

# Navigating the complexity of sustainable transition in the textile and apparel industry: a comprehensive analysis across disciplines, geographies and stakeholders

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## ABSTRACT – REZUMAT

### Navigating the complexity of sustainable transition in the textile and apparel industry: a comprehensive analysis across disciplines, geographies and stakeholders

*This research study provides an exhaustive bibliometric analysis of the sustainability transitions within the textile and apparel sector. Utilizing the advanced tools of Biblioshiny and VOSviewer, the study maps out the intellectual structure of this field, elucidating co-citation, co-word, and collaboration networks. The prominence of keywords such as "sustainable development", "sustainability", and "textile industry" emphasizes the sector's growing focus on sustainable practices. Furthermore, an assessment of gender and ethical dimensions in research revealed a potential gap in inclusivity, prompting a call for more equitable research representation. Geographically, the prominence of contributions from regions like China and India suggests the need for region-tailored sustainable strategies. Simultaneously, the fusion of technological innovations with sustainability highlighted the interdisciplinary nature of current research. Real-world impacts of this academic discourse were examined, spotlighting the translation of theory into tangible industry practices. Despite the significant insights, the study recognizes its limitations, including potential geographical and publication biases. For policymakers, stakeholders, and academics, this study offers invaluable insights into the current landscape of sustainability research in the textile and apparel industry, suggesting areas of focus and potential opportunities for future exploration.*

**Keywords:** sustainability transitions, textile and apparel sector, bibliometric analysis, interdisciplinary research, sustainable practices

### Navigarea prin complexitatea tranziției sustenabile în industria textilă și de îmbrăcăminte: o analiză exhaustivă între discipline, zone geografice și actori implicați

*Acest studiu de cercetare oferă o analiză bibliometrică exhaustivă a tranzițiilor sustenabile în sectorul textil și de îmbrăcăminte. Folosind instrumentele avansate precum Biblioshiny și VOSviewer, studiul evidențiază structura intelectuală a acestui domeniu, elucidând rețelele de co-citare, co-word și colaborare. Proeminența cuvintelor cheie precum „dezvoltare durabilă”, „sustenabilitate” și „industrie textilă” subliniază accentul tot mai mare al sectorului pe practicile sustenabile. Mai mult, o evaluare a dimensiunilor etice și de gen în cercetare a relevat un potențial decalaj în ceea ce privește incluziunea, determinând un apel pentru o reprezentare mai echitabilă a cercetării. Din punct de vedere geografic, importanța contribuțiilor din regiuni precum China și India sugerează necesitatea unor strategii sustenabile adaptate regiunii. Simultan, fuziunea inovațiilor tehnologice cu sustenabilitatea a evidențiat caracterul interdisciplinar al cercetării actuale. Au fost examinate efectele reale ale acestui discurs academic, punând în evidență traducerea teoriei în practici tangibile din industrie. În ciuda perspectivelor semnificative, studiul își recunoaște limitările, inclusiv potențialele segmentări geografice și de publicare. Pentru factorii de decizie, actorii implicați și cadrele academice, acest studiu de cercetare furnizează perspective de neprețuit asupra peisajului actual al cercetării în domeniul sustenabilității în industria textilă și de îmbrăcăminte, sugerând domenii de interes și potențiale oportunități de explorare viitoare.*

**Cuvinte cheie:** tranziții sustenabile, sector textil și de îmbrăcăminte, analiză bibliometrică, cercetare interdisciplinară, practici sustenabile

## INTRODUCTION

The textile and apparel industry, with its intricate supply chains, vast consumer base, and economic significance, is undeniably one of the keystones of global commerce. From the raw materials extracted and synthesized for fabric production to the intricate designs that cater to multifaceted fashion demands,

this industry touches nearly every corner of human society. However, along with its economic and cultural imprint, the textile and apparel sector also holds a more dubious distinction: it ranks among the world's most polluting and resource-intensive industries. As a mid-rising environmental and social concern, sustainability has become an inescapable imperative. The

term "sustainability" is not merely a catchphrase but encapsulates a comprehensive approach that seeks to harmonize environmental, social, and economic dimensions. In the context of textiles and apparel, this means not only the adoption of eco-friendly materials and practices but also ensuring fair labour conditions, ethical business practices, and long-term economic viability. However, the sustainability journey is not without its complexities. It requires a collective effort that transcends disciplines, borders, and sectors. This research seeks to chart the intricate pathways of sustainable transition in the textile and apparel industry, exploring its myriad facets through a comprehensive lens. In doing so, the study underscores the significance of a unified approach that intertwines disciplines, geographies, and stakeholders. Historically, the textile and apparel industry has been both celebrated and criticized. On one hand, it has been an essential source of livelihood for millions and a canvas for cultural expression. On the other, it has faced criticism for unsustainable practices, ranging from excessive water use in cotton farming to the detrimental effects of fast fashion cycles leading to monumental waste. The rise of consumer awareness, coupled with mounting evidence of environmental degradation and climate change, has brought the industry's sustainability challenges to the forefront. As globalization took root, the geographical complexity of the textile and apparel industry expanded. Production hubs emerged in regions that balanced cost-effectiveness with skill availability. Yet, with this geographical spread came a disparity in sustainability practices and standards. Some regions, driven by stringent regulations and informed consumer bases, made significant strides in sustainable practices. In contrast, others lagged, often due to economic pressures or a lack of awareness and infrastructure.

Navigating the sustainable transition in the textile and apparel industry requires understanding its inherent multidimensionality. Technological advancements, especially from related fields like biotechnology and material science, have presented opportunities for more sustainable fabrics and production processes. Innovations such as bio-fabrics, waterless dyeing techniques, and closed-loop recycling have not just emerged from dedicated textile research but also from interdisciplinary efforts. Furthermore, the ethical dimension of sustainability has gained prominence. Fairtrade, ethical sourcing and labour rights are now integral to sustainability discussions. Yet, there's also an imperative to understand the nuanced challenges across geographies, from the sweatshops of some regions to the advanced, automated factories in others. Moreover, the role of gender cannot be underestimated. Historically, the textile and apparel industry has been a significant employer of women, often in roles and regions where female labour is undervalued and sometimes exploited. As the industry navigates its sustainability journey, it's essential to ensure it's also a journey toward gender equity and inclusivity.

No transition to sustainability can occur in a vacuum. It demands the collective effort of a plethora of stakeholders. Academic institutions drive research and innovation, businesses adapt and implement these innovations, governments create the regulatory landscape, and consumers, with their choices, drive demand for sustainable products. Each stakeholder plays a distinct and critical role. However, it's also crucial to recognize that some voices and contributors often remain underrepresented or unheard. These could be from lesser-known academic institutions, emerging economies grappling with their unique sustainability challenges, or interdisciplinary researchers whose work doesn't fit neatly into traditional categorizations.

Given the aforementioned complexities, this study aims to provide a comprehensive analysis of the sustainable transition in the textile and apparel industry. By examining the confluence of disciplines, geographies, and stakeholders, this study aspires to map the current landscape, identify gaps, and highlight opportunities for more cohesive and effective sustainable transitions. In charting this course, the research underscores the interwoven tapestry of challenges and solutions, emphasizing the need for a collaborative, holistic approach to truly realize sustainability in the textile and apparel sector.

### Research questions

The study sets out to the following research questions:

**RQ1:** What are the dominant theories and conceptual frameworks underpinning sustainability transitions in the textile and apparel industry?

**RQ2:** How have gender and ethical considerations been incorporated into the research and practices of sustainable textiles and apparel?

**RQ3:** Which regions and institutions have been the primary contributors to sustainability research in this industry, and how do their contributions differ?

**RQ4:** How are technological advancements in related disciplines influencing the sustainability transition in textiles and apparel?

**RQ5:** What are the real-world impacts of research contributions in the textile and apparel industry in terms of environmental, economic, and social outcomes?

