

Emerging technologies to optimize environmental sustainability in the textile industry: a systematic review

Tecnologías emergentes para optimizar la sostenibilidad ambiental en la industria textil: una revisión sistemática

Sebastián Cardona-Acevedo

Instituto Tecnológico Metropolitano, Colombia
sebastiancardona272247@correo.itm.edu.co
<https://orcid.org/0000-0002-6192-2928>
<https://ror.org/03zb5p722>

Alejandro Valencia-Arias

Professor and researcher at Instituto Tecnológico Metropolitano, Colombia,
jhoanyvalencia@itm.edu.co
<https://orcid.org/0000-0001-9434-6923>
<https://ror.org/03zb5p722>

Jackeline Valencia

Professor and researcher at Universidad de Los Lagos, Chile
jvalenciaa@unap.cl
<https://orcid.org/0000-0001-6524-9577>
<https://ror.org/05jk8e518>

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Abstract: the textile industry is characterized by high resource use and a significant environmental impact, associated with high water and energy consumption, chemical pollution, and waste generation. In this context, emerging technologies seek to reduce the environmental footprint of production processes and strengthen organizational competitiveness. The objective of this study is to systematically analyze technological innovations applied in the textile industry aimed at mitigating environmental impacts, with an emphasis on transformed production processes, environmental performance metrics, adoption barriers, and emerging trends. The methodology is based on a systematic literature review conducted according to the PRISMA 2020 guidelines, with a descriptive quantitative synthesis of a bibliometric nature based on the frequency analysis of coded variables. The results show that digital platforms, clean technologies, recycling systems, and advanced materials are the most recurrent innovations, contributing to greater resource efficiency, waste reduction, and improved energy performance. Significant barriers persist, such as high implementation costs, regulatory restrictions, and financial limitations in supply chains.

Keywords: sustainability, innovation, technology, pollution, efficiency, competitiveness, energy, industry.

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Resumen: la industria textil se caracteriza por una elevada intensidad en el uso de recursos y un impacto ambiental significativo, asociado al alto consumo de agua y energía, la contaminación química y la generación de residuos. En este escenario, la innovación tecnológica ha adquirido un papel estratégico para disminuir la huella ambiental de los procesos productivos y, simultáneamente, fortalecer la competitividad organizacional. El objetivo de este estudio es analizar de manera sistemática las innovaciones tecnológicas aplicadas en la industria textil orientadas a la mitigación de impactos ambientales, con énfasis en los procesos productivos transformados, las métricas de desempeño ambiental, las barreras de adopción y las tendencias emergentes en sostenibilidad. La metodología se fundamenta en una revisión sistemática de la literatura desarrollada conforme a las directrices PRISMA 2020, complementada con una síntesis cuantitativa descriptiva de carácter bibliométrico basada en el análisis de frecuencias de variables codificadas. Los resultados evidencian que las plataformas digitales, las tecnologías limpias, los sistemas de reciclaje y los materiales avanzados constituyen las innovaciones más recurrentes, contribuyendo a una mayor eficiencia en el uso de recursos, la reducción de residuos y mejoras en el desempeño energético. Sin embargo, persisten barreras relevantes, como altos costos de implementación, restricciones regulatorias y limitaciones financieras en las cadenas de suministro.

Palabras clave: sostenibilidad, innovación, tecnología, contaminación, eficiencia, competitividad, energía, industria.

Introduction

The status of current global environmental problems poses a significant threat of the 21st century, particularly from continued deterioration of ecosystems due to production and mass consumption (Leal *et al.*, 2024). Within this frame, the textile sector takes on special importance as it is one of the most polluting industries globally. The water and energy consumption of the industry, heavy chemical use, solid waste production, and the release of microplastics into the environment are highlighted sectors of the sustainability agenda (Orisadare *et al.*, 2025).

The environmental footprint denotes the set of impacts a specific productive activity creates on the earth and is therefore a significant measure in evaluating how detrimental textile business is to the environment. This dimension incorporates natural resource use, greenhouse gas emissions, and soil and water pollution that are important aspects to guide sustainable development strategies (Bibi *et al.*, 2024). Technological advances are considered a key driver of the change in productive behavior and their environmental impact amelioration. Technologies towards energy efficiency, fiber recycling, use of biodegradable materials and the digitalization of processes are areas where transition opportunities can be considered from this sector to a cleaner and more sustainable industry (Dutta & Bansal, 2024). Globally, integrating clean technologies has yielded promising outcomes, and initiatives emerging in Latin America reflect a greater interest in integrating sustainability as an economic factor to drive competitiveness within the textile industry. The textile indus-

try is recognized as one of the biggest industries to impact the environment and is even more affected, due to the volume of production techniques and to the consumption model promoted through it. Textile production requires a lot of water and resources - a huge water use, energy, and chemicals. Excessive extraction of these resources has severe consequences for the ecosystems. Planting natural fibers like cotton consumes huge amounts of water.

In synthetic fiber production, heavy energy loading and a reliance on petroleum derivatives are striking. Dyeing, bleaching and other chemicals that, in many cases, end up in rivers and seas add to the pollution. Industry, on the other hand, creates waste in bulk, such as textile waste and microplastics, which only serve to worsen environmental pollution and threaten human health and biodiversity (Hossain *et al.*, 2024). In recent years, several technological advancements have been invented to alleviate these impacts. Nonetheless, their deployment is disconnected and misaligned. Recent achievements have been observed around energy efficiency and fiber recycling, biodegradable materials and production processes that are in the process of digitalizing. The adoption of these innovations is now uneven across the sector. The scientific literature focuses on single innovations or processes without consideration for the broader picture, which may cover what has changed or must still be solved (Bibi *et al.*, 2024).

