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ASEAN geology bibliometric analysis: A way forward for sustainable development

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Abstract: Geology has facilitated societal growth and development. This study analysed the latest development in geology research within 10 ASEAN countries. The VOSviewer software was utilised to examine the distribution of bibliometric maps. The data was acquired from the Scopus database through a data filtering process using the "geology" terms contained in the title, keyword, and abstract. A total of 2,319 articles published between 2018 and 2022 were chosen to capture the prevailing latest circumstances. The findings showed a notable change in geology study throughout the five-year duration, with the number of articles published decreasing from 407 in 2018 to 265 in 2022. The VOSviewer association strength method further revealed the five terms with the highest frequency occurrences, namely geology (794 occurrences), structural geology (259 occurrences), engineering geology (278 occurrences), geophysics (240 occurrences), and remote sensing (214 occurrences). The terms were further categorised into seven distinct clusters, consisting of geology, structural geology, seismology, economic geology, deposits, engineering geology, and volcanoes. Both Indonesia and Malaysia were the most significant countries associated with the geology terms. The emerging latest terms adopted were gas engineering, environmental technology, tourism, machine learning, and sustainable development. This study serves as a valuable point of reference and a source of contemplation for researchers seeking to explore additional research areas, particularly in the field of geology within the ASEAN territory.

Keywords: Bibliometric, environment technology, gas engineering, geology, sustainable development, tourism, VOSviewer

INTRODUCTION

Geology is regarded as a significant academic discipline. The field of geology science integrates scientific principles and technological advancements to comprehend the processes involved in the formation of the Earth. It is also classified within the natural sciences due to its utilisation of principles and methodologies from various natural science disciplines alongside common subdivides, such as mineralogy, petrology, structural geology, volcanology, geomorphology, palaeontology, stratigraphy, and astrogeology. Geological research is a scholarly pursuit aimed at advancing theoretical and practical knowledge in specific domains, such as mining geology and petroleum geology. Other closely related fields include geophysics and geochemistry. The responsibilities of a geologist cover various tasks, including the formulation and execution of surveys, data analysis, documentation of natural resources, evaluation of environmental consequences, and the production of reports.

The history of geology can be traced back to the beginning of the eighteenth century, with the late nineteenth century witnessing a massive extension of the scope of the geology field (Verma *et al*., 2022), particularly associated with industry revolution in western countries. Geology is a discipline that investigates earth formation, including the structure and composition and processes acting on it, for the well-being of the society (Manduca & Kastens, 2012). Geology rock formation is a science that assists in understanding the planet and its inhabitant's evolution. Fundamentally, the study of geologic history offers a conceptual framework and comprehensive understanding of the Earth's evolutionary processes. One of the initial advancements in the field pertains to stratigraphy, which focuses on examining the arrangement and progression of sedimentary rocks in layers. Besides, geology has proven to be successful in facilitating a significant role in the society's growth development, such as waste management, selection of sites for mega-projects construction, remedial

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measurements for environmental issues, and risks magnitude for hazards events (Sarmiento, 2009; Nikishin *et al*., 2021a; Nikishin *et al*., 2021b; Roy *et al*., 2022; Cobos-Mora *et al*., 2023; Wolters *et al*., 2023; Pedroletti & Ciabuschi, 2023; Thiombane *et al*., 2023; Jamal-ud-din *et al*., 2023).

In September 2015, the Sustainable Development Goals 2030 (SDG 2030) officially replaced the Millennium Development Goals (MDGs). SDG 2030 encompasses a comprehensive collection of 17 goals and 169 targets that aim to address various global challenges and promote sustainable development. The main objectives are to eliminate global poverty, cease unsustainable consumption patterns, and promote continuous and inclusive economic growth, social development, and environmental protection within a 15-year period. The Geological Society of London stressed that geological sciences have a direct contribution to SDG 2030. The 11 areas of geological sciences related to SDG 2023 are divided by two broad categories, namely earth materials, process, and management (eight areas) as well as skills and practice (three areas) (Figure 1). The eight key areas of the first category consist of agroecology, climate change, energy, engineering geology, geohazards, geoheritage and geotourism, hydrogeology and contaminant geology, as well as minerals and rock materials. However, there is a lack of studies that analyse the current trends related to SDG 2030. Such literary gap has prompted the present study to explore and identify the current knowledge in the field of geology within SDG 2030.

Initially, the focus concentrated on earth-related aspects, such as 'earth sciences' in 1852, 'geoscience' in 1929, and 'geological sciences' in 1938 (Verma *et al*., 2022). However, the typography of geology research has experienced rapid evolution growth since its establishment. In this context, bibliometric analysis is a viable approach for assessing the progression of research in the field of geology as it enables the capture of dynamic changes occurring within this domain. Bibliometric analysis is a valuable tool for researchers to examine bibliographic content and conduct citation analysis of articles published in scientific literature. It holds the reputation as an effective and widely-accepted methodology to generate comprehensive datasets that can be leveraged to enhance the quality of scholarly research (Pedroletti & Ciabuschi, 2023; Thiombane *et al*., 2023; Jamal-ud-din *et al*., 2023; Akhtar *et al*., 2023; Mushtaq *et al*., 2023). Bibliographies appropriate for bibliometric analysis incorporate various factors, such as publication type, research topic area, researcher's country of origin, journal of publication, and language employed within the article (Pedroletti & Ciabuschi, 2023; Thiombane *et al*., 2023; Jamal-ud-din *et al*., 2023; Akhtar *et al*., 2023).

