Research article

Apuntes del **CENES**
ISSN 0120-3053
E -ISSN 2256-5779
Volumen 44 - N° 80
july - december 2025 Págs. 153 - 187

The Sustainability of the Fashion Industry: A Bibliometric Analysis

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Reception date: 24th august 2024
Approval date: 15th june 2025

Abstract: The current environmental crisis is primarily driven by excessive consumption, and the fashion industry is one of the sectors that contributes the most to global pollution. In response there has been growing interest in sustainability in fashion within the academic community and in society at large. This study uses a bibliometric analysis of global scientific production to better understand the relationship between fashion and sustainability. To this end, the Scopus and Web of Science databases were consulted for the period 2010 to 2024. Bibliometric tools such as Biblioshiny and Tree of Science were used to analyze 2,144 records, identifying the most relevant documents and providing insights into how this field of research has evolved. The results highlight three major research trends. The first examines how consumerism represents one of the greatest challenges for the transition of fashion towards a circular model, thereby reducing its social, economic, and environmental impact. The second addresses key aspects such as the use of advanced technology, efficient supply chain management, and the implementation of sustainable practices, all of which are essential to achieving sustainability in this industry. Finally, the third emphasizes the crucial role of governments in creating policies that promote the circular economy within the fashion sector. These findings underscore the importance of continuing research and propose a future research agenda aimed at promoting a more responsible and sustainable fashion industry.

Keywords: Sustainable development, exhaustible resources and economic development, circular economy, natural resources, circular fashion, consumerism, fast fashion, environment and growth, pollution, bibliometrics.

JEL Classification: O44; P28; Q01; Q57; T32.

How to cite
Duque, P., Caulin, J., & Patiño, M. (2025). The Sustainability of the Fashion Industry: A Bibliometric Analysis. *Apuntes del Cenes*, 44(80) Págs. 153 - 187. https://doi.org/10.19053/uptc.01203053.v44.n80.2025.19159

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La sostenibilidad de la industria de la moda: un análisis bibliométrico

Resumen

La crisis ambiental actual está impulsada principalmente por el consumo excesivo, y uno de los sectores que más contribuyen a la contaminación global es la industria de la moda. En respuesta a esta problemática, la sostenibilidad en la moda ha cobrado creciente interés tanto en la comunidad académica como en la sociedad en general. Este estudio busca entender mejor la relación entre moda y sostenibilidad mediante un análisis bibliométrico de la producción científica mundial. Para ello, se consultaron las bases de datos Scopus y Web of Science entre los años 2010 y 2024. Se utilizaron herramientas bibliométricas como Biblioshiny y Tree of Science para analizar 2144 registros, identificar los documentos más relevantes y aportar información sobre cómo ha evolucionado esta área de investigación. Los resultados destacan tres grandes tendencias investigativas. La primera explora cómo el consumismo representa uno de los mayores desafíos para la transición de la moda hacia un modelo circular que reduzca su impacto social, económico y ambiental. La segunda aborda aspectos clave como el uso de tecnología avanzada, la gestión eficiente de la cadena de suministro y la implementación de prácticas sostenibles como elementos esenciales para alcanzar la sostenibilidad en esta industria. Y la tercera enfatiza el rol crucial de los gobiernos en la creación de políticas que promuevan la economía circular en el sector moda. Estos hallazgos subrayan la importancia de seguir investigando y sugieren una agenda futura que contribuya a promover una moda más responsable y sostenible.

Palabras clave: desarrollo sostenible, recursos agotables y desarrollo económico, economía circular, moda circular, consumismo, recursos naturales, moda rápida, medio ambiente y crecimiento, contaminación, bibliometría.

INTRODUCTION

The fashion industry is known for having a high environmental impact (Costa et al., 2020). Therefore, it is necessary to transform this industry by adopting business models that promote circularity and reduce environmental impact through strategies of recycling, reutilization, use of non-polluting materials and energy efficiency (Battesini Teixeira et al., 2023; De Ponte et al., 2023). The growth of production and consumption in this industry poses significant sustainability challenges, such as overconsumption and fast fashion, issues that need to be addressed not only from an environmental perspective but also from economic and social viewpoints (Aynul et al., 2022; Papamichael et al., 2023). The adoption of a more sustainable corporate model can bring competitive advantages for companies, brand loyalty and enhanced corporate status (Aynul et al., 2022; Papamichael et al., 2023).

To achieve this transition towards a more sustainable economy, a change in the mindset of both industry and consumers is required, adopting circular economy practices such as an efficient use of resources and the re-evaluation of business models (D'Adamo et al., 2022; Papamichael et al., 2023). Thus, educating consumers about sustainability in the fashion industry and promoting responsible practices, such as slow fashion, is crucial (Mukendi et al., 2020; Teta & Xhafka, 2024). Likewise, it is important to integrate circular economy principles into business models and adopt sustainable practices at all stages of the supply chain, from material development to waste management (Battesini Teixeira et al., 2023; De Oliveira et al., 2022).

On this path to sustainability, innovation is needed to face such a high global competition, especially in the context of the circular economy, which demands an innovative approach to obtain competitive advantages (Papamichael et al., 2023). Consequently, practices such as producing biotextile products from waste or creating smart waste management systems have increased in recent years, helping to reduce environmental impact, to promote efficiency, and to foster the circular economy (Ezhilarasan & Umakanta, 2023; Provin

et al., 2021). It is also worth highlighting the role of industry 4.0, which, with technologies such as the internet of things (IoT), artificial intelligence (AI), virtual reality (VR), augmented reality (AR), 3D printing, and big data, has helped reduce the environmental impact of the textile industry (Konina, 2023).

To understand the environmental impact and bring effective solutions, monitoring sustainable performance is essential (Jia et al., 2020; Papamichael et al., 2023). However, in order to reach a more sustainable model, it is important to promote policies and regulations that encourage the adoption of these sustainable practices, as well as to promote cooperation between all the interested parts of the supply chain and improve waste management infrastructures (Adamkiewicz et al., 2022).

Sustainability has become a key priority for the global fashion industry, capturing the attention of various stakeholders, including brands, consumers, researchers, and professionals, with a particular focus on environmental and social aspects (Ruslan et al., 2023). However, academic research on sustainability in fashion remains underdeveloped (Prado et al., 2022). This lack of consolidation, combined with the dynamic and constantly evolving nature of the sector, underscores the need for periodic reevaluations of existing knowledge. Such reevaluations not only help to update the state of the art but also provide industry professionals, policymakers, and stakeholders with tools to better understand advancements and make more informed decisions (Islam et al., 2020).

However, to date, no research yet addressed the following questions: ¿Which countries/regions, authors, and journals are the most important in this field?, ¿How has global research on the fashion industry and sustainability evolved?, ¿What are the most prominent research trends in this area? In light of the identified knowledge gap, this paper aims to conduct a scientific mapping of global research on the fashion industry and sustainability to answer the aforementioned questions.

