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RESEARCH TRENDS ON LIQUEFACTION IN 2011-2021: A REVIEW AND BIBLIOMETRIC ANALYSIS

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ABSTRACT

Since the 2018 Palu earthquake in Central Sulawesi of Indonesia, many researchers worldwide have been concerned about the ground liquefaction phenomenon associated with seismic events. The present study analyzes research trends related to liquefaction through bibliometric methods and examines the contributions of Indonesian authors to the Scopus metadata. In performing this analysis 3,489 documents were identified, 95 of which were from Indonesia. The findings indicated that the number of scientific publications related to ground liquefaction had increased significantly, and that most of these studies were published in the United States. At the same time, the University of Canterbury in New Zealand has been a leading contributor. The most prolific author in this subject was G. Owen. Visualization of liquefaction research trends results in the following five clusters: (1) Reliability and accuracy of the occurrence of liquefaction; (2) Liquefaction consistency; (3) Map and city where such liquefaction occurred; (4) Ground deformation resulting from liquefaction; (5) The country(s) that experienced such liquefaction. The present study helps identify global trends and developments related to ground liquefaction by providing in addition a map for further studies.

Keywords: *Liquefaction, Review, Bibliometric Analysis*

1. INTRODUCTION

Collision and movement of tectonic plates along subduction zones often result in major and great earthquakes and generate destructive tsunamis. Destructive tsunamis also are generated by landslides, volcanic eruptions, volcanic flank collapses, atmospheric disturbances and falling meteorites. Traveling at high speed when such tsunami waves reach coastal areas, their heights can increase significantly, and even reach heights of up to 30 meters (Pararas-Carayannis, 2003; 2019; 2020; UNDRR, 2019). Often, other earthquake-related effects, such as landslides and ground liquefaction, can cause more damage and human casualties far greater than that of tsunami (Setyabudi, 2013; Sonmez & Gokceoglu, 2005).

Earthquake-caused ground liquefaction results in a decrease in soil strength due to increase in pore water pressure and in adequate pressure of the soil layer due to dynamic repetitive loading (Anda et al., 2021; Lee et al., 2003). In the soil layer, dynamic periodic stresses are generated by seismic wave propagation of crustal motions. According to Seed et al. (1975) and Liou (1976), liquefaction is a process by which water saturated granular soil changes from a solid-state and behaves like a liquid due to the increase in pore water pressure, and its value becomes equal to the total pressure by dynamic loading. Liquefaction can occur when loose saturated with water sediment near the surface loses strength due to a strong earthquake (Yogatama, 2012; Youd & Perkins, 1978).

The phenomenon of ground liquefaction has attracted the attention of experts, especially in the field of engineering geology, after the dramatic events that occurred from the 1964 Alaska earthquakes and the 2011 Japan. In Niigata, Japan, ground liquefaction from the latter earthquake caused the sand to boil, loss of soil bearing capacity, subsidence, and downward slope movement. These occurrences along a vast area, caused many buildings to loose their foundation support and to collapse. Similar ground liquefaction and landslides occurred in Valdez, Seward, and Anchorage during the 1964 earthquake in Alaska (Seed, 1968).

Some other known earthquake events that caused ground liquefaction was the 1971 Van Norman Earthquake in southern California which resulted in the collapse of the Fernando Dam, the 2004 Aceh and Nias Earthquakes in Indonesia, the 2006 Yogyakarta earthquake in Indonesia, and the 2011 Christchurch earthquake in New Zealand (Cubrinovski et al., 2011; Mase, 2013; Tonkin & Taylor International Ltd., 2013; Van Ballegooy et al., 2014).

A 2018 earthquake in Palu Central Sulawesi, Indonesia, also triggered ground liquefaction. This earthquake's magnitude was 7.5 SR, its focal depth was 11 km and epicenter 26 km from the city (Anda et al., 2021; Cilia et al., 2021; Ho et al., 2021; Zhao, 2021) and was caused by seismic stress horizontal fault structure deformation along Parcolo Fault north of Donggala, which also generated a tsunami that struck the city of Palu Bay. The deformation of the fault’s structure caused liquefaction in the Petobo and Baraloa Region (Hidayat et al., 2021; Kusumawardani et al., 2021). The ground liquefaction at these two areas was the latest and biggest disaster in Indonesia and caused the destruction of hundreds of buildings. The combined impact of the tsunami, of the earthquake-induced effects and of ground liquefaction in this area, amounted to losses in which in Palu amounted to about IDR 18.48 trillion (Wijanarko, 2019).

The extent of the ground liquefaction effect was enormous. Damage in Baraloa and Petobo extended over an area of about 158 hectares, while the area most impacted was about 34.5 hectares with a circumference of 2.5 km (Yulianur et al., 2020). In general, the land in both areas is residential. The extent of destruction was mostly due to geological and hydrological conditions of this area which are very responsive to effects of ground liquefaction (Soekamto et al. 1973).

In general, according to the opinion of some experts and the history of liquefaction, there are three conditions which contribute to its occurrence.

1. Saturated non-cohesive soil
2. Shallow groundwater level
3. Shallow earthquake (minimum 5.0 SR)

Technically, liquefaction occurs in soils that are saturated with water. This water is located between the cracks in the soil and forms the pore water pressure. During a powerful seismic impact, the pore water pressure rises suddenly, sometimes exceeding the frictional strength of the soil. As a result, the land loses its load-carrying capacity.

Phenomena related to liquefaction are of flow and cyclic mobility. It is crucial to consider both when assessing the potential risk of liquefaction. Flow liquefaction is the event that causes the undercurrent. It occurs when the calculated static shear stresses reach equilibrium at a mass much greater than the shear stress in the liquefied soil. In other words, the deformation that occurs results from static shear stress. A river liquefaction event has two characteristics: flow velocity and huge base material displacements (as in the case of the,2018 Palu earthquake in Central Sulawesi).

In contrast to flow liquefaction, cyclic mobility is another phenomenon that can cause enormous permanent strain due to earthquake impacts. (Yulianur et al., 2020). In cyclic mobility, the condition of the static shear stress is less than the shear stress in liquid soil. In this phenomenon, repeated loads and static shear stresses cause the deformation. In this case, the deformation is lateral (horizontal spread). The phenomenon is cracked soil, the water seems to carry sand, and the wells are filled with sand as if there had been sandblasting.

This study presents further discussion utilizing a bibliometric analysis because of the importance of further research related to liquefaction. “Performing a bibliometric analysis conveniently assesses article contributions toward advancing knowledge” (Suprapto et al., 2021a). The number of documents, documents source, languages source, country and institutional distribution, top authors, top citations, and top keywords are usually used to analyze research trends (Prahani et al., 2022; Zakhiyah et al., 2021). Therefore, the present study analyzes research trends related to liquefaction disasters through bibliometric analysis, and examines the contribution of Indonesian researchers to the Scopus database. Finally, the study focuses on research trends related to liquefaction disasters and presents the following six questions:

a) To what extent was the publication output of the liquefaction profile for 2011-2021?
b) To what extent was the distribution of liquefaction publications across countries and institutes globally?
c) Who were the top authors involved in liquefaction research globally?
d) How effective were the publication patterns of liquefaction?
e) How did the visualization results affect the trend in liquefaction research?
f) What were Indonesian authors' research extent and contributions to the understanding of liquefaction?