**RQ6:** How does the textile and apparel industry's sustainability research adapt to global events, such as economic downturns, pandemics, or significant policy shifts?

**RQ7:** Who are the underrepresented voices in sustainability research for textiles and apparel, and what unique perspectives or solutions do they offer?

**RQ8:** To what extent are academic insights on sustainability in the textile and apparel industry being translated into practical implementations?

### Objectives

The study sets out to achieve the following objectives:

- To map out the intellectual structure of sustainability transitions in the textile and apparel sector using co-citation and co-word analysis.
- To analyse the gender and ethical dimensions of sustainability research in the textile and apparel industry, assessing representation and focus areas.
- To evaluate the geographical and institutional distribution of research contributions and identify dominant trends and potential research gaps by region.
- To examine the influence of technological and interdisciplinary innovations on the sustainable practices and research of the textile and apparel industry.
- To quantify the real-world impacts of sustainability research in the textile and apparel sector, focusing on case studies, policy changes, and environmental metrics.
- To investigate the adaptive nature of sustainability research in textiles and apparel, especially in response to significant global events and challenges.
- To spotlight and evaluate contributions from lesser-known institutions, developing regions, and cross-disciplinary researchers in the textile and apparel sustainability domain.
- To assess the translation of academic insights into tangible industry practices, focusing on implementation success stories, barriers, and scalability challenges.

## REVIEW OF LITERATURE

The textile and apparel industry has long been recognized for its substantial economic and socio-cultural contributions. However, in recent decades, the industry's environmental footprint and the intricate dynamics governing its sustainability transition have garnered significant attention. The literature on sustainable transition in this industry is vast, traversing multiple disciplines, geographies, and stakeholders. A fundamental starting point for discussions about sustainability in the textile and apparel industry centres around its environmental impact. The textile industry alone accounts for nearly 10% of global carbon emissions and remains a significant contributor to water pollution, especially in cotton-producing regions [1]. Similarly, it is elucidated that the rapid cycles of fashion production and consumption, known colloquially as "fast fashion", have exacerbated waste and resource depletion [2]. Chemical pollutants are another concern. As highlighted [3], dyes, and chemical treatments, essential for textile production, often lead to harmful discharges, impacting aquatic ecosystems. However, environmental challenges are not solely limited to production. It is emphasized that post-consumer waste, reveals that an alarming proportion of garments end up in landfills without recycling [4]. Another study utilized a Window DEA Approach to analyse the efficiency of Indian Oil and Gas Companies, which informs the study's analytical approach [5]. The significance of sentiment

analysis provides insights into consumer behaviour in e-commerce sectors like Flip Kart and Amazon [6]. Transitioning to sustainable practices demands technological evolution. Innovations such as bio-fabrics and alternative fibres suggest that these materials could substantially reduce the environmental footprint of textile production [7]. Additionally, waterless dyeing techniques noted their potential to curb water pollution significantly [8].

However, technology's role isn't merely about new materials. They underscore the importance of integrating information technology, particularly in streamlining supply chains to minimize waste and enhance resource efficiency. Such integrations, as per the authors, can create transparency, enabling consumers to make informed, sustainable choices. Beyond environmental aspects, the textile and apparel industry faces ethical challenges. It offers an empirical study on stock market volatility, with a case study focusing on the BSE Ltd. of India [9]. The linkage between behavioural finance and investment decisions among Indian Gen Z investors is also evaluated [10]. The cryptocurrency market's volatility and its relationship with the energy market were detailed, which has parallels with volatility patterns in the textile industry [11]. Further insights into the dynamics of financial technology and environmental sustainability [12] and the challenges of blockchain technology in the financial sector are discussed [13]. The labour-intensive nature of the industry, especially in garment production, has led to concerns about workers' rights, wages, and working conditions. As noted, some production hubs, especially in developing nations, have been marred by incidents of labour exploitation [14]. Fairtrade also enters the sustainability discourse. The fair-trade practices in the textile and apparel sector can not only ensure just compensation but can also foster sustainable production practices by creating incentives. The interconnectedness of ethical and environmental sustainability underscores the industry's multidimensionality.

The gendered nature of the textile and apparel industry, especially in production roles, has been a notable point of discussion. Women, who constitute a significant portion of the workforce, particularly in countries like Bangladesh and Cambodia, face challenges ranging from low wages to workplace safety issues [15]. Addressing these gender-specific challenges is not just a matter of equity but also crucial for the industry's holistic sustainable transition. The global nature of the textile and apparel industry leads to significant geographical disparities in sustainability practices and challenges. While regions like Europe have seen stringent regulations promoting sustainability, other regions grapple with different socio-economic dynamics. It is noted that while Scandinavian countries have seen substantial advancements in sustainable textile production, other areas face challenges of infrastructure, awareness, and economic constraints. Stakeholders, as pointed out, play pivotal roles in navigating these disparities [16]. While governments can enforce regulations and incentivize



sustainable practices, businesses have the onus of implementation. Moreover, academic institutions, as champions of research and innovation, are the bedrock on which many sustainability transitions are built. One cannot overlook the pivotal role consumers play in propelling sustainability in the textile and apparel industry. The modern consumer is increasingly informed, discerning, and values-driven [17]. This shift has placed pressure on brands to prioritize sustainability, not merely as a marketing tool but as an intrinsic part of their business ethos. An empirical study underscores the impact of the COVID-19 pandemic on volatility patterns in the textile industry, focusing on the Shanghai Stock Exchange of China [18]. Another study was conducted to check the assessment of energy efficiency based on CO<sub>2</sub> emissions, which offers perspectives on sustainable practices [19]. The illicit practices' repercussions on banking stability were explored [20]. Moreover, the circular economy in fashion has emerged as a transformative model to counteract the industry's waste issues. Circular fashion refers to designing, producing, using, and recycling clothes with longevity, efficiency, and sustainability in mind [21]. This circular approach not only addresses waste concerns but also promotes a more conscientious consumer culture. The rapidly evolving landscape of the textile and apparel sector is notably influenced by technological advancements and financial inclusions. Recent literature emphasizes the integration of digital financial services within the FinTech sector as pivotal in driving economic development and financial inclusion within industries like textiles and apparel [22]. Such digital interventions not only bridge the financial divide but can potentially revolutionize the supply chains, consumer engagement, and business models in the textile sector. Moreover, the emergence and influence of artificial intelligence, exemplified by platforms like ChatGPT, are starting to find relevance in this sector as well. A comprehensive exploration of the potential of AI underscores its transformative capability, which, when applied to the textile and apparel industry, could herald unprecedented operational efficiencies and market dynamics [23].

The fashion and textile industries have faced extensive criticism for their substantial environmental impact, including high carbon emissions, significant waste generation, and extensive resource use [24]. Processes such as manufacturing and dyeing in these sectors contribute to the pollution of air, water, and soil [25]. The industry's approach to sustainability, encompassing environmental, social, and economic aspects, is notably deficient. Fashion products, often trend-driven, have a brief life cycle, encouraging consumers to frequently update their wardrobes, leading to excessive production and waste accumulation [26]. The demand for constant new offerings places immense pressure on retailers in the textile and apparel sectors, often resulting in compromised labour standards and cost-cutting measures [27, 28]. Research indicates that in 2014, the global textile industry produced approximately

92 million tons of waste, with only a small fraction being recycled, and the remainder ending up in landfills or incinerated [29]. Projections show a 60% annual increase in textile waste from 2015 to 2030, exacerbating the waste management challenge [30]. In response to these concerns, the United Nations launched the Sustainable Development Goals (SDGs) in 2015, comprising 17 objectives aimed at global sustainability [31]. Apparel companies have since been striving towards these goals, focusing on sustainable manufacturing and consumption, reducing water usage, and improving working conditions [32]. Despite these efforts, the focus on water and energy conservation overshadows the critical issue of managing textile waste [33, 34].