The article is organized into five main sections. The first section analyzes previous bibliometric reviews related to the study topic. The second section provides a detailed description of the methodology used for the search, selection, verification, and analysis of publications according to the defined search criteria. The third section presents an analysis of the publications, offering clarity on the topic and classifying them based on their citation frequency in other works within the field. The fourth section discusses the results obtained in the study. The fifth section includes the conclusions, study limitations, and recommendations for future research on sustainability in the textile industry.

LITERATURE REVIEW

Research on sustainable fashion is in a promising stage of development, characterized by a growing interest in addressing the challenges related to sustainability within this industry (Wanzhen et al., 2024). This interest is reflected in multiple bibliometric and systematic reviews that have explored various perspectives, enriching the understanding of sustainable practices, emerging technologies, and innovative strategies in the sector (see Table 1). These reviews not only consolidate progress in this field but also help identify emerging trends and highlight areas requiring further research attention.

Table 1. Previous Reviews

Author(s)/ year	Method	Databases Used	Time Frame	Aim	Documents Analy-zed
Ramos et al. (2023)	Systematic Literature Review (PRISMA Method)	Scopus , ScienceDirect, ACM Digital Library, IEEE Xplore, Springer Link, Google Scholar	2010-2022	Explore how AI can contribute to the sustainability of the fashion industry, highlighting its potential benefits and limitations.	37
Islam et al. (2020)	Bibliometric and Content Analysis	Scopus, Web of Science, Science Direct, MDPI, Emerald Insight and Springer Link	2010-2022	Analyze the literature on environmentally sustainable practices in the textile, apparel, and fashion industries.	91
Luján-Ornelas et al. (2020)	Literature Review	Scopus ScienceDirect Google Scholar	2009-2020	Identify the initiatives being developed internationally towards a sustainable textile industry.	50
Thorisdottir & Johannsdottir (2020)	Systematic Literature Review (PRISMA Method)	Web of Science EBSCO	1970-2019	Explore corporate social responsibility and its influence on sustainability within the fashion industry.	209
Wanzhen et al. (2024)	Bibliometric Analysis and Historical Review	Web of Science	1993-2023	Bibliometric analysis and historical review of research on sustainable fashion.	573
Prado et al. (2022)	Literature Review and Bibliometric Analysis	Web of Science	2009-2021	Explore and analyze recent scientific production on sustainability in the fashion retail sector.	93
Ruslan et al. (2023)	Bibliometric Analysis	Web of Science Scopus	2015-2023	Establish dominant trends and central ideas in the area of sustainable consumer behavior in Muslim fashion through a bibliometric analysis.	90
Saxena et al. (2022)	Bibliometric Analysis	EBSCO, ProQuest, Emerald Springer, Science Direct, MDPI	2018-2022	Analyze the thematic structures and trends in scientific publications examining the use of blockchain technology for implementing sustainability in apparel and textile supply chains.	30
Wu et al. (2022)	Systematic Literature Review	Web of Science Google Scholar	1980-2021	Conduct a systematic literature review on sustainable merchandising in the fashion industry	103

Source: own elaboration.

For instance, recent studies have examined the impact of emerging technologies such as artificial intelligence and blockchain on sustainability. Ramos et al. (2023) analyzed how artificial intelligence can enhance sustainable practices in the fashion industry; however, their analysis was limited to 37 documents from databases such as Scopus and ScienceDirect, which restricts the diversity of sources. Similarly, Saxena et al. (2022) explored the implementation of blockchain in textile and apparel supply chains. Nevertheless, the reduced temporal scope (2018-2022) and the small number of documents analyzed (30) constrain the generalizability of their findings.

Furthermore, studies such as those by Islam et al. (2020) and Luján-Ornelas et al. (2020) have examined environmental practices and life cycle approaches in fashion, reviewing 91 and 50 documents, respectively. While these works provide valuable insights into sustainable strategies, their reliance on specific databases like Scopus and ScienceDirect might limit the breadth of their analyses. Complementing these efforts, Wu et al. (2022) conducted a review of sustainable merchandising, analyzing 103 documents from Web of Science and Google Scholar. This allowed them to explore commercial strategies associated with sustainability more deeply. However, these studies tend to focus on specific areas, which could limit the integration of broader perspectives within the general context of sustainable fashion.

Additionally, other studies have explored the role of corporate social responsibility (Prado et al., 2022) and the retail sector (Thorisdottir & Johannsdottir, 2020) in promoting sustainability. Although robust in terms of the number of documents analyzed (209 and 93, respectively), these works lack a focus on recent technological developments and often overlook other geographical and cultural perspectives. Conversely, analyses such as that by Wanzhen et al. (2024) have adopted a broader approach, utilizing 573 documents from Web of Science to identify trends and gaps in sustainable fashion research. However, studies like Ruslan et al. (2023) emphasize the need to investigate specific contexts, such as consumer behavior in Muslim fashion, revealing a lack of generalization in certain analyses.

Overall, previous reviews share methodological similarities, such as the use of established databases (Web of Science, Scopus, and ScienceDirect) and bibliometric approaches to map existing knowledge. However, they present significant limitations, including restricted temporal scopes, incomplete articulation of sources, and the exclusion of diverse cultural and linguistic contexts. These gaps highlight a knowledge vacuum and an opportunity to develop more comprehensive research that combines qualitative and quantitative approaches, integrates robust databases such as Web of Sciences (WoS) and Scopus, and considers larger datasets.

To address these limitations, this study incorporates the recommendation of Islam et al. (2020) by including books, conference proceedings, and specialized journals in its analysis. Moreover, the scope has been expanded to include documents indexed in Scopus and WoS from 2010 to 2024, without additional restrictions, to ensure an exhaustive and representative analysis that contributes to the global understanding of sustainability in the fashion industry.

METHODOLOGY

Scientometrics, introduced by Nalimov and Mulchenko (1971), deals with the study of the development of science through the application of quantitative methods, focusing on science as an information process. One of its branches, science mapping, facilitates the understanding and visualization of metrics related to scientific literature, which are based on bibliographic data (Li et al., 2021). Although these techniques have a quantitative foundation, they are often applied to make inferences about qualitative characteristics (Wallin, 2005).

Within the sphere of scientometrics, scientific mapping analysis plays an important role in understanding the intellectual structure of a particular field by examining the social and structural interconnections between different elements of research (Donthu et al., 2021; Zupic & Čater, 2015). These tools have gained popularity in the scientific community due to their ability to process and analyze large volumes of data, allowing researchers to identify changing trends in specific fields (Donthu et al., 2020, 2021), and to shed light on emerging areas of research (Verma & Gustafsson, 2020). For this reason, the main purpose of such investigations is to acquire information on the progress of scientific investigation related to a specific topic, a broader research field, or even the entirety of the scientific body of knowledge (Li et al., 2021).

This research adopts a scientific mapping perspective and employs bibliometric tools to visualize the structure and dynamics of a specific area of knowledge (Leydesdorff, 1987; Noyons et al., 1999). Different analytical methods are employed, including indicators and metrics that count publications by author, country, institution, and journal (Zupic & Čater, 2015), as well as graph theory to elaborate co-citation networks linking authors, documents and countries (Herman et al., 2000). Additionally, the Tree of Science is implemented to highlight and classify the most relevant documents in the field of study (Restrepo, Patiño, et al., 2023).

