Susceptibility Mapping; Deep Learning

1. Introduction

Landslides represent significant geohazards that cause widespread damage to infrastructure, disrupt economic activities, and result in considerable loss of human life globally (Carrión-Mero et al., 2021; Poddar & Roy, 2024). For instance, global reports indicate that hundreds of thousands of people are affected by landslides annually, resulting in substantial economic losses (Das et al., 2022; Fan et al., 2023). Consequently, understanding and mitigating landslide risks are paramount for sustainable development and societal resilience, necessitating robust research into assessment methodologies (Mohammady et al., 2012). This is particularly true in regions like the Indian Himalayas, where rainfall-induced landslides are prevalent and pose a continuous threat to various sectors (Dikshit et al., 2020). This region, characterized by complex geology, rugged topography, and heavy monsoonal rainfall, is exceptionally prone to these events, accounting for approximately 15% of global rainfall-induced landslides (Das et al., 2022; Dikshit et al., 2020). The heightened exposure to landslide risks in such areas underscores the urgent need for comprehensive research to inform effective hazard mapping and risk governance strategies (Dikshit et al., 2020). Such efforts are crucial for providing a general overview of the state-of-the-art in landslide research, offering a valuable reference for new researchers and practitioners, and identifying critical areas for improvement in addressing landslide hazards (Das et al., 2022; Dikshit et al., 2020). A systematic review, coupled with bibliometric analysis, can effectively trace the evolution of landslide research, highlighting key trends, methodologies, and geographical foci that have emerged over time (Zhu et al., 2025). This approach enables the identification of research gaps and overlooked areas, thereby guiding future investigations toward a more comprehensive understanding of landslide phenomena and their mitigation (Dikshit et al., 2020). This study aims to address this need by systematically analyzing the existing literature on landslide risk assessment, utilizing the Dimensions database to provide a broad, interdisciplinary perspective on the field. Specifically, this review will synthesize findings to delineate the predominant themes, influential publications, and collaborative networks that characterize landslide risk assessment research, thereby offering a structured overview of the academic landscape.

Furthermore, this analysis will pinpoint methodological advancements and regional research concentrations, particularly in vulnerable areas such as the Indian Himalayas, where diverse approaches have been applied to address landslide susceptibility mapping (Das et al., 2022). This critical examination will encompass the diverse range of techniques employed, from empirical methods and numerical simulations to advanced remote sensing and GIS applications, which have become increasingly prominent in recent decades (Kainthola et al., 2025). The overarching goal is to provide a reference for stakeholders and researchers, highlighting both the strengths and shortcomings of current research and pointing towards future developments needed for substantial progress in landslide risk reduction (Dikshit et al., 2020). By synthesizing the current knowledge and identifying research gaps, this study endeavors to contribute to the formulation of more effective strategies for landslide preparedness and mitigation (Zou & Zheng, 2022). This systematic review not only consolidates existing knowledge but also critically evaluates the methodologies and data utilized in landslide susceptibility mapping within such high-risk areas (Das et al., 2022; Dikshit et al., 2020). It will further evaluate how different modeling approaches and the assessment of model performance have shaped the current understanding and predictive capabilities in landslide research (Mafigiri et al., 2025).

This paper presents a comprehensive systematic literature review (SLR) coupled with a bibliometric analysis of landslide risk assessment research, specifically focusing on the use of AI, ML, and geospatial tools. By analyzing publications from the Dimensions Database, the review aims to map the evolution of scientific output in this field and explore the key technologies that have driven these advancements. In doing so, it provides a nuanced understanding of the growing body of research on landslides, tracking the rise of key topics such as machine learning-based prediction models, the role of remote sensing in monitoring, and the increasing importance of integrating AI for improving landslide risk assessments.

A significant aspect of this study is the examination of publication trends over time. The findings reveal that the number of publications in landslide risk assessment research has skyrocketed since 2010, particularly with the integration of AI and ML methodologies. This surge in research output highlights the increasing significance of these technologies in addressing the challenges posed by landslide hazards. Furthermore, the trend toward open-access publishing has played a crucial role in facilitating the widespread dissemination of research findings, contributing to the global exchange of knowledge and collaborative efforts in landslide risk management.

By evaluating citation trends, publication volumes, and the thematic evolution of research, this review not only highlights the significant developments in landslide risk assessment but also provides critical insights into the future directions of this field. As the scientific community continues to explore innovative solutions for landslide prediction and mitigation, understanding the trajectory of research will be pivotal for advancing strategies aimed at reducing landslide risks and improving disaster preparedness on a global scale.

2. Methodology

2.1 Data Source and Search Strategy

The bibliographic data for this study were retrieved from the Dimensions database, a comprehensive academic search engine that provides extensive coverage of scientific publications, grants, and clinical trials. A systematic search strategy was employed to identify literature addressing the intersection of landslide risk assessment, economic impact, and advanced computational techniques (Artificial Intelligence and Machine Learning).

The search query was constructed using Boolean operators (AND, OR) to combine two primary thematic clusters. The asterisk () *wildcard was utilized to include various suffixes of the root words (e.g., "predict*" retrieves "prediction," "predictive," and "predicting").

2.2 Search Criteria and Keyword Selection

The search string combined the following keyword categories:

2.2.1 Landslide and Risk Assessment Terms:

To define the physical hazard and the scope of the study, the following terms were used:

- *"landslide* risk*", *"rock-fall"*, *"shallow landslide"*, *"Landslide predict*"* (prediction), *and "Landslide susceptibility"*.

2.2.2 **Methodological and Technological Terms (AI & ML):**

To capture the evolution of analytical techniques, a comprehensive list of AI and statistical keywords was included:

- **General AI/ML:** *"artificial intelligence"*, *AI*, *"machine learning"*, *ML*, *"machine intelligence"*, *"deep learning"*, *DL*, *"soft computing"*, *"hybrid machine learning"*, and *"data-driven model"*.
- **Neural Networks:** *"neural network"*, *ANN*, *"artificial neural network"*, *"hybrid neural network"*, and *"autoencoder"**.
- **Algorithms and Models:** *"support vector machine"* (*SVM*), *"random forest"* (*RF*), *"decision tree"*, *"boost"* (e.g., boosting, gradient boosting), *"bagg"* * (bagging), *"naive bayes"*, *"discriminant analysis"* (*DA*), and *"nearest neighb"** (e.g., k-NN).
- **Advanced Deep Learning & Time Series:** *"long short-term memory"* (*LSTM*), *"extreme learning machine"* (*ELM*), *"hidden markov model"* (*HMM*), and *"gaussian mixture model"* (*GMM*).
- **Statistical Approaches:** *"linear regression"*, *"logistic regression"* (*LR*), *"principal component analysis"* (*PCA*), *"multivariate adaptive regression spline"* (*MARS*), and *fuzzy* logic systems.

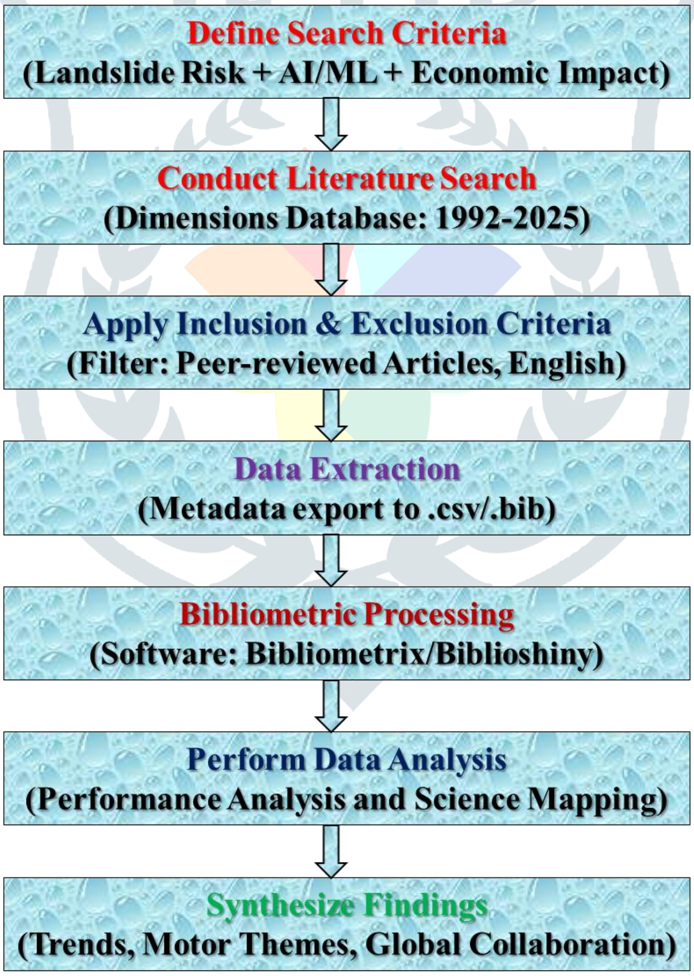

Fig. 1 Methodological Flowchart

2.2.3 Economic Impact Terms

To account for the socio-economic dimension of landslide hazards, the search also included:

- *"Economic Loss"**, *"economic impact"*, and *"economic evaluation"*.

The final search query logic effectively functioned as:

(Landslide Keywords) **AND** *(AI/ML Keywords* **OR** *Economic Impact Keywords).*

2.2.4 Data Screening and Bibliometric Analysis

Following the initial retrieval, the dataset was filtered to ensure relevance and quality. The results were restricted to peer-reviewed articles to maintain academic rigor. The final dataset was exported in a bibliographic format for further analysis. The bibliometric analysis and scientific mapping were conducted using the Bibliometrix R-package and its web-based interface, Biblioshiny. This software was employed to generate the performance analysis (annual production, citation metrics) and science mapping (co-authorship networks, thematic evolution, and keyword co-occurrence) presented in the subsequent results section.

3. Results and Discussion

3.1 Annual Scientific Production

The volume of scientific output per year is considered to be the annual scientific production. The figure (Fig. 1.2) illustrates that the number of articles on landslide studies published annually, which involve multiple technologies such as artificial intelligence (AI), machine learning (ML), geospatial analyses, and remote sensing, is increasing. The data points appear to represent articles published in journals belonging to the UGC Journal List Group II, and that are not restricted. Based on the graph (Fig. 1), we can observe the following:

3.3.1 Minimal Production in Early Years

Between the early 1990s and approximately 2010, there was hardly any publication of articles per year, practically none. It is likely also the time when research on landslides began, and the most recent technologies, including AI and remote sensing, were introduced. The discipline might have been relatively new, and not many individuals would have known how such technologies could be utilized as predictors of landslides and as tools for hazard analysis.

3.3.2 Rapid Increase Post-2010

The situation began to change in 2010, when the number of published articles increased significantly, and this growth accelerated further after 2015. This indicates an increase in overall interest and research in the field of landslide hazards, particularly in relation to the application of new technological tools, including AI, ML, and geospatial tools. This growth may be driven by the increasing popularity of AI and remote sensing, which have become important in analyzing environmental and disaster risks.

3.3.3 Current Trend

Over the past few years, scientific production has reached its highest point, and publications continue to increase at a rapid rate. This implies that AI, ML, geospatial analysis prediction, susceptibility, and hazard assessment of landslides have become essential fields of scientific inquiry in geotechnical and environmental studies. The sudden growth of these sectors can probably be explained by the development of computing power, better algorithms, and a larger availability of data sources (satellite images).

3.3.4 Open Access Trend

The chart does not explicitly indicate whether the growth of publications is linked to the development of Open Access formats, Open Access (OA), Open Access (Gold): open access, Open Access (Green): open access, Open Access (Hybrid): open access, Open Access (Bronze): open access. However, it is assumed that the more journals switch to open access, the more they will be able to disseminate the results of their research. This may be one reason behind the increase in the number of articles produced, whereby researchers are prompted by the improved visibility and accessibility offered by OA.

