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Jurnal Penelitian

# Research Growth in the Topic of Soil Liquefaction between Indonesia and New Zealand: A Bibliometric Analysis from Scopus Database

# Perkembangan Riset pada Topik Tanah Likuefaksi antara Indonesia dan Selandia Baru: sebuah Analisis Bibliometrik Berbasis data Scopus

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***ABSTRACT***

*Soil liquefaction is important in geotechnical engineering, particularly in seismically active areas like Indonesia and New Zealand. With an emphasis on publications written by researchers from Indonesia and New Zealand between 2015 - 2025, This research is a bibliometric analysis that uses data from the Scopus database and the VOS viewer application to assist in interpreting the gathered bibliometric data. The author from New Zealand (Misko Cubrinovski) seems to be the most productive in researching and writing related to soil liquefaction, with 48 articles. Authors from Indonesia are relatively more evenly distributed, with 10-20 articles dominated by Sito Ismanti, Lindung Zalbuin Mase, and Teuku Faisal Fathani. In addition, compared to Indonesian institutions, New Zealand institutions are more likely to collaborate with external parties such as the United States (University of California, University of Texas, University of Washington, etc.), enabling them to obtain greater funding to encourage research productivity. The research map used Scopus RIS data showing three clusters: red (general liquefaction terms), blue (New Zealand-focused, e.g., CPT and shear waves), and green (Indonesia-focused, e.g., seismic response). Minor clusters (purple, yellow) link related topics.*

## 1. Introduction

In geotechnical engineering, soil liquefaction is crucial, especially in areas that experience seismic activity. It happens when saturated cohesionless soil becomes weaker and acts more like a liquid due to increased pore water pressure, usually brought on by dynamic loads like earthquakes [1][2][3]. Serious repercussions, such as ground failure, lateral spreading, settlement, and structure damage, may result [4][5]. The liquefaction process starts when an external force from cyclic loading (usually seismic activity), causes the soil to shear monotonically or cyclically. As a result of this shearing, the soil's effective stress decreases, and its pore water pressure rises [2][6]. As the soil is subjected to dynamic loading, the soil particles are pushed closer together; there is less space for water, which raises the pore water pressure. This increase in pore water pressure reduces the effective stress, which is the stress that actually holds the soil particles together [7][8].

With the effective stress reduced, the soil particles lose contact with each other, resulting in the "semi-fluidized regime" when the soil acts more like a viscous fluid than a solid. This loss of contact and strength can lead to significant ground deformation and lateral spreading [2][9].

Indonesia is one of the countries with high seismic activity. Its geological and tectonic circumstances are highly complex because Indonesia is at the meeting point of multiple major tectonic plates, such as the Indo-Australian, Eurasian, and Pacific. Significant tectonic activity, including regular earthquakes, volcanic eruptions, and tsunamis, is caused by this unique location [10][11]. The tectonic evolution of Java is influenced by the subduction of the Indo-Australian plate beneath the Eurasian plate, resulting in diverse geological structures and active tectonic zones [12][13]. The considerable liquefaction potential in this region was brought to light by the Bantul earthquake in 27 May 2006, especially in the vicinity of the Kretek 2 Bridge in the Opak River Estuary. With differing degrees of severity, liquefaction mostly happened between 1.5 and 6 meters below the surface [14].

On the other hand, the Sunda Arc and the Great Sumatra Fault are very seismically active and volcanically active, delineating Sumatra's western coast [15]. Due in part to liquefaction, the 7.6-magnitude earthquake that struck Padang Pariaman, West Sumatera, on 30 September 2009, severely damaged infrastructure and buildings. Due to liquefaction-induced foundation failures, numerous buildings collapsed [16][17]. Due to their poor grade and predominance of fine sand with a particularly loose quality, the sandy soils around Padang's coast are highly prone to liquefaction [18].

Furthermore, from the western part of Indonesia, the Palu Koro fault shifted as a result of the Mw 7.5 earthquake in Central Sulawesi, causing multiple disasters. Large-scale soil liquefaction displaced objects on the surface by hundreds of meters, and entire settlements sank into the mud. The existence of a constrained aquifer in Palu made the liquefaction worse. Significant groundwater ejection resulted from the earthquake-induced interaction between the confined and unconfined aquifers, raising the possibility for liquefaction [19]. This event was particularly severe in areas like Balaroa, Petobo, and Jono Oge [20]. According to studies, the soil is primarily sandy and fine-grained, making it highly prone to liquefaction. From 1 m to 20 m depth, the Standard Penetration Test (SPT) value varied from 3 to 54 blows, showing different levels of soil density and liquefaction potential [21][22].

