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Bibliometric approach for innovations analysis on Disaster Risk Reduction

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ABSTRAK

Pendahuluan. Penelitian ini menerapkan teknik bibliometrik untuk analisis inovasi dalam bidang Pengurangan Risiko Bencana (PRB) di Indonesia. Penelitian ini berkontribusi dalam menunjukkan manfaat metode bibliometrik, terutama analisis *co-occurence* untuk analisis inovasi. Selain itu, penelitian ini akan menjabarkan kelebihan dan kekurangan metode bibliometrik.
Metode penelitian. Artikel jurnal bidang pengurangan risiko bencana yang diterbitkan antara 2008-2020 ditelusur pada database Scopus menggunakan kata kunci "*Disaster Risk Reduction*" dan Indonesia.
Data analisis. Analisis *co-occurrence* kata kunci dan penulis digunakan untuk menunjukkan inovasi yang berkembang serta penulis yang terlibat dalam pengembangan inovasi pengurangan risiko bencana di Indonesia.
Hasil dan Pembahasan. Jumlah publikasi bidang PRB mengalami peningkatan dari tahun ke tahun, terutama antara tahun 2017 hingga 2020. Lima puluh inovasi PRB dapat diidentifikasi, di mana beberapa produk inovatif tampak menjadi tren, contohnya *remote sensing, evacuation modelling*, dan GIS. Beberapa peneliti paling produktif juga teridentifikasi dalam tulisan ini.
Kesimpulan. Metode bibliometrik dapat digunakan dalam menganalisis inovasi yang berkembang pada suatu bidang. Meskipun membutuhkan dataset yang lengkap dan dukungan sistem komputasi, metode ini dapat digunakan untuk menganalisis data besar, mengidentifikasi jenis inovasi dan periode munculnya inovasi, dan memprediksi inovasi di masa depan.

Kata kunci: bibliometrik; pengurangan risiko bencana; visualisasi; pemetaan

ABSTRACT

Introduction. *This study demonstrates a bibliometric method for innovation analysis of Disaster Risk Reduction (DRR) in Indonesia. The paper explores the ability of the bibliometric method, particularly co-occurrence analysis in mapping research innovation. In addition, the paper explains advantages and disadvantages of the bibliometric method.*
Data Collection Method. *DRR journal articles published between 2008-2020 were retrieved from the Scopus database using the keyword of "Disaster Risk Reduction" and "Indonesia".*
Data Analysis. *Co-occurrence analysis, using keywords and authors, was conducted to show the emerging innovation and authors involved in DRR innovations development in Indonesia.*
Results and Discussion. *The results reveal that the number of DRR publications has increased over time, particularly between 2017 and 2020. Fifty innovations were identified with several innovative products became a trend, such as remote sensing, evacuation modelling, and GIS. The most prolific authors were identified with 3-5 articles produced.*

Conclusion. *Bibliometrics is a powerful method for analyzing emerging innovations in DRR field. Although it requires a complete dataset and computational system support, this method enables analyzing big data, identifying the types of innovations and the emerging period, and predicting future innovations.*

Keywords: *bibliometric; disaster risk reduction; visualization; mapping*

A. INTRODUCTION

Disasters are a topic of concern, considering the magnitude of the losses incurred. CRED (2021) recorded 389 natural disasters around the world in 2020, occurring with the Covid-19 pandemic. The disaster claimed 15,080 deaths, 98.4 million people affected, and economic losses of at least US$ 171.3 billion. The natural disasters during 2020 recorded a higher number of events and caused economic losses are higher than the annual average. Furthermore, there were 26% more storms, 23% more floods and 18% more flood deaths than the annual average. Asia is the region with the highest impact, accounted for 41% of disaster events and 64% of the total affected people. In Asia, there are eight countries with the highest number of natural disasters. Among these eight countries, Indonesia has the highest incidence with 29 total events. Worldwide, the most common types of natural disaster are floods. In 2020 there were 201 flood disasters, of which 25 occurred in Indonesia. Flood disasters cause the second most deaths after extreme temperatures. The number of people affected and the amount of economic loss are also in the second position compared to the hurricane.

Meanwhile, based on the records of the National Disaster Management Agency of the Indonesian government, there were 2,925 natural disasters in Indonesia during 2020. The highest type of disaster was hydrometeorology, such as floods, landslides, and hurricanes. Other types were droughts as well as forest and land fires. Furthermore, the disaster in 2020 claimed 370 people died, 39 were missing, and 536 were injured. Meanwhile, the area of forest and land fires in 2020 will reach 300 thousand hectares. This figure decreased to 81 per cent compared to 2019 (Arifin, 2020).

