An overview of the evolution of global debris flow related research from 2010 to 2019 — A bibliometric analysis on based on Web of Science Core Collection

Li XIANG
Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, Chengdu 610041, China

Abstract: Debris flow has become one of the most dangerous types of natural disasters in the world with the increase of human population, expansion of human activity disturbance, speed-up of climate change and frequent occurrence of extreme weather events. However, there is a lack of bibliometric analysis and visualization on global debris flow research in the recent decade from a quantitative perspective. This paper provides quantitative investigation into the general landscape of debris flow research over the last decade, aiming to develop a systematic overview for scientific community interested in this research field. Toward this end, we used the Web of Science (WoS) citation database to identify pertinent papers on the topic of debris flow on a ten-year time span (2010–2019). For a complete bibliographies of these selected articles and reviews, software tools including Bibexcel, Citespace, and Vosviewer were adopted to conduct a series of bibliometric analysis, geographical mapping and network visualization. Major findings are as follows: China is the dominant contributor in scientific output of debris flow research. Among the Top 10 productive countries, the H index of USA outperforms China and ranks the first, followed by Italy, China, France, and UK. The top five publishing the largest number of papers are *Landslides*, *Geomorphology*, *Journal of Mountain Science*, *Natural Hazards and Earth System Sciences* and Natural Hazards. Among the list of the top prolific authors, Markus STOFFEL (University of Geneva, Switzerland), Richard M. Iverson (US Geol Survey, USA) and Peng CUI (IMHE, CAS, China) are the leading three authors and their H index are 21, 11 and 18. Chinese Academy of Sciences contribute the most papers on the institutional level, followed by Chengdu University of Technology, University of Chinese Academy of Sciences, and US Geological Survey (USGS). Debris flow hazard assessment (including in situ experiment and numerical modeling) is a long during topic in this scientific research field. Rainfall threshold for debris flows and the design of debris flow mitigation structures are the two burst words in recent years which may indicates the hot research topic.

1. Introduction

Debris flow has become one of the most dangerous types of natural disasters in the world with the increase of human population, expansion of human activity disturbance, speed-up of climate change and frequent occurrence of extreme weather events. It causes considerable economic loss and sometimes also casualties because of its high velocity, large impact force and long runout distance. It has the potential to destroy infrastructure, buildings, and human life (Faria Lima Lopes LDC, Prado Bacellar LDA, Amorim Castro P. 2016. Assessment of the debris-flow susceptibility in tropical mountains using clast distribution patterns. Geomorphology. 275:16-25.). Research on debris flow has emerged significantly over the last decades, evidenced by an extensive concern of governments, the public and scientific community.

Research related to debris flow is multidisciplinary, as it interact with geography, geology and disaster science, and covers a wide range of topics, including its dynamic mechanism and process, influencing factors (climate change, meteorological indicators and hydrological factors), debris flow early warning, monitoring, prediction and prevention, experimental and numerical simulation (remote sensing monitoring) and impact of debris flow on human property, social economy and living environment. Increasing debris flow activities, which are documented by the increasing number of published research items, have been observed in recent years. How to extract useful information from so many existing publications, and then identify the research status quo and trace the development trend in this field is a research topic of great interest. However, there have been few attempts to collect systematic data for giving a comprehensive insight into global production, distribution and temporal evolution of debris flow related research.

It is difficult to summarize a large number of documents using traditional statistical methods. Bibliometrics refers to the use of mathematical and statistical methods to quantitatively analyse the status quo and development trend of science and technology (Yu DJ, Xu ZS, PedryczW,WangWR (2017) Information sciences 1968–2016: a retrospective analysis with text mining and bibliometric. Inf Sci 418:619–634. Elango, B. and Ho, Y. S., A bibliometric analysis of highly cited papers from India in Science Citation Index Expanded. Curr. Sci., 2017, 112(8), 1653–1658. Merigó, J. M. and Yang, J. B., A bibliometric analysis of operations research and management science. Omega, 2017, 73, 37–48. Yu, D. J., Xu, Z. S. and Wang, W. R., Bibliometric analysis of fuzzy theory research in China: A 30-year perspective. Knowl. Based Syst., 2018, 141, 188–199. Yu, D. J., Xu, Z. S. and Fujita, H., Bibliometric analysis on the evolution of applied intelligence. Appl. Intell., 2019, 49(2), 449–462.). As firstly introduced by Pritchard (Pritchar A, 1969. Statistical bibliography or bibliometrics. Journal of Documentation, 25(4): 348–349.), it is proven to be a common and effective research tool to quantitatively analyze the research performance and the scientific contributions of authors, journals, regions or specific works, analyze the dissemination and cognitive process of scientific knowledge, monitor scientific developments, and identify emerging topical areas and intellectual structures(Fu H, Ho Y (2013) Independent research of China in science citation index expanded during 1980–2011. J Informetr 7(1): 210–222; Liu X, Zhan F, Hong S, Niu B, Liu Y (2012) A bibliometric study of earthquake research: 1900–2010. Scientometrics 92(3):747–765. Silva, E. G., & Teixeira, A. A. C. (2008). Surveying structural change: Seminal contributions and a bibliometric account. Structural Change and Economic Dynamics, 19(4), 273–300. Chen, C., Hu, Z., Liu, S., & Tseng, H. (2012). Emerging trends in regenerative medicine: A scientometric analysis in CiteSpace. Expert Opinion on Biological Therapy, 12(5), 593–608.). Recently, bibliometric studies have been widely in many areas, including medical science (Takahashi, R. and Kajikawa, Y., Computer-aided diagnosis: a survey with bibliometric analysis. Int. J. Med. Informat., 2017, 101, 58–67.), environmental science (Zhang, S., Mao, G., Crittenden, J., Liu, X. and Du, H., Ground-water remediation from the past to the future: a bibliometric analysis. Water Res., 2017, 119, 114–125.), management (Oraee, M., Hosseini, M. R., Papadonikolaki, E., Palliyaguru, R. and Arashpour, M., Collaboration in BIM-based construction net-works: a bibliometric-qualitative literature review. Int.J.ProjectManage., 2017, 35(7), 1288–1301.), business (Sarin, S., Haon, C. and Belkhouja, M., A bibliometric analysis of the knowledge exchange patterns between major technology and innovation management journals (1999–2013). J. Prod. Innov. Manage., 2018, 35(1), 2–8.), information and computer science (Yu, D. J., Xu, Z. S. and Wang, X. Z., Bibliometric analysis of support vector machines research trend: a case study in China. Int. J. Machine Learn. Cyber., 2019, in press, doi:10.1007/s13042-019-01028-y. Yu DJ, Xu ZS, Kao Y, Lin CT (2018) The structure and citation landscape of IEEE transactions on fuzzy systems (1994–2015). IEEE Trans Fuzzy Syst 26(2):430–442.).