In New Zealand, soil liquefaction has been a severe problem, especially during large-scale earthquakes. Soil liquefaction caused by the 2010–2011 Canterbury Earthquake Sequence (CES) severely damaged bridges, underground utilities, commercial buildings, and residential buildings in Christchurch [23]. Telecommunication cables and wastewater lines were among the underground infrastructures that suffered the most damage from liquefaction-induced lateral spreading and ground subsidence [24]. Five years after the CES, Liquefaction was produced mainly by the 2016 Kaikoura earthquake in locations with young, loose alluvial deposits and reclaimed lands, including the floodplains close to Blenheim. Buildings, wharves, and container ports were all impacted by lateral spreading and settlement induced by the liquefaction, which was less severe than the CES [25]. The occurrence of liquefaction in the Kaikoura event was closely linked to the geomorphology and depositional settings of the sediments, highlighting the importance of these factors in assessing liquefaction hazards.

Liquefaction can drastically reduce both axial and lateral bearing capacities of pile foundations, leading to increased displacements and potential structural failure [26]. Buildings on liquefiable soils may experience significant settlement and tilting, which can compromise structural integrity and safety. Furthermore, liquefaction-induced settlement can cause downward shear stress along piles, known as negative skin friction, further exacerbating foundation settlement also the lateral movement of soil during liquefaction can lead to additional stresses on foundations, potentially causing further damage [27][28].

This study examines the bibliometric trends of published research on soil liquefaction, focusing on works authored by researchers from Indonesia and New Zealand between 2015 and 2025. The analysis explores the bibliographic features, such as publication year, authorship patterns, and citation metrics, as well as the thematic content, including key research topics, methodologies, and emerging trends in liquefaction studies. The data was sourced exclusively from the Scopus database to maintain academic rigor, ensuring the selection of high-quality, peer-reviewed publications. The study employs VOSviewer to visualize research clusters, revealing distinct thematic focuses between the two countries—such as New Zealand's emphasis on geophysical testing and Indonesia's interest in seismic response and soil-structure interaction. By comparing these trends, the research highlights regional differences in liquefaction research priorities and contributes to a deeper understanding of global advancements in geotechnical earthquake engineering.

## 2. Method

This research is a bibliometric analysis that uses data from the Scopus database (from Q1-Q4) and the VOS viewer application to assist in interpreting the gathered bibliometric data. A key limitation of this study is its reliance solely on Scopus, which may exclude relevant soil liquefaction research indexed in other databases, such as Web of Science or regional repositories. It could introduce bias, as some high-quality studies or regionally significant publications might be overlooked. For instance, Indonesian journals that are not indexed in Scopus but are present in local databases could provide additional insights into localized liquefaction studies. Similarly, New Zealand's research output in specialized geotechnical engineering sources might not be fully captured.

This restriction could affect the comprehensiveness of bibliometric trends, potentially skewing cluster analysis by underrepresenting specific themes or authors. Future studies should incorporate multiple databases to ensure a more robust and representative dataset. Despite this limitation, Scopus remains a widely recognized source for high-impact literature, and the findings still offer valuable insights into liquefaction research trends in the two countries.

The Boolean search query in Scopus was structured to systematically retrieve publications on soil liquefaction related to earthquakes while applying specific filters for relevance and comparability. The core search terms TITLE-ABS-KEY(soil AND liquefaction) AND TITLE-ABS-KEY(earthquake) ensured that only documents containing all three key terms—"soil," "liquefaction," and "earthquake"—in their titles, abstracts, or keywords were included. The query incorporated a publication year restriction (PUBYEAR > 2014 AND PUBYEAR < 2026) to focus on recent research, limiting results to studies published between 2015 and 2025. Additionally, the search was performed separately for each country of interest using LIMIT-TO(AFFILCOUNTRY, "Indonesia") and LIMIT-TO(AFFILCOUNTRY, "New Zealand"), ensuring that only publications with at least one author affiliated with institutions in these countries were retrieved. This approach guaranteed a targeted bibliometric analysis dataset while consistently comparing research trends between the two seismically active regions. Using this search strategy, 243 articles from Indonesia and 156 articles from New Zealand were identified that contained the keywords "Soil Liquefaction" and "Earthquake". Following that, a bibliometric study using the VOS viewer software was performed. The bibliographic data include the publications per year, affiliations, authors and co-authors, and keywords.