2. RESEARCH METHOD

In answering these research questions, the present study uses bibliometric analysis methodology recommended in published articles (Nurhasan et al., 2022; Suprapto et al., 2022; Suprapto et al., 2021a). Data on liquefaction is taken from the Scopus metadata. After entering keywords in the metadata search, “TITLE ("liquefaction") AND TITLE-ABS-KEY (earthquake OR tsunami)” a total of 3,489 documents related to liquefaction appeared. With the final search, 2,029 document results appeared with the keywords “TITLE ("liquefaction") AND TITLE-ABS-KEY(earthquake OR tsunami), AND (LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015) OR LIMIT-TO (PUBYEAR, 2014) OR LIMIT-TO (PUBYEAR, 2013) OR LIMIT-TO (PUBYEAR, 2012) OR LIMIT-TO (PUBYEAR, 2011))”.

Metadata search results are saved in .csv and .ris formats for further analysis (Prahani et al., 2022; Suprapto et al., 2021b; Zakhiyah et al., 2021). Subsequently the authors used the software *VOSviewer* and Microsoft Excel to display data in tables, graphs, and maps. In addition, the study uses *VOSViewer* to identify trends in liquefaction studies (Suprapto et al., 2021c; Van Eck & Waltman, 2020). Besides that, publication profiles, distribution of publications across countries and laboratories, top authors studying liquefaction and containment of liquefaction worldwide, publication patterns, visualization results, and contributions in Indonesia which include authors involved in liquefaction research.

3. FINDINGS

3.1 Publication Output Profile

As previously mentioned, 3,489 documents related to liquefaction were found in the Scopus database, as shown in Figure 1 below, from 2011 to 2021. However, the documents have fluctuating data with an apparently increasing trend. From 2011 until 2014, there were more than 100 documents per year, but in 2016, there was a decrease by 27 documents from the previous year - the highest data was 327 documents in 2019. The number of papers and documents has decreased twice, in 2016 and 2020 as shown this Figure 1. However research trends have increased significantly over the last ten years and if this trend continues, it is expected to significantly increase the number of articles from the next following years.

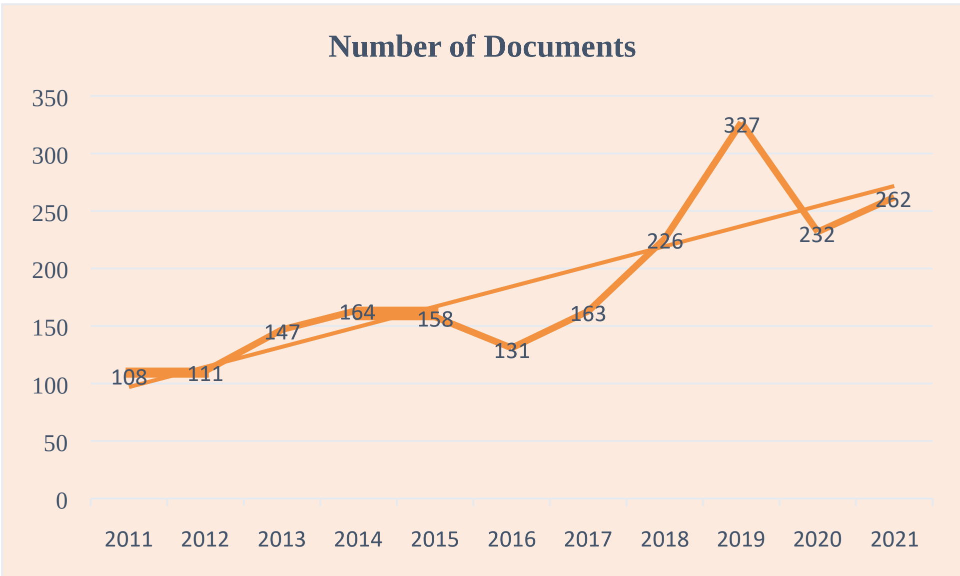

Figure 1. Number of documents on liquefaction (2011-2021)

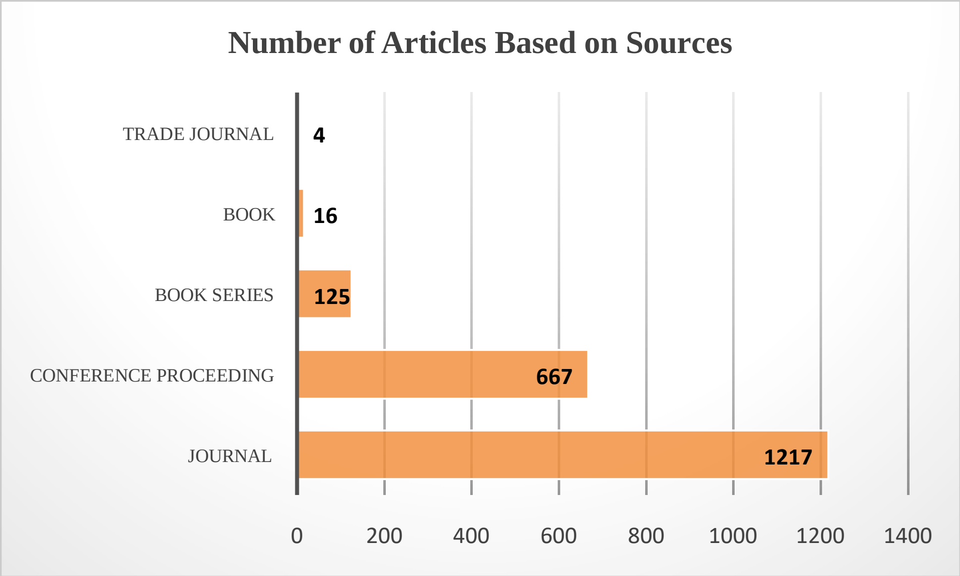

Figure 2. Documents' source types

As illustrated in Figure 2, there are five sources of documents relating to liquefaction. These include journals, conference proceedings, book series, books, and trade journals. Also, Figure 2 indicates that journals are more prominent in the number of documents amounting to 1,217 publications. Subsequently, conference proceedings contained up to 667 documents and a book series 125 documents. Books and trade journals were the fewer sources of documents.

Furthermore, there are 11 document types relating to liquefaction. These are articles, conference papers, book chapters, reviews, notes; data papers, erratums, editorials, letters, retractions, and conference reviews. As shown in Figure 3, the type of documents was a majority of 1,180 articles, followed by 758 conference papers and 41 book chapters.