The traditional bibliometric method analyzed research trends of certain field mainly from publication output, subject category and journal, author, country and research institute, and keyword frequencies, etc. [Liu, X. J., Zhan, F. B., Hong, S., Niu, B. B., & Liu, Y. L. (2012). A bibliometric study of earthquake research: 1900–2010. Scientometrics, 92(3), 747–765. Chiu, W. T., & Ho, Y. S. (2007). Bibliometric analysis of tsunami research. Scientometrics, 73(1), 3–17. Almeida-Filho, N., Kawachi, I., Pellegrini, A., & Dachs, J. N. W. (2003). Research on health inequalities in Latin America and the Caribbean: bibliometric analysis (1971–2000) and descriptive content analysis (1971–1995). American Journal of Public Health, 93(12), 2037–2043. Grossi, F., Belvedere, O., & Rosso, R. (2003). Geography of clinical cancer research publications from 1995 to 1999. European Journal of Cancer, 39(1), 106–111.]. In recent years, the bibliometric network analysis was increasingly applied to analyze the inter-relationships of keywords, country and research institute, and so on. The common network analysis included co-word analysis [Zhao, L. M., & Zhang, Q. P. (2011). Mapping knowledge domains of Chinese digital library research output, 1994–2010. Scientometrics, 89(1), 51–87. Ding, Y., Chowdhury, G. G., & Foo, S. (2001). Bibliometric cartography of information retrieval research by using co-word analysis. Information Processing and Management, 37(6), 817–842.], co-citation analysis [Lai, K. K., & Wu, S. J. (2005). Using the patent co-citation approach to establish a new patent classification system. Information Processing and Management, 41(2), 313–330. He, Y. L., & Hui, S. C. (2002). Mining a web citation database for author co-citation analysis. Information Processing and Management, 38(4), 491–508.], co-authorship analysis [Glanzel, W. (2000). Science in Scandinavia: a bibliometric approach. Scientometrics, 48(2), 121–150. Seglen, P. O., & Aksnes, D. W. (2000). Scientific productivity and group size: a bibliometric analysis of Norwegian microbiological research. Scientometrics, 49(1), 125–143.], and co-publication analysis [Schmoch, U., & Schubert, T. (2008). Are international co-publications an indicator for quality of scientific research? Scientometrics, 74(3), 361–377.], etc.

In order to reveal the knowledge structure of debris flow research in the recent decade, the present study carried out a systematic and in-depth analysis of publications associated with debris flow on a global scale. Descriptive statistics including literary composition and distribution, journal source, productive countries and institutions, and core authors are given based on conventional bibliometric methods. In addition, we uses knowledge mapping and visualization method to give a review mainly focusing on document co-citation, co-occurring terms, citation burst detection, and co-cited references to investigate the current research hotspots, trace the research progression, as wells as to capture the emerging research trends. The target of this paper is to answer three critical questions that have been previously unaddressed. (1) What are the most productive research subjects (journals, authors, institutions and countries) in the last decade? (2) What about the collaboration scope, structure and intensity between different subjects? (3) What topics were most examined in the past, and what are the emerging trends and future research focuses?

2. Data Acquisition and Methods

2.1 Data source and search strategy

Web of Science (WoS) is the largest and most comprehensive academic database in the world (He, X. R., Wu, Y. Y., Yu, D. J. and Merigó, J. M., Exploring the ordered weighted averaging operator knowledge domain: a biblio-metric analysis. Int. J. Intell. Syst., 2017, 32(11), 1151–1166. Yu, D. J., Xu, Z. S, Pedrycz, W. and Wang, W., Information Sciences 1968–2016: a retrospective analysis with text mining and bibliometric. Inform. Sci., 2017, 418, 619–634.). It includes more than 21000 journals and comprises four citation databases: Science Citation Index Expanded (1900–present), Social Sciences Citation Index (1900–present), Arts and Humanities Citation Index (1975–present), and Emerging Sources Citation Index (ESCI) (2005–present). (Clarivate Analytics (2019) Web of Science. https://apps.webofknowledge.com/) Up to now, it has been regarded as the most significant and frequently used scientific data source for the assessment of worldwide scientific output in many research fieds because of its multidisciplinary and international coverage (Liao, H., Tang, M., Luo, L., Li, C., Chiclana, F., & Zeng, X. J. (2018). A bibliometric analysis and visualization of medical big data research. Sustainability, 10(2), 166. Tang, M., Liao, H., & Su, S. F. (2018). A bibliometric overview and visualization of the international journal of fuzzy systems between 2007 and 2017. International Journal of Fuzzy Systems, 20(5), 1403–1422. Yu, D., Xu, Z., Kao, Y., & Lin, C. T. (2018). The structure and citation landscape of IEEE Transactions
on Fuzzy Systems (1994–2015). IEEE Transactions on Fuzzy Systems, 26(2), 430–442. Cui, T. N., & Zhang, J. M. (2018). Bibliometric and review of the research on circular economy through the evolution of Chinese public policy. Scientometrics, 116, 1013–1037.)

