ORIGINAL ARTICLE

OVERVIEW OF THE RESEARCH ON VULNERABILITY AND FLOOD: BIBLIOMETRIC AND SYSTEMATIC REVIEW OF THE LITERATURE

Panorama das pesquisas com a temática vulnerabilidade e inundações: revisão bibliométrica e sistemática da literatura

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Abstract
The discussions regarding vulnerability in contemporary society have been the focus of several researches, mainly due to recurring natural disasters, floods being amongst them, that can impact all of the population, particularly the groups that are located in places that are more prone to such events. Furthermore, in the face of climate change which projects even more intense and extreme events, the current studies about vulnerability are of utmost value for the drafting of mitigation and adaptation actions. Viewing what has been presented, the use of reviews based on research and referenced by many researchers are important tools to fill in the blanks, to disseminate methods and techniques and create knowledge. The goal of this article is to identify the most relevant studies and key aspects that underpin the subject of vulnerability and flood, based on a systematic and bibliometric analysis using the *Web of Science* (WoS) database based on its terms "vulnerability and "flood". After the introduction of search filters and pre-established criteria, 485 publications have been found all over the continents, prominently in Asia and Europe. Associating to the subject, the articles address the discussions regarding climate change, social vulnerability, hazard, resilience, exposure and adaptation. Such approach is taken for different geographical clippings and scales signaling the need to amplify the methodological and conceptual knowledge, in order to contribute to the precautionary measures and adaptaions by funding effective actions by public administrators and civil society facing the direct and indirect impacts caused by environmental disasters.

Keywords: Web of Science; Periodic; Indicators; Hazard; Scientific Production.

Resumo

As discussões acerca da vulnerabilidade na sociedade contemporânea têm sido foco de diversas pesquisas, principalmente em virtude do recorrente registro de desastres naturais, dentre eles as inundações, que podem impactar toda a população, sobretudo, as que estão em locais mais suscetíveis a ocorrência de tais eventos. Ademais, frente às mudanças climáticas que projetam eventos extremos mais intensos, os frequentes estudos sobre vulnerabilidade são de extrema valia para a elaboração de ações voltadas à mitigação e à adaptação. Diante do exposto, o uso de revisões com base em pesquisas e referenciadas por diversos pesquisadores são ferramentas importantes para preencher lacunas, disseminar métodos e técnicas e gerar conhecimentos. O objetivo deste artigo é identificar os estudos mais relevantes e os aspectos centrais que embasam a temática da vulnerabilidade e das inundações, com base numa análise sistemática e bibliométrica utilizando o banco de dados da *Web of Science* (WoS), com base nos termos "*vulnerability*" e "*flood*". Após a aplicação de filtros de busca e critérios pré-estabelecidos, foram localizadas 485 publicações distribuídas em todos os continentes, com destaque para a Ásia e Europa. Associado à temática, os artigos abordam as discussões sobre mudanças climáticas, vulnerabilidade social, risco, *hazard*, resiliência, exposição e adaptação. Tal abordagem é realizada para diferentes recortes geográficos e escalas sinalizando a necessidade de ampliar o conhecimento conceitual e metodológico, a fim de contribuir com medidas preventivas e adaptações subsidiando ações efetivas por parte dos gestores públicos e da sociedade civil frente aos impactos diretos e indiretos causados pelos desastres ambientais.

Palavras–chave: Web of Science; Periódicos; Indicadores; Hazard; Produção científica.

1. INTRODUCTION

Vulnerability, analyzed from the perspective of environmental issues, takes on a major role in the scientific productions taking into consideration the interrelations between dangers and the modified environment, whether for the pollution in the area, ecological imbalance, water shortage, growth and concentration of the population in urban areas, among other factors (BARRETO *et al.*, 2017). Despite it being a polysemic concept with room for different interpretations, in Geoscience and other areas of expertise, when interpreted under the aspect of the theoretical and methodological framework, it allows the integrated and analytical comprehension of social and environmental conditions that the population is subjected to.

According to Almeida (2011), the lack of a consensus of interpretation of the concept of vulnerability comes from the multidimensionality of the reality under analysis (cultural, social, environmental, economic, among others), from epistemological diversity (taking to consideration the vast field of sciences that works with this topic) and from the applied methodological practices. Despite this, the definitions complement and reformulate each other over time.

The discussion of the concept of vulnerability is constructed from a combination of factors, which allow maintenance of specificities of the variables that were constituted as an object of analysis, as well as enabling systemic analysis. It is pertinent to highlight that its analysis is complementary to other concepts, such as: risk to natural events, environmental disasters, resilience, and adaptability of the population. Therefore, associating vulnerability with the occurrence of risks enables a more effective intervention in the geographic space, providing subsidies to the planning and management processes of the territories, to the implementation of integrated public policies and inputs for mitigating measures.

According to Balica (2009, 2012), vulnerability can be considered as the extent of damage, which ends up being individualized due to the conditions of exposure, the susceptibility of geographical clippings and the ability to face, recover or adapt to the circumstances of the environment. Rufat *et al.,* (2015), more specifically, state that geographic and temporally varied characteristics are fundamental to deconstruct vulnerability, once they describe the precursors, human and environmental interactions that make individual disasters unique.

Even if there is no consensus between conceptual approaches, it is widely known that there's a need for effective implementation of proposals that ensure improvement in the quality of life of the population and minimize social, economic, and environmental conflicts that end up becoming more prominent over the last decades. Currently, technical-scientific works are more common in this direction, however, quantifying, qualifying, and structuring multidimensional networks of the variables involved, still presents itself as a challenge to be exceeded.

According to the United Nations Office for Disaster Risk Reduction - UNISDR (2020), flood-related disasters are the most recurrent in the world, accounting for 44% of the total recorded between 2000 and 2019. It is pertinent to highlight that the floods, in 2021 alone, corresponded to 51.62% of the total disasters recorded in the world. In relation to the average for the period from 2001 to 2020, it presented a 36.81% increase, according to The Emergency Event Database (EM-DAT). Also in 2021, it is noteworthy that flood events accounted for 39.5% of deaths, reached 29.2 million people and caused an economic loss of approximately 74.4 billion dollars (UNISDR, 2022) for the affected countries.

Corroborating, Kind *et al.,* (2016) also points to floods as one of the recurrent and destructive disasters around the globe, causing substantial impacts on society and economic losses. Given this scenario, Yang *et al.,* (2018) state that disasters related to

extreme events that result in flooding become an important factor that restricts the development of society and, consequently, the economy.

The assessment of vulnerability to floods becomes increasingly relevant and urgent, which suggests the drafting of targeted studies that bring advances to methodological processes, technological innovations and, above all, to results closer to realities, a fact that allows decision makers to adopt preventive measures to flood in advance, minimizing the subsequent impact. It should be noted that these studies are not easy, in view of urbanization and climate change, which are factors that significantly impact the increase in flood risks (Arnone *et al.*, 2018). In addition, it requires the understanding and combination of several factors that are essential, such as population, nature and climate change, that generate different scenarios for each location.

In times when the increasing availability of bibliographic databases, with quick access through advances in technology, this is because, as the number of publications grows frighteningly, it makes it more difficult for the researcher to research and choose the most relevant journals and articles for their research, and it is in this context that studies based on bibliometric and systematic search are important.

