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A GREEN APPROACH ON RISK MANAGEMENT: EXPLORING CONSTRUCTS IN A CONCEPT MAPPING FRAMEWORK

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Purpose: The study aims to explore the constructs within concept mapping related to the concept of green risk management and to assess the chronological development of this academic discussion through the analysis of bibliographic data.
Design/methodology/approach: Using SciMAT software, a systematic review was conducted of 493 academic articles in the Scopus database, selected according to the PRISMA statement guidelines and published between 2000 and 2024.
Findings: The study reveals a growing academic interest in green risk management, particularly in integrating environmental, social, and governance (ESG) factors into traditional risk frameworks. Key research themes identified include sustainable supply chains, green building, ESG-focused investment, and public sector financial risk management. The analysis highlights a substantial rise in both publication and citation rates on these topics over the past five years, signaling their importance in risk management discourse.
Research limitations/implications: The field remains at an early development stage, with theoretical foundations not yet fully established. The research gap points to opportunities for future studies, specifically in systematizing theories and creating robust models that integrate environmental and social considerations within risk management frameworks.
Practical implications: Findings underscore the necessity for businesses to implement proactive risk management strategies, especially in supply chain sustainability, green construction, and ESG investments. The study suggests that regulatory frameworks and automated supplier risk assessments are critical for enhancing resilience and meeting stakeholder expectations.
Social implications: By promoting a holistic view of risk that includes social and environmental dimensions, the research may guide corporate social responsibility (CSR) and public policies, fostering greater transparency and environmental accountability. This shift in risk management could encourage sustainable practices that improve quality of life and align with societal values.
Originality/value: The paper contributes novel insights by tracking the thematic evolution of green risk management, offering value to academics and practitioners in finance, management, and sustainability. The use of SciMAT software provides an innovative method for visualizing thematic development, making this research a valuable resource for understanding the maturation of green risk management.
Keywords: Risk management, Sustainable Development, Bibliometric analysis, Systematic literature review, Scopus.
Category of the paper: Research paper.

1. Introduction

The integration of sustainability into an organization's risk management framework is increasingly recognized as a critical factor in achieving long-term viability and resilience. As organizations face a growing array of environmental, social, and governance (ESG) risks, traditional risk management paradigms must evolve to incorporate sustainability considerations. This evolution is driven by the need to address a broader spectrum of risks that not only threaten financial performance but also impact social and environmental outcomes. Sustainability acts as a catalyst for enhancing risk management practices by necessitating a more comprehensive risk identification process. According to Haywood, sustainability encourages organizations to identify, quantify, and manage risks that extend beyond conventional financial metrics, integrating environmental and social impacts into the risk assessment framework (Haywood, 2021). This perspective is supported by Gomez-Valencia et al., who emphasize the importance of stakeholder perspectives in risk management, advocating for a communicative approach that considers the broader implications of sustainability (Gomez-Valencia et al., 2021). Moreover, the incorporation of sustainability into risk management practices can lead to improved organizational performance. Lambert's study highlights that effective risk communication and reporting are essential for enhancing sustainability performance within manufacturing projects (Lambert, 2023). This aligns with findings from Krysiak, who posits that risk management tools can be effectively aligned with sustainability objectives, thereby fostering a culture of ethical responsibility and proactive risk mitigation (Krysiak, 2009). The integration of sustainability criteria into risk management not only enhances risk prediction but also supports better decision-making processes, as illustrated by Weber et al., who discuss the benefits of including sustainability risks in credit risk assessments (Weber et al., 2008). The relationship between sustainability and risk management is further reinforced by the need for organizations to engage with their supply chains. As noted by Hofmann et al., managing supply chain sustainability risks requires a proactive approach to identifying social and ecological issues that could provoke stakeholder backlash (Hofmann et al., 2013). This proactive stance is echoed by Bakhtawar et al., who argue that extending risk identification to encompass environmental and social risks is vital for project management in sustainability contexts (Bakhtawar et al., 2021). The emphasis on stakeholder engagement and the recognition of the interconnectedness of risks across the supply chain underscore the necessity for organizations to adopt a holistic view of risk management that aligns with sustainability goals. In conclusion, the integration of sustainability into risk management is not merely a trend but a fundamental shift in how organizations approach risk. By recognizing the multifaceted nature of risks associated with sustainability, organizations can enhance their resilience and ensure long-term success. This integration facilitates a more comprehensive understanding of risks, promotes stakeholder engagement, and ultimately leads to improved sustainability performance across various sectors.

A green approach to risk management in the context of sustainability encompasses the integration of environmental and social considerations into traditional risk management frameworks. This approach recognizes that risks are not solely financial but also encompass ecological and social dimensions, which are increasingly critical in today's business environment. The incorporation of sustainability into risk management practices allows organizations to address stakeholder concerns, comply with regulatory requirements, and enhance their long-term viability. One of the primary drivers for adopting a green approach to risk management is the pressure from stakeholders, including consumers, investors, and non-governmental organizations (NGOs), who demand greater accountability regarding environmental and social impacts (Freise, Seuring, 2015). Companies that fail to manage these risks may face reputational damage, legal challenges, and financial losses. For instance, Freise and Seuring highlight that stakeholder management is essential for sustainable supply chain management, indicating that environmental and social risks must be prioritized alongside economic objectives (Freise, Seuring, 2015). This sentiment is echoed by Weber, who emphasizes the importance of integrating environmental credit risk indicators into financial assessments, thereby enhancing transparency and accountability in risk management processes (Weber, 2011). Furthermore, the concept of sustainability risk management (SRM) extends traditional enterprise risk management (ERM) frameworks by focusing specifically on environmental and social responsibility risks (Aziz et al., 2016). This integration is crucial as it allows organizations to identify, assess, and mitigate risks that could adversely affect their sustainability goals. For example, Dobler et al. argue that effective environmental risk management is not merely about compliance but also about achieving superior environmental performance, which is increasingly linked to overall business success (Dobler et al., 2012). This perspective is supported by Xue et al., who found that corporate environmental performance significantly influences firm risk, particularly in industries with substantial environmental impacts (Xue et al., 2019). The implementation of a green approach to risk management also involves the development of comprehensive frameworks that facilitate the identification and assessment of sustainability risks. For instance, Eller et al. propose a method for multidimensional risk identification that disaggregates complex cause-effect relationships into manageable components, allowing for more effective risk analysis in urban water systems (Eller et al., 2016). Similarly, Shao et al. discuss an integrated environmental risk assessment model that addresses various stages of risk management in the chemical industry, highlighting the importance of systematic approaches to managing environmental risks (Shao et al., 2013). In conclusion, a green approach to risk management is essential for organizations aiming to achieve sustainability in their operations. By integrating environmental and social considerations into risk management frameworks, companies can better respond to stakeholder demands, enhance their reputational capital, and ensure long-term viability. This approach not only mitigates risks but also positions organizations to capitalize on opportunities associated with sustainable practices.

Despite the growing interest in green approaches to risk management, there are few academic studies that synthesise the existing body of work in this area, which represents a research gap. With this in mind, the aim of this study is to explore the constructs within concept mapping related to the concept of green risk management and to assess the chronological development of this academic discussion through the analysis of bibliographic data. The study combines bibliometric results and scientific map analysis of 493 articles retrieved from Scopus databases and published in the last 5 years. SciMAT software was used to analyse changes in five consecutive time periods and to show the thematic evolution of the field. This study aims to contribute to the existing body of knowledge on green risk management approach, which has been reviewed in a limited manner thus far (Nyugen, Macchion, 2023, Sipa, Sitek 2024). The aim of this study is to fill previously identified research gaps and contribute to the development of research on green approaches to risk management by:

- to provide a broader perspective on risk management research in the context of sustainable (green) approaches by creating relevant research databases and multifaceted analysis,
- to methodically identify and highlight analysis periods to show the different stages of research development,
- to clearly identify the themes of popular research during each period,
- to measure the strength of connections between themes during each period.

It traces the growth trajectory of this research field, guided by the following research questions:

This study aims to answer the following research questions:

1. What is the size and growth trajectory of the field of green risk management (GRM)?
2. What is the nature of the GRM field in terms of 'performance outcomes', i.e. impact of citations, most influential authors, journals and publications?
3. How do distinctive, emerging and disappearing themes change over time?
4. How have conceptual and thematic threads evolved over time?

The current study adds several original elements to the existing body of knowledge. Firstly, this analysis focused exclusively on research addressing green approaches to risk management in the areas of management and finance, rather than the field of science as a whole. Thus, the approach taken in this way may produce more focused and complementary results.

Furthermore, this study uses SciMAT software to conduct the analysis. Compared to other analytical tools used, such as CiteSpace or VOSViewer, SciMAT is able to reveal the thematic landscape of a given research field at different periods of its development. These results are also presented in four different categories according to the strength of their impact on the development of research in a given period. In addition, SciMAT reveals sub-themes related to the main themes and thus offers a more meaningful understanding of their scope and development. More importantly, SciMAT can identify the thematic evolution of the field,

illuminating the trends and connections of themes in different periods on a single map, which sets this software apart from others.

