Visualization of semantic networks in academic publications on environmental risk communication

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Abstract:

Environmental risk communication has been gaining importance as a strategic research field in the context of growing climate, health, and social crises, both at the levels of public governance, emergency management, and participation in the formation of a more critical citizenry. This study aims to analyze thematic trends in scientific production on environmental risk communication using a bibliometric approach. To this end, a co-occurrence analysis of metadata terms corresponding to articles indexed in Scopus between 2010 and 2023 was performed, with the development of semantic networks using VOSviewer software.

The results show that environmental risk communication has several predominant conceptual cores, such as public health, risk perception, climate change, environmental pollution, and the emergence of approaches focused on public trust, misinformation, and community resilience. Semantic visualization allowed for identifying interconnected clusters that reflect the field's evolution toward greater interdisciplinary complexity. Finally, the implications of the analysis are discussed, highlighting its usefulness in guiding future research, communication policies, and participatory risk management projects.

Keywords: public health, crisis, climate justice, resilience, pollution, communication.

Introduction

In a world experiencing increasingly visible and frequent climate crises, the way in which environmental risk is communicated has become central to decision-making, public opinion formation, and the activation of social responses (Stoknes, 2014). Beyond the technical or scientific context, the messages issued in relation to certain natural disasters, pollution, forest fires, or climate change determine how people assess the severity of the threat, perceive their vulnerability or empowerment, and how they react to uncertainty (Mayhorn & McLaughlin, 2014). In this way, environmental risk communication becomes a complex space that encompasses ethical, political, emotional, and cognitive dimensions.

Several authors have explored the topic of risk communication from different perspectives: some focused on institutional and governmental communication models such as Reynolds & Seeger (2005); others on risk perception and decision-making such as Fischhoff (2013); and more recently, the role of digital media and emotions in the face of a crisis (Abbas et al., 2021). Research in risk communication also explores the ways in which such messaging can be more effective and has focused its study on the use of images, metaphors and narratives

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(Doyle et al., 2022), but also on the use of social movements and non-governmental actors in the construction of environmental discourse (Ritter & Thaler, 2023).

However, even though much research has been published, a more structured perspective is needed to visualize an overview of how the field is organized, what concepts are related to each other, and what trends dominate or emerge in current research (Cox & Depoe, 2022). The problem that guides this study arises precisely from this need and leads to the question: how are the key themes and concepts structured in scientific production on environmental risk communication? What thematic connections predominate, and how have they evolved over time? Faced with a multidisciplinary and dynamic field, having an overview of the knowledge produced can be essential to guide future research, avoid duplications, detect gaps, and promote more effective interdisciplinary articulations.

Therefore, this paper aims to map the semantic networks derived from the academic literature on environmental risk communication by analyzing the keywords present in indexed scientific articles. By using bibliometric analysis and data visualization tools, the aim is to offer a clear representation of the thematic cores, the most relevant conceptual associations, and the main lines of development that the area of study has undergone in recent years (Galeano et al., 2022). That is, unlike previous studies focused on thematic reviews or qualitative approaches, this research offers a semantic cartography of the field using advanced bibliometric tools.

The general objective is to analyze the semantic configuration of the scientific literature on environmental risk communication, while the specific objectives revolve around identifying the most frequently used key concepts, graphically representing relationships in the form of semantic networks, and observing thematic evolution over time. This approach is based on the assumption that the keywords chosen by the authors not only reflect the central concerns of each of the studies but also show the epistemological, methodological, and applied currents in the field.

On the other hand, it was hypothesized that there are predominant conceptual cores linked to topics such as climate change, risk perception, institutional communication policy, and digital media, but at the same time that there are emerging approaches related to climate justice, emotional communication, and participatory technologies. These networks allow for seeing the current situation of the field and indicate its possible future development (de Barros et al., 2022). In this sense, among the main contributions of this research is the possibility of carrying out a visual, conceptual, and methodological synthesis that contributes to the understanding of the current state of environmental risk communication, and a useful tool for researchers in this sector, decision-makers who seek to understand how knowledge is produced and communicated regarding issues that directly impact society and the planet.