Previous bibliometric analysis of geology research had focused on research articles published within the period of more than five years (Camargo *et al*., 2019; Irawan *et al*., 2021; Lima *et al*., 2023; Martinez-Garcia *et al*., 2023). However, the Movement Control Order (MCO) as a result of COVID-19 had altered the topography of geology

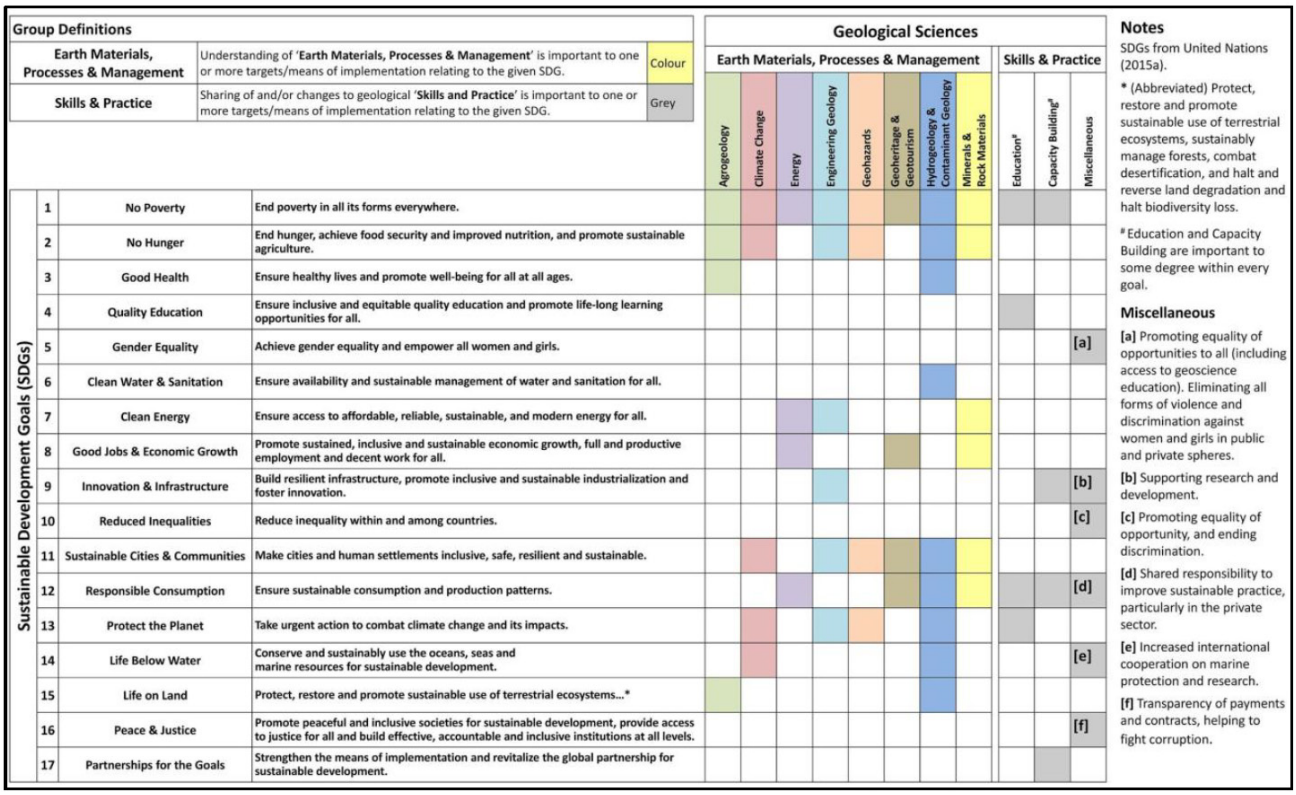


Figure 1: Matrix illustrating the contribution of geological sciences in facilitating SDG 2030 (Gill, 2017).

study (Alias *et al*., 2022; Giotopoulos *et al*., 2023). The traditional research geology application approach has shifted to digital teaching and learning approach (Senger *et al*., 2021; Alias *et al*., 2022; Verma *et al*., 2022; Engel *et al*., 2023; Giotopoulos *et al*., 2023). The changes in teaching landscape have also shifted to hybrid techniques, such as the use of mobile phone applications in mineralogical courses (Giotopoulos *et al*., 2023) and virtual microscope in petrology courses (Engel *et al*., 2023). However, there is a lack of scholarly investigation on the application of bibliometric analysis in the geology domain research, particularly concentrating on journal articles indexed by the Scopus Scholar database. Thus, the objective of this study is to analyse the latest development in geology research using bibliometric analysis. Numerous fields have employed bibliometric analysis, including in the context of green supply chain management, agriculture, healthcare, political science, smart homes, tourist, omnichannel marketing, and Islamic marketing (Carammia, 2022; De-la-Fuente-Robles *et al*., 2022; Fahim & Mahadi, 2022; Florido-Benitez, 2022; Hassan *et al*., 2022; Hong *et al*., 2022; Lopes *et al*., 2022; Misara *et al*., 2022).

VOSViewer is a software application designed for the purpose of generating, constructing, and visualising bibliometric maps (Eck & Waltman, 2010; Thiombane *et al*., 2023). The software is capable of conducting diverse forms of bibliometric analysis by providing support for multiple prominent bibliographic databases and is primarily designed for performing text-processing tasks. VOSViewer provides a range of features, including a text-mining function that enables the construction and visualisation of co-relationships in article citations. The utilisation of mapping system, searching, and scrolling functionalities enables the presentation of publication maps (Pan *et al*., 2018; Donthu *et al*., 2021). Furthermore, VOSviewer can be employed for mapping purposes by utilising model and cluster layout techniques to determine the quantity and current status of a certain term. Hence, the specific objective of this study is to analyse the bibliometric geology research articles indexed by Scopus Scholar through the utilisation of mapping analysis. This study addresses the research gap associated with the limited amount of research conducted on bibliometric analysis by utilising large datasets. Consequently, it enables the authors to establish a correlation between geology research and various other associated academic disciplines, particularly in the global SDG 2023 initiative. It is also possible to assess the recent advancements in the geology field due to previous studies of bibliometrics analysis of more than five years. Thus, this study is expected to serve as a scholarly resource that assists researchers in the selection and identification of geology research topics or themes for future studies. This study introduces several novel aspects. First, a bibliometric analysis was conducted on geology research articles published in journals available on the Scopus Scholar database. Secondly, the mapping visualisation method was employed for the bibliometric analysis. Finally, the VOSviewer application was employed as a tool for conducting the mapping analysis. Additionally, bibliometric maps enable the analysis, depiction, and interpretation of associations within the field domain terms (Orduña-Malea & Costas, 2021).