Various studies have explored sustainability in the textile industry from different angles. One study highlighted that increasing resource efficiency can foster sustainable textile production [35]. Another set of research advocated for a product-as-a-service or rental model in the textile sector to reduce environmental impact and enhance user value [36]. Many firms are now opting for biodegradable and recycled materials to minimize their carbon footprint [37]. Additionally, the involvement of external stakeholders is crucial for ensuring a circular economy in the industry [38]. Recently, there has been a shift in consumer behaviour, with a growing segment becoming more environmentally conscious and altering their shopping habits to reduce waste [39].

Given the multifaceted challenges the textile and apparel industry faces, interdisciplinary approaches are gaining momentum. By merging insights from material science, technology, social sciences, and even the humanities, more holistic solutions can emerge. As posited, interdisciplinary research can offer nuanced insights into consumer behaviour, production techniques, and policy-making, ensuring that sustainability efforts are both effective and inclusive [40]. To reiterate, the sustainable transition in the textile and apparel industry is not linear. It's a confluence of environmental, ethical, sociocultural, and technological dynamics, shaped by a myriad of stakeholders across various geographies. The literature provides a rich tapestry of insights, highlighting both progress made and challenges ahead.

## METHODOLOGICAL FRAMEWORK

The foundation of this investigation is built upon a sophisticated methodological structure that integrates both Biblioshiny and VOSviewer tools for a rigorous bibliometric analysis. This combination facilitates a deep dive into the academic narrative and research progression on sustainable transitions within the textile and apparel industry. For data collection, the Scopus database has been identified as the primary research tool.

### Choice of database and retrieval of data

For this endeavour, the Scopus database, renowned as the most extensive abstract and citation archive of

reviewed scholarly literature, has been utilized. The preference for Scopus is grounded in its unparalleled global reach, interdisciplinary range, and the depth of bibliographic details it offers. The temporal scope of this research encompasses a period from 2000 to 2023, bringing under its purview a compilation of 1913 documents disseminated through 522 distinct sources.

### Constructing the search query

The following search string has been meticulously crafted to encapsulate the myriad dimensions of sustainable transitions in the textile and apparel domain: ("sustainable transition" OR "sustainable transformation" OR "sustainable change" OR "eco-friendly transition" OR "sustainable development") AND ("textile industry" OR "apparel industry" OR "fashion industry" OR "garment industry") AND ("sustainable practices" OR "sustainable technologies" OR "waste management" OR "carbon emissions" OR "ethical considerations" OR "lifecycle analysis" OR "material science" OR "consumer behaviour" OR "gender dynamics" OR "geographical analysis" OR "corporate involvement" OR "policy impact" OR "funding" OR "ethical concerns" OR "interdisciplinary research").

### Analysis through Biblioshiny

Biblioshiny, an intuitive interface within R's bibliometrix package, has been employed for extensive bibliometric scrutiny. This tool offers a wealth of insights about the dataset, delineating metrics such as the literature's annual progression rate, the median age of documents, and the mean citation count per publication. For this research, Biblioshiny was instrumental in pinpointing pivotal publications, notable authors, influential institutions, and leading nations based on metrics like document counts, citation frequencies, and cumulative link strength. Additionally, it unravelled patterns of collaboration amongst authors and illuminated the diverse array of publication types populating the research canvas.

### Exploration through VOSviewer

After the insights derived from Biblioshiny, VOSviewer steps into the analytical process, offering enriched bibliometric visual depictions and network explorations. This tool is adept at crafting and manifesting bibliometric networks, encompassing facets like collaborative authorship, thematic co-occurrence, and the web of citations. For this investigation, VOSviewer played a pivotal role in unveiling predominant keywords, charting clusters of interrelated terms, and plotting the intricate co-authorship matrix, thereby illuminating emergent research trajectories and synergistic authorial groupings.

By leveraging this comprehensive methodological paradigm, the investigation is poised to deliver a cohesive, multifaceted, and visually engaging panoramic view of the research ecosystem, mirroring the expansive and nuanced dialogue on sustainable transitions in the textile and apparel sector.

## DATA ANALYSIS THROUGH BIBLIOSHINY

### An In-depth glimpse into the literature of the textile and apparel industry

The bibliometric analysis, summarized in table 1, of the textile and apparel industry literature from 2000 to 2023 revealed 1,913 documents sourced from 522 distinct publications. These documents experienced an annual growth rate of 26.91%. The average age of documents stood at 2.42 years, and they garnered an average of 23.25 citations each. A vast repository of keywords was identified, with 9,569 from "Keywords Plus" and 5,557 author-specified. Of the 5,830 contributing authors, 108 penned single-authored papers. Each paper, on average, represents nearly four authors, with 35.23% showcasing international collaborations. Notably, all the analysed documents were articles.

Table 1

DATA DESCRIPTION	
Description	Results
<i>Main information about the data</i>	
Timespan	2000:2023
Sources (Journals, Books, etc)	522
Documents	1913
Annual Growth Rate %	26.91
Document Average Age	2.42
Average citations per doc	23.25
References	143848
<i>Document contents</i>	
Keywords Plus (ID)	9569
Author's Keywords (DE)	5557
<i>Authors</i>	
Authors	5830
Authors of single-authored docs	108
<i>Authors collaboration</i>	
Single-authored docs	110
Co-Authors per Doc	3.92
International co-authorships %	35.23
<i>Document types</i>	
Article	1913

### Yearly Citation Impact of the analysed literature

Table 2 reflects the citation impact of articles on the textile and apparel industry from the year 2000 to 2023. The year 2000, with two articles, observed an average of 22 citations per article, translating to an annual mean citation rate of 0.92 over 24 years. Similar citation averages persisted in 2001. A notable spike in citations was observed in 2002 with a singular article obtaining 119 citations, leading to an average of 5.41 citations annually over 22 years. Interestingly, 2003 was devoid of any articles, yet a prior article from 2002 continued its citation momentum. By 2018, the article counts surged to 94, with each article accruing a yearly average of 10.16 citations

YEARLY CITATION IMPACT				
Year	N	MeanTCperArt	MeanTCperYear	CitableYears
2000	2	22	0.92	24
2001	2	22	0.92	24
2002	1	119	5.41	22
2002	0	119	5.41	22
2004	2	134.5	6.72	20
2005	2	51	2.68	19
2006	5	52.4	2.91	18
2007	3	83	4.88	17
2008	3	12	0.75	16
2009	6	76	5.07	15
2010	4	14.25	1.02	14
2011	5	99.8	7.68	13
2012	10	89.1	7.42	12
2013	19	82.74	7.52	11
2014	33	67	6.7	10
2015	34	78.82	8.76	9
2016	37	71	8.88	8
2017	61	47.31	6.76	7
2018	94	60.95	10.16	6
2019	107	35.2	7.04	5
2020	209	36.42	9.11	4
2021	309	22.09	7.36	3
2022	487	9.4	4.7	2
2023	480	2.09	2.09	1

Note: MeanTCperArt represents the average total citations per article; N represents the number of articles published that year; MeanTCperYear indicates the average number of citations per year for the articles published that year; CitableYears measures the number of years an article has been available to be cited.

over six years. The peak in the number of articles was reached in 2022 with 487 articles, albeit with a lower average citation count of 4.7 per year for two years. By 2023, 480 articles had been produced, currently averaging 2.09 citations in their first year.

