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Green Innovation in Supply Chain Management: A Theoretical and Bibliometric Analysis of Environmental Gaps

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Abstract

This article examines the evolution of green supply chain management (GSCM) with emphasis on green innovation and sustainability. Through an extensive literature review, we identify theoretical and practical gaps in the environmental dimension of GSCM. We propose a renewed conceptual framework based on three principles: environmental centrality, regenerative innovation, and systemic integration. The article highlights the role of advanced technologies in transforming sustainable supply chains and outlines future research perspectives.

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Introduction

Supply chain management has undergone a major transformation due to the combined impact of technological advances, globalization, and sustainability requirements, which has significantly complicated the current manufacturing landscape (Christopher, 2016). In this evolving context, green supply chain management (GSCM) has become an essential strategy to address increasing ecological and climate challenges.

Today, organizations are increasingly encouraged to improve their sustainable practices due to the growing importance of the environmental dimension (Rao & Patel, 2023). Sustainable supply chain management (GSCM) has as its main objective to reduce ecological impact at all stages of the logistics chain (Sarkis, 2012; Zhu et al., 2013). Despite the profusion of work exploring various aspects of GSCM, the absence of an integrative bibliometric synthesis, as highlighted by Choudhary & Sangwan (2022), hinders a holistic understanding of the field, as pointed out by Dhillon et al. (2023). This fragmentation often leads to underestimation of the importance of methodological rigor and a lack of attention to geographical and sectoral specificities crucial for effective implementation of GSCM principles (Ososanmi et al., 2022).

The objective of this study is to address this gap by conducting an in-depth bibliometric analysis aimed at mapping emerging trends in GSCM and identifying specific gaps in its environmental aspect. The purpose of this approach is to provide researchers and practitioners with a structured reference framework to effectively address crucial challenges related to environmental sustainability in the design and management of contemporary supply chains.

1. Conceptual Evolution of Green Supply Chain Management

1.1 From Traditional Supply Chain Management to Green Supply Chain Management

The field of supply chain management (SCM) has experienced significant evolution since its emergence in the 1980s, evolving from a logistics-focused perspective to an integrated approach encompassing all physical, informational, and financial flows between various stakeholders in a value chain (Lambert and Cooper, 2000).

The concept of sustainability, introduced by the Brundtland Report in 1987, has gradually impacted supply chain theories and practices (WCED, 1987). Elkington (1998) introduced the concept of "triple bottom line," which proposes that organizational performance evaluation should not be limited to economic criteria but should also include environmental and social aspects.

Within the SCM framework, this approach has led to the emergence of the concept of "Sustainable Supply Chain Management" (SSCM), as defined by Seuring and Müller (2008) as "the management of material, information, and capital flows, as well as collaboration among companies within the supply chain, while taking into account the objectives of the three dimensions of sustainable development."

GSCM, or Green Supply Chain Management, focuses on environmental dimensions within SSCM. According to Srivastava's (2007) definition, green supply chain management encompasses the integration of environmental thinking at all stages, from product design to end-

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of-life product management, through material sourcing, manufacturing processes, and distribution of the final product to consumers.

1.2 Conceptual Frameworks of Environmental Innovation in the Supply Chain

Environmental innovation, as defined by Kemp and Pearson (2007) as any new technology, process, or approach aimed at reducing environmental impacts, plays an essential role in the evolution of supply chains. The literature classifies innovation according to its typology (technological/non-technological), degree (incremental/radical), application domain (product/process/organization/marketing), and objective (preventive/curative).

Research on green innovation in supply chains is framed by several theoretical frameworks.

The Theory of Innovation Diffusion, developed by Rogers (2003), aims to explain the process of adoption and propagation of environmental practices within supply networks. It emphasizes the importance of perceived characteristics of innovations (relative advantage, compatibility, complexity, testability, observability) as well as adopter attributes in the diffusion process.

Developed by Lawrence and Lorsch (1967), Contingency Theory suggests that the effectiveness of green innovations in supply chain management essentially depends on their adequacy with specific contextual factors. These elements include industrial configuration, position in the value chain, level of competition, and institutional constraints.

According to Teece and colleagues (1997), Dynamic Capabilities Theory highlights organizations' ability to reconfigure their resources and competencies to effectively develop and implement green innovations in a constantly evolving environment.

Stakeholder Theory, developed by Freeman (1984), explains how various stakeholder pressures impact the integration of sustainable practices.

Finally, Institutional Theory (DiMaggio and Powell, 1983) highlights isomorphism mechanisms that lead to the adoption of similar practices within the same organizational field.

2. Current Research on Green Supply Chain Management

In terms of sustainable supply chain management, it is pertinent to adopt a dual analytical approach. On one hand, in-depth literature analysis allows highlighting fundamental conceptual frameworks, revolutionary technological advances, and emerging circular economic models that influence this research field. On the other hand, bibliometric analysis enables mapping quantitative knowledge, revealing connections between different research and evolution of trends in the studied domain.