The high losses in various aspects due to disasters have led to the development of innovation in this field. According to Anand et al. (2021), most of innovation within and from developing countries are shaped by the challenge to keep pace with developed countries in a sustainable manner, especially in terms of the economy. Moreover, Lee et al. (2018) emphasized the importance of policy encouragement for converging between science and technology and its implications for increasing the innovations. Meanwhile, the Sendai Framework for Disaster Risk Reduction (DRR), launched in 2015, is recognized as being able to encourage countries to develop policies to boost technology innovation and development (Mizutori, 2020; Zuccaro et al., 2020; Calkins, 2015). However, it is necessary to understand which DRR innovation is more optimal for a country. Based on The United Nations Office for Disaster Risk Reduction (UNDRR), DRR is defined as strategies, goals, objectives, activities and policies related to the disaster risk management, which are outlined in the form of real targets, indicators and time frames. Izumi et al. (2019) Conveyed that innovation, including approaches and frameworks, can provide change and influence people's thinking and behavior. There is a method called bibliometrics from the library and information sciences to measure the science and technology development using the publications. This method has been widely applied in various fields, including to identify the development of innovation.

Bibliometrics is a method of choice for studying trends, topics, issues, innovations and frameworks dealing with DRR. Milán-García et al. (2021) reported that the term DRR became one of the new trends in the last five years while discussing climate change and human migration. Moreover, Poratelli et al. (2020) concluded that nature-based solutions and technical measures are equally effective for disaster risk reduction. Busayo et al. (2020)

demonstrated that the implementation of the Sendai Framework for Disaster Risk Reduction (SFDRR) (2015–2030) at the local level is still low, so public policymakers and stakeholders working at the local government level require to develop new strategies for implementing SFDRR and other international frameworks. SFDRR was a reference for understanding the complexity of disaster risk in the current situation and developing global Disaster Risk Reduction (DRR) policies. Additionally, Wang et al. (2021) showed that the focus of DRR research, among others on various frameworks development and research in key regions and countries. Meanwhile, Rana (2020) studied epistemology and integrating research on climate change and disaster resilience. The author argued that the philosophy of disaster risk reduction and climate change adaptation is considered more appropriate to understand resilience.

The use of the bibliometric approach for study innovation in any subject seems to be increasingly popular. Meanwhile, in the field of DRR is emerging. Among others, Orimoloye et al. (2021) examined the focus of innovations in the field of DRR. They conveyed that social aspects such as disaster management and science and ecosystem services are the focus. Meanwhile, areas such as disaster risk insurance and social networking systems must be improved at the implementation stage. In technological innovations such as geographic information systems, remote sensing, drones, and disaster-resistant materials are very useful but difficult to implement. Tang et al. (2021) found potential ways to develop and innovate in social media-based disaster research. However, researches that identify the benefits of the bibliometric method in measuring innovation development are still missing. Furthermore, what are the advantages and disadvantages of the method are still unclear.

The authors fill a research gap, where bibliometrics has been widely applied to innovation analysis in any subject, but the value of the approach has not been studied. This paper aims to apply a bibliometric technique called co-occurrence analysis to identify emerging innovations in a field. This study uses the field of Disaster Risk Reduction (DRR) in Indonesia as a case study. Co-occurrence analysis is a technique that is the most applied in various researches to identify innovations. The contributions of this research are showing the effectiveness of bibliometrics, particularly the co-occurrence technique, in analyzing the emerging innovations in the context of the DRR field in Indonesia and discussing the advantages and disadvantages as well. This research proves that bibliometrics is an innovative approach to identify emerging innovations in the DRR field. The method can describe the types of innovations, the period of emergence, their interaction among the innovations and other fields, the types of innovations that have not been or have been developed, the future innovation trends and the authors involved. The information helps develop policies and programs related to the selection of innovations and financing required by a country.

B. LITERATURE REVIEW

Disaster risk reduction innovations

The Sendai Framework for Disaster Risk Reduction (SFDRR) has encouraged innovations in the DRR field. Science-based evidence of innovations allows effective DRR and management by decision-makers. According to Izumi et al. (2019), innovations in DRR include both products and any form, such as approach, framework, concept, and others. Table 1 shows DRR main innovations and suggested additional innovations by Izumi et al. (2019). These innovations would be used in this paper as a reference.

Innovation analysis in disaster risk reduction

Several approaches have been developed to analyze DRR innovations: a systematic literature review (Djalante, 2018) and a discussion survey (Izumi et al., 2019). The SLR conducted by Djalante (2018) aimed to measure the trends, key topics, and authorship of disasters and climate change publications in Indonesia indexed by Scopus from 1900 to 2016. The search terms used by the author were natural hazard, disaster, disaster management,

disaster risk reduction, climate change, climate change adaptation, resilience, vulnerability, geology, volcanology, and Indonesia. Once the first stage results were found (8077 documents), the author applied several inclusion and exclusion criteria (i.e. language, document type, subject area, and research scope/ appropriateness with the topics) to retrieve more relevant findings (the final results were 921 articles). The SLR is an explicit and transparent method to address a common research question. It enables researchers to work upon existing research, avoid bias, identify critical research topics and future research directions (Gill & Malamud, 2014; Djalante, 2018). Nonetheless, this method requires well-established eligibility criteria, and the evaluation techniques should be reasonably consistent across the multistage selection.