2. Methods

This research adopts a multi-faceted approach to explore the constructs of risk management from green perspective as a concept mapping framework. This analysis employs the concept mapping technique, a well-established method for visualizing conceptual structures and relationships. The study uses several tools and methods. First, abstracts and citations are searched in leading databases of peer-reviewed scientific publications (e.g. Scopus). The decision was taken to concentrate the study on the analysis of data from the SCOPUS database, given that it indexes a greater number of journals in the fields of management, economics and finance than other databases, such as Web of Science. In order to identify the most recent trends, a temporal limitation was imposed, restricting the search to articles published in the last five years. In order to extract relevant articles that directly relate to risk management in the context of the green approach, the data search was initially guided by the titles, abstracts and keywords of the articles, with the objective of focusing the search on keywords in the next step. The search was conducted according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Page et al., 2020). The bibliometric dataset was selected by searching for the terms 'risk management' and 'sustainability' or 'green'. The author's dataset was then analysed using the specialist scientific mapping software SciMAT (v1.1.04). It should be noted that this study focuses on knowledge mapping as a distinct approach from a systematic literature review. The methodologies employed in scientific mapping encompass co-citation analysis, co-expression analysis and the examination of collaborative networks. These techniques facilitate the construction of a comprehensive representation of the scientific landscape (Gonzales-Aguilar, 2023; Cobo et al., 2011). The creation of visual representations through scientific mapping enables the illustration of intricate relationships and trends within a given field. This facilitates the identification of areas of interest and potential avenues for further research (Martins et al., 2022; Cobo et al., 2012). Although the SciMAT software is not among the most widely used bibliometric mapping tools (these include VOSviewer, CiteSpace and Bibliometrix (Tomaszewski, 2023; Colina Vargas et al., 2022; Gorzeń-Mitka, Wieczorek-Kosmala, 2024), it has been found to be particularly useful for exploring and tracking the process of research development, as it is the only open access software of its kind that allows the evolutionary exploration of research. It also stands out, among other things, for the versatility of its database preprocessing options (available methods for deduplication process, time slice, stop words and data editing) (Moral-Muñoz et al., 2020).

3. Results

The analysis of the bibliometric data reveals several key insights on the development of research on green approaches to risk management. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram in Figure 1 illustrates the process of building a knowledge base of constructs related to risk management in the context of sustainability and green approaches. An initial search was conducted in May 2024, resulting in the retrieval of 93 556 documents. The criteria for the inclusion of documents for further analysis from this extensive collection were based on those illustrated in Figure 1. Finally, in the process of mapping knowledge on green approaches in risk management, data on 493 scientific papers was used for analysis.

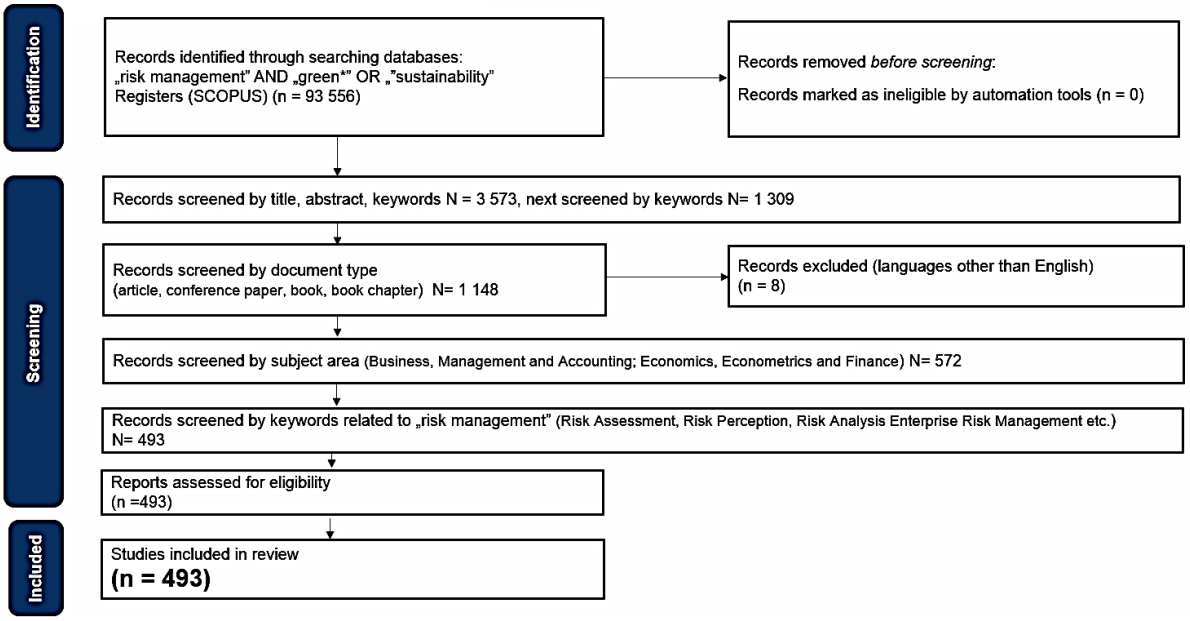

Figure 1. Mapping green risk management constructs - the PRISMA flow diagram.
Source: own elaboration.

As a first step, a bibliometric performance analysis was conducted. The resulting metadata was uploaded to SciMAT and subjected to a bibliometric analysis. This analysis included the calculation of the annual distribution of publications and citations (Figure 2). Figure 2 illustrates the number of papers published annually, with the dashed line indicating the number of citations received. The initial publications addressing risk management within the context of a balanced approach were released in 2004. Thereafter, a gradual increase in the number of publications can be observed. The last five years have seen a surge in both the number of publications and citation trends on this topic. The examination of these trends over the past five years is the subject of further detailed analyses.

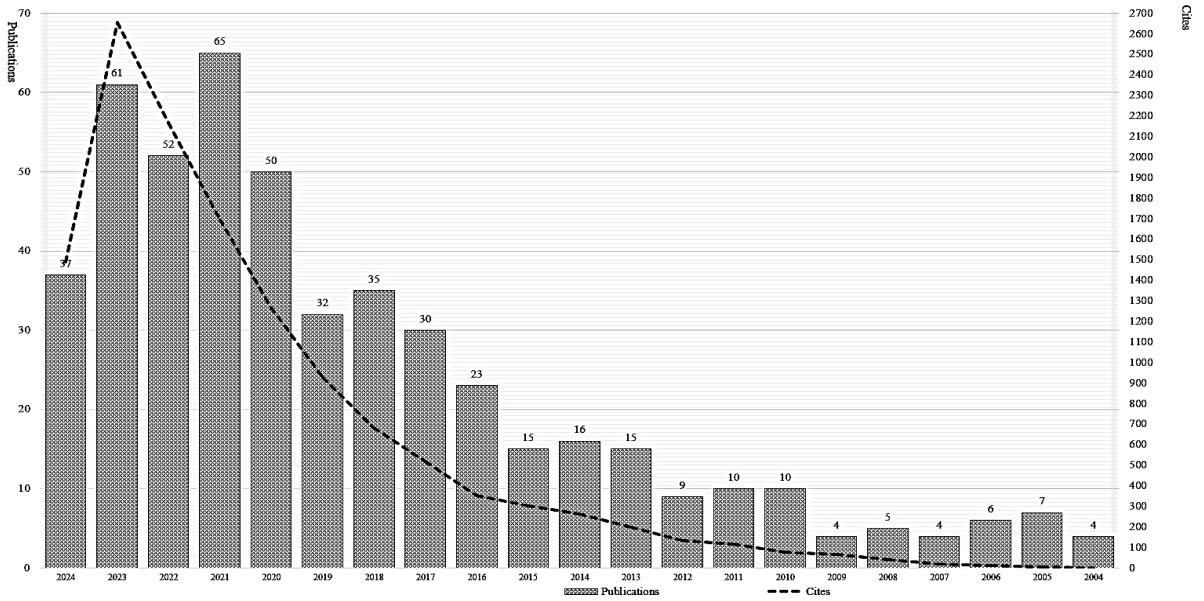

Figure 2. Mapping green risk management constructs - distribution of publication and citations by year. Source: own elaboration.