In our study, WoS was selected as a search engine owing to its extensive acceptance in the analysis of scientific publications. The topic search string "TS=("debris flow*" or "lahar" or "mud rock flow*" or "mud avalanche*" or "debris avalanche*" or "mudflow*" or "hyperconcentrated flow*" or "mud slide*")" was adopted for extracting records of English research articles or reviews published between the year 2010 and 2019. A total of 4634 original records were derived from the WoS Core Collection including SCI-Expanded and CPCI-S on 5 January 2020 by initial search. This search string covered a relatively broad publications scope. With the intention of choosing the targeting papers, all the original records were manually refined by a domain expert to exclude non-related topics. By inspection of the title, the complete abstract and the keywords of the papers, publications associated with "post-fire flooding", "snow avalanche" , "submarine landslides", as well as those related to "mass flow on Mars"are excluded, the papers holding the abovementioned keywords in the titles and/or abstracts and/or keywords are included in the dataset. Finally 2246 records were retained after eliminating duplicates.

2.2 Bibliometric and visualization software tools

Bibexcel, a versatile bibliometric tool developed by Olle Persson (Persson, O., Danell, R., Schneider, J.W., 2009. How to use Bibexcel for various types of bibliometric analysis. Celebrating Scholarly Communication Studies A Festschrift for Olle Persson at His Birthday 2009, 9–24.) is widely regarded as a flexible data management and analytical tool (Zheng, T., Wang, J., Wang, Q.,

Nie, C., Smale, N., Shi, Z., et al., 2015. A bibliometric analysis of industrial wastewater research: current trends and future prospects. Scientometrics 105, 863–882.). It allows users to easily import data from research databases such as Web of Science and Scopus, and links with other software tools, such as Pajek, Excel, SPSS, and Gephi (Fahimnia, B., Tang, C.S., Davarzani, H., Sarkis, J., 2015. Quantitative models for managing supply chain risks: a review. Eur. J. Oper. Res. 247, 1–15.). For a detailed description of Bibexcel see Persson et al. (2009) and Šubelj et al. (2014).
(Šubelj, L., Fiala, D., Bajec, M., 2014. Network-based statistical comparison of citation topology of bibliographic databases. Sci. Rep. 4, 6496.)

CiteSpace, developed by Chaomei Chen is widely used software package for analyzing and visualizing networks of scientific information which facilitates to deliver the results of knowledge domain (Chen, C. (2004). Searching for intellectual turning points: progressive knowledge domain visualization. Proc. Natl. Acad. Sci. U.S.A. 101(Suppl. 1), 5303–5310. doi: 10.1073/pnas.0307513100). It provides multiple network analysis including collabrative analysis of co-authors (or their institutes and countries), co-occurrence analysis of terms (or keywords and categories), and co-citation analysis of cited references (or authors and journals). Additionally, in CiteSpace, a current research front can be identified based on such burst detection. CiteSpace also makes it easier for users to identify pivotal points by recognizing the nodes with high betweenness centrality (Freeman, C. L. (1978). Centrality in social networks conceptual clarification. Soc. Networks 1). In our study, a key-word co-occurrence and a reference co-citation network were constructed and visualized using Citespace based on a combined set of 2246 papers published in the timespan from 2010 to 2019. A time slice of 1 was chose for the analysis and the selection criteria was the top 50 most appearing keywords and top 100 most cited references, respectively,

VOSviewer is another software tool designed specifically for constructing and visualizing bibliometric networks, and it can be used to construct and visualize co-authorship, co-occurrence networks and so on [Van Eck, N., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84(2), 523–538.]. VOSviewer uses a modularity-based clustering technique, which is closely related to the multidimensional scaling technique [Waltman L, van Eck NJ, Noyons ECM. A unified approach to mapping and clustering of bibliometric networks. Journal of Informetrics. 2010; 4(4):629–35. doi: 10.1016/j.joi.2010.07.002 PMID: WOS:000281616200017.] and is based on the smart local moving algorithm [Waltman L, van Eck NJ. A smart local moving algorithm for large-scale modularity-based community detection. Eur Phys J B. 2013; 86(11):14. doi: 10.1140/epjb/e2013-40829-0 PMID:WOS:000326811500007.]. Compared with Citespace, the analysis results in some aspects fit more closely with the real records retrieved from Web of Science. (2016-Vosviewer 与 Citespace 应用比较研究_宋秀芳). In our study, in order to analyze the collaboration density and degree on individual, institutional and country level, a threshold or minimum of papers written in collaboration between authors, institutions or countries was applied to correctly visualize the networks.

2.3 Data Analysis

The aforementioned records that were included after the manual check were imported into Bibexcel for bibliometric analysis. After the basic information about the authorship, country, sources, affiliation, and citations were extracted, SPSS was adopted for statistically analyzing the occurrence frequency of the core authors, flagship journals, productive countries, prolific organizations and important keywords. In addition, VOSviewer is used for the network analysis of cooperation scale and intensity between different subjects and co-occurrence of keywords as well as noun phrases extracted from titles and abstracts. In order to give an insight into the turning fronts and hotspots of debris flow research, such visualization modes of CiteSpace as cluster view, time line, time zone, and key word burst detection (Cobo et al. 2011; Chen 2006) were also adopted.