The second method by Izumi et al. (2019) analyzed DRR innovations through a survey towards representatives of academia (disaster experts and researchers from universities), government, NGOs, and the private sector. The representatives were gathered in a series of discussions to generate a shortlist of main DRR innovations. Based on these findings, a further survey was conducted to identify the most effective innovations and additional innovations that are more effective than those previously listed (Table 1). The results and analysis reveal that community-based DRR and risk management are the most influential innovations. Moreover, innovative approaches for both products and approaches contribute to the improvement of DRR, and it has implications for the collaborations and approaches to strengthen strategies and capacities for DRR.

Among both methods, the SLR would be used in this paper as a comparative method to the bibliometric approach. Both methods have the same principle approach to analyze existing works. Hence, it should be more reliable in comparing the resulting DRR innovations.

Overview of Bibliometrics

Bibliometric analysis is a quantitative information analysis method used to provide a macroscopic overview of many scientific publications. The bibliometric method can map specific discipline development and research patterns, such as the number of articles, key authors, key journals, affiliations, and cooperations (van Nunen et al., 2018). This method can also reveal the latest progress, future research directions, and hot topics of a particular research area. Hence, this method can identify research gaps, both content-wise and geographically (Gall et al., 2015). Moreover, bibliometric results play an essential role in supporting policymakers in the decision-making process related to science and funding agencies in allocating research funding (van Nunen et al., 2018).

Bibliometrics for knowledge visualization

There are several types of bibliometric mappings for knowledge visualization, namely co-citation or bibliographic coupling, co-words, co-authorship, and others. Co-citation represents a condition where two documents are being cited altogether by two documents. Co-words analysis shows the occurrences of keywords extracted from the title, abstract, or full-text articles, while co-authorship is used to analyze collaboration between two or more authors (Nadzar et al., 2017). Among bibliometric mapping types, this paper uses the co-occurrence keyword analysis to reveal research innovations, while the co-authorship mapping depicts influential authors of DRR research in Indonesia.

The bibliometric mapping visualizes the relationship of nodes, which represent either author, journals, titles, keywords (Nadzar et al., 2017), or countries in the form of a cluster of a group. Many applications are used to visualize bibliometric maps; one of them used in this paper is the VOSviewer software. It is a freely available software based on text mining functionality (Nadzar et al., 2017; van Nunen et al., 2018). This software can create, visualize, and explore bibliometric data from databases such as Web of Science, Scopus, and PubMed. The two-dimensional maps generated from the software show the relationship between terms, authors, countries, and co-citations. Using the

VOS clustering technique, terms are clustered into different groups with different colors. In general, the bibliometric map can be interpreted as follows: the size of the circles and the font label of terms represents the number of occurrences, while the distance between two circles represents the similarity and relatedness between them (van Nunen et al., 2018).

Bibliometrics in disaster risk reduction research

Several studies have reported the use of a bibliometric approach to analyze innovations in various research subject areas. However, only a few publications reported the use in the DRR field. Orimoloye et al. (2021) used bibliometrics to identify the evolution of research trends in disaster risk reduction. Based on Web of Science data published between 1990 and 2019, they reported that DRR research had increased over time during the period. Various technological innovations were identified, including GIS and remote sensing, disaster risk insurance, SNS, and materials that are resilient to disasters; technologies that Orimoloye et al. claimed to be very useful but difficult to implement. Moreover, Orimoloye et al. also revealed that social aspects such as disaster management and science and ecosystem services focus on DRR research. Meanwhile, areas such as disaster risk insurance and social networking systems must be improved at the implementation stage.

The following study to use a bibliometric approach was conducted by Wang et al. (2021). They combined descriptive statistical and bibliometric approaches to study research progress related to integrated disaster risk management in a changing climate. Using CiteSpace data from 2008 to 2020, the study revealed the exponential growth of publications, the cooperation characteristics of authors across the world, the issues mainly discussed in the literature, and the focus of integrated disaster risk research, i.e.: (1) disasters; (2) climate change adaptation; (3) climate change impacts; (4) health, insurance, critical infrastructure, communities, and various frameworks; and (5) research on crucial regions and countries.