Table 1 indicates the ten most-cited papers related to different aspects of risk management in the context of a sustainable approach. Despite the earlier indication that the first papers in the selected set of publications date back to 2024, four of the ten most-cited papers are from the last five years, including the publication with the highest total number of citations and the highest citation index per year. The paper most frequently cited by Škare, Soriano and Porada-Rochoń (2021) analyses the impact of the Covid-19 pandemic on the tourism sector, identifying a number of key aspects that shape the current tourism landscape. The article highlights the necessity for the tourism sector to adapt to a new reality in which technological innovation and sustainability are becoming pivotal factors. In the context of a pandemic, the authors propose that tourism models must incorporate social responsibility and long-term sustainability in order to attract tourists in the future (Abbas et al., 2021). It is notable that a significant proportion of the most frequently cited papers (up to four out of ten) address the topic of sustainable risk management in the context of supply chain issues. The study conducted by Giannakis and Papadopoulos (2016) offers significant insights into the function of risk management in the context of supply chain sustainability. Furthermore, the authors contend that effective sustainability risk management is crucial for long-term success and operational efficiency in today's complex business environment. In this regard, they corroborate and extend the conclusions previously established by Govindan et al. (2014), who underscored the significance of integrating sustainability practices into operational strategies and collaborating with stakeholders to attain long-term benefits for both companies and the environment. The most frequently cited studies on the topic of supply chain management in the context of sustainable risk management employed the TOPSIS-CRITIC approach (Abdel-Basset, Mohamed 2020; Rostamzadeh et al., 2018). Other papers have conducted analyses of sustainable risk management in relation to the challenges of transformational processes in sustainable

production: (Pusavec et al., 2010), Industry 4.0 (Birkel et al., 2019), oil and gas pipelines (Shahriar et al., 2012) and smart cities governance (Ullah et al., 2021).

Table 1.
Mapping green risk management constructs – top 10 of the most cited papers

General rank (by TC)	TITLE OF THE PAPER	AUTHOR	JOUR.	YEAR	TC	TCY
1	Impact of COVID-19 on the travel and tourism industry	Škare, M., Soriano, D.R., Porada-Rochoń, M.	TFSC	2021	488	122
2	Supply chain sustainability: A risk management approach	Giannakis, M., Papadopoulos, T.	IJPE	2016	487	60,9
3	Transitioning to sustainable production - Part I: application on machining technologies	Pusavec, F., Krajnik, P., Kopac, J.	JCP	2010	419	32,2
4	Evaluation of sustainable supply chain risk management using an integrated fuzzy TOPSIS-CRITIC approach	Rostamzadeh, R., Ghorabaee, M.K., Govindan, K., Esmaeili, A., Nobar, H.B.K.	JCP	2018	298	59,6
5	Development of a risk framework for Industry 4.0 in the context of sustainability for established manufacturers	Birkel, H.S., Veile, J.W., Müller, J.M., Hartmann, E., Voigt, K.I.	S	2019	282	70,5
6	A methodology to identify sustainability indicators in construction project management - Application to infrastructure projects in Spain	Fernández-Sánchez, G., Rodríguez-López, F.	EI	2010	275	21,2
7	Risk analysis for oil & gas pipelines: A sustainability assessment approach using fuzzy based bow-tie analysis	Shahriar, A., Sadiq, R., Tesfamariam, S.	JLPPI	2012	265	24,1
8	Impact of supply chain management practices on sustainability	Govindan, K., Azevedo, S.G., Carvalho, H., Cruz-Machado, V.	JCP	2014	249	27,7
9	A novel plithogenic TOPSIS- CRITIC model for sustainable supply chain risk management	Abdel-Basset, M., Mohamed, R.	JCP	2020	237	79,0
10	Risk management in sustainable smart cities governance: A TOE framework	Ullah, F., Qayyum, S., Thaheem, M.J., Al-Turjman, F., Sepasgozar, S.M.	TFSC	2021	169	56,3

Abbreviations: JOUR. = Journal; TC = Total citations; TCY = Total citations per year; TFSC = Technological Forecasting and Social Change; CG_IR = International Journal of Production Economics; JCP = Journal of Cleaner Production; EI = Ecological Indicators; S = Sustainability; JLPPI = Journal of Loss Prevention in the Process Industries.

Source: own elaboration.

Furthermore, it is noteworthy that four of the most frequently cited papers on this topic were published in the Journal of Cleaner Production. This is corroborated by a list of the top 10 journals that adopt a sustainable (green) approach to risk management (Table 2). The most frequently published articles in the area were those appearing in Sustainability journal. Of these journals, half are indexed in the ABS journal quality ranking. An analysis of the impact and citation rates of the journals provides confirmation of the quality of the research on this topic. Six out of the ten journals have a Journal Impact Factor greater than ten, while eight out of the ten journals have a Citescore greater than ten, which undoubtedly confirms that a sustainable approach to risk management is currently one of the major research trends in recognized journals.

Table 2.
Mapping green risk management constructs – Top 10 of the most influential journals

Rank	Journal	Document counts	Percentage	Journal Impact Factor™ *	CiteScore*	ABS Ranking **
1	Sustainability (Switzerland)	81	**16,43**	3,9	6,8	n/a
2	Journal of Cleaner Production	27	5,46	11,1	20,4	**2**
3	Environmental Science And Policy	12	2,43	6,0	10,9	**3**
4	Ecological Indicators	12	2,43	6,9	11,8	n/a
5	Resources Policy	9	1,82	10,2	13,4	**2**
6	Business Strategy and the Environment	8	1,62	13,4	22,5	**3**
7	Technological Forecasting and Social Change	7	1,41	12,0	21,3	**3**
8	Water Switzerland	6	1,21	3,4	5,8	n/a
9	Sustainable Cities and Society	6	1,21	11,7	22,0	n/a
10	Resources, Conservation and Recycling	6	1,21	22,9	13,2	n/a

Note: * - 2023 year; ** - 2022; *** - SCOPUS database.

Source: own elaboration.

The following section presents the results of a scientific mapping analysis conducted using the SciMAT software. This analysis identifies the thematic structure and evolution of risk management research that incorporates a sustainable (green) approach over the last five years.

The principal strands of research in each year are discussed in order to illustrate the nature of each of the main themes and sub-themes. The main themes have been identified from the analysis of the strategy diagrams (left side of figures 3-10) while the sub-themes have been identified from the thematic network analysis of the main themes (right side of figures 3-10). The latter provide additional insight into the development of the main themes. Furthermore, as the objective of this article is to examine the latest trends and potentialities in research, the indications of quadrants III and IV in the strategy diagrams are described in detail. Quadrant III (the bottom-left quadrant of the strategy diagram) indicates underdeveloped themes of marginal importance (low density and low centrality according to Cobo et al., 2012) for the research domain. This may indicate the emergence or decline of themes. Quadrant IV (bottom-right quadrant of the strategy diagram) indicates underdeveloped themes of high importance (low density and high centrality according to Cobo et al., 2012) for the research domain. These may be cross-cutting themes that are relevant to the research field but have yet to be fully explored.

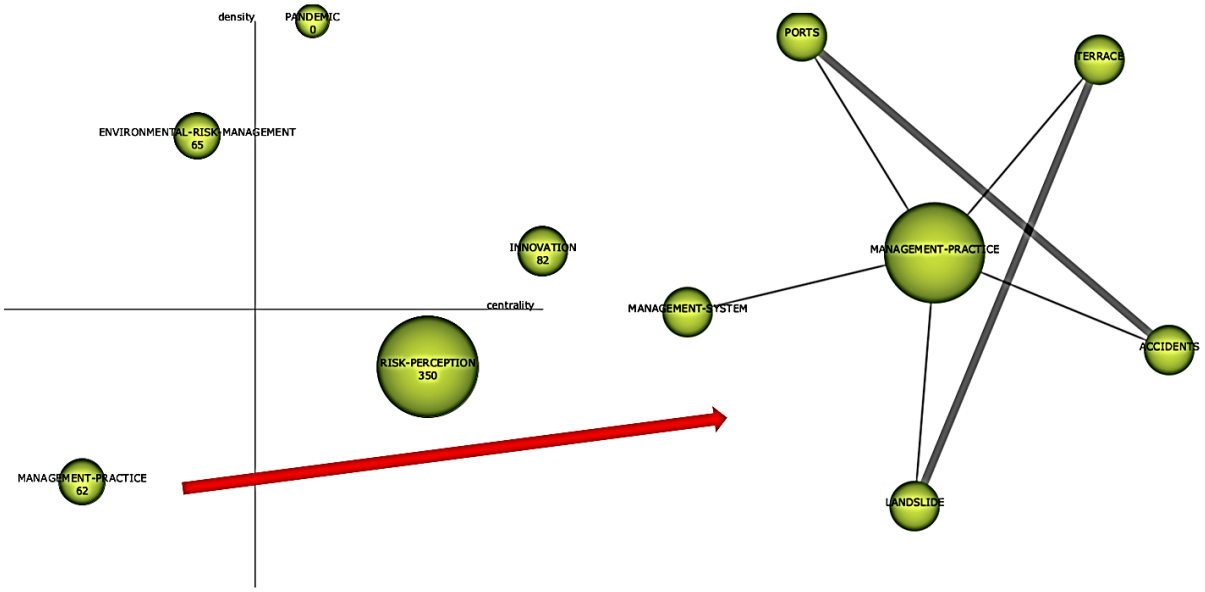

Figure 3. Mapping green risk management constructs - strategic chart (left) and thematic network (right) - 2020 quadrant 3.