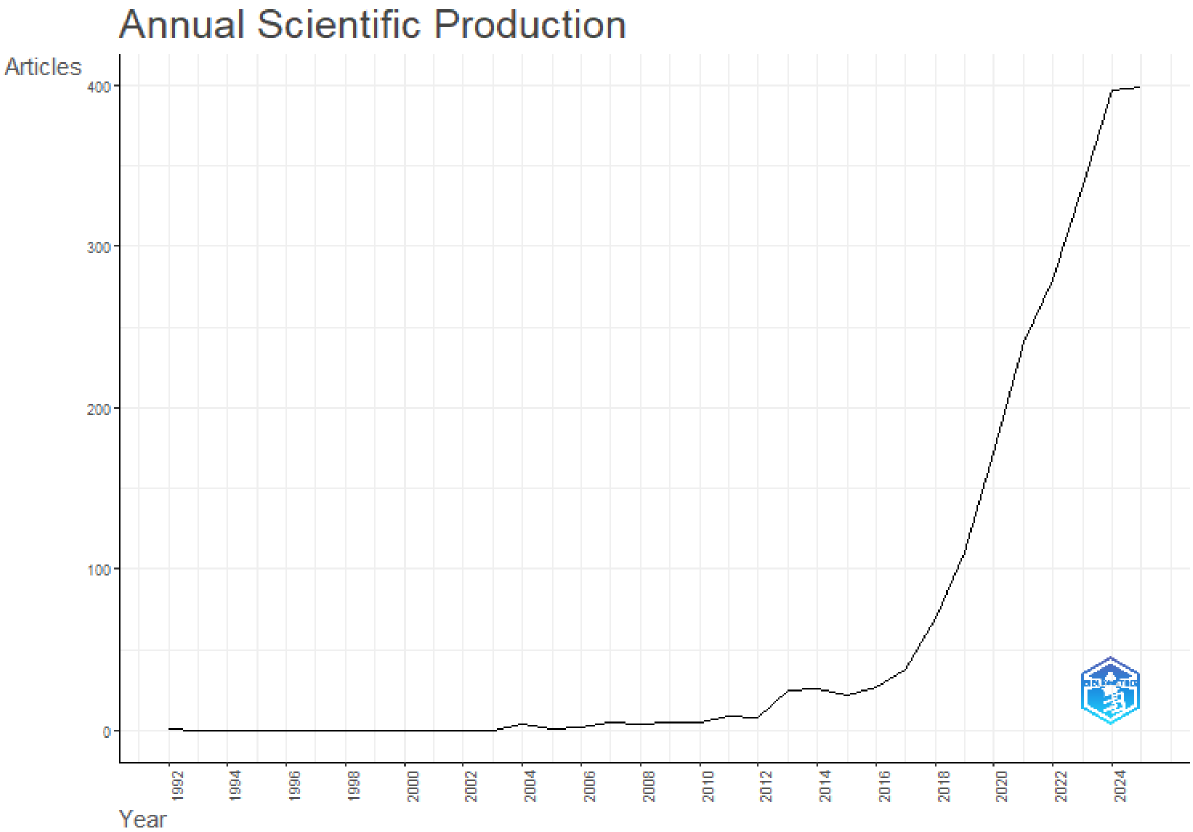

Fig. 2 Annual scientific production

Overall, the graph indicates an increasing amount of literature in the landslide prediction and risk analysis field, prompted by the development of new technologies, especially AI, ML, and geospatial approaches. The fact that the number of publications has dramatically increased since 2010 can be interpreted as meaning that these technologies are being increasingly viewed as an important tool in managing landslide hazards, and numerous scholarly concerns are being expressed regarding the enhancement of predictive models and risk evaluation. The shift to open-access publication modes further expands the scope and influence of this growing body of knowledge.

3.2 Average citations per year

As shown in the graph (Fig. 3) of Average Citations per year for articles on landslide risk, artificial intelligence (AI), machine learning (ML), and geospatial analysis, key trends are evident in academic research. The citation in the period between the early 1990s and approximately 2004 was very low, indicating that the development of using sophisticated technologies in predicting landslides and risk analysis was relatively small and niche during the same period. Since approximately 2005, there has been a significant increase in citations, suggesting a breakthrough or a series of impactful publications that garnered the attention of the research community. This influx is likely indicative of the preliminary studies that developed the interplay between AI, ML, and geospatial analytics in landslide hazard research, which propelled the discipline.

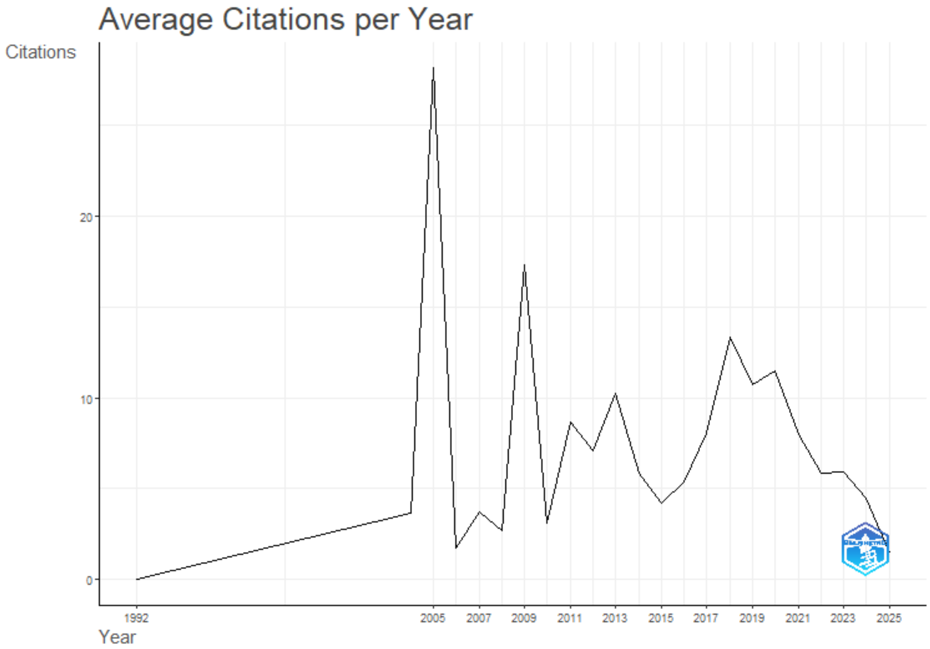

Fig. 2 Average citations per year

After this peak, the number of citations started to fluctuate significantly, with rises and falls. This oscillation can be an indication of changing research interests, where more recent methodologies are employed, or the research has shifted its focus to other areas of landslide research, such as improving model accuracy or utilizing new technological developments. Lastly, the graph indicates a discernible decline in citations after 2022, which may be related to several factors, including saturation on the topic, the introduction of new methods, or a shift in research priorities within the broad field of environmental sciences. Overall, the information indicates that there is a growing interest in integrating AI, ML, and geospatial analysis to manage landslides, and that the academic community has shown consistent yet variable interest in this area.

3.3 Most relevant sources of documents

The chart (Fig. 3) presents the most pertinent sources in the study of landslides, AI, and geospatial technologies identified during the systematic literature review process. The chart indicates the number of documents published by each source with the term 'Remote Sensing', with the most active publication source being 243 documents. This implies that there is a considerable amount of research on the subject of remote sensing, which has been commonly applied to landslides monitoring and analysis using satellite and aerial images.

Applied Sciences closely follows with 108 documents, as this is a wide-ranging area of interdisciplinary applications that includes environmental and geotechnical studies. Other resources that are also impressive include Water (99 papers), Sustainability (88), and Natural Hazards and Earth System Science (82), which illustrate the increasing significance of sustainability and natural hazards studies, particularly in the context of landslide risk management.

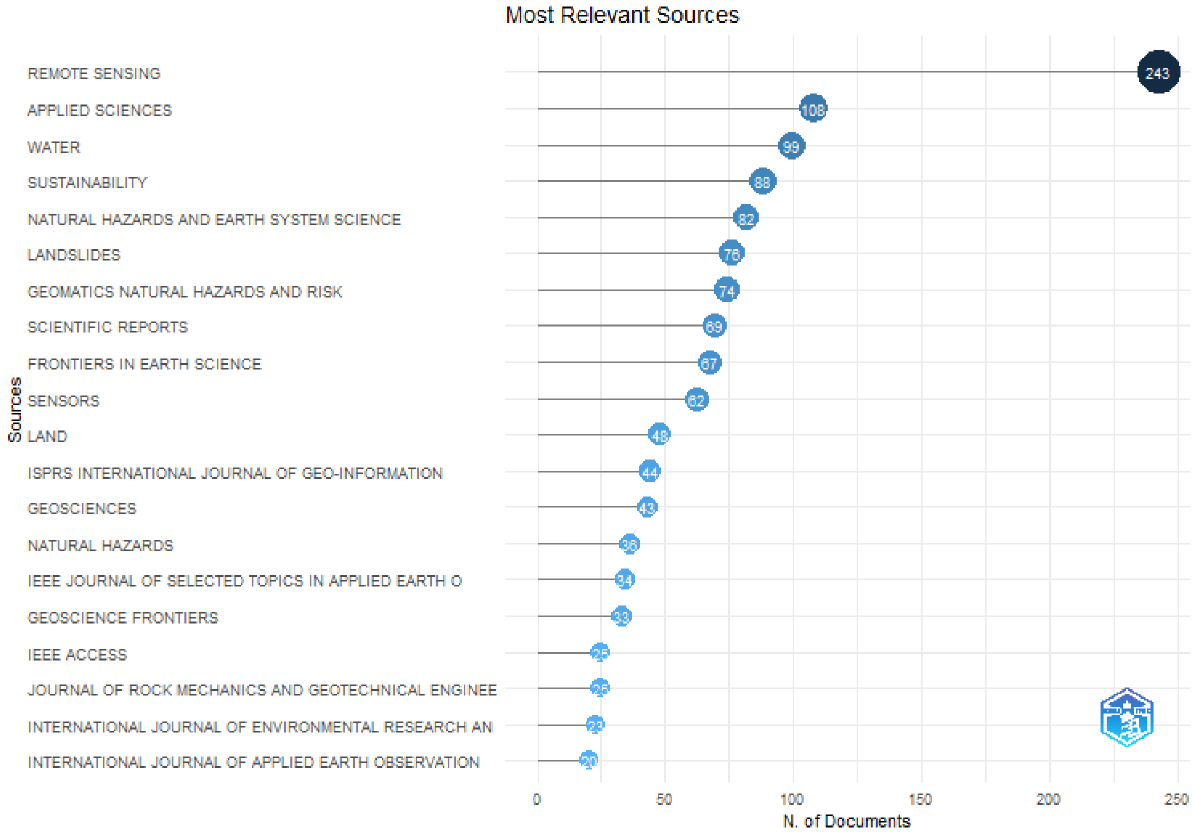

Fig. 3 Most relevant sources of documents

The combination of a multidisciplinary approach, which involves geospatial, environmental, and engineering fields, is evident in sources such as Geomatics Natural Hazards and Risk (74), Scientific Reports (69), and Frontiers in Earth Science (67). Moreover, the growing role of sensor technologies, geographic information systems (GIS), and spatial data analysis in landslide monitoring and prediction is also described in journals such as Sensors, Land, and the ISPRS International Journal of Geo-Information. The chart indicates that a robust network of journals focusing on landslides already exists, with a prevailing interest in geospatial and remote sensing approaches. This trend highlights the increasing significance of technological advancements in understanding and mitigating the risks associated with landslides.

3.4 Core sources of documents by Bradford's Law

Bradford Law was applied to the literature about landslides, remote sensing, and geospatial analysis to identify the core sources as shown in the chart (Fig. 4). According to the Law formulated by Bradford, a small set of journals (core sources) appears to make a considerable percentage of the literature in a particular discipline, and other journals make lesser percentages. In this chart, the fundamental sources are highlighted in the section where the Remote Sensing journal is the most active source of publications, due to its high number of articles. Other journals, such as Applied Sciences, Water, and Sustainability, also make significant contributions to the literature. The curve becomes very steep, meaning that the number of articles published rapidly decreases as we move away from the heart of the sources.

