Bibliometric Analysis of Paleotsunami Research: Current Trend and Research Overview

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Abstract

Paleotsunami studies provide information that is crucial as the primary data for tsunami mitigation planning and action. However, hithertho studies that explicitly assess and evaluate paleotsunami are not available. This study aimed to identify trends in paleotsunami studies based on the literature published until 2022. The study was conducted by entering the keywords "PALEOTSUNAMI" or “PALEOTSUNAMIS" into the search field section of the SCOPUS database. Relevant publications that included information on the document type, year, access type, author, journal, and language were selected. The results were subsequently descriptively and quantitatively analyzed based on annual progression, country, affiliation, author, journal, publication, area of study, and keywords. A total of 199 documents related to paleotsunami were identified, representing 193 authors from 39 countries. Japan, the United States of America, and Russia were the leading countries in the field of paleotsunami research. The journal with most publications on palaeotsunami was Marine Geology. Goto was the most productive and the most cited

author in this field. Most frequently used keywords in the paleotsunami studies were tsunami, paleotsunami, Holocene, and geological record. There was a shift in the trend of paleotsunami studies beginning from 2018. This study carried out the quantitative analysis and statistics of published documents in the field of paleotsunami using bibliometric study. A comprehensive picture of previous paleotsunami studies is essential and can be an objective consideration in setting research policies.

Key words: paleotsunami; bibliometric; visualization; geology

INTRODUCTION

Progress on paleotsunami studies has been very rapid, especially since the 2004 Indian Ocean Tsunami. Since the 2011 Tohoku-Oki Tsunami, Japan, new paleotsunami identification and characterization proxies have rapidly developed. Recently, a geochemical proxy has been introduced and developed for paleotsunami identification[1–5]. Use of geophysical proxies in paleotsunami studies is also increasing[6,7]. Locations for paleotsunami studies are expanding to many areas worldwide, although the dominance of studies is still focused on specific countries. Paleotsunami studies must be comprehensive and use multiple proxies, as identification of paleotsunami is complex. Paleotsunami studies provide information on the recurrence interval of past tsunamis and the characteristics of tsunami sources in an area. Paleotsunami studies provide information that is crucial as the primary data for tsunami mitigation planning and action. However, hithertho studies that explicitly assess and evaluate paleotsunami are not yet available. As a critical study for mitigation, the trends and general figures of paleotsunami study are needed to understand the newly emerging areas of research and the research gaps. To resolve this issue, a bibliometric study of paleotsunami research has been conducted. A

comprehensive picture of previous paleotsunami studies is essential and can be an objective consideration in evolving research policies and helping creation of opportunities for future studies.

MATERIALS AND METHODS

Bibliometric method was utilized to summarize, assess and evaluate previous scientific publications using specific database based on keywords. The SCOPUS high-quality database is reliable in providing guaranteed information and has been scientifically recognized in various fields of science[8]. Keywords are essential in expressing particular descriptions or explanations and can describe the main topic or content of the publication. The stages of this study are illustrated in Figure 1. The method used for this study was after Yang et al[9]. The first step was determining the relevant keywords: "PALEOTSUNAMI" OR "PALEOTSUNAMIS" in the SCOPUS database. Publications up to 2022 were included, excluding the years of 2023 to account for ongoing publishing processes. Subsequently, all subject areas except for less relevant areas were selected and identified,. The type of access, author, journal, and language used was not restricted. The selected data were extracted into a comma-separated value (CSV) file format. The extracted data in CSV files were then processed and visualized using Microsoft Excel, Tableau Public (version 2022.3), and VOSviewer (updated 1.6.18)[10,11]. Microsoft Excel was used for statistical analysis of year, country, affiliation, author, and journal. Tableau Public was used to map the distribution of contributing countries, while VOSviewer was used for network, density, and overlay visualizations. The VOSviewer visualization was set with threshold options varying from a minimum of one to five documents. The results

were subsequently descriptively and quantitatively analyzed based on annual progression, country, affiliation, author, journal, publication, areas of study, and keywords.