Source: own elaboration.

An analysis of Figure 3 shows that research analysing management practices was relevant to the development of research on risk management in the context of a green approach. Work from this period demonstrates the importance of integrating risk management and sustainability in a variety of business areas (Addison et al., 2020; Kadir et al., 2020). The implementation of risk management frameworks and sustainability indicators is key to achieving results that are consistent with responsible development and environmental protection, which are central to modern governance.

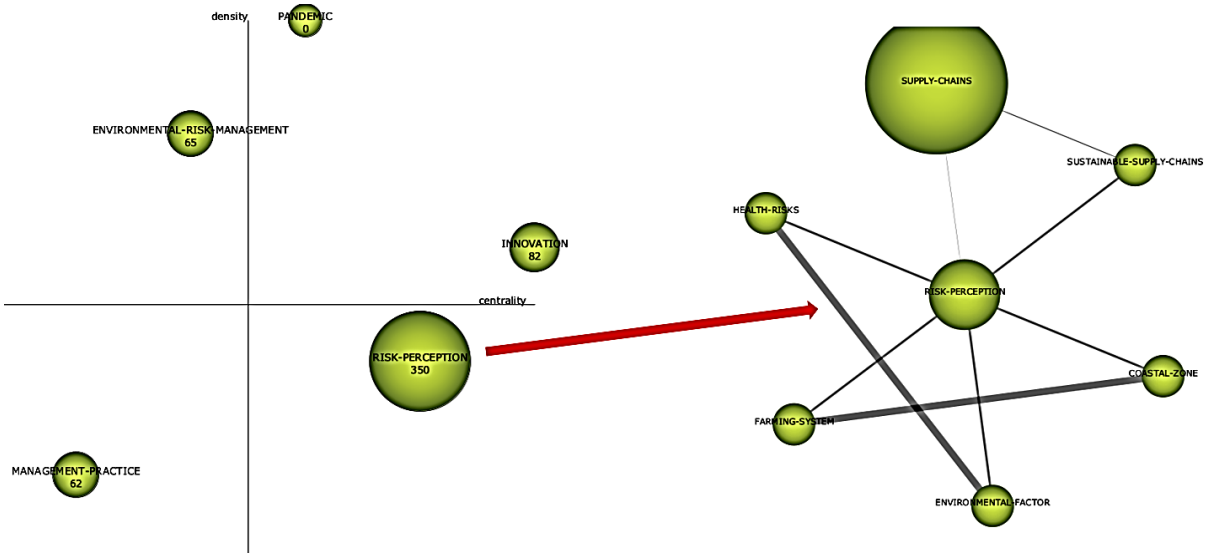

Figure 4. Mapping green risk management constructs - strategic chart (left) and thematic network (right) - 2020 quadrant 4.

Source: own elaboration.

The analysis of figure 4 indicates an emerging theme regarding risk perception. Abdel-Basset and Mohamed (2020), presenting a new model for risk management, pointed out the key role of participants' risk perception, which can vary according to their positions and roles. Adopting this approach allows risk management activities to be aligned with participants' actual concerns and perceived risks, which can improve their effectiveness. This is supported by research by Hallikas, Lintukangas and Kähkönen (2020), who showed that sustainability practices can influence the perception of risk within companies, contributing to a more informed approach to risks associated with supply uncertainty and environmental hazards. Sustainability can shape an organisational culture in which risk is seen as an integral part of strategy, rather than simply a threat to be eliminated.

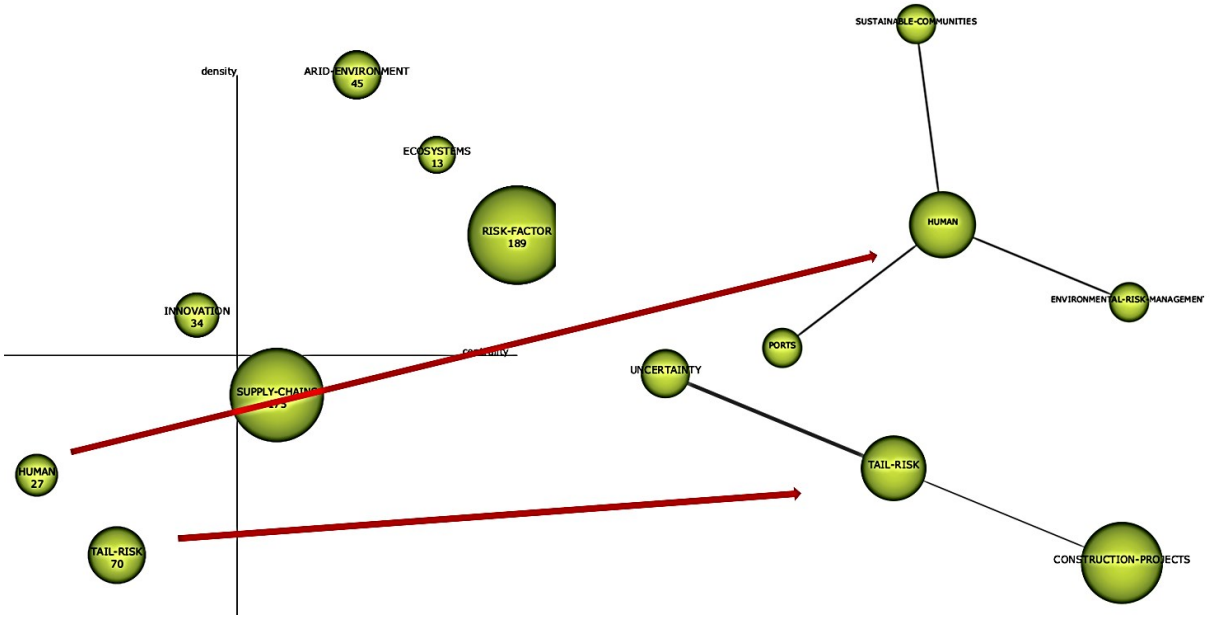

Figure 5. Mapping green risk management constructs - strategic chart (left) and thematic network (right) – 2021 quadrant 3.

Source: own elaboration.

An analysis of Figure 5 shows that research on tail risk analysis and human aspects has been relevant to the development of risk management research in the context of a green approach. Work from this period highlights the importance of tail risk management as a key element in several areas: sustainable construction and public finance (Qazi et al., 2021; Zenios et al., 2021). In the context of construction projects, tail risk management helps to better prepare for unexpected, extreme events that can affect the success and sustainability of a project. In public debt financing, identifying and managing tail risks enables sustainable debt management, which contributes to economic stability and the protection of public interests.

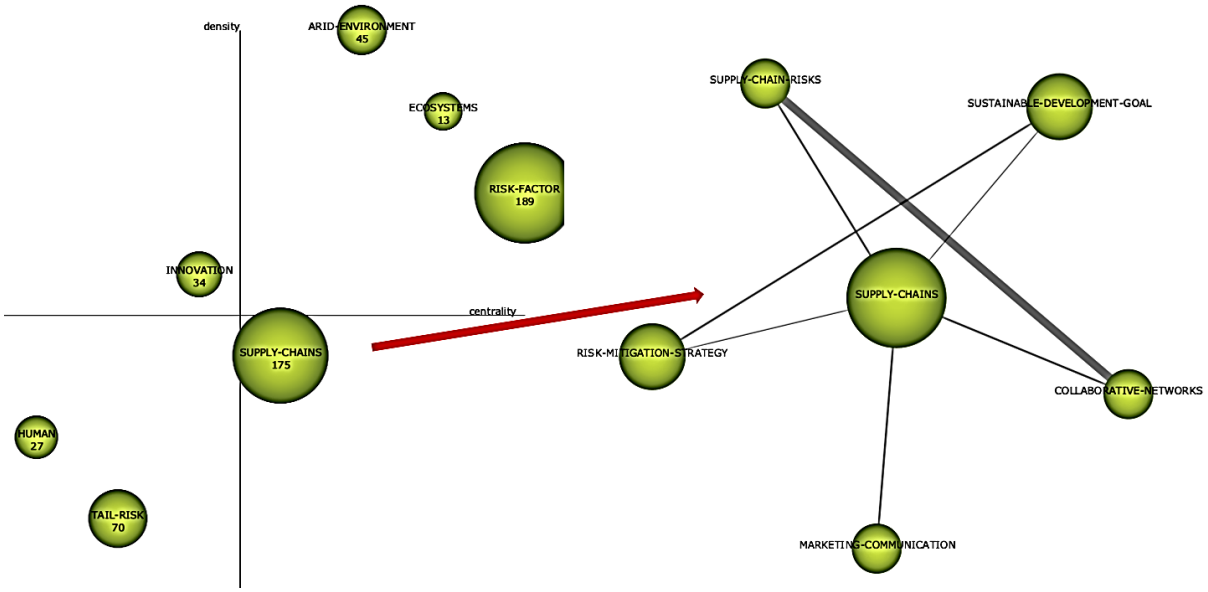

Figure 6. Mapping green risk management constructs - strategic chart (left) and thematic network (right) – 2021 quadrant 4.

