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**Nemzetközi tudományos konferencia
a Magyar Tudomány Ünnepe alkalmából**
International Scientific Conference
on the Occasion of the Hungarian Science Festival

Sopron, 2023. november 23.
23 November 2023, Sopron

**FENNTARTHATÓSÁGI ÁTMENET:
KIHÍVÁSOK ÉS INNOVATÍV MEGOLDÁSOK**
SUSTAINABILITY TRANSITIONS: CHALLENGES AND INNOVATIVE SOLUTIONS

Szerkesztők / Editors:

OBÁDOVICS Csilla, RESPERGER Richárd, SZÉLES Zsuzsanna, TÓTH Balázs István

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TARTALOMJEGYZÉK / CONTENTS

Plenáris szekció

Plenary Session

How to Make European Integration Fair and Sustainable? <i>István P. SZÉKELY</i>	13
---	----

1. szekció: Fenntartható gazdálkodás és menedzsment, körforgásos gazdaság Session 1: Sustainable Economy and Management, Circular Economy

A zöld ellátási láncok aktuális kérdései - Kritikai szakirodalmi összefoglalás <i>PIRICZ Noémi</i>	27
--	----

Well-being - kulcs a fenntartható működéshez <i>KÓPHÁZI Andrea – KOVÁCSNÉ LACZKÓ Éva Mária</i>	36
--	----

Szervezeti kultúra és fenntarthatóság <i>KOVÁCSNÉ LACZKÓ Éva Mária</i>	48
--	----

Az új mexikói kvótakereskedelmi rendszer és erdészeti vonatkozásai <i>KIRÁLY Éva – BOROVICS Attila</i>	61
--	----

A designesztétika gazdasági megközelítésének lehetőségei <i>REMÉNYI Andrea – ZALAVÁRI József</i>	76
--	----

A körforgásos üzleti modellek a vállalati gyakorlatokban <i>KRIZA Máté</i>	98
--	----

2. szekció: Társadalmi kihívások és társadalmi innovációk a fenntartható fejlődésben Session 2: Social Challenges and Innovations in Sustainable Development

Társadalmi kihívások a divatipari fogyasztás terén <i>VIZI Noémi</i>	119
--	-----

Klímaszorongás jelenléte az X, Y és Z generáció életében <i>SZEBERÉNYI András</i>	128
---	-----

Közelségi torzítás – a home office egyik kihívása <i>IONESCU Astrid</i>	147
---	-----

Megérti-e a választ, ha megkérdezi kezelőorvosát, gyógyszerészét? Az egészségműveltség mérésének aktuális kérdései Magyarországon <i>PORZSOLT Péter</i>	154
---	-----

A digitális egészségügyi ellátás, mint innováció mérési lehetőségei <i>KOVÁCS Erika</i>	168
---	-----

3. szekció: Fenntartható pénzügyek és számvitel
Session 3: Sustainable Finance and Accounting

A közösségi költségvetési számvitel koncepciója és dilemmái <i>SISA Krisztina A. – SIKLÓSI Ágnes – VERESS Attila – DENICH Ervin</i>	181
Az iszlám banki számvitel digitalizációjának elméleti és filozófiai megközelítése <i>CSEH Balázs</i>	193
A vállalkozások csőd kockázatának és a kötvényminősítések együttmozgása <i>SZÁNTÓ Tünde Katalin</i>	202
A globális minimumadó következményei és megvalósíthatósága a multinacionális vállalatok számára <i>MATTIASSICH Enikő – SZÓKA Károly</i>	211

4. szekció: Fenntartható turizmus és marketing
Session 4: Sustainable Tourism and Marketing

A fenntartható turizmus: valóság vagy átverés? <i>PALANCSA Attila</i>	221
Metamarketing: fenntartható innovációk a valós és virtuális lehetőségek imperatív szimbiózisa mentén <i>REMÉNYI Andrea</i>	237
A fennmaradás és fenntarthatóság aspektusainak vizsgálata a szálláshely-szolgáltatással foglalkozó KKV-szektorban rendkívüli helyzetek idején <i>VARGYAS Daniella – KERESZTES Gábor</i>	261
Tudatosság és fenntarthatóság a nyaralás alatt is <i>MÉSZÁROS Katalin – HOSCHEK Mónika – Németh Nikoletta</i>	270
A soproni egyetemisták külföldi tervei <i>OBÁDOVICS Csilla – RUFF Tamás</i>	283
Country Branding of the Hashemite Kingdom of Jordan <i>Mohammad Hani KHLEFAT</i>	295
Community-Based Tourism in Southeast Asia <i>Thi Thuy Sinh TRAN – Nikoletta NÉMETH – Md. Sadrul Islam SARKER – Yuan ZHANG – NHAT ANH NGUYEN</i>	309

5. szekció: Sustainable Finance and Accounting, Sustainable Development
Session 5: Sustainable Finance and Accounting, Sustainable Development

Stakeholder Engagement in the Development of the Sustainability Reporting Standards of the Global Reporting Initiative (GRI) and of the International Sustainability Standards Board (ISSB)

Alina ALEXENKO 329

The IFRS and the Financial Accounting System in Algeria: A Literature Review

Asma MECHTA – Zsuzsanna SZÉLES – Ágnes SIKLÓSI 342

Potential Effects of Industry 4.0 Technologies on Environmental Sustainability - A Systematic Literature Review

Mohamed EL MERROUN 351

The Use of Geothermal Energy for Sustainable Development and Economic Prosperity

Nadjat KOUKI – Andrea VITYI 365

6. szekció: Sustainability Transformation and Circular Economy
Session 6: Sustainability Transformation and Circular Economy

A fenntarthatóság, a társadalmi szerepvállalás és a felelős vállalatirányítás szabályozásának szerepe a vállalati innovációban

BARTÓK István János 381

Circular Economy Research Trends in the Textile and Apparel Industries: A Bibliometric Analysis