METHODOLOGY

This bibliometric analysis study adopted the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) technique, which involves the identification, screening, eligibility, and included stages (Moher *et al*., 2009). The data utilised in this study was obtained from the Scopus Scholar database. The justification is that Scopus is the priority and target of many researchers opting for quality publications besides gaining worldwide recognition. This is because Scopus is an Elsevier database and an international-class citation, which is considered to be the most widely indexed abstract and citation database for research. All journals included in the Scopus database are audited for high quality annually according to four types of quality measurements, namely h-index, CiteScore, SJR (SCImago Journal Rank), and SNIP (Source Normalised Impact per Paper). The data was acquired through a comprehensive literature review pertaining to the selected theme by using a reference management application known as RefWorks. Various types of documents were acquired to conduct further analyses. All articles indexed by Scopus Scholar and fulfilled the criteria for article type and relevance to the research themes of this study were stored in a file for utilisation in VOSviewer.

In this study, the scholars selectively chose articles exclusively focusing on geology. The data retrieval process involved the researchers employing the title, keyword, and abstract criteria to search for information pertaining to the field of geology. A total of 2,319 articles were acquired and subsequently evaluated based on the selected thematic criteria (Figure 2). The articles utilised in this research consisted of publications spanning the period from 2018 to 2022 and from 10 countries within the Association of Southeast Asian Nations (ASEAN) region. A duration of five years is sufficient to encompass contemporary patterns in research yet allowing for the inclusion of academic disciplines that progress at a slower pace. It also reflects the COVID-19 pandemic research related to the geology field. This timeframe also reveals the impact of pandemic events and related policy changes on research output as how the pandemic has influenced research directions and volume quantity.

The final query for the dataset was TITLE-ABS-KEY (geology) AND PUBYEAR > 2017 AND PUBYEAR < 2023 AND (LIMIT-TO (AFFILCOUNTRY , "Brunei Darussalam") OR LIMIT-TO (AFFILCOUNTRY , "Cambodia") OR LIMIT-TO (AFFILCOUNTRY , "Indonesia") OR LIMIT-TO (AFFILCOUNTRY , "Laos") OR LIMIT-

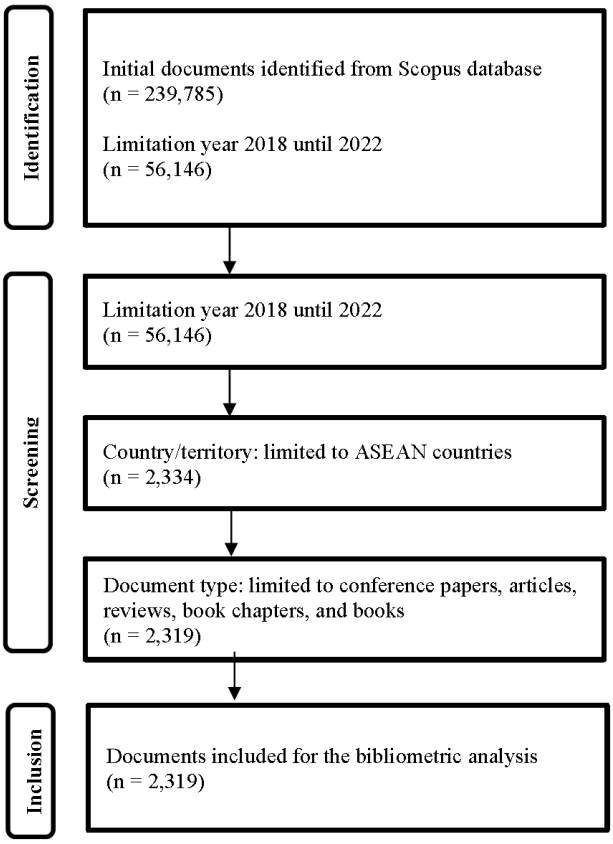


Figure 2: Flowchart of the methodology adopted in this study.

TO (AFFILCOUNTRY , "Malaysia") OR LIMIT-TO (AFFILCOUNTRY , "Myanmar") OR LIMIT-TO (AFFILCOUNTRY , "Philippines") OR LIMIT-TO (AFFILCOUNTRY , "Singapore") OR LIMIT-TO (AFFILCOUNTRY , "Thailand") OR LIMIT-TO (AFFILCOUNTRY , "Viet Nam")) AND (LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re") OR LIMIT-TO (DOCTYPE , "ch") OR LIMIT-TO (DOCTYPE , "bk")).

All retrieved articles were stored in the *.csv file format. The researchers then employed the VOSviewer software to visually represent and examine patterns in the form of bibliometric maps. The data mapping process began by extracting articles from database sources that had been appropriately curated. Data mapping encompasses three distinct types: network mapping, density mapping, and visualisation overlay. VOSviewer is a software application designed to create and display bibliometric networks. These networks may involve article journals, researchers, or personal articles, which are often constructed based on citations, bibliographic data, or co-authorship. VOSviewer is highly suitable for analysing huge amount of scientific literature research and for visually representing patterns and trends of the data (Eck & Waltman, 2010; Tomaszewski, 2023). This analysis is primarily done through the utilisation of co-citation and keyword-based approaches, whereby they are subsequently visualised on a network that illustrates the relationships between various terms. VOSviewer employs a multi-step process to visualise bibliometric networks, which usually includes data collection, data import input and preparation, network creation development, and visualisation (Donthu *et al*., 2021). During the creation of the bibliometric map study, the keyword frequency determines a minimum frequency of 10 occurrences from the prepared database, with 588 keyword items obtained after the keyword harmonisation process. Furthermore, the researchers employed a filtering process to determine the terms that would be incorporated into the VOSviewer network mapping visualisation.