Literature examination proposes different conceptual frameworks for green supply chains. Sarkis et al. (2011) consider three essential dimensions: ecological, economic, and social. This method is enriched by the contribution of Seuring and Müller (2008) who propose a structured framework for sustainable supply chain management. Dubey and colleagues (2017) developed a reference framework to evaluate the degree of sustainable practices incorporation within organizations.

In the field of technological innovations and digital transformation, emerging technologies are observed to impact the evolution of green supply chains. According to Ben-Daya et al. (2019), the Internet of Things offers improved traceability and optimization of logistics flows. According to Saberi et al. (2019), blockchain contributes to increasing transparency and integrity of

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environmental data, while artificial intelligence facilitates optimization of logistics networks to reduce carbon footprint, as highlighted by Choi et al. (2018).

This also applies to Circular Economy and reverse logistics, where incorporation of circular economy is observed to profoundly modify supply chain design. Govindan and Soleimani (2017) highlight the growing importance of reverse logistics models and closed-loop chains. Genovese et al. (2017) illuminate synergies between circular economy practices and established sustainable supply chain management frameworks, identifying new innovation opportunities.

However, despite their importance, green supply chains face significant obstacles. Luthra et al. (2016) identified main barriers as high initial costs, lack of technical expertise, and resistance to change. Conversely, Walker and colleagues (2008) emphasize the importance of enabling factors such as management involvement and consumer expectations, while Diabat and Govindan (2011) highlight the role of institutional constraints and anticipated economic benefits.

This conceptualization therefore allows better circumscribing the domain of bibliometric analysis, highlighting the complementarity of these two approaches in understanding green supply chain management. Our analysis of conceptual foundations, green innovation theories, and contemporary trends such as circular economy also allows qualitatively apprehending this domain. Bibliometric analysis is used to improve this approach by providing quantitative and relational mapping of scientific literature.

3. Bibliometric Analysis

This analysis allows us to concretely observe the manifestation of theoretical concepts presented in publications, the formation of research communities around these themes, and especially to identify little-explored areas, particularly in the environmental dimension. By analyzing collaboration networks and thematic groupings, it is possible to transcend individual interpretations to understand collective trends that influence this constantly evolving domain.

3.1 Evolution of Research Over Time and in Different Contexts

It is important to consider significant progress made in this field to understand the evolution of green supply chain research over time, its main field of expression within scientific journals, as well as disciplines that have participated in its development. Chronological analysis is crucial to identify decisive stages of growth or domain mutation, understand its current development level, and anticipate future evolutions.

Examination of the "Documents per Year" graph allows highlighting the chronological progression of publications concerning green supply chains and sustainable innovation from 2015 to 2025.

This illustration highlights three well-defined stages in the evolution of this study domain: a first emerging stage (2015-2018) characterized by a limited but stable number of publications; a second intensification stage (2019-2021) during which publication volume doubled; finally, a third rapid growth stage (2022-2024) reaching more than 160 documents in 2024, representing an eight-fold multiplication compared to 2015.

The increase observed in 2024 confirms the current and contemporary relevance of research focus in this domain. This notable increase testifies to the growing importance given to green supply chains in the face of global environmental challenges and sustainable development objectives.

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This growing trend reinforces the idea of incorporating environmental aspects more explicitly in sustainable supply chain analysis, thus filling a conceptual gap in this booming field.

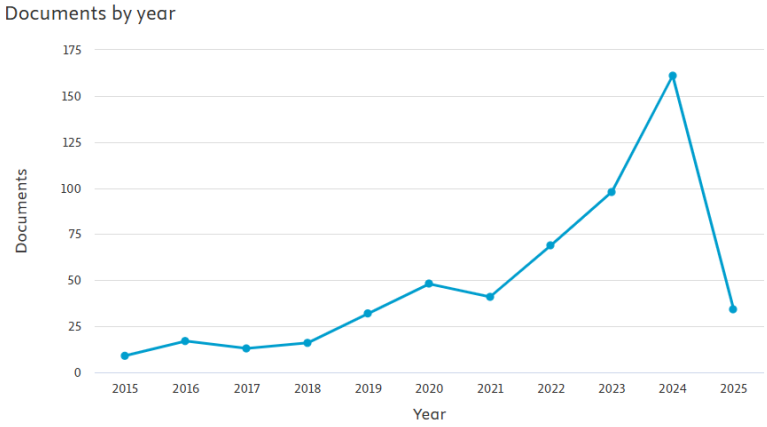


Figure01 : document per year vos viewer

Regarding distribution by academic sources, examination of the "Documents per Year by Source" graph highlights publication trends concerning green supply chains from five main sources. Sustainability in Switzerland occupies a predominant place in the academic field, showing constant growth until reaching a peak of approximately 16 publications in 2024. The "Journal of Cleaner Production" maintains continuous presence throughout the studied period, while "Environmental Science and Pollution Research" shows significant but late emergence between 2021 and 2023. The journals "Business Strategy and the Environment" and "Web of Conferences" provide less significant contribution, characterized by irregular trajectories. The variety of sources from various specialties such as sustainability, cleaner production, and environmental sciences illustrates the interdisciplinary nature of this domain and the growing demand for integration of environmental aspects in sustainable supply chain analysis.