3. Results and Discussion

3.1 Publication output growth trends and citation characteristics

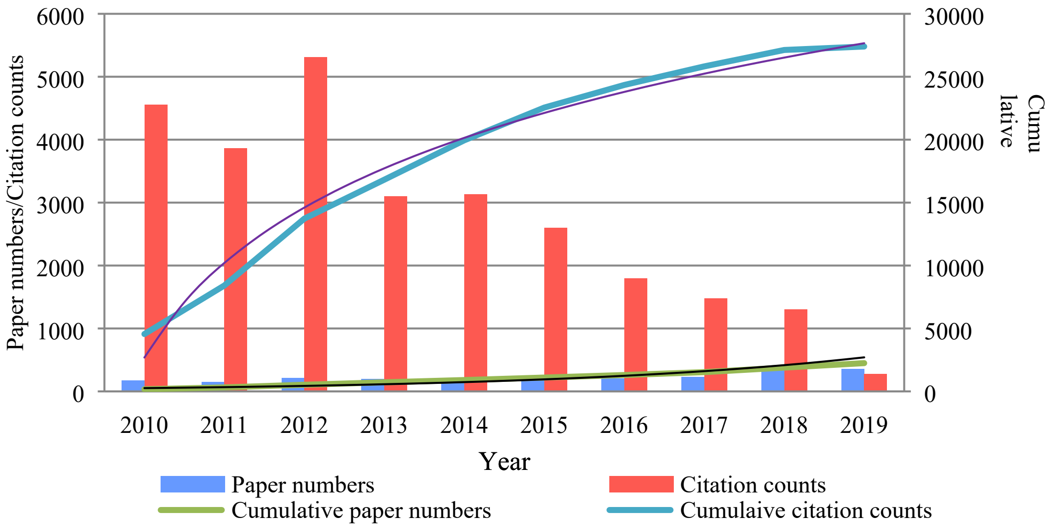


Figure 1 Publication output counts per year in debris flow research publications during 2010 and 2019.

3.2 Journal performance

Table 1 Top 10 key/core journals based on paper count in debris flow research between 2010 and 2019

Rank	Journal Name	TP (%)	TC (rank)	TC/TP	IF (2018)	Subject category*	Quartile**
1	Landslides	175	1975 (2)	11.3	4.252	Engineering, Geological	Q1
2	Geomorphology	165	3153 (1)	19.1	3.681	Geography, Physical	Q2
3	Journal of Mountain Science	132	745 (8)	5.6	1.423	Environmental Sciences	Q4
4	Natural Hazards and Earth System Sciences	118	1723 (4)	14.6	2.883	Geosciences, Multidisciplinary	Q2
5	Natural Hazards	111	2202 (3)	19.8	2.319	Geosciences, Multidisciplinary	Q2
6	Engineering Geology	94	1271 (6)	13.5	3.909	Engineering, Geological	Q1
7	Environmental Earth Sciences	66	417 (10)	6.3	1.871	Environmental Sciences	Q3
8	Earth Surface Processes and Landforms	56	823 (7)	14.7	3.598	Geography, Physical	Q2
9	Journal of Volcanology and Geothermal Research	53	591 (9)	11.2	2.617	Geosciences, Multidisciplinary	Q2
10	Journal of Geophysical Research-Earth surface	43	1662 (5)	38.7	4.253	Geosciences, Multidisciplinary	Q1

Notes: TP means total number of published papers, TC means total citations of the journal's papers, TC/TP means average number of citations of a paper; Data under * and ** are from the 2019 JCR report provide by Clarivate Anylytics

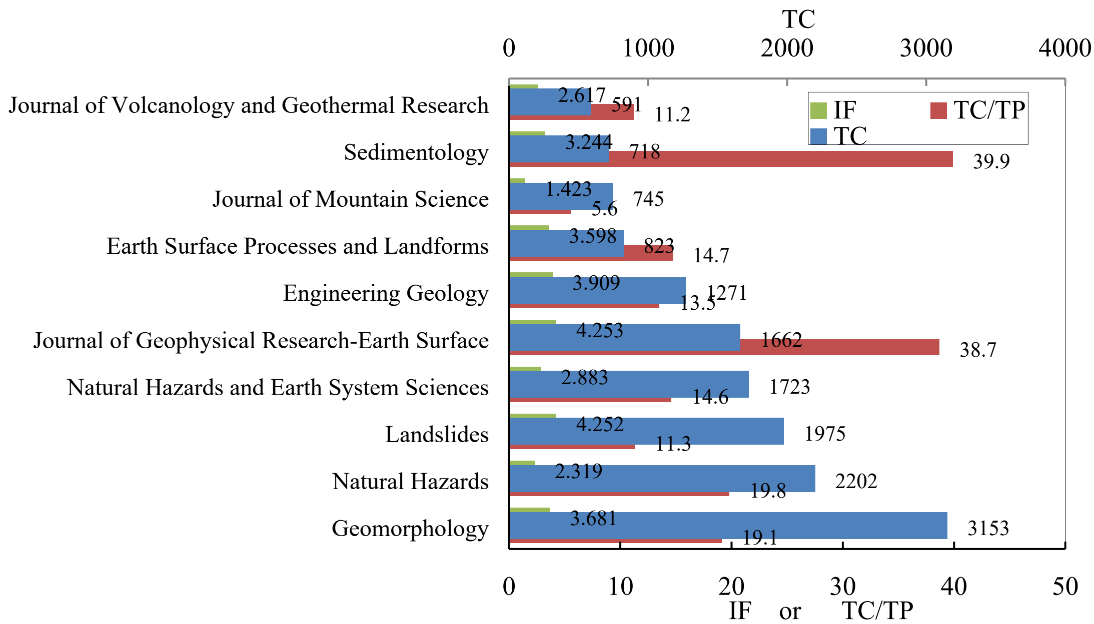


Figure 2 Top 10 most cited journals in debris flow research between 2010 and 2019