#### Annual literature output across dominant publications

Table 3 provides insights into the yearly literature production related to the textile and apparel industry from key journals between the years 2000 to 2023 (figure 1). For the initial six years (2000–2005), there was no publication from the enlisted sources. It wasn't until 2006 that "Journal of Cleaner Production" began contributing with two articles. This source consistently maintained its output with a steady increase over the years, peaking at 262 articles in 2023. "Sustainability (Switzerland)" started its contributions in 2013 with one article, but witnessed substantial growth over the years, reaching its zenith in 2023 with 281 articles. "Environmental Science and Pollution Research" initiated its contributions in 2009, slowly building its repository and reaching 61 articles in 2023. "Business Strategy and the Environment" began its contributions slightly later, in 2017, but

swiftly expanded its output, reaching 60 articles by 2023. "Sustainable Production and Consumption", though starting its contributions in 2017, remained relatively conservative in its outputs until a noticeable uptick in 2021 and 2022, producing 35 articles in 2023. While initial years showed limited research output from these sources, a significant uptick has been observed in recent years, indicating a growing scholarly interest in the domain.

#### Assessment of Top 10 journals by local impact

Table 4 delineates the local impact of the top 10 sources (journals) based on various bibliometric indicators. The "Journal of Cleaner Production" stands out as the most influential journal, with an h-index of 62, reflecting its substantial impact in the field since its inception in 2006. Furthermore, it possesses a g-index of 93 and an m-index of 3.44. With a total of 10,468 citations across 262 articles, it is evident that this source has significantly contributed to the domain. Next in line, "Sustainability (Switzerland)" initiated its contributions in 2013 and has already achieved an h-index of 32, a g-index of 46, and an m-index of 2.91, accruing 3,601 citations from 281 papers. "Business Strategy and the Environment",

YEARLY PRODUCTION OF LITERATURE ACROSS MAJOR SOURCES					
Year	Sustainability (Switzerland)	Journal of Cleaner Production	Environmental Science and Pollution Research	Business Strategy and the Environment	Sustainable Production and Consumption
2000	0	0	0	0	0
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	0	0	0	0	0
2006	0	2	0	0	0
2007	0	2	0	0	0
2008	0	2	0	0	0
2009	0	2	1	0	0
2010	0	3	1	0	0
2011	0	3	1	0	0
2012	0	3	1	0	0
2013	1	5	2	0	0
2014	3	9	2	0	0
2015	5	13	2	0	0
2016	9	27	2	0	0
2017	19	38	3	2	1
2018	32	61	5	6	2
2019	53	75	8	8	2
2020	88	114	10	20	2
2021	147	158	16	27	14
2022	213	205	30	40	29
2023	281	262	61	60	35

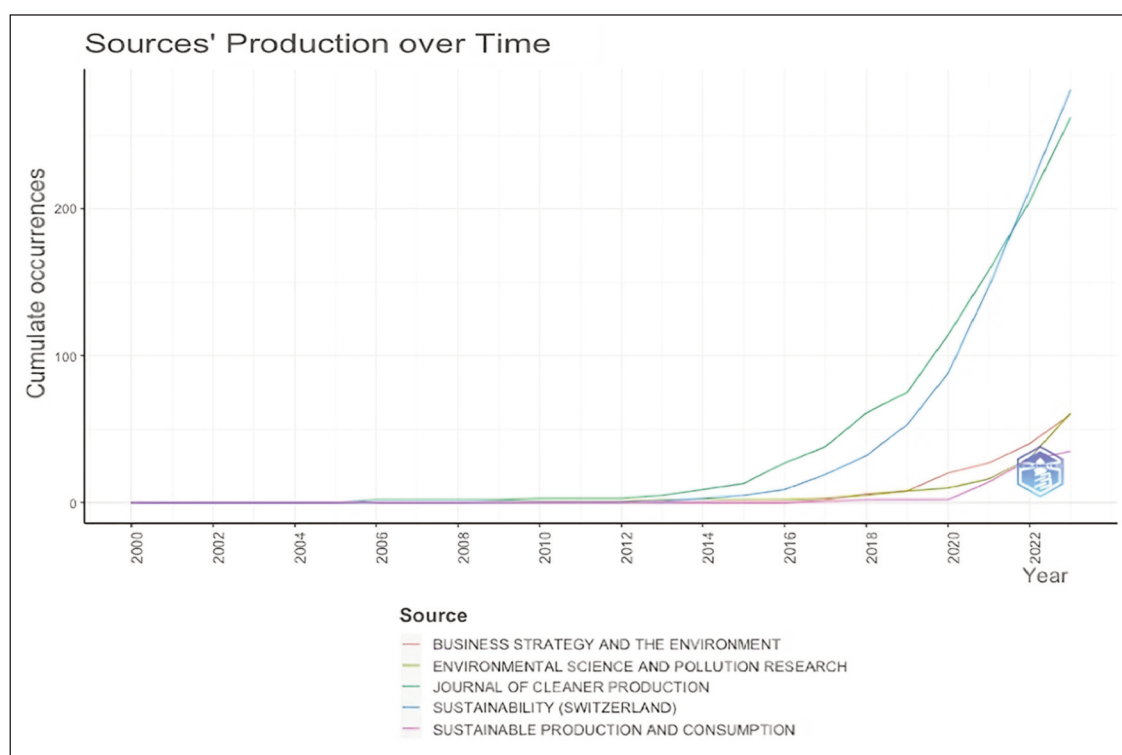


Fig. 1. Sources' production over time



SOURCES' LOCAL IMPACT						
Element	H_INDEX	G_INDEX	M_INDEX	TC	NP	PY_START
Journal of Cleaner Production	62	93	3.44	10468	262	2006
Sustainability (Switzerland)	32	46	2.91	3601	281	2013
Business Strategy and the Environment	23	43	3.29	1938	60	2017
International Journal of Production Economics	18	29	1.80	1876	29	2014
Resources, Conservation and Recycling	17	29	0.71	1157	29	2000
Energy	16	24	1.33	1220	24	2012
Environmental Science and Pollution Research	15	26	1.00	767	61	2009
Science of the Total Environment	14	24	2.00	816	24	2017
Sustainable Production and Consumption	13	22	1.86	512	35	2017
Chemosphere	12	19	2.40	502	19	2019

which began in 2017, holds an h-index of 23, a g-index of 43, and an m-index of 3.29, collecting 1,938 citations from 60 articles. Following these are journals like "International Journal of Production Economics", "Resources, Conservation and Recycling", and "Energy", which have similarly made significant contributions. They've established themselves with high h-indices, g-indices, and substantial citation counts, even though some started their contributions relatively late, like "Science of the Total Environment" and "Sustainable Production and Consumption" in 2017.

The list concludes with "Chemosphere", which started in 2019 and has an h-index of 12, a g-index of 19, and an impressive m-index of 2.40. It has collected 502 citations from 19 articles, indicating its rising prominence in the field. This analysis showcases the key journals that have made significant strides in terms of their scholarly impact within the domain of the textile and apparel industry's sustainable transition.

#### Yearly contributions by key authors

The provided dataset demonstrates the annual scholarly contributions and impact of prominent authors in a specific research domain (figure 2). Notably, authors Li Y., Wang Y., Kumar A., and Zhang Y. have had considerable contributions over the years, evidenced by the Total Citations (TC) and Citations per Year (TCpY). For instance, in recent years, LI Y's work in 2022 amassed significant citations, with a peak TC of 25 and a TCpY of 13. Similarly, KUMAR A had a prominent contribution in 2020 with a TC of 270 and a TCpY of 68. The list includes several other authors, each showcasing their impact and contributions over the years.

#### Words' frequency over time

Table 5 showcases the frequency of key terms over the years, from 2000 to 2023 (figure 3 and figure 4). Notably, the term "Sustainable development" has seen a steady increase, reaching its peak in 2023

with 1,019 mentions. "Textile industry" also gained traction over the years, reaching 488 occurrences in 2023. "Sustainability" surged dramatically in recent years, hitting 407 by 2023. Interestingly, terms like "Textiles" and "China" have also seen significant growth, especially post-2010. The terms "Recycling" and "Decision making" demonstrated notable increases, with both reaching over 200 mentions by 2023. The trends suggest a growing focus on sustainability, the textile industry, and related themes in the specified domain.