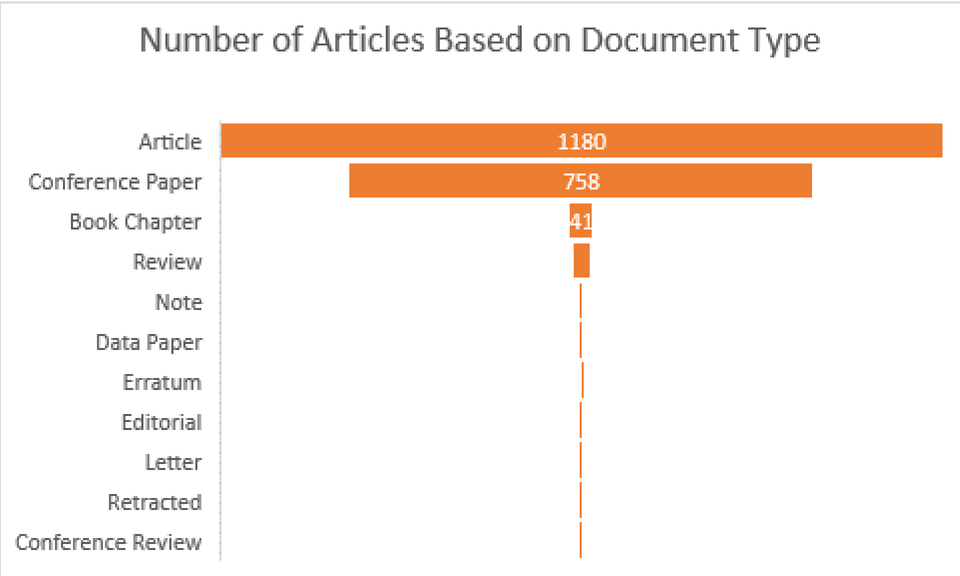

Figure 3. Types of documents

As illustrated in Figure 4 below, of the 3,489 documents, 878 documents were written in English. Other documents were 126 documents in Chinese, 10 in Turkish, 7 in Japanese, 5 in Spanish, 3 in German, 2 in Korean, and 1 in French.

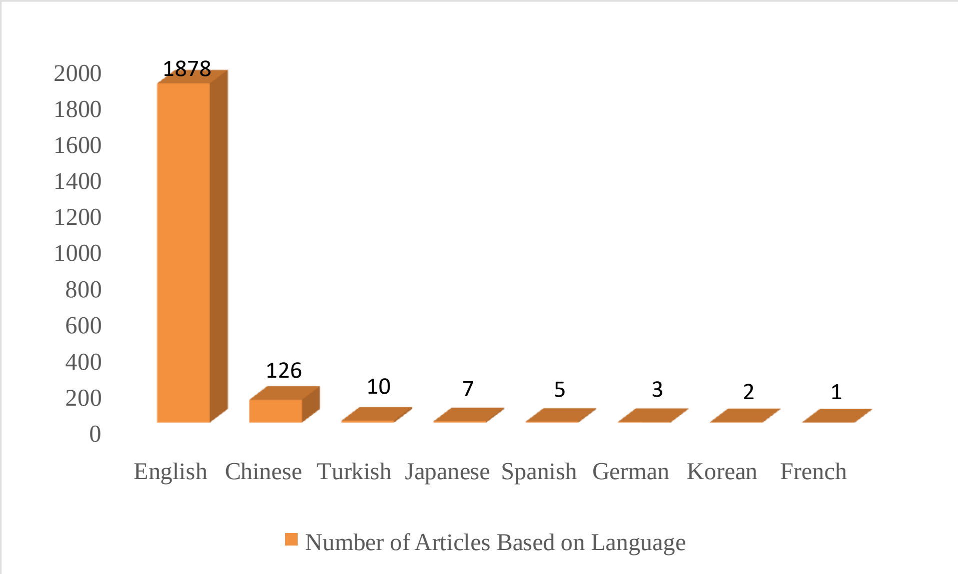

Figure 4. Language used

Furthermore, Figure 5 shows several keywords that were used in searches for the topic of liquefaction. Accordingly, the term "Liquefaction" was used in the search of 1,308 documents and "Soil Liquefaction" of 1,233 documents. The term "Earthquakes" was used in the search of 1056 documents, "Soils" with 691 documents, "Geotechnical Engineering" with 378 documents, "Liquefaction Potentials" with 337 documents, "Soil Mechanics" with 322 documents, "Earthquake Engineering" with 320 documents, "Sand" with 272 documents, and the last "Earthquake" with 236 documents.

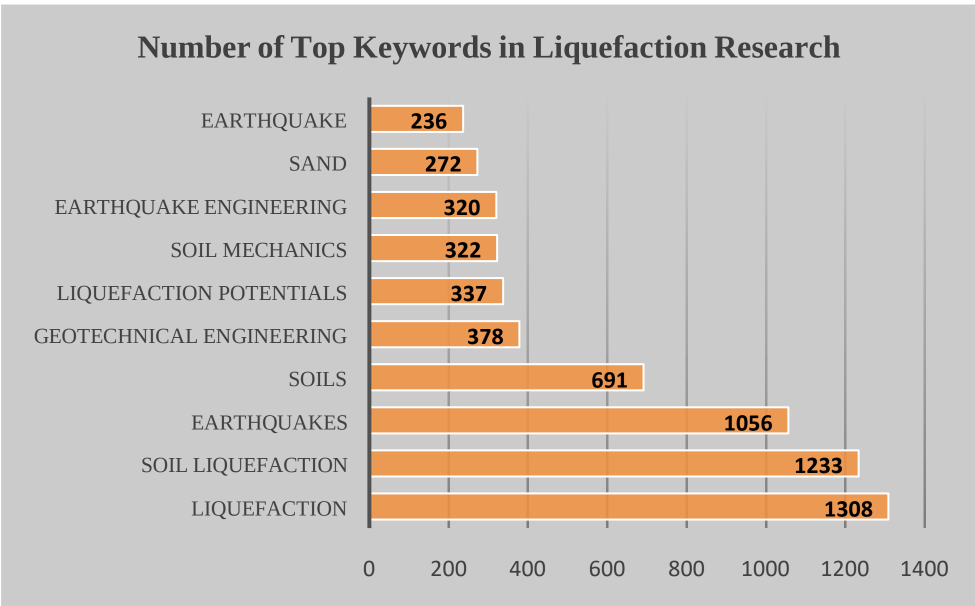

Figure 5. Top Keywords to search for Liquefaction

Some dominant subject areas related to liquefaction are listed in Table 1. The three most prominent subject areas were found in "Earth and Planetary Sciences" with 1,535 documents, in "Engineering" with 932 papers, in "Environmental Science," with 474 documents.

Table 1. Subject Area in studies related to Liquefaction

No	Subject Area	Number of Documents
1	Earth & Planetary Sciences	1,535
2	Engineering	932
3	Environmental Science	474
4	Agricultural & Biological Sciences	282
5	Computer Science	97
6	Materials Science	75
7	Energy	62
8	Physics and Astronomy	60
9	Social Sciences	51
10	Mathematics	43

3.2 Distribution of Publication across Countries and Institutions

The distribution of published papers among different countries can be seen in Figure 6. As shown in Figure 6, 461 papers originated from the US has, 395 followed from China, 302 from Japan, 195 from India, 127 from Italy, 125 from New Zealand, 100 from Turkey, 95 from Indonesia, 95 from Iran, and 94 from the United Kingdom.