Data Collection

To carry out the scientific mapping of the research relating the fashion industry to sustainability, we consulted the Scopus and Web of Science databases, the two most important databases worldwide (Martín-Martín et al., 2018;

Pranckutė, 2021). During the search process, the search terms ("fashion industry" OR "textile industry" OR "apparel industry") and ("sustainability" OR "sustainable" OR "environment sustainab*" OR "sustainable development" OR "sustainable development goals" OR "sdg") were used, considering as inclusion criteria those articles that include these terms in their title/keywords. No exclusion parameters were set, such as date of publication, journal, area of knowledge or any other options given by the database, in order to guarantee a real vision of the development of this field. Based on these criteria, a total of 2,144 records were obtained (date of consultation 20/05/2024).

Information Processing and Analysis

For bibliometric analysis, the Bibliometrix package, developed by Aria and Cuccurullo (2017) and available in R-Studio, was used. This freely available software offers a wide range of functionalities that facilitate the performance of bibliometric studies, including compatibility with data from various databases and in multiple formats, as detailed in Aria et al. (2020). Its effectiveness and versatility have been demonstrated in multiple previous studies (Derviş, 2020; Donthu et al., 2021; Feliciano-Cestero et al., 2023).

Based on the above, this study presents descriptive analyses that incorporate publication trends by years, journals, authors, countries and institutions, including productivity and impact indicators such as citation and publication counts, the h-index (Hirsch, 2005), and the SJR (Scimago Journal & Country Rank, 2022). Network analyses are also presented, including co-citations and collaborations.

In addition, the ToS package, also known as "tree metaphor", was used, a tool that is supported by the graph theory to analyze the references of the records obtained from databases, facilitating the construction of citation networks and obtaining bibliometric metrics, such as citation and co-citation indicators, which are essential to identify and classify the most relevant documents in a specific field. This metaphorical approach to the tree of science categorizes documents into classics (root), structural (trunk) and perspectives (branches), providing a structured view of knowledge in the discipline. The value and efficacy of ToS have been corroborated by multiple studies, with applications reported in research in various fields (Grisales et al., 2023; Aguirre & Paredes Cuervo, 2023).

Gephi, an open source graph analysis and visualization tool (Bastian et al., 2009) is used to visualize the network generated by ToS. Gephi allows a detailed interaction with the network data, offering insights on each document that composes it. Its accessibility and flexibility have consolidated its use

in network studies, as reflected in previous research (Salazar et al., 2023).

This methodology has proven to be effective through its application in a variety of academic and research contexts, which has resulted in the identification of key trends and a greater understanding of the knowledge structures of various fields, as can be seen in works that have implemented it. Figure 1 details the procedure for bibliometric analysis.

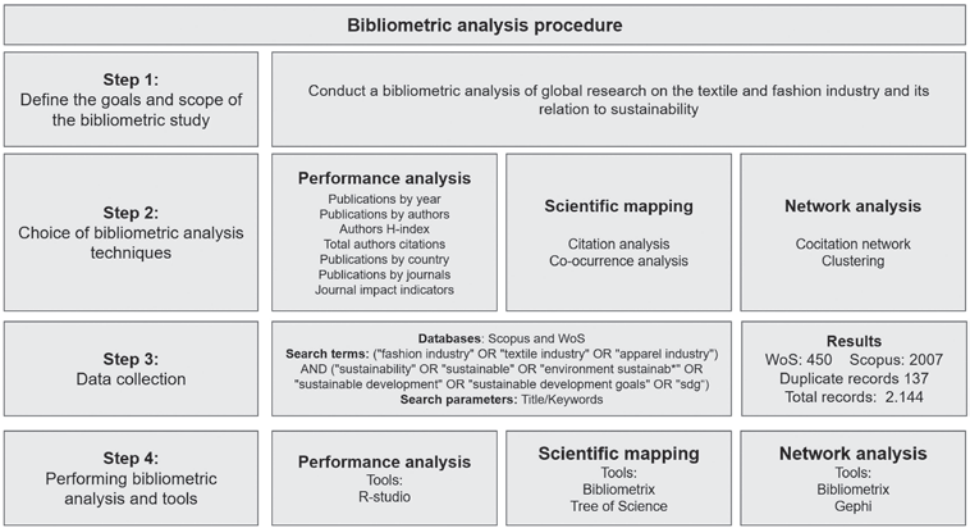

Figure 1. Methodological procedure

RESULTS

Figure 2 presents the trend and evolution of research in the fashion industry and sustainability from 2010 to the date of consultation (20/05/2024), by analyzing the number of publications registered in the two databases used for this study: Web of Science and Scopus, as well as the total between the two databases. It should be remarked that for this and the following analyses, the publications found in both databases have been counted just once. In total, 2144 publications related to sustainability and the fashion industry were identified, with Scopus always leading in terms of the total number of records. There has been a growing trend in the number of records can be appreciated, being mostly accentuated since 2019, presenting an annual growth rate of 23% since 2010. Additionally, 60% of the papers have been published since 2021, information that shows that the interest in sustainability in the textile industry is experiencing a boom among the scientific community, as well as being an attractive topic for the general population.

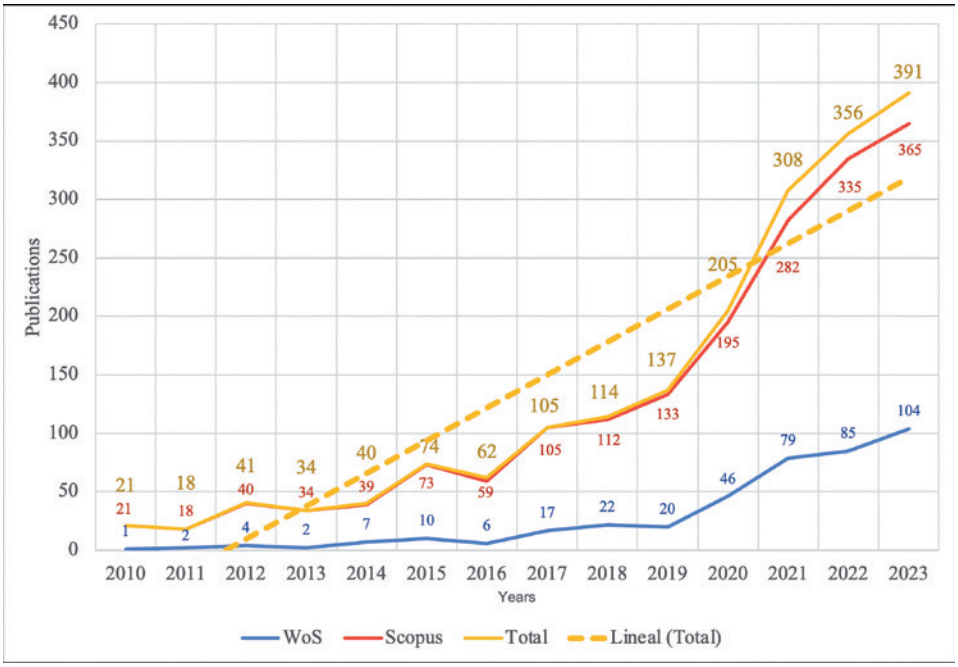

Figure 2. Trends in publications 2010-2024

Main Journals

Figure 3 lists the ten journals with the most publications on fashion and sustainability from the two databases used in this study, WoS and Scopus. The total number of publications between the two databases has also been included, taking into consideration that the documents appearing in both databases have been counted only once. Additionally, the impact indicators registered in Scimago such as h-index, quartile and Scimago Journal Rank 2023 (SJR) are listed. The journal with the highest number of publications is "Sustainability Switzerland", with 197 in total, followed by "Journal of Cleaner Production", with 128 publications. The journal "Science of The Total Environment" stands as the most influential among the scientific community according to its impact indicators, with an H-index of 353 and an SJR of 2 in 2023, as well as being classified in quartile 1. Also remarkable is the SJR of the journal "Resources Conservation and Recycling", situated at 2.77 in 2023, although its H-index is 196. Of the ten journals, nine are considered TOP journals (Q1-Q2) and 80% of them are European journals.