3.3 Geographic distribution of publications and collaboration network

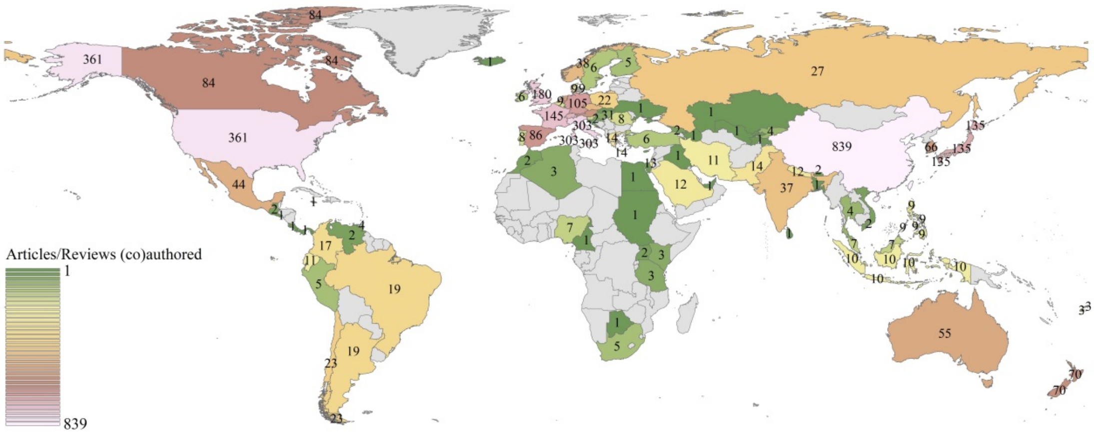


Figure 3 Publication counts related to debris flow research of different countries around the world during 2010 and 2019.

Table 2 Top 10 productive countries/territories based on paper count in debris flow research field between 2010 and 2019

Rank	Country/Territory	SP	CP	TP	TC	H Index	CCN	MC (NC)
1	Peoples R China	534	202	736	5882	33	37	USA (39) Japan (37) UK (32)
2	USA	191	170	361	5345	36	48	Peoples R China (39) Italy (27) UK (26)
3	Italy	160	143	303	5053	35	39	USA (27) Spain (19) France (18)
4	UK	49	131	180	3056	28	42	Peoples R China (32) USA (26) France (20)
5	France	34	111	145	2880	29	41	UK (20) Italy (18) Switzerland (18)

6	Switzerland	47	91	138	3079	33	32	Austria (21) France (18) Germany (16)
7	Japan	59	76	135	1068	15	29	Peoples R China (37) Taiwan (10) France (8)
8	Germany	18	87	105	1521	22	37	USA (21) UK (19) Switzerland (16)
9	Taiwan, China	68	35	103	974	17	17	Peoples R China (12) Japan (10) USA (4)
10	Spain	25	61	86	1350	19	27	Italy (19) UK (10) Switzerland (9)
	Total	1185	1108	2292				

Notes: SP means number of papers published by an independent country, CP means number of internationally collaborative papers, TP total number of papers published by a country, TC means total citations of the country's papers, CCN means numbers of collaborative country numbers; MC (NC) means major collaborator (the number of collaborative papers between two countries/territories).

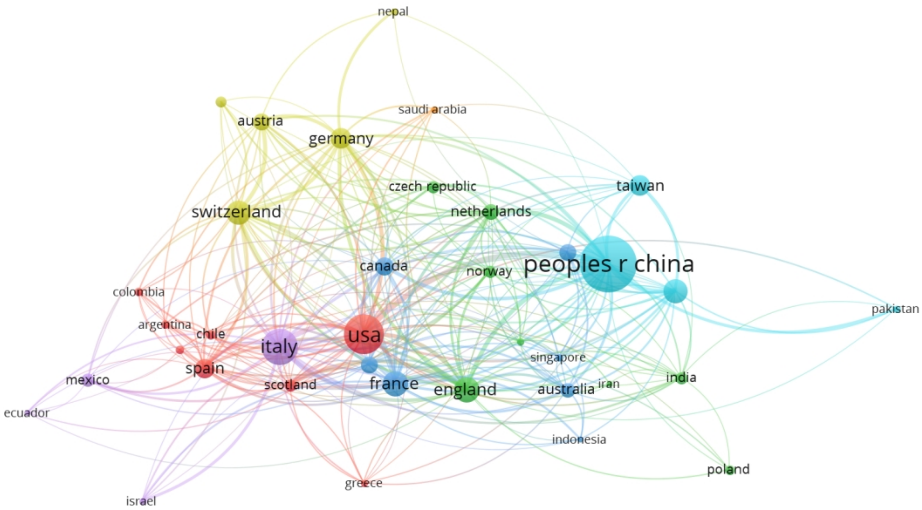


Figure 4 Collaboration network on country level in debris research during 2010 and 2019. (A country with a minimn number of 10 papers is displayed in the visualization map. Thus, the network consists of 37 nodes and generates 7 clusters: cluster 1 (red points, n=8), cluster 2 (green points, n=8) and cluster 3 (dark blue points, n=7), cluster 4 (yellow green points, n=5), cluster 5 (purple points, n=4), cluster 6 (blue points, n=4), cluster 7 (orange points, n=1).