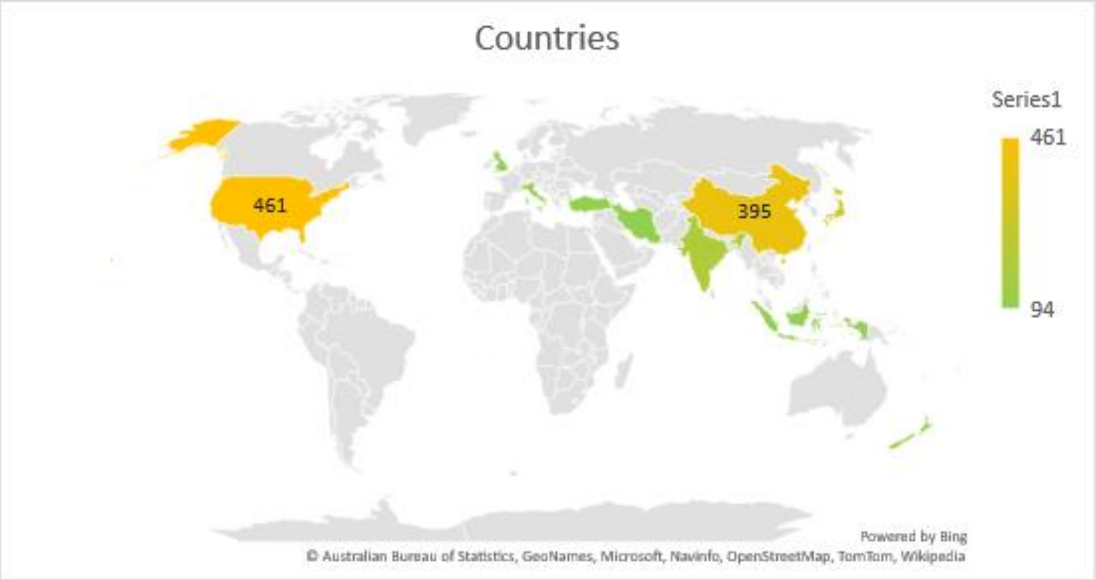

Figure 6. Number of documents across countries

Table 2 shows the classification of the number of documents related to liquefaction published by institutions. The University of Canterbury in New Zealand published 77, the China Earthquake Administration 60, the Ministry of Education China and the University of Tokyo 49 each, the University of California 44, the University of Auckland, the Virginia Polytechnic Institute, and State University 43 documents, Tongji University 42, the University of California at Davis 40, and the Brigham Young University 39.

Table 2. Documents by institutions

No	Institution	Number of Documents
1	University of Canterbury	77
2	China Earthquake Administration	60
3	Ministry of Education China	49
4	The University of Tokyo, Japan	49
5	University of California, Berkeley, USA	44
6	The University of Auckland	43
7	Virginia Polytechnic Institute and State University	43
8	Tongji University	42
9	University of California, Davis	40
10	Brigham Young University	39

3.3 Top Ranking of Authors in Researching Liquefaction

The list of research authors on liquefaction is shown in Figure 7. The most prolific authors for 2011 to 2021 were Owen, Kayen, Boulanger, Xiao, Cubrinovski, Yasuda, Van Ballegooy, Bhattacharya, Zhang, and Boulanger.

Figure 7. Top authors in researching liquefaction

The list of the top 10 citations on liquefaction research is indicated in Table 3 and Figure 8. Most of the articles cited were by Owen and Moretti (2011), with 240 based on the distribution. Kayen et al. (2012) had 212, Boulanger and Idriss (2016) had 173, Xiao et al. (2018) had 143, Cubrinovski et al. (2011) had 142, Yasuda et al. (2012) had 140, Van Ballegooy et al. (2014) had 136, Bhattacharya et al. (2011) had 130, Zhang J.M (2012) with 123, and Boulanger and Idriss (2012) had 107.

Table 3. Top citations on liquefaction documents

Author (s)	Journal	Number of Citations
Owen, G., Moretti, M. (2011)	Sedimentary Geology 235(3-4), 141-147	240
Kayen, R., Moss, R.E.S., Thompson, E.M., Tokimatsu, K. (2013)	J._ Geotechnical & Geoenvironmental Engineering 139(3), 407-419	212
Boulanger, R.W., Idriss, I.M. (2016)	J. Geotechnical and Geoenvironmental Engineering 142(2),04015065	173
Xiao, P., Liu, H. Liu, H., Xiao, Y., Stuedlein, A.W., Evans, T.M. (2018)	Soil Dynamics & Earthquake Engineering 107, 9-19	143
Cubrinovski, M., Bray, J.D., Taylor, M., Zupan, J. (2011)	Seismological Research Letters 82(6), 893-904	142
Yasuda, S., Harada, K., Ishikawa, K., Kanemaru, Y. (2012)	Soils & Foundations 52(5), 793-810	140
Van Ballegooy, S., Malan, P., Lacrosse, V., Cowan, H. (2014)	Earthquake Spectra 30(1), 31-55	136
Bhattacharya, S., Hyodo, M., Goda, K., Tazoh, T., Taylor, C.A. (2011)	Soil Dynamics and Earthquake Engineering 31(11), 1618-1628	130
Zhang, J.-M., Wang, G. (2012)	Acta Geotechnica 7(2), 69-113	123
Boulanger, R.W., Idriss, I.M. (2012)	J. Geotechnical and Geoenvironmental Engineering 138(10), 1185-1195	107

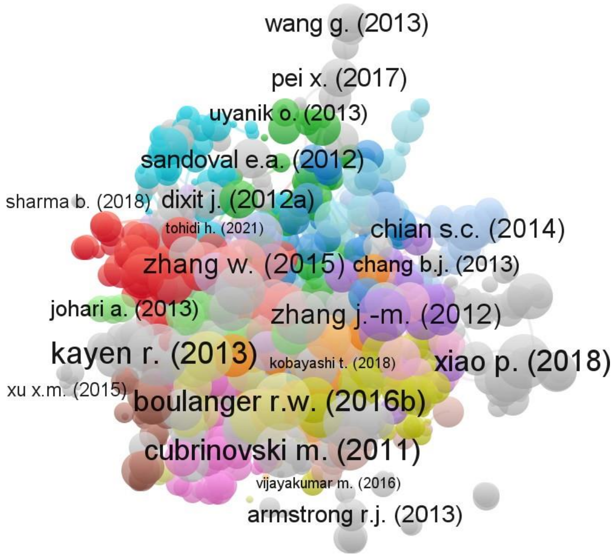

Figure 8. Top citations in researching liquefaction

3.4 Publication Patterns

Table 4 lists 12 journals and proceedings that contributed the most to liquefaction. At the top of the ranking, the journal Geotechnical Special Publication published the most documents on liquefaction (144 documents) and “Earthquake Geotechnical Engineering for Protection and Development of Environment and Constructions Proceedings of the 7th International Conference on Earthquake Geotechnical Engineering”, and “Soil Dynamics and Earthquake Engineering” with 137 and 128 papers, respectively.

Table 4. Source title of documents

No	Source Title	Number of Documents
1	Geotechnical Special Publication	144
2	Earthquake Geotechnical Engineering for Protection and Development of Environment and Constructions Proceedings of The 7th International Conference on Earthquake Geotechnical Engineering 2019	137
3	Soil Dynamics and Earthquake Engineering	125
4	Journal of Geotechnical and Geoenvironmental Engineering	68
5	Lecture Notes in Civil Engineering	53
6	Engineering Geology	46
7	Bulletin of Earthquake Engineering	34
8	Soils and Foundations	34
9	Earthquake Spectra	31
10	Iop Conference Series Earth and Environmental Science	30
11	Yantu Gongcheng Xuebao Chinese Journal of Geotechnical Engineering	30
12	Natural Hazards	28

3.5 Visualization Maps of Liquefaction

This study used VOSViewer software and 3,489 liquefaction documents in the Scopus database. Figure 9 below is a visualization of liquefaction topics from 2011 to 2021. Scientists worldwide visualizations produce five colors: yellow, red, green, blue, and purple clusters. The first cluster (green) relates to the reliability and accuracy of the liquefaction documents. Followed by the second cluster (yellow) corresponds to liquefaction consistency. The third cluster (red) is regarding the map and city of liquefaction. The fourth cluster (blue) relates to the deformation of liquefaction. Moreover, the last cluster (purple) is for the country that experienced effects of liquefaction. Figure 10 indicates the central dominance of research in the interval of 2016-2018 from an overlay visualization.