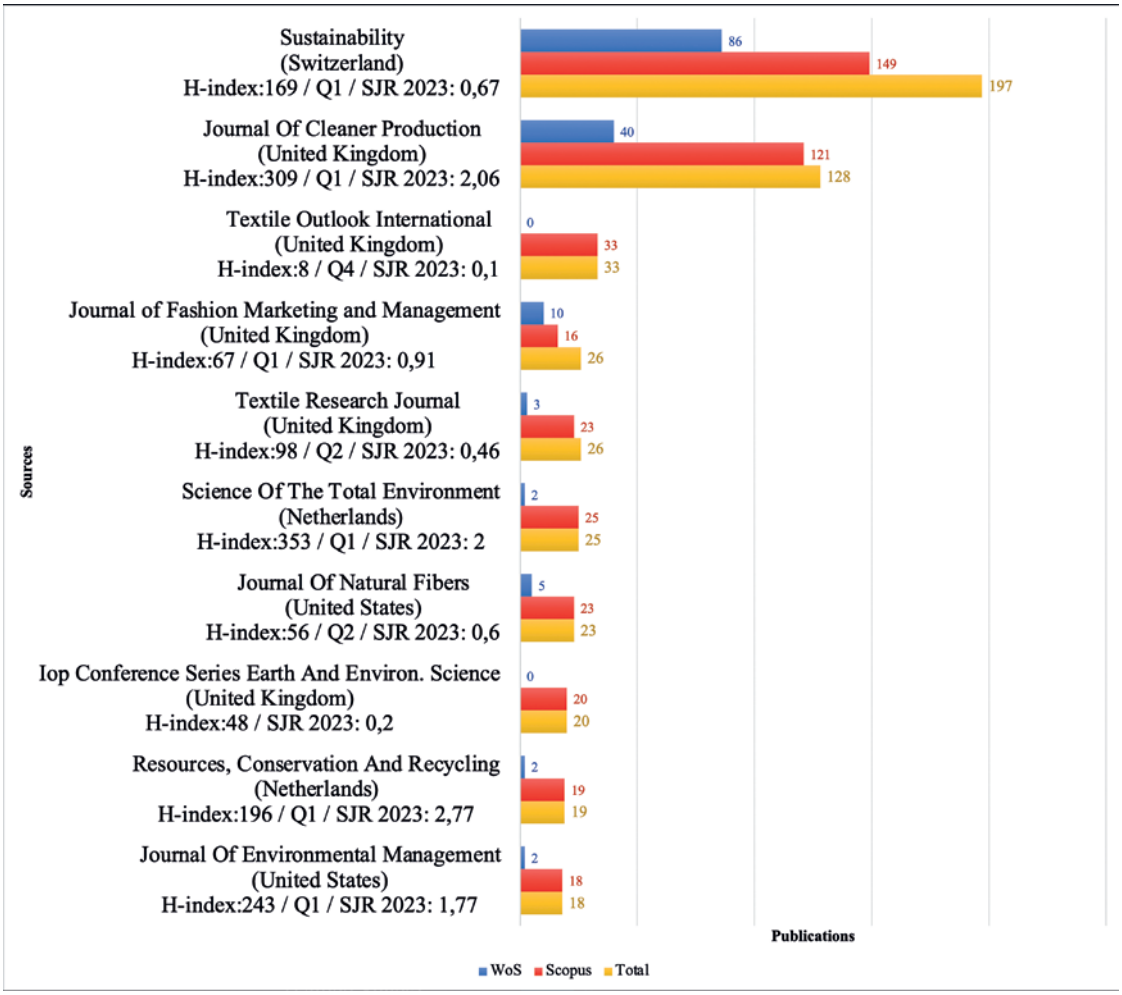

Figure 3. Main journals

Main Countries/Regions

Table 2 shows the 10 countries with the most publications on sustainability and the fashion industry. China leads the list as the country with the highest number of publications, with 13.85% of the total. It is closely followed by India with 13.62% and the United States with 8.16%. Of the ten countries with the highest number of publications, four are Asian, contributing with 35.17% of the field of study. Another four countries are European, having 22.33% of the total number of publications. North America is represented only by the United States, while South America is represented by Brazil in this ranking, with 74 publi-

cations, 3.96% of the total. These data are graphically reflected in the country collaboration network, in which China, as the country with the largest number of publications in the field, is located at the center of the network and connected with Asiatic countries and other countries from the rest of the world. This analysis highlights the global nature of sustainability in the textile industry, showcasing contributions from countries around the world that enrich the scientific community.

Table 2. Main countries

Country	WoS	Scopus	Total	Percentage over Total	Countries Collaboration Network
China	60	281	297	13,85%	
India	34	284	292	13,62%	
U.S.A.	50	168	175	8,16%	
U.K.	34	144	149	6,95%	
Italy	59	138	145	6,76%	
Germany	30	103	109	5,08%	
Brazil	31	74	85	3,96%	
Pakistan	17	79	84	3,92%	
Turkey	15	79	81	3,78%	
Portugal	14	73	76	3,54%	

Main Authors

Table 3 presents the ten authors with the highest number of publications on sustainability in the fashion industry, indicating also the number of citations in Scopus and their H-index. The top three authors, with ten publications each, are Yiqi Q. Yang linked to the University of Nebraska-Lincoln (USA), Shahid Adeel from the University of Faisalabad (Pakistan) and Claudia E. Henninger from the University of Manchester (UK). Out of these three authors, Yiqi Q. Yang has the highest number of citations and a higher H-index, although there are two other authors with great influence in the field who have a higher number of citations and a higher H-index: Tsan Ming Choi, linked to the University of Liverpool-School of Management (UK), followed closely by Minglang Tseng, from the Asian University (Taiwan). Four of the ten authors listed in the table are affiliated to universities in the United Kingdom, two of them to institutions in Pakistan and the rest four to universities in the United States, India, Italy and Taiwan. This

fact points to the geographic diversity of the leading researchers in the field and highlights the significant influence of certain authors between the scientific community.