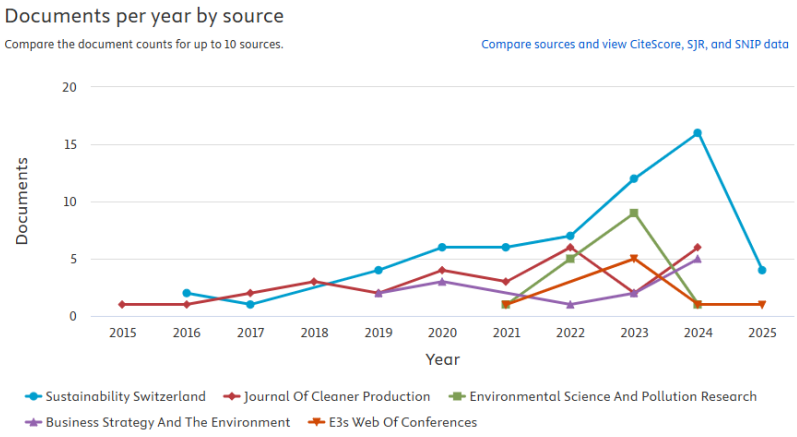


Figure02 : document per year by source vos viewer

Examination of the circular graph "Documents by Study Domain" highlights the disciplinary distribution of publications concerning green supply chains and sustainable innovation. Environmental sciences stand out representing 17.5% of publications, immediately followed by management and business sciences (16.1%) as well as engineering (15.0%). Social sciences also represent an important share at 11.8%, as does the energy sector with 10.6%.

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The diversity of disciplines involved in this research domain highlights its transversal nature, combining environmental sciences and management disciplines. The predominance of engineering and energy highlights the importance of technical and operational aspects, while the contribution of social sciences testifies to consideration of behavioral and societal dimensions.

The under-representation of earth sciences disciplines (1.8%) and mathematics (1.8%) is significant and confirms the previous observation that specific environmental aspects are not sufficiently integrated in this domain. This gap reinforces the necessity to propose research aimed at developing a conceptual framework that more explicitly integrates environmental aspects in sustainable supply chain analysis.

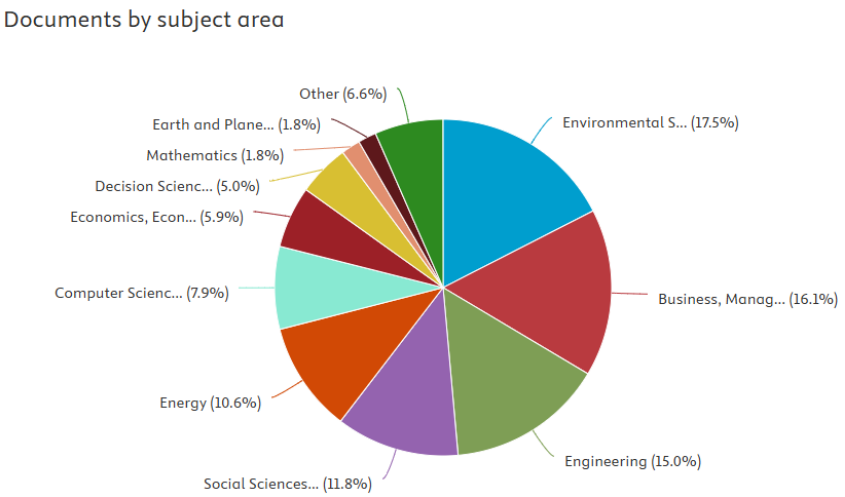


Figure 03: document by subject area scopus

3.2 Global Mapping of Scientific Contributions and Collaborations

This section offers us the possibility to analyze in depth the origin of scientific contributions and underlying collaboration patterns. By jointly analyzing geographical, institutional, and individual distribution of research, as well as associated collaboration networks, it is possible to grasp not only the identity of domain contributors but also how these actors interact to collaborate in creating knowledge on green supply chains.

Cross-examination of the geographical research ecosystem and international collaborations highlights China as the main contributor with approximately 170 publications, followed by India with approximately 75 publications, then the United Kingdom, United States, and Malaysia. Analysis of the collaborative network reveals that this quantitative hierarchy manifests through structural centrality, where China occupies an important nodal position, being mainly connected to the United Kingdom, Malaysia, and Pakistan. In parallel, a European grouping centered on the United Kingdom develops privileged relationships with India and various Asian countries. This polycentric organization, based on transcontinental axes (China-United Kingdom, India-Europe), highlights the global aspect of green supply chain challenges. It also indicates regional diversification of strategies while encouraging exchange of methods and concepts between different scientific communities.