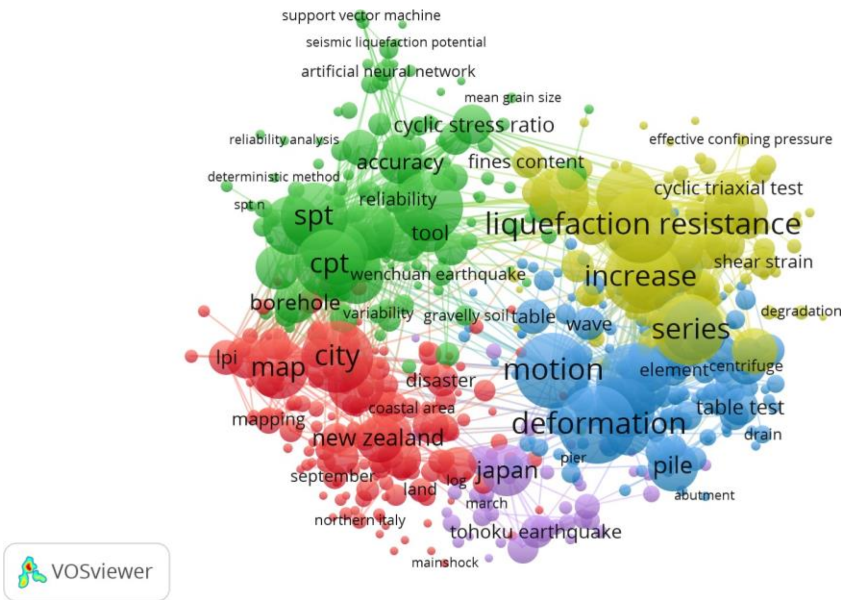

Figure 9. Network visualization (all years)

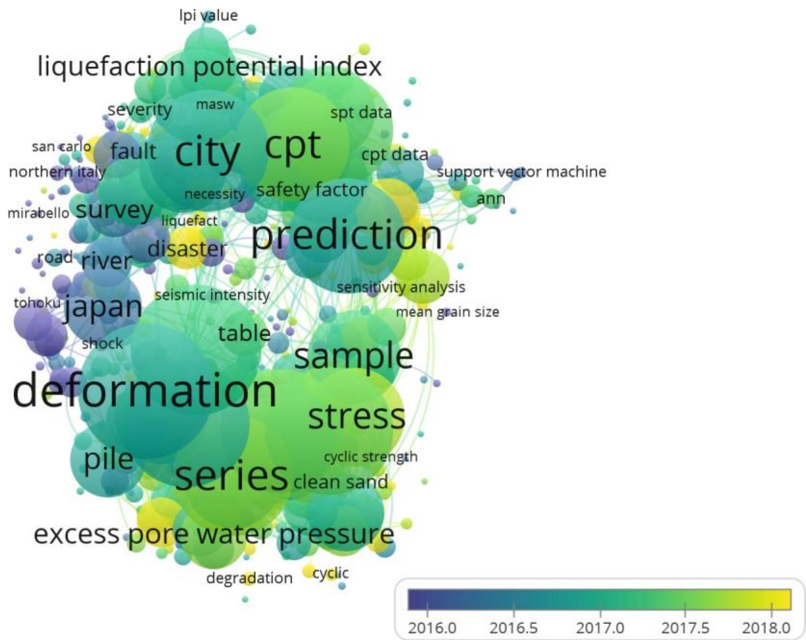

Figure 10. Overlay visualization (for 2016-2018)

Figure 11a shows the principal authors, co-authors, and the most influential authors of publications regarding Liquefaction. The visualization differentiates six main groups of writers, such as Cubrinovski et al., Boulanger R.W et al., Yuan X et al., Orense R.P et al., Kramer S.L et al., and Flora A et al. Moreover, in Figure 11b, a visualization of co-occurrence across all keywords is mapped, which indicates that "Liquefaction" is the most frequent keyword, followed by "liquefaction potential" and "liquefaction resistance".