Further, Rana (2020) used a bibliometric approach to study epistemology and research integration on climate change and disaster resilience. Using Web of Science data from 1992 to 2019, the study revealed increasing publication growth in both climate change and disaster resilience. Rana proposed vulnerability and adaptation as the fundamental concepts linking integrated research on resilience. Further, Rana recommended developing and adopt a shared understanding of resilience thinking for DRR and climate change philosophy. Rana argued that those are considered more appropriate to develop an understanding of resilience.

C. RESEARCH METHODS

Data collection

This research uses bibliometric method. Publication data was collected from the Scopus database on August 29, 2021. We used Scopus because it is one of the most reliable sources for preliminary research of innovation analysis using the bibliometric approach. It is a comprehensive abstract and citation database for peer-reviewed science and technology literature (Nadzar et al., 2017). Scopus ensures that only high-quality literature is included with a rigorous protocol (Milán-García et al., 2021). In addition, Scopus also provides a publication analysis feature to enable offline analysis from the exported bibliographic data. Publication data was retrieved using the terms “disaster risk reduction” AND Indonesia. The terms were searched from the title, abstract, and keyword fields to ensure complete coverage of publications. In total, 282 documents were retrieved. Further selection to only journal articles in English retrieved 142 documents. Then among the documents, this research obtained 94 documents containing the keywords category of innovation. The innovation-related keywords were chosen manually using the DRR innovation lists (Table 1) developed by Izumi et al. (2019). Next, this paper downloaded the data of 'Year of Publication', 'Name of Authors' and 'Keywords' for further analysis.

Data analysis

Data analysis was divided into three parts: (1) the number of publications per year, (2) the co-occurrence keyword analysis to measure DRR innovations, and (3) the co-authorship analysis to identify the most prolific authors and affiliations as well as its collaboration patterns. For the number of publications per year, bibliographic data of selected journal articles were analyzed using the Scopus publication analysis feature. Documents were analyzed to create a chart informing the number of publications and the growth trend. Next, for the co-occurrence keyword analysis, a bibliographic mapping based on innovation-related keywords' co-occurrence was created using VOSviewer software (1.6.17 version). It is an open-source software developed by the Centre for Science and Technology Studies at Leiden University (The Netherlands) designed specifically to create and visualize a bibliographic network (Cobo et al., 2011). The software uses the VOS (Visualization Of Similarities) clustering method to cluster topics into different groups. A two-dimensional map with different colors and distances reflects the similarity or relatedness of items as accurately as possible (van Nunen et al., 2018). An overlay visualization of keywords was also created to identify the innovations' period. Last, the most prolific authors and affiliations were also identified using the VOSviewer. A total of 84 author data were included in collaboration analysis. Meanwhile, the authors with less than three documents were excluded from the analysis to find the most prolific authors and their institutions.

D. RESULT AND DISCUSSION

The number of publications

Researchers in the field of disaster require an approach that can identify hidden patterns and trends from a large number of publications. Bibliometrics is an approach that has this capability. Wang et al. (2021) conveyed that just a few researchers use Bibliometrics to analyze big data. Currently, researchers require an approach to analyzing data categorized as big data. Bibliometrics uses mathematical and statistical approaches to uncover the context of developments and research trends of essential issues. Meanwhile, other approaches may exhibit limitations, such as subjectivity, one-sided analysis, and fuzzy conclusions.

Figure 1 shows the publication of DRR in Indonesia in the period 1997-2021. DRR publications in Indonesia first appeared in 1997. It seems that Figure 1 shows that there are three periods. In the first period (1997-2007), the publication appears inconsistent. Then, the number of publications fluctuated with an increasing trend from 2008 to 2016. Furthermore, the number of publications increased sharply from 2017 to 2020. The number of disasters in Indonesia experienced an upward trend between 2016 – 2019 (Puspasari, 2020). The increase in the number of publications was indicated by the increase of research, presumably due to a large number of disasters in that period. There are nine articles discussing floods, two documents discussing landslides, 23 publications discussing tsunami, and eight papers discussing earthquakes in the data set.

Co-occurrence analysis of keywords categorized as innovation

Table 2 displays all keywords from 94 papers containing keywords with the innovation category. The bolded letters are keywords categorized as innovations based on Table 1 proposed by Izumi et al. (2019). The method identified about fifty kinds of innovation, including the main and additional innovation of Izumi et al. (2019). In detail, there are 14 innovations in cluster one, 17 innovations in cluster two, four innovations in cluster three, 13 innovations in cluster four and two innovations in cluster five.