Table 3. Main Authors

Author	Publications			Scopus	
	WoS	Scopus	Total	Number of Citations	H-index
Yang, Yiqi Q.	2	10	10	11.965	56
Adeel, Shahid	2	10	10	3.167	33
Henninger, Claudia E.	0	10	10	1.003	16
Hassan, Mohammad Mahbubul	0	9	9	1.701	21
Mia, Rony	0	8	8	596	15
Choi, Tsan Ming	3	7	7	16.318	71
Tseng, Minglang	0	7	7	15.710	68
D'Adamo, Idiano	7	4	7	5.389	45
Mohsin, Muhammad Mubeen	0	7	7	1.947	24
Sun, Danmei	1	7	7	1.151	17

Authors Network

Co-citation analysis is a scientific mapping technique that assumes authors who are frequently cited together have similar themes (Hjørland, 2013). The benefit of using this analysis is that it allows the discovery of seminal publications and authors in a field (Donthu et al., 2021). In the author collaboration network created, Figure 3, three main groups of authors can be appreciated:

The first group of researchers, led by leading figures such as Niinimäki, Fletcher and Kozlowski, focuses primarily on the intersection between fast fashion and sustainability. Kirsi Niinimäki, from Aalto University in Finland and a recognized expert in fashion research, holds at the time of the consultation 6,169 citations on Google Scholar and an H-index of 26. Kate Fletcher, a pioneer of the slow fashion movement, accumulates 7,041 citations on Google Scholar and has an H-index of 25. Finally, Anika Kozlowski, professor of fashion design, ethics and sustainability at Metropolitan University in Toronto, Canada, has also contributed significantly to the field.

The second group of authors is specialized in supply chain management and corporate social responsibility, highlighting names such as Seuring, Elkington and Govindan. Among them, the work done by Stefan Seuring in the last five years (since 2019) stands out, with remarkable metrics in Google Scholar, accumulating 19,894 citations and an impressive H-index of 61 since 2019.

Finally, the third group, smaller than the other two, focuses their research on circularity in the fashion industry and sustainability and includes authors such as Li Y., Wang Y., and Sandin. In recent years, Gustav Sandin, affiliated to the Swedish Environmental Research Institute IVL, has gained attention, with 2,635 citations in Google Scholar since 2019 and an H-index of 21.

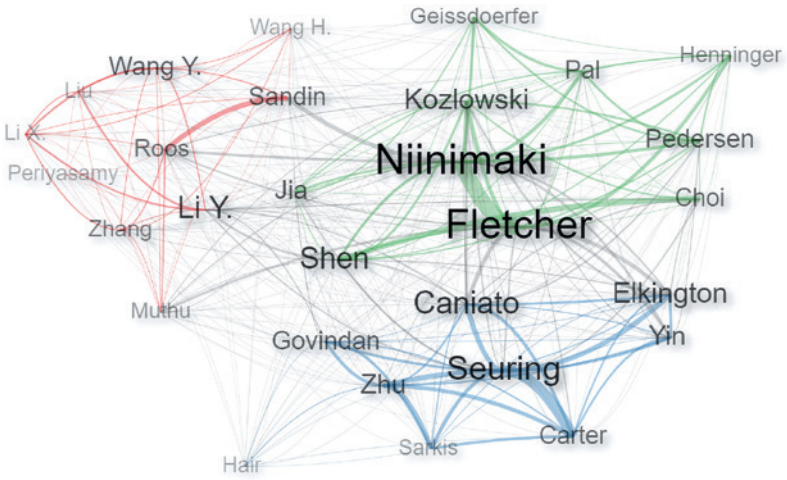

Figure 4. Authors Co-citation Network

Metaphor of the Tree of Science

The metaphor of the tree of science, represented in Figure 5, is a valuable conceptual tool used to classify academic papers using citation indicators such as indegree, betweenness and outdegree. In this metaphor, papers considered classic or seminal are identified by a high indegree (Wallis, 2007), which indicates a frequent citation by other works in their field, representing the roots of the tree. The outdegree (Wallis, 2007) measures the citations that a paper emits towards others in the same scientific community; papers with a high outdegree tend to be more recent research, which resembles the branches of the tree, extending towards new directions of thought and research. Finally, betweenness (Freeman, 1977) captures the level of centrality of a document; those with high betweenness act as the trunk of the tree, connecting the roots and branches; in other words, they quote the fundamental documents and, in turn, are cited by the most recent works (Zhang & Luo, 2017), thus facilitating the transmission and expansion of knowledge in the field. By using this tool, it was possible to identify the most important documents (classic and structural), considered as theoretical references of this important area of knowledge.

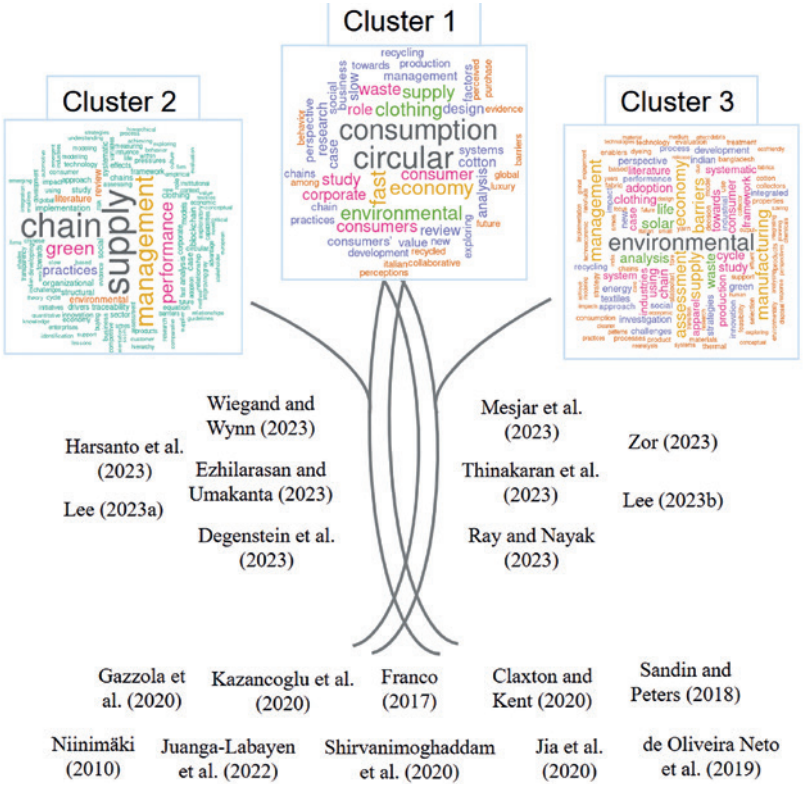

Figure 5. Tree of Science

The branches of the tree of science work as indicators of current trends in a given field. To discern these directions, the technique of bibliographic linkage, which is fundamental in scientific mapping, is used. This technique assumes that publications with shared references are likely to address similar topics, an assumption that highlights the relationship between shared citations and thematic proximity (Donthu et al., 2021; Weinberg, 1974). Through this approach, it is possible to clarify the themes that form the intellectual structure of a field and to understand how these have evolved over time (Zupic & Čater, 2015). Through cluster analysis, specifically the method proposed by Blondel et al. (2008), it is possible to group studies by related topics (clusters), which makes it easier to establish the main lines of research and discussions that dominate the area of study. Finally, by means of text mining programmed in R-studio, specifically with the WordCloud package (Ohri, 2013), the keywords and titles of each publication in each cluster are identified and used to generate word clouds, thus facilitating the identification of the

main topics. In this process, three main clusters were identified and will be discussed below.