#### Trend topics

Figure 5 enumerates the frequency and distribution across years of various trending topics. The term "Sustainable development" dominates with 1019 mentions, having a median occurrence year of 2021. It, along with "Textile industry", "Sustainability", "Textiles", and "China", saw significant mentions post-2019, indicating a recent emphasis on these areas. "Environmental protection" and "Energy conservation" also display substantial frequencies, 91 and 46 respectively, illustrating a heightened focus on environmental concerns and conservation efforts in recent years. Terms like "Coffee" and "Eurasia" have a more sporadic appearance, with both initial and recent mentions. Other topics like "Textile processing" and "Gossypium hirsutum" have frequented discussions around the middle of the surveyed period, hinting at evolving concerns within the textile industry. The newest trending topics, appearing prominently around 2023, include "Ecosystem", "Eco-Friendly", and "Business models", signalling a potential shift or expansion of focus in discussions related to sustainable development and environmental considerations. This data conveys an evolving narrative and changing focal points within dialogues on sustainability, development, and industrial processes over time.



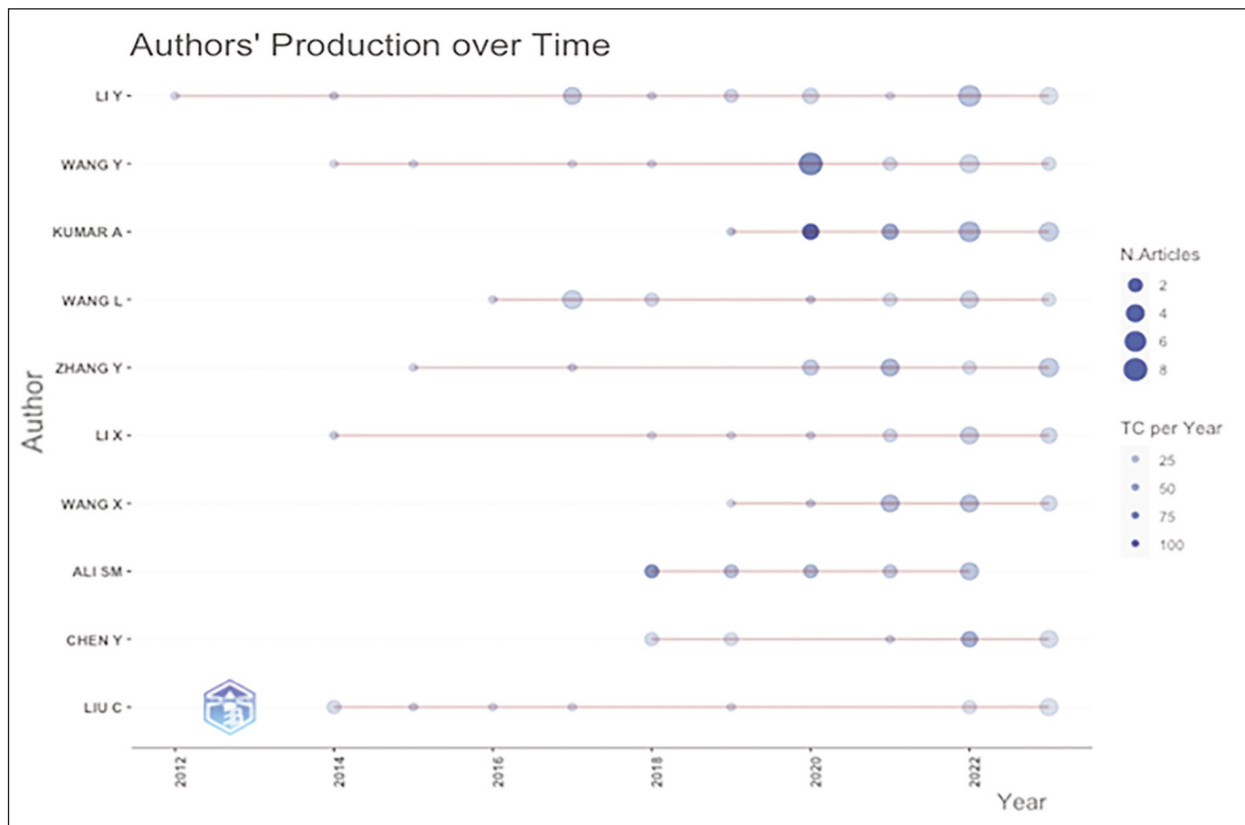


Fig. 2. Authors' production over time

Table 5

WORDS' FREQUENCY OVER TIME										
Year	Sustainable development	Textile industry	Sustainability	Textiles	China	Recycling	Decision making	Waste Management	Article	Supply chain Management
2000	1	1	1	0	0	1	0	2	1	0
2001	1	1	1	0	0	1	0	2	1	0
2002	1	3	1	0	0	1	0	4	2	0
2003	1	3	1	0	0	1	0	4	2	0
2004	3	3	1	1	0	1	0	4	2	0
2005	4	4	2	2	0	4	0	5	3	0
2006	7	9	4	4	0	8	0	11	4	0
2007	8	10	4	4	0	8	0	12	4	0
2008	11	14	4	5	0	9	0	13	4	0
2009	13	18	5	6	1	9	0	14	7	0
2010	16	21	5	6	1	12	0	16	8	0
2011	19	26	5	9	3	12	2	16	9	1
2012	20	29	5	12	3	13	4	16	9	1
2013	29	33	8	14	3	16	5	18	10	3
2014	45	42	9	18	7	22	6	21	14	5
2015	68	62	12	27	11	26	10	27	21	7
2016	85	75	17	35	17	27	12	32	24	8
2017	116	90	34	42	28	35	19	41	27	22
2018	169	113	52	57	45	40	31	51	36	33
2019	228	134	82	70	67	50	41	64	50	57
2020	336	185	131	100	97	65	64	74	64	76
2021	512	249	206	144	132	105	99	100	95	107
2022	759	379	308	239	204	156	156	162	149	152
2023	1019	488	407	315	270	218	209	208	192	186