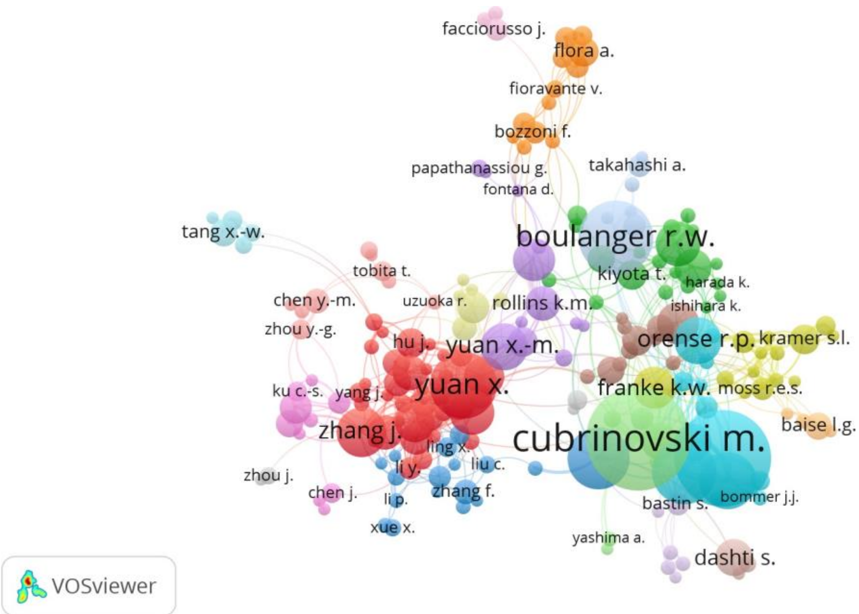

Figure 11 (a) "A network visualization of co-authorship",

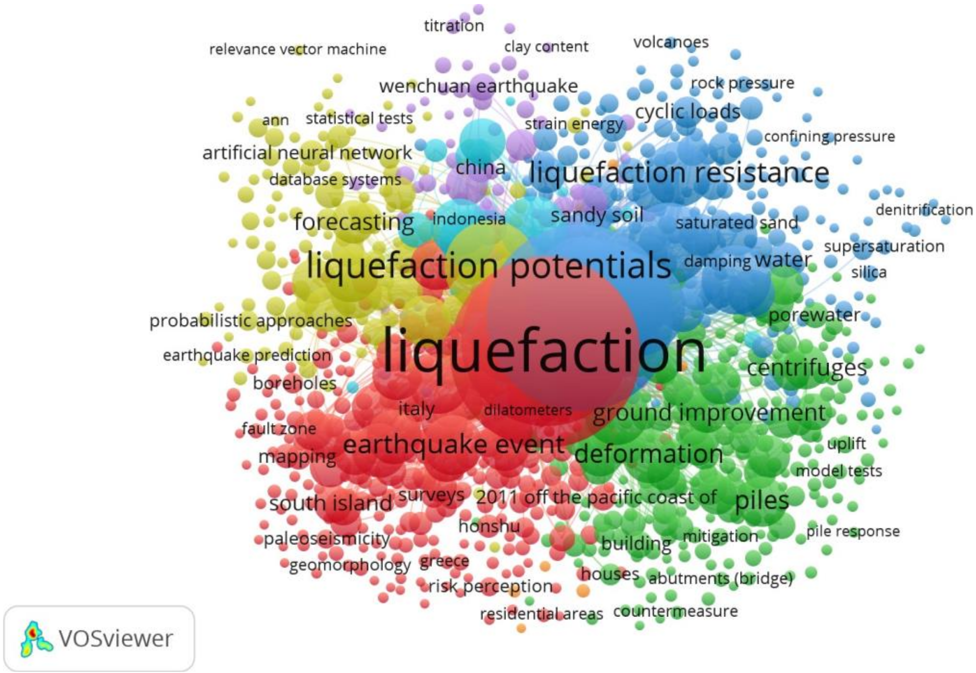

Figure 11 (b) "A network visualization of co-occurrence across all keywords"

Since ground liquefaction is a natural disaster that occurs in numerous parts of the world, researchers from across countries are involved in researching it. Therefore, it is necessary to indicate the countries of researchers involved in the topic of liquefaction research. Figure 12 depicts the visualization of co-authorship from different countries, and Figure 13 shows the visualization of co-citation from different authors (Figure 13a) and the visualization of citations from countries (Figure 13b).