RESULTS

Publication year and citations

A total of 199 paleotsunami documents were identified. In 2005, following the 2004 Indian Ocean Tsunami, there was a significant increase in the number of documents (Figure 2). From 2005 to 2011 the number of documents was relatively steady, no more than eight documents per year. Despite fluctuations, the average number of documents remained high, surpassing 12 from 2012 to 2018. There was a decrease in the number of publications in 2018 (seven documents). The year with the most publications was 2020 (25 documents). From 2018 to 2022, the number of documents increased from seven to 25. The citation trend shows an opposite pattern from the number of documents (Fig. 2). The highest number of citations per document occurred in 2003, with 112. From 2005 to 2011, the number of citations per document increased slightly from 30 to 54 citations per document. This trend then decreased from 2011 to 2022.

Contributing countries and collaboration

Authors from 39 countries have published articles on paleotsunamis. Figure 3 shows the distribution of the top 15 countries with the highest productivity and citation rates per document. The United States leads in productivity, followed by Japan, Russia, Australia, Indonesia, and Germany. The United States also contributed the highest total citations. Poland and the United Kingdom had the highest total citations per document.

The collaboration network of authors between countries in paleotsunami studies was identified. The United States is the most productive country mostly in collaboration with Japan, Canada, Australia, Indonesia, and Singapore. France collaborated with Germany, Greece, Israel, Italy, and Chile. Australia mostly collaborated with New Zealand, Indonesia, Japan, Poland, and United Kingdom. Researchers from Chile mostly working on paleotsunami with researchers from Belgium, Turkey, Australia, United Kingdom, United States, and Singapore. From 39 contributor countries, 24 countries were interconnected in collaboration with the minimal output of three publications. China and Venezuela are countries that have yet to collaborate in paleotsunami studies.

Institution/Affiliation

The top ten most productive affiliations are listed in Table 1. The two top affiliations were Tohoku University and Hokkaido University, with 23 and 16 documents, respectively. The Russian Academy of Sciences ranked third (16 documents). As for total citations, the two top affiliations also dominated. Hokkaido University, had the highest total citations per document, followed by UNSW, and Tohoku University. The top ten affiliations belonged to six countries. These six countries are all listed among the top 15 most productive countries, as shown in Figure 3.

Authors and Collaboration Network

A total of 193 authors of paleotsunami documents were identified. The top ten most productive authors and citation rates are listed in Table 2. Goto was the most productive author with 20 documents. Sugawara and Peterson published 12 and 11 documents, respectively. Authors ranked 4 to 6 have the same number of documents (10). Goto also

ranked one as the author with the highest total citations, followed by Sugawara, Nishimura, and Szczuciński. In general authors who published their documents tend to collaborate and create a network. The visualization on the paleotsunami topic shows that it consists of 12 clusters, seven of which were collaborations of more than three authors.

Journal and Publication

Marine Geology was the journal that published highest number of articles on paleotsunamis, with 15 documents published. The journal Natural Hazard ranked second with 12 documents, followed by Sedimentary Geology and Earth Science Reviews with six documents in each. The highest total citations also belonged to the articles published in Marine Geology, followed by the Pure and Applied Geophysics, Journal of Geophysical Research - Solid Earth, Sedimentary Geology, Natural Hazards and Earth Science Reviews. Seismological Research Letters has the highest total citations per document, followed by Journal of Geophysical Research Solid Earth, and Marine Geology. Natural Hazard ranked second in total documents, but only eight in total citations per document, indicating that publication citation rates do not correlate with the most productive publications. Of the 199 documents, the publication with the highest number of citations was ‘New insights of tsunami hazard from the 2011 Tohoku-oki event’ by Goto et al., cited in 230 publications until 2022. The second most cited paper was ‘Validation and verification of tsunami numerical models’ by Synolakis et al. cited by 216 publications. Fewer than 200 publications cited the other documents in the list. The third most cited paper was ‘Sedimentologic and geomorphologic tsunami imprints worldwide - A review’ by Scheffers et al. cited by 197 publication, followed by paper of Tuttle et al. entitled ‘Distinguishing Tsunami from storm deposits in eastern North

America: The 1929 Grand Banks Tsunami versus the 1991 Halloween storm‘ cited by 185 publication. The number ten document in the list of most cited paper was ‘Horizontal and vertical variation of 2004 Indian tsunami deposits: An example of two transects along the western coast of Thailand’ by Hori et al. cited by 97 publication.