Md. Sadrul Islam SARKER – Thi Thuy Sinh TRAN – István János BARTÓK 389

The Historical Evolution of Employee Idea Management: A Comprehensive Review

Viktória ANGYAL 405

7. szekció: Sustainable Economy and Management
Session 7: Sustainable Economy and Management

Bewältigungsstrategien eines nachhaltigen Managements von Organisationen innerhalb einer VUCA-Umwelt: Eine systematische Literaturrecherche

Mike WEISS 421

Influences of Autonomous Vehicles on Sustainability: A Systematic Literature Review

Phillipp NOLL – Zoltán SZABÓ 436

Trends in Sustainable Leadership

Roland SEESE – Katalin DIÓSSI 452

Recruiting for Resilience: An Economic Approach to Mitigate Candidate Ghosting

Laureana Anna Erika TEICHERT 460

Führung auf Distanz - Herausforderungen für Führungskräfte durch die Nutzung von Home-Office

Norbert KLEIN 473

A Generative AI and Neural Network Approach to Sustainable Digital Transformation: A Focus on Medical and Marketing Sectors

Alexander Maximilian RÖSER – Cedric BARTELT 483

Allgemeine Alterswahrnehmung bei StudentInnen in den österreichischen und ungarischen Grenzregionen

Dorottya PAKAI – Csilla OBÁDOVICS 498

8. szekció: Társadalmi kihívások és társadalmi innovációk a fenntartható fejlődésben
Session 8: Social Challenges and Innovations in Sustainable Development

Fenntartható olvasás a digitális korban

MOLNÁR Csilla 509

Okos és fenntartható városfejlesztés felelősségteljes digitális innovációval

GYULAI Tamás – NAGY Marianna 518

A coaching szerepe a vezetőfejlesztésben

KÓPHÁZI Andrea – Éva LÖWE 535

9. szekció: Fenntartható gazdálkodás és menedzsment
Session 9: Sustainable Economy and Management

A szolgáltatók szerepe és felelőssége a desztinációk fenntartható turizmusának megteremtésében, illetve kialakításában: Szisztematikus irodalmi áttekintés

TEVELY Titanilla Virág – BEHRINGER Zsuzsanna 548

Bükkfürdő imázsának élménymarketing alapú vizsgálata

HORVÁTH Kornélia Zsanett 563

A public relations (PR) tevékenység határai és viszonya a marketinghez - Egy PR szakemberek körében végzett kvantitatív kutatás eredményei

KÁROLY Róbert – LUKÁCS Rita – PAPP-VÁRY Árpád Ferenc 572

Márkázott superhősök: Hogyan formálják a különböző termék- és szolgáltatásmárkák Amerika kapitány és Vasember karakterét a Marvel filmekben?

PAPP-VÁRY Árpád Ferenc – RÖNKY Áron 591

Sztármárka-építés hosszú távon: Cristiano Ronaldo és CR7 márkájának megítélése – Egy kvalitatív kutatás tapasztalatai

KORIM Dorina – PAPP-VÁRY Árpád Ferenc 609

10. szekció: Sustainable Economy and Management I.
Session 10: Sustainable Economy and Management I.

The Role of Mountain Tourism Activities and Facilities on Domestic Tourism Consumption in Tourism Destinations <i>Deborah KANGAI – Eliyas Ebrahim AMAN – Árpád Ferenc PAPP-VÁRY – Viktória SZENTE</i>	624
Sustainable Project Management <i>Attila LEGOZA</i>	633
The Effect of Sustainability Development Using the Example of Green Washing <i>Dijana VUKOVIĆ – Tanja UNTERSWEG</i>	641
Sustainable Strategies in Case of Start-Up Enterprises <i>Peter IMRICKO</i>	654
Sustainable Strategic Management at Multinational Companies <i>Peter IMRICKO</i>	663
The EU as a “Leadiator” in Climate Governance - a Successful Soft Power Instrument? An Analysis with a Focus on Sustainable Mobility <i>Sarah DIEHL</i>	674
Az irodater komfortjának vizsgálata a munkavállalók szempontjából – Út a jövő optimális irodája felé <i>GROZDICS Anett Tímea – BORSOS Ágnes</i>	684
Mögliche Auswirkungen von CSRD & ESRS auf die digitale Wirtschaft und der Fertigungsindustrie in Deutschland: aus der Perspektive der Industriepformance und der nachhaltigen Entwicklung <i>Mohammad Reza ROBATIAN</i>	696

11. szekció: Sustainable Economy and Management II.
Session 11: Sustainable Economy and Management II.

Sustainability and Climate Protection in Hospitals - Green Hospitals in the Future in Germany <i>Patricia Carola MERTEN</i>	719
Territoriality in Climate Adaptation? Space Interpretations of Different Disciplines and Fields and their Potential Utilization in the Examination of Climate Adaptation’s Territorial Aspects <i>Attila SÜTŐ</i>	727
Sustainable Unity in the European Insurance Market: Calculating Personal Injury Claims (From Experience to Methodology) <i>Zsolt Szabolcs EKE</i>	745

12. szekció: Poszter szekció
Session 12: Poster Session

A dendromassza-hasznosítás, mint megújuló természeti erőforrás szerepe a fenntartható, körkörös gazdaságban <i>SZAKÁLOSNÉ MÁTYÁS Katalin</i>	755
Az I szektor karbonhatékonyságának vizsgálata Magyarországon <i>KOVÁCSNÉ SZÉKELY Ilona – MAGYAR Norbert – JAKUSCHNÉ KOCSIS Tímea</i>	761
A visegrádi országok egészségügyi reformjainak és intézkedéseinek összehasonlítása <i>VITÉZ-DURGULA Judit – SÓTONYI Tamás Péter</i>	766
A márkaépítés hatása a fogyasztói lojalításra a Magyar Telekom esetében <i>TAKÁTS Alexandra – SZÁSZ Zsombor Levente</i>	780
Examining the Impact of Certain Factors on the Delivery Time of a Manufacturing Firm Using Data Science Methods <i>Zsolt TÓTH – József GARAB</i>	800
Artificial Intelligence with an Economic Growth Perspective <i>Firat ŞAHİN</i>	809