These studies concern, in short, to the organization of selected articles in a structured way based on pre-established criteria and, therefore, allows any person to retrace the steps and find the same answers and gaps (MARTINEZ-SILVEIRA *et al.*, 2014; QUEVEDO-SILVA *et al.,* 2016; MEDEIROS; VASCONCELOS, 2020). This type of analysis is important in order to expand the possibilities of more in-depth studies, more robust methodological adaptations that help in understanding the reality around the theme of vulnerability and flood.

Thus, the objective of this article is to identify the most relevant studies and the central aspects that support the topic of vulnerability and flood, based on a systematic and bibliometric analysis using the Web of Science database.

The theme of vulnerability to floods, due to the different possibilities of approaches, methods and the growing socio-environmental problems arising from significant changes in the society-nature relationship, becomes relevant as an academic reflection. A critical eye on the part of researchers is necessary, so that knowledge is accessible to society in general and that it awakens new research in the face of the reality that materializes.

2. MATERIALS AND METHODS

This research was planned and carried out from the perspective of a work with a bibliometric and systematic approach, based on the bibliographic and documentary literature survey, aiming to subsidize discussions, methodologies and techniques used in academic papers that have the theme of vulnerability and floods.

Bibliometrics is a quantitative technique for evaluating scientific production (ARAÚJO, 2006) and is based on three laws: Lotka's Law (analysis of authors), Bradford's Law (analysis of journals) and Zipf's Law (relationship between words) (RODRIGUES; VIEIRA, 2016). These analyses allow the identification of patterns and gaps in the production of scientific knowledge on a given theme. In addition, it enables the analysis of literature from different perspectives (SILVA; SILVA; EL-DEIR, 2021).

The Systematic Literature Review (RSL) consists of a qualitative scientific method, which promotes the use of a set of activities, namely: collection, analysis, synthesis, aid and search for documents from a certain area, to achieve a certain objective (BERLATO; FIGUEIREDO; FERREIRA, 2018). The systematic review is essential to integrate information and studies that were created separately, allowing, for example, the analysis and identification of pre-established aspects and/or answering questions (BARBOSA *et al.*, 2019).

Therefore, the present study promoted the use of the combination of bibliometrics and systematic literature review. Therefore, with regard to research techniques, this is a documentary research, considering the analysis of published scientific productions, carried out from material already prepared to subsidize knowledge, as the collection, classification, selection and use of a wide range of information available in the texts was carried out (FACHIN, 2001). As for the nature of the research, it is considered quantitative in relation to the data survey, but it is qualitative in face of the procedures of analysis and interpretation of these in relation to the criteria and delimitations adopted by the authors in the documentary research.

In order to achieve the proposed objective, a systematized research protocol was developed in this paper, aiming at mapping and surveying relevant scientific productions (articles) at national and international levels in the Web of Science (WoS)[1] Main Collection (Clarivate Analytics) database.

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[1] The WoS is considered a world-leading platform of scientific quotes and analytical information research. As well as one of the biggest and the most inclusive resources of academic information of the world, covering over 12.000 main academic journals.

The survey of articles in WoS was carried out on March 21, 2022, from the access to the Journal Portal maintained by the Coordination for the Improvement of Higher Education Personnel. In this process, descriptors were applied, including terms related to the research theme in English, "vulnerability" and "flood*"[2]. In addition, the boolean operator and, an intersection connective, was used as a search strategy, seeking documents that have both terms in their title.

Additionally, for a refinement, the following criteria were used, according to Figure 1: i) only article-type document (excluding Early access[3]); ii) English, Spanish and Portuguese; iii) articles that belonged to categories or areas of the Web of Science directly linked to the environmental sciences; and iv) time frame from 2000 to 2022. This cut-out was chosen as a result of the scientific production on this subject starting to have annual progression from 2000. Prior to this period there are only three articles, which are: (i) Nations Increasing Vulnerability to Flood Catastrophe by James E. Goddard published in 1976; (ii) What determines vulnerability to floods: a case study in Georgetown, Guyana written by Mark Pelling in 1997 and; (iii) Structural causes of vulnerability to flood hazard in Pakistan by Daanish Mustafa in 1998, which will not be included in the analyzes of this article.

Based on the demarcation, 485 records were identified, which will be the *corpus* of the research, exported for analysis in a single file, in the Information Systems Research (ISR) format with numerous information, among them: title, authors, magazine, year of publication, keywords, keywords-plus, and abstract.

Taking into consideration the quantity of selected articles, it was decided to demarcate this study based on the most cited articles for further detail. Therefore, a threshold of articles with 100 times or more citations was set, resulting in a total of 18 articles. Regarding the download, they were accessible through the Portal of Periodicals of CAPES (Coordination for the Improvement of Higher Education Personnel), with access by UFPB (Federal University of Paraiba) and Google Scholar. After collecting the articles, a quantitative (descriptive) and textual analysis were done, i.e., all 18 articles were read in full, in order to identify the concepts used, methodologies, data adopted, vulnerability components, and others.

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[2] The asterisk (*) inserted to the right of the terms, sets a wildcard character so the research perspective is amplified, enabling the inclusion of the variations of the word, for example, floods, flooding.
[3] It is defined by WoS as the content of the Version of Record that is published online before final attribution in a completed volume/issue.
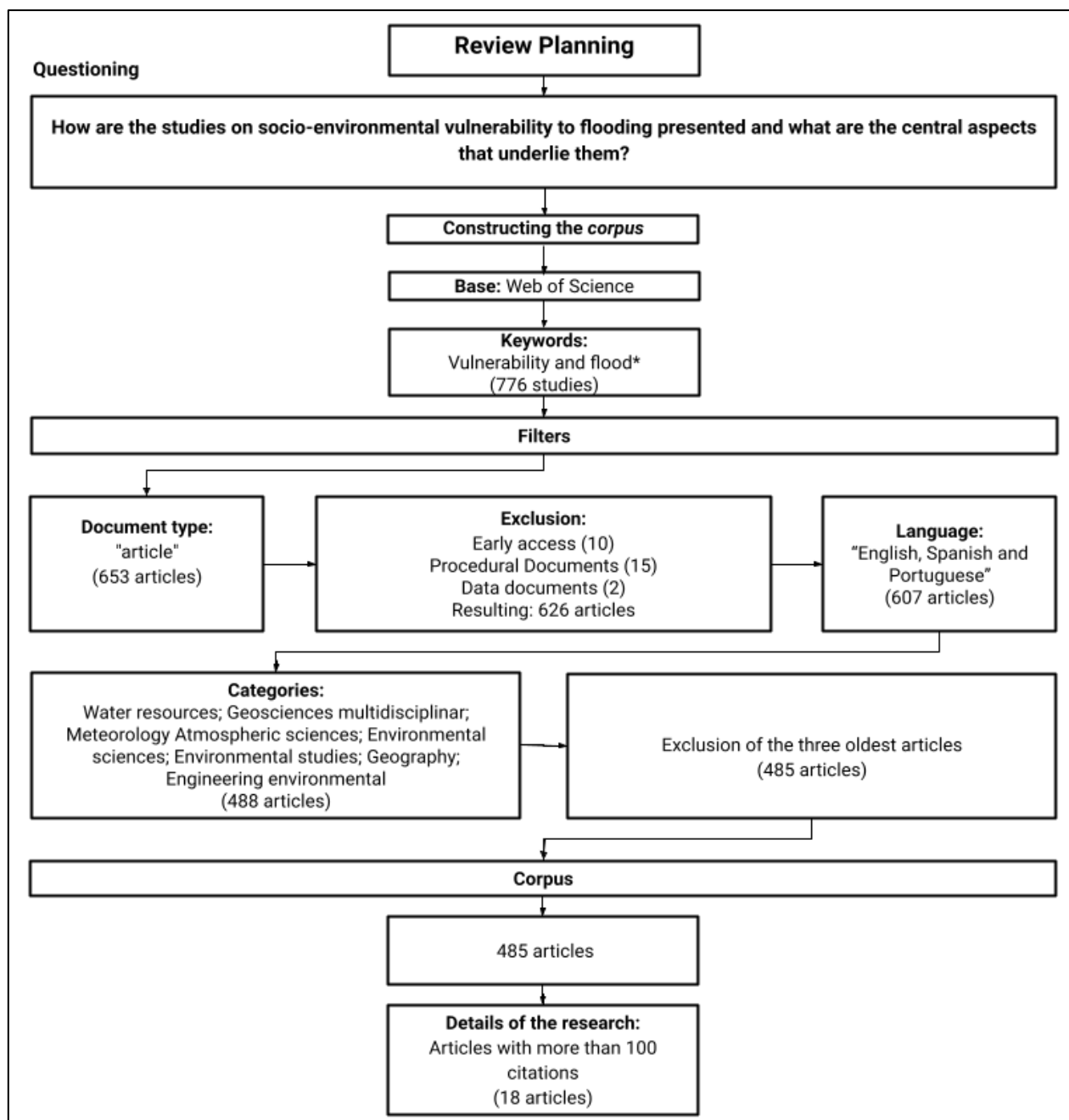
Figure 1 – Research protocol.
Elaboration: The authors (2022).