The extraneous sources, including Natural Hazards and Earth System Science and Geomatics, have fewer articles. This fact was predicted by Bradford's Law of Concentration, which states that most publications are thinly dispersed among other, less specific journals. This trend suggests that a select group of journals is dominating the research landscape and making significant contributions to the literature on landslides and related studies.

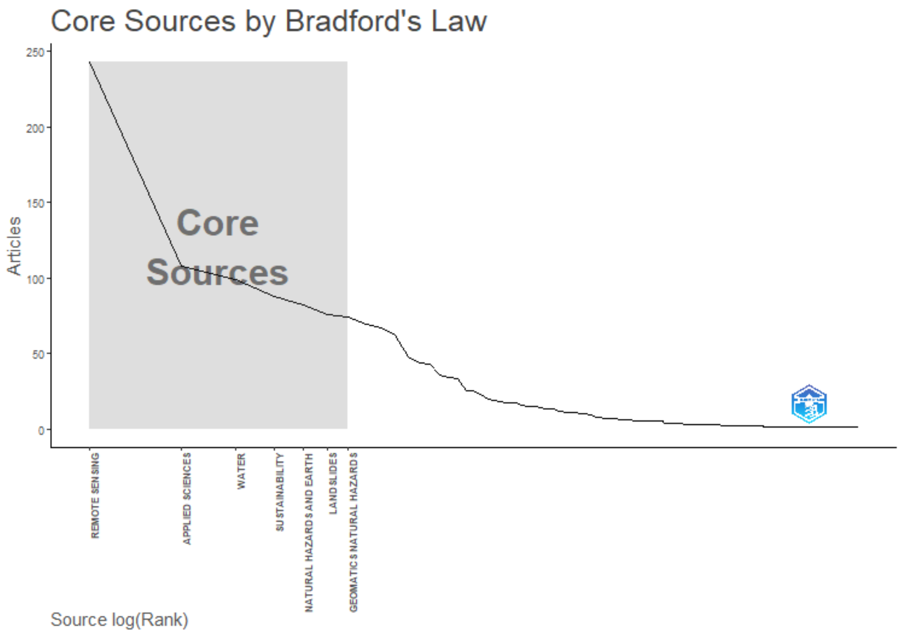

Fig. 4 Core sources of documents by Bradford's Law

3.5 Local impact of sources by H Index

The H-index of different sources of academic literature concerning landslides, remote sensing, and other topics is presented in the chart (Fig. 5). The H-index is a statistic used to gauge the productivity and impact of

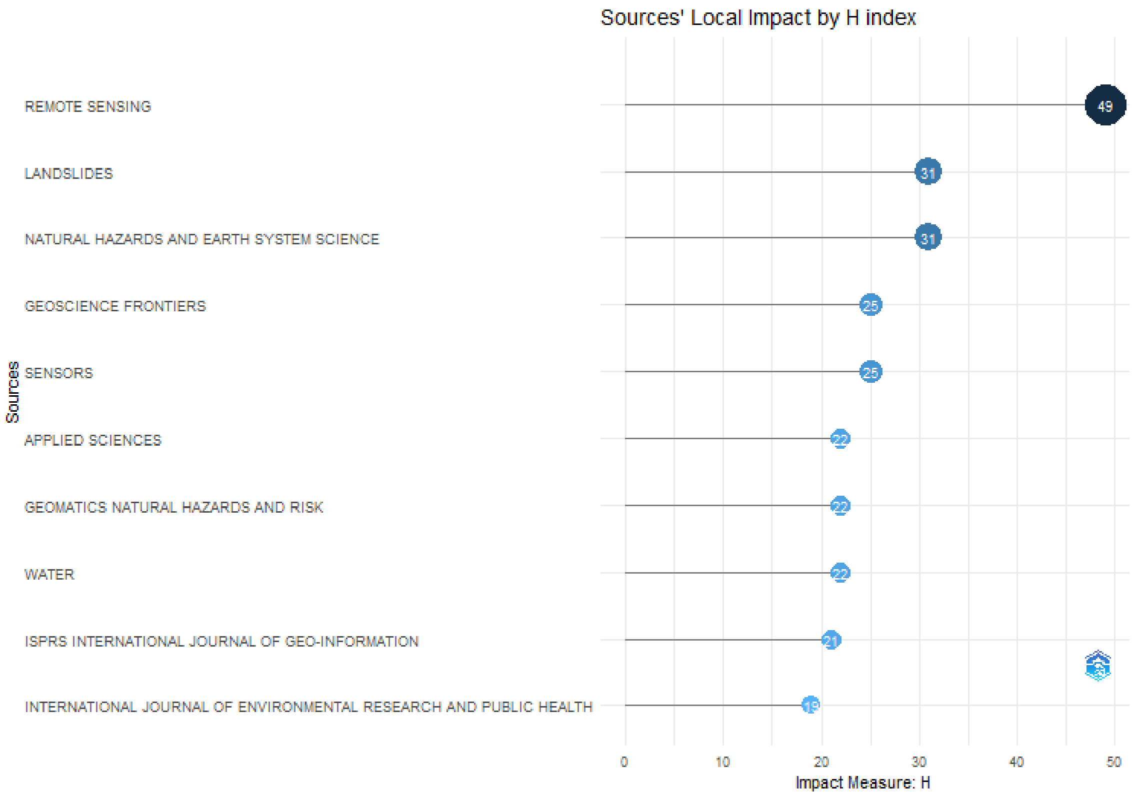

Figure 5 Sources' local impact by H Index

publications from a particular source of data. It indicates the number of times the articles published in such sources have been referenced. Remote Sensing is the most academically rigorous, with the highest H-index of 49, and many of its publications are regularly cited. Next, journals such as Landslides, Natural Hazards, and Earth System Science, as well as Geoscience Frontiers, also have an H-index above 25, indicating that they serve the field well, albeit slightly less so than Remote Sensing in terms of citation impact. Sources such as Sensors, Applied Sciences, Geomatics, Natural Hazards and Risk, and Water all have an H-index of 22, indicating a moderate impact and frequency of citation. On the lower end, ISPRS

The H-indexes of 21 and 19, respectively, indicate that the International Journal of Geo-Information and the International Journal of Environmental Research and Public Health have a relatively low academic impact in comparison. In general, the chart indicates the varying degrees of influence of journals in the sphere of landslide studies and remote sensing, with "Remote Sensing and Landslides" being the most commonly cited and essential studies.

3.6 H Index by local impact of authors

The table (Fig. 6) illustrates the H-index of various authors, representing their impact in academia through their published works and the citations of those works. Shahabi H has the best H-index of 28, indicating that he has made significant contributions to the field and his articles are widely cited. Several other authors (Wang Y, Lee S, Pham BT, Pradhan B, and Shirzadi A, as well as Catani F) also possess an H-index of 26, which means that they can significantly influence research. The next resident in the H-Index ranking is Chen W, with an H-index of 23, indicating a significant academic standing, albeit at a higher disadvantage relative to the top in terms of citation rate. Bui DT and Lombardo L hold the least endowment in this dataset, with an H-index of 20 each, which demonstrates a comparatively lower impact on academic literature than other scholars in this field. This chart identifies the most influential researchers who have made significant contributions to the study of landslides and related issues. Some of the authors appear to be leaders in terms of their academic contributions and the number of citations.

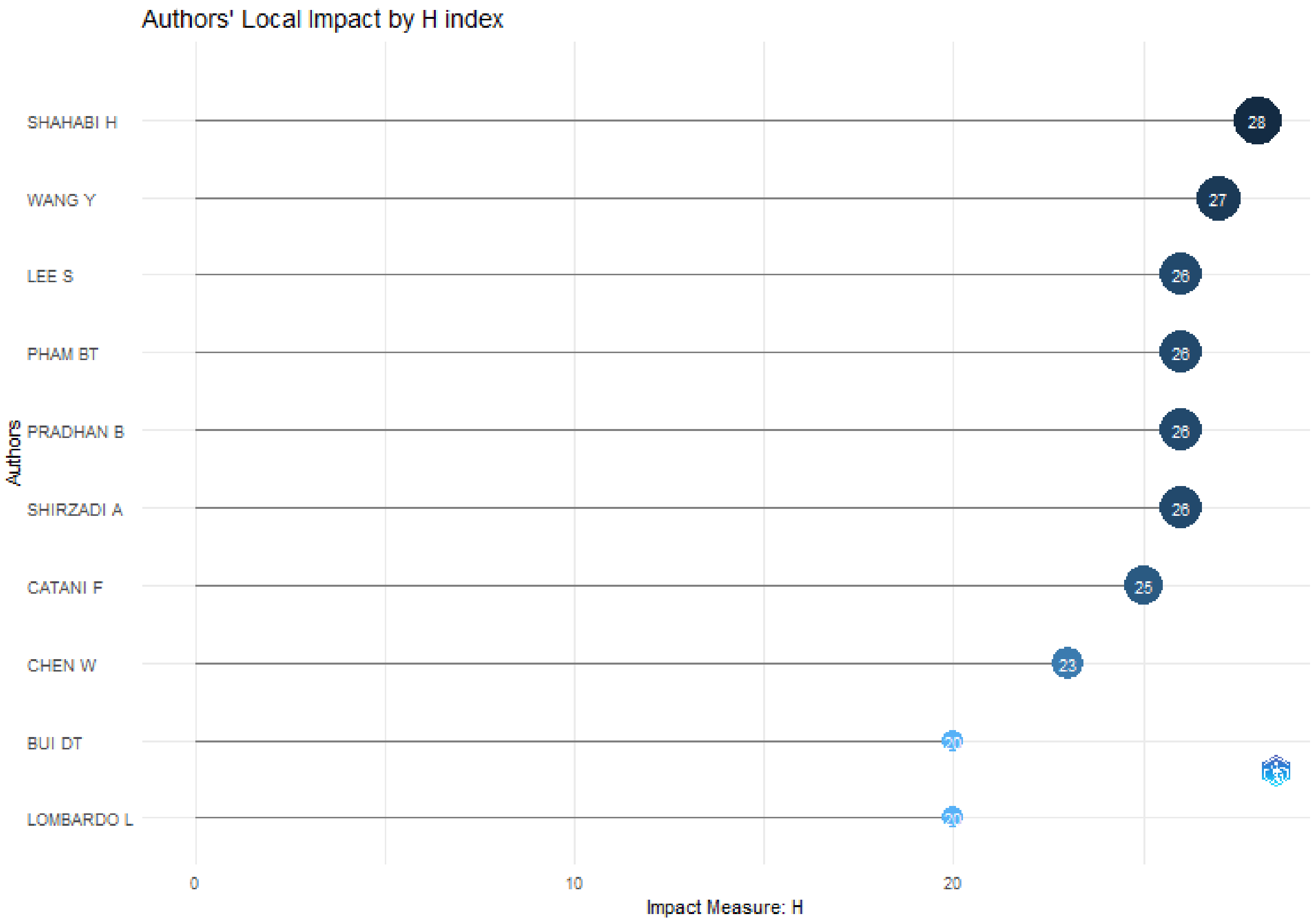

Fig. 6 Authors' local impact by H Index

3.7 Authors' production over time

The chart **(Fig. 7)** visualizes the production and citation impact of authors over time. The size of the circles represents the number of articles each author published in a particular year. The color gradient indicates the total number of citations (TC) received per year, with darker shades reflecting higher citation counts. For example, Wang Y and Zhang Y are the most prolific authors in terms of article count, particularly in recent years (2019-2023), with their articles consistently receiving high citation counts as indicated by the darker blue shades. Zhang J, on the other hand, shows a more modest output, with fewer articles published and a lower citation count per year. This could suggest a more niche research focus or an emerging contribution to the field. The chart **(Fig. 7)** further indicates how the scholarly impact of these authors has evolved, with a notable increase in production and citations in the later years, especially for Wang Y and Zhang Y. Authors like Liu Y and Chen W demonstrate a steady but less frequent output, with fewer articles published in recent years, reflected in the smaller circles and lighter colors for citation impact. This analysis helps track the growth in research activity and the evolving academic influence of these authors in the domain of landslide studies.