Circular Economy Research Trends in the Textile and Apparel Industries: A Bibliometric Analysis

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Abstract:

The circular economy (CE) has gained significant global attention as a potential solution to environmental and socio-economic issues, such as pollution, waste generation, and resource depletion, arising from the textile and clothing industries. The objective of this bibliometric review is to explore the trends and patterns of circular economy research in the apparel industry. Data were collected from the Scopus database while the bibliometric data were analysed using VOSviewer software. A comprehensive search of pertinent keywords linked to circular economy in the textile industry yielded 697 empirical and review articles. The analysis revealed significant aspects of the evolution of textile circularity research and voids in the discipline. This review also uncovered the central research themes, the countries, the influential journals, and the productive articles in this field. The Journal of Cleaner Production was the most prolific outlet, and the United Kingdom was the most productive country in circular clothing research. The results of this study can assist scholars in identifying novel research methodologies in this domain. Therefore, the study serves as a valuable addition towards identifying the primary patterns in circular economy research in the textile industries and suggesting potential avenues for future research endeavours.

Keywords: circular economy, textile industry, bibliometric analysis

JEL Codes: L67, Q56, Q57

1. Introduction

The circular economy (CE) has gained significance in the textile and apparel (T&A) industries due to the growing global attention to sustainability in recent years. Though T&A industries contribute significantly to the global economy by generating revenues amounting to \$2.4 trillion annually and employing 300 million people, they are recognised as the second largest polluting

sector in the world (Adamkiewicz et al., 2022; Kazancoglu et al., 2020; Sarker & Bartok, 2023). The current clothing system is almost linear in how clothes are made, distributed, and used. A linear system wastes economic opportunities, pollutes the environment, strains scarce resources, and harms societies' economies (Niinimäki et al., 2020).

Production and consumption of textiles have increased dramatically in the past few years due to high population growth and rising incomes and living standards. This rapid growth of the clothing business has resulted in environmental, social, and economic issues such as natural resource depletion, waste generation, water, air and soil pollution, climate change, human toxicity, and eco-toxicity (Chen et al., 2023; Moazzem et al., 2022; Shirvanimoghaddam et al., 2020). The apparel industry contributes almost 8% of the global carbon budget and roughly 20% of industrial water pollution (Hora et al., 2023). Moreover, the manufacturing phase accounts for approximately 80% of textiles' overall climate change impact (Appolloni et al., 2023; Sarker & Bartok, 2024). Annually, almost \$400 billion of clothing is wasted, with an anticipated increase of 60% between 2015 and 2024. In contrast, the recycling or reuse of textile material waste is limited to 25%, with the remaining 75% deposited in landfills (Thinakaran et al., 2023). Consequently, concerns regarding sustainable development stem from unsustainable textile production and consumption patterns. CE has emerged as a potential solution for reducing the challenges caused by the clothing supply chain (Goyal et al., 2021).

The CE is a regenerative model of economic operations that promotes sustainability by optimising the use of resources, water, and energy in production, distribution, and consumption while also minimising CO₂ emissions and waste (Niinimäki et al., 2020). It covers a range of terms, for instance, product life cycle extension, introduction of a renewing economy, application of cradle-to-cradle strategy, use of industrial ecology, and incorporation of the R policies (reduce, reuse, recycle and repair) (Goyal et al., 2021). The CE emerges as a substitute for the linear approach, characterised by the take-make-use model, by introducing a closed-loop circular framework (Aus et al., 2021; Kazancoglu et al., 2020). The circular principles maximise resource efficiency, reduce waste generation, and mitigate environmental consequences. Therefore, we define CE as a model of business operations that emphasises product longevity, materials and resource efficiency, and waste reduction.

In the past few years, the CE has received substantial attention from researchers and professionals in the apparel business. Therefore, many researchers made attempt for conducting research on circular textiles. For example, Saha et al. (2022) uncovered the current state of the circular economy (CE) in the textile and apparel sector based on a sample dataset of 114 textile firms from Bangladesh, Vietnam, and India. Thinakaran et al. (2023) identified the challenges of implementing CE in Indian fashion industry. Camacho-Otero et al. (2019) studied consumer perspectives on accepting and adopting circular offerings. They revealed that one of the obstacles to the shift towards a circular economy is that consumers are concerned about textile prices due to circular practices. Besides, Kazancoglu et al. (2022) identified several barriers to implement circular economy in the textile industry from Stakeholders' perspective. However, several researchers have demonstrated the benefits of CE (D'Agostin et al., 2020; Roy et al., 2022; Salvador et al., 2021; Urbinati et al., 2017). By applying CE principles, the textile sector may promote sustainability by enhancing resource efficiency, reducing waste, and increasing design variety (Hora et al., 2023; Khairul Akter et al., 2022). In addition to empirical works, there are also a plenty of systematic and bibliometric review studies on CE which focus on the conceptualisation, drivers, and barriers to implementing CE concepts (Chrispim et al., 2023; Goyal et al., 2021; Lieder & Rashid, 2016; Theeraworawit et al., 2022). Previous reviews on CE were based on various contexts; for example, regional perspective (Arsova et al., 2022), management perspective (Ahmad et al., 2023), waste management (Tanveer et al., 2022). However, despite plethora of bibliometric studies on CE, limited numbers of bibliometric review could be found

on the textile and apparel industries and most of the reviews were remained limited to the traditional bibliometric techniques, such as, citation count, journal, authors and keyword analysis. Hora et al., (2023) conducted the most recent bibliometric reviews on CE in the textile industry using data from Web of Science but the study has less emphasis on relational nature of knowledge creation of CE research in the textile and apparel supply chains. Considering these contexts, we have undertaken this study to fulfil the knowledge gaps in the literature by applying co-relational technique, for instance, co-citation analysis along with traditional bibliometric techniques. This research will respond to the following research queries:

RQ1: *What is the current status of the CE research in the textile industry?*

RQ2: *What are the productive journals and country collaboration network in the CE textile research?*

RQ3: *What is the intellectual structure and knowledge base of the CE research in the textile and apparel industries?*

To the best of the researchers' knowledge, there is no bibliometric review on the CE in the textile and apparel industries that used both traditional and augmented bibliometric techniques and systematic review guidelines. The researcher used performance analysis techniques for answering RQ1, RQ2 and RQ3 were addressed by using science mapping techniques.