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Figure 04 : collaboration entre pays vos viewer

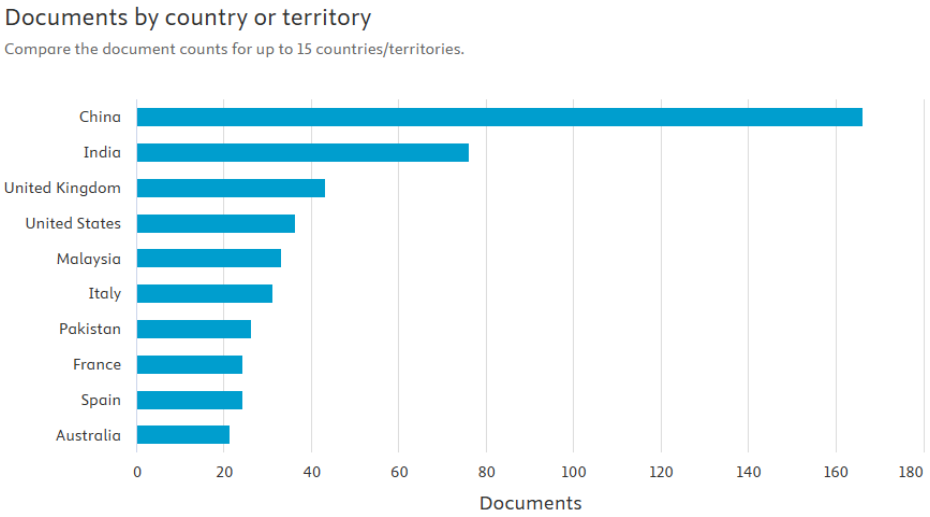


Figure05 : document by county scopus

Regarding cross-analysis of individual contributions and researcher networks, it reveals a hierarchy of influence distinct from productivity in green supply chain research. Sarkis J. dominates by impact (451 citations, link strength 9918), followed by Zhu Q. and Govindan K., establishing conceptual foundations of the domain. Paradoxically, the most productive authors (Garza-Reyes, Khan, Mangla) present lesser citational impact, suggesting emergence of a new generation of researchers actively developing the field. This configuration illustrates the maturation of the green supply chain domain, characterized by coexistence of highly cited founding figures and new prolific contributors, reflecting expansion and diversification of approaches in this emerging discipline.

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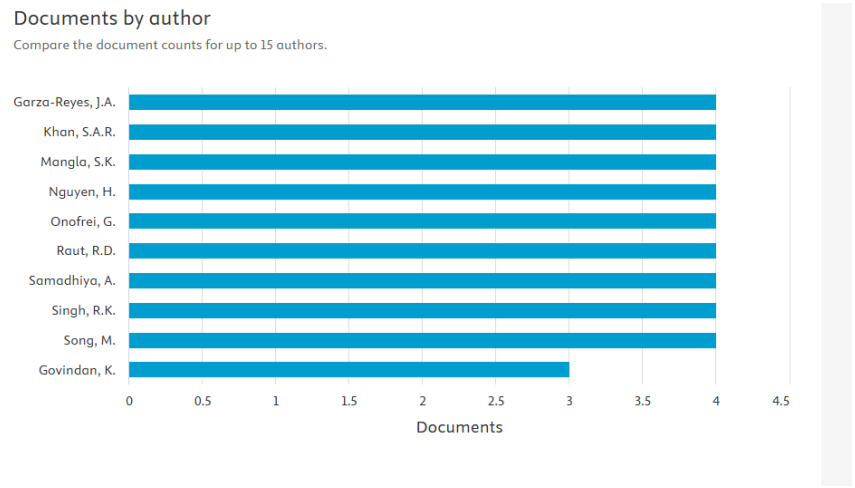


Figure 06 : document by author scopus

Selected	Author	Citations	Total link strength
☑	sarkis j.	451	9918
☑	gunasekaran a.	246	8331
☑	zhu q.	321	7294
☑	govindan k.	301	7077
☑	dubey r.	148	6116
☑	khan s.a.r.	149	4697
☑	wang y.	226	4666
☑	sarstedt m.	171	4605
☑	zhang y.	198	4325
☑	ringle c.m.	148	4207
☑	childe s.j.	92	4125
☑	hair j.f.	150	4117
☑	liu y.	202	4088
☑	kumar a.	151	3768
☑	papadopoulos t.	89	3586
☑	li y.	179	3579
☑	wamba s.f.	73	3261
☑	yu z.	102	3190
☑	jabbour c.j.c.	122	3135
☑	luthra s.	107	3102

Figure 07 : collaboration entre auteurs vos viewer

Cross-analysis of publication typology and institutional partnerships contributes to shaping the academic structure of the green supply chain and sustainable innovation domain. The collaborative network illustrates a structure where schools of economics and management are connected to engineering and administration departments, thus reflecting the essential interdisciplinarity of this domain. This institutional convergence favors integration of technical, economic, and managerial aspects essential to logistics innovation sustainability.