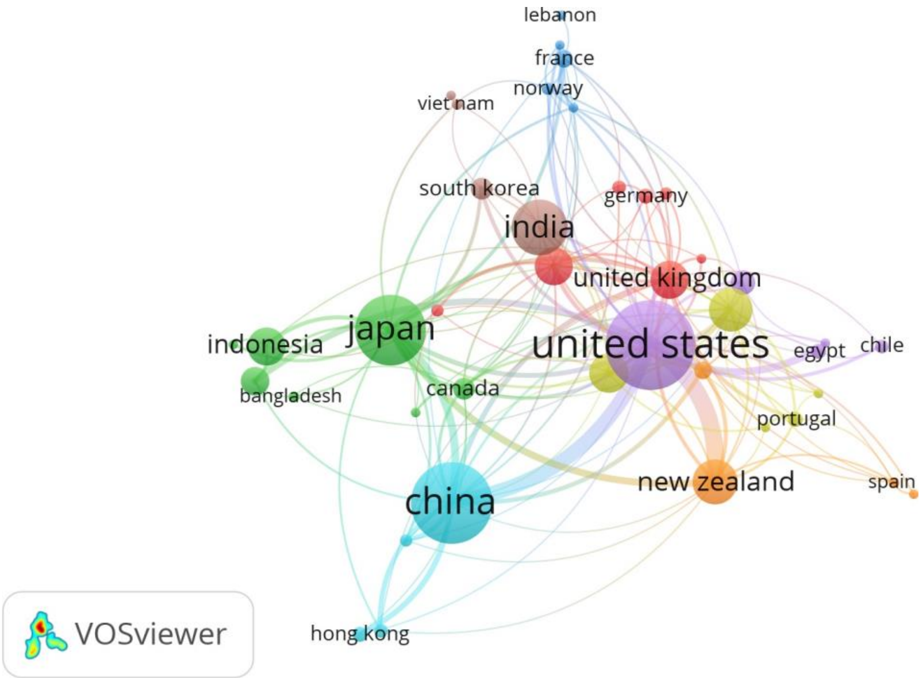

Figure 12. A network visualization of co-authorship across countries

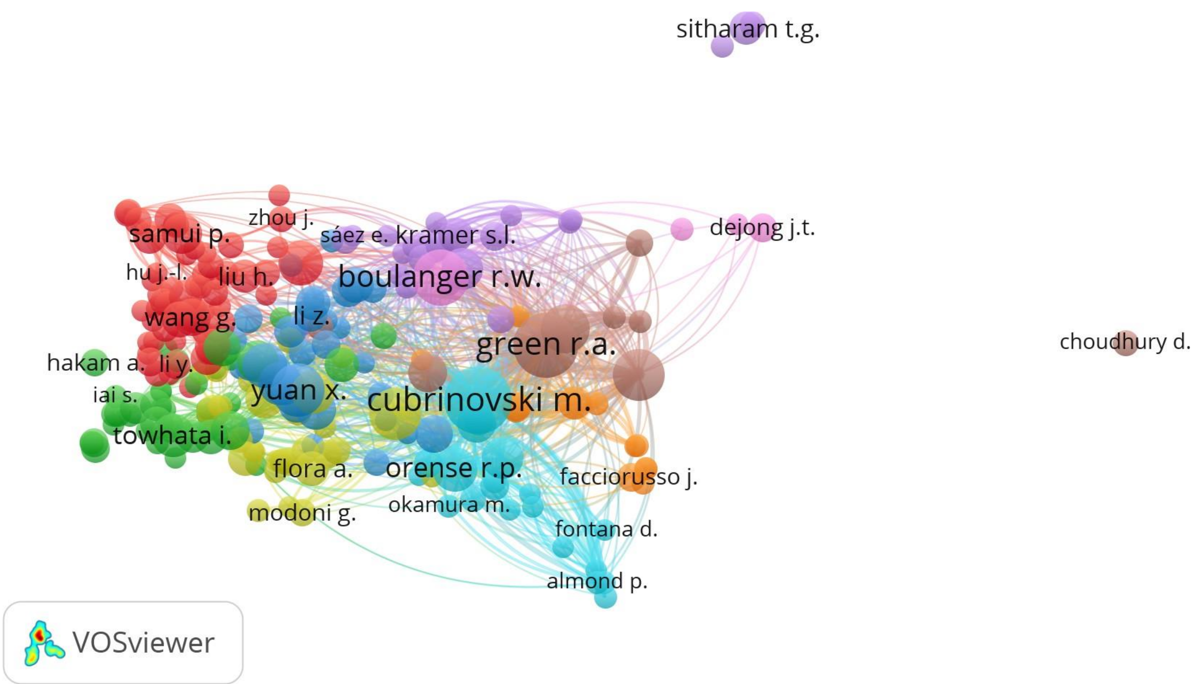

Figure 13 Visualization of co-citation from different authors

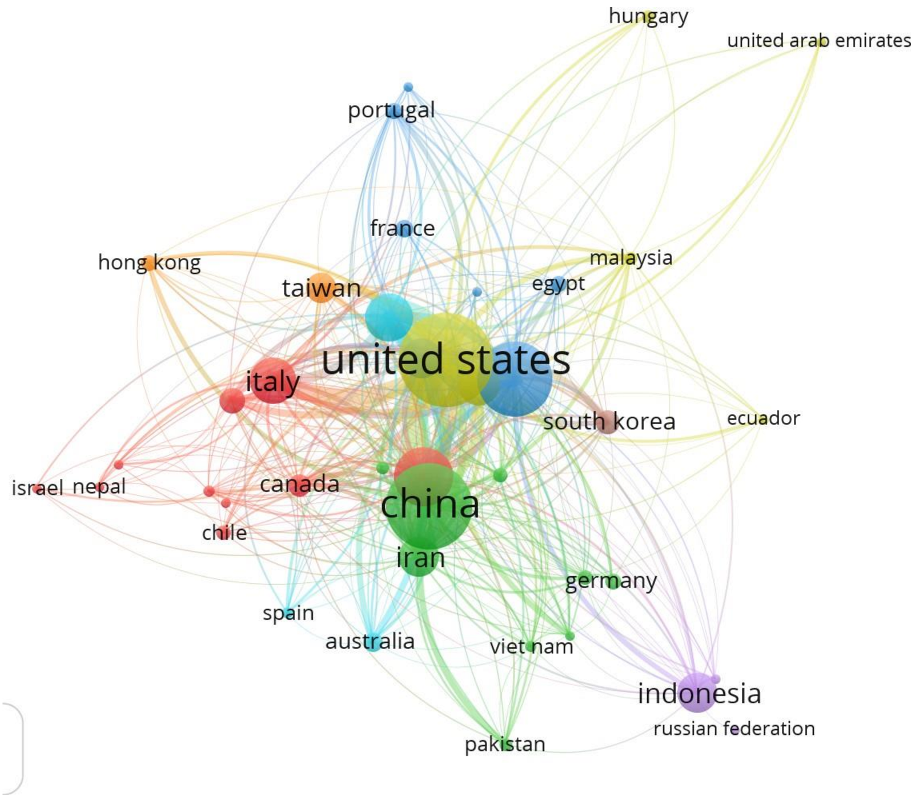

Figure 13. (b) Network visualization of citation across countries”

3.6 Indonesian Contribution to the Topic of Ground Liquefaction

Indonesia participated with 95 published documents on liquefaction in the last ten years (2011-2021). It can be seen in Figure 14 that there has been an enhancement in paper numbers in the previous four years, from 2017 to 2020.

Figure 14. Annual number of research documents on liquefaction in Indonesia

As international scientists delivered five clusters related to ground liquefaction research, Indonesian authors had three clusters (red, green, and blue) of similar work, as shown in Figure 15. The first cluster (green) related to the terminology of liquefaction. The second cluster (red) relates to the type of liquefaction and the potential of liquefaction. The last cluster (blue) refers to the effect of liquefaction.

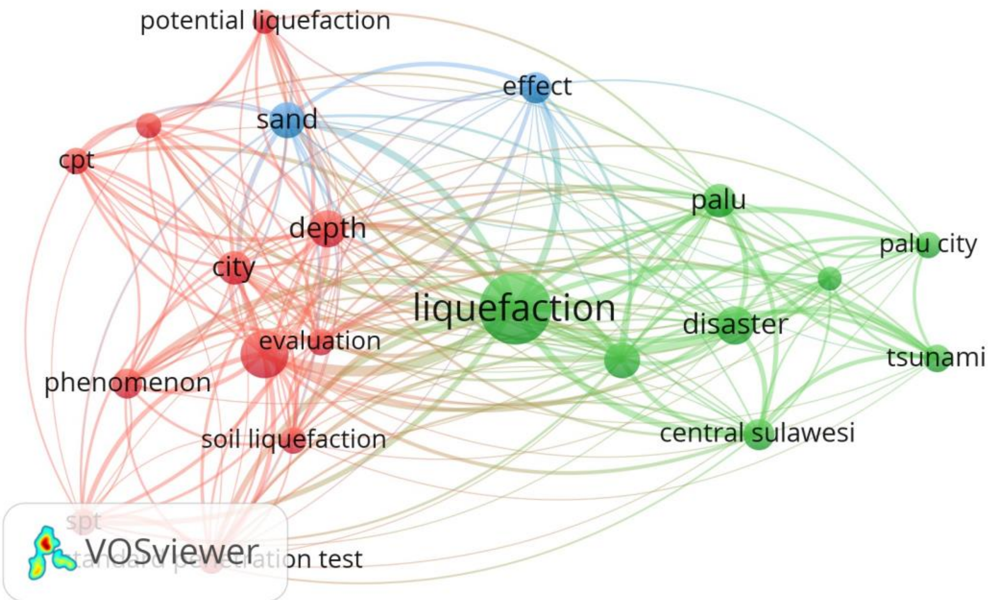

Figure 15. A network visualization of metadata (Indonesian documents)

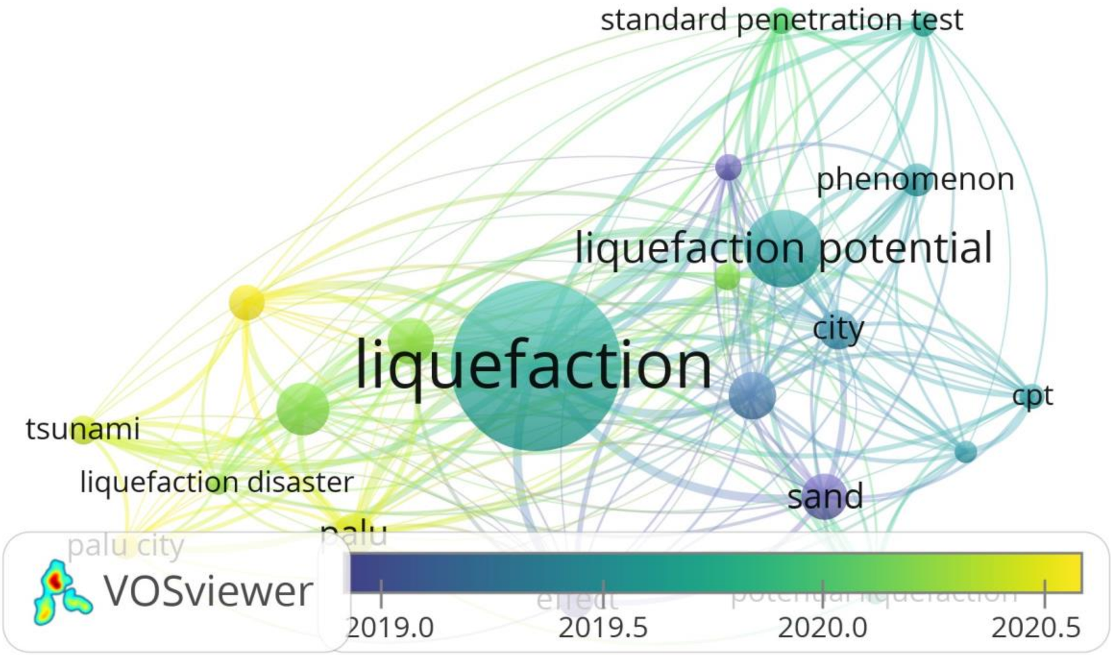

Figure 16. An overlay visualization 2019- 2020.5 (Indonesian documents)

The top 10 rankings of sources among Indonesian liquefaction researchers are presented in Table 5. First of those was “the IOP Conference Series Earth and Environmental Science” with 20 papers, followed by “the E3s Web of Conferences” with 11 papers. Then “IOP Conference Series Materials Science and Engineering” and “Journal of Physics Conference Series” with six papers, respectively. At the same time, other journals or proceedings published less than six documents.