The subsequent sections of this research are as follows: Section 2 presents the methodology adopted for this study. Section 3 provides results and discussion Section 4 presents the conclusion, limitation, and future research avenues.

2. Methodology

2.1. Data source and searching approach

The initial stage of the bibliometric study involves selecting a database. This review used the Scopus database. The primary rationale for utilising the Scopus database in this study is its broader coverage. Scopus is an extensive and interdisciplinary database that encompasses a wide array of scientific journals, conference proceedings, books, and other publications (Bang et al., 2023). The study used rigorous, reproducible, and transparent criteria to minimise bias and conducted thorough literature searches of published articles. The search field was title, abstract and keywords for searching relevant papers in the field of circular economy in the textile and apparel industries. Researchers used the advanced search option in the Scopus database. The keywords were determined by considering the topic of the study and the keywords employed in earlier review papers on a related subject. The chosen search string was *TITLE-ABS-KEY (("Circular economy") AND ("Apparel industr*" OR "Fashion industr*" OR textile* OR "Textile industr*" OR "Clothing Sector*" OR apparel OR garments OR clothing OR fashion)) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (LANGUAGE , "English"))*. The searches took place on November 2, 2023. Only journal articles and review papers written in English were considered. The authors didn't set any restriction on timeframe. By applying inclusion and exclusion criteria in the Scopus database, the researchers identified 706 documents which were exported in the csv format for cleaning the data set as the raw data set is not appropriate for bibliometric analysis. In this phase, researcher perform two tasks namely, data cleaning and screening the dataset. Subsequently, researchers checked the desired data field and column whether there is any missing or incorrect data and read the titles and abstracts of the papers for determining relevance and found nine documents are appropriate for data analysis. After cleaning screening dataset researcher got 697 documents for bibliometric analysis. The search procedure has been shown in Figure 1.

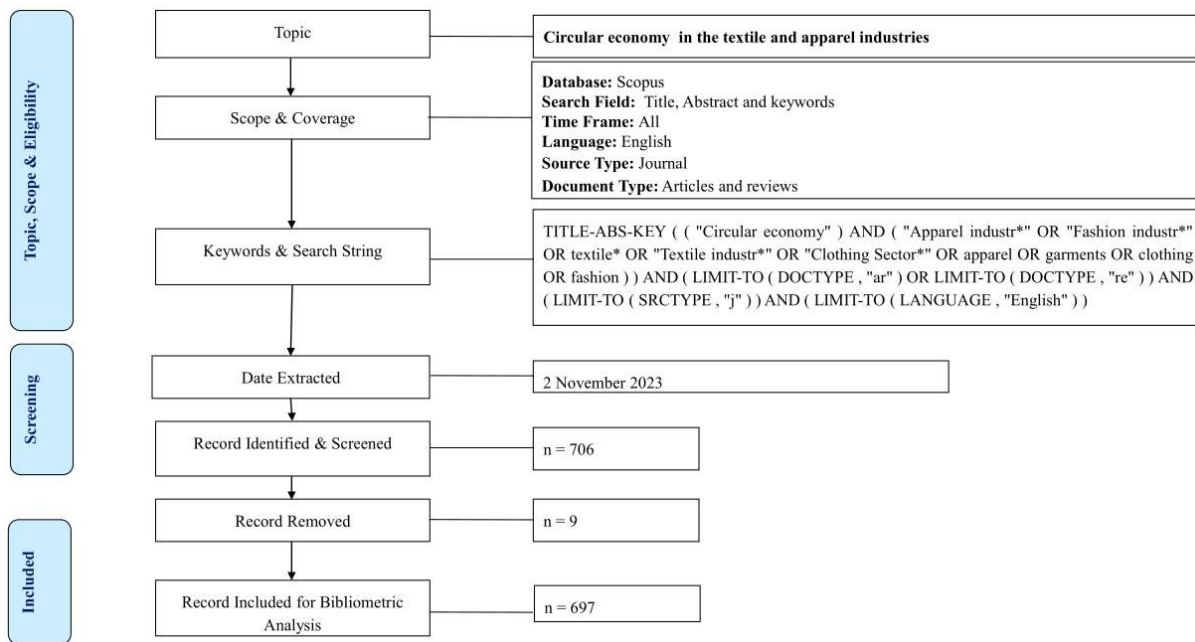


Figure 1: Search flow chart

Source: Adapted from Page et al. (2021:19) and Zakaria et al. (2021:360)

2.2. Data analysis

The data analysis was organised systematically to address the research inquiries. We used performance analysis to show the current state of the CE research in the textile industry. The number of papers, year of publication, kind of publication, subject areas of publication, leading publishers, and leading nations in terms of publication in the field are some of the characteristics used to provide the results. Bibliometric metrics, including total publications, number of cited papers, and overall link strength, were utilised to assess the impact and significance of the identified publications. In addition, we employed keyword co-occurrence network analysis, co-citation analysis, and bibliographic coupling analysis to visually represent and highlight important themes and concepts in the field. These visualisations facilitated the identification of clusters of correlated subjects, revealed concealed patterns, and provided insights into the interrelationships among different study subdomains (Donthu et al., 2021).