Publication distribution is largely characterized by scientific articles (67.5%), followed by conference communications (10.8%) and literature reviews (9.1%). This configuration is representative of a domain in consolidation phase that places particular importance on empirical validation while favoring active exchange within international forums. The appearance of book chapters (7.1%) testifies to advanced conceptual evolution favoring structuring syntheses in the domain of interface between sustainability and logistics.

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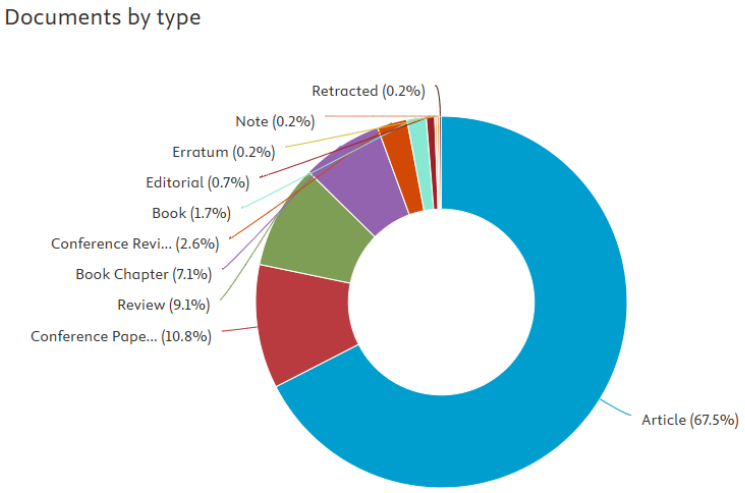


Figure08 : Document by type scopus



Figure 09 : Collaboration entre institutions

3.3 Conceptual and Thematic Mapping

Once contextual and dynamic aspects of these domains are analyzed, it is appropriate to study how concepts, ideas, and research subjects are interconnected in the green supply chain domain. Figures 10-11-12 offer us a visual representation of the domain's conceptual organization, thus facilitating identification of predominant and emerging concepts, as well as highlighting potential gaps in existing literature.

3.4 Keyword Co-occurrence Mapping

A bibliometric analysis conducted using VOSviewer on a sample of 538 articles from the Scopus database, focusing on keywords "Sustainable supply chain innovation" and "Green supply chain," reveals several significant observations.

Observation of the keyword co-occurrence network highlights an organization in distinct but interconnected thematic clusters. Key concepts of "sustainability," "green supply chain management," and "circular economy" occupy a central place in the network, representing the main conceptual pillars of research in this domain.

The red cluster, centered on notions of "sustainability" and "environmental sustainability," includes global environmental aspects such as "climate change," "food security," and "environment." This group defines the conceptual framework of environmental sustainability as presented in literature.

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The green cluster encompasses operational and strategic dimensions such as "green procurement," stakeholder engagement, sustainable supply chain management, and competitive advantage, emphasizing orientation toward management practices and competitive benefits.

The blue cluster, grouping domains of eco-innovation, manufacturing, and green innovation, focuses mainly on production processes and technological innovation.

A significant observation from this analysis reveals the relatively marginal position of "environmental sustainability" compared to "green supply chain management," suggesting that research specifically highlighting detailed environmental impacts is less frequent than that focusing on managerial or economic aspects. This finding supports the research proposition aimed at deepening integration of environmental aspects in sustainable supply chain analysis.

This gap in existing literature represents a research opportunity that this article strives to fill, by presenting a more integrated framework that clearly establishes the link between green supply chain practices and specific and measurable environmental indicators.