Based on the best literature review we have conducted, there were two methods to identify innovation in DRR. The first is Systematical Literature Review (SLR), which analyzed various topics in the field of disaster in Indonesia (Djalante, 2018). There are topics related to innovation from various topics found, among others tsunami early-warning systems, the role of knowledge and information for

community preparedness for disasters; and culture, gender or religion in supporting community resilience in the face of disasters. Second is a survey method, which identifies innovations through discussion and meeting with experts and researchers (Izumi et al., 2019). This paper proves that the bibliometric approach is able to identify innovations, especially in the field of DRR. Furthermore, Izumi et al. (2019) has not mentioned some innovations, including computational methods; modelling; natural hazard-triggered technological; transportation networks; and benchmarking.

The visualization of the keywords network is presented in Figure 2. The visualization showed that several innovative products such as early warning systems, remote sensing, evacuation modeling, and Geography Information Systems (GIS) became a trend. A relatively large circle indicates it on the visualization map. Meanwhile, some innovations appeared in Table 2 but do not appear in visualization, such as artificial intelligence, emergency shelter, Internet of Things (IOT), and natural disasters participatory approaches. It is due to the innovations are not widely researched. It seems that disaster management is currently the focus of innovation. In the context of Izumi et al. (2019), the innovation term seems to be called Community-Based Disaster Risk Reduction/Management.

Figure 2 shows a visualization of emerging innovations from year to year. These figures provide examples of innovations that emerged in the 2014-2020 period. Bibliometrics can display a time series that provides information when an issue first appeared, whether it would be bigger, disappeared or undeveloped. The approach can show the various innovations and the development of the innovations over time. Knowing the status of each innovation will be helpful in developing science policies and strategies in the future. It could be that a number of innovations in the field of DRR that have not been developed are more effective than others that have been developed. Izumi et al. (2019) said that a number of innovative approaches and tools had been developed, but it is necessary to analyze which innovations are most effective.

Disclosure of scientific developments from year to year will help researchers better understand the evolution of an issue for building a model. Sundberg (2015) revealed that the 1717 Christmas flood in the area between Denmark and northern Holland was one of the greatest disasters of the early modern era. He/she reported that past disasters need to be uncovered as a process to describe the situation more fully environmental conditions. The information is helpful for risk analysis and comparative model development.

However, it seems that the use of bibliometrics to reveal the history of innovation, particularly in DRR has not been explored in detail. We all know that the results of the bibliometric analysis will produce recommendations, such as research on environment/disaster conducted by Hou & Wang (2021), Yevide et al. (2016), Zhou et al. (2019), Barnes et al. (2019), and Dhamija & Bag (2020). However, to what extent, how, and what are the results that the policymakers adopt these recommendations to become a disaster policy framework still has a long way to go and struggle and need to be considered in further research. Orimoloye et al. (2021), Tang et al. (2021), and Wang et al. (2021) used bibliometrics for similar things, such as trend disclosure, analysis of authorship patterns, and institutional collaboration. Meanwhile, Rana (2020) was considered to have successfully linked disaster resilience and climate change to better understand historical trends and development.

The most prolific authors and affiliations

The paper found that 84 authors were involved in 94 documents of innovation in DRR. Table 3 shows the authors who have the most publications.

The five DRR innovation documents written by Imamura, F. from Tohoku University, includes: (1) People's response to potential natural hazard-triggered technological threats after a sudden-onset earthquake in Indonesia;

(2) Analysis of complexities in natech disaster risk reduction and management: A case study of Cilegon, Indonesia; (3) Global tsunami risk assessment: Collaboration between industry and academia in the Willis research network (WRN); (4) Vulnerability characteristics of tsunamis in Indonesia: Analysis of the global centre for disaster statistics database; and (5) A Decade After the 2004 Indian Ocean Tsunami: The Progress in Disaster Preparedness and Future Challenges in Indonesia, Sri Lanka, Thailand and the Maldives. These papers generally highlight innovation from the approach aspect, especially for natech (natural hazard-triggered technological) disasters. Imamura F. collaborates in discussing human behavior, including disaster awareness of the community, emergency preparedness, contingency plan, and collaboration efforts from multiple stakeholders that would be needed.

Next, the four DRR innovation documents written by Muhari, A. from National Disaster Management Authority of Indonesia, Jakarta, consist of (1) Global tsunami risk assessment: Collaboration between industry and academia in the Willis research network (WRN); (2) Vulnerability characteristics of tsunamis in Indonesia: Analysis of the global centre for disaster statistics database; (3) A Decade After the 2004 Indian Ocean Tsunami: The Progress in Disaster Preparedness and Future Challenges in Indonesia, Sri Lanka, Thailand and the Maldives; (4) Generating tsunami risk knowledge at the community level as a base for planning and implementation of risk reduction strategies. Overall, the papers discuss innovations in terms of the approach and tool regarding tsunami disasters. Besides outlining the collaboration model for a tsunami risk assessment, Muhari A. collaborates on developing a database to collect disaster data (e.g. characteristics of people, the number of population, natural, and physical building, and DRR activities that have been done in the local area). In terms of approach, in his papers, Muhari contributes to developing risk reduction strategies that can be used for local planning in disaster mitigation.