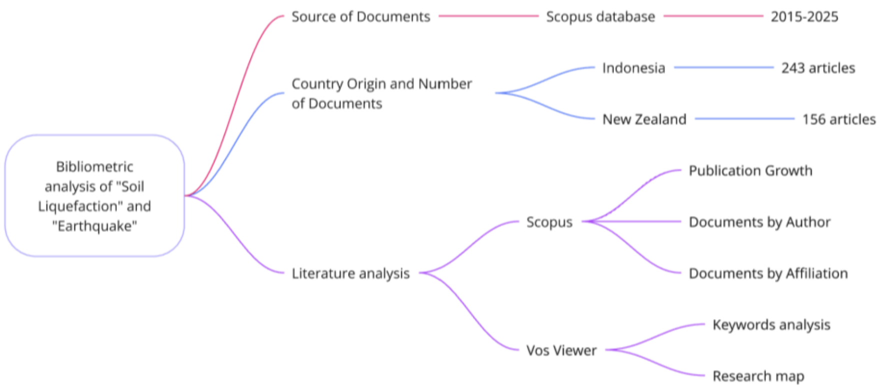


Fig 1. Flow chart of bibliometric analysis
*Source: Miro*

## 3. Result and Discussion

### *3.1 Publication Growth*

The first graph (Figure 2) illustrates Indonesia's evolving research output on soil liquefaction over an eleven-year period. While lacking specific numerical values, the visualization clearly demonstrates three key phases of development. From 2015-2017, the country maintained a baseline level of publications, reflecting steady but limited research activity. This pattern changed dramatically in 2018, when publication numbers surged significantly - a direct response to the devastating Palu earthquake and subsequent liquefaction disaster that occurred in September 2018. The elevated output persisted through 2020-2022, indicating both immediate post-disaster studies and longer-term research initiatives. Recent years (2023-2025) suggest either a stabilization or modest decline in publications, potentially signaling the completion of major post-earthquake studies or a shift in research priorities. This trajectory highlights how catastrophic events can dramatically accelerate research output in vulnerable nations, while also revealing Indonesia's growing capacity to sustain liquefaction studies beyond immediate disaster responses.