Keywords

The co-occurrence of keywords in paleotsunami studies from 2000 – 2022 reveals five significant clusters (Figure 4). The first cluster (blue color) was related to past records of tsunamis and was composed of primary keywords of tsunami, paleotsunami, Holocene, and geological record. The second cluster (red color) was related to the sedimentology of tsunami deposits and paleotsunami and included major keywords such as tsunami, deposits, sedimentology, and sediment transport. The third cluster (yellow color) related to the geomorphic condition of the study area included major keywords such as geomorphic, coastal morphology, coastal zone, and Indian Ocean. The next cluster (green color) was associated with the tsunami source dominantly caused by earthquakes, featuring keywords such as earthquake, earthquake magnitude, subduction zone, and Pacific Ocean. The last cluster (violet color) comprised keywords such as sea level, tsunami inundation, and hazards. Based on the co-occurrence with a minimum limit of one document from 2000 to 2022, the highest to moderately high topics include tsunamis, tsunami deposits, paleotsunami, earthquakes, Pacific Ocean, Holocene, tsunami event, coastal zone, geological record, and sedimentation. Moderately low to low topics include bathymetry, geo-archeology, grain size, inverse model, megathrust, microfossil, paleotsunami dating, and xrf analysis.

The latest research topics for the period 2018 – 2022, based on the co-occurrence, were also classified. The research topics with the highest frequency (10 to 30) were tsunamis, tsunami deposits, paleotsunamis, and earthquakes. This was followed by a frequency of 5-10, composed of Holocene, tsunami event, Pacific Ocean, hazard assessment, geological record, subduction zone, sedimentology, and coastal zone. Frequencies of 3-5 included geomorphology, subduction zones, stratigraphy, radiocarbon dating, depositional environment, earthquake rupture, sediment transport, and paleoseismology. Frequencies of 1-2 included keywords such as age determination, coastal hazards, diatoms, foraminifera, geochemistry, grain size, magnetic susceptibility, portable xrf, database, recurrence interval, tsunami modeling, hazard management, and event deposits. There was a shift in the trend of paleotsunami studies beginning from 2018 up to 2022. Paleotsunami studies in 2018 mostly related to keywords of subduction zone, coastal zone, earthquake magnitude, sampling, and grain size. The trends from 2018 to 2020 shifted to studies related to keywords such as tsunami, tsunami deposit, paleotsunami, earthquakes, stratigraphy, and hazards. The trends of paleotsunami studies between 2020 and 2022 shifted to studies related to keywords depositional risk assessment, geochemistry, tsunami inundation, paleoseismicity, paleoseismology, floods, and depositional environment.

DISCUSSION AND CONCLUDING REMARKS

This paper presents the results of the first bibliometric study of paleotsunamis. Very few documents were published on paleotsunami topic before 2005, with an average of less than two documents per year. After the 2004 tsunami, geoscientists began to realize that information on tsunami hazards based on paleotsunami studies is vital and should form

the basis for tsunami mitigation. Beginning in 2005, the average number of publications per year increased significantly. This upward trend indicates a consistent and growing interest in the field, with promising prospects for the future. The citation trend was the opposite of the increasing number of published documents. A large number of documents with a relatively shorter publication period affects the citation rate; therefore, relatively recent publications have a low citation rate. Countries and levels of collaboration could also affect the number of citations[12]. There is a positive correlation between collaboration and citations, the top-cited documents resulting from a solid international collaboration.