From this reading, a database was created, which constituted important information for the proposed analysis. For this, the following software was used: Microsoft Excel spreadsheet, to prepare the graphs, and VOSviewer. VOSviewer is a free software program used to construct and visualize bibliometric networks, thus facilitating the analysis. It allows working with large data sets and offers several options for analysis and investigation, making bibliometric maps in an easy-to-interpret manner that assists in data analysis and evaluation (VAN ECK; WALTMAN, 2010).

3. RESULTS AND DISCUSSION

3.1. Bibliometric analysis of the *corpus* research

According to Yuan and Sun (2022) the number of published academic studies is an important indicator to measure the development trend of certain scientific research. Therefore, the temporal evolution of the corpus publications (485 articles), Figure 2, registered in the Web of Science database, reveals an increasing trend in research on vulnerability and flood studies. It can be noticed that the rate of studies in the first eight years of analysis was relatively low, 39 articles altogether. From 2010 on, an increasing rise in research is observed. However, a more significant progression is perceived from 2015, corresponding to a concentration of 79% in the last eight years. It is noteworthy that the number of publications in 2022 includes only the records until the research deadline, i.e., the theme continues to expand.
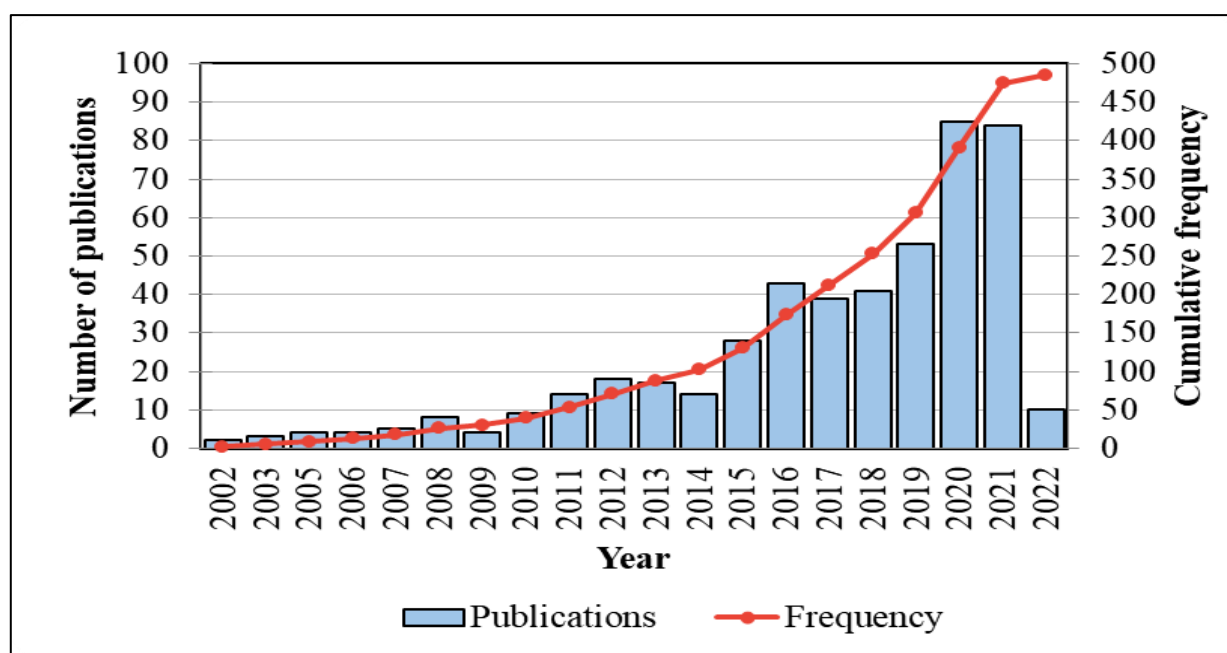
Figure 2 - Time evolution of the publications of the corpus which encompass the theme vulnerability and floods (2002 - 2022). **Source:** Datas of the Web of Science.
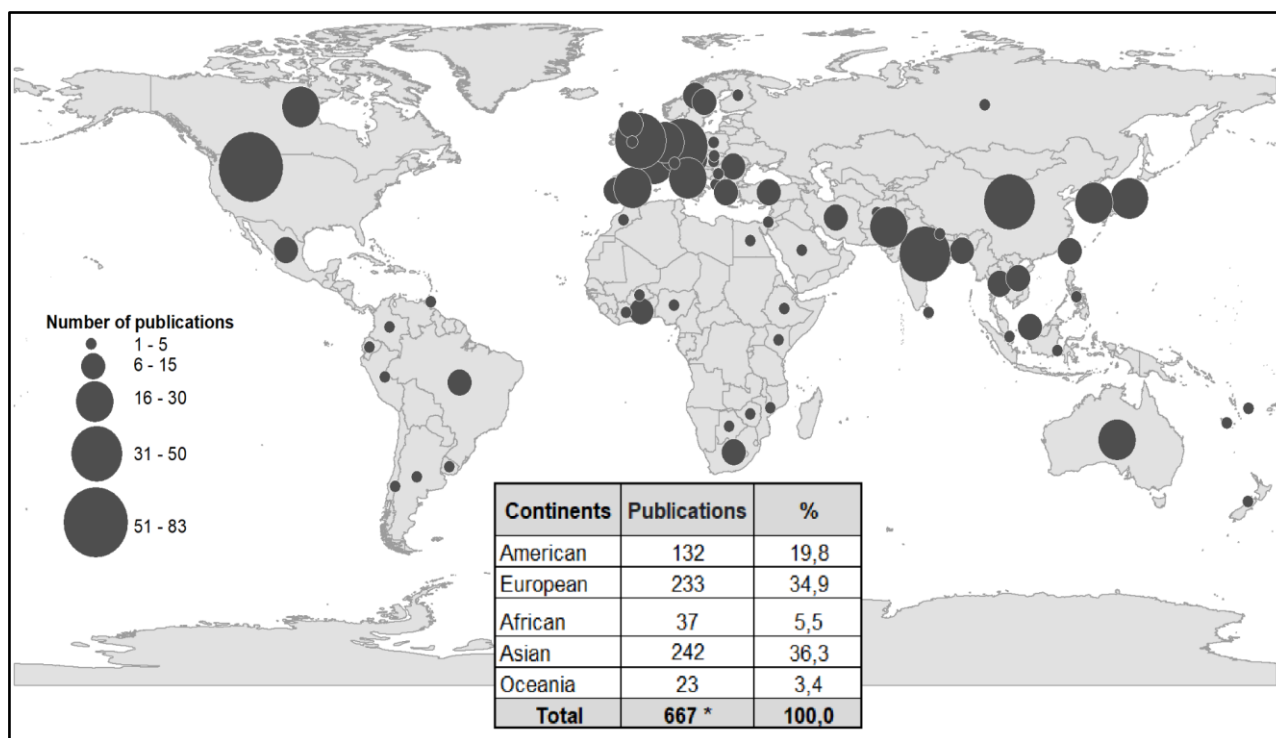**Elaboration:** The authors (2022).