Another prolific author, Suppasri, A. from Tohoku University, collaborates on three DRR innovation documents. They are (1) Global tsunami risk assessment: Collaboration between industry and academia in the Willis research network (WRN); (2) Vulnerability characteristics of tsunamis in Indonesia: Analysis of the global centre for disaster statistics database; and (3) A Decade After the 2004 Indian Ocean Tsunami: The Progress in Disaster Preparedness and Future Challenges in Indonesia, Sri Lanka, Thailand and the Maldives. Suppasri A. collaborates with Muhari A. in all the papers, which generally discuss the approach for tsunami disaster (i.e. the risk assessment model, the collaboration of multiple stakeholders, and DRR strategies) and the tool to help mitigate tsunami disasters in the future.

Last, Paulik, R. from National Institute of Water and Atmospheric Research, New Zealand, produces three DRR innovation documents. The papers include (1) Tsunami Fragility Functions for Road and Utility Pole Assets Using Field Survey and Remotely Sensed Data from the 2018 Sulawesi Tsunami, Palu, Indonesia; (2) Development and application of the real-time individual asset attribute collection tool; and (3) Vulnerability characteristics of tsunamis in Indonesia: Analysis of the global center for disaster statistics database. In general, Paulik R. papers outline the use of an advanced information technology approach and tools to collect disaster data. These include a field survey and remotely sensed data to measure tsunami fragility functions for infrastructure and a database for tsunami data. These tools are capable of describing pre-disaster physical characteristics and post-disaster damage of assets and would be helpful in assisting the decision-making process for disaster mitigation and post-disaster relief and recovery efforts.

Figure 3 visualizes the collaboration network among the 84 authors. The visualization shows seven clusters of authors, marked by the presence of seven different colors. It is seen that the authors with the highest publication, namely Imamura, F. Suppasri, A., and Muhari, A. are in a similar cluster. Authors

who are in the same cluster have an interest in the same issues, or they collaborate on several studies. Imamura, F., Suppasri, A., and Muhari, A. collaborated on nine papers that focused on tsunami issues from 2012-2021. They all come from the same institution, namely Tohoku university.

In the meantime, Suppasri, A., Muhari, A., Imamura, F., and Paulik, R. has one paper collaboration about tsunami in Indonesia. Paulik comes from a different institution than the other three colleagues, Suppasri, A., Muhari, and Imamura, F. Paulik, R. also has another paper collaboration with Suppasri, A. and Muhari, A. Although Suppasri, A., Muhari, A., and Imamura, F. wrote the same affiliation, four authors are from different countries. They all are the authors with the highest number of papers.

Research collaboration is the key in increasing author's productivity especially in the field of disaster research. Zyoud and Fuchs-Hanusch (2020) mapped the climate change researches in the Arab world and found a pattern that high productivity countries have high levels of research collaboration with other countries. In addition, to achieve success and progress in studying climate change and its impacts, it is necessary to strengthen research collaborations and partnerships at the regional and international levels. Meanwhile, Nita (2019) argued that innovation, knowledge exchange, and collaboration are fundamental to environmental studies. By mapping international collaborative studies, they reveal that developed and developing countries need to ignore geographic and jurisdictional boundaries as well as address political, economic, social and technological barriers in an international collaboration in order to produce high productivity in research. This is reminiscent of the opinion that science cannot contribute to the evolution of knowledge without collaboration between stakeholders (McAllister et al., 2014). In addition, collaboration in environmental science is difficult to implement when it comes to large-scale or global research targets (Guerrero et al., 2015).

Limitations

This paper has weaknesses; the researchers themselves carry out the determination of innovation based on a list of innovations determined through the literature. In the future, improvements need to be made, for example, using expert opinion to avoid subjectivity. Therefore, the robustness of research findings could be more accomplished. In addition, bibliometrics approach has disadvantages. This method requires a database with a complete library collection. This study only uses the Scopus database which indexes international journals. In fact, publication in local journals is also very important in the context of the emergence of innovations in the field of DRR. The use of multiple databases will affect database compatibility, which requires more complicated computational techniques. This can be used as follow-up research to get more comprehensive results.

E. CONCLUSION

Bibliometrics is a powerful method for analyzing emerging innovations in a field. This paper shows that this method can be used to analyze the emergence of innovations in the field of DRR in Indonesia. This ability is shown by the detection of 30 innovation terms that have been assigned to keywords. Moreover, this method shows advantages such as being able to analyze big data because of the availability of applications for visualization, such as VOSviewer. Another advantage of this method is the ability to display innovations that emerged within a specific range of years. Therefore, bibliometrics can analyze data in a time series. This ability can be used to identify innovations that have not and have been developed. In addition, bibliometrics is able to identify the relationship among the innovations and with other keywords. This ability is helpful in forecasting new innovations and also predicting future innovation trends. This technique can also provide the most productive researchers and their collaborative strengths.