This method allows us to analyze the evolution and trends in global research on the fashion industry and sustainability. Figure 5 shows the metaphorical scheme of the science tree.

Classic Documents (Root)

This section contains the analysis of the classic articles, which constitute the root of our tree of science. As it can be observed in Figure 5, those articles are older and work as the base for more recent papers. They analyze the preference of young people for brands that have a sustainable production and marketing process, as well as the need to promote the circular economy in the retail sector. However, there are a number of challenges, discussed below, that complicate both sustainable production and circularity in the fashion industry.

New generations, particularly women, are expressing more interest in brands that are committed to the environment, which proves that sustainability in the fashion industry is becoming more and more important (Gazzola et al., 2020). However, their purchasing decisions do not always correspond to their beliefs or values, as they sometimes opt for brands that do not carry out sustainable manufacturing processes (Niinimäki, 2010).

Regarding the under-exploited second-hand market, consumers tend to discard clothing items due to damage, fit problems or personal preferences, which stimulates the implementation of more circular ways of working in the industry (Gazzola et al., 2020). This is why it is necessary to understand and address the environmental impact at each stage of the life cycle of textile products (Sandin & Peters, 2018). The role of manufacturers and designers is also crucial, as they must understand the needs, desires and values of consumers to increase their attachment to the product (Claxton & Kent, 2020; Niinimäki, 2010).

In order to address environmental, social, and economic issues, the fashion industry must adopt circular practices (Shirvanimoghaddam et al., 2020). However, the implementation of a circular model in this industry has to face multiple challenges along the supply chain, including complexity in product design, high investment costs, price competitiveness, low demand and lack of awareness (Jia et al., 2020; Juanga-Labayen et al., 2022). There are also technological barriers that add complexity to the effective implementation of the circular economy, such as the need to improve collection systems, automate textile sorting, and discover new recycling technologies (Juanga-Labayen et al., 2022).

To overcome these challenges, collaboration and commitment of all

participants in the supply chain, awareness raising, government support, innovation and development of new technologies are fundamental elements (De Oliveira Neto et al., 2019; Jia et al., 2020; Shirvanimoghaddam et al., 2020). The implementation of sustainable practices would not only reduce environmental impact, but also generate economic benefits (De Oliveira Neto et al., 2019; Shirvanimoghaddam et al., 2020).

Structural Documents (Trunk)

The following analysis focuses on the recent structural documents that form the foundation of our scientific knowledge. They discuss the need to transform the textile industry into a more sustainable model, supported by changes in production processes, communication strategies, technology use, and waste management. They also emphasize the importance of continuous research and innovation in this field.

The transition of the textile industry to a more sustainable model is needed, and requires the adoption of sustainable business strategies, the application of circular economy principles and the integration of digital technologies (Degenstein et al., 2023). Although sustainability is a strategic priority for many companies, the adoption of circular economy practices is not carried out by all of them, but the implementation of regulations and changes in consumer perception are likely to encourage the adoption of these practices (Wiegand & Wynn, 2023).

In order to reduce the environmental impact and improve circularity in the fashion industry, one of the keys is the implementation of a reverse supply chain, which would allow the efficient collection and management of materials discarded by consumers and their subsequent reintroduction into the textile industry to be reused or recycled (Thinakaran et al., 2023). There are multiple options for responsible product management, such as the possibility of converting textile waste into value-added products, such as new clothing, cloth bags, carpets, second-hand clothing, etc. (Degenstein et al., 2023; Ezhilarasan & Umakanta, 2023).

The growth of the demand for sustainable products, together with the need to meet certain regulations, has also led to a boost in sustainability innovation (Harsanto et al., 2023). Among the main sustainable innovation practices in the textile industry we can find eco-design, eco-labeling, life cycle assessment, waste management and business collaboration (Harsanto et al., 2023; Lee, 2023b). Strategies such as creative fabric creation, which implies the aesthetic and practical recycling of clothing waste, offer an innovative method to promote the incorporation of waste recycling into everyday life, accessible even to those without fashion experience (Lee, 2023a). Innovations in

immersive technologies, such as virtual and augmented reality, have significant potential to reduce waste, educate consumers, and improve sustainability in the fashion industry. However, more research is needed to understand their impact and monitor their adoption (Mesjar et al., 2023).

Considering that marketing can influence consumer purchasing decisions, promoting sustainable fashion products and approaching sustainability challenges in the fashion industry is essential (Ray & Nayak, 2023). However, financial barriers and lack of government support make it difficult to implement the circular economy in the textile industry (Degenstein et al., 2023). Challenges such as the high cost of raw materials, lack of certifications, problems in the collection and separation of materials, lack of technical know-how or lack of a shared vision hinder the adoption of circular economy practices in the fashion industry (Thinakaran et al., 2023). Well-designed environmental regulations could facilitate the sustainable transition of textile companies, benefiting both companies and the environment (Zor, 2023).

Branches (Clusters)

An analysis of the three clusters identified is presented below.

Cluster 1: Circular Fashion and Consumerism

The textile industry, one of the world's most polluting industries, needs to move towards a more circular model, in which the mitigation of the current consumerist mentality is essential. The factors that can facilitate this transition, as well as the vision of today's consumer, are analyzed next.

The strong environmental impact of fast fashion requires a transition to a more sustainable fashion model that reduces the waste generated (Centobelli et al., 2022; Dan et al., 2023). For this transition to be successful, the collaboration of all participants in the supply chain, from designers to consumers, is essential to help minimize waste throughout the product life cycle and thus maximize the value of materials (Dan et al., 2023; Seidu et al., 2023). In addition to the involvement of companies in the industry, government support is also needed (Centobelli et al., 2022; García-Ortega et al., 2023). At the same time, the role played by technological innovation on the road to sustainability in the fashion industry is noteworthy (Seidu et al., 2023).

A more sustainable model in the fashion industry would also help companies to improve their social status, attract more customers and, in the end, create business opportunities (Centobelli et al., 2022; Quiles-Soler et al., 2022). It has

been demonstrated that implementing environmentally friendly production processes adds value to the final product, making consumers be willing to pay more (Spindler et al., 2023). However, when it comes down to it, and despite the fact that customers are aware of the environmental impact of the textile industry, they continue to opt for fast fashion products (De Aguiar Hugo et al., 2023; Seidu et al., 2023).

Therefore, one of the most important aspects of improving sustainability in the fashion industry is to raise consumer awareness, being essential for designers and brands to understand how consumers perceive circular fashion and how they can influence their buying decision (De Aguiar Hugo et al., 2023; Seidu et al., 2023). The role of social media is also significant and can also be used as a tool to promote sustainable fashion consumption practices and influence consumers' purchasing decisions (Centobelli et al., 2022; Vladimirova et al., 2023). Finally, it is important that customers make informed purchasing decisions so they can themselves promote a more sustainable consumption behavior (García-Ortega et al., 2023).