The peak occurred in 2020 and 2021 with 169 published articles (approximately 35% of the total). One possible reason for this increase in the number of publications is the need to investigate how flooding events occur, where and what they provoke in the geographic areas, considering the significant increase in occurrences, as already presented. In this sense, it is clear that the theme is not recent; however, it reveals a positive trend as to the scientific interest in the subject and the attention dedicated to this

area of research in recent years. It is noteworthy that the discussion of this theme and the concepts attributed to it are not restricted to the academic community, since society in general currently glimpses the need for greater understanding and argumentation about the issues involved. Moreover, according to Van-Nunes *et al.,* (2017), the number of publications is an indicator to be considered, since it reveals that there is still the possibility of an exponential growth because of many aspects of the theme that still need to be better explored and understood. This fact also ends up working as an attraction to more recent researchers.

Furthermore, this theme is highlighted all over the globe, as it is pertinent to verify from the geographical distribution in relation to the countries that produced the releases (Figure 3). What can be emphasized is the inequality in the production of knowledge on the subject, with a geographic concentration, in continental terms, with Asia and Europe standing out with 71.2%, on the other hand, Africa and Oceania with only 8.9%.


Continents	Publications	%
American	132	19,8
European	233	34,9
African	37	5,5
Asian	242	36,3
Oceania	23	3,4
Total	**667 ***	**100,0**

Note: * The total number of publications is larger than the corpus since some coauthors do not necessarily belong to the same continent.
Figure 3 - Geographical distribution of the publications of the corpus about the theme vulnerability and floods (2000 - 2022). **Elaboration:** The authors (2022).

Regarding countries, the United States, China and India stand out. The United States corresponds to 17.11% (83) of the articles published in the period, which is approximately twice as much as the second country, with 46 articles. It is also noteworthy that the corpus

identified articles from 73 different countries, which reaffirms the importance of this subject on a global scale. This spatial distribution is similar when compared to the number of disasters indicated by EM-DAT (Figure 4-A), as well as the number of disasters per continent in the 10 largest cities in 2021 (Figure 4-B).
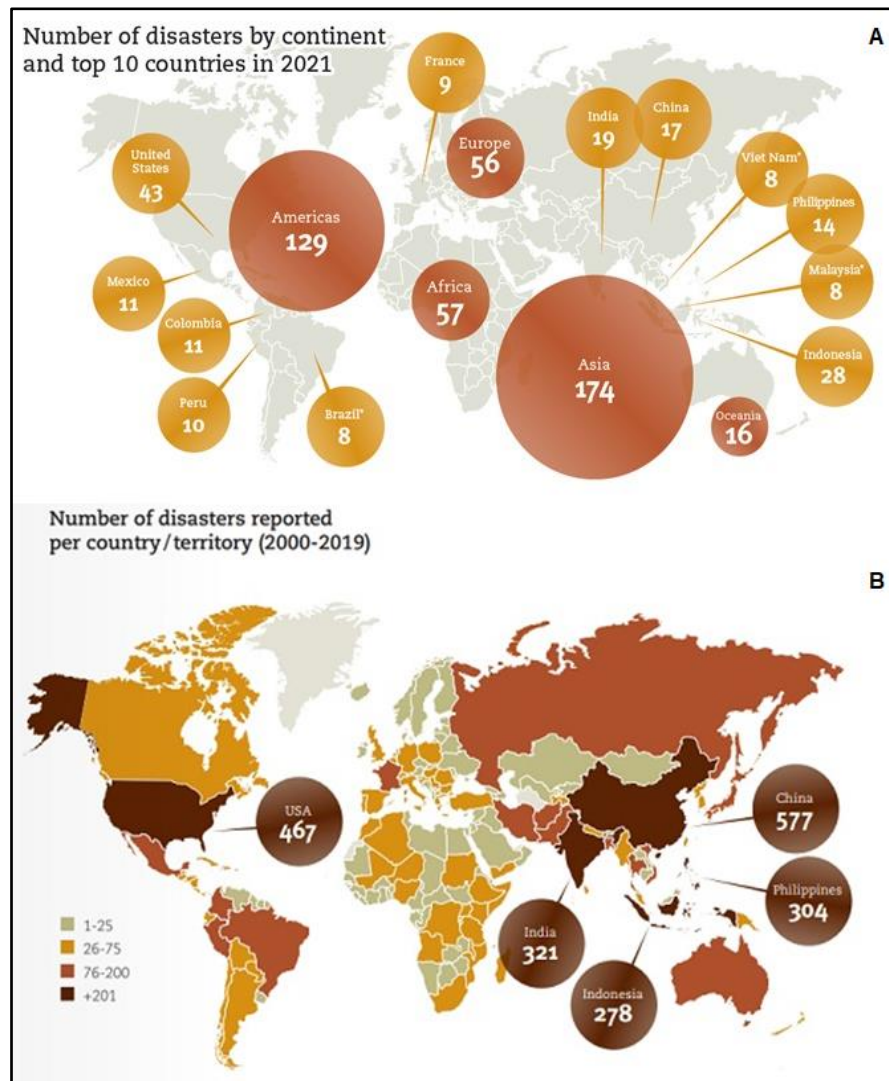
Figure 4 - Distribution of the number of disasters: (A) by continents in 2021
and (B) by countries in the period of 2000 to 2019.
Source: UNDRR (2020 and 2022).