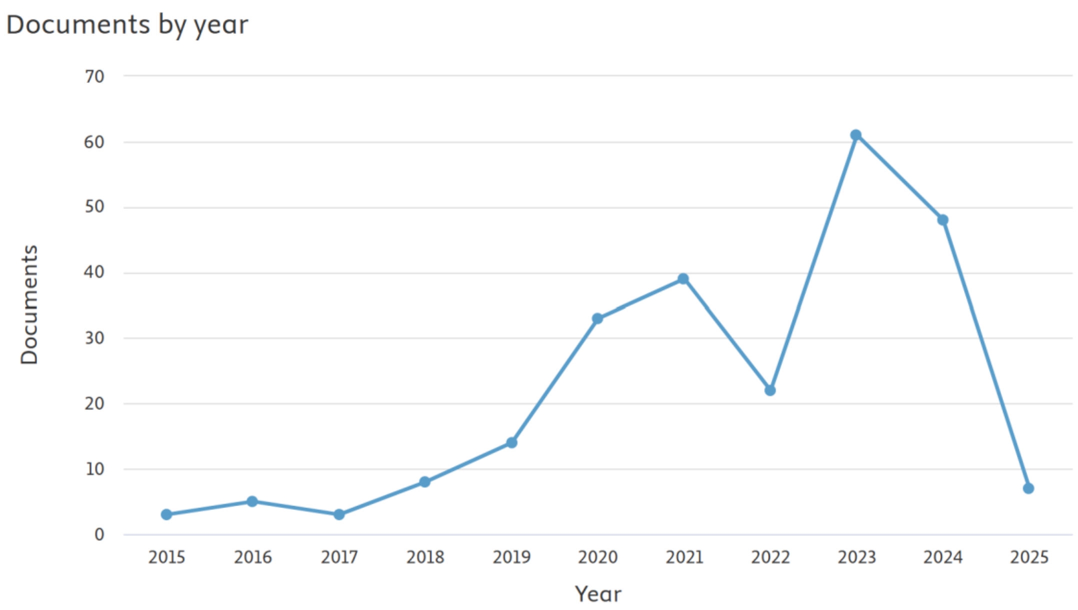


Fig 2. Indonesian publication growth in the topic of soil liquefaction

*Source: Scopus*

The second graph (Figure 3) provides precise quantitative data on New Zealand's research publications, revealing distinct patterns in the country's approach to liquefaction studies. Between 2015-2017, New Zealand maintained a consistent output of 14-15 annual publications, reflecting its established research infrastructure and ongoing interest in geotechnical risks. The graph shows an explosive growth in 2019, with publications peaking at 28 publications - a delayed but intensive research response to the 2016 Kaikōura earthquake. Unlike Indonesia's more sustained growth, New Zealand's pattern shows a gradual decline beginning in 2021, returning to 10-15 publications by 2023. The 2024-2025 data suggests a potential return to pre-earthquake baseline levels. This "surge-and-stabilization" pattern characterizes New Zealand's disaster research model, where major events trigger concentrated bursts of scientific activity that eventually taper back to normal levels, demonstrating the country's mature but event-driven research ecosystem.