The number of published paleotsunami documents peaked in 2014. This year, most publications referenced the results of the studies of the 2011 Tohoku-Oki tsunami deposit as a modern analog for paleotsunami studies. The most cited paper by Goto et al.[13], highlighted that data on the 2011 event suggest that previous estimates of paleotsunamis in the Sendai area, Japan have probably been underestimated. Their finding led to the realization that the risk from tsunami hazards in Japan is much greater than previously recognized. This information significantly changes the perspective on the study of paleotsunamis worldwide. As the second most cited publication, Synolakis et al.[14] provide an understanding of the need to validate and verify tsunami numerical models before they are used to predict the inundation distance of paleotsunamis. The third most-cited publication, Scheffers et al.[15] reviewed state-of-the-art knowledge of tsunamis' sedimentologic and geomorphic imprints to highlight the importance of more detailed studies of paleotsunami depositional and geomorphological traces. In general, all publications listed in the top 10 most cited documents mainly discussed the characterization of modern analogs of paleotsunami as well as some general aspects of paleotsunami identification. As paleotsunami identification is complex, the use of new

proxies (e.g.for geochemical proxies[1,5], and for paleoDNA of foraminifera [16,17]) remains limited and is currently applied only in restricted locations.

Visualization and clustering of keywords support this hypothesis. Based on the co-occurrence analysis, paleotsunami studies can be divided into five significant clusters. The new proxies for paleotsunami identification are not included in these five significant clusters, suggesting that new proxies for paleotsunami identification should be applied more widely, not only to test the effectiveness of these new proxies, but also to re-analyze unidentified paleotsunami candidates. Based on this study, it can also be concluded that research on the formation of a new paleotsunami identification proxy has not been widely and intensively conducted.

From the list of most productive countries combined with data from top affiliations and authors, it was identified that some countries are dominant only as the locus for paleotsunami studies. Authors from these countries who have contributed to paleotsunami studies are still inadequate. For example, Indonesia was listed in the top five most productive countries; however, no authors or affiliations from this country were included in the top ranking. This is unacceptable, as Indonesia, like Japan, the United States, and Russia, is one of the most tsunami-prone countries. However, the awareness and willingness of geoscientists to study paleeotsunami still need to be improved. Researchers interested in paleotsunamis are limited. The government's willingness to use and apply the results of paleotsunami studies for development planning and mitigation efforts remains minimal. Geographical and geological factors, along with past experiences, play a significant role in determining the involvement of countries in the field of paleotsunami.

It is noteworthy that some countries known for their history of tsunamis, such as Madagascar, Sri Lanka, the Philippines, Solomon Islands, Papua New Guinea, as well as certain countries in Latin America and Africa, have not actively engaged in this field. Considering the contributions of more advanced countries, their affiliations, and experts can be a valuable factor for fostering future collaborations. The results of this study indicate that Japan and the United States dominated paleotsunami studies and provided the most highly cited documents. These two countries also had excellent authors. Encouraging researchers in tsunami-prone countries outside Japan, the United States, and Russia to be more involved in paleotsunami studies is imperative.

As the first bibliography analysis of paleotsunami, this study has provided significant information on the trends in paleotsunami studies. A comprehensive picture of previous paleotsunami studies is essential and can be an objective consideration in setting paleotsunami research policies and arranging the best possible future research that will be very insighful for tsunami hazard mitigation.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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DATA AVAILABILITY

Please contact the corresponding author for data availability.

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REFERENCE

1. Avşar, U., Sedimentary geochemical evidence of historical tsunamis in the Eastern Mediterranean from Ölüdeniz Lagoon, SW Turkey. *J Paleolimnol*, 2019, **61**, 373–385.
2. Chagué-Goff, C., Andrew, A., Szczuciński, W., Goff, J., and Nishimura, Y., Geochemical signatures up to the maximum inundation of the 2011 Tohoku-oki tsunami — Implications for the 869 AD Jogan and other palaeotsunamis. *Sediment Geol*, 2012, **282**, 65–77.
3. Chagué-Goff, C., Szczuciński, W., and Shinozaki, T., Applications of geochemistry in tsunami research: A review. *Earth Sci Rev*, Elsevier B.V., 2017, February 1, pp. 203–244.
4. Irizuki, T., Fujiwara, O., Yoshioka, K., et al., Geochemical and micropaleontological impacts caused by the 2011 Tohoku-oki tsunami in Matsushima Bay, northeastern Japan. *Mar Geol*, 2019, **407**, 261–274.