RESULTS

From the findings of 2,319 digital geology documents indexed by Scopus journals, the development of research related to geology has had a volatility trend in the last five years (Figure 3). Most of the research was done during the COVID-19 pandemic period. Among the studies period, most documents were published in the year 2019 (585 documents), followed by 2021 (554 documents), 2020 (508 documents), 2018 (407 documents), and 2022 (265 documents). The most significant decrease occurred between 2021 (554 documents) to 2022 (265 documents), showing a decrease of more than half. This could be attributed to the mobility restrictions imposed during the Movement Control Order (MCO), which limited the collection of geological data. Moreover, the redirection shift of authorities funding during the pandemic prioritised more on medical and public health research in order to address the urgent issue. This shift has also had an impact on non-medical and health-related fields. The top five affiliated institutions with the highest number of documents published were from Indonesia and Malaysia, namely Institute Teknologi Bandung (151 articles), Universiti Malaysia Pahang (107 articles), Nanyang Technological University (98 articles), Universitas Gadjah Mada (98 articles), and Universiti Teknologi Malaysia (91 articles) (Figure 4). The top five documents by subject areas were related to earth and planetary, environmental science, engineering, energy, as well as physics and astronomy

Table 1: Top five types of documents by sources of geology research.

No.	Documents	Total Articles
1	IOP Conference Series: Earth and Environmental Science	526
2	Journal of Physics Conference Series	135
3	E3S Web of Conferences	110
4	International Geoscience and Remote Sensing Symposium IGARSS	53
5	Lecture Notes in Civil Engineering	33

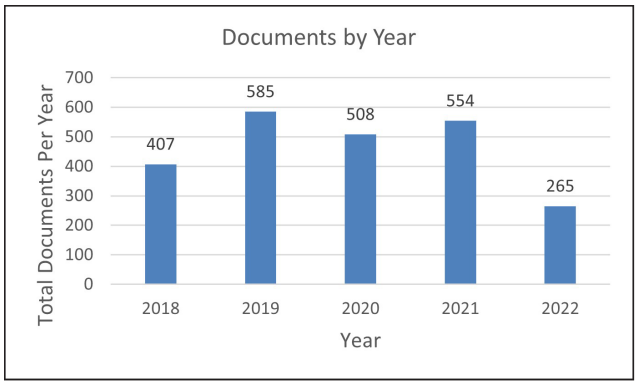


Figure 3: Total documents development in geology research by year.

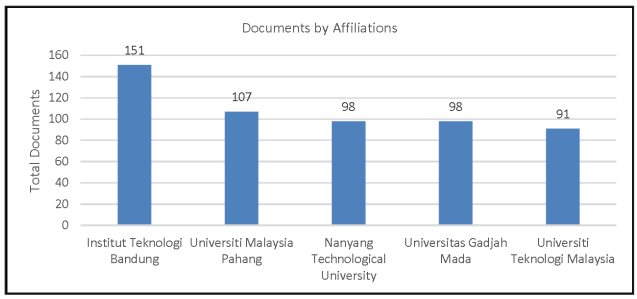


Figure 4: Total documents development in geology research by top five affiliations.

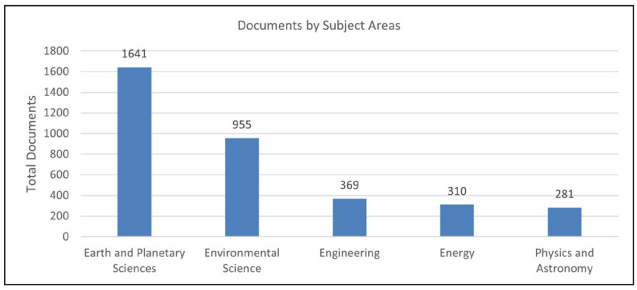


Figure 5: Total documents development in geology research by top five subject areas.

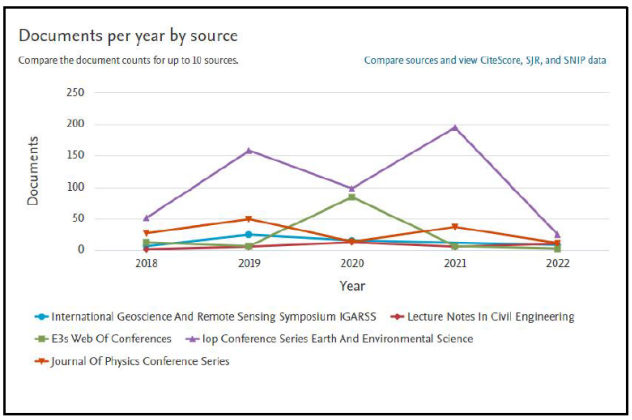


Figure 6: Total documents per year by source in geology research by year. Source: Scopus.

(Figure 5). Table 1 shows the top five total documents by sources within the year 2018 and 2022 in the field of geology. The top five document sources amount to 857 articles, which is equivalent to 55.3 percent of the total articles. Figure 6 depicts that the documents' sources development of research related to geology has decreased in the last five years, particularly the IOP Conference Series: Earth and Environmental Science in the year 2022.