Methodology

To carry out this research, a quantitative and exploratory approach was used (Sampieri, 2018), focusing on bibliometric analysis and the visualization of semantic networks. The primary objective was to identify the most important and frequent concepts in the scientific literature on aspects related to environmental risk communication and to understand how these concepts converge over time.

The first step was to extract information from the Scopus database, which was chosen based on its breadth of subject areas and because it provides detailed information on peer-reviewed publications (Zhu & Liu, 2020). A search strategy was selected that combined the terms "risk communication," "environmental," "climate change," and "disaster," and filters were applied to limit the results to articles and reviews published between 2010 and 2023. The search was

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carried out on documents written in English and Spanish, belonging to the areas of communication, environmental studies, public health, and social sciences.

The query string used was: TITLE-ABS-KEY ("risk communication" AND ("environmental" OR "climate change" OR "natural disasters" OR "environmental hazard")) AND (LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "ENVI") OR LIMIT-TO (SUBJAREA, "EART")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (LANGUAGE, "English") OR LIMIT-TO (LANGUAGE, "Spanish")).

Once the most important metadata, such as title, abstract, keywords, authors, and year of publication, were exported, all of this data was processed using VOSviewer software, which is an ideal tool for bibliometric analysis, as it allows the creation of visual maps to study relationships between terms, in addition to detecting co-occurrence patterns, and, through its modular clustering algorithms, automatically extract clusters (Deng & Xia, 2020). It should be noted that for this entire procedure, the 1,085 retrieved documents were cleaned and normalized, with the preparation of a thesaurus file to unify and group synonymous terms and eliminate generic terms or those that provided little information.

The semantic network obtained showed how the most frequently used concepts in this field are grouped together, where each term is positioned as a two-dimensional node (each with a size proportional to its frequency of occurrence) and each link connects terms that frequently co-occur in the articles analyzed. The concepts were automatically grouped into thematic clusters to identify consolidated lines of research (inscribed in one of the clusters) and emerging lines of research that emerged during the review.

This way of visualizing the semantic network offered the opportunity to identify the most researched topics, how they evolved, and even which areas offered options for future academic exploration. Although the research was based on publicly available secondary data, no additional ethical procedures were required. Furthermore, data traceability was ensured, and the data were processed following good transparency practices throughout each phase of the analysis.

Results

The results obtained from the semantic network generated from the bibliometric analysis using data from 1,085 documents from the Scopus database processed with VOSviewer are presented below. Figure 1 shows the network comprised of 682 items and identifies 10 thematic clusters that represent subfields within risk communication. The visualization reveals a dense semantic structure, with nodes of varying size depending on their frequency of occurrence, and connecting lines that indicate relevant co-occurrences between terms.

As can be seen, the most prominent node is "risk communication", which validates its role as a central axis for the field. Its centrality is reflected in both the size and density of connections with other nodes, such as risk management, public health, and climate change. This indicates that risk communication is increasingly conceptualized as a multidisciplinary tool that transcends the health field to encompass environmental, political, and technological aspects.

Figure 1. Map of co-occurrence of keywords in publications on environmental risk communication (2010–2023)
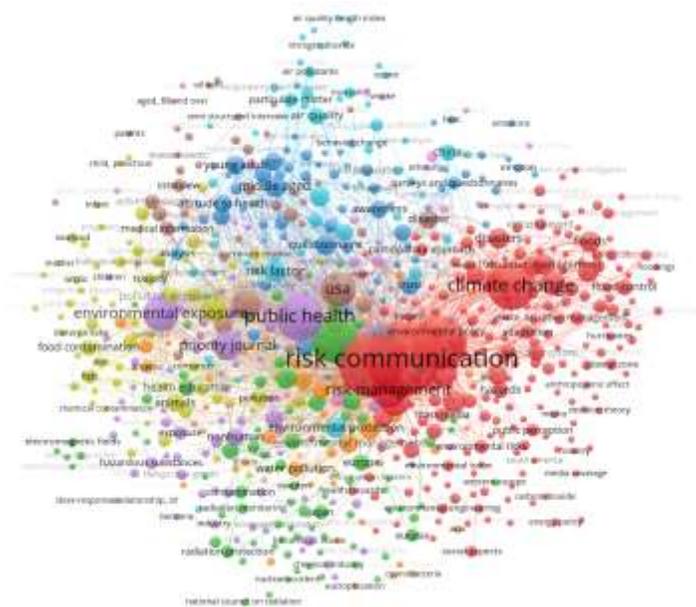
Source: Authors based on SCOPUS data