3.4 Author Performance

Table 3 Top 20 prolific authors in debris flow research based on paper count between 2010 and 2019

Rank	Author Name	Country	RP	FP	TP	TC	TC/TP	H Index
1	Cui, Peng	China	24	10	27	597	22.1	18
2	Chen, Ning-sheng	China	17	5	19	89	4.7	6
3	Zhang, Li-min	Hong-kong, China	18	1	18	352	19.6	12
4	Stoffel, Markus	Switzerland	16	9	16	720	45.0	21
5	Chen, Xiao-qing	China	15	2	15	90	6.0	8
6	Silhan, Karel	Czech Republic	11	9	11	145	13.2	8
7	Hu, Kai-heng	China	14	8	14	139	9.9	11
8	Wei, Fang-qiang	China	14	3	14	73	5.2	7
9	Choi, Clarence	Hong-kong,	11	5	13	157	12.1	10

	Edward	China						
10	He, Si-ming	China	12	3	13	71	5.5	5
11	Chen, Jian-ping	China	12	0	12	78	6.5	6
12	Zhou, Jia-wen	China	12	3	12	108	9.0	4
13	Xu, Qiang	China	5	4	5	222	44.4	12
14	Peng, Jian-bin	China	8	4	10	120	12.0	5
15	Yu, Bin	China	10	8	10	89	8.9	5
16	Zhou, Gordon G. D.	China	1	9	10	114	11.4	6
17	Cuomo, Sabatino	Italy	9	2	9	253	28.1	7
18	de Haas, Tjalling	England	9	9	9	134	14.9	6
19	Iverson, Richard M.	USA	9	7	9	769	85.4	11
20	Pudasaini, Shiva P.	Germany	7	6	7	336	48.0	9
	Total							

Notes: RP means number of papers published by an corresponding author, FP means number of papers published by a first author, TP total number of papers published by an author, TC means total citations of the author's papers.

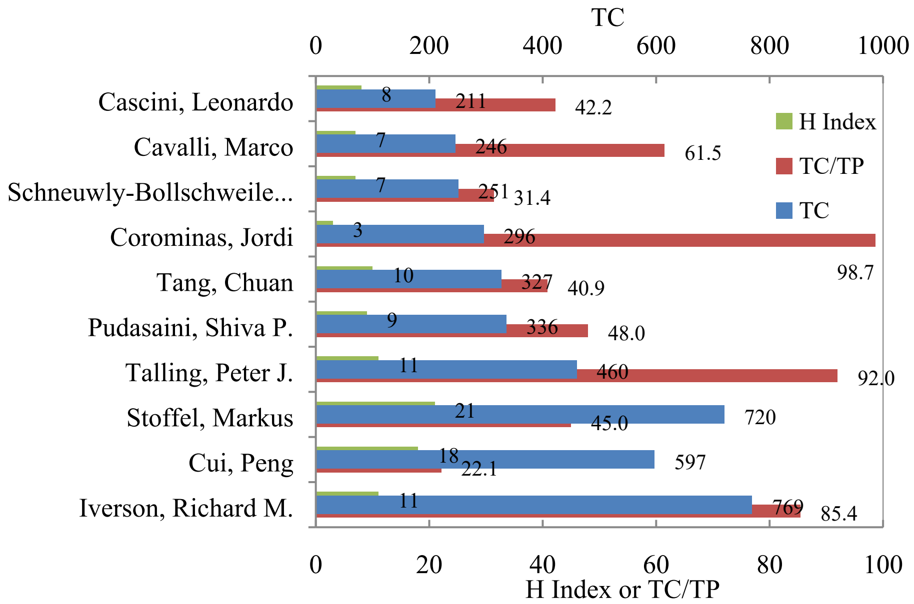


Figure 5 Top 10 most cited authors in debris flow research between 2010 and 2019

3.5 Institution performance and collaboration network

Table 4 Top 20 most productive institutes based on paper count in debris flow between 2010 and 2019.

Rank	Institute Name	Country	SI	CI	TP	CIN	MI (NI)
1	Chinese Acad Sci	China	40	281	321	217	Univ Chinese Acad Sci (84) Minist Water Conservancy & Power (20)
2	Chengdu Univ Technol	China	21	83	104	93	Chinese Acad Sci (17) Univ Utrecht (13)
3	Univ Chinese Acad Sci	China	0	86	86	68	Chinese Acad Sci (84) Hong Kong Univ Sci & Technol (9)
4	US Geol Survey	USA	24	52	76	69	Colorado Sch Mines (8) Univ Arizona (7) Univ Colorado (7)
5	Hong Kong Univ Sci & Technol	China	13	48	61	53	Chinese Acad Sci (15) Univ Chinese Acad Sci (9) HKUST Jockey Club Inst Adv Study (8)
6	Univ Geneva	Switzerland	0	50	50	66	Univ Bern (35) Univ Nat Resources & Appl Life Sci (4) Univ Zurich (4)
7	CNR	Italy	5	49	54	73	Univ Padua (7) Univ Genoa (4)