This study utilised two kinds of techniques to conduct an extensive bibliometric analysis. The first data cleansing and organising were performed using Microsoft Excel. After that, VOSviewer, a user-friendly computer program, version 1.6.16 data was used for displaying bibliographic data (van Eck & Waltman, 2009). Keyword co-occurrence, co-citation and bibliographic coupling network analysis were performed for clustering data and identifying knowledge theme and hotspots of CE research in the textile and apparel industries.

3. Results and discussion

3.1. CE research status in the textile and apparel industries

The study evaluates publications through the following descriptive statistics: year-wise publication trends, patterns of publications, the subject area of the existing research, and trend of publications in major publishers, and countries with the highest productivity. These techniques of bibliometrics are used to answer the first research question.

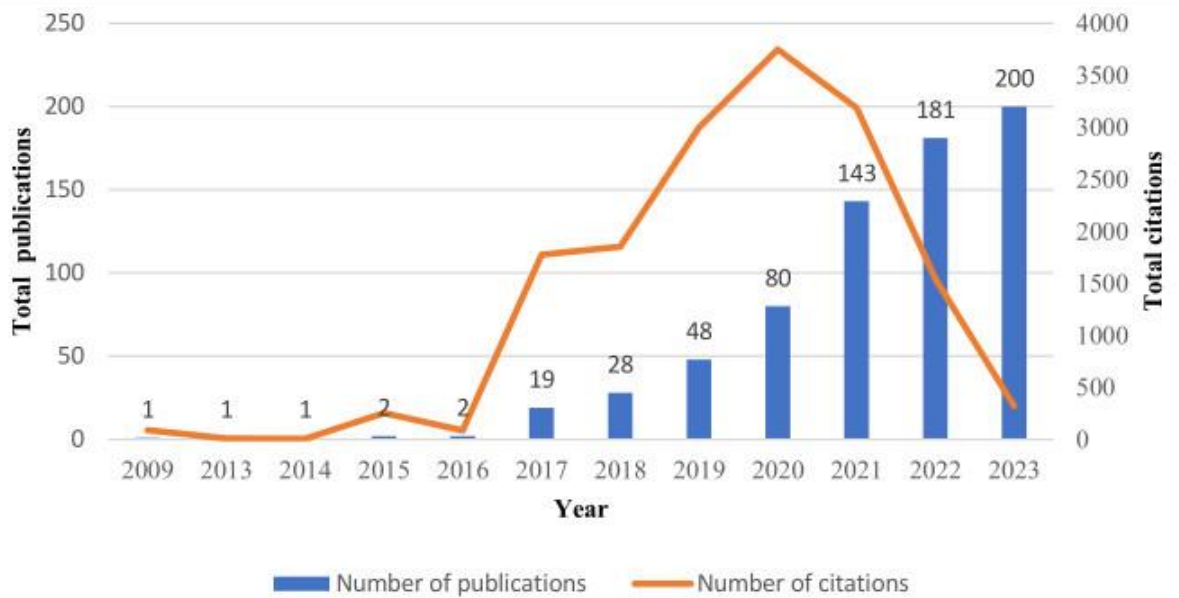


Figure 2: Publications trends

Source: Authors' illustration based on Scopus data (2023)

Figure 2 illustrates the growth trajectory of CE research in the textile and apparel industries from 2009 to 2023 by presenting total publications and citations. Out of 697 papers, a significant majority of 524 were released in the past three years, representing more than 75% of the data sample. The bar chart demonstrates a progressively increasing pattern of publications. Simultaneously, the line graph highlights the escalating number of citations, indicating the growing impact of this research. Consistent with Hora et al. (2023) this notable surge in scholarly papers and citations over the past three years indicates that the concept of CE in the clothing sector has garnered increased attention.

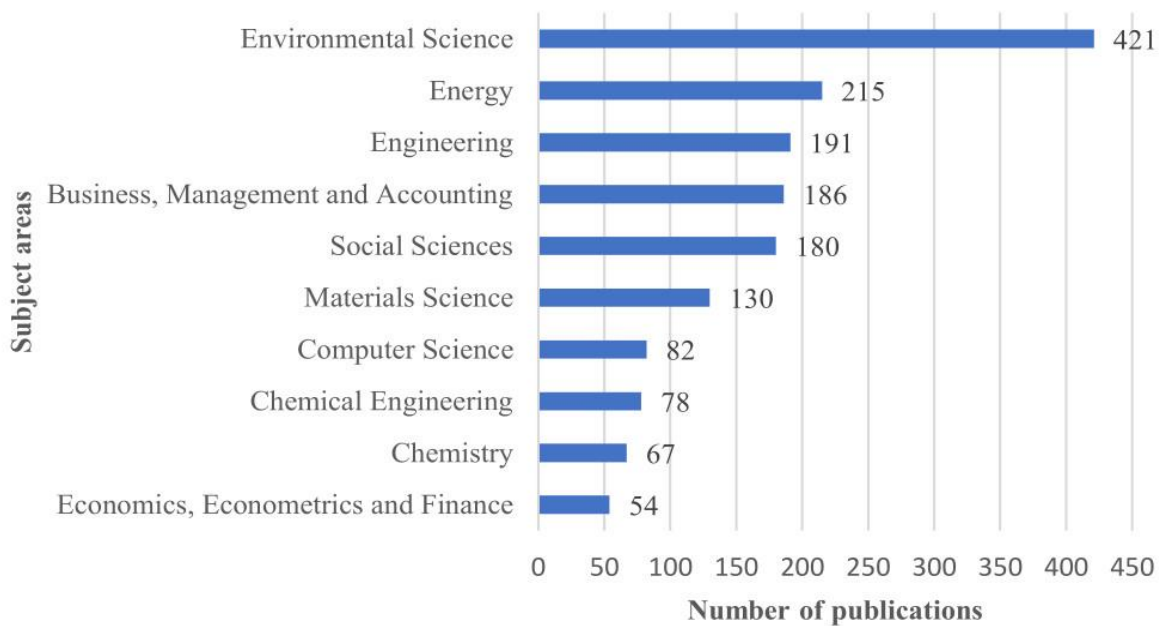


Figure 3: Top 10 subject area of publications

Source: Authors' illustration based on Scopus data (2023)

In order to demonstrate the most leading areas of contribution, the topic areas were extracted from Scopus (Figure 3). A single paper can cover multiple fields of study. Of all the categories, the Environmental Science one stands out with 421 papers. Therefore, this study shed light on the multidisciplinary character of CE research in the textile industry by categorising the published research papers according to their subject area.