5. Shinozaki, T., Geochemical approaches in tsunami research: current knowledge and challenges. *Geosci Lett*, Springer Science and Business Media Deutschland GmbH, 2021, December 1.
6. Velasco-Reyes, E. R., Sugawara, D., Velasco, E., Goto, K., Daisuke Sugawara, ;, and Nishimura, Y., *A scheme for effective selection of survey sites in paleotsunami research, Hachinohe case, Aomori Prefecture, Japan A Scheme Proposal for an Effective Selection of Survey Sites in Paleotsunami Research, Hachinohe case, Aomori Prefecture, Japan* 2019.
7. Velasco-Reyes, E. R., Goto, K., Sugawara, D., Nishimura, Y., Shinohara, T., and Chiba, T., Paleotsunami history of Hachinohe, northern Japan: a multiproxy analysis and numerical modeling approach. *Prog Earth Planet Sci*, 2022, **9**, 19.
8. Baas, J., Schotten, M., Plume, A., Côté, G., and Karimi, R., Scopus as a curated, high-quality bibliometric data source for academic research in quantitative science studies. *Quantitative Science Studies*, 2020, **1**, 377–386.
9. Yang, H., Liu, L., Yang, W., et al., A comprehensive overview of geopolymer composites: A bibliometric analysis and literature review. *Case Studies in Construction Materials*, 2022, **16**, e00830.
10. Moral-Muñoz, J. A., Herrera-Viedma, E., Santisteban-Espejo, A., and Cobo, M. J., Software tools for conducting bibliometric analysis in science: An up-to-date review. *Profesional de la Informacion*, El Profesional de la Informacion, 2020.
11. van Eck, N. J. and Waltman, L., Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, 2010, **84**, 523–538.
12. Zahedi, Z. and Haustein, S., On the relationships between bibliographic characteristics of scientific documents and citation and Mendeley readership

counts: A large-scale analysis of Web of Science publications. *J Informetr*, 2018, **12**, 191–202.

13. Goto, K., Chagué-Goff, C., Fujino, S., et al., New insights of tsunami hazard from the 2011 Tohoku-oki event. *Mar Geol*, 2011, **290**, 46–50.

14. Synolakis, C. E., Bernard, E. N., Titov, V. V., Kânoğlu, U., and González, F. I., Validation and verification of tsunami numerical models. In *Pure and Applied Geophysics* 2008, pp. 2197–2228.

15. Scheffers, A. and Kelletat, D., Sedimentologic and geomorphologic tsunami imprints worldwide—a review. *Earth Sci Rev*, 2003, **63**, 83–92.

16. Szczuciński, W., Pawłowska, J., Lejzerowicz, F., et al., Ancient sedimentary DNA reveals past tsunami deposits. *Mar Geol*, 2016, **381**, 29–33.

17. Yap, W., Switzer, A. D., Gouramanis, C., et al., Investigating geological records of tsunamis in Western Thailand with environmental DNA. *Mar Geol*, 2023, **457**, 106989.

333 Table 1. Top 10 most productive affiliations in the field of paleotsunami.

Rank.	Affiliation	TD	TC	TC/TD	Country
1	Tohoku University	23	760	33.0	Japan
2	Hokkaido University	16	695	43.4	Japan
3	Russian Academy of Sciences	16	229	14.3	Russian
4	The University of Tokyo	15	139	9.3	Japan
5	UNSW Sydney	11	419	38.1	Australia
6	National Institute of Advanced Industrial Science and Technology	11	309	28.1	Japan
7	Geological Survey of Japan	11	296	26.9	Japan
8	Institute of Marine Geology and Geophysics of the Far East Branch, Russia	11	153	13.9	Russian
9	Portland State University	11	116	10.5	USA
10	Pacific Geographical Institute of the Far Eastern Branch of the Russian Academy of Sciences	10	63	6.3	Russian

Note: TD Total Documents, TC Total Citations, TC/TD Total Citations per Documents

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335 Table 2. Top 10 Authors with the most contributions.