The corpus under analysis registers 1,542 authors and co-authors, which is equivalent to an average of approximately 3.2 authors per published paper. Whereas, 89.62 of these produced only a single article. These results are consistent with Lotka's Law (1926), which analyzes the scientific productivity of authors, that is, it verifies the individual contribution to the academic deepening in the area of knowledge. The Law recognizes that authors with a single contribution make up around 60%. However, a

reflection is necessary; the topic in question is recent and has shown exponential growth in the years 2020 and 2021. Thus, authors with one publication account 78.52%.

In continuity, Price's Law (of 1963) stands out, known as Academic Elitism, which is characterized by the concentration of publications by few authors in a few journals, which consequently the most cited articles are included. The outstanding authors are Greg Oulahen and Stefania Balica, each with six publications; and Dushmanta Dutta, Sven Fuchs, Irfan Ahmad Rana, Ashfaq Ahmad Shah, and Nigel G. Wright, each one of them with five releases. It is important to emphasize that, although these authors participate in several publications, not all of them are among the most cited, as will be discussed later.

The degree of relevance of journals in a given area of knowledge can be ascertained from Bradford's Law (1934), which states that a few journals will have a greater number of publications with regard to the subject, therefore, more academic influence, in reverse, many journals produce just a few articles. In this research, there were 153 scientific journals. Based on the survey of journals whose publication volume was at least greater than ten articles in the analyzed time frame (Table 1), it also mentions the impact factor based on the JIF (Journal Impact Factor), which is a journal-level metric calculated based on data indexed in the Web of Science Core Collection platform[4].

Table 1 - Main journals within the corpus on the subject of vulnerability and floods (2000 - 2022).

Periodics	Number of articles published	JIF (base year 2021)
Natural Hazards	74	3.158
International Journal of Disaster Risk Reduction	39	4.842
Water	22	3.530
Sustainability	21	3.889
Journal of Flood Risk Management	19	4.005
Natural Hazards and Earth System Sciences	18	4.580

Source: Web of Science.
Elaboration: The authors (2022).

It appears that approximately 40% of the articles are found in these 6 journals, supporting Bradford's Law. The journal Natural Hazards is the most popular, comprising 15.3% of the publications, followed by the International Journal of Disaster Risk Reduction with 8.0%. It must also be noted that, regarding the JIF, the most relevant are: The

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[4] Journal Impact Factor is calculated using the following metrics: Citations in 2021 to items published in 2019 + 2020 / Number of citable items in 2019 + 2020. It is important to mention that on the *Clarivate Analytics* website (https://jcr.clarivate.com/), this indicator should be used carefully, once the parameters have multiple influences. However, it serves as a parameter to evaluate the importance of scientific journals in their respective fields.

International Journal of Disaster Risk Reduction, Natural Hazards and Earth System Sciences, and Journal of Flood Risk Management.

Among the categories of the 485 articles (Table 2), four of them showed more significant percentages, namely: Water Resources (267 articles, 55.05% of the total), Geosciences Multidisciplinary (198 articles, 40.82%), Environmental Sciences (173 articles, 35.70%) and Meteorology Atmospheric Sciences (168 articles, 34.60%). It should be stressed that some articles are counted in more than one category, which is why the total exceeds the number of analyzed records.

Table 2 - Categories of the corpus on the theme of vulnerability and floods (2000 - 2022).

| Categories	Number of articles
Water Resources	267
Geosciences Multidisciplinary	198
Environmental Sciences	173
Meteorology Atmospheric Sciences	168
Environmental Studies	89
Geography	46
Engineering Environmental	15

Source: Web of Science.
Elaboration: The authors (2022).

Regarding words' frequency of occurrence, there is Zipf's Law, which according to Quoniam *et al.,* (2001) can be presented in three zones: I) trivial information (central themes); II) zones of peripheral themes that can show innovative information; and III) noise zone with not yet emerging concepts. In Figure 5, it is possible to see the co-occurrence of the keywords chosen by the occurrence of at least 15 times, identified using the VOSviewer software, in all the keywords, i.e., those entered by the authors and the keywords plus.

The central themes, zone I, deals with terms such as vulnerability, climate change, social vulnerability and risk. These are fundamental concepts for the thematic discussion of the research in focus. In zone II, as stated in Quoniam *et al.,* (2001) there are approaches that involve more specific themes on the basic or trivial topics, permeated with potentially innovative information.

Zone III not shown in Figure 5, in view of a large number of words found (446) and its low recurrence (below 15), are related to more individualized concepts and characteristics, for example, it deals with extreme events such as hurricanes, storms, and extreme precipitation; analysis techniques, such as fuzzy, analytical hierarchy process, remote sensing, artificial neural-networks and hydrodynamics model; specific locations such as Canada, Pakistan and urban areas; and more current topics involving epidemics.

environmental justice, environmental resilience, disaster risk reduction, projections, sensitivity analysis, and countless other subjects.
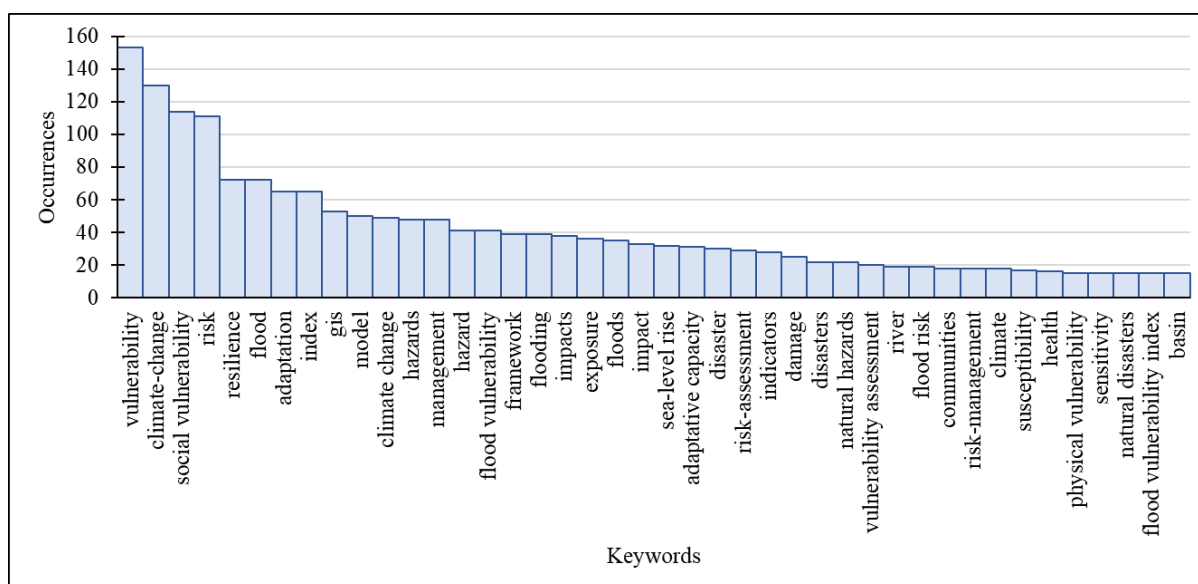
Figure 5 – Keywords occurrences.
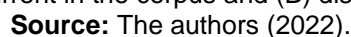**Source:** Web of Science.
Elaboration: The authors (2022).