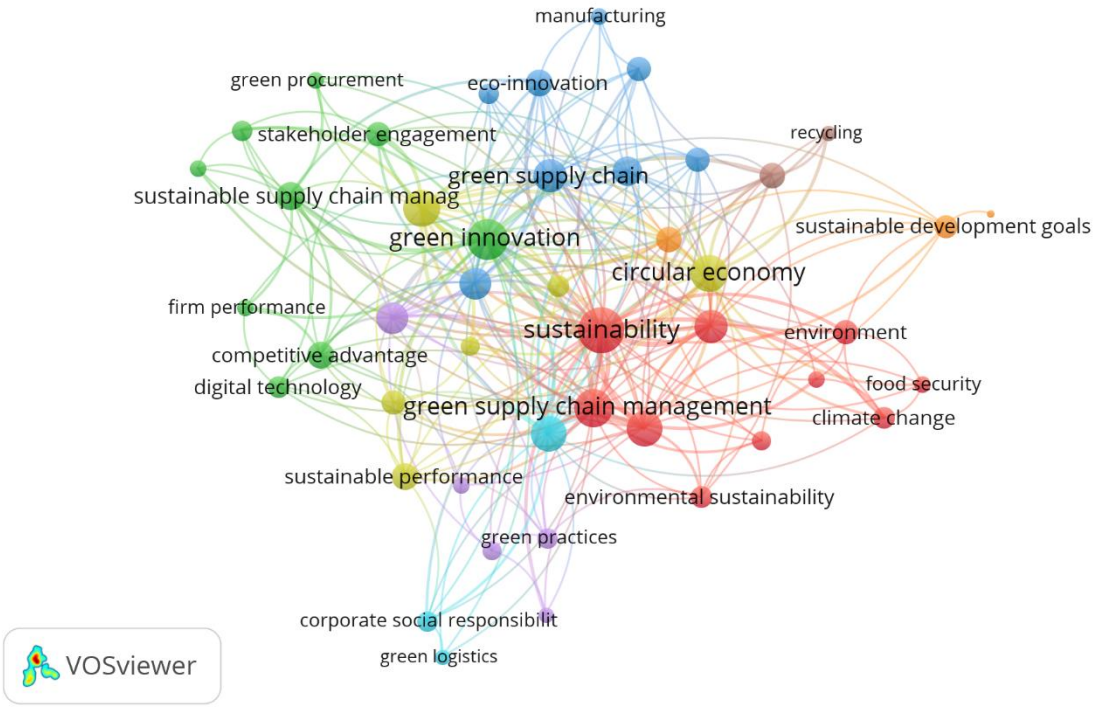


Figure10 : carte de co-occurrence de mots clés vos viewer

3.5 Bibliographic Coupling Map

Author co-citation analysis conducted using VOSviewer highlights the intellectual configuration and temporal progression of research in the green supply chain and sustainable innovation domain. In-depth analysis of this bibliometric network reveals several important structural phenomena.

The spatial configuration of this network is marked by significant centrality of studies by El-Kassar (2019) and Bag (2020), which clearly represent key references in this domain. Their central position and density of their connections suggest they have developed essential conceptual frameworks that have significantly impacted subsequent research orientations. This centrality implies that these authors have advanced theoretical or methodological paradigms that have been widely accepted by the scientific community.

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Analysis of publication chronology (2015-2023) offers the possibility to study temporal evolution of this research domain. A significant concentration of publications was observed between 2019 and 2022, testifying to a recent increase in academic interest for this subject. This chronology confirms the theory of a domain in full conceptual expansion, potentially influenced by growing urgency of environmental issues in industrial and commercial environments.

Network modularity, illustrated by various chromatic clusters, highlights epistemic differentiation within the domain. The grouping consisting of Zhang (2020), Ma (2021), and Wang (2023) could be considered as a school of thought emphasizing technological approaches or innovation, while the group including Lazaroiu (2020) and Fathollahi-Fard (2019) could translate a perspective more focused on operational or strategic models.

The network periphery includes more individual works such as those by Stratton (2021), O'Connor (2016), and Rowan (2020), which could offer alternative or emerging approaches, likely to present innovative perspectives but not yet completely assimilated in the predominant discourse.

Analysis of this bibliometric network, in association with previous observations on the marginal position of specific environmental considerations among keywords, indicates the existence of a "conceptual compartmentalization" phenomenon within literature. While notions of sustainability and green supply chains are frequently addressed, there seems to be an important analytical gap regarding explicit and in-depth integration of specific environmental aspects.

This bibliometric study provides solid legitimization to my research orientation toward stronger integration of environmental aspects in green supply chain analysis, thus establishing my contribution as a critical extension of pre-existing conceptual frameworks developed by key authors in this domain.