Rank.	Author Name	Affiliation	TD	TC	TC/TD	Country
1	Goto, K.	The University of Tokyo	20	764	38.2	Japan
2	Sugawara, D.	Tohoku University	12	620	51.7	Japan
3	Peterson, C.D.	Portland State University	11	126	11.5	USA
4	Goff, J.	UNSW Sydney	10	316	31.6	Australia
5	Grebennikova, T.A.	Pacific Geographical Institute of the Far Eastern Branch of the Russian Academy of Sciences	10	66	6.6	Russian
6	Nishimura, Y.	Hokkaido University	10	610	61.0	Japan
7	Szczuciński, W.	Uniwersytet im. Adama Mickiewicza w Poznaniu	9	568	63.1	Poland
8	Pantosti, D.	Istituto Nazionale Di Geofisica E Vulcanologia	8	138	17.3	Italy
9	De Martini, P.M.	Istituto Nazionale Di Geofisica E Vulcanologia	8	138	17.3	Italy
10	Kaistrenko, V.M.	Institute of Marine Geology and Geophysics of the Far East Branch of the Russian Academy of Sciences	8	61	7.6	Russian

Note: TD Total Documents, TC Total Citations, TC/TD Total Citations per Documents

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Figure 1. Stages of this paleotsunami bibliometric study.

Figure 2. Publication and citation trends of published paleotsunami studies.

Figure 3. Distribution of the top 15 countries with the highest productivity in paleotsunami studies.

Figure 4. Visualization and clusterization based on co-occurrences.

Figure 1

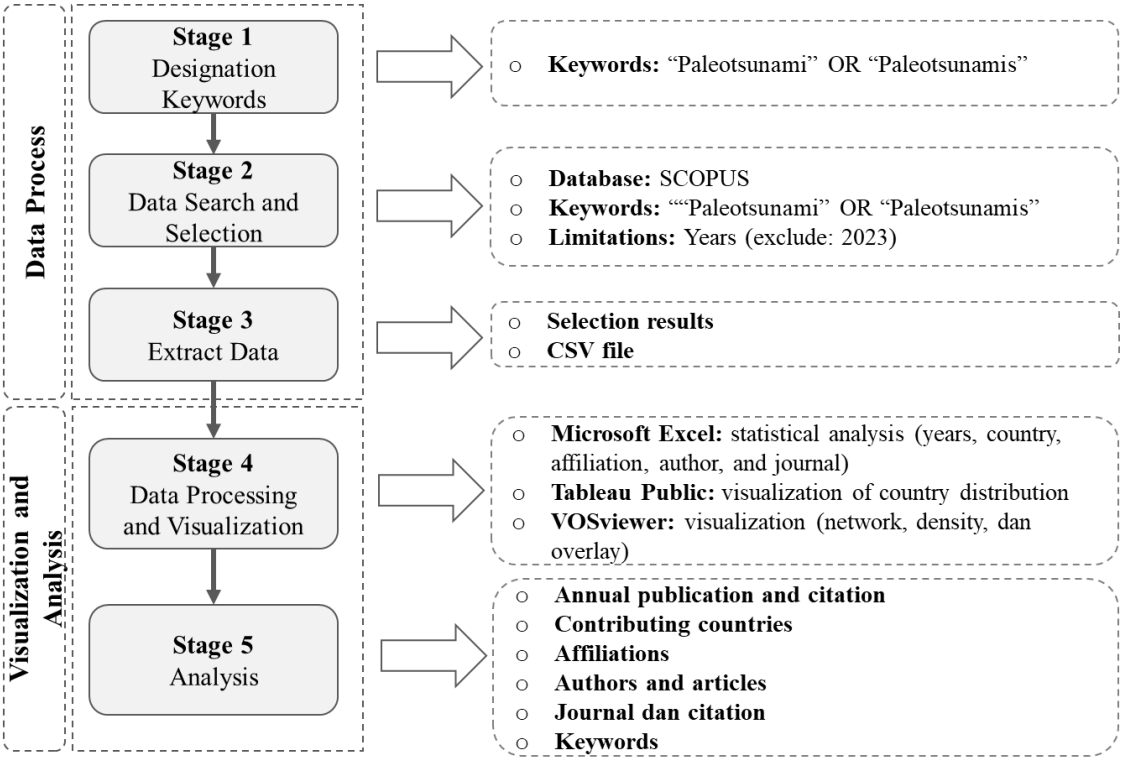
Data Process
Visualization and Analysis
Stage 1
Designation Keywords
Stage 2
Data Search and Selection
Stage 3
Extract Data
Stage 4
Data Processing and Visualization
Stage 5
Analysis
Keywords: "Paleotsunami" OR "Paleotsunamis"
Database: SCOPUS
Keywords: ""Paleotsunami" OR "Paleotsunamis"
Limitations: Years (exclude: 2023)
Selection results
CSV file
Microsoft Excel: statistical analysis (years, country, affiliation, author, and journal)
Tableau Public: visualization of country distribution
VOSviewer: visualization (network, density, dan overlay)
Annual publication and citation
Contributing countries
Affiliations
Authors and articles
Journal dan citation
Keywords