The word cloud from the corpus (Figure 6A), reveals the existence of three distinct, yet complementary groups. In the blue cluster (6A), there is more periodicity of the vulnerability concept correlated with the words flood, hazards, structure, adaptation. These same concepts, when analyzed temporally (6B) are also those that appear in the oldest publications. This leads to the reflection that these records may address basic concepts that inform subsequent analyses.

The red cluster (6A) refers to another axis of analysis which correlates the themes of risk, flooding, flood vulnerability indices, impacts, risk assessment, susceptibility, exposure, and models. It appears that these words are more contemporary (6B), which demonstrates the insertion of new dialogues and correlations with other areas of knowledge, including the insertion of analysis techniques related to the topic.

Lastly, the green cluster (6A), whose evidence is based on the concepts of climate change, resilience, social vulnerability, health, and hazards. It is also the most temporally recent (6B). This demonstrates a conceptual maturing and a differentiated possibility of interpreting the theme, focusing more specifically on disaster risk management than on the materialized disaster or on the techniques for identifying risk areas. This aspect is gaining strength taking into consideration the expansion of discussions about climate change and the consequences for wider society.

Figure 6 - Word cloud: (A) recurrent in the corpus and (B) distributed in the temporal clipping.
Source: The authors (2022).

For a scientific field study, keyword analysis is relevant because it can reflect the root content of articles and its compilation can identify a pattern and trends of specific academic research (BADALUDDIN *et al.*, 2021). Furthermore, Figure 6 (A and B) shows the interconnection between the words, demonstrating the strength of the areas and topics involved.

3.2. Detailed analysis based on articles with more than 100 citations within the *corpus*

Although many articles have been published in the period under review, a relatively small contingent of such research is recurrent in the citations. Thus, using as a criterion the existence of at least 100 citations of the same article, the quantitative corpus for a more detailed analysis corresponded to 18 articles (Table 3). The 18 articles selected for a more detailed analysis are distributed throughout the study period, as well as published in journals with different scopes in the scientific sphere, the oldest being the work of Kron (2005) whose central theme is the correlation between flood risk and other related concepts, such as vulnerability and hazard. It is also interesting to note that this article addresses, in a more applied way, the role of insurers, the government, and society in general in the face of adverse events.

Table 3 - Articles in the corpus with more than 100 citations from 2000 to 2022*.

| Order	Author(s)	Title	Year	Magazine	Citation
1	Balica, S. F.; Wright, N. G.; Van der Meulen, F.	A flood vulnerability index for coastal cities and its use in assessing climate change impacts	2012	Natural Hazards	324
2	Rufat, S.; Tate, E.; Burton, C. G.; Maroof, A. S.	Social vulnerability to floods: review of case studies and implications for measurement	2015	International Journal of Disaster Risk Reduction	287
3	Fekete, A.	Validation of a social vulnerability index in context to river-floods in Germany	2009	Natural Hazards and Earth System Sciences	267
4	Koks, E. E.; Jongman, B.; Husby, T. G.; Botzen, W. J. W.	Combining hazard, exposure and social vulnerability to provide lessons for flood risk management	2015	Environmental Science & Policy	232
5	Ouma, Y. O.; Tateishi, R.	Urban flood vulnerability and risk mapping using integrated multi-parametric AHP and GIS: methodological overview and case study assessment	2014	Water	213
6	Kron, W.	Flood risk = hazard.values.vulnerability	2005	Water International	213
7	Zahran, S.; Brody, S. D.; Peacock, W. G.; Vedlitz, A.; Grover, H.	Social vulnerability and the natural and built environment: a model of flood casualties in Texas	2008	Disasters	155
8	Kleinosky, L. R.; Yarnal, B.; Fisher, A.	Vulnerability of Hampton roads, Virginia to storm-surge flooding and sea-level rise	2007	Natural Hazards	138
9	Balica, S. F.; Popescu, I.; Beevers, L.; Wright, N. G.	Parametric and physically based modelling techniques for flood risk and vulnerability assessment: a comparison	2013	Environmental Modelling & Software	135
10	Kazmierczak, A.; Cavan, G.	Surface water flooding risk to urban communities: analysis of vulnerability, hazard and exposure	2011	Landscape and Urban Planning	134
11	Adelekan, I. O.	Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria	2010	Environment & Urbanization	131
12	Balica, S. F.; Douben, N.; Wright, N. G.	Flood vulnerability indices at varying spatial scales	2009	Water Science & Technology	127
13	Ruin, I.; Creutin, J-D.; Anquetin, S.; Lutoff, C.	Human exposure to flash floods - relation between flood parameters and human vulnerability during a storm of september 2002 in southern France	2008	Journal of Hydrology	111
14	Scheuer, S.; Haase, D.; Meyer, V.	Exploring multicriteria flood vulnerability by integrating economic, social and ecological dimensions of flood risk and coping capacity: from a starting point view towards an end point view of vulnerability	2011	Natural Hazards	109
15	Yamano, H.; Kayanne, H.; Yamaguchi, T.; Kuwahara, Y.; Yokoki, H.; Shimazaki, H.; Chikamori, M.	Atoll island vulnerability to flooding and inundation revealed by historical reconstruction: Fongafale Islet, Funafuti Atoll, Tuvalu	2007	Global and Planetary Change	109
16	Ajibade, I.; McBean, G.; Bezner-Kerr, R.	Urban flooding in Lagos, Nigeria: patterns of vulnerability and resilience among women	2013	Global Environmental Change	107
17	Strauss, B. H.; Ziemlinski, R.; Weiss, J. L.; Overpeck, J. T.	Tidally adjusted estimates of topographic vulnerability to sea level rise and flooding for the contiguous United States	2012	Environmental Research Letters	106
18	Fedeski, M.; Gwilliam, J.	Urban sustainability in the presence of flood and geological hazards: the development of a GIS-based vulnerability and risk assessment methodology	2007	Landscape and Urban Planning	104

Note: * until March 21st, 2022
Source: Research data.
Elaboration: The authors (2022).