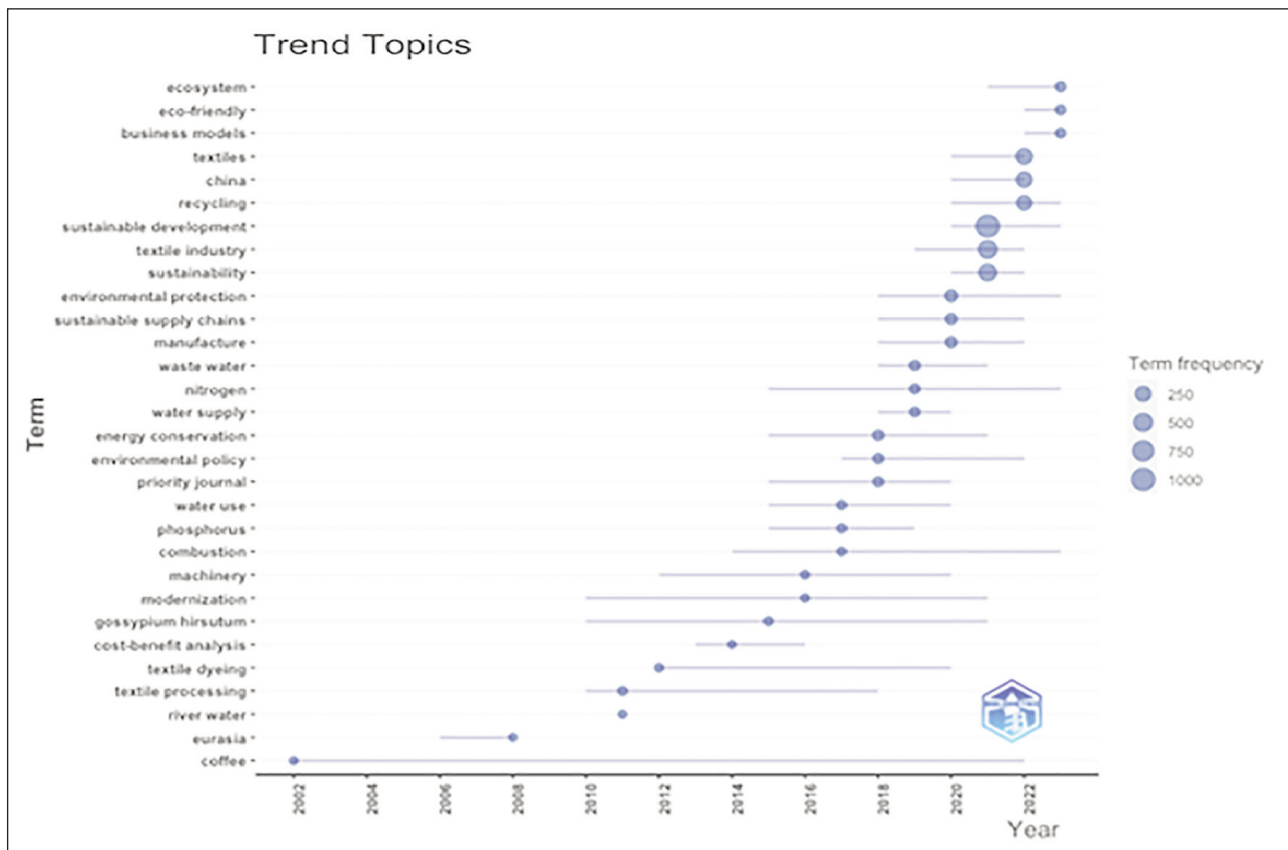


Fig. 5. Trend topics

tie among many of them, each boasting 1 document with 721 citations. This suggests the possibility that these organizations collaborated on one influential publication. Prominent institutions such as the China Agricultural University, the Chinese Academy of Sciences, and Columbia University are among them. Each of these institutions presents a total link strength of 13, suggesting strong co-authorship ties. On the geographical front, China stands out prominently. It is the most cited country with 454 documents amassing 11,962 citations. Following China are India and the United States, garnering 7,345 and 6,391 citations, respectively. It's intriguing to note that the United Kingdom, even though it has produced more documents than the United States, lags slightly behind in citations. This disparity might point to the depth, reach, or global impact of the research emerging from these nations. Furthermore, it's noteworthy that countries with fewer documents, like Denmark and the Netherlands, still feature prominently in the citation count, indicating the significant influence of their research contributions. This VOSviewer co-authorship analysis vividly highlights the leading voices and contributors in the research domain under consideration.

#### Co-occurrence of most frequently occurring keywords

Table 7 showcases the co-occurrence of frequently appearing keywords and provides a snapshot of the central themes and topics of discussion in a given

dataset (see figure 6 for visualization). Among the keywords, "sustainable development" stands out as the most frequent, with 997 occurrences and a significant total link strength of 5,897. This suggests that the term is not only frequent but also highly interconnected with other keywords in the dataset. Following closely is "sustainability" with 831 occurrences and a link strength of 3,876. Interestingly, terms specific to the textile domain like "textile industry" and "textiles" have appeared 416 and 280 times, respectively, underlining the emphasis on sustainability in the textile sector. The keyword "circular economy" reflects a more recent trend in sustainability discussions and has been mentioned 241 times with a link strength of 1,502. Furthermore, the term "article" has 192 occurrences, yet its high link strength of 2,289 indicates its significant interrelation with other terms.

Geographically, "China" stands out with 174 mentions, and given its global manufacturing dominance, it's unsurprising to see it associated with keywords such as "recycling" and "environmental impact."

It's noteworthy that even though terms like "carbon" and "energy efficiency" have fewer occurrences when compared to leading terms, their relevance in discussions about environmental impact and sustainability remains prominent. This is evident from their respective link strengths of 1,056 and 901. Additionally, themes related to waste management, including "wastewater treatment" and "waste management" itself, underline the urgency and attention towards waste treatment and disposal methods. The

CO-AUTHORSHIP AMONG AUTHORS, COUNTRIES, AND ORGANISATIONS			
Top cited authors	Documents	Citations	Total link strength
Liu J.; Hull V.; Batistella M.; Defries R.; Dietz T.; Fu F.; Hertel T.W.; Cesar Izaurralde R.; Lambin E.F.; Li S.; Martinelli L.A.; Mcconnell W.J.; Moran E.F.; Naylor R.; Ouyang Z.; Polenske K.R.; Reenberg A.; Rocha G.M.; Simmons C.S.; Verburg P.H.; Vitousek P.M.; Zhang F.; Zhu C.	1	721	0
Sagar N.A.; Pareek S.; Sharma S.; Yahia E.M.; Lobo M.G.	1	599	0
Carpenter A.W.; De Lannoy C.-F.; Wiesner M.R.	1	527	0
Stević Ž.; Pamučar D.; Puška A.; Chatterjee P.	1	519	0
Cheng C.C.J.; Yang C.-L.; Sheu C.	1	354	0
Afroze S.; Sen T.K.	1	337	0
Cherrafi A.; Elfezazi S.; Chiarini A.; Mokhlis A.; Benhida K.	1	323	0
Choudhary D.; Shankar R.	1	321	0
Chen L.; Zhao X.; Tang O.; Price L.; Zhang S.; Zhu W.	1	312	0
Glover J.L.; Champion D.; Daniels K.J.; Dainty A.J.D.	1	286	0
Top cited organisations	Documents	Citations	Total link strength
Cena University of São Paulo (Usp), Piracicaba, Sp, Brazil	1	721	13
China Agricultural University, Beijing, China	1	721	13
Chinese Academy of Sciences, Beijing, China	1	721	13
Columbia University, United States	1	721	13
Embrapa Satellite Monitoring, Campinas, Sp, Brazil	1	721	13
Federal University of Pará, Brazil	1	721	13
Institute For Environmental Studies, Vu University Amsterdam, Netherlands	1	721	13
International Union for Conservation of Nature, China	1	721	13
Massachusetts Institute of Technology, United States	1	721	13
Michigan State University, United States	1	721	13
Top cited countries	Documents	Citations	Total link strength
China	454	11962	311
India	264	7345	241
United States	163	6391	191
United Kingdom	196	6150	282
Italy	116	3141	107
Australia	95	2956	134
Brazil	98	2582	60
Germany	85	2066	105
Denmark	30	2022	64
Netherlands	39	1972	50

presence of terms like "environmental economics" and "economic and social effects" suggests a broader perspective on sustainability, one that considers the socio-economic implications alongside the environmental ones. The co-occurrence of these keywords paints a comprehensive picture of the evolving discourse on sustainability, indicating both established concerns and emerging focal points.

#### **Bibliometric coupling analysis of Top cited sources, authors, organizations, and countries**

The bibliometric coupling analysis in table 8 shows interrelatedness and influence within the research community, emphasizing the importance of

various sources, authors, organizations, and countries (figures 7–9). When considering the most cited sources, the "Journal of Cleaner Production" stands prominently with 262 documents, amassing 10,468 citations and a total link strength of 5,731. "Sustainability (Switzerland)", though having more documents at 281, has considerably fewer citations at 3,601 but still retains a noteworthy link strength of 2,154. Other pivotal journals in the realm of sustainability and environmental research include "Business Strategy and the Environment", "International Journal of Production Economics", and "Resources, Conservation and Recycling".





supply chain management intricacies, are reflected in the varied range of topics covered in the research [41]. When examining the yearly citation impact of the analysed literature, a clear upward trend is noticeable. This reflects the increasing relevance and recognition of research contributions in this area. The textile and apparel industry's evolution, especially its increasing focus on sustainability, mirrors findings

posited that sustainable practices in textile manufacturing have become indispensable in recent times [42]. Annual literature output also provides crucial insights. Dominant publications, like the "Journal of Cleaner Production" and "Sustainability (Switzerland)", emerge as essential sources for disseminating industry-related knowledge.