Source: own elaboration.

An analysis of Figure 6 shows that there has been mainstream research in the area of risk management in the context of a green approach, with research on supply chain issues. Work from this period emphasises the need for supply chains to evolve towards more sustainable, resilient and technology-based solutions to meet the challenges of modern markets (Fan et al., 2021; Kumar et al., 2021).

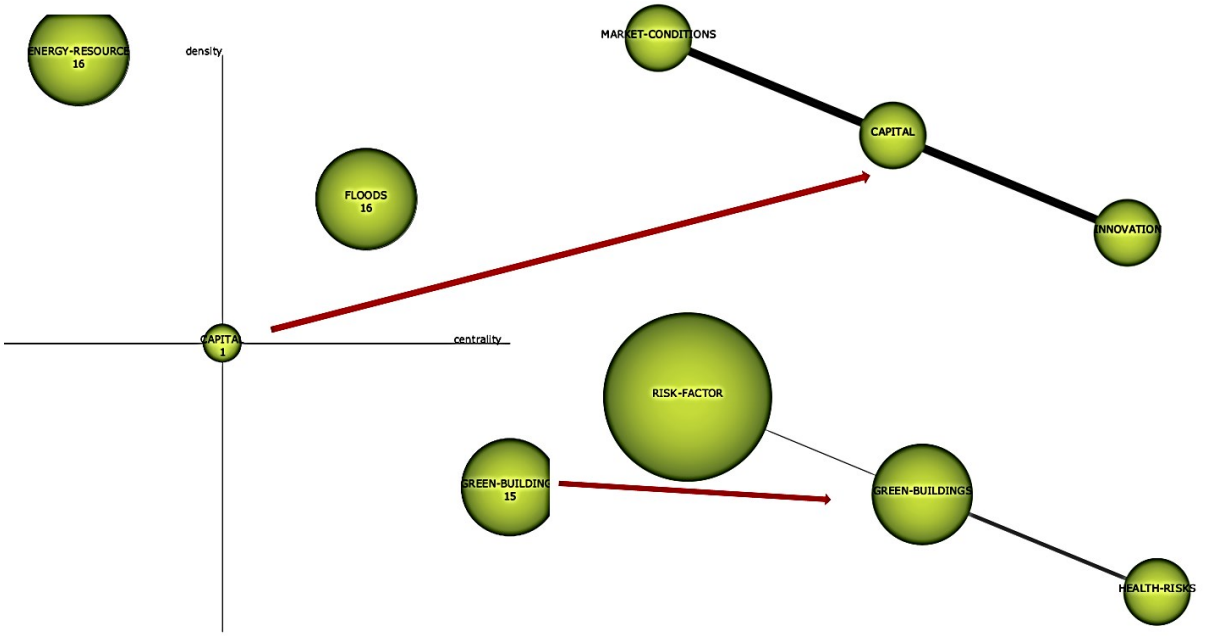

Figure 7. Mapping green risk management constructs - strategic chart (left) and thematic network (right) – 2022 quadrant 4

Source: own elaboration.

An analysis of Figure 7 shows that there has been mainstream research on green building issues in the context of risk management. Work from this period points to different aspects and challenges that are central to green risk management. In the context of sustainable construction, effective risk management means adapting assessment tools, removing financial and technological barriers, and building a stable legal and educational framework (Nguyen, Macchion, 2022; Błach, Klimontowicz, 2021). Such a multi-faceted risk management strategy is essential for the successful implementation of green building projects, especially in resource-constrained environments and emerging markets.

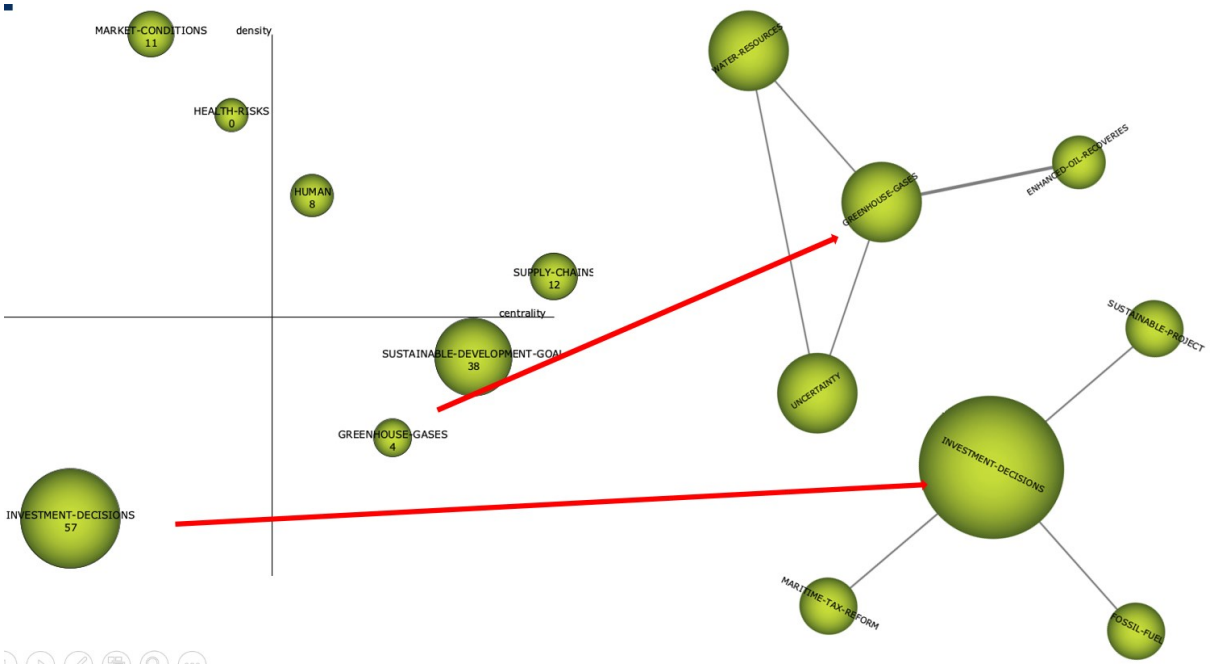

Figure 8. Mapping green risk management constructs - strategic chart (left) and thematic network (right) – 2023 quadrant 3 and 4.

Source: own elaboration.

The analysis of Figure 8 shows that research on risk management in sustainability investing has developed over the next period. They confirm that the integration of ESG factors is crucial for sound investment decisions, pointing in particular to the role of risks arising from the lack of technological synergies and ESG management, the instability of subsidy and incentive policies, the lack of standards and risk assessments of green finance (Alkaraan et al., 2023; Algarvio, 2023). Thus, they suggest that the key challenge in green risk management remains the creation of stable, predictable policy and regulatory frameworks, the implementation of which will minimize the risks associated with sustainability investments.

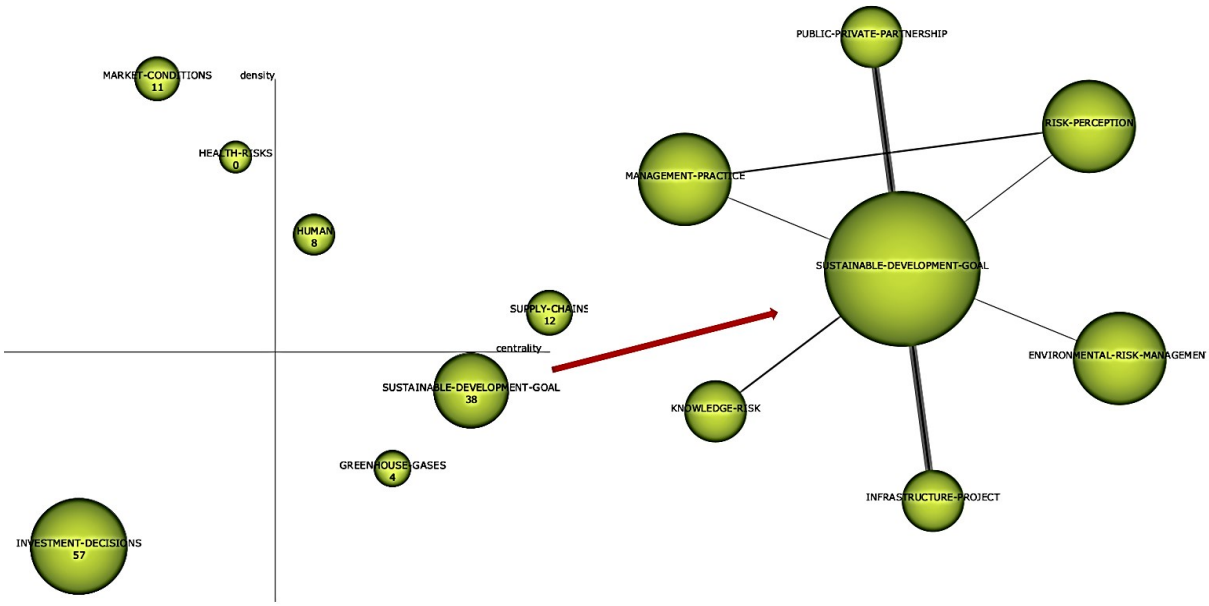

Figure 9. Mapping green risk management constructs - strategic chart (left) and thematic network (right) – 2023 quadrant 4.