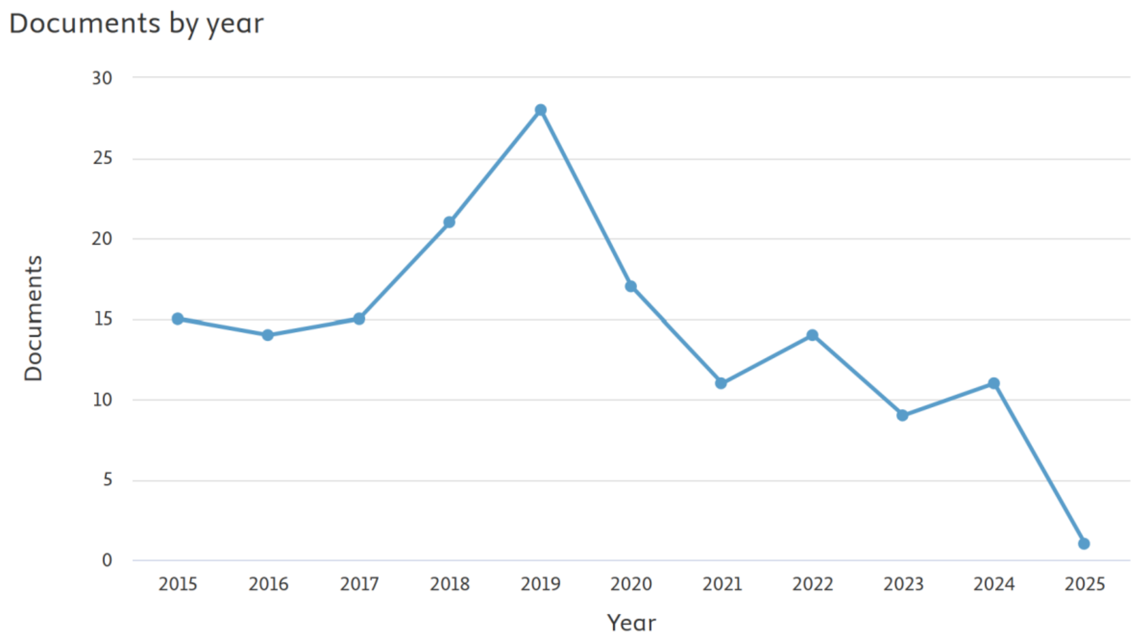


Fig 3. New Zealand publication growth in the topic of soil liquefaction

*Source: Scopus*

Both graphs reveal important contrasts in how Indonesia and New Zealand approach liquefaction research. Both nations show clear research surges following major seismic events, but with different temporal patterns - Indonesia's response to the 2018 Palu disaster appears more prolonged, while New Zealand's reaction to the 2016 Kaikōura earthquake was more intense but shorter-lived. The quantitative data from New Zealand highlights its stronger baseline research capacity (10-15 steady publications vs Indonesia's presumably lower pre-2018 output), while Indonesia's sustained post-disaster growth suggests developing research infrastructure. These differences likely reflect variations in national research ecosystems, with New Zealand's established institutions enabling rapid response and Indonesia demonstrating growing but still evolving capabilities. Both patterns underscore how local seismic risks shape national research priorities, with disaster events serving as critical drivers of scientific output in both developing and developed country contexts.

### *3.2 Articles by Author*

Figure 4 highlights the research output of prominent Indonesian authors studying soil liquefaction, measured by their number of published documents. The graph shows a range of contributions, with most authors having between 2 to 18 publications. The most prolific researchers, such as Sito Ismanti (research concentration: Soil liquefaction, Liquefaction potential, Cyclic resistance, and Sand stabilization) and Lindung Zalbuin Mase with research interest to practical, field-based assessments (SPT, Vs) combined with numerical modeling to address liquefaction risks in Indonesian (especially Bengkulu Region) coastal and alluvial soils, appear toward the higher end of the spectrum, likely reflecting their leading roles in Indonesia's geotechnical engineering especially on the topic of soil liquefaction. Other contributors, including Fikri Faris, Teuku Faisal Fathani, and Hary Christadi Hardiyatmo, demonstrate moderate but consistent output, suggesting their active involvement in liquefaction-related studies. The presence of multiple authors with varying publication counts indicates a collaborative research environment, where expertise is distributed across different institutions and specializations. However, the absence of extremely high numbers (e.g., above 20 documents) may reflect limitations in funding, laboratory access, or international collaboration opportunities compared to more research-intensive countries.

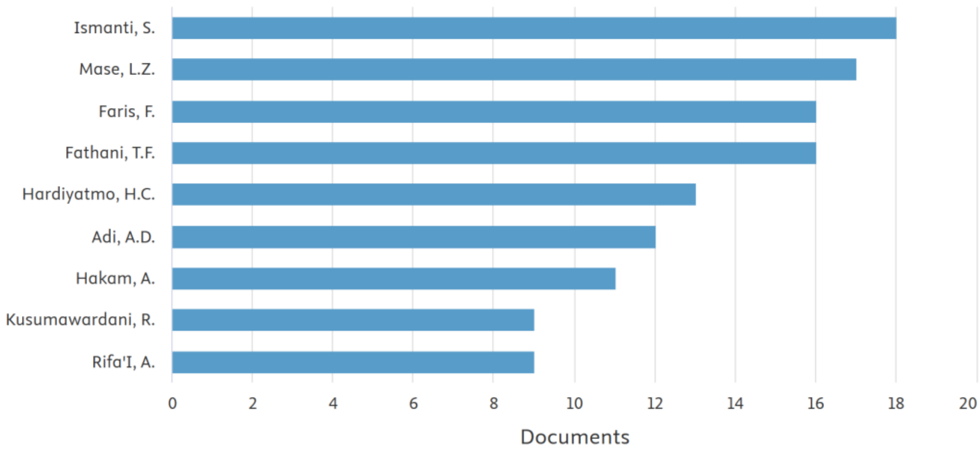


Fig 4. Indonesian author publication number in the topic of soil liquefaction

*Source: Scopus*

Figure 5 illustrates the publication records of key New Zealand-based researchers in soil liquefaction, revealing a significantly higher output compared to their Indonesian counterparts. Leading experts such as Misko Cubrinovski which his areas of expertise and research interest are in geotechnical earthquake engineering, namely issues related to soil-structure interaction, liquefaction, and the seismic response of earth constructions. Also, Rolando P. Orense with his research interest to particularly geotechnical earthquake engineering and ground disaster mitigation engineering. Misko Cubrinovski dominate with up to more than 45 documents, demonstrating his extensive contributions to the field. Other notable researchers, including Bray, J.D., Green, R.A., and Bradley, B.A., also show strong publication records, reinforcing New Zealand's reputation as a global leader in liquefaction research. The graph highlights a well-established research ecosystem, with many authors producing a substantial volume of work—likely due to advanced infrastructure, strong institutional support, and frequent collaboration with international peers. The higher overall output compared to Indonesia may also be attributed to New Zealand's high seismic risk, which drives continuous investment in geotechnical studies.