To better understand the influence between the responsible authors for these articles on the researched topic, Figure 7 was created, in which it is possible to visualize nine clusters, whose "nodes" represent the degree of centrality, while the thickness of the line is associated with the intensity of collaboration. It is evident that the largest "nodes" are those that also have the largest number of citations, constituting foundational research that ends up influencing others through the theoretical conception and methods used.
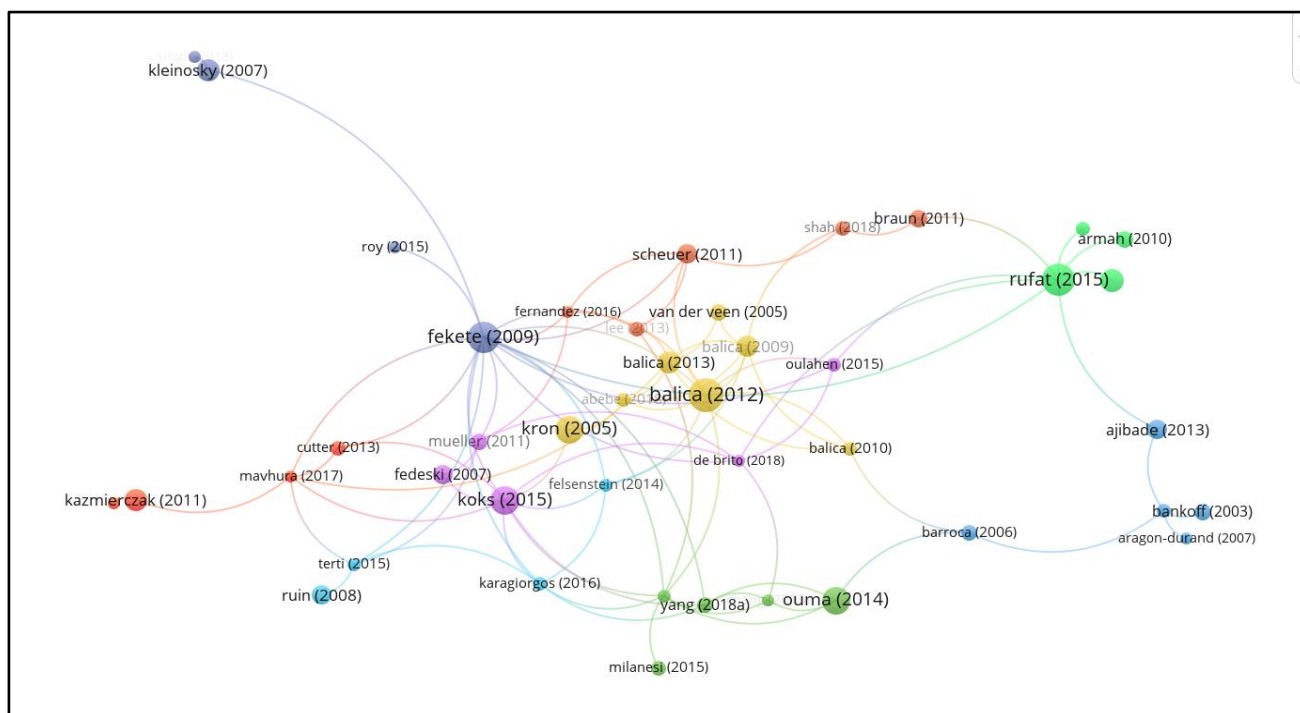
Figure 7 - Citation network based on the research corpus
Elaboration: The authors (2022).

The five articles, as it is possible to see in Figure 7, with the largest "nodes", are also located in the center of the network, although they are interrelated through the lines, each one of them composes a different cluster, and thus, can be considered central publications, recognized by other researchers and that subsidize other research. This can be confirmed, as they are among the most cited works. The following will be mentioned by way of an overview of the issues addressed, objectives, and procedures adopted.

The article published in 2012 by Balica and collaborators (yellow cluster and the most centralized publication) is noteworthy once it has reached, up to the date of collection of the information expressed here, a total of 324 citations. The main objective of this research was to develop a Coastal City Flood Vulnerability Index based on an understanding of the concepts of flood exposure, susceptibility, and resilience. To do so, they used nine coastal cities distributed over different continents as a spatial cutout. The methodology adopted

consisted of analysis of selected indicators by means of specific statistical analysis techniques.

The article by Rufat *et al.,* (2015), which corresponds to a contingent of 287 citations, addresses the correlation between social vulnerability and environmental disasters by flooding, to do so, 67 articles present in the Web of Science and Google Scholar platforms, were used as the focus resource for the literature analysis. Therefore, it is not an applied study, but presents a general conception of the indicators that are directly related to the disaster in question.

The article by Fekete (2009), cited 267 times, corresponds to an applied research with the objective of creating a Social Vulnerability Index in the context of river flooding in Germany. In order to do that, a methodological procedure factor analysis and logistic regression of a database obtained from the Federal Institutes of statistics in the mentioned country was used.

Starting from a household-scale analysis, the article by Koks *et al.,* (2015), aimed to assess flood risk by joint analysis of flood hazard, exposure, and social vulnerability. As a form of methodological testing, the procedures were applied in a case study in the Rotterdam region. This publication reached a total of 232 citations.

The paper published by Ouma and Tateishi (2014), which totals 213 citations, aimed to provide subsidies for mapping areas affected by flooding, as well as those susceptible to flooding in urban centers. To do this, the authors used the hierarchical process analysis associated with the overlapping of thematic bases in geographic information systems, a fact that enabled the integration of technical processes for more effective decision-making.

The author Balica, besides having the most cited manuscript, has two other works in the most cited list, which were published in partnership with other researchers in the years 2009 and 2013. Both maintain vulnerability as the main axis of analysis, however, with different technical processes.

Another matter that should be mentioned in the detailed analysis of the 18 articles is directly related to the occurrence parameters of the words. This was done in VOSviewer, based on the words contained in the abstract unit, using the Binary Counting method and with a minimum frequency of 3 occurrences, see Figure 8.
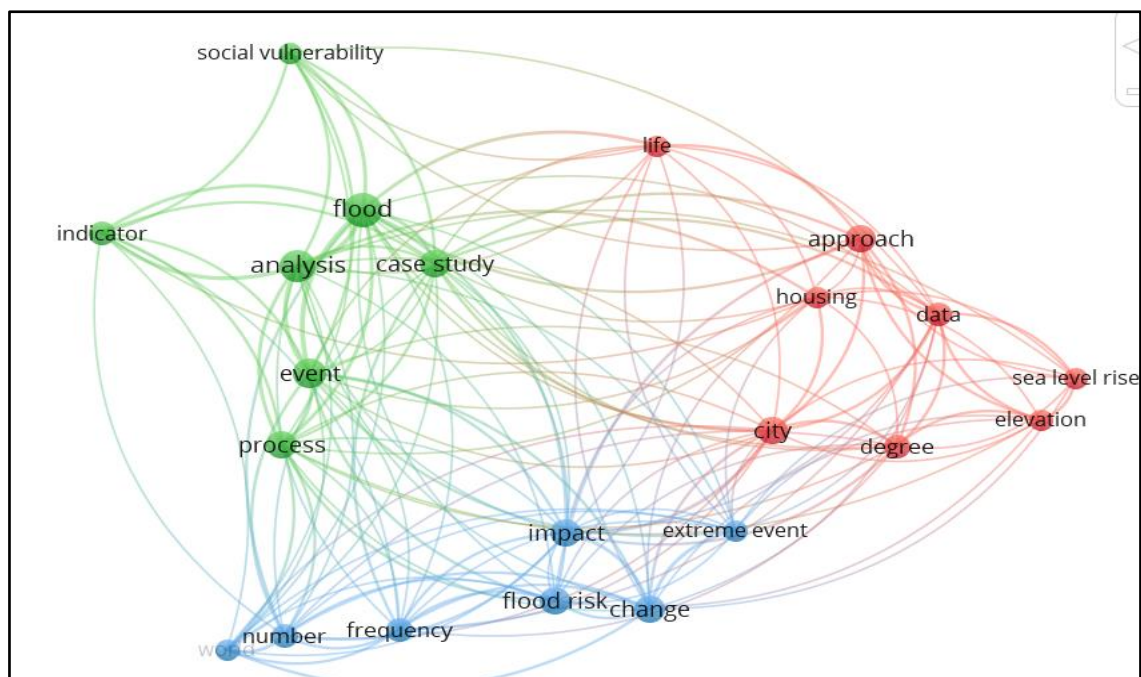
Figure 8 - Strength and relevance among the words included in the abstract of the 18 most cited manuscripts. **Elaboration:** The authors (2022).