Figure 2

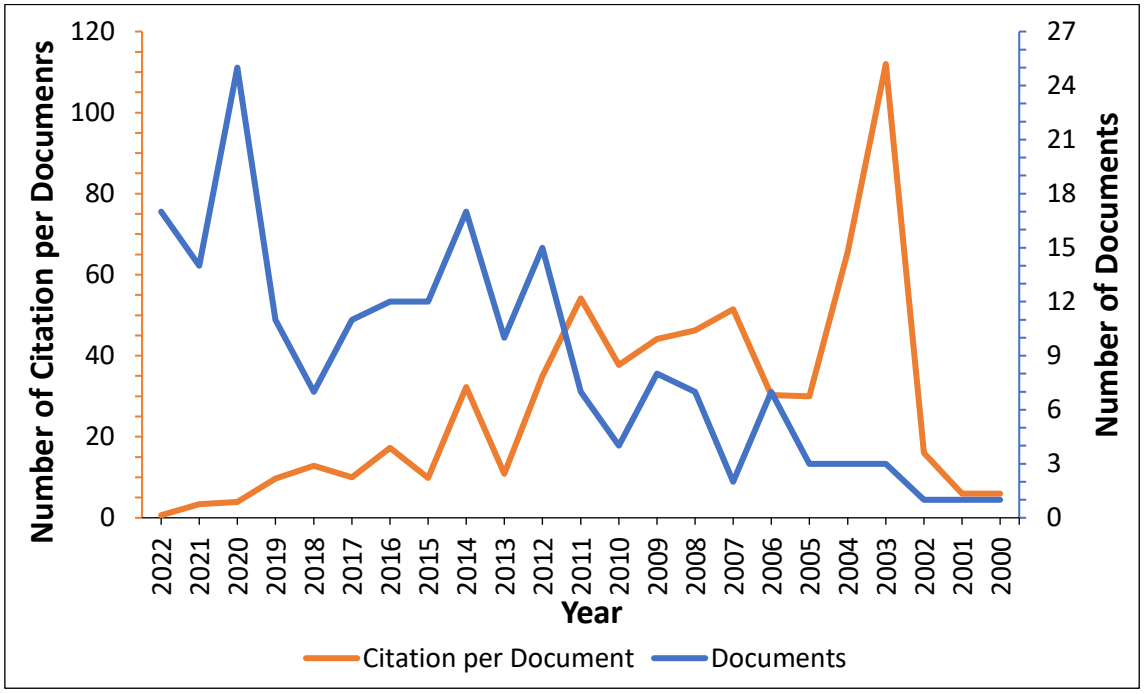
Number of Citation per Documenrs
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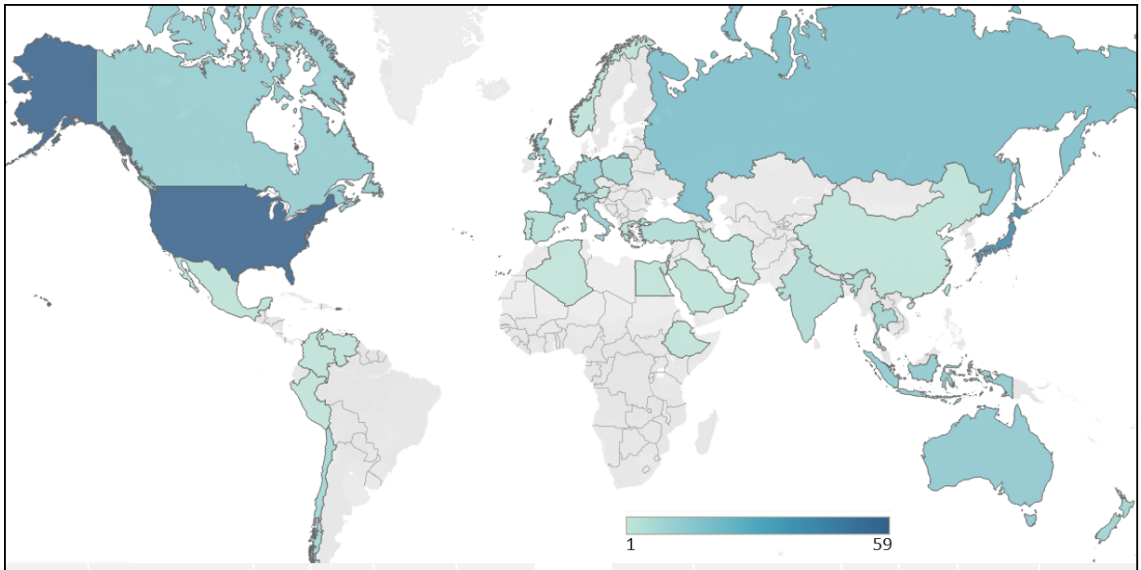
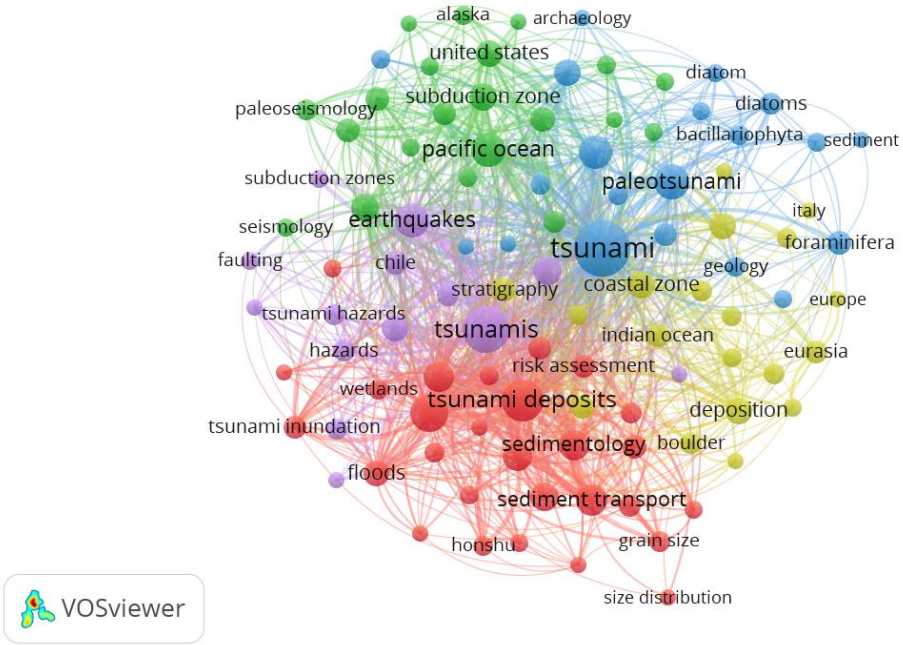
Figure 3



Rank.	Country	TD	TC	TC/TD	TLS
1	United States	59	2057	34.9	70
2	Japan	51	1270	24.9	42
3	Russian	22	323	14.7	9
4	Australia	21	546	26.0	39
5	Indonesia	16	439	27.4	19
6	Germany	16	295	18.4	36
7	United Kingdom	15	650	43.3	48
8	Canada	15	476	31.7	25
9	France	14	230	16.4	35
10	Chile	11	255	23.2	27
11	Italy	11	224	20.4	11
12	New Zealand	10	122	12.2	10
13	Poland	9	568	63.1	17
14	Belgium	9	214	23.8	27
15	Thailand	8	256	32.0	9

Note: TD Total Documents, TC Total Citations, TC/TD Total Citations per Documents, TLS Total Link Strength

406 Figure 4



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