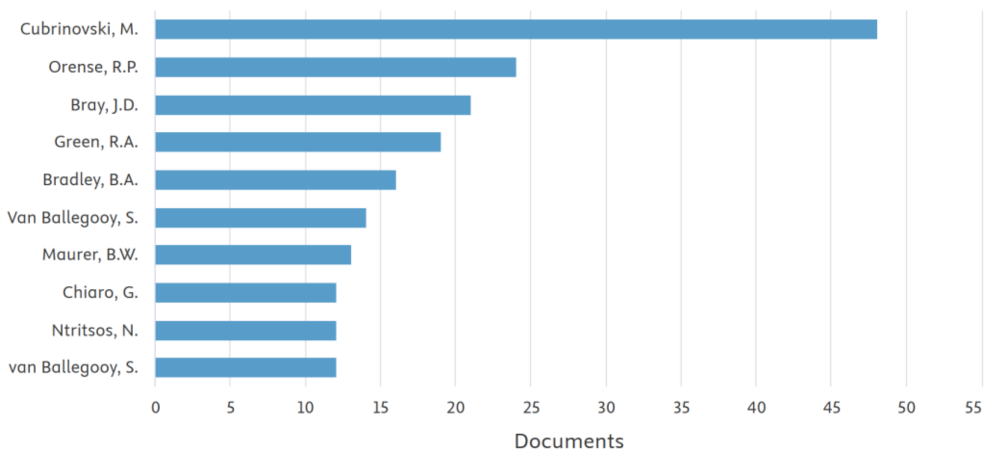


Fig 5. New Zealand author publication number in the topic of soil liquefaction

*Source: Scopus*

New Zealand's researchers exhibit significantly higher productivity, with top contributors publishing up to more than 50 documents, while Indonesia's most prolific authors reach around 18. This difference likely stems from variations in research funding, access to advanced technology, and integration into global academic networks. However, Indonesia's growing number of active researchers suggests a developing capacity in liquefaction studies, potentially fueled by recent seismic disasters that have heightened awareness and investment in geotechnical engineering. Both graphs underscore the importance of sustained research efforts in seismically active regions, with New Zealand serving as a model for long-term expertise development, while Indonesia demonstrates emerging potential in addressing its unique liquefaction challenges.

### *3.3 Articles by Institution*

Figure 6 presents the publication output of Indonesian institutions conducting research on soil liquefaction, revealing a diverse yet uneven distribution of contributions. Leading the group is Universitas Gadjah Mada, which appears to be the most prolific, likely producing between 60-80 documents, reflecting its established role as a hub for geotechnical research in Indonesia. Other notable contributors include Institut Teknologi Bandung and Universitas Indonesia, both recognized for their engineering programs, though with comparatively lower output. Government involvement is evident through the Ministry of Public Works and Housing, suggesting policy-driven research initiatives. Regional universities such as Universitas Tadulako (near the 2018 Palu earthquake epicenter) and Universitas Andalas (in seismic area of West Sumatera) demonstrate localized expertise, though their publication numbers remain modest. The graph highlights a collaborative network of academic and governmental institutions, but the limited output of many universities—particularly those outside Java (e.g., Universitas Bengkulu, Universitas Andalas)—points to disparities in research funding, infrastructure, or access to international collaborations.