Table 5. Document by source title (Indonesia data)

No	Source Title	Number of Documents
1	IOP Conf. Ser. Earth & Environmental Science	20
2	E3s Web of Conf.	11
3	IOP Conf. Ser. Materials Science and Engineering	6
4	Journal of Physics Conf. Series	6
5	AIP Conference Proceedings	5
6	International Journal of Geomate	5
7	Geoenvironmental Disasters	3
8	Journal of Engineering and Technological Sciences	3
9	16th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering ARC 2019	2
10	Indonesian Journal on Geoscience	2

Figure 17. (a) Indonesia's leading authors on liquefaction. (b) A network visualization of Indonesian co-authorships

The visualizations of the top Indonesian authors and their colleagues who have contributed to research trends on liquefaction are presented in Figures 17a and 17b. Based on the graphs, it can be seen that Hakam, A. is the most voluminous author on this topic in Indonesia, followed by Fathani, T.F, and Mase L.Z.

Almost the same as the keywords related to research trends on liquefaction globally, in Indonesia, the keywords are voluminous by liquefaction, soil liquefaction, earthquake, and disasters (Figure 18).

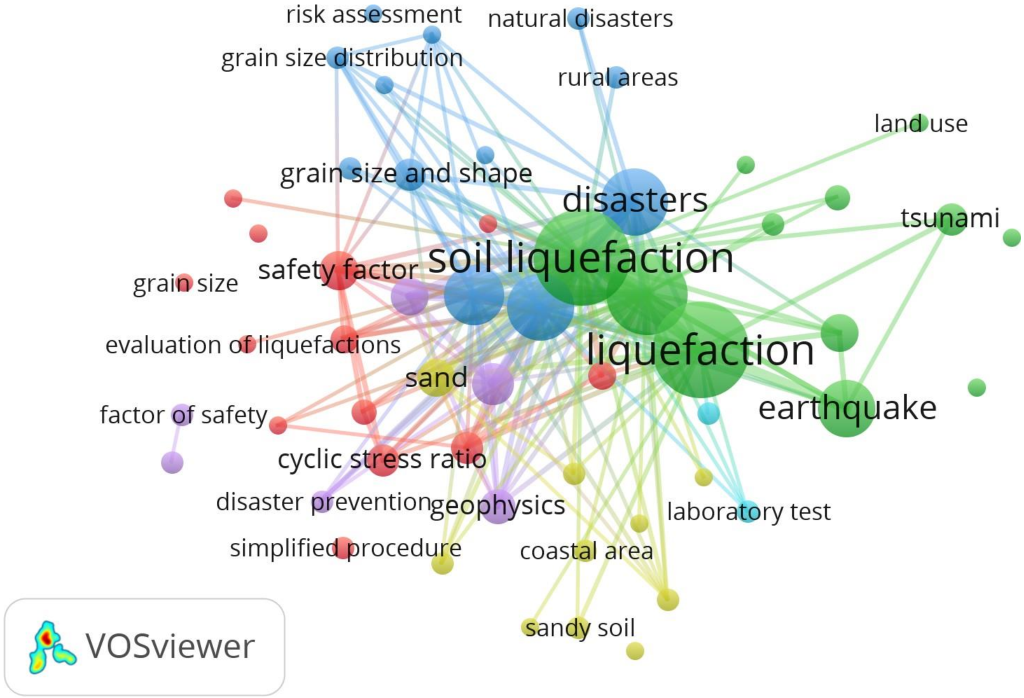

Figure 18. “A network visualization of co-occurrence among all keywords”

4. SUMMARY OF FINDINGS

As explained before, liquefaction decreases soil strength due to increased pore water pressure and a decrease in the adequate pressure of the soil layer due to dynamic repetitive loading. In the soil layer, dynamic periodic stresses are generated by seismic wave propagation of crustal motions. The phenomenon of liquefaction has attracted the attention of experts, especially in the field of engineering geology, after dramatic events resulting from the 1964 Japan and Alaska earthquakes. The number of papers related to ground liquefaction fluctuated year by year. Hundreds of documents on this crucial topic are being completed every year. This research trend has increased significantly in the last ten years. Based on this trend, it is expected that there will be a significant increase in the number of articles in the next five years.

Based on the distribution of papers among different countries, most of them originated in the United States, followed by China, Japan, India, Italy, New Zealand, Turkey, Indonesia, Iran, and the United Kingdom. The University of Canterbury topped the rankings with 77 documents, followed by the China Earthquake Administration with 60. The Ministry of Education of China and the University of Tokyo were ranked 4th and 5th with 49 documents each. The University of California published 44 documents, and he University of Auckland, the Virginia Polytechnic Institute, 43 documents. The Tongji University published 42 documents, the University of California at Davis published 40, and the Brigham Young University 39.

Based on the distribution, most of the cited articles were 240 by Owen G. (2011), 212 by Kayen R. (2012), 173 by Boulanger R.W. (2016), 143 by Xiao P. (2018), 142 by Cubrinovski M. (2011), 140 by Yasuda S. (2012), 135 by Van Ballegooy (2014), 130 by Bhattacharya S. (2011), 123 by Zhang J.M. (2012), and 107 by Boulanger R.W. (2012).

The top 10 rankings of document sources which contributed most to liquefaction research are presented in Table 5. First was the IOP Conference Series Earth and Environmental Science with 20 papers, followed by the E3s Web of Conferences with 11 papers. The IOP Conference Series Materials Science and Engineering and the Journal of Physics Conference Series published six papers, respectively. All other journals or proceedings published were less than six documents.

Scientists worldwide visualizations produced five distinct clusters on ground liquefaction. The first relates to the reliability and accuracy of the liquefaction. The second corresponds to liquefaction consistency. The third provides the map and city where such liquefaction occurred. The fourth relates to the type of deformation of liquefaction. Finally, the last cluster shows the countries that experienced such impact of ground liquefaction. Specifically, in the last ten years (2011-2021), Indonesia contributed and published 95 documents on this subject. From 2017 to 2020, there has been an increase in the number of papers. Hakam, A. is the most prolific author on this topic in Indonesia, followed by Fathani, T.F, and Mase L.Z.

CONCLUSIONS

During the period 2011 to 2021, some crucial points regarding research on liquefaction increased significantly throughout the years, dominated by articles in journals. Based on the number of documents published by countries, most papers were those by the United States. The institution that produced the more significant number of papers relating to liquefaction was the University of Canterbury in New Zealand.

The most contributing author on the subject of liquefaction for the present study period was Owen G.. The source that contributed most to liquefaction research for the study period was “the IOP Conference Series Earth and Environmental Science”. Visualization of research trends on liquefaction showed in five clusters: (1) Reliability and accuracy in reporting liquefaction; (2) Liquefaction consistency; (3) Map and city of liquefaction; (4) deformation due to liquefaction; and (5) The country that experienced liquefaction.

Indonesia contributed to documents related to liquefaction, which were published in the last ten years (2011-2021). There has been an enhancement in the number of papers in the previous four years, from 2017 to 2020. Hakam, A. is the most prolific author on this topic in Indonesia, followed by Fathani, T.F., and Mase L.Z. The above cited work can help researchers and readers identify trends related to liquefaction globally and provide an overview for future investigative work.

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