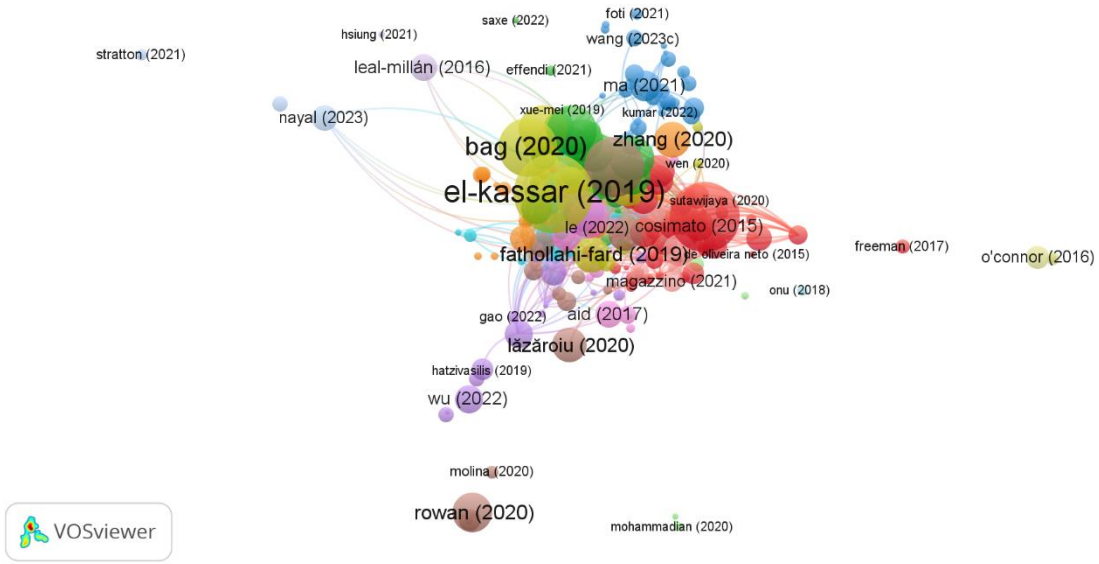


Figure11 : carte de couplage bibliographique vos viewer

3.6 Thematic Cluster Map

The cartographic representation of density generated by VOSviewer allows apprehending in a complementary manner the conceptual structure of the green supply chain and sustainable

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innovation domain. Unlike the previous network visualization, this representation highlights the intensity and density of relationships between concepts through color gradients.

Examination of this map highlights several significant phenomena addressed in scientific literature:

The conceptual topography is distinguished by four main intensity poles, materialized by high-density zones (red-yellow). The predominant central concept revolves around "sustainability," which clearly represents the central theme of the domain. Its role as an integrating concept in literature is confirmed by its position and intensity.

Another notable intensity center emerges around the concept of "green supply chain management," highlighting the importance of this operational domain in research. The proximity of this pole with that of "sustainability" testifies to close conceptual integration between these two dimensions.

The third intensity domain, located in the green zone of the map, includes concepts of "sustainable supply chain management," "green procurement," and "stakeholder engagement," emphasizing a set of concepts focused on management and organizational practices.

The fourth pole, situated in the blue region, encompasses concepts of "eco-innovation," "green innovation," and "manufacturing," highlighting a specific sub-domain focused on technological and productive innovation processes.

The spatial organization of concepts highlights distinct thematic segmentation: concepts associated with particular environmental aspects such as "climate change," "food security," and "environmental sustainability" are mainly grouped in the red-orange zone, while concepts related to organizational performance such as "competitive advantage," "firm performance," and "digital technology" are concentrated in the green-purple zone.

The marginal position of the "environmental sustainability" concept relative to the central domain of "green supply chain management" underlines the lack of integration of specific environmental aspects in this domain. This configuration therefore legitimizes the objective of this study which seeks to develop a conceptual framework integrating environmental aspects more explicitly in sustainable supply chain analysis.

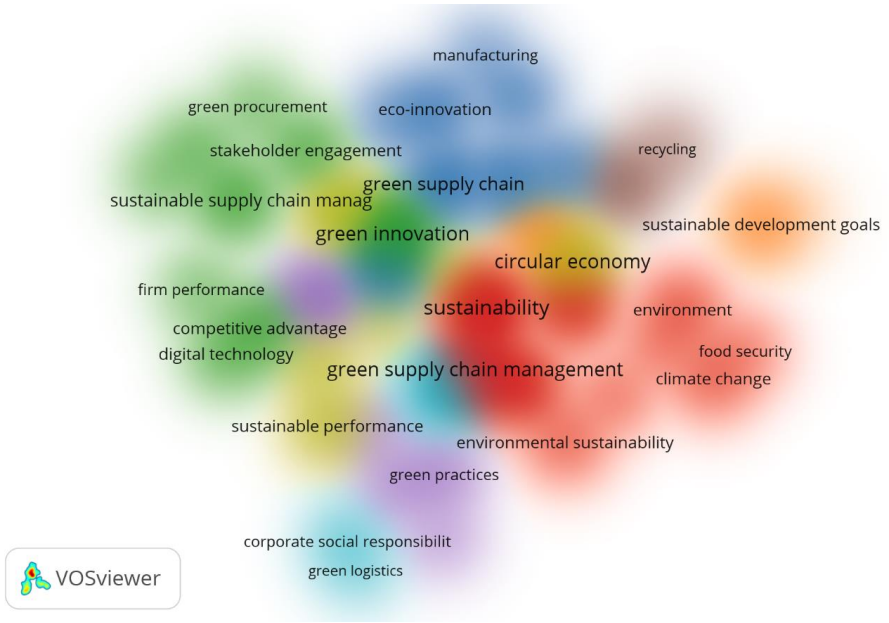


Figure12 : carte de cluster thématiques vos viewer

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4. The Environmental Paradox within Green Supply Chains

Conclusions drawn from previous analyses allow summarizing a critical observation that emerges from all visualizations: although designated as such, research on "green" supply chains shows a significant gap regarding integration of fundamental environmental sciences.

A comprehensive bibliometric analysis reveals an essential paradox: although qualified as "green," the truly environmental dimension remains insufficiently explored in studies on supply chains. Systematic analysis of thematic groupings, co-citation networks, and emerging trends confirms this initial observation and reveals its extent.