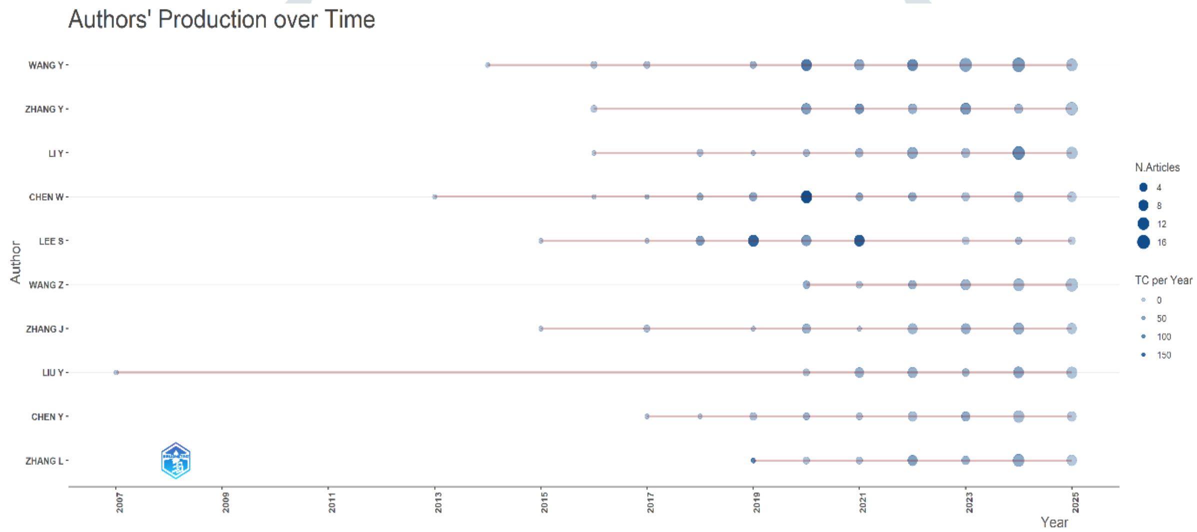

Fig. 7 Authors' production over time

3.8 Most globally cited document

Fig. 8 charts the production and citation impact of the authors over time. The size of the circles illustrates the quantity of articles published in a given year, which is the output of each author. The color gradient represents the cumulative number of citations (TC) per year, with darker shades indicating a greater number of citations. As an illustration, Wang Y and Zhang Y are the most prolific writers in terms of the number of articles, especially in recent times (2019-2023), and their articles have continued to attract a high number of citation counts, as denoted by the darker blue color. Zhang J, in turn, is less prolific, with fewer articles published and a lower number of citations per year.

This may indicate a narrower research area or a new input into the field. The chart (Fig. 8) also shows the change in the production and the number of citations per year of these authors, as Wang Y and Zhang Y have a noticeable rise in output and the number of citations, and the citation effects are smaller and lighter in color in the latter years, also illustrated by the decreasing in size and the usage of lighter shades. This review enables the tracking of the development of the research activity and the changing academic impact of these authors in the field of landslide research.

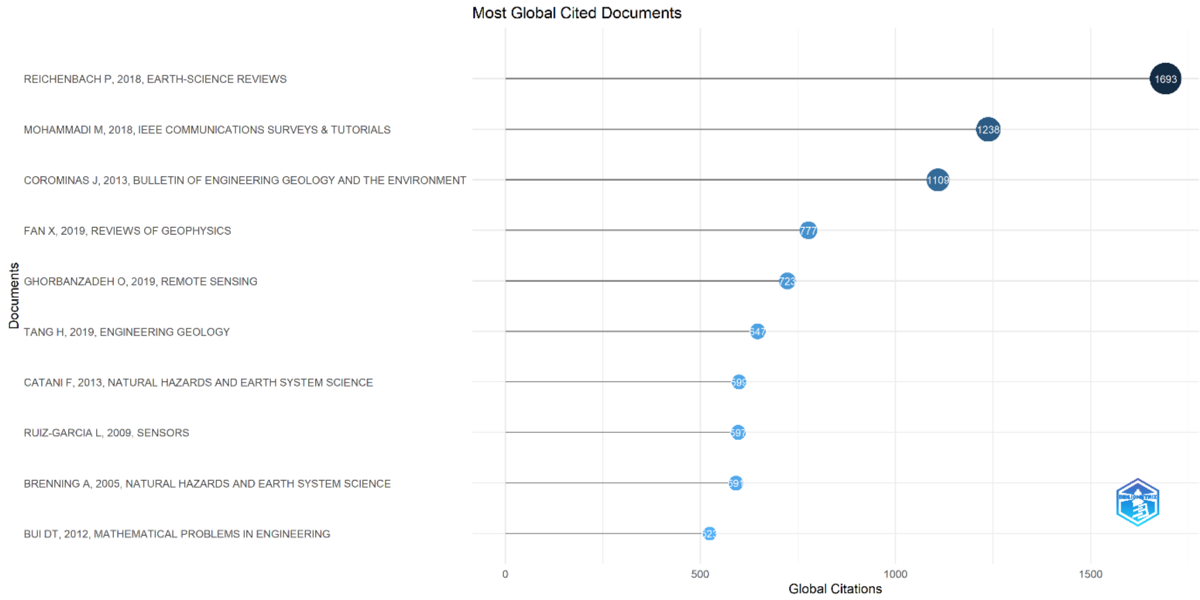

Fig. 8 Most globally cited documents.

3.9 Sources' production over time

The graph (Figure 9), titled Sources Production over Time, reveals how various sources have contributed to the area of landslide research over several decades cumulatively. Based on the graph, it is evident that the number of publications has increased sharply since the beginning of the 2010s. The sources belonging to the Applied Sciences have experienced the highest production growth, starting approximately in 2016 and continuing to grow at a steep curve, indicating a surge of interest and research in this field. This growth can be attributed to the rise of data science and technologies, which have enabled researchers to consider new data-related approaches, such as machine learning, remote sensing, and AI, to predict and control landslides and monitor their threats. The sources in Natural Hazards and Earth System Science also exhibit growth, though it is less steep than in Applied Sciences. This constant growth could be a sign of ongoing investigation into environmental hazards, with a focus on how landslides are researched in the context of natural catastrophes and processes within the Earth system. The satellite-based monitoring and geospatial analysis of the world, known as Remote Sensing, has gradually gained prominence in the research literature, reaching its peak in 2020. This is an indication of the increased application of sophisticated technologies in landslides monitoring, analysis, and mitigation measures. Water records the most moderate increase in the articles, indicating that water-related variables, such as rainfall and water movement, are becoming part of landslide research, particularly insofar as they relate to the cause of landslides.

Of the categories, the concept of Sustainability seems to have the least acute curve. The increase in the number of publications since 2020 is indicative of growing interest in the context of sustainable development and environmental protection in the study of landslides, which manifests itself in a multidisciplinary paradigm for addressing landslide hazards. Lastly, the graph indicates that landslide studies have undergone significant development, particularly in recent years, driven primarily by the application of the sciences and natural hazard studies. This tendency suggests a growing global concern regarding disaster management, predictive modeling, and sustainable interventions for landslides.

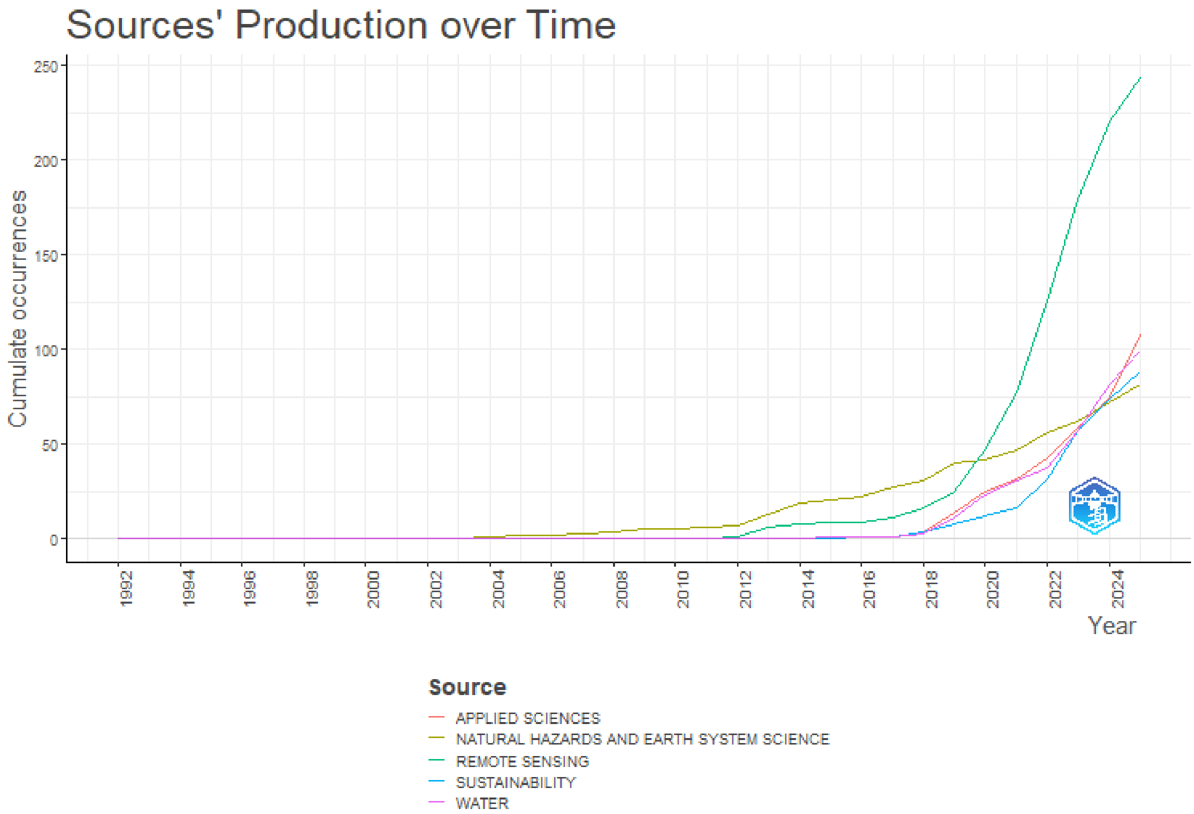

Fig. 9 Sources' production over time

3.10 Most relevant authors

The most relevant authors' graph (Fig. 10) illustrates the role of prominent authors in the area of landslide research, specifically in articles concerned with landslide risk, hazards, prediction, and machine learning or geospatial analysis. The x-axis is used to indicate the number of documents published, and the y-axis is used to list the authors according to the number of documents they published. According to the graph, Wang Y is the only one with a high number of publications, specifically 78 papers, followed by Zhang Y, who has 50 papers.