Through groupings visualized in Figure 8 it is possible to observe the main addressed topics, as well as reflecting the relationship between them and their respective strength of relevance. According to Kaczam *et al.*, (2022), the size of the "node" is directly associated with the frequency of occurrence of a given keyword, while the strength of the relationship between them can be assessed by their respective proximity. Three very clear clusters are identified, but they all have correlations with each other. Based on the words that form each cluster it can be seen that the one identified in red addresses issues focused on studies for coastal areas, such as the research published by Kleinosky *et al.,* (2007), Balica *et al.,* (2009) and Koks *et al.,* (2015).

The green cluster is directly related to the articles that address methodologies through indicators to evaluate, for example, social vulnerability, considering, for this, more individualized analyses, portraying the local reality through case studies. For example, the publications by Ouma *et al.,* (2014) and Adelekan *et al.,* (2010). Finally, the blue cluster, which aggregates discussions concerning extreme events, climate change, and flood risks, such as the approaches taken by Yamano *et al.,* (2007) and Strauss *et al.*, (2012).

In the analysis of these 18 articles, the theoretical and conceptual aspects and data used were also investigated, as well as the geographical scope, the technical-operational procedures, the main products, and, finally, the most relevant considerations addressed in the publications.

As for the theoretical aspects, the publications has show that the definitions of vulnerability and its respective components (exposure, adaptive capacity, and sensitivity) present multiple interpretations, reinforcing the polysemic character already pointed out by several studies and confirmed by the various areas and consequently by researchers working with the topic for numerous purposes. Even though there is an expressive number of publications, widely publicized, and consolidated knowledge, it can be observed that there is no consonance among the authors, once the concepts and theoretical reflections are built from each experience. Some articles do not bring a clear definition of what they understand by the main topic analyzed, but in function of the presentation and discussion of the results and even the references used as a justification, it is possible to infer.

Regarding the used data, there is a predominance of secondary data, systematizing information about the physical-natural and socioeconomic conditions, from agencies and public institutions in the study areas. Only two articles used primary data from field collection and interviews for their analysis. This reveals, on the one hand, the existence of responsible institutions that work in the systematization of data and their availability for research, and on the other hand, it shows the difficulty of developing research that requires detailed scales, which requires on-site collection.

The geographic clippings adopted are restricted to coastal areas, river channels, and political-administrative clippings. The first two mentioned clippings are recurrent in these surveys, as they correspond to the areas most susceptible to flooding events. Table 4 shows the spatial clipping directly associated with the articles that used them. The two articles that do not present a spatial clipping correspond, respectively, to a systematic literature review (RUFAT *et al.*, 2015) and the interaction between public entities, society, and insurers in the face of flood risk (KRON, 2005).

Regarding the technical-methodological procedures, it was noticed that the articles under analysis use different approaches that are recognized by science and achieve the objectives they propose, applying techniques such as: use of indicators, multivariate statistical techniques, geospatial analysis, physical-mathematical models, among others.

The products generated as a result of the research are systematized in tables, graphs, and maps that allow a more assertive interpretation by the readers, as well as serving as subsidies for possible decision-making by public managers and civil society. Such actions are important for the mitigation and adaptation to the risks related to environmental disasters caused by flooding.

Table 4 - Spatial clipping and respective articles.

Spatial Clipping	Articles
Coastal Area	1 - Balica, S. F.; Wright, N. G.; Van der Meulen, F. (2012) 4 - Koks, E. E.; Jongman, B.; Husby, T. G.; Botzen, W. J. W. (2015) 8 - Kleinosky, L. R.; Yarnal, B.; Fisher, A. (2007) 15 - Yamano, H.; Kayanne, H.; Yamaguchi, T.; Kuwahara, Y.; Yokoki, H.; Shimazaki, H.; Chikamori, M. (2007) 17 - Strauss, B. H.; Ziemlinski, R.; Weiss, J. L.; Overpeck, J. T. (2012)
River channel	3 - Fekete, A. (2009) 9 - Balica, S. F.; Popescu, I.; Beevers, L.; Wright, N.G. (2013) 12 - Balica, S.F.; Douben, N.; Wright, N G. (2009)
Political-administrative cut	5 - Ouma, Y.O.; Tateishi, R. (2014) 7 - Zahran, S.; Brody, S. D.; Peacock, W. G.; Vedlitz, A.; Grover, H. (2008) 10 - Kazmierczak, A.; Cavan, G. (2011) 11 - Adelekan, I.O. (2010) 13 - Ruin, I.; Creutin, J-D.; Anquetin, S.; Lutoff, C. (2008) 14 - Scheuer, S.; Haase, D.; Meyer, V. (2011) 16 - Ajibade, I.; McBean, G.; Bezner-Kerr, R. (2013) 18 - Fedeski, M.; Gwilliam, J. (2007)
Not applicable	2 - Rufat, S.; Tate, E.; Burton, C. G.; Maroof, A.S. (2015) 6 - Kron, W. (2005)

Elaboration: The authors (2022).

To finish the detailed analysis of the 18 most cited articles, it was observed that the authors address as final considerations, the following reflections: (i) Most articles are built on events that have already occurred. These serve as a way to investigate how and where they occur and, consequently, the subsequent impacts; (ii) From different procedures applied it is possible to map the risks in order to offer robust and effective results for knowledge and decision-making; (iii) The diffusion of knowledge allows greater awareness and reflection for the proposition of mitigation and adaptation actions in the face of a variety of (iii) The dissemination of knowledge allows greater awareness and reflection for the proposition of mitigation and adaptation actions in various scenarios and realities that differ from one country to another.(iv) The importance of combined efforts for the discussion of the problems faced.

4. CONCLUDING REMARKS

Based on the Web of Science database, a detailed analysis of the research on the topic of vulnerability and flooding during the time frame 2000 to March 2022 was performed using bibliometric and systematic methods.

The results showed the panorama on the subject of vulnerability and floods and present the following notes and reflections:

(i) a considerable increase in the number of publications after 2015;

(ii) there was a studies concentration in Asia and Europe; however, there are also studies in other continents;

(iii) it is clear, in most of the works, the concern with the impact of climate change in different geographies and at various scales;

(iv) even though there is a significant number of publications on the topic of vulnerability and floods, there is still no consonance among researchers regarding conceptual definitions, a fact that reveals the need to expand discussions among all users and researchers; and

(v) concern in quantifying disasters and their consequences in such a way as to make knowledge accessible to different audiences, based on different technical-methodological procedures; and

(vi) it is also noticeable in the discussions regarding social vulnerability, risk, resilience, and adaptation, which is of great value for society to know and recognize, so that they can act against environmental disasters and impacts on society and the environment.

Lastly, the bibliometric and systematic literature review presented tools that allowed mapping the research on the subject of vulnerability and flooding and identifying theoretical, methodological and applicability bases that can help and guide future research.

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