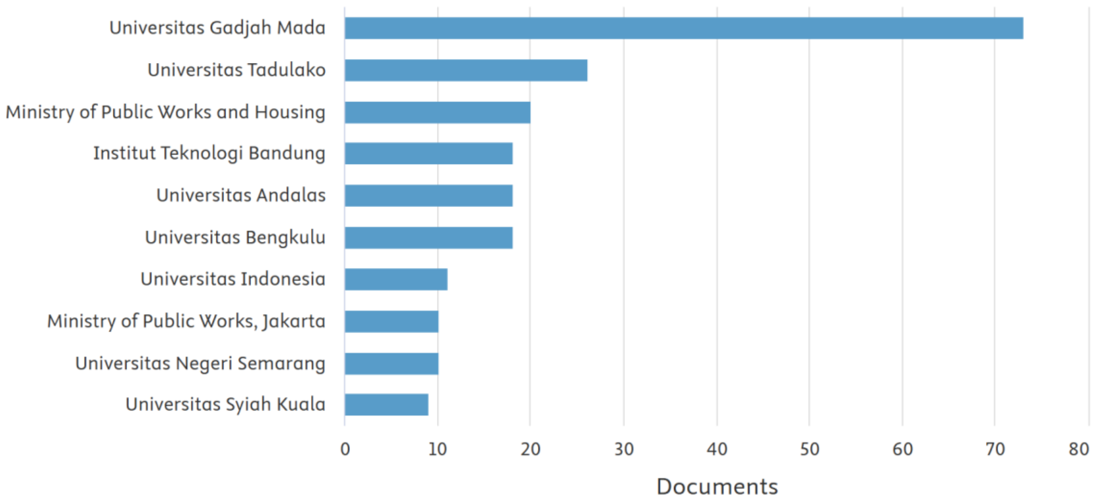


Fig 6. Number of articles in the topic of soil liquefaction from Indonesian institution

*Source: Scopus*

Dominating the chart (Figure 7) is University of Canterbury, a global leader in seismic engineering, with publications likely exceeding 80 documents—a testament to its focus on post-2010 Christchurch earthquake research. The University of Auckland and GNS Science (New Zealand's geological survey) also feature prominently, reflecting strong national coordination. Notably, the graph includes several non-New Zealand institutions (e.g., University of California, Berkeley, University of Texas at Austin), underscoring extensive international collaborations. Private sector participation is visible through Tonkin & Taylor, a geotechnical consultancy, indicating industry-academia partnerships. The high output across institutions—with many exceeding 30 publications—demonstrates systematic investment in liquefaction research, driven by New Zealand's high seismic risk and advanced engineering culture.

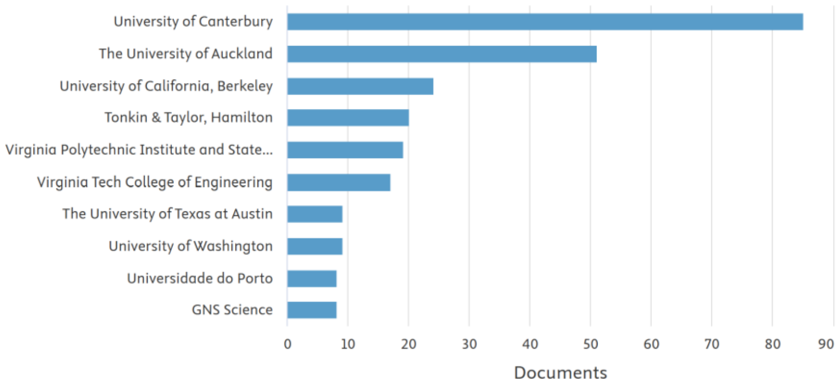


Fig 7. Number of articles in the topic of soil liquefaction from New Zealand institution

*Source: Scopus*

The contrast between the two graphs reveals structural differences in research ecosystems. New Zealand institutions produce significantly more publications, with top performers like the University of Canterbury dwarfing even Indonesia's leading Universitas Gadjah Mada. This gap reflects disparities in funding, technology, and long-term research prioritization. On the other hand, New Zealand's inclusion of U.S. and European institutions highlights its global networks, while Indonesia's graph remains domestically focused, suggesting fewer international ties. New Zealand also integrates academia, government (e.g., GNS Science), and private firms, whereas Indonesia's efforts are concentrated in universities and ministries, with less industry involvement.

### *3.4 Research Map and Keyword Analysis*

The research map from Figure 8 was made by using VOS viewer. The meta data used in this process is the RIS data that obtained from Scopus database with the keyword soil liquefaction and earthquake. The Scopus database was limited to only from Indonesia and New Zealand country and year of publication in range 2015-2025. The research map divided to three major cluster indicated by the red, blue and green color. It also has two minor cluster that indicated by color of purple (between red and blue) and yellow (between red and green).