Source: own elaboration.

The analysis of figure 9 shows that the research on risk management developed in the subsequent period points to the need for an integrated approach to risk management, taking into account the complexity and the need for clear regulation and access to resources, a holistic approach, transparency of information, while looking critically at the SDG indicators (Akomea-Frimpong et al., 2023; Eckert, Giacona, 2023; Lyytimäki et al., 2023). Research from this period highlights the importance of comprehensive risk management, taking into account environmental, social and information risks, which is crucial for effective green risk management.

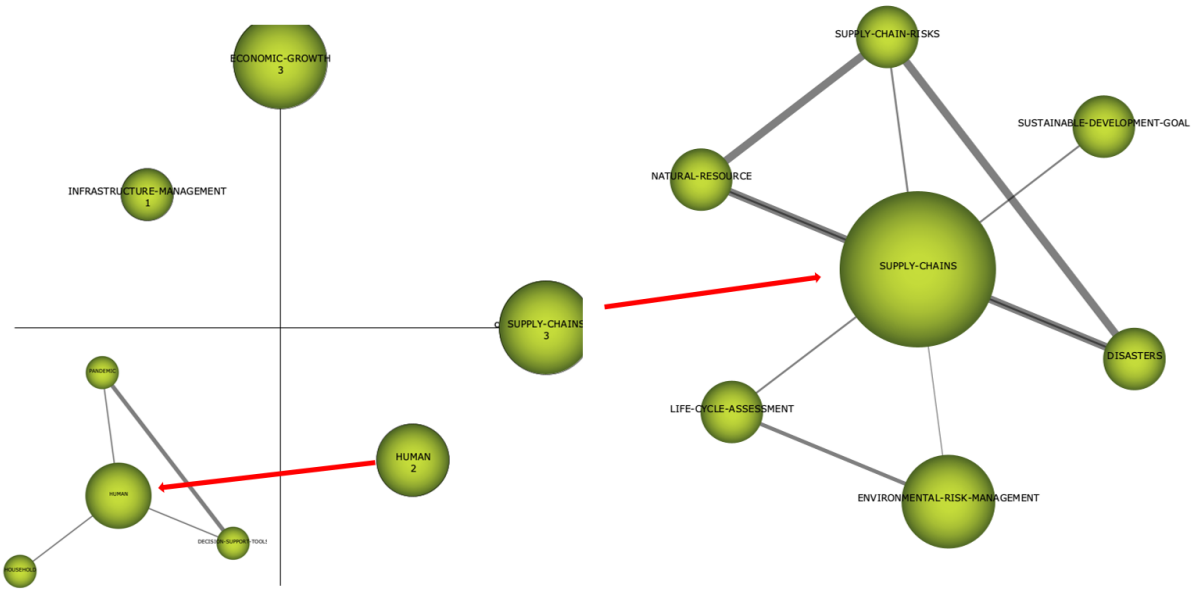

Figure 10. Mapping green risk management constructs - strategic chart (left) and thematic network (right) – 2024 quadrant 4.

Source: own elaboration.

Analysis of Figure 10 shows that recent research on supply chain issues has continued and research on intellectual capital issues has developed. Recent research makes important contributions to the development of green risk management, including the need to automate supplier risk assessment (Chiu et al., 2024), the role of education and CSR as a tool in green risk management and the role of intellectual capital as a basis for building risk resilience (Nazir et al., 2024). Studies continue to support an integrated approach to risk management (Scolobig et al., 2024) as relevant to understanding the interconnectedness of different types of risk and the importance of collaboration and data sharing.

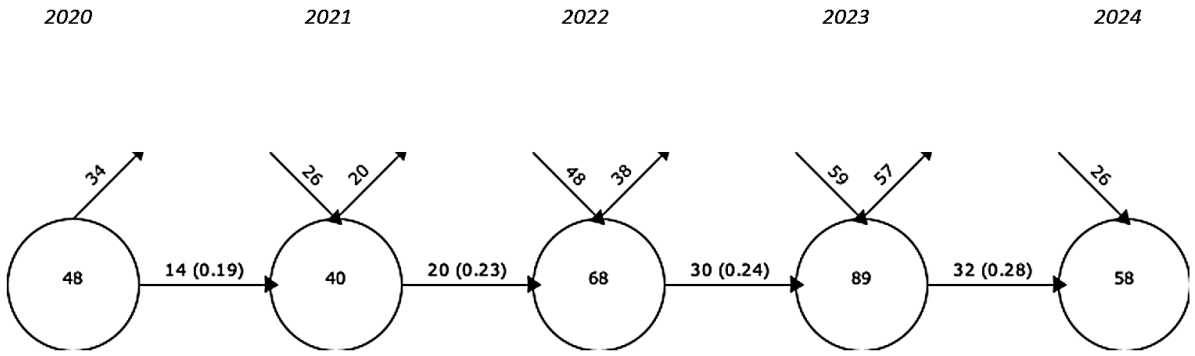

Figure 11. Mapping green risk management constructs - the overlay graph (2020-2024).
Source: own elaboration.

The next step was to analyse the data presented in the overlay graph (Fig. 11). It shows the number of keywords entering and leaving each period (arrows to and around the circles), the number of keywords for consecutive periods (number inside the circle) and, above all, the value of the stability coefficient, which indicates the level of development of the study area. A value of this coefficient close to 1 indicates the maturity of the studied area. The value of the coefficient for green risk management research is currently 0.28, indicating a relatively early stage of development of this research, which is relatively dispersed and lacks established theoretical input. At the same time, the value of the stability index indicates that this is an under-recognised area and therefore one in which researchers may find many research gaps.

The final step in this analysis of green risk management research is to present the identified research trends (discussed in detail earlier in this analysis) together in an evolutionary map (fig. 12). This allows the links between the different areas to be traced over the period analysed.

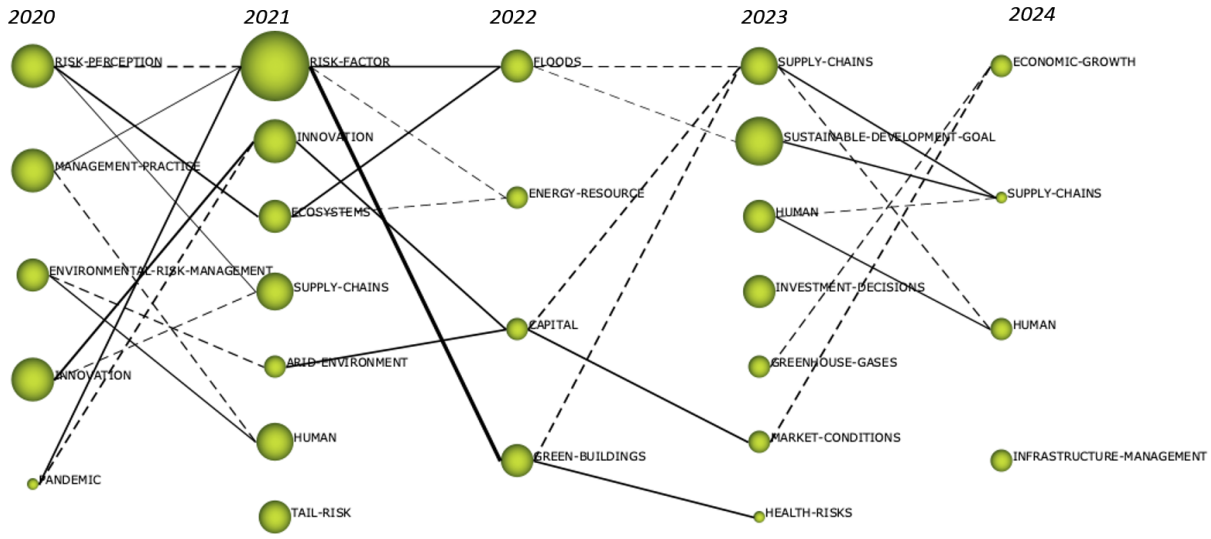

Figure 12. Mapping green risk management constructs - the thematic evolution (2020-2024).
Source: own elaboration.