Concerning impactful research, Table 1 displays the ten papers with the highest number of citations in the dataset. The Journal of Cleaner Production has published four out of 10 highly cited articles demonstrating its important contribution to textile supply chain CE. The work by Urbinati et al., (2017) which is the first and most extensively referenced, has garnered 488 citations since its publication in the Journal of Cleaner Production in 2017. This study provided a new taxonomy to categorise the various degrees of circularity that various industries have adopted. Subsequent research works that have received substantial citations include those of Sandin & Peters (2018) and Vanapalli et al. (2021), which examine the environmental consequences of textile reuse and recycling and waste management strategies, respectively.

Table 1: 10 highly cited articles in the circular textile research

Authors	Title	Year	Journal	Citation
Urbinati et al. (2017)	Towards a new taxonomy of circular economy business models	2017	Journal of Cleaner Production	488
Sandin & Peters (2018)	Environmental impact of textile reuse and recycling – A review	2018	Journal of Cleaner Production	429
Vanapalli et al. (2021)	Challenges and strategies for effective plastic waste management during and post COVID-19 pandemic	2021	Science of the Total Environment	376
Rhodes (2018)	Plastic pollution and potential solutions	2018	Science Progress	290
Todeschini et al., (2017)	Innovative and sustainable business models in the fashion industry: Entrepreneurial drivers, opportunities, and challenges	2017	Business Horizons	266
Jia et al. (2020)	The circular economy in the textile and apparel industry: A systematic literature review	2020	Journal of Cleaner Production	255
Franco (2017)	Circular economy at the micro level: A dynamic view of incumbents' struggles and challenges in the textile industry	2017	Journal of Cleaner Production	248
Nosratabadi et al. (2019)	Sustainable business models: A review	2019	Sustainability (Switzerland)	243
Solis & Silveira (2020)	Technologies for chemical recycling of household plastics – A technical review and TRL assessment	2020	Waste Management	223
Kjaer et al. (2019)	Product/Service-Systems for a Circular Economy: The Route to Decoupling Economic Growth from Resource Consumption?	2019	Journal of Industrial Ecology	222

Source: Authors' illustration based on Scopus data (2023)

Figure 4 shows the top publishers in circular textiles. Due to increasing significance of CE in the textile industry, many publishers are now accepting papers for publications. The prospective researchers can gain idea to publish their research works in this publishing agencies.

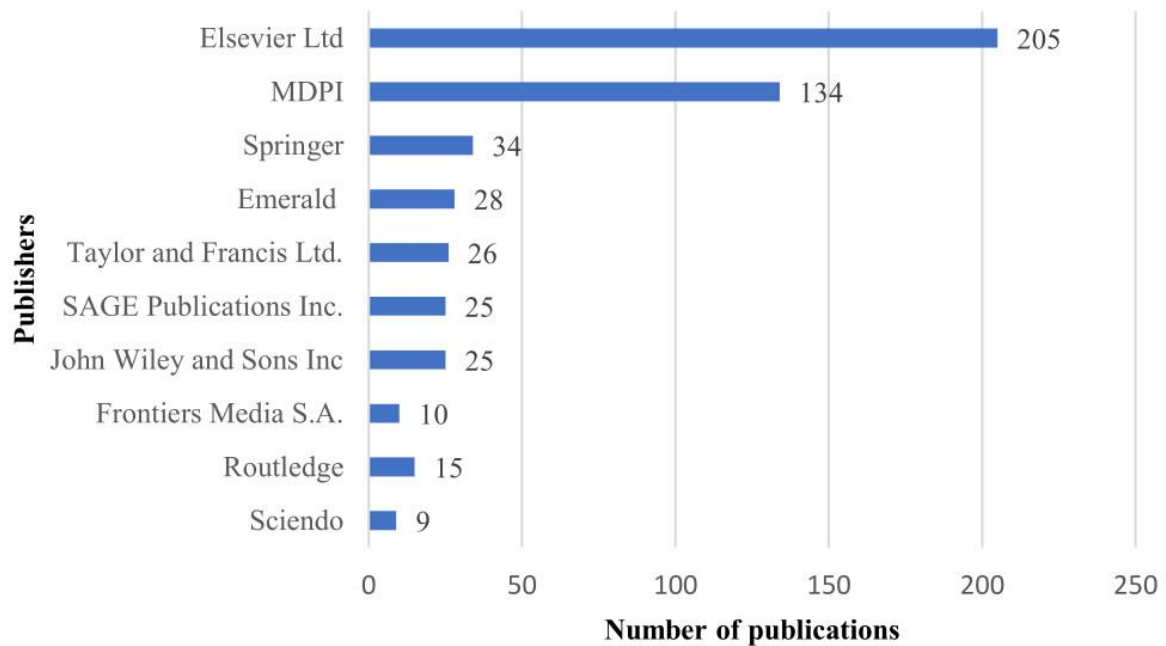


Figure 4: Top 10 publishers

Source: Authors' illustration based on Scopus data (2023)