Therefore, to transition to a more sustainable model in the fashion industry, it is necessary to involve companies, government institutions and consumers themselves, who, together with the use of new technologies and innovations, can facilitate this transition.

Cluster 2: Supply Chain and Environmental Impact

One of the key aspects for textile and fashion companies to implement sustainable manufacturing is proper supply chain management. Together with other sustainable practices and industry modernization, this will enhance sustainability in the sector.

The implementation of sustainable supply chain management has been proven to improve company performance and minimize environmental impact, thus increasing end-consumer satisfaction (Asha et al., 2023; Khan et al., 2023). Other benefits that companies obtain from the implementation of sustainable practices in the supply chain are a more efficient use of their resources, cost savings or competitive advantages (Zeleke & Hailemariam, 2023). In addition, it is important to conduct supply chain management that minimizes environmental impact in order to comply with environmental regulations (Khan et al., 2023).

Additional sustainable practices that can contribute to improve the environmental performance of a company are innovation in sustainable marketing (Roh et al., 2022) or the implementation of Industry 4.0, with technologies such as the Internet of Things or big data analytics (Aynul et al., 2022; Chatchawanchanchanakij et al., 2023; Khan et al., 2023). At the same time, the role of blockchain tech-

nology can help to improve the control and traceability of supply chains, increasing internal efficiency and the consumer and fashion retailers' trust (Moretto & Macchion, 2022). The adoption of sustainable technologies in the fashion industry not only has a positive impact on environmental performance, but can also improve the competitiveness of companies and contribute to a country's economic development (Aynul et al., 2022).

It is important to remember the significance of organizational culture, as it can enhance the quality of the final product (Asha et al., 2023) as well as good customer relations management, because it could have a positive impact on companies' performance in the textile industry (Roh et al., 2022).

In addition to environmental challenges, there are also social challenges that need to be addressed in the textile industry that can add value to the final product, such as issues related to labor rights and decent work, worker health and safety, human rights, governance and community infrastructure (Muñoz-Torres et al., 2022; Spindler et al., 2023). Textile companies can implement the following strategies to efficiently manage social impact: strong labor rights regulations, safety throughout the supply chain, responsible sourcing, supporting community development initiatives, promoting transparency or collaborating with other stakeholders (Muñoz-Torres et al., 2022).

It can be concluded that implementing sustainable management in the supply chain, along with other sustainable practices and attention to the social aspects, can benefit textile industry companies and, therefore, contribute to their growth and to the economic development of a country.

Cluster 3: Environment and Circular Economy

The environmental impact of the textile industry is continuously increasing, making the introduction of circular economy practices more and more necessary. However, depending on the country's development, this implementation may be more or less straightforward. The following analysis examines the benefits, barriers, and facilitators of adopting circular economy practices in the textile and fashion industries.

The textile industry is increasingly impacting climate change and the consumption of natural resources, so the need to adopt circular economy practices is becoming even more necessary (Jain et al., 2022; Ponnambalam et al., 2023), which can also improve the companies' reputation and competitiveness, generate opportunities for innovation and encourage the development of business models that are more respectful of

the environment. Some of the potential circular economy practices that companies can implement include the efficient use of energy and resources, the use of cleaner technologies, and the promotion of the materials reuse and recycling (Jain et al., 2022).

The successful adoption of these practices requires the coordination and collaboration of all the agents involved in the supply chain (Chourasiya et al., 2024; Jianguo & Solangi, 2023). The introduction of environmental regulations and the granting of economic incentives by governments can also facilitate the transition of companies to a more sustainable model, as well as helping to build consumer awareness (Jianguo & Solangi, 2023; Mahiat et al., 2023; Zor, 2023).

However, the textile industry, particularly in developing countries, faces barriers that complicate the implementation of those circular economy practices, such as high investment costs, low demand for recycled textile products, lack of support for waste management in the industry, the need to modernize infrastructure and technology, lack of supportive policies, lack of technical and theoretical know-how, challenges in product design, resistance to change or lack of awareness about sustainability (Alayón et al., 2022; Chourasiya et al., 2024; Jianguo & Solangi, 2023; Khairul Akter et al., 2022; Ponnambalam et al., 2023).

Some of the practices that could help companies overcome these barriers are: enhancing support from large customers, implementing policies to improve recycling practices, external cooperation, collaboration between textile companies and governments, encouraging the demand of recycled textile products, implementing environmental management systems, promoting education and awareness about the importance of textile recycling, etc. (Alayón et al., 2022; Ponnambalam et al., 2023).

Thus, it is highlighted the need to implement circular economy practices in the fashion industry that can mitigate the negative impact of the industry on the environment, being essential the collaboration of all the agents of the supply chain and the support of governments, as there are multiple barriers that make the change very challenging.

To conclude this section, Table 4 presents a research agenda resulting from the review of each cluster/branch.

Table 4. Research Agenda

Cluster	Topic	Reference
Circular fashion and consumerism	To study the integration of Circular Design Strategies with the use of artificial intelligence and the influence that new digital technologies (such as blockchain) have on corporate decision making and consumer purchasing decisions.	(Centobelli et al., 2022; Dan et al., 2023)
	To investigate the reasons that influence clothing consumption and how to change behavior towards more sustainable clothing consumption.	(Spindler et al., 2023)
	To analyze people's behavior and opinions on sustainable fashion in different countries, as well as in other industries (besides textile), different age groups, different social classes, etc.	(De Aguiar Hugo et al., 2023; García-Ortega et al., 2023; Seidu et al., 2023)
	To better understand the motivations and actions of consumers regarding sustainable fashion and social media.	(Quiles-Soler et al., 2022; Vladimirova et al., 2023)
	To investigate the influence of governments and regulations on the transition from fast fashion to slow fashion and sustainable fashion consumption.	(Centobelli et al., 2022; Garcia-Ortega et al., 2023)
Supply chain and environmental impact	To evaluate the costs and benefits of adopting Industry 4.0 technologies in textile companies of different sizes, as well as in different industries and different countries.	(Chatchawanchanchanakij et al., 2023; Khan et al., 2023)
	To analyze the impact of implementing sustainable supply chain management in textile companies in different countries and in other industries.	(Asha et al., 2023; Roh et al., 2022; Zeleke & Hailemariam, 2023)
	Examine how the adoption of sustainable technologies in the apparel industry can affect customer satisfaction and brand loyalty.	(Aynul et al., 2022)
	To develop social sustainability evaluation tools to measure the efficiency of implementing social sustainability initiatives.	(Muñoz-Torres et al., 2022)
	To identify factors that could make it easier or harder to implement blockchain in supply chains.	(Moretto & Macchion, 2022)
Environment and circular economy	To explore strategies that could improve waste management in the textile industry and develop innovative and sustainable business models for textile waste recycling.	(Ponnambalam et al., 2023)
	To develop better computational models for more accurate Life Cycle Assessments (LCA) in the textile industry.	(Jain et al., 2022)
	To study the relationship of implementing sustainable practices in the supply chain to business performance, including financial, environmental and social aspects, as well as the role of external factors in their implementation.	(Jianguo & Solangi, 2023)
	To evaluate environmental and social impacts of other manufacturing industries as well as the textile industry in other countries and regions, in addition to environmental regulations and the effects of adopting sustainable manufacturing processes.	(Chourasiya et al., 2024; Mahiat et al., 2023; Zor, 2023)
	To empirically validate the barriers and facilitators that small and medium enterprises have to the adoption of sustainable manufacturing practices in different industrial sectors.	(Alayón et al., 2022)
	To conduct research on the management of material waste, considering all phases of the life cycle of textile products, from design to disposal.	(Khairul Akter et al., 2022)