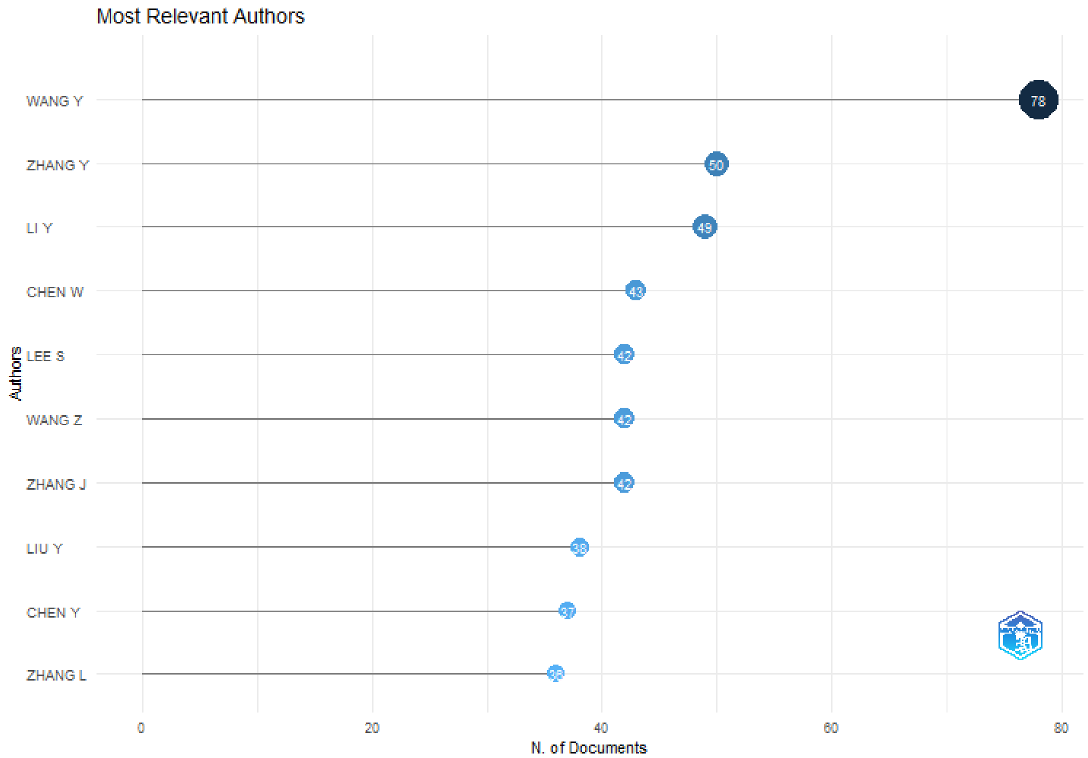

Fig. 10 Most relevant authors

There are other notable writers, such as Li Y (49), Chen W (43), and Lee S (42), who make valuable contributions to the literature in this field. These authors are leaders in landslide research and are likely operating at various levels, including the development of landslide prediction models, spatial analysis, and the incorporation of machine learning methods to assess landslide risk. The distribution indicates that these authors have published a substantial number of papers, making them influential figures in the field of landslide research. This graph demonstrates that there are a few very productive authors.

In contrast, the remaining authors, such as Zhang J, Liu Y, and Chen Y, have fewer document counts but are also making significant contributions in the field. To sum up, the given visual analysis demonstrates that some researchers are at the forefront of studying the issues surrounding landslides, and their work contributes to the development of the current perception of landslide hazards, forecasts, and control. These authors contribute to the ongoing development and application of modern technologies, such as AI and geospatial analysis, to analyze landslides.

3.11 Authors' productivity through Lotka's Law

The graph, "Author Productivity through Lotka Law," provides the distribution of author productivity in terms of the number of documents published. The frequency of authorship in scientific research is often explained by the Lotka Law, which suggests that the majority of authors publish a small number of articles. In contrast, a small number of authors publish a considerable number of articles. We can see from this graph (Fig. 11) that the percentage of authors decreases sharply as the number of documents written increases. The rate of those who have written over 20 papers is minimal, with most having written fewer than 10 papers. This is based on Lotka's Law, according to which a small number of authors (the core contributors) produce a substantial fraction of the total publications.

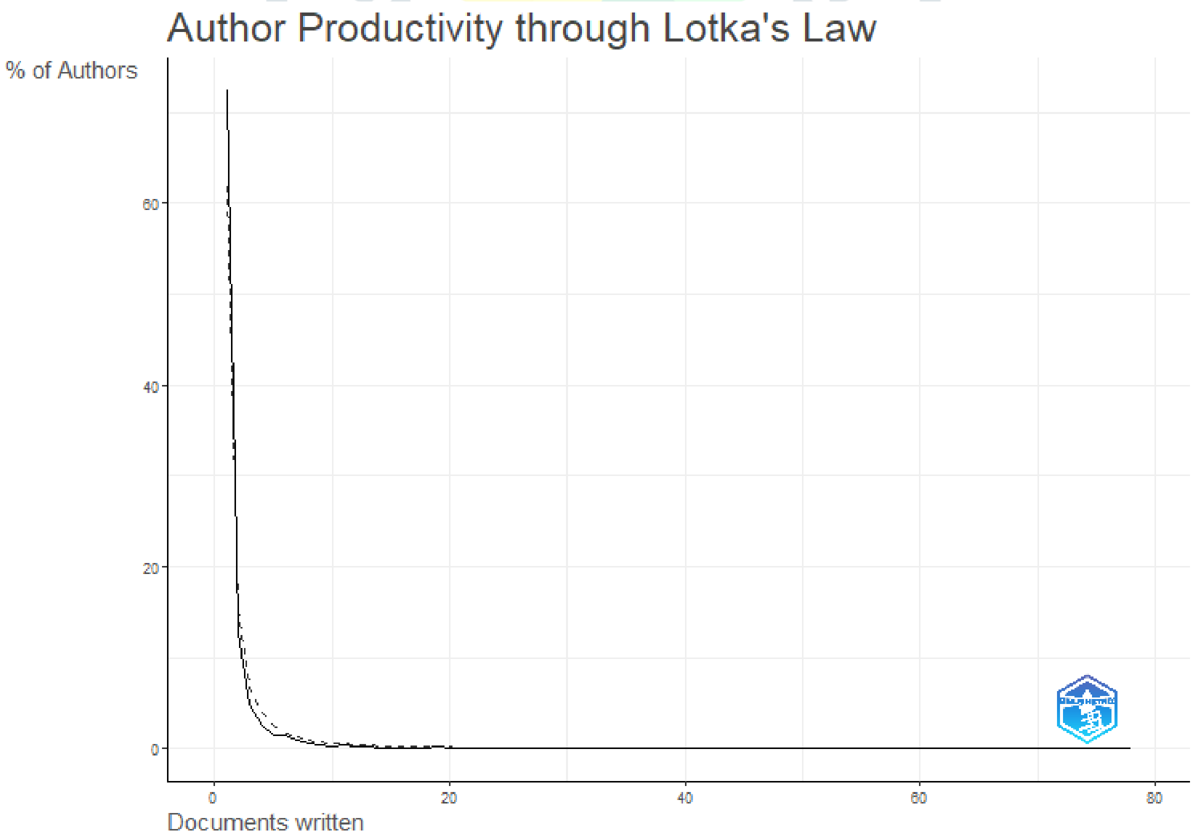

Fig. 11 Author's productivity through Lotka's Law

In contrast, the other authors typically produce only one or two works. The steep curve indicates that although numerous authors have published very few works, a few prolific authors have published a large number of works. This illustrates the degree of scientific production within a limited number of authors of the scientific field, which is common in most areas of research. The distribution can be used to study the framework of the scientific literature and identify the major players in landslide research or any other research sphere.

3.12 Most relevant affiliations

The most applicable affiliations are the names of the graphs, which are titled accordingly, and they represent the distribution of articles published under different affiliations, likely academic or research institutions. The affiliations are listed in this chart on the left side, and the number of articles published by each affiliation as the right side. The circles are also determined by the number of articles contributed by each affiliation, which is the amount of research. Based on the chart, it is evident that some affiliations, namely Y.L., Y.Z., and W.L., have a considerably higher number of articles compared to others. Y.L. leads in the number of articles (114), followed by Y.Z. (110) and W.L. (101). Such affiliations are likely to be major institutions or research centers that contribute significantly to the scientific literature on landslides or other related issues. As we progress down the chart, the number of articles decreases, and the distribution of research output becomes hierarchical, with a small number of affiliations contributing significantly to the research output. This is common in science, where a small number of dominant institutions or research institutions publish a significantly high percentage of articles, while many other affiliations have fewer publications. This distribution can help understand not only which particular institutions are most actively engaged in landslide research, but also the level of concentration of research activity to a small set of key affiliations.

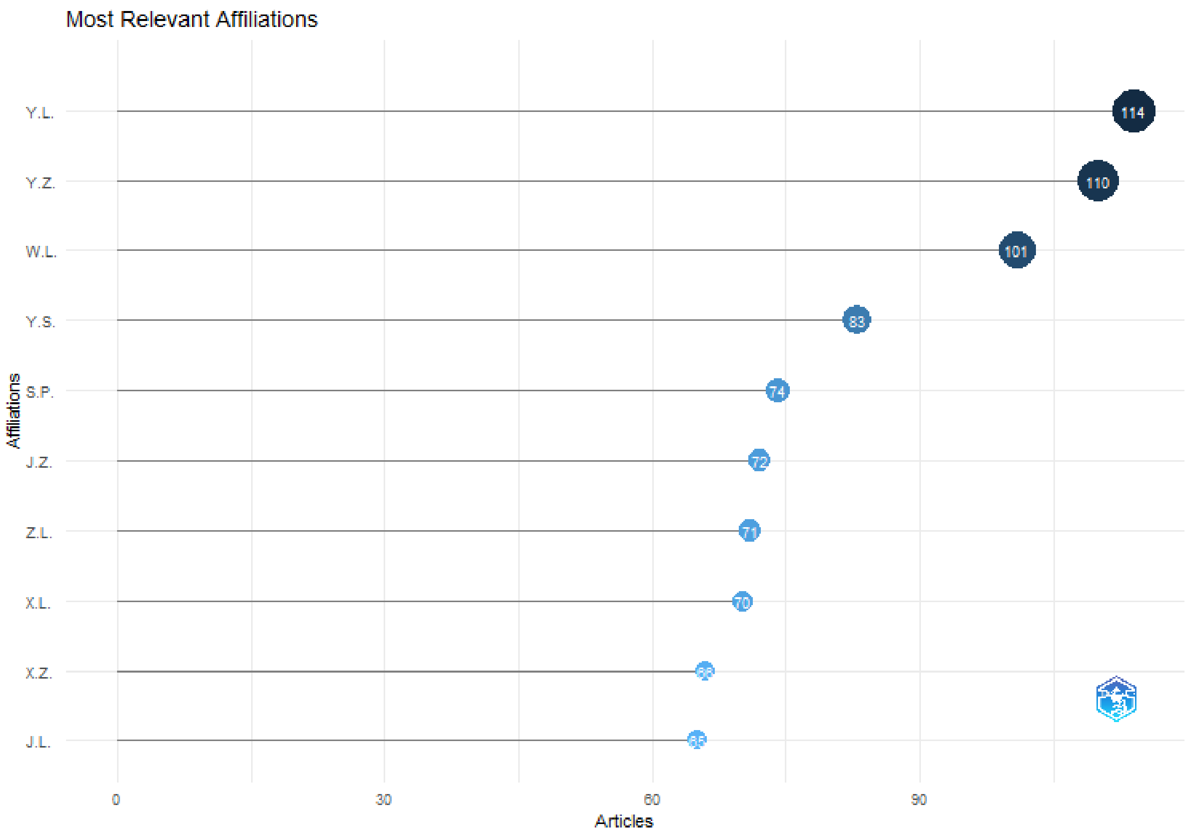

Fig. 12 Most relevant affiliations

3.13 Production of Affiliations in a year

The figure entitled 'Affiliations Production over Time' shows the number of articles published by various affiliations over the years, from 2004 to 2024. The affiliations are illustrated by colored lines in the graph that are associated with a specific research group or institution. The articles are represented by the Y-axis and the years by the X-axis. Based on the graph, it is evident that the number of publications from all affiliations was relatively low until approximately 2019-2020, when production increased significantly. Such a rush suggests a sudden increase in research activity in the area of landslides or related fields, especially regarding affiliations such as Y.L., W.L., Y.S., and Y.Z. Of the affiliations, Y.L. has the most and longest-lasting growth in articles over time, which was particularly notable in recent years. The other memberships, such as Y.Z., S.P., and W.L., have also experienced significant growth. However, the trends are not as steep as those of Y.L. This tendency suggests that these institutions have become increasingly interested and invested in landslide-related research over the past few years, possibly due to technological advancements and government investments in research. The sharp rise in the number of publications after 2020 might also be explained by the broader international or regional focus on landslide studies, potentially due to environmental issues, technical advances (such as the adoption of AI and remote sensing), or the outbreak of more natural disasters, which need more research and the development of solutions. Such a rapid increase in the number of research studies is essential in understanding the new trends in landslide research and the contributions of these institutions.