4. Discussion

This analysis fills an important research gap by identifying dominant, emerging and evolving themes in environmental risk management. In doing so, it helps to place the research discussed in other articles in the context of evolving scientific and practical trends, highlighting the need to integrate technology, intellectual capital, stakeholder engagement and holistic and cross-sectoral approaches in modern environmental risk management practices. This study contributes to a deeper understanding of the evolution of green risk management using analytical tools. In line with research by Moral-Muñoz et al. (2020), among others, the analysis carried out confirms that advanced bibliometric analysis tools make it possible not only to identify major trends, but also to follow the development of key thematic threads. Furthermore, it confirms the relevance of research on risk management in sustainable supply chains, especially in the context of the integration of social and environmental risks in companies' operational strategies and the complexity of modern supply chains (Giannakis, Papadopoulos, 2016; Cui et al., 2024). This research highlights the importance of social aspects and stakeholder engagement as an indispensable component of the effectiveness of companies' green risk management efforts. This perspective can be found, among others, in the work of Freise and Seuring (2015), who highlight the importance of managing stakeholder expectations and their impact on the achievement of a company's environmental and social goals as an approach to reducing reputational risk and increasing transparency of operations. The study shows a low stability coefficient for green risk management (0.28), indicating that the field is still at an early stage of development. This is in line with a study by Martins et al. (2022),

which examines the maturity of different research disciplines, noting the lack of consolidation and high dynamics of change in emerging fields, suggesting ample opportunities for future research in this area. The study highlights that the sustainable approach to risk management is evolving towards a holistic, multi-faceted approach that considers environmental, social and financial risks. These findings are consistent with the work of Billio et al. (2024), who point to the importance of including sustainable risks in credit assessments in the context of transparency and financial accountability of organisations, which determine their long-term sustainability.

In summary, the paper is a valuable development of the existing literature and points to areas for further academic exploration in the field of sustainable risk management.

5. Summary

The study analyses the development of research on green risk management, an approach that integrates environmental and social considerations into a traditional risk management framework. The paper focuses on the identification and development of key research themes and the recognition of their relevance to business and financial practice. The analysis was based on 493 articles from the Scopus database published in the last five years. The SciMAT tool was used, which allows thematic analysis over time and shows the evolution of the research field in the context of green risk management.

Key findings from the analysis include several areas:

1. Increased interest and development of research

   There has been a gradual increase in the number of publications on green risk management since 2004, but there has been a significant increase in both the number of publications and citations over the last five years, indicating the growing importance of the topic. The analysis shows that there has been a particular focus on risk management related to supply chains, sustainable construction, ESG (environmental, social and governance) investment and financial risk management in the public sector.

2. Main and sub-thames

   The analysis identified a variety of main and sub-themes, such as supply chain risk management, green building, sustainable investment management, risk perception and the role of intellectual capital. The SciMAT software used made it possible to track changes over time by classifying themes into main and sub-themes and assessing their relevance. Among other things, it showed that the early stages of the research (2004-2019) were dominated by themes related to risk in sustainable supply chains, which later evolved to include areas such as ESG-related investment risk and intellectual issues in risk management.

3. Research is at a relatively early stage of development
   Research is scattered and the theoretical underpinnings are not well established, suggesting that there are significant research gaps and scope for further research into the underlying constructs of the topic.
4. Identifying and developing key trends
   The issues of risk in green building and risk management in ESG investment have received particular attention in recent years. The findings suggest that the challenge remains to create a stable policy and regulatory framework to effectively support risk management in these areas. The research points to the need for an automated supplier risk assessment system and the growing importance of environmental education and CSR as elements to support long-term sustainability. It also highlights the role of intellectual capital in increasing companies' resilience to risk and supporting a culture of sustainability.

6. Potential for further research

The research suggests that despite growing interest, green risk management remains an area in need of more established theories and research approaches, particularly in terms of research systematisation and conceptual integration with other disciplines. Further research is needed that could focus on the development of robust tools and models, and the integration of environmental and social approaches into risk management.

The paper highlights the critical importance of integrating environmental and social aspects into risk management, indicating that green risk management is evolving towards more complex and integrated approaches. The analysis suggests that companies need to adapt to new market and regulatory requirements, leading to an increasing emphasis on proactive approaches to risk management in areas such as construction, supply chains, finance and ESG.

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References

1. Abbas, J., Mubeen, R., Iorember, P.T., Raza, S., Mamirkulova, G. (2021). Exploring the impact of covid-19 on tourism: transformational potential and implications for a sustainable recovery of the travel and leisure industry. *Current Research in Behavioral Sciences, 2, 100033*. Retrieved from: https://doi.org/10.1016/j.crbeha.2021.100033.
2. Abdel-Basset, M., Mohamed, R. (2020). A novel plithogenic TOPSIS-CRITIC model for sustainable supply chain risk management. *Journal of Cleaner Production, 247*, *119586*.
3. Abdel-Basset, M., Mohamed, R. (2020). A novel plithogenic TOPSIS-CRITIC model for sustainable supply chain risk management. *Journal of Cleaner Production, 247, 119586*.
4. Addison, P.F., Stephenson, P.J., Bull, J.W., Carbone, G., Burgman, M., Burgass, M.J., Milner-Gulland, E.J. (2020). Bringing sustainability to life: A framework to guide biodiversity indicator development for business performance management. *Business Strategy and the Environment, 29(8),* pp. 3303-3313.
5. Akomea-Frimpong, I., Jin, X., Osei-Kyei, R., Kukah, A.S. (2023). Public–private partnerships for sustainable infrastructure development in Ghana: a systematic review and recommendations. *Smart and Sustainable Built Environment, 12(2),* pp. 237-257.
6. Algarvio, H. (2023). The Economic Sustainability of Variable Renewable Energy Considering the Negotiation of Different Support Schemes. *Sustainability, 15(5), 4471.*
7. Alkaraan, F., Elmarzouky, M., Hussainey, K., Venkatesh, V.G. (2023). Sustainable strategic investment decision-making practices in UK companies: The influence of governance mechanisms on synergy between industry 4.0 and circular economy. *Technological Forecasting and Social Change, 187, 122187.*
8. Aziz, N., Manab, N., Othman, S. (2016). Sustainability risk management (srm): an extension of enterprise risk management (erm) concept. *International Journal of Management and Sustainability, 5(1), 1-10*. Retrieved from: https://doi.org/10.18488/ journal.11/ 2016.5.1/11.1.1.10.
9. Bakhtawar, B., Thaheem, M., Arshad, H., Tariq, S., Mazher, K., Zayed, T., Akhtar, N. (2021). A sustainability-based risk assessment for p3 projects using a simulation approach. *Sustainability, 14(1), 344*. Retrieved from: https://doi.org/10.3390/su14010344.
10. Billio, M., Costola, M., Hristova, I., Latino, C., Pelizzon, L. (2024). Sustainable finance: A journey toward ESG and climate risk. *International Review of Environmental and Resource Economics, 18(1-2).*
11. Birkel, H.S., Veile, J.W., Müller, J.M., Hartmann, E., Voigt, K.I. (2019). Development of a risk framework for Industry 4.0 in the context of sustainability for established manufacturers. *Sustainability*, *11*(2), *384.*

12. Błach, J., Klimontowicz, M. (2021). The Determinants of PayTech's success in the mobile payment market—the case of BLIK. *Journal of Risk and Financial Management, 14(9), 422.*
13. Chiu, M.C., Tai, P.Y., Chu, C.Y. (2024). Developing a smart green supplier risk assessment system integrating natural language processing and life cycle assessment based on AHP framework: An empirical study. *Resources, Conservation and Recycling, 207, 107671.*
14. Cobo, M.J., López-Herrera, A.G., Liu, X., Herrera, F. (2012). Scimat: a new science mapping analysis software tool. *Journal of the American Society for Information Science and Technology, 63(8),* pp. 1609-1630. Retrieved from: https://doi.org/10.1002/asi.22688.
15. Cobo, M.J., López-Herrera, A.G., Liu, X., Herrera, F. (2011). Science mapping software tools: review, analysis, and cooperative study among tools. *Journal of the American Society for Information Science and Technology, 62(7),* pp. 1382-1402. Retrieved from: https://doi.org/10.1002/asi.21525
16. Cui, Z., Lu, S., Liu, J. (2024). Research on risk management incentive strategy based on the green financial ecosystem. *Plos One, 19(4), e0300629*.
17. Dobler, M., Lajili, K., Zéghal, D. (2012). Environmental performance, environmental risk and risk management. *Business Strategy and the Environment, 23(1),* pp. 1-17. Retrieved from: https://doi.org/10.1002/bse.1754.
18. Eckert, N., Giacona, F. (2023). Towards a holistic paradigm for long-term snow avalanche risk assessment and mitigation. *Ambio, 52(4),* pp. 711-732.
19. Eller, M., Beck, J., Hedrich, M., Urban, W. (2016). A new sustainability controlling approach for urban water systems: multidimensional risk identification and system analysis. *Journal of Environmental Science and Engineering - A, 5(8).* Retrieved from: https://doi.org/10.17265/2162-5298/2016.08.005
20. Fan, D., Xiao, C., Zhang, X., Guo, Y. (2021). Gaining customer satisfaction through sustainable supplier development: The role of firm reputation and marketing communication. *Transportation Research Part E: Logistics and Transportation Review, 154, 102453.*
21. Freise, M., Seuring, S. (2015). Social and environmental risk management in supply chains: a survey in the clothing industry. *Logistics Research, 8(1).* Retrieved from: https://doi.org/10.1007/s12159-015-0121-8.
22. Freise, M., Seuring, S. (2015). Social and environmental risk management in supply chains: a survey in the clothing industry. *Logistics Research, 8,* pp. 1-12.
23. Giannakis, M., Papadopoulos, T. (2016). Supply chain sustainability: A risk management approach. *International Journal of Production Economics, 171,* pp. 455-470.
24. Gomez-Valencia, M., González-Pérez, M., Gómez-Trujillo, A. (2021). The "six ws" of sustainable development risks. *Business Strategy and the Environment, 30(7),* pp. 3131-3144. Retrieved from: https://doi.org/10.1002/bse.2794.