Table 8

BIBLIOMETRIC COUPLING ANALYSIS OF TOP CITED SOURCES, AUTHORS, ORGANIZATIONS, AND COUNTRIES			
Most cited sources	Documents	Citations	Total link strength
Journal of Cleaner Production	262	10468	5731
Sustainability (Switzerland)	281	3601	2154
Business Strategy and the Environment	60	1938	2341
International Journal of Production Economics	29	1876	1655
Energy	24	1220	195
Resources, Conservation and Recycling	29	1157	1010
Science of the Total Environment	24	816	313
Environmental Science and Pollution Research	61	767	282
Computers and Industrial Engineering	11	766	433
Journal of Retailing and Consumer Services	8	720	243
Most cited authors	Documents	Citations	Total link strength
Liu J.; Hull V.; Batistella M.; Defries R.; Dietz T.; Fu F.; Hertel T.W.; Cesar Izaurralde R.; Lambin E.F.; Li S.; Martinelli L.A.; Mcconnell W.J.; Moran E.F.; Naylor R.; Ouyang Z.; Polenske K.R.; Reenberg A.; Rocha G.M.; Simmons C.S.; Verburg P.H.; Vitousek P.M.; Zhang F.; Zhu C.	1	721	0
Sagar N.A.; Pareek S.; Sharma S.; Yahia E.M.; Lobo M.G.	1	599	0
Carpenter A.W.; De Lannoy C.-F.; Wiesner M.R.	1	527	0
Stević Ž.; Pamučar D.; Puška A.; Chatterjee P.	1	519	1
Cheng C.C.J.; Yang C.-L.; Sheu C.	1	354	3
Afroze S.; Sen T.K.	1	337	0
Cherrafi A.; Elfezazi S.; Chiarini A.; Mokhlis A.; Benhida K.	1	323	10
Choudhary D.; Shankar R.	1	321	0
Chen L.; Zhao X.; Tang O.; Price L.; Zhang S.; Zhu W.	1	312	30
Glover J.L.; Champion D.; Daniels K.J.; Dainty A.J.D.	1	286	14
Most cited organisations	Documents	Citations	Total link strength
Department Of Industrial and Production Engineering, Bangladesh University of Engineering and Technology, Dhaka, 1000, Bangladesh	12	695	1758
UTS Business School, University of Technology Sydney, Australia	5	616	1019
Institute of Leather Engineering and Technology, University of Dhaka, Dhaka, 1209, Bangladesh	5	569	1341
School of Management and Economics, Beijing Institute of Technology, Beijing, 100081, China	6	339	584
China Institute of FTZ Supply Chain, Shanghai Maritime University, Shanghai, 201306, China	8	334	1763
Guildhall School of Business and Law, London Metropolitan University, London, United Kingdom	8	325	709
Department of Business Administration, ILMA University, Karachi, Pakistan	6	251	1179
Sustainable Development Research Institute for Economy and Society of Beijing, Beijing, 100081, China	4	246	559
Sustainable Development Research Institute for Economy and Society of Beijing, Beijing, China	4	228	501
School of Management and Engineering, Xuzhou University of Technology, Xuzhou, China	4	219	952

Table 8 (continuation)

Most cited countries	Documents	Citations	Total link strength
China	454	11962	47155
India	264	7345	46839
United States	163	6391	27728
United Kingdom	196	6150	51003
Italy	116	3141	24571
Australia	95	2956	22325
Brazil	98	2582	13847
Germany	85	2066	17618
Denmark	30	2022	10314
Netherlands	39	1972	10489

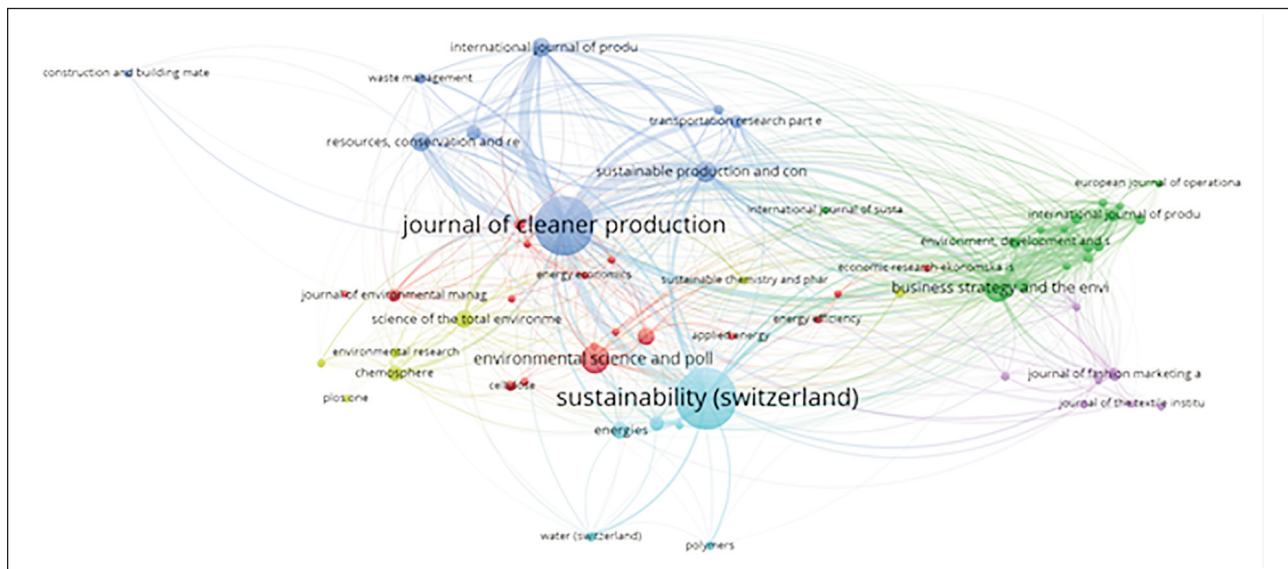


Fig. 7. Bibliometric coupling of sources

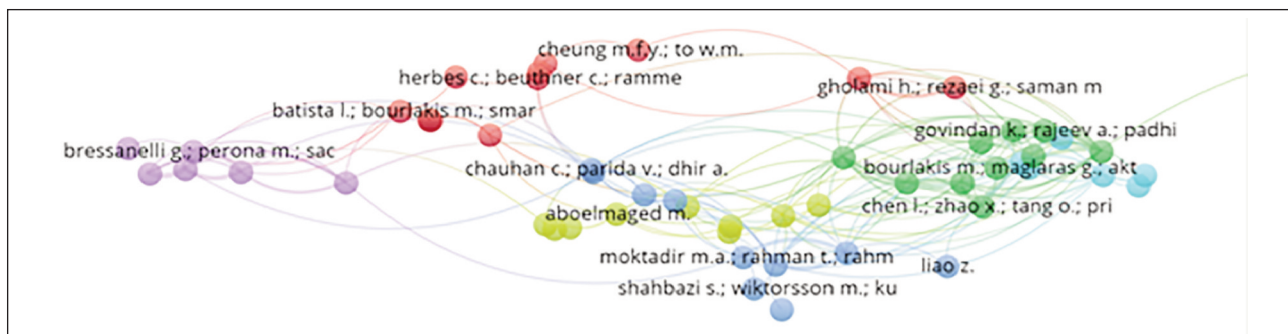


Fig. 8. Bibliometric coupling of authors

The prominence of these journals highlights the global push towards environmentally conscious manufacturing and business practices. Assessing the local impact of top journals indicates the depth and breadth of research in this domain. For instance, "Business Strategy and the Environment" boasts a commendable impact, emphasizing the amalgamation of business strategies with environmental considerations in the textile sector [43].