Table 2: Leading 20 countries publishing CE research in the textile industry

Country	Total publications (TP)	Total citations (TC)	Average citations (AC)
<i>United Kingdom</i>	103	3280	31.84
<i>Italy</i>	90	2372	26.35
<i>India</i>	61	1221	20.01
<i>Spain</i>	48	592	12.33
<i>China</i>	47	1622	34.51
<i>Brazil</i>	40	849	21.22
<i>United States</i>	39	746	19.12
<i>Germany</i>	36	1071	29.75
<i>Sweden</i>	34	1610	47.35
<i>Netherlands</i>	33	1290	39.09
<i>United Kingdom</i>	32	1005	31.40
<i>Finland</i>	32	566	17.68
<i>Portugal</i>	30	1691	56.36
<i>Australia</i>	24	532	22.16
<i>Romania</i>	20	1153	57.65
<i>Denmark</i>	20	278	13.90
<i>Poland</i>	20	664	33.20
<i>Turkey</i>	18	117	6.50
<i>Canada</i>	18	417	23.16
<i>France</i>	15	480	32.00

Source: Authors' illustration based on Scopus data (2023)

Table 2 displays the research output of the top 20 countries on the topic of CE in the garment business, specifically focusing on countries that have published at least 15 articles. The United Kingdom (UK) ranks first in terms of productivity, with a TP score of 103. The substantial TC of 3286 provides additional evidence of the United Kingdom's research excellence in the field of circular textiles.

3.2. Productive journals and country collaboration network in the CE textile research

To answer the second research question about productive journal and national collaboration network, we analysed Scopus database using VOSviewer. Productive and influential journals can be assessed based on citation and document publications. Table 3 shows top 10 productive journals in the CE research in the textile and apparel industries. Researchers used TC, TP and h-index for assessing the quality of journals and ranked the productive journals by considering total citation of the journal.

Table 3: Productive journals in the CE research in the textile industry (ranking based on TC)

Journal	TC	TP	h-index
<i>Journal of Cleaner Production</i>	4000	64	268
<i>Sustainability (Switzerland)</i>	1009	69	136
<i>Science of The Total Environment</i>	947	15	317
<i>Resources, Conservation and Recycling</i>	696	20	170
<i>Business Strategy and The Environment</i>	689	17	131
<i>Waste Management</i>	594	14	201
<i>Journal of Fashion Marketing and Management</i>	460	7	61
<i>Journal of Industrial Ecology</i>	394	6	123
<i>Waste Management and Research</i>	322	12	92
<i>Polymers</i>	197	14	113

Notes: TP= Total publications, TC= Total citations

Source: TP and TC from Scopus database and h-index from scimagojr (2023)

The worldwide network of scientific collaboration identifies countries that actively research the major field. Out of 83 countries contributing to our sample, the most contributing countries to collaborative research in circular textiles are illustrated in Fig. 5. Researchers applied a threshold of a minimum of six articles published, each having a minimum of 50 citations, for determining the most active collaborative countries, which selected 36 countries. These countries were then categorised into five distinct groups which are shown in country collaboration network map.

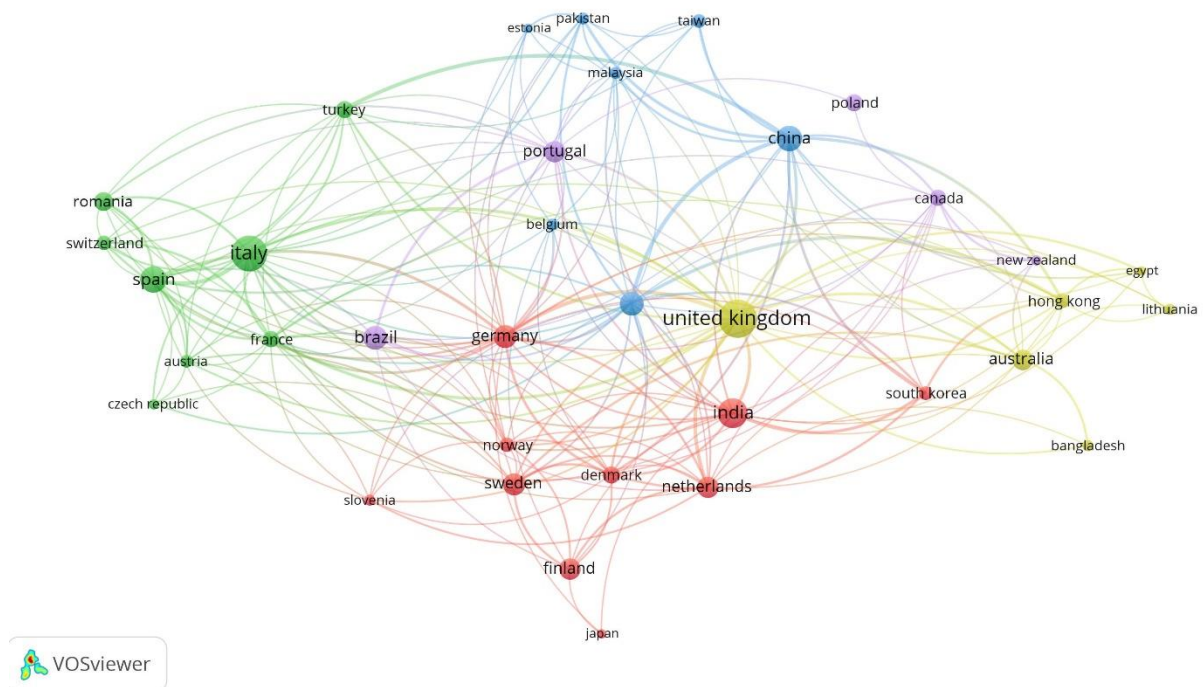


Figure 5: Country collaboration network for CE research in textiles
 Source: Authors' illustration based on Scopus data (2023)

The size of each circle in this diagram is directly proportional to the number of documents associated with the respective country. Furthermore, the greater the density of the connection between the circles, the higher the level of collaboration that has taken place between them. This study has identified the most active countries network by applying co-authorship country network analysis of VOSviewer software. Based on collaboration UK, China and Germany are the top collaborative countries in this field. Italy, India, and Spain have a more significant number of publications than China and Germany. However, they are ranked out of the top three nations due to lower link strength, indicating less collaborative research. This why, circular textiles research of leading three countries are highly visible and receiving scholars' attention.