25. Gonzales-Aguilar, A., Colmenero-Ruiz, M., Paletta, F., Verlaet, L. (2023). Loet leydesdorff: bibliometric analysis and mapping of his scientific production. *El Profesional De La Información*. Retrieved from: https://doi.org/10.3145/epi.2023.dic.09.
26. Gorzeń-Mitka, I., Wieczorek-Kosmala, M. (2023). Mapping the energy sector from a risk management research perspective: A bibliometric and scientific approach. *Energies, 16(4), 2024.*
27. Govindan, K., Azevedo, S.G., Carvalho, H., Cruz-Machado, V. (2014). Impact of supply chain management practices on sustainability. *Journal of Cleaner Production, 85,* pp. 212-225.
28. Hallikas, J., Lintukangas, K., Kähkönen, A.K. (2020). The effects of sustainability practices on the performance of risk management and purchasing. *Journal of Cleaner Production, 263, 121579.*
29. Haywood, L. (2021). Putting risk management into the corporate sustainability context. *Social Responsibility Journal, 18(8), 1485-1504*. Retrieved from: https://doi.org/10.1108/ srj-06-2019-0201.
30. Hofmann, H., Busse, C., Bode, C., Henke, M. (2013). Sustainability-related supply chain risks: conceptualization and management. *Business Strategy and the Environment, 23(3), 160-172*. Retrieved from: https://doi.org/10.1002/bse.1778.
31. Iliescu, A.N. (2024). Green Knowledge Management—Bibliometric Analysis. *Encyclopedia, 4(2),* pp. 923-935.
32. Kadir, A.Z., Mohammad, R., Othman, N., Amrin, A., Muhtazaruddin, M.N., Abu-Bakar, S.H., Muhammad-Sukki, F. (2020). Risk management framework for handling and storage of cargo at major ports in Malaysia towards port sustainability. *Sustainability, 12(2), 516.*
33. Krysiak, F. (2009). Risk management as a tool for sustainability. *Journal of Business Ethics, 85(S3),* pp. 483-492. Retrieved from: https://doi.org/10.1007/s10551-009-0217-7.
34. Kumar, A., Mangla, S.K., Kumar, P., Song, M. (2021). Mitigate risks in perishable food supply chains: Learning from COVID-19. *Technological Forecasting and Social Change, 166, 120643.*
35. Lambert, H. (2023). Effects of project risks management and sustainability of manufacturing industry projects in Rwanda - a case study of Sulfo Industries Ltd. *Cognizance Journal of Multidisciplinary Studies, 3(10),* pp. 361-376. Retrieved from: https://doi.org/10.47760/ cognizance.2023.v03i10.024.
36. Lyytimäki, J., Eckert, N., Lepenies, R., Mosoni, C., Mustajoki, J., Pedersen, A.B. (2023). Assuming accuracy, pretending influence? Risks of measuring, monitoring and reporting sustainable development goals. *Ambio, 52(4),* pp. 702-710.
37. Martins, T., Braga, A., Ferreira, M.R., Braga, V. (2022). Diving into social innovation: a bibliometric analysis. *Administrative Sciences, 12(2), 56*. Retrieved from: https://doi.org/10.3390/admsci12020056.

38. Moral-Muñoz, J.A., Herrera-Viedma, E., Santisteban-Espejo, A., Cobo, M.J. (2020). Software tools for conducting bibliometric analysis in science: An up-to-date review. *Profesional de la Información, 29(1).*
39. Nazir, S., Ali, M., Saeed, M., Mubarik, M.S., Jalil, Q. (2024). Sustainable performance and disaster management in the oil and gas industry: An intellectual capital perspective. *Resources Policy, 92, 105042.*
40. Nguyen, H.D., Macchion, L. (2022). Exploring critical risk factors for Green Building projects in developing countries: The case of Vietnam. *Journal of Cleaner Production, 381, 135138.*
41. Page, M.J., McKenzie, J., Bossuyt, P., Boutron, I., Hoffmann, T., Mulrow, C., Moher, D. (2020). *The PRISMA 2020 statement: an updated guideline for reporting systematic reviews*. Retrieved from: https://doi.org/10.31222/osf.io/v7gm2.
42. Pusavec, F., Krajnik, P., Kopac, J. (2010). Transitioning to sustainable production–Part I: application on machining technologies. *Journal of Cleaner Production, 18(2),* pp. 174-184.
43. Qazi, A., Shamayleh, A., El-Sayegh, S., Formaneck, S. (2021). Prioritizing risks in sustainable construction projects using a risk matrix-based Monte Carlo Simulation approach. *Sustainable Cities and Society, 65, 102576.*
44. Rostamzadeh, R., Ghorabaee, M.K., Govindan, K., Esmaeili, A., Nobar, H.B.K. (2018). Evaluation of sustainable supply chain risk management using an integrated fuzzy TOPSIS-CRITIC approach. *Journal of Cleaner Production, 175,* pp. 651-669.
45. Scolobig, A., Santos, M.J., Willemin, R., Kock, R., Battiston, S., Petchey, O., Stoffel, M. (2024). Learning from COVID-19: A roadmap for integrated risk assessment and management across shocks of pandemics, biodiversity loss, and climate change. *Environmental Science & Policy, 155, 103726.*
46. Shahriar, A., Sadiq, R., Tesfamariam, S. (2012). Risk analysis for oil & gas pipelines: A sustainability assessment approach using fuzzy based bow-tie analysis. *Journal of Loss Prevention in the Process Industries, 25(3),* pp. 505-523.
47. Shao, C., Yang, J., Tian, X., Mei, J., Huang, L. (2013). Integrated environmental risk assessment and whole-process management system in chemical industry parks. *International Journal of Environmental Research and Public Health, 10(4),* pp. 1609-1630. Retrieved from: https://doi.org/10.3390/ijerph10041609.
48. Sipa, M., Sitek, M. (2024). Research Trends in Knowledge Management and Innovation: a Bibliometric Review. *In European Conference on Knowledge Management, Vol. 25, No. 1,* pp. 761-770.
49. Škare, M., Soriano, D.R., Porada-Rochoń, M. (2021). Impact of covid-19 on the travel and tourism industry. *Technological Forecasting and Social Change, 163, 120469*. https://doi.org/10.1016/j.techfore.2020.120469.

50. Tomaszewski, R. (2023). Visibility, impact, and applications of bibliometric software tools through citation analysis. *Scientometrics, 128(7),* pp. 4007-4028.
51. Ullah, F., Qayyum, S., Thaheem, M.J., Al-Turjman, F., Sepasgozar, S.M. (2021). Risk management in sustainable smart cities governance: A TOE framework. *Technological Forecasting and Social Change, 167, 120743.*
52. Weber, O. (2011). Environmental credit risk management in banks and financial service institutions. *Business Strategy and the Environment, 21(4),* pp. 248-263. Retrieved from: https://doi.org/10.1002/bse.737.
53. Weber, O., Scholz, R., Michalik, G. (2008). Incorporating sustainability criteria into credit risk management. *Business Strategy and the Environment, 19(1),* pp. 39-50. Retrieved from: https://doi.org/10.1002/bse.636.
54. Xue, B., Zhang, Z., Li, P. (2019). Corporate environmental performance, environmental management and firm risk. *Business Strategy and the Environment, 29(3),* pp. 1074-1096. Retrieved from: https://doi.org/10.1002/bse.2418.
55. Zenios, S.A., Consiglio, A., Athanasopoulou, M., Moshammer, E., Gavilan, A., Erce, A. (2021). Risk management for sustainable sovereign debt financing. *Operations Research, 69(3),* pp. 755-773.