From the generated network, ten main clusters were identified, color-coded according to VOSviewer. The most representative clusters are described below based on their size and thematic relevance. The Red Cluster (Climate Crisis and Natural Disasters), with terms such as climate change, floods, natural disasters, hazards, and adaptation, forms a strongly connected group. This cluster, with 212 items, represents research on how risk is communicated in the face of extreme natural events. The analysis shows a growing integration between environmental studies and public communication, suggesting an interest in predictive models, risk perception, and citizen participation in the face of climate change. The Green Cluster (Technological and Radiological Risks) with 86 items includes terms such as radiation protection, radioactive, electromagnetic fields, and nuclear accident. This cluster brings together studies focused on technological risks and public perceptions associated with radiation exposure or industrial accidents, with significant influence from regulatory agencies and public policies.

The Strong Blue Cluster (Risk Behavior and Perception) with 72 items incorporates concepts such as behavior change, emotion, questionnaires, leadership, and attitude toward health. It groups together studies focused on the role of social psychology, individual perception, and emotional response to risk messages. A predominant focus is on qualitative and mixed methodologies to explore how different audiences process and respond to critical situations. The Yellow Cluster (Pollution and Public Health), consisting of 72 items, links pollution exposure, toxicity, dietary exposure, food contamination, and water pollutants. It highlights a research trend related to the communication of specific environmental risks, especially those related to contaminants in food and water, and their impact on health. Communicating these risks has a significant educational and preventive dimension.

The Violet Cluster (Childhood, Health, and Consumer Affairs) with 71 items includes child, infant, medical information, consumer, and fish, highlighting topics related to pediatric health and exposure to risks arising from consumer affairs. It has a biomedical and health-policy focus.

The visualization of this network reveals a cohesive yet diverse semantic structure. The focus on public health, climate change, and environmental risks as key topics demonstrates the

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growing interdisciplinary nature of risk communication studies. Furthermore, the emergence of terms related to perception, leadership, and emotions indicates a strong trend toward user-centered approaches and the improvement of communicative effectiveness. Table 1 shows the most frequent terms found in the analysis, which reinforces the network in Figure 1 with concrete data.

Table 1. Most frequent terms

Key term	Frequency	Links	Cluster
risk communication	562	5335	red
risk assessment	415	5549	red
perception of risk	302	3659	red
public health	238	3769	green
climate change	234	2204	red
communication	222	3091	green
usa	132	2019	brown
risk management	132	1879	red
environmental exposure	129	2378	violet
decision making	100	1319	red

Source: Authors based on SCOPUS data

Figure 2 shows the overlay visualization of the co-occurrence network of scientific terms associated with the topic of risk communication. This visualization allows not only for seeing the semantic relationships between key terms but also for analyzing the temporal dynamics of their appearance or impact (such as the average year of publication). Each node represents a key term (co-occurrences in titles, abstracts, or keywords). The connections between nodes indicate that these terms frequently appear together in scientific documents. The size of the node indicates the frequency of the term, while the color of the node indicates the average year of appearance of the term (according to the color scale): Yellow: most recent terms; Green: middle-aged terms; Blue/Violet: oldest terms.

One of the advantages of this visualization is to observe how emerging terms like COVID-19, trust, resilience, and climate change adaptation connect directly with classic topics like risk communication, public health, and pollution. This indicates a process of thematic updating of the field, in which contemporary challenges reconfigure existing frameworks.