							Univ Naples Federico II (3)
8	Sichuan Univ	China	13	28	41	36	Chinese Acad Sci (18) Univ Chinese Acad Sci (5) Chengdu Univ Technol (4)
9	Univ Bern	Switzerland	0	41	41	43	Univ Geneva (34) Univ Nat Resources & Appl Life Sci (4) Univ Zurich (4)
10	Tsinghua Univ	China	5	31	36	37	Chinese Acad Sci (17) Beijing Normal Univ (4) Minist Water Conservancy & Power (4)
11	Univ Utrecht	Netherlands	3	32	35	42	Chengdu Univ Technol (12) Univ Durham (4) Univ Technol (4)
12	Univ Padua	Italy	8	26	34	27	Hebrew Univ Jerusalem (9) Univ Connecticut (5) CNR (5)
13	Kyoto Univ	Japan	3	30	33	53	Chengdu Univ Technol (4) Chinese Acad Sci (4) Univ Utrecht (3)
14	Univ Nacl Autonoma Mexico	Mexico	7	25	32	39	UNAM (4) Univ Geneva (3) SUNY Buffalo (2)
15	Natl Cheng Kung Univ	China	3	29	32	37	Natl Taiwan Univ (5) Acad Sinica (5) Natl Sci & Technol Ctr Disaster Reduct (4)
16	Natl Taiwan Univ	China	7	21	28	31	Natl Sci & Technol Ctr Disaster Reduct (9) Natl Cheng Kung Univ (5) Natl Cent Univ (3)
17	Tongji Univ	China	8	19	27	25	Hong Kong Univ Sci & Technol (7) Chengdu Univ Technol (3) Nanyang Technol Univ (2)
18	Jilin Univ	China	6	19	25	25	Changchun Sci Tech Univ (3) Commiss Water Conservancy Yangzi River (3) Jilin Inst Geol Environm Monitoring (3)
19	Massey Univ	New Zealand	2	23	25	31	Univ Clermont Ferrand (6) Univ Auckland (3) CVGHM (2)
20	China Geol Survey	China	4	20	24	20	Chengdu Univ Technol (7) Chinese Acad Sci (5) Chinese Acad Geol Sci (4)
	Total		172	988	1160		

Notes: SI means number of papers published by an independent institution, CI means collaborative papers cross involving institutions, TP total number of papers published by a institution, CIN means collaborative institution numbers, MC (NC) means major collaborator (the number of collaborative papers between two institution).

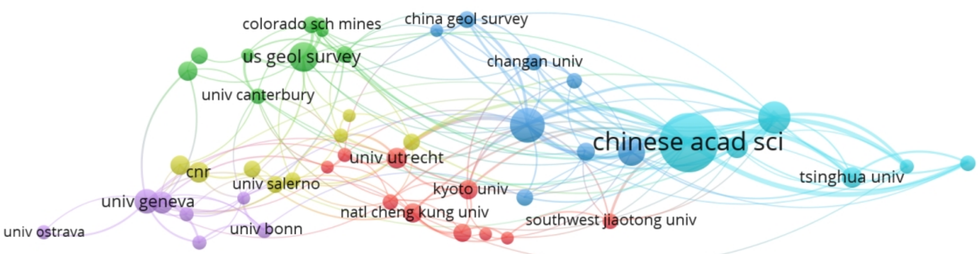
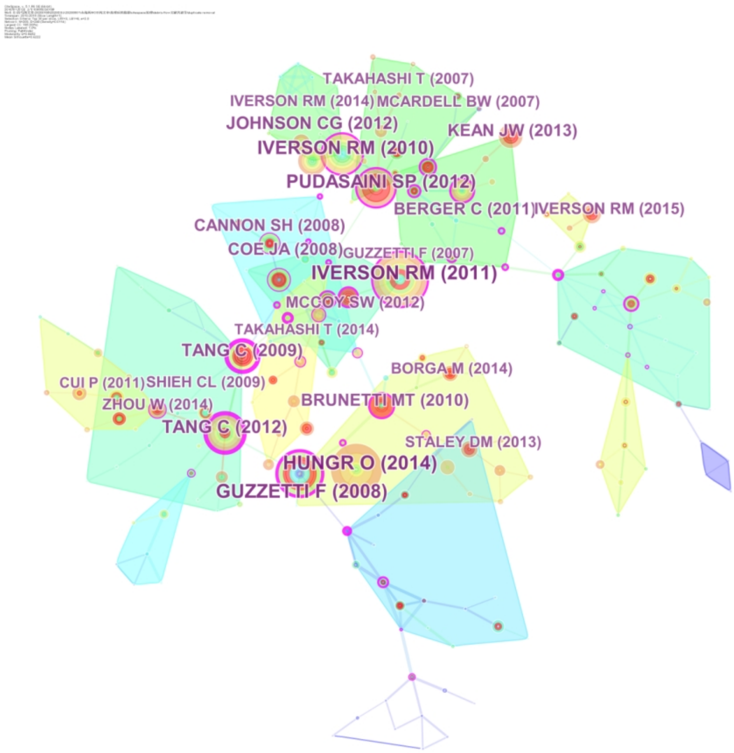
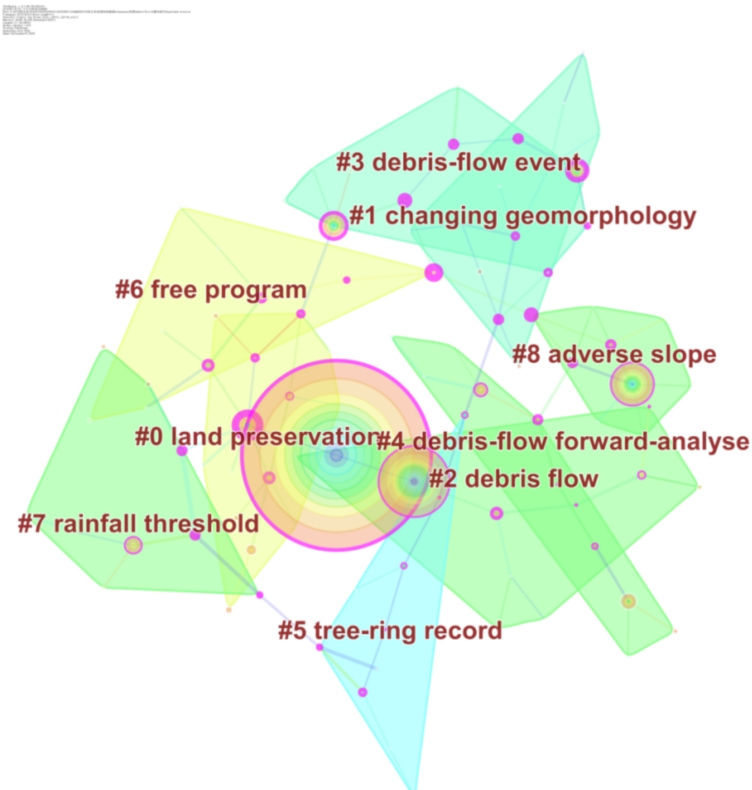