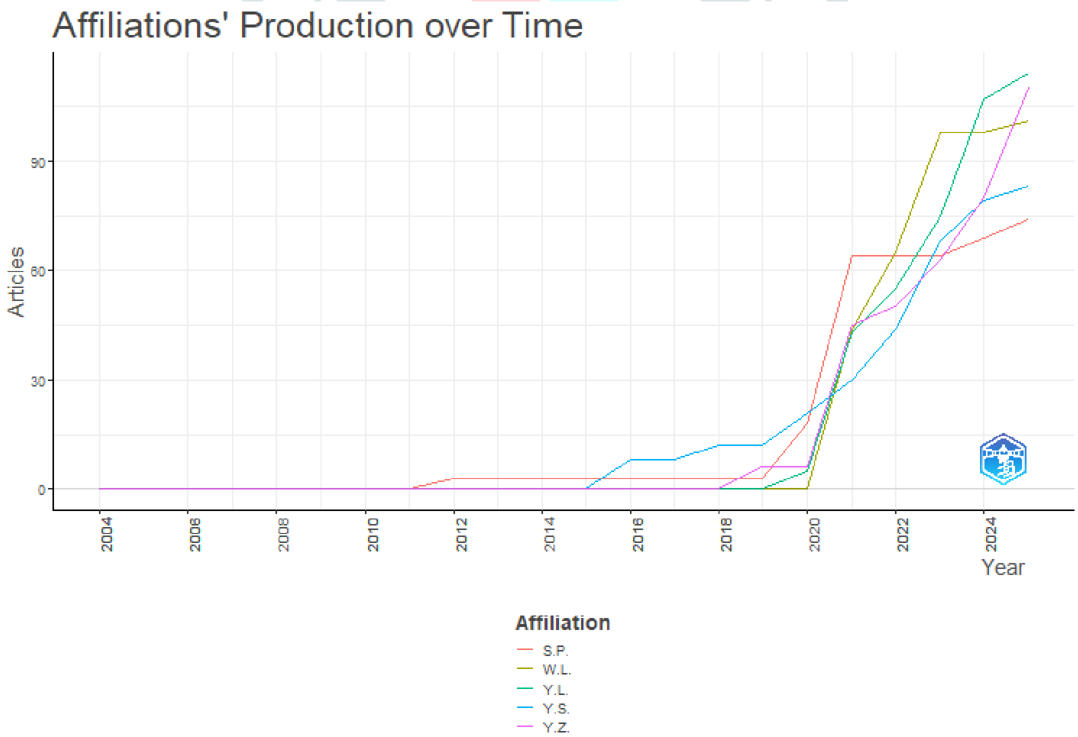

Fig. 13 Affiliations' productions over the year

3.14 Countries of corresponding authors

The chart titled "Corresponding Author Countries" provides the count of documents published by corresponding authors from different countries, with a specific distinction between single-country publication (SCP) and multiple-country publication (MCP). The graph highlights the trends in collaboration among countries in studies related to landslides or other relevant areas. Based on the graph, it is evident that China has the most total publications, both solo and collaborative, followed by Italy, India, the USA, and Korea. These nations demonstrate a significant contribution to the sphere. The chart also represents a large number of collaborations with several countries, including China, Italy, and India, which have more multiple-country publications (MCP) than single-country publications (SCP). This suggests that landslide studies are highly collaborative, with authors from various countries collaborating to publish works. Even the most cooperative nations, such as China and Italy, have robust international research networks, which may be due to a combination of resources, knowledge, and a shared interest in mitigating the problem of landslide risks. This implies an increasing trend of international collaboration in the research and prevention of landslide consequences, considering countries from different geographical locations. Such visualization can be used to explain that it is not only the distribution of research on landslides that the cooperation among various countries is an essential contributor to the scientific production in the field.

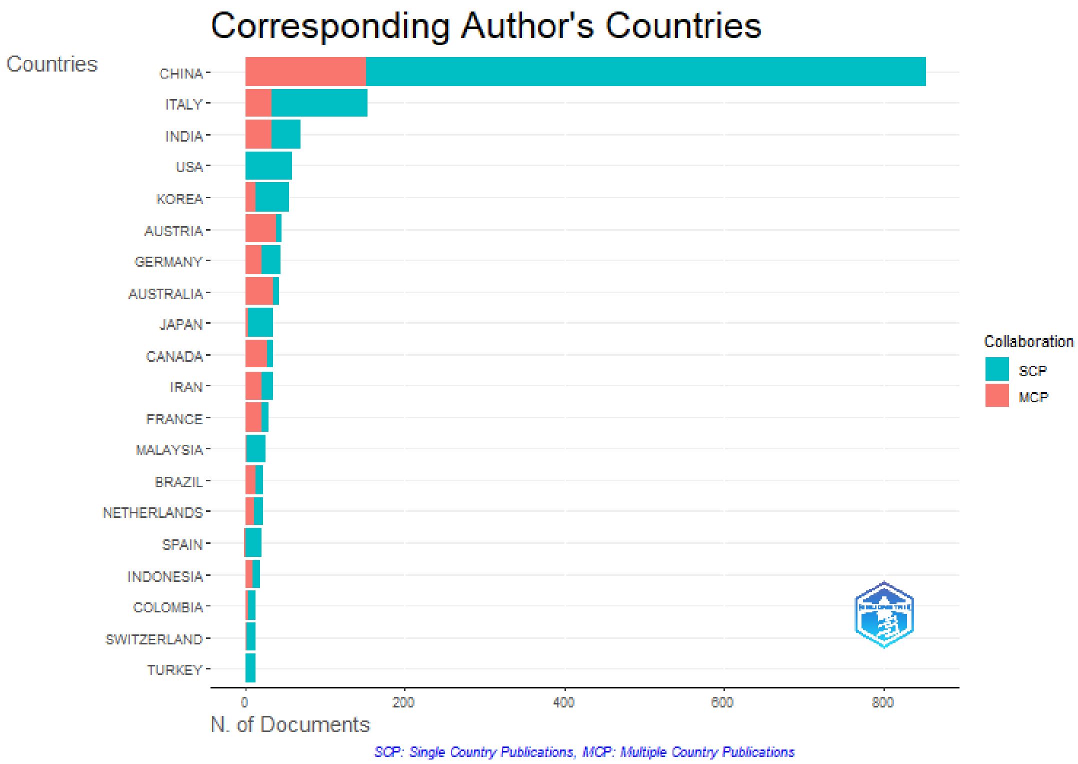

Fig. 14 Corresponding authors' countries

3.15 Scientific productions of the country

The map's name is Country Scientific Production, which will present a visualization of the distribution of scientific production related to landslides and associated disciplines worldwide. The map also presents the countries in terms of different degrees of blue, whereby the more intense the blue, the greater the scientific production, and the darker the blue and gray, the lesser the scientific contribution in this field. China is represented by the darkest blue color on the map, indicating its leading position in scientific production. This underlines China's supremacy in landslide research, as the preceding graphs have demonstrated its dominance in terms of publications and collaborations. Other nations, such as Italy, the USA, and India, also dominate the scientific scene, indicating their immense contributions, but are colored in a lighter blue as compared to China. There is a notable level of scientific production in countries and regions such as Europe, North America, and Asia, with some European countries, including Germany and France, also playing a significant role in the field. By comparison, some other parts of the world, such as Africa and certain regions of South America and Oceania, record less scientific activity on landslides, and these areas are highlighted in bluer or grayer colors. This map graphically supports the results of the previous graphs, highlighting the worldwide scope of landslide studies, with more effort concentrated in certain areas, such as China and other well-developed countries. The statistics indicate that the risks of landslides are recognized worldwide, and it is necessary to investigate scientifically effective mitigation measures. However, there are also disparities in research performance at the regional level.

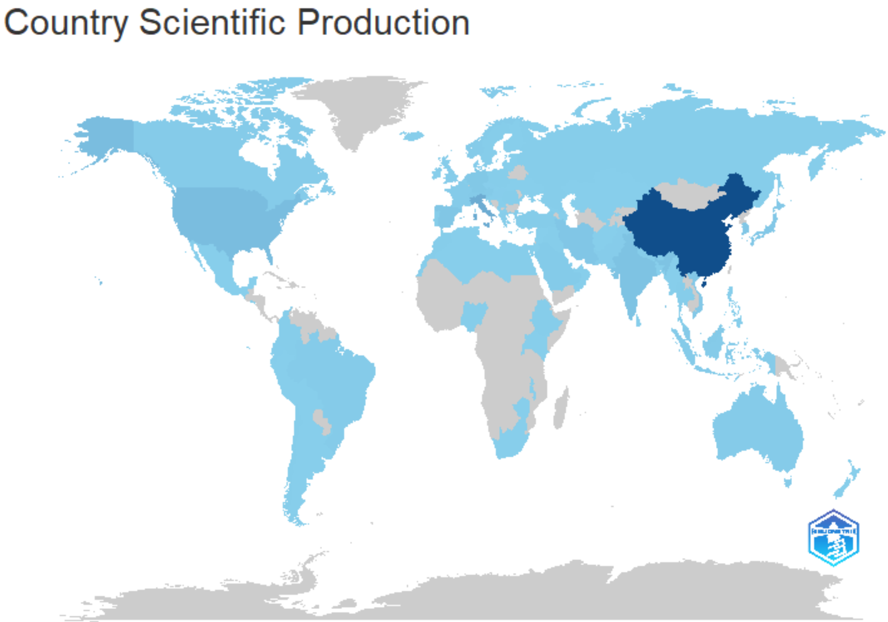

Fig. 15 Country scientific productions

3.16 Country collaboration map

Figure 16 is the collaboration map that depicts the international network of scientific collaborations in landslide research. This map illustrates the collaborations between countries through lines, with China (represented by the