Figure 2. Semantic network (overlay display) on risk communication
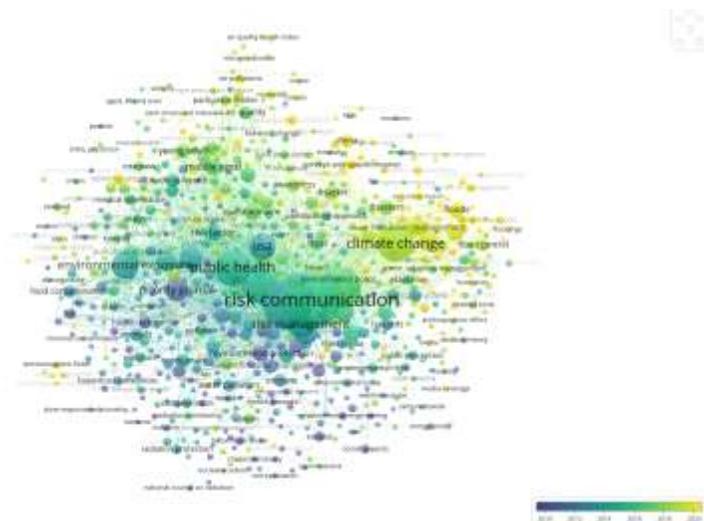
Source: Authors based on SCOPUS data

The most recent trends (2020 onwards) are terms that appear in bright yellow: climate change, disaster management, floods, COVID-19, community resilience, media coverage, trust, and adaptive management. These terms highlight the recent surge in research on risk management in the context of climate and health crises.

Medium-dominant terms have a lime green hue and include concepts such as air pollution, particulate matter, risk perception, awareness, and public perception. These terms indicate topics that have continued but are linked to recent interests, such as public perception of pollution.

On the other hand, traditional and established terms in shades of blue and violet, such as radiation protection, pollution, toxic substances, public health, environmental exposure, and animals, reflect the roots of the field, which focus on chemical risks, environmental exposure, and toxicology. The above can be seen in Table 2.

Table 2. Key points of the overlay display

Thematic area	Temporal Trend	Color	Key comment
Climate Change and Resilience	Most recent	Yellow	Emerging post-2020, especially after extreme events and COVID-19.
Public Health and Perception	Continuous	Green	Intersection between social psychology and environmental risk.
Pollution and Toxicology	Traditional	Blue	Foundational field of risk communication.
Technological Risks	Historical	Violet	Radiation and technology as dominant themes prior to 2010.

Source: Authors based on SCOPUS data

Discussions

The results obtained from the co-occurrence analysis reveal a broad and expanding thematic ecosystem around risk communication, highlighting densely interconnected conceptual nodes that reflect contemporary research priorities. The term "risk communication" is positioned as a central axis of the network, closely linked to concepts such as "public health,"

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"risk management," "climate change," and "environmental exposure". This discovery demonstrates that risk communication is beginning to emerge as a valuable interdisciplinary tool for addressing the challenges that generate uncertainties in health and the environment, particularly when epidemics or extreme weather events occur.

The reading of this semantic network suggests that a fundamental shift is taking place in the way the scientific community describes and addresses risk communication. A clear shift can be seen from a technical approach focused on exposure to physical or chemical risks to much richer frameworks that include components related to social perception, public trust, misinformation, and decision-making mechanisms. The emergence of terms such as "trust," "social media," "participatory approach," and "awareness" reveals the importance of social and cognitive aspects within risk management. In a sense, this epistemological shift is in line with the recent global context, particularly the COVID-19 pandemic, which highlighted the urgent need for efficient, rapid, and culturally sustainable communication strategies.

When comparing research findings with the scientific literature, there is a strong overlap. Research by Dong et al. (2021) and Cao et al. (2023) highlights how COVID-19 has driven a transition from the priority structure of risk communication research, which tends to increase the role of institutional trust (Dryhurst et al., 2022) and exposure to fake news in the perception of behavior regarding adherence to health measures. Research by Kouz et al. (2020), for its part, provides evidence of the viralization of false information on social media, pointing to its effects on risk perception. Research by Depoux et al. (2020) and Weible et al. (2020) highlights the thematic overlap between COVID-19 management and climate change management, allowing for cross-learning regarding risk communication strategies, scientific transparency, and social mobilization.