Figure 6 Collaboration network on instituttion level in debris research during 2010 and 2019. (A institution with a minimn number of 15 papers is displayed in the visualization map. Thus, the network consists of 49 nodes and generates 6 clusters: cluster 1 (red points, n=10), cluster 2 (green points, n=9) and cluster 3 (dark blue points, n=8), cluster 4 (yellow green points, n=8), cluster 5 (purple points, n=7), cluster 6 (blue points, n=6).

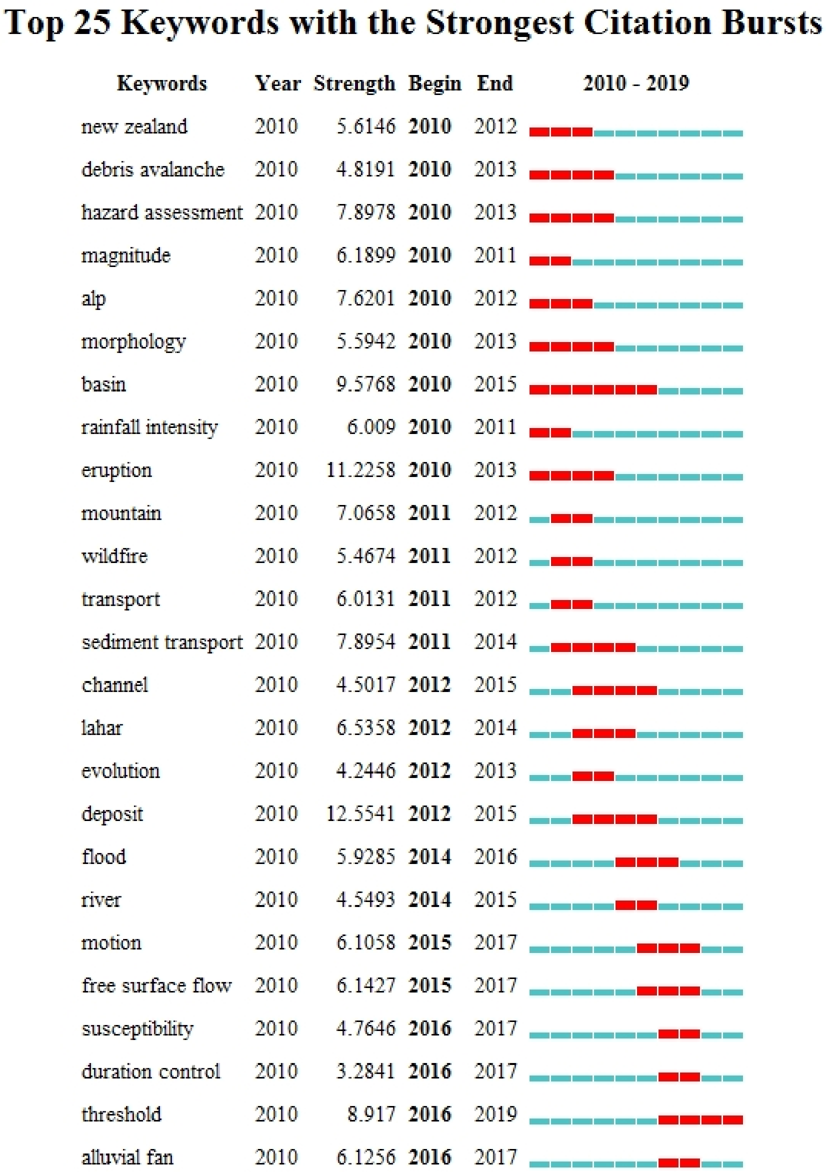
3.6 Reference Co-citation analysis



3.7 Keyword co-occurrence analysis



3.8 Burst Detection



4 Conclusions

China is the dominant contributor in scientific output of debris flow research. Among the Top 10 productive countries, the H index of USA outperforms China and ranks the first, followed by Italy, China, France, and UK. The top five publishing the largest number of papers are *Landslides*, *Geomorphology*, *Journal of Mountain Science*, *Natural Hazards and Earth System Sciences* and Natural Hazards. Among the list of the top prolific authors, Markus STOFFEL (University of Geneva, Switzerland), Richard M. Iverson (US Geol Survey, USA) and Peng CUI (IMHE, CAS, China) are the leading three authors and their H index are 21, 11 and 18. Chinese Academy of Sciences contribute the most papers on the institutional level, followed by Chengdu University of Technology, University of Chinese Academy of Sciences, and US Geological Survey (USGS). Debris flow hazard assessment (including in situ experiment and numerical modeling) is a long during topic in this scientific research field. Rainfall threshold for debris flows and the design of debris flow mitigation structures are the two burst words in recent years which may indicates the hot research topic.