DISCUSSION OF RESULTS

A bibliometric analysis reveals a significant and consistent surge in scholarly interest in sustainability within the fashion industry over the past decade. This confirms that environmental degradation, resource depletion, and ethical consumption have become pivotal topics of research in this field. By merging records from Web of Science and Scopus into a unified corpus of 2,144 documents, the coverage limitations of each database are overcome, ensuring a

robust sample; the combined use of the Bibliometrix tool for quantitative indicators, the Tree of Science metaphoric framework for structural mapping, and Gephi for network visualizations constitutes a novel, multi-layered protocol that strengthens the reliability of co-occurrence and co-citation analyses.

The Tree of Science metaphor revealed three interrelated research streams that together form an integrative conceptual scaffold for sustainable fashion. The circular fashion and consumerism branch clarifies the interactions between design strategies and consumption patterns; the supply chain and environmental impact branch highlights the role of procurement practices and life-cycle assessment in mitigating ecological harm; and the environment and circular economy branch situates fashion within broader socio-economic systems of waste valorization and regulatory incentives. This synthesis highlights key points of intersection: it shows how consumers' pro-environmental intentions drive innovations in the supply chain and how circular-economy principles are transforming production processes.

Based on these findings, clear practical recommendations emerge for different stakeholders. Brands should adopt circular-design principles—such as modular garment architecture, take-back schemes, and digital life-cycle tracking—to foster more responsible consumption habits. Supply-chain managers should implement transparent procurement protocols, environmental management systems, and multi-stakeholder partnerships to reduce resource depletion and ensure regulatory compliance. Policymakers and waste-management entities face the challenge of developing recycling infrastructure, offering incentives for material reuse, and removing socio-economic barriers to facilitate the transition to closed-loop operational models.

Among the strengths of this study are its methodological rigor—thanks to the database fusion and the Tree of Science approach—and the breadth of its bibliographic sampling. However, this review also presents limitations that should be considered when interpreting the results: although an exhaustive search of Web of Science and Scopus was conducted, other relevant sources may not have been included; the application of inclusion criteria may have introduced selection biases; and reliance on English-language publications, along with potential indexing delays, could underrepresent very recent studies or those published on other platforms.

For future research, it is suggested to explore the integration of circular-design strategies with emerging technologies such as artificial intelligence and blockchain in the fashion industry; to investigate the motives influencing the adoption of circular-economy practices by textile companies; to analyze in greater depth the barriers and enablers of imple-

mentation, especially in developing countries; to assess the environmental and social impacts of the textile industry in different regions. Finally, it should empirically validate the obstacles and drivers that small and medium-sized enterprises face when adopting sustainable production practices.

Furthermore, to advance the monitoring of these research lines, future studies could employ overlay visualization techniques to track the emergence of subtopics within each theoretical stream. Table 4 presents a research agenda derived from this review, designed to systematically guide these efforts.

Overall, this bibliometric review not only consolidates the dispersed knowledge on sustainable fashion but also provides a robust methodological model and a clear theoretical framework, thus offering a comprehensive roadmap for researchers, practitioners, and policymakers committed to guiding the fashion industry toward genuine sustainability.

CONCLUSIONS

This literature review contributes to the knowledge, understanding and analysis of sustainability in the fashion industry, which is one of the most polluting industries worldwide. The study includes a bibliometric analysis of current literature and its posterior classification using the metaphor of the tree of science, an innovative tool that allows conducting a systematic review of the literature, with previous research in the WoS and Scopus databases as a source of the documents.

Between 2010 and the cut-off date, May 20, 2024, a total of 2144 articles on sustainability in the fashion industry were found in the two previously mentioned databases, performing the search in English, and highlighting the contribution of journals such as Sustainability Switzerland or Journal Of Cleaner Production.

There is a boom in the interest expressed by the scientific community in this field, represented by an annual growth rate of 23% in the number of publications, having published 60% of the 2144 papers from 2021 onwards. China is the country with the largest contribution number of articles, contributing 13.85% of the total, followed by India (13.62%) and the United States (8.16%). Out of the ten countries with the highest number of publications in sustainability and the fashion industry, four of them are Asian, contributing 35.17%, another four are European, with 22.33%, and two belong to the American continent, contributing 12.12%. The authors with the highest number of publications in this field are Yiqi Q. Yang, Shahid Adeel, Claudia E. Henninger, Mohammad Mahbubul Hassan, Tsan, Ming Choi, Minglang Tseng, Idiano D'Adamo, Govind Sharan

Dangayach, Muhammad Mubeen Mohsin and Dan Mei Sun.

Three main lines of research were identified in this area of knowledge thanks to the network analysis of co-citation between authors. The first of them, specialized in fast fashion and sustainability, includes figures such as Kirsi Niinimäki, Kate Fletcher and Anika Kozlowski. The second group is focused on supply chain and corporate social responsibility, and is led by authors like John Elkington, Stefan Seuring and Kannan Govindan. The third group, represented by researchers like Yuhong Li, Yuanhao Wang and Gustav Sandin, is specialized in circularity in the textile and fashion industry.

On account of the metaphor of the tree of science, a series of academic studies were identified that have become the base of more recent publications, creating the root of our tree and highlighting publications such as "The environmental Price of Fast Fashion", by Kirsi Niinimäki or "Environmental impact of textile reuse and recycling: A review", by Gustav Sandin and Greg M. Peters. Other more recent articles, such as "Conservation or revolution? The sustainable transition of textile and apparel firms under the environmental regulation: The evidence of China" or 'Sustainable innovation in the textile industry: A systematic review', have served to constitute the trunk of the tree of science. Finally, three major clusters have been identified in this field, constituting the branches of the tree: circular fashion and consumerism, supply chain and environmental impact, and environment and circular economy.

DECLARATION OF CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

AUTHOR CONTRIBUTIONS

All authors participated in every phase of the research process that led to the creation of this article.

FUNDING

This article is the result of the research project entitled "Socially Responsible Consumption and Its Influence on the Purchasing Decisions of Young Consumers," which is affiliated with and funded by the Vice-Rector's Office for Research and Graduate Studies at the University of Caldas.

DECLARATION OF AI USE

During the preparation of this work, the authors used ChatGPT 4o in the writing process to enhance readability, refine the manuscript's language, and conduct grammatical, spelling, and bibliographic reviews. After utilizing this tool, they reviewed and edited the content as necessary and assume full responsibility for the published article's content.

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