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FIGURE LIST

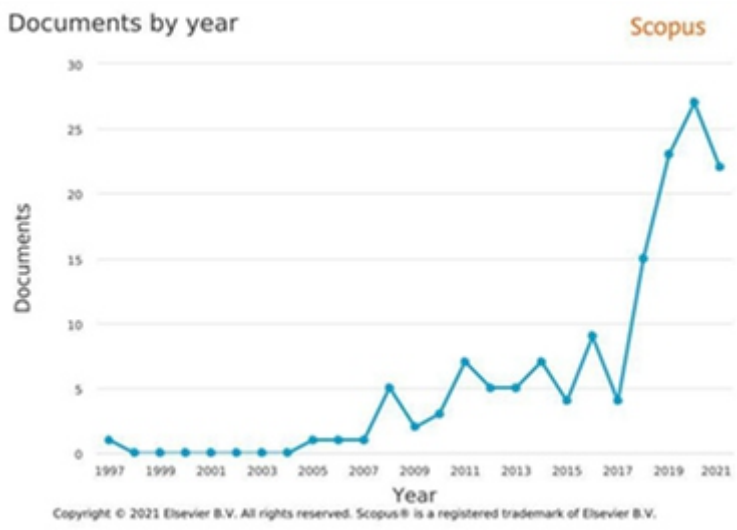

Figure 1. The number of publications per year
Source: Scopus, 2021

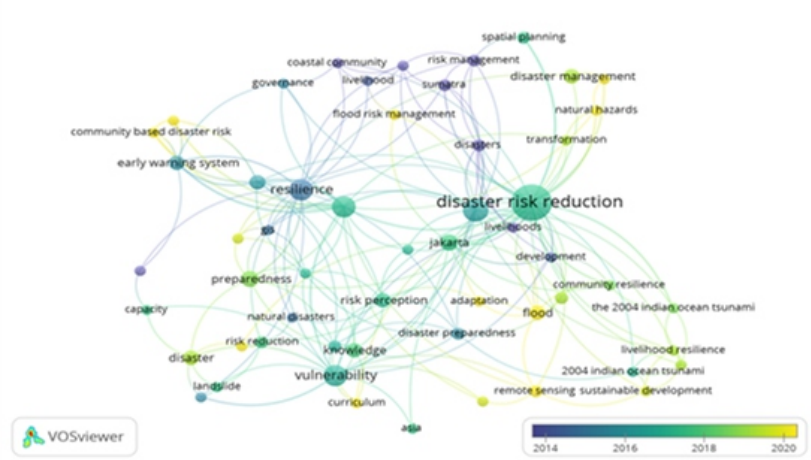

Figure 2. Network visualization of innovation-categorized keywords per year
Source: VOSviewer, 2021