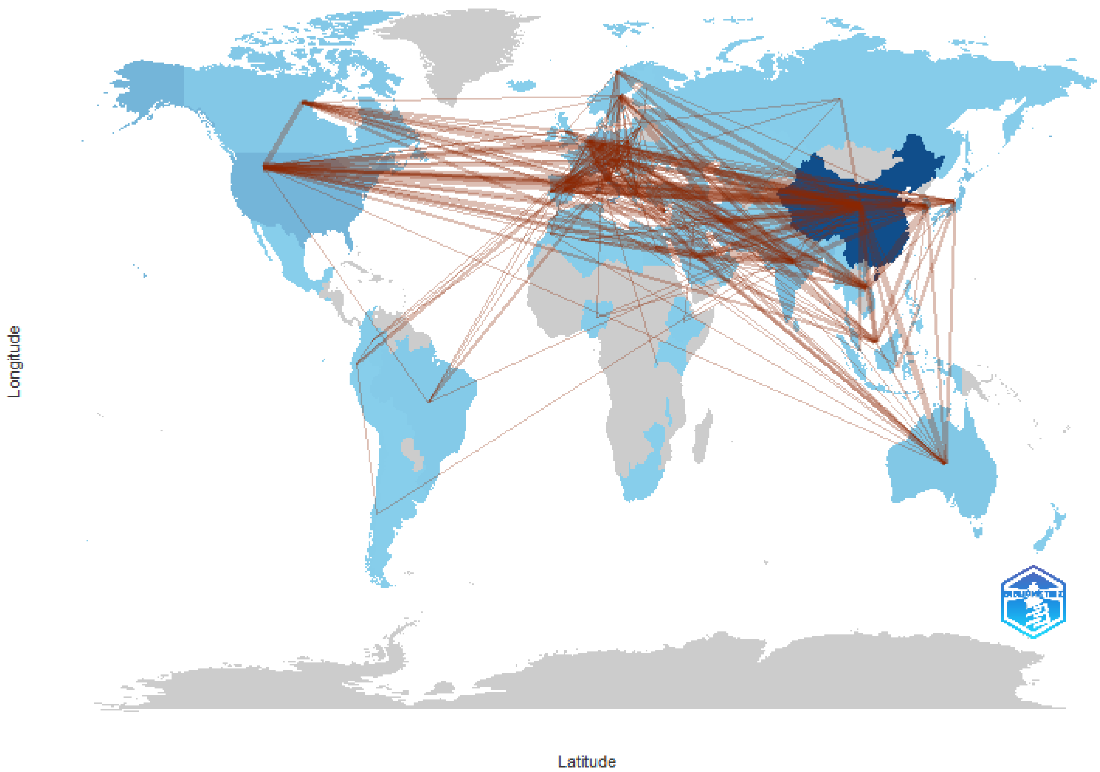

Fig. 16 Country collaboration

bright blue color) playing a dominant role as the center point of the map. The thick orange lines emanating from China to other nations represent the highest level of cooperation, indicating that China is at the center of research networks concerning landslides across nations. Countries such as the USA, Italy, India, and several European countries are also well-connected, as indicated by the numerous lines connecting them to other countries in the network. The line thickness can be related to the strength or frequency of collaboration, implying that countries with more lines are more proactive in conducting research globally. Asian countries, such as Japan and South Korea, have observable connections with China and other parts of the world, resulting in high levels of cooperation among Asian countries. Conversely, some regions in Africa, Oceania, and South America are less connected, meaning they are not involved in international joint research on landslides. This map (Figure 1.18) highlights the increasing trend in international cooperation for landslide research, with a notable focus in certain regions, such as Asia and Europe, where more active research on landslides and geohazards is conducted. It further highlights China's dominant role as a partner, given the high level of investment in natural hazard scientific studies.

3.17 Country production over time

As depicted in the graph (Fig. 17), the trends in scientific production of several countries are presented through the number of articles published following research on landslides. The statistics take the form of the number of

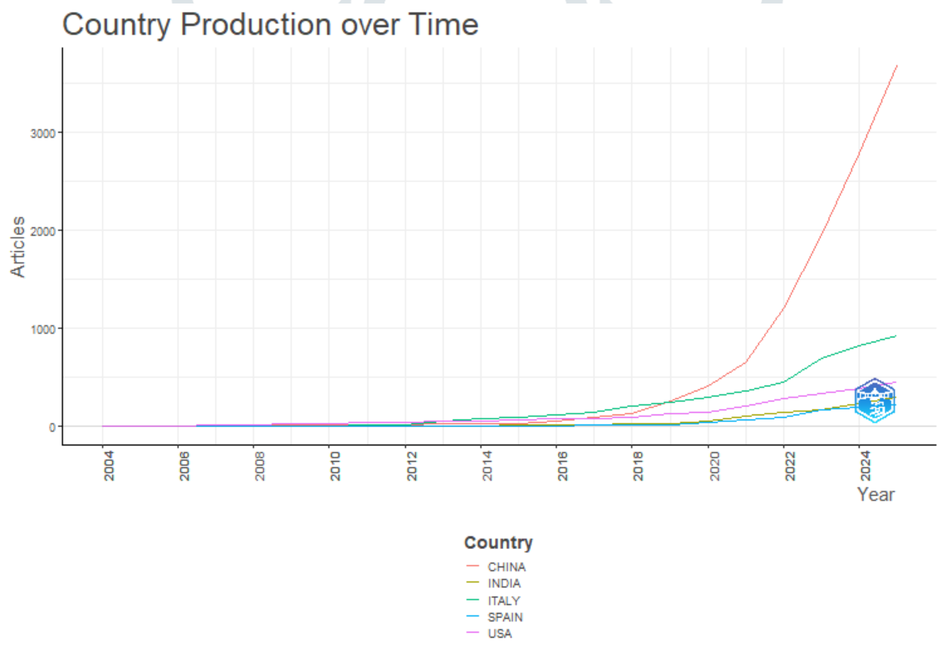

Fig. 17 Country production over time

articles published by a particular country each year, beginning in 2004 to date. As the graph illustrates, China has experienced exponential growth in research output, with a notable rise starting in 2018. The red line of China is clearly the tallest, as it is the leading country in landslide research, particularly in recent years. This implies that China has made substantial investments in natural hazards research, which makes a significant contribution to international research on landslides. India comes next with considerable growth in the articles; however, the growth rate is not as high as that of China. The green line represents the output of research in India, which has been increasing, with some of the most significant contributions recorded since the mid-2010s. This means that India is becoming an increasingly important contributor to the study of landslides, but its contribution is still relatively low compared to that of China. Italy, Spain, and the USA reveal less impressive, yet confident, growth throughout the years, and the number of publications has been growing slowly since approximately 2010. The growth trends in Italy and Spain are also similar, but significantly lower than those in China and India. The USA also experiences improvement, but it is not as advanced as China and India in terms of total output. In general, the graph illustrates a clear preeminence of China in terms of landslide-related studies, followed by India, and then Italy, Spain, and the USA, which have a lesser but consistent rate of contribution. The upward trend in the case of all countries suggests that landslide studies have gained significance in recent years, with China and India taking the lead.

3.18 Thematic evolutions

The figure (Fig. 18) excludes the yearly coverage of the thematic developments in landslide-related research topics, providing figures for the issues over four periods: 1992-2010, 2011-2015, 2016-2020, and 2021-2025. The chart highlights the outstanding trends and changes in the research focus, particularly in landslide hazards, susceptibility, and prediction.

a) **1992-2010:** The key issues in this era were concerned with landslide hazard, landslide susceptibility, and international landslides. These were the major themes of the research, with a focus on the general hazards of landslides, mapping, and understanding susceptibility. The purpose of wireless sensors was also identified, but at a smaller scale.

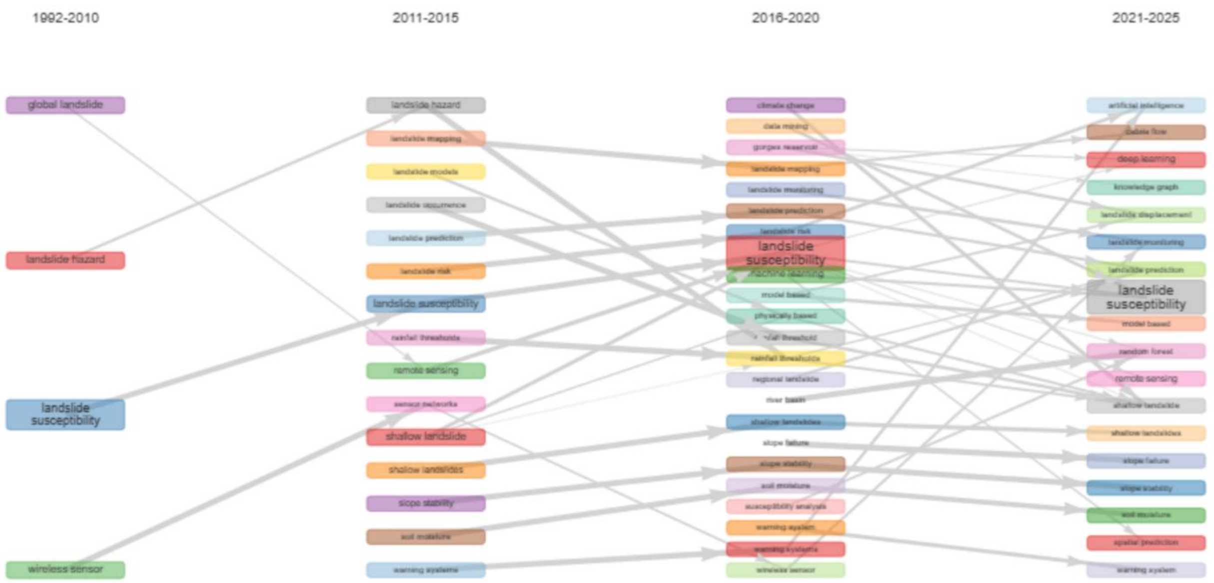

Fig. 18 Thematic evolutions

b) **2011-2015:** The theme became narrower, shifting to more focused issues, including landslide mapping, landslide prediction, and landslide risk assessment. The significance of remote sensing technology was recognized, along with its high correlation with matters such as shallow landslides and soil moisture. The theory of landslide susceptibility has been on the rise, becoming one of the most prominent themes in landslide studies.

c) **2016-2020:** The research focus was further narrowed during this period, though landslide susceptibility was at the centre. Nevertheless, new topics emerged, particularly climate change, artificial intelligence, machine learning, and data mining. This period also saw the integration of big data and AI to predict landslides. Slope stability, model-based approaches, and shallow landslides received more attention.

d) **2021-2025:** The most recent period focuses on current trends in research, including artificial intelligence, deep learning, landslide displacement, and landslide modeling. A predictive model based on AI and machine learning is gaining attention, as well as addressing issues related to landslide susceptibility and landslide prediction. Studies on landslide warning systems and remote sensing are also significant, and the development of new analytical tools, such as knowledge graphs and spatial prediction models, should be explored further.

In general, the chart indicates that the generalized research on landslides has been replaced with more narrow and technology-oriented methods. Machine learning and artificial intelligence are now essential tools in enhancing landslide prediction and modeling, indicating the growing use of sophisticated technology in disaster management. The ever-increasing landslide susceptibility as a theme underscores the increasing importance of evaluating and mitigating landslide threats in high-risk regions.

3.19 Relevance and development of a theme in the landslide research field

This is the figure (Fig. 19) that allows visualizing the correspondence between thematic formation and relevance in the sphere of landslide research. The degree of significance (centrality) is assigned to the x-axis, and the degree of development (density) is assigned to the y-axis. The themes fall into four quadrants:

a) Motor Themes (top-right quadrant)

These are the most focal and well-developed themes related to landslides. Some of the significant themes include landslide susceptibility, machine learning, deep learning, landslide prediction models, and the impact of climate change. These are the state-of-the-art, high-impact issues in slide research, and considerable academic interest has been generated.

b) Principles (top-left quadrant)

These themes are principal, though not so developed as the motor themes category. Displacement caused by landslides, landslide hazard, and landslides triggered by rainfall are among the issues well established in landslide research, although they have not been thoroughly developed as the more modern methods.

c) Emerging or Declining Themes (bottom-left quadrant)

In this quadrant, the themes are not well developed, and their relevance is low. Some are in decline, while others have subjects that are still new but have not received much attention. Some examples that can be categorized under this category include geostatistical analysis, rainfall-related landslides, and spatial heterogeneity. They are still helpful in some areas of niche research, but are not the focus of the current trends in landslide research.

d) Niche Themes (bottom-right quadrant)

These are high-development, low-relevance themes. They represent specialized research subjects that may not be of general use but are evolving rapidly in specific fields. Explainable AI, landslide prediction improvements, and slope unit analysis belong to this category, which underscores the increasing popularity of new methods, albeit some of them are less centralized than mainstream topics such as landslide susceptibility and deep learning.

The chart (Fig. 1.29) shows that themes such as motor ones (e.g., AI, deep learning, and landslide susceptibility) are very central and well-developed, whereas niche ones are advancing rapidly but do not have a broader scope of the matter. Themes that are newly introduced or that are being phased out indicate themes that are less central and less developed, which means they are either being replaced by newer methodologies or remain in the process of development in a niche situation. This distribution provides a concise summary of the evolving emphasis and trends in landslide studies, particularly the increasing role of AI and machine learning in predicting and mitigating landslide risks.