In theory, these results reinforce the concept of risk communication as a transdisciplinary discipline that must include not only technical and scientific knowledge but also contributions from the psychology of risk, the sociology of science, and public communication (Wendling, 2012). In practice, the implications are conclusive, as the capacity for strategic communication within public institutions must be strengthened, in addition to including principles of transparency, bidirectionality, and cultural inclusion in risk messages. Furthermore, platforms that actively combat disinformation must be promoted.

The bibliometric visualization used in this study offers an effective tool for knowledge managers, allowing them to detect thematic gaps, new trends, and nodes of interdisciplinary collaboration. However, the study is not without limitations because the analysis is performed on a specific sample of indexed publications obtained through controlled terms (papers that use different terminology or originate from databases not considered may be inadvertently eliminated). Similarly, the term co-occurrence technique, although powerful for mapping conceptual networks, does not allow for inferring causality or conceptual depth (Catone et al., 2020).

On the other hand, topics such as AI applied to risk management or the use of citizen surveillance technologies are still poorly represented, which could be due both to their novelty and to the fact that they have not yet been consolidated in recurring keywords. However, this alludes to a certain lag between technological innovation and its theoretical integration in the field.

Now, based on the results obtained, it is recommended that future work use qualitative and mixed studies that complement the bibliometric approach, which, with narrative and content analysis, allow for a better understanding of risk communication, as well as searches that

address how risk communication approaches are contingent on geographical and cultural conditions, while also investigating the use of comparative studies between the Global North and the Global South. Another interesting line of research could be to analyze how the arrival of new technologies such as AI, big data, or digital early warning systems can modify the way of communicating risks and their social acceptance, in addition to their ethical perception.

In summary, this bibliometric study not only sheds light on the state of the art in the field of risk communication but also demonstrates a profound transformation in epistemological orientations, in the relationship with global problems, as well as in its capacity to adapt to multidimensional crises. Through a rich and dynamic semantic network, it is verified that risk communication is not only complementary to crisis management but also constitutes a fundamental area for informed governance, community resilience, and, ultimately, collective action.

Conclusions

The study presented here allowed for the identification and mapping of the main thematic areas that define the field of environmental risk communication, revealing a complex, changing, and ever-expanding structure. Through the analysis of co-occurrence of terms, it was evident that this field has been advancing from unidimensional positions focused on technical or health aspects toward a more comprehensive, multidisciplinary, and socio-cognitive conception. The term "risk communication" emerged as the unifying core of a dense network of concepts, among which stand out "public health", "climate change", "risk management", and "environmental exposure", which reflects its growing centrality in global crisis management.

The configuration of this semantic network corroborates the fact that current research priorities not only focus on the content of risk but also on the mechanisms of transmission, perception, and social adaptation. Thus, issues such as trust, public perception, participatory approaches, and misinformation have gained critical relevance, which is a symptom of a transformation in the way the relationships between science, citizenship, and decision-making are conceived. This theoretical and practical transformation finds support in various recent studies, particularly those conducted in the context of the COVID-19 pandemic, which have emphasized the central role of transparent communication, scientific literacy, and community engagement.

A critical reading of the information obtained leads to the conclusion that risk communication is not only a technical dimension of risk management but also a structural element of contemporary governance, as well as an element in building resilient, prepared, and informed societies. The analysis is extremely useful for researchers, policymakers, and communicators, as it allows for the identification of emerging trends, thematic gaps, or opportunities for interdisciplinary interaction.

Finally, it is assumed that a bibliometric approach has limitations regarding the qualitative depth of concepts and the exclusion of terms not indexed in formal databases. Therefore, it is considered appropriate to complement this type of work through qualitative and contextualized approaches capable of capturing the many dimensions, such as symbolic, cultural, and emotional, that articulate the ways of perceiving and communicating risks in different social realities. Ultimately, advancing environmental risk communication not only requires more research but also more human connection, more social listening, and more political creativity.

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