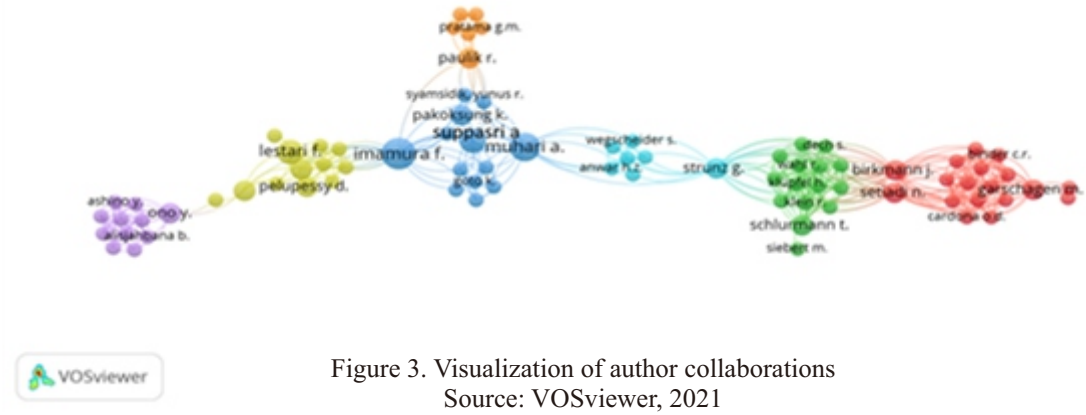

Figure 3. Visualization of author collaborations
Source: VOSviewer, 2021

TABLE LIST

Table 1. DRR innovations

Main innovations	Suggested additional innovations
Products	**Products**
1. GIS and remote sensing	1. Drought resistant crops
2. Drones	2. Communication technologies
3. Social Networking Services (SNS)	3. Mobile application based on smart water solution
4. Concrete and steel: building material and infrastructure	4. AI technology
5. Disaster risk insurance	5. Sanitation technology during emergency
6. Disaster prevention radio (Bosai musen) and telemetry system	6. Susceptibility mapping for a changing climate
7. School cum cyclone shelter	7. Digital management information system
8. Seismic code	8. Virtual Reality in DRR education
9. Seismic micro zonation	9. Solar energy used for response such as mobile water treatment
10. Earthquake early warning for high speed train	10. Early warning by emergency phone ringing/Disaster alerts through mobile phone
11. Doppler radar	
12. Disaster resilient material	
13. Rainwater harvesting	
14. Electricity resistant survey	
Approaches	**Approaches**
1. Community-based disaster risk reduction/management	1. Impact based forecasting
2. Hyogo Framework for Action	2. CCA and DRR
3. Hazard mapping	3. Shaking table demonstration
4. National Platforms for Disaster Risk Reduction	4. Ecosystem-based adaptations and DRR
5. Safe schools and hospitals	5. Religious organization involvement
6. Assessments and index approach: vulnerability assessment, resilient index, sustainability	6. Regional and national response mechanism
7. Crowdsourcing	7. Nowcasting
8. Sphere standard	8. Land-use regulation
9. Terminologies of resilience and vulnerability (R&V)	9. DRR fund
10. Post disaster needs assessment	10. Go Bag
11. Transnational initiative on resilient cities	11. Weather-based agriculture
12. Mobile payment: a tool for accessing distribution/funds after a disaster	12. Forecast based financing
13. A dollar for DRR saves seven dollars in disaster response/recovery	
14. Traditional practices and evacuation behaviors	
15. Indigenous DRR technology	
16. River engineering	

Sumber: Data primer diolah tahun 2021

Table 2. Innovation category keywords

Number of Cluster	Keywords of innovation category
Cluster 1 (35 items)	**agen-based evacuation**; agent-based modelling ; **building safety ; built environment**; climate change adaptation; communication; community resilience; **computational methods**; conceptual framework; controlled study; culture; disaster management; **evacuation; evacuation - modelling**; **indigeneus cultures; indigenous knowledge** ; international educat ion; **modeling**; **multistorey building** ; **natural hazard -triggered technological (natech)** ; protective actions; risk assessment; safety; scenario development; scenario technique; **shelter**; social behavior; socio-economic development; socioeconomic impact; stakeho lder; stochastic inundation maps; transcultural care**; transportation network**; **tsunami evacuation plan**; **vertical evacuation**
Cluster 2 (30 items)	**artificial intelligence** ; capacity building; **community-based disaster risk management; community-based disaster risk reduction (cbdrr)**; decision support system; decision support systems; **early warning system**; earthquake early warning; **emergency evacuation route map**; **emergency shelter** ; emergency traffic control; **geographic information system (gis)** ; **government regulation**; information services **; information systems**; **internet of things (iot)**; leader election; maps; **message broadcasts** ; **mobile application** ; refugee camp; resource management; smartphones; **social network; social networking (online**); social su pport; **volcano monitoring system**; wireless communication system; wireless sensor network; wireless sensor networks
Cluster 3 (29 items)	Attitude; attitude to health; **community-based disaster risk management** ; cooperative behavior; coping strategy; **crowdsourcing**; cultural factor; curriculum; **education program** ; experience; funding; health care personnel; health care surveys; health personnel attitude; health program; human security; humanitarian aid; internatio nal cooperation; internet; knowledge; multicenter study; organization and management; partnership approach; psychoeducation; **psychologic assessment**; residence characteristics; social welfare ; support group; training
Cluster 4 (24 items)	Benchmarking; **coastal community** ; community relocation; decision making; ecosystem management; emergency care; **governance; governance approach** ; **health facilities**; holistic approach; image analysis; **local participation**; multi-level institutional arrangements; **natural disasters participatory approaches; participation**; **policy implementation; politics**; **poverty alleviation**; **recovery policies and programs**; relocation; relocation governance; social aspect; technology; urbanization
Cluster 5 (24 items)	adaptation planning; bearing capacity; community development; disaster prevention; evacuation facilities; fragility function; **gis**; infrastructure; land use; landslide analysis; lifeline networks; megacity; modelling; regional spatial plan; **remote sensing**; remotely sensed data; risk maps; roads and streets; safety factor; satellite imagery; spatial analysis; spatial interpolation; spatiotemporal analysis; warning system

Sumber: Data primer diolah tahun 2021

Table 3. DRR innovation authors

Author	Number of document
Imamura, F.	5
Muhari, A.	4
Suppasri, A.	3
Paulik, R.	3

Source: VOSviewer processed data, 2021