3.3. Intellectual structure and knowledge base of circular textiles research

The keywords used by authors in their studies serve as a representation of the central theme and scope of their research. Keyword analysis, which examines the recurrence of terms together, can aid in finding prominent areas of research within a specific academic discipline (Dixit & Jakhar, 2021; Ranjbari et al., 2021). We performed co-occurrence analysis of author keywords for the period of 2009 to 2023 using VOSviewer. A minimum threshold of eight keyword occurrences was set, and a full counting method was chosen for conducting the analysis. The analysis yielded 27 keywords from a total of 2,208. The results indicate the presence of six distinct clusters, as shown in Figure 6.

which researchers are clustered according to their co-cited papers' similarity. Researchers set a minimum citation requirement of 20 for each author. The analysis yielded four clusters (Figure 7).

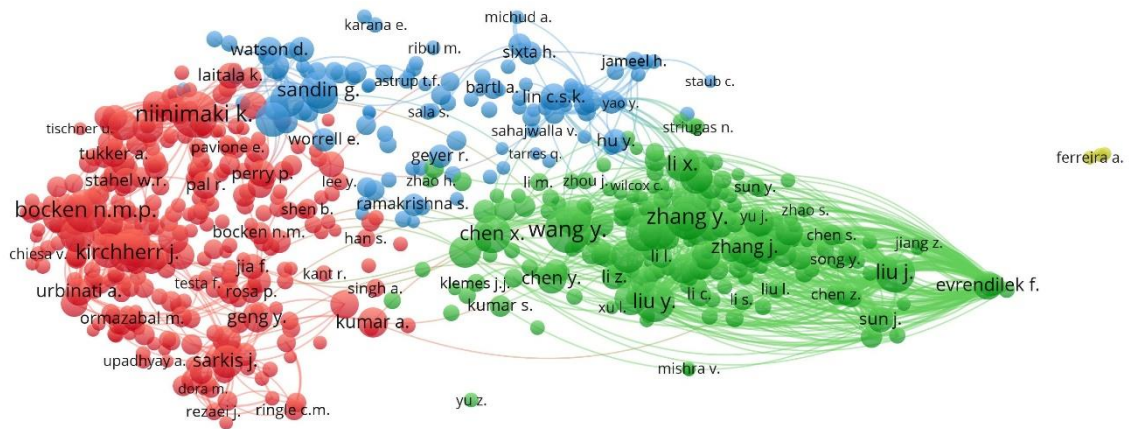


Figure 7: Co-citation network map
Source: Authors' illustration based on Scopus data (2023)

When analyzing the intellectual framework depicted in a co-citation map, researchers scrutinize the characteristics of the shared scholarly work of authors inside each cluster. The author's co-citation analysis results in four clusters: Fast fashion, circular business model, environmental sustainability, textile wastewater treatments. The insights gleaned from the analysis of the co-citation network provide researchers with crucial information about seminal and influential articles and their contributors that may be considered the roots of circular textile research.



Figure 8: Bibliographic coupling network of the CE research in the textile industry
Source: Authors' illustration based on Scopus data (2023)

We also examined the references listed in our data set to identify any recurring themes in the literature concerning CE research in the textile sector. A bibliometric coupling was run on VOSviewer to accomplish this. For analysis, we applied a minimum threshold of 85 citations of a document. The network was constructed exclusively for the 32 interconnected items out of the total 49 references. The results indicate the generation of six clusters of articles, each shown by a distinct colour in Figure 8.

The six main clusters of articles are circular business practices (red cluster), resources efficiency (green cluster), CE understanding and application (blue cluster), CE challenges (yellow cluster), environmental issues (purple cluster), and waste management (cyan cluster). Cluster themes were identified based on the most influential articles within each identified cluster.

4. Conclusions, limitations, and future research directions

CE research has grown in the recent decade. Although several studies have reviewed this literature from different perspectives, there is a lack of a comprehensive assessment that highlights the interconnectedness of knowledge creation in the emerging and diverse field of the textile and apparel industries. This study was undertaken to review the CE research in the clothing industry using bibliometric techniques. The study revealed the current trends and patterns of circular textile research. The study showed that CE research in the garment sector has increased exponentially since 2020. This study found that circular textiles research is multidisciplinary. *Journal of Cleaner Production* is the productive journal and UK the leading contributor for collaborative research in the domain of CE research. The study also uncovered the recurrent thematic areas of CE research. Moreover, this study made two unique contributions in circular textile research: First, this study made a methodological contribution by applying augmented bibliometric techniques along with traditional methods to gain a more comprehensive understanding of the interconnections among concepts, authors, and research streams, as well as the structure of the field. Second, the study made a theoretical contribution by identifying hot-spots of circular textile research using keyword co-occurrence, co-citation and coupling network analysis. Thus, this has both academic and practical significance. However, this research is not out of limitations. First, the database for this study is limited to Scopus. Other databases, like PubMed, Web of Science, or Dimensions, are not covered. Second, this study involved only articles and review papers published in English and other important literature published in different languages or other types of literature that are not covered. Therefore, future research could be undertaken by considering these limitations. Moreover, Science mapping analysis of this study uncovered the boundary of circular textile research which direct us that in future this kind of research can be conducted in other sectors such as leather manufacturing industry, which is also pollutive sector, thus, potential researcher can undertake similar kind of research in this field. In addition to that, in future, qualitative reviews could be undertaken with qualitative reviews which may provide comprehensive result for circular textile research. This research has identified the intellectual structure of circular textiles using keyword co-occurrence, co-citation, and bibliographic coupling analysis. In future research, citation analysis could also be employed with others for similar research to reveal comprehensive results. Finally, the necessity for more discussion of this research's performance analysis and science mapping techniques offers an opportunity for potential scholars.

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