Visualisation of geology discipline using VOSviewer

By setting the minimum 10 occurrences keywords in the articles, there were a total of 588 items pertaining to the field of geology. The top five keywords by occurrences consisted of geology with 794 occurrences (4,661 total link strength), engineering geology with 278 occurrences (1,573 total link strength), structural geology with 259 occurrences (1,943 total link strength), geophysics with 240 occurrences (1,495 total link strength), and earthquake engineering with 231 occurrences (1,318 total link strength). The dataset of 588 items was further categorised into seven distinct clusters, namely: (i) cluster 1, encompassing 154 items marked in red; (ii) cluster 2, consisting of 102 items in green; (iii) cluster 3, comprising 86 items in blue; (iv) cluster 4, containing 71 items represented by yellow; (v) cluster 5, consisting of 63 items in purple, (vi) cluster 6, encompassing 56 items in cyan, and (vii) cluster 7, comprising 56 items marked in orange (Table 2). Each cluster visually represents the relationship between a specific term and another term (Table 3). Every term is assigned a coloured circle for labelling purposes. A positive association was found between the size of the circle and the frequency of terms that appear in the title and abstract. The frequency of occurrence determines the size of letters and circles while the frequency of the term's occurrence directly correlates with the magnification of the letters and circles. VOSviewer has the capability to present bibliometric maps using three distinct visual representations, namely network visualisation, overlay visualisation, and density visualisation.

Bibliometric analysis by countries

The country-wise analysis revealed four countries that have a direct association with geology – Indonesia, Malaysia, Viet Nam, and Thailand. For Indonesia, the terms are wider in range within the geology discipline, which include structural geology, earthquakes, engineering geology, sustainable development, remote sensing, submarine geology, economic geology, mineralogy, and deposits (Figure 7a). For Malaysia, the terms of geology focus on the oil and gas industry. The related terms involve geographic location (e.g., West Malaysia, East Malaysia, and Sarawak) and offshore oil well production (Figure 7b). This is rational as the country's geographic location with the oil production is mainly offshore-based. For Viet Nam, the related terms focus on the application of technology, such

Table 2: Cluster terms group of geology.

Cluster	Terms	Colour	Links	Total links strength	Occurrences
1	Geology	Red	548	4,661	794
2	Structural geology	Green	421	1,943	259
3	Seismology	Blue	282	1,080	139
4	Economic geology	Yellow	330	1,317	161
5	Deposits	Purple	306	1,123	91
6	Engineering geology	Cyan	275	1,573	278
7	Volcanoes	Orange	317	906	95

Table 3: Cluster group associated terms.

Cluster	Terms	Within cluster associated terms	Non-within cluster associated terms
1	Geology	Remote sensing, sustainable development, groundwater, landslides, land use, etc.	Geophysics, soils, earthquakes, seismology, Indonesia, sea levels, etc.
2	Structural geology	Earthquakes, fault slip, wave propagation, receiver function, Indonesia, etc.	Geothermal fields, deposits, seismology, geophysics, remote sensing, etc.
3	Seismology	Gasoline, petroleum geology, carbon dioxide, stratigraphy, well logging, etc.	Wave propagation, anisotropy, structural geology, faulting, engineering geology, etc.
4	Economic geology	Sediments, gold mine, mercury, tailings, rivers, etc.	Sustainable development, soils, deposits, sediment, rocks, etc.
5	Deposits	Mineralogy, sulfur compounds, clay alteration, copper, gold, etc.	Economic geology, submarine geology, sediments, Indonesia, stratigraphy, etc.
6	Engineering geology	Earthquake engineering, geophysics, reinforced concrete, soils, etc.	Sustainable development, risk assessment, weathering, faulting, survey, etc.
7	Volcanoes	Geothermal systems, faulting, geothermal fields, flow of fluids, 3D modelling, etc.	Remote sensing, landslides, structural geology, deposits, geothermal system, etc.

as geographic information system and machine learning (Figure 7c). Thailand showed less association, whereby the terms were only related directly to geology itself (Figure 7d). Besides, the three countries were mentioned in articles without any link terms but categorised in different clusters: (i) Philippines in deposits cluster (Figure 7e), (ii) Singapore in economic geology cluster (Figure 7f), and (iii) Myanmar in structural geology cluster (Figure 7g).