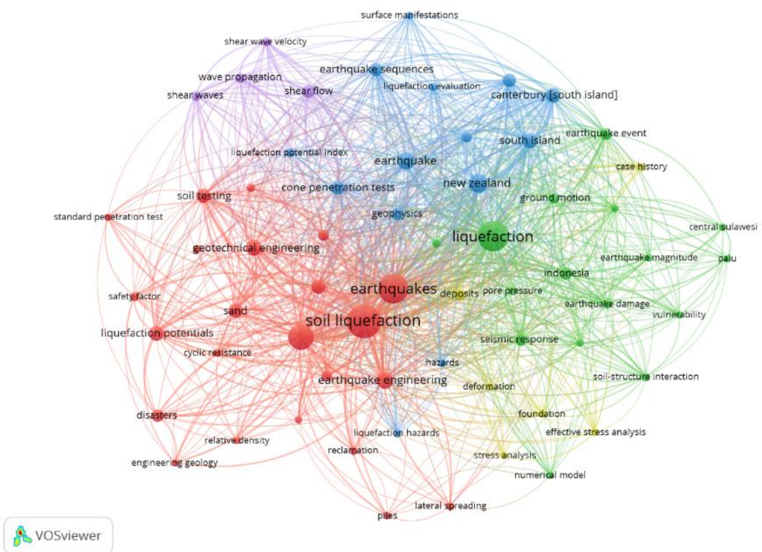


Fig 8. Research map based on keyword co-occurrence network visualization of soil liquefaction between Indonesia and New Zealand

*Source: VOS Viewer*

The red cluster was mostly the general keyword used in the area of soil liquefaction research. General terms like soil liquefaction, earthquakes, disasters and liquefaction potential filled this cluster. Besides, the terms like sand, soil testing, standard penetration test, cyclic resistance, relative density, and safety factor are the main data used that related to liquefaction analysis process. The blue cluster was the most keyword used in the liquefaction research especially in New Zealand. It was indicated by the presence of the name of locations such as New Zealand, South Island, and Canterbury. Soil liquefaction research in New Zealand mostly using cone penetration test and geophysics data to analyze the liquefaction potential. Discussion in the terms of shear wave velocity, wave propagation, and shear flow was also dominant among the soil liquefaction research from New Zealand authors (seen from purple cluster).

The green cluster represented the area of liquefaction research from Indonesian authors that indicated from the keyword of Indonesian region (*Indonesia, Central Sulawesi,* and *Palu*). Indonesian authors mainly discussed around the topic with keywords like *ground motion, numerical model, seismic response,* and *soil-structure interaction*. Also, discussion about effective stress analysis and foundation response due to soil liquefaction was picked by Indonesian authors (yellow cluster).

## 4. Conclusion

This study examines the evolution of liquefaction research in Indonesia and New Zealand over the past decade using Scopus data, revealing significant growth following major seismic events - particularly after New Zealand's Canterbury Earthquake and Indonesia's Palu Earthquake. The analysis highlights distinct research patterns: New Zealand's efforts, led by prolific researcher Misko Cubrinovski (48 publications), demonstrate strong international collaborations, particularly with U.S. institutions, while Indonesian researchers like Siti Ismanti, Lindung Zalbuin Mase, and Teuku Faisal Fathani show more evenly distributed productivity (10-20 publications each) with predominantly local focus. These findings carry important implications for both policymakers and researchers. For policymakers, we recommend prioritizing international research partnerships to facilitate knowledge transfer and secure funding, establishing dedicated post-disaster research funds to capitalize on timely data collection opportunities, and fostering stronger academia-industry-government networks to accelerate practical applications of research findings. Researchers should consider broadening their investigation scope by incorporating related terminology beyond "soil liquefaction" and "earthquake" to ensure comprehensive literature coverage while adopting integrated methodologies combining field observations with advanced numerical modeling. The establishment of shared regional databases could significantly enhance collaborative research efforts. While this study provides valuable insights into current research trends, we acknowledge its limitations due to database constraints and suggest future work could be strengthened through multi-platform analysis and the inclusion of more diverse search parameters to capture the full spectrum of liquefaction-related research better. These recommendations aim to enhance research quality, promote knowledge sharing, and contribute to more effective liquefaction mitigation strategies in seismically active regions.

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