The contributions of key authors on a yearly basis exhibit the dynamic nature of research in this domain.

Liu J. and his collaborators, for instance, have been instrumental in shaping discourse, even though their significant citation count contrasts starkly with their low link strength [44]. This discrepancy could be attributed to the diverse nature of collaborations and partnerships they engage in a chronological analysis of word frequency reveals the shifting paradigms within the industry. Words like "sustainable development" and "sustainability", which have grown in frequency over time, resonate with global trends in various industries aiming for sustainable growth [45].



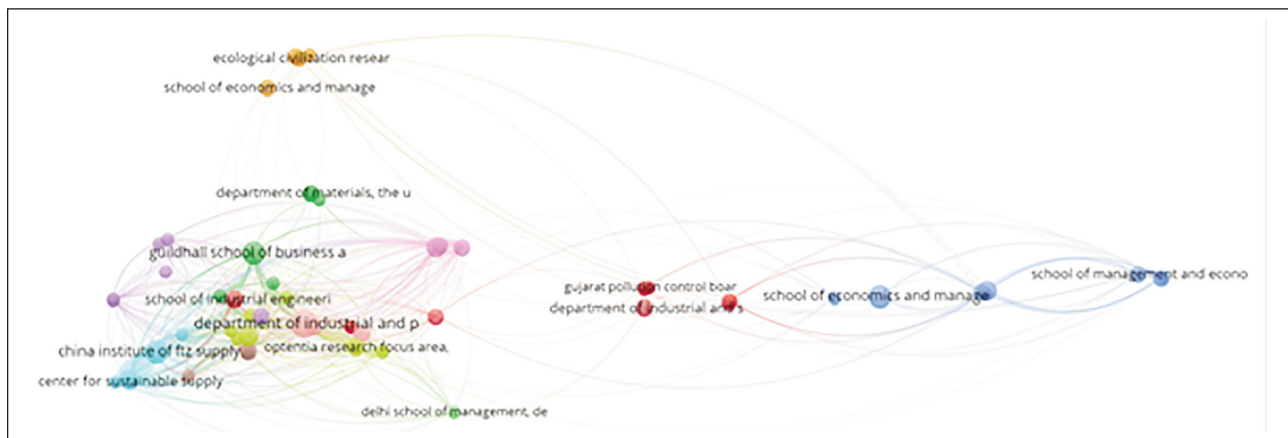


Fig. 9. Bibliometric coupling of organizations

Moreover, the emergence of trend topics, such as "energy conservation" and "environmental policy", underscores the industry's ongoing efforts to align with global environmental objectives. Data derived from the VOSviewer further enriches our understanding. The co-authorship analysis reveals vast networks of collaboration spanning authors, countries, and organizations. The expansive collaboration, particularly among nations like China, India, and the US, corroborates findings noted in the global nature of textile research [46]. The frequent co-occurrence of keywords, including "sustainability" and "textile industry", accentuates the growing convergence of environmental concerns with industry practices. This trend is consistent with observations which highlighted the industry's shift towards green manufacturing processes [47, 48]. Lastly, the bibliometric coupling analysis affirms the interconnectedness in this research domain. The dominant role of institutions like the "Department of Industrial and Production Engineering" at the Bangladesh University of Engineering and Technology illustrates the global spread and collaborative nature of research endeavours. However, the decision-making process represents a challenging issue in the modern era [49]. The comprehensive analysis of literature on the textile and apparel industry reveals an evolving narrative centred around sustainable practices, global collaborations, and innovative methodologies, reflecting broader global trends and imperatives. On the other hand, according to [50] in the emerging country of India, the "fintech segment is currently one of the most rapidly growing industries".

## CONCLUSION

In synthesizing the vast volume of data unearthed from our meticulous analysis, it becomes lucidly clear that sustainability transitions in the textile and apparel sector have evolved to occupy a dominant space in academic discourse. The intellectual structure, elucidated via co-citation and co-word analyses, underlines the intertwining of sustainable development with the intricate workings of this industry, effectively addressing our first objective. Moreover, by navigat-

ing the gender and ethical dimensions, an intriguing observation emerges regarding the representation and thematic focal areas within the research. Not only does this help grasp the diversity of voices and perspectives in this field but also underscores the imperative to foster a more inclusive research environment, adhering to the second objective.

Geographically, a compelling concentration of research has emanated from countries like China, India, and the United States. This distribution not only reflects the region's inherent industrial prowess but also pinpoints both the leading lights and the existing lacunae in sustainability research. Institutions from Bangladesh, for instance, have showcased commendable research contributions, emphasizing our pursuit of highlighting works from lesser-known institutions and developing regions, encapsulating objectives three and seven. Technological and interdisciplinary innovations have left an indelible mark on sustainable practices within the industry. Through analysis, we note an upswing in research themes focusing on technological integrations, such as supply chain management and waste management, solidifying our fourth objective. When delving into the real-world impacts, the pertinence of case studies and policy reforms becomes unmissable. The emphasis on "sustainable development" and "sustainability" as recurring keywords lends credence to the industry's efforts in translating academic insights into tangible practices, manifesting the sixth and eighth objectives. Additionally, the influence of significant global events and challenges on research trends underscores the adaptive and responsive nature of sustainability research in this realm, ticking off our sixth objective. The recurring focus on "sustainable practices" and the emphasis on innovative topics such as "circular economy" in the literature reveals the industry's effort to embed sustainability holistically. It resonates to quantify real-world impacts, specifically looking at environmental metrics and policy shifts, as outlined in our fifth objective.

The textile and apparel industry, as mirrored in the analysed literature, stands at the crossroads of sustainability, innovation, and inclusivity. The academic



landscape, populated by myriad voices and perspectives, not only chronicles the sector's past endeavours but also charts a promising roadmap for the future. This comprehensive study effectively bridges the academic-industry nexus, offering actionable insights while fulfilling its objectives, from understanding the intellectual underpinnings to spotlighting tangible industry successes and challenges in the domain of sustainability.

## POLICY IMPLICATIONS

In light of the comprehensive bibliometric analysis, several crucial policy implications emerge. Firstly, the literature underscores the urgency of sustainable development and overall sustainability in the textile and apparel industry. Policymakers are urged to enact regulations that nudge industries towards more sustainable practices, whether through positive incentives for eco-conscious operations or stiffer penalties for environmental transgressions. Moreover, an observation from the study indicates a potential gap in inclusive research, particularly in gender and ethical dimensions. This points to the need for policy guidelines that ensure research grants and platforms embrace diversity. By ensuring an equitable distribution of research opportunities, we can cultivate a more comprehensive academic discourse enriched by varied perspectives.

Additionally, considering the geographical distribution of research, there's a clear indication that one-size-fits-all strategies might be suboptimal. Policymakers must craft region-specific strategies, considering the unique challenges, strengths, and cultural nuances of each region. This not only enhances the efficacy of policies but also ensures localized relevance.

Technological innovation emerges as a strong theme, signifying the convergence of technology and sustainability. Policymakers could capitalize on this by channelling resources into interdisciplinary research, spurring the growth of technological solutions tailored for the textile and apparel sector. Furthermore, the dynamic nature of the industry, especially its agility in reacting to global events, implies that static policies could be obsolete in a short span. Policymakers must cultivate a culture of adaptability, revisiting, and recalibrating policies based on the current global context and the latest research findings. Lastly, a pivotal observation is the necessity to bridge the academia-industry divide. Policymakers can be instrumental in catalysing this by endorsing and facilitating partnerships between academic researchers and industry professionals. This symbiotic relationship ensures that academic discoveries don't remain ensconced in journals but find palpable expression in the industry, driving tangible change.

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