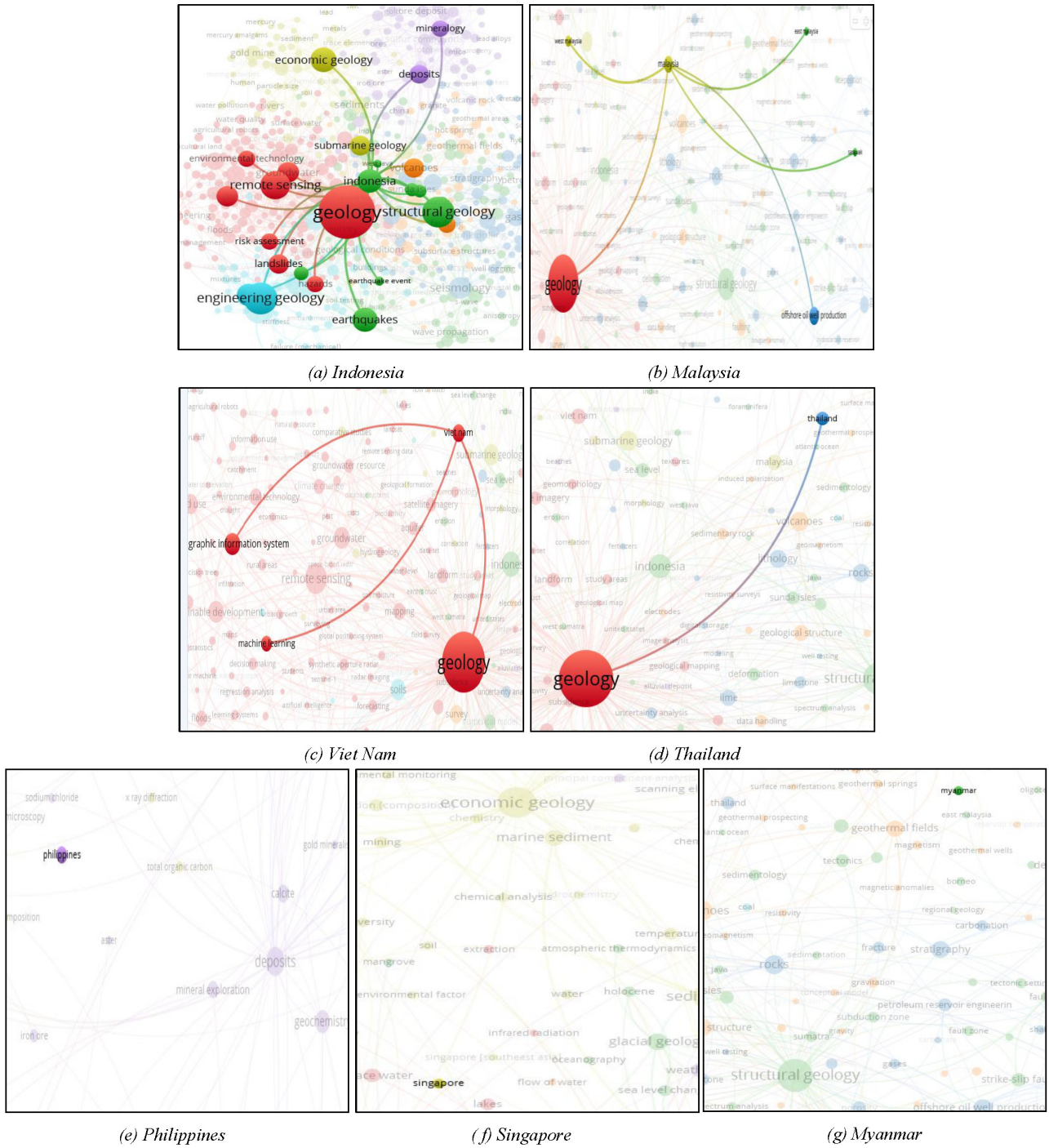
Density visualisation diagram

The density visualisation diagram demonstrates the intensity of the yellow colour while the size of the circle represents the term that is positively correlated with the frequency of that term's occurrence. This indicates that the quantity of terms studied on connected concepts is increasing. On the contrary, when the colour of the term gradually diminishes toward the background colour, there will be a reduction in the quantity of research conducted on that particular term. The findings showed that the terms of geology, engineering geology, and structural geology have a high number of studies (Figure 8).

In order to accomplish the research objective, bibliometric software was employed to examine the references of scientific articles within journals, map the scientific domain of a journal, and categorise scientific papers based on their respective research fields. Bibliometrics facilitates the analysis and categorisation of research data based on necessities. This study used bibliometric analysis to categorise research material included in the Scopus database based on predetermined keywords, concentrating on the discipline of geology. The researchers employed the VOSviewer software tool to facilitate the bibliometric analysis and extract the results of the data mapping procedure.

Overlay visualisation in ASEAN geology studies

Figure 9 demonstrates the overlay visualisation in geology studies, which provides a depiction of the progression of each phrase. In a dataset, the terms that align with the relevant category and pertain to the field of geology are limited to the time period spanning from June 2019 to April 2020. The colour of each term corresponds



(a) Indonesia *(b) Malaysia*

(c) Viet Nam *(d) Thailand*

(e) Philippines *(f) Singapore* *(g) Myanmar*

Figure 7: Analysis of geology terms by ASEAN countries.

to the degree of originality associated with the term. The intensity of the colour yellow is directly proportional to the degree of renewal. The findings denote that the latest research trend is related to geology-remote sensing clusters, such as gas engineering, environmental technology, tourism, machine learning, and sustainable development. This can serve as a valuable resource for future scholars seeking to explore subjects pertaining to the discipline of geology.

Overlay visualisation in ASEAN geology studies on Industry Revolution

In the view of technology advancement, ASEAN countries, particularly Viet Nam, demonstrated high Fourth Industry Revolution (IR4.0) adoption. The most prominent IR4.0 term adopted is machine learning (Figure 10a). During early 2020, machine learning was associated with geology application terms, such as land use and groundwater. Circa

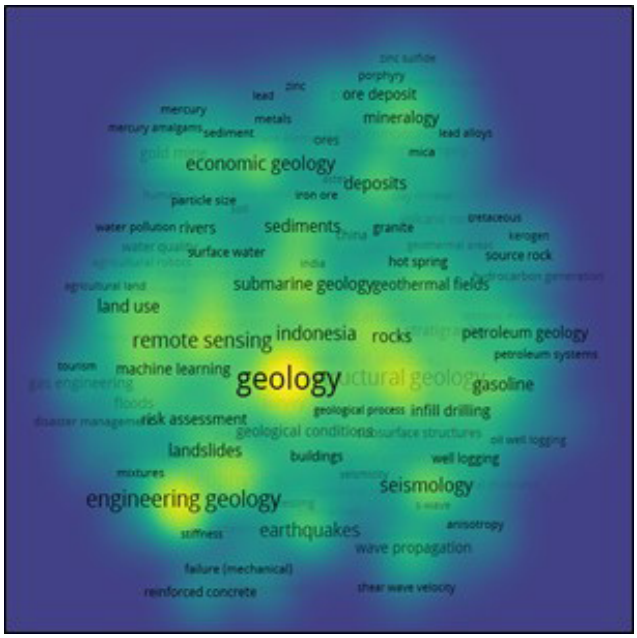


Figure 8: Density visualisation in geology research.