Scientific domains such as ecology, conservation biology, and climatology are curiously underrepresented among the most frequently cited references. Predominant indicators and methodologies remain largely dissociated from ecosystem science knowledge. This gap manifests at various levels:

From a conceptual point of view, predominant definitions of "green supply chain" generally omit including concepts of planetary boundaries, ecosystem functions, or biodiversity.

From a methodological point of view, evaluation instruments focus more on simplified indicators such as CO2 emissions and energy consumption, to the detriment of more complex ecological impacts.

There are few collaborations between management/engineering researchers and natural science scientists.

This paradox represents both an essential questioning of the current state of research and a significant perspective for its future evolution. By reintegrating deep ecological understanding into supply chain design, research could surpass the current approach focused on reducing negative impacts, to create truly regenerative models that make positive contributions to natural systems on which they depend.

Discussion, Analysis and Recommendations

The bibliometric analysis we conducted highlights a fundamental contradiction in green supply chain studies: although qualified as "green," the ecological component remains insufficiently explored in all its ecosystem complexity. Environmental evaluation methods are often fragmented, emphasizing specific indicators such as carbon emissions, instead of adopting a holistic approach that considers the entire life cycle (Ahi and Searcy, 2015). Analysis of thematic groupings also reveals marked insufficiency regarding biodiversity and ecosystems, emphasizing more energy efficiency and carbon emission reduction. Furthermore, the circular dimension, although present in 7.2% of examined publications, is generally treated superficially, often limiting itself to its material recovery aspects without leveraging its transformative potential (Kirchherr et al., 2017).

Faced with these constraints, we suggest a new conceptual framework based on three fundamental principles. First, the concept of environmental centrality reaffirms the central role of ecology in supply chain management (Montabon et al., 2016), manifested by systematic incorporation of environmental aspects in all decision-making and revision of performance criteria emphasizing ecological parameters (Tuni et al., 2018). Second, the concept of regenerative innovation goes beyond simple mitigation of negative effects by actively seeking to

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restore ecosystems. The transition from the notion of "less harmful" to "positively contributive" (Elkington et al., 2020) is based on principles of regenerative economy (Fullerton, 2015; Raworth, 2017) and manifests through adoption of regenerative circular models, restorative agricultural practices, and a bio-inspired approach. Third, the concept of systemic integration highlights the essential interdependence of economic and ecological systems (Whiteman et al., 2013; Williams et al., 2019), envisioning them as integrated elements within complex socio-ecological systems.

Emerging technologies open important perspectives for realizing this integrated vision. Use of artificial intelligence contributes to improving environmental decision-making (Bai and Sarkis, 2020), while blockchain technology strengthens transparency and traceability of ecological actions (Saberi et al., 2019). Additionally, the Internet of Things facilitates real-time monitoring of essential environmental parameters (Manavalan and Jayakrishna, 2019). However, it is essential to remain vigilant about the environmental impact of these technologies during their adoption (Bag et al., 2021).

To promote this paradigm transition, we suggest various research axes. First, it is essential to promote development of in-depth case analyses that study in detail interactions between supply chains and specific ecosystems. Subsequently, multidimensional environmental evaluation instruments have been developed that consider ecosystem health, biodiversity, and ecosystem services (Brandenburg et al., 2014). Additionally, there is an increase in interdisciplinary collaborations between logistics management researchers and environmental science experts (Gold et al., 2010). Finally, more precise geographical contextualization is necessary, recognizing that environmental consequences differ significantly according to local ecosystems.

The ecosystem conceptual revision of green supply chains is essential to enable them to fully realize the transformative ambition they seek to achieve. This implies surpassing reductionist environmental approaches in favor of strategies recognizing ecosystem complexity inherent to our logistics systems. The sector's future depends on its capacity to recognize that sustainable supply chains cannot be developed independently of natural ecosystems to which they are intrinsically linked and which they can beneficially influence.

Conclusion

The comprehensive bibliometric examination of green supply chain research highlights a dynamic domain, marked by exponential increase in publications and diversification of approaches. Visual representations of thematic links, collaboration networks, and influence structures depict a complex, though fragmented intellectual landscape. Three major observations emerge from this analysis:

Research remains compartmentalized in disciplinary and geographical silos, restricting a truly integrated approach to environmental issues.

The specific ecological aspect is often neglected, creating a gap between the "green" designation and concepts and methodologies actually used.

However, emerging trends indicate encouraging progress toward more systemic approaches that integrate advanced technologies, circular economy, and social considerations.

The future of this study domain will depend on its capacity to resolve current divisions, incorporate more deeply fundamental ecological knowledge, and develop truly transdisciplinary

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frameworks. Only by respecting this condition can the study of green supply chains truly play a role in the environmental transition essential to meet climate and ecological challenges of the 21st century.

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