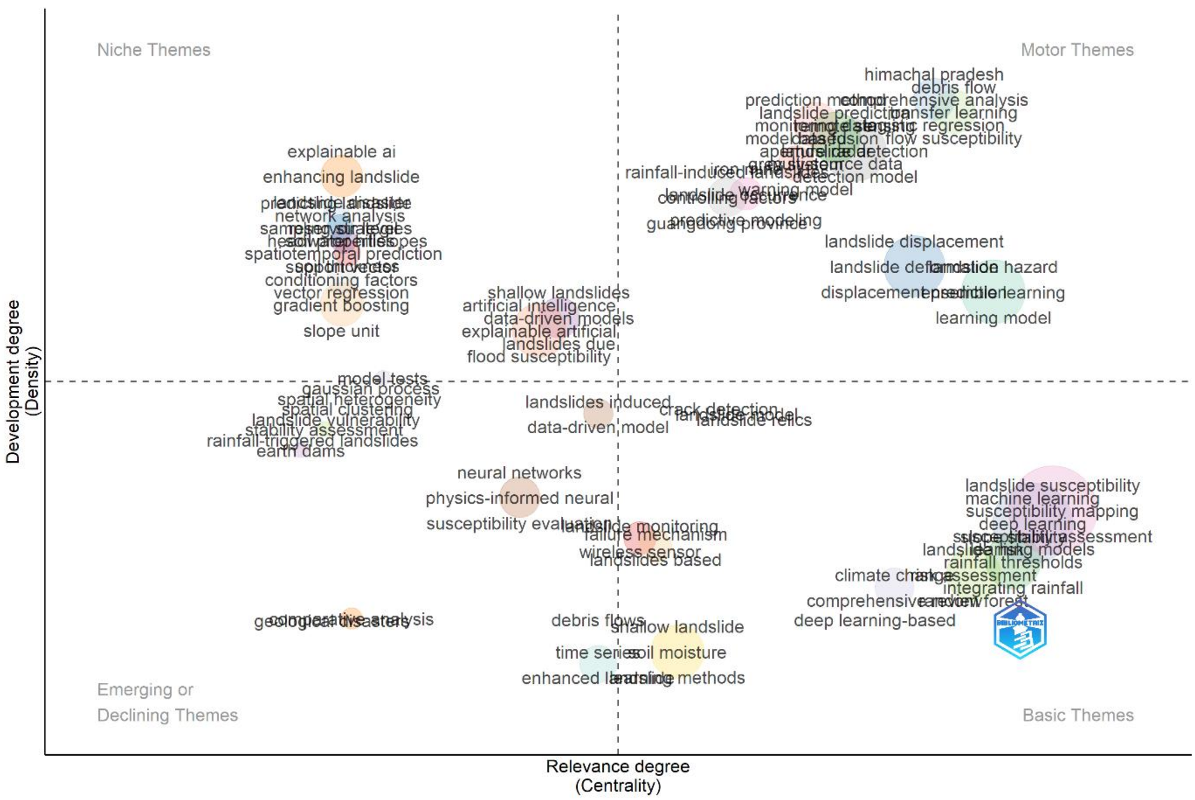

Fig. 19 Relevance of development

3.20 Factorial Map

Figure 1.20 is the Factorial Map, which illustrates the dimensionality reduction process of complex data, with the axes (Dim 1 and Dim 2) capturing the main factors that explain the variance in the data. Dim 1, with a more significant share of the variance (24.64%), distinguishes the terms according to their overall conceptual category. The 2nd dimension can be further refined with the help of Dim 2, which contributes 8.35 percent; it is a cluster of related terms that the initial dimension may have overlooked. Terms within the map that are located at the same level are conceptually connected, which implies that they share similar themes or patterns. Notably, humidity, temperature, and dengue are closely related, which may suggest that they are closely tied to weather and climatic research. In the same vein, climate change and rainfall appear to be linked, suggesting that they are part of a broader environmental discourse. In contrast, terms such as COVID-19, clinical decision-making, and inpatients are placed much further down the list of terms related to the environment, indicating that they are focused on health-related issues.

The factorial map is an intuitive representation of the relationships between various notions in the dataset and one another, including the two main areas that intersect, as well as those that are distinct, such as climate science, healthcare, and environmental risk management. The closeness of words can help reveal associations that are not evident, or assist in identifying groups of research topics that could guide future research or interventions in these areas.

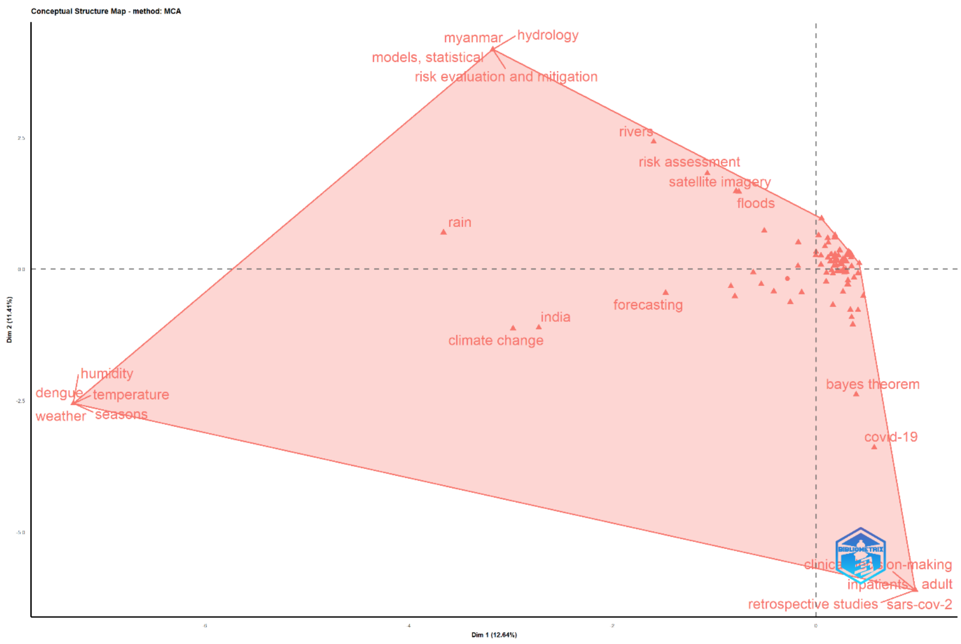

Figure 20 Factorial map

4. Conclusion

This study presented a systematic literature review and bibliometric analysis of global research on landslide risk assessment, utilizing data from the Dimensions database to map the field's evolution from 1992 to 2025. The findings highlight a profound transformation in this scientific domain, driven by technological innovation and global collaboration. The analysis of annual scientific production reveals that landslide research has transitioned from a niche discipline with minimal output before 2010 into a rapidly expanding field. This exponential growth, particularly evident after 2015, is inextricably linked to the integration of advanced technologies. The surge in publications correlates with the widespread adoption of Artificial Intelligence (AI), Machine Learning (ML), and Remote Sensing, which have revolutionized the accuracy and efficiency of landslide susceptibility mapping and hazard analysis.

Geographically, the research landscape is heavily dominated by China, which leads the world in both total publication volume and international collaboration. The rapid rise of China's scientific output, especially after 2018, underscores substantial national investment in natural hazard mitigation. India and Italy also play pivotal roles, contributing significantly to the global body of knowledge, with India showing consistent growth since the mid-2010s. The network analysis confirms that this is a highly collaborative field, with strong research ties connecting Asia, Europe, and North America. In terms of dissemination, the study identified a core group of high-impact journals through Bradford's Law. *Remote Sensing*, *Applied Sciences*, and *Landslides* serve as the primary venues for this research, reflecting the multidisciplinary nature of the field that bridges geotechnical engineering, environmental science, and data analytics.

The thematic evolution analysis provides the most critical insight into the future direction of the discipline. The focus has shifted from foundational concepts, such as "landslide hazard" and general mapping (1992–2010), to sophisticated, data-driven approaches. Currently, "Deep Learning," "Machine Learning," and "Landslide

Susceptibility" are established as "motor themes"—central and fully developed topics driving the field. Furthermore, the emergence of niche themes such as "Explainable AI" suggests that the next frontier of research will focus not only on the predictive power of models but also on their interpretability and transparency. In summary, landslide risk assessment has evolved into a high-tech, data-intensive science. Future research is expected to continue this trajectory, with increasing reliance on deep learning algorithms and satellite-based monitoring to manage the growing complexities of disaster risk reduction globally.

References

Carrión-Mero, P., Montalván-Burbano, N., Morante-Carballo, F., Quesada-Román, A., & Apolo-Masache, B. (2021). Worldwide Research Trends in Landslide Science [Review of *Worldwide Research Trends in Landslide Science*]. *International Journal of Environmental Research and Public Health*, *18*(18), 9445. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/ijerph18189445

Das, S., Sarkar, S., & Kanungo, D. P. (2022a). GIS-based landslide susceptibility zonation mapping using the analytic hierarchy process (AHP) method in parts of Kalimpong Region of Darjeeling Himalaya. *Environmental Monitoring and Assessment*, *194*, 234. https://doi.org/10.1007/s10661-022-09851-7

Das, S., Sarkar, S., & Kanungo, D. P. (2022b). A critical review on landslide susceptibility zonation: recent trends, techniques, and practices in Indian Himalaya [Review of *A critical review on landslide susceptibility zonation: recent trends, techniques, and practices in Indian Himalaya*]. *Natural Hazards*, *115*(1), 23. Springer Science+Business Media. https://doi.org/10.1007/s11069-022-05554-x

Dikshit, A., Sarkar, R., Pradhan, B., Segoni, S., & Alamri, A. (2020). Rainfall Induced Landslide Studies in Indian Himalayan Region: A Critical Review [Review of *Rainfall Induced Landslide Studies in Indian Himalayan Region: A Critical Review*]. *Applied Sciences*, *10*(7), 2466. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/app10072466

Fan, H., Lu, Y., Shao, S., Li, L., Wang, Y., Lu, M., Li, J., Yao, K., & Sun, Y. (2023). Evaluation and analysis of statistical and coupling models for highway landslide susceptibility. *Geomatics, Natural Hazards and Risk*, *14*, 2167612. https://doi.org/10.1080/19475705.2023.2167612

Kainthola, A., Pandey, V. H. R., Kushwaha, G., Kumari, P., Singh, P. K., & Singh, T. N. (2025). Evolution and trend of landslide research in India based on a decade long publication record. *Discover Geoscience*, *3*(1). https://doi.org/10.1007/s44288-025-00111-y

Mafigiri, A., Khanan, M. F. A., & Abdullah, R. A. (2025). A review of GIS-based landslide susceptibility and hazard modeling considering the influence of topographic parameters on rainfall spatial variability [Review of *A review of GIS-based landslide susceptibility and hazard modeling considering the influence of topographic parameters on rainfall spatial variability*]. *Modeling Earth Systems and Environment*, *11*(6). Springer Science+Business Media. https://doi.org/10.1007/s40808-025-02615-5

Mohammady, M., Pourghasemi, H. R., & Pradhan, B. (2012). Landslide susceptibility mapping at Golestan Province, Iran: A comparison between frequency ratio, Dempster–Shafer, and weights-of-evidence models. *Journal of Asian Earth Sciences*, *61*, 221. https://doi.org/10.1016/j.jseaes.2012.10.005

Poddar, I., & Roy, R. (2024). Application of GIS-based data-driven bivariate statistical models for landslide prediction: a case study of highly affected landslide prone areas of Teesta River basin. *Quaternary Science Advances*, *13*, 100150. https://doi.org/10.1016/j.qsa.2023.100150

Zhu, H., Zhu, X., Xu, Q., Fu, X. C. X. Y. K., Li, M., Jia, X., & Fan, Z. (2025). From hazard mapping to risk governance: 20-year trajectory of land use/cover change impacts on landslide susceptibility via multi-modal scientometrics. *Humanities and Social Sciences Communications*, *12*(1). https://doi.org/10.1057/s41599-025-05831-7

Zou, Y., & Zheng, C. (2022). A Scientometric Analysis of Predicting Methods for Identifying the Environmental Risks Caused by Landslides. *Applied Sciences*, *12*(9), 4333. https://doi.org/10.3390/app12094333