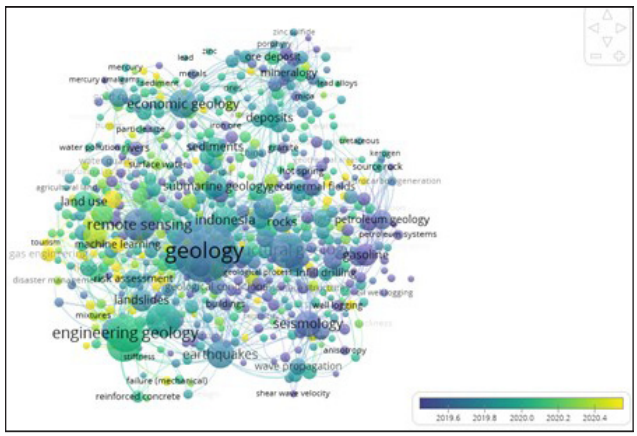


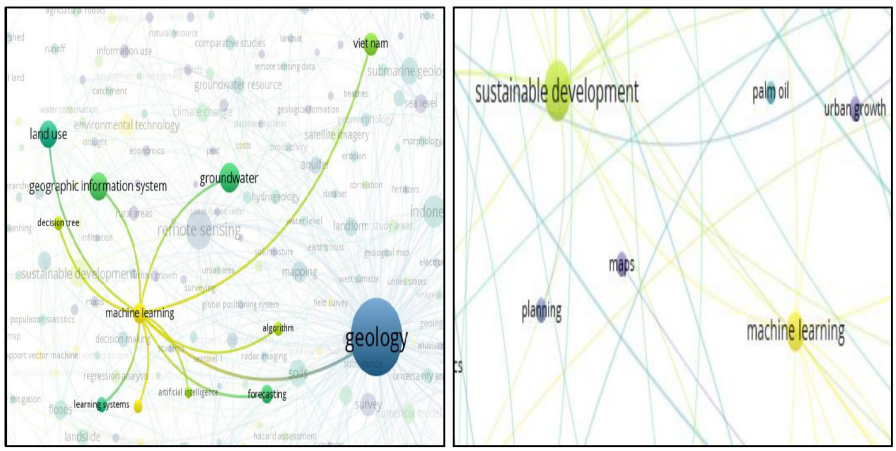
Figure 9: Overlay visualisation in geology research.

the middle of 2020, the machine learning term was associated with the technology application context, such as algorithm, artificial intelligence, and decision tree. The machine learning term was found to be closely related with the sustainable development term, however it is not interconnected (Figure 10b). Hence, it would be an interesting research interest for the future studies of interconnection between machine learning and sustainable development within the geology field. This data-driven integration approach holds the key to addressing complex environmental and social challenges in a rapidly changing world and enables informed decision-making through the availability of better geological information and sustainable decision-making to balance developmental needs with environmental preservation initiatives. Some of the suggestions on future studies pertaining to geology include resource exploration, environmental impact assessment, natural disaster prediction and mitigation, climate change, groundwater management, as well as mineral recycling and circular economy.

Overlay visualisation in ASEAN geology studies on sustainable development

ASEAN countries demonstrated relatively little research in the global SDG 2023 initiative (Figure 11). From the findings, the three latest sustainable development-associated terms of studies were tourism, environmental technology, and gas engineering. These associated terms would be an interesting focus for future study. Additionally, this integration will enable researchers to fill the gap and promote SDG 2023 overall.

The first recommendation is the integration between tourism and environmental technology, which is essential for responsible practices within the tourism industry. This integration involves the development of innovative environmental technology applications to mitigate the ecological impact of tourism activities and promote conservation efforts, thus ensuring long-term sustainable



(a) Machine learning *(b) Sustainable development*

Figure 10: Overlay visualisation in machine learning and environmental technology keywords.

tourism destinations. Some of the research that enables sustainable development for future studies include embracing eco-friendly accommodations, adopting renewable energy sources, implementing efficient waste management systems, and utilising advanced monitoring tools. The findings of these studies enable the tourism sector to minimise its environmental footprint while offering enriched experiences to travellers. Besides preserving natural cultural resources, the combination synergy between tourism and environmental technology also enhances the overall quality of tourism, making it both environmentally conscious and economically beneficial.

The second suggestion is the integration between tourism and gas engineering. Gas engineering is related to the extraction, production, and distribution of natural gas, which plays a significant role in supporting sustainable tourism. By providing cleaner energy solutions, such as natural gas-powered transportation and eco-friendly infrastructure, gas engineering contributes toward reducing the carbon footprint associated with tourism activities. Some of the research that supports sustainable development for future studies include clean energy solutions for tourism, environmental ecosystem conservation, energy-efficient infrastructure development, and resilient energy crisis management system.

The third recommendation is the integration between gas engineering and environmental technology, thereby exploring the intersection between energy production and environmental conservation. By integrating these concepts, a holistic approach to energy production emerges that prioritises environmental conservation, reduces greenhouse gas emissions, and promotes the development of sustainable energy solutions. Collaboration between these fields is essential for transitioning toward a more environmentally responsible energy landscape. Some of the research that helps to achieve sustainable development for future studies include clean energy production, carbon capture and storage,

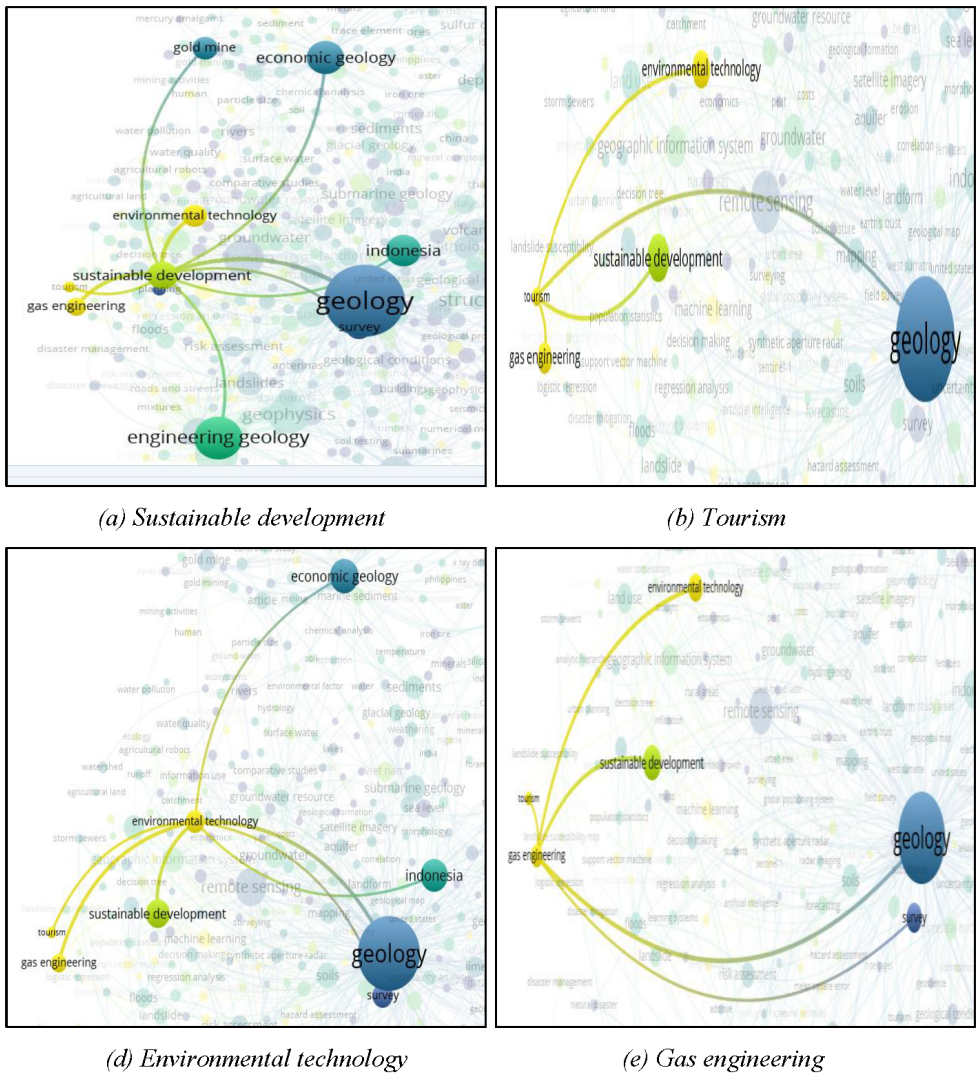


Figure 11: Overlay visualisation in sustainable development and related terms.

renewable gas production, waste-to-energy conversion, as well as smart grids and energy efficiency

CONCLUSION

The objective of this study was to conduct a bibliometric analysis on the bibliographic data of geological research articles in the Scopus journal. The analysis utilised the VOSviewer software to examine the distribution of bibliometric maps. The bibliographic data obtained was the result of filtering based on the keyword geology and concerned the topic areas, titles, keywords, and abstracts. This study obtained 2,319 relevant documents published between 2018 to 2022 within the ASEAN region. The findings indicate that research in the field of geology has exhibited a pattern of variability throughout the preceding five-year period, but shows a decreasing trend between the period. The VOSviewer association strength method was used to determine the five terms with the highest occurrence frequency, namely geology, engineering geology, structural geology, geophysics, and earthquake engineering. Furthermore, the geology terms show a high association between Indonesia and Malaysia. The findings from VosViewer mapping analysis illustrated the latest terms adopted related to geology clusters consisting of gas engineering, environmental technology, tourism, machine learning, and sustainable development.

This study provides an insight pathway to future research. With the emerging gas engineering, tourism, and environment technology term, more integration is recommended in future studies, such as innovative technologies to mitigate ecological impact, cleaner energy solution, as well as energy production. There is also a need for more integration between machine learning and sustainable development to support the SDG 2030 initiative, particularly to support economical and environmental development. Some of the integration suggestions include resource exploration, environment impact assessment, natural disaster production, climate change, groundwater management, and mineral recycling.

This research offers significant theoretical, practical, and policy contributions. Theory-wise, it enables researchers to identify knowledge gaps and map prominent evolution in the field of geology. A study using bibliometrics assists in identifying areas within the geology discipline that have not been extensively investigated, indicating potential opportunities for further theoretical growth. Besides, analysing the emergence and decline of topics throughout time can provide insights into the development of scientific knowledge, therefore contributing to hypotheses about its progression, such as gas engineering, tourism and environment technology terms. This study guides future research, aiming to identify innovative studies and practical uses and assist in the efficient distribution of resources funding based on developing trends and significant research fields. Policy-wise, the findings may assist administrators in designing curricula that incorporate current and influential research while helping scientific policymakers in allocating funds to areas of significant research importance. This data-centric strategy guides the process of strategic development and allocation of resources in academia and beyond.

Finally, this study serves as a valuable point of reference and a source of deep reflection for researchers seeking to explore future research areas, particularly in the field of geology within the ASEAN territory. Nevertheless, the scope of this bibliometric analysis is restricted to scholarly articles exclusively published in academic publications and documented within the Scopus database. In order to enhance the scope of future academic investigations, it is advisable to conduct a comprehensive assessment of research data pertaining to geology without limiting the attention solely to the Scopus database, such as using the Web of Science, Dimensions, and Lens databases. Other bibliometric analysis tools like Biblioshiny, CiteSpace, and HistCite can also be adopted to provide better contemporary assessment in the field of geology.

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AUTHORS CONTRIBUTION

KTW: Manuscript draft, paper conceptualisation, literature review, analysis, and interpretation; BM: paper conceptualisation, discussion, and interpretation; KUMARA: analysis, editing, and review; CKF: administration, coordination, and review; OMW: editing and review; PKT: editing and review.

DECLARATION OF COMPETING INTEREST

The authors declare that there is no conflict of interest in relation to this article.

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