This situation exposes the gap between the present stage of technology application and its systematic use within textiles. There is no consolidated framework that allows us to assign which innovations are applied most often,

which production processes undergo the most transformations, which indicators are used to measure environmental outcomes, or which technical, economic and social barriers limit their adoption (Chourasiya & Pandey, 2024). The lack of this articulation has a limiting impact between the sector, which may be moving towards sustainable production models, and decreases the utility of the academic findings in the decision-making process. The implications created in the latter context indicate the pressing need of taking a rigorous and systematic approach to understand in depth the achievements and constraints and opportunities technological innovation has created in minimizing the environmental footprints within textile sectors (Glogar *et al.*, 2025).

Therefore, the objective of this study is to systematically analyze technological innovations applied in the textile industry aimed at mitigating environmental impacts, with an emphasis on transformed production processes, environmental performance metrics, adoption barriers, and emerging trends. Accordingly, the questions considered are:

- Which technological innovations are most frequently applied in the textile sector?
- Which production processes have been most transformed?
- What metrics or indicators are used to evaluate progress?
- What technical, economic, or social barriers limit adoption?
- Which recent trends show the greatest potential for consolidating sustainability in the textile industry?

The findings will contribute to the academic literature by proposing a comprehensive framework that allows understanding technological advances within the textile industry in relation to environmental sustainability, and recognizing emerging trends, evaluation metrics, and barriers to adoption.

Materials and Methods

PRISMA 2020 provides a standardized and transparent framework for conducting and reporting systematic reviews, ensuring that the steps of identification, selection, eligibility, and inclusion can be carried out rigorously, consistently, and reproducibly (Page *et al.*, 2021). In this context, PRISMA is particularly relevant for managing the heterogeneity of the literature and facilitating the structured synthesis and comparison of evidence, as well as for evaluating the environmental performance of the textile sector.

Eligibility Criteria

Priority was given to research based on empirical evidence and systematically reviewed in scientific journals, academic books, and conference proceedings, which were considered valid sources with methodological rigor. Documents chosen for the studies were necessary to state technological innovations applied to the textile industry regarding a reduction in the environmental footprint, or carbon footprint, water footprint, life cycle analysis, sustainability, or the circular economy. In addition, submissions needed to include works proposing or evaluating eco-innovative practices within processes, materials, products, or business models in the textile and fashion industry. To capture most of the relevant scientific productions and to facilitate an appropriate interpretation of the findings, only publications in English and Spanish were included in the inclusion language. This includes not only advances that were made after 2000, but also those up to 2025 that have further consolidated the notion of textile sustainability.

The exclusion process took place in three stages sequentially. Duplicate records or those with indexing errors were removed as the first step. Second, documents lacking full text were discarded, as this prevented a detailed examination of methods and results. Third, studies that, while meeting formal requirements, did not satisfy the defined thematic or methodological criteria were excluded. These included

studies focused on sectors other than textiles, articles addressing environmental dimensions only tangentially, and studies in which technological innovation was not an explicit focus.

Sources of Information

Scopus and Web of Science were chosen because they are recognized as high-impact databases worldwide, in addition to having rigorous indexing standards and covering a wide range of disciplines that reinforce the scope and validity of systematic reviews. Their emphasis on peer-reviewed and highly cited articles provides reliable and relevant studies in engineering, innovation, and sustainability for a robust and methodologically rigorous academic analysis.

The database is characterized by a wide range of indexed documents and a rich multidisciplinary body of literature the areas of circular economy, eco-innovation and sustainable practices. This renders it a suitable framework for investigating the complexity of the environmental footprint of textile use as a single project through this systematic review. Web of Science, managed by Clarivate Analytics, is unique in the selectivity of the indexing rules, and its ability to trace citations of documents, as records go back to the early 20th century. The analysis here is of interest to the academic fields of environmental science, engineering, and sustainability management with a basis of comparability between research on technological innovation and environmental impact reduction. Integration of the two databases reduces bias and increases the representativeness of findings. Asubiaro *et al.* (2024) showed that there are substantial differences between regions in the representation of scientific production in textile sustainability, highlighting the importance of linking to receive an all-encompassing perspective on the topic.

Search Strategy

The search strategy was defined based on the inclusion criteria and consisted of a specific equation for each database. In Scopus, Boolean operators and keywords related to innovation,

sustainability, and environmental footprint in the textile industry were used, with the fields being limited to the title and abstract to narrow the results to relevant studies. The equation utilized was:

- *Scopus*: TITLE (innovation OR “eco-innovation” OR “technological change” OR “new product development”) AND TITLE (“environmental footprint” OR “ecological footprint” OR “environmental impact” OR “carbon footprint” OR “water footprint” OR “life cycle assessment” OR sustainability OR “sustainable development” OR “circular economy” OR “green practices” OR eco-friendly) AND TITLE-ABS-KEY (“textile industry” OR textiles OR “apparel industry” OR clothing OR “fashion industry” OR garment)
- In Web of Science, the same conceptual structure was adapted to database-specific syntax using topic and keyword fields: *Web of Science*: TS=(innovation OR “eco-innovation” OR “technological change” OR “new product development”) AND TS=(“environmental footprint” OR “ecological footprint” OR “environmental impact” OR “carbon footprint” OR “water footprint” OR “life cycle assessment” OR sustainability OR “sustainable development” OR “circular economy” OR “green practices” OR “eco-friendly”) AND AK=(“textile industry” OR textiles OR “apparel industry” OR clothing OR “fashion industry” OR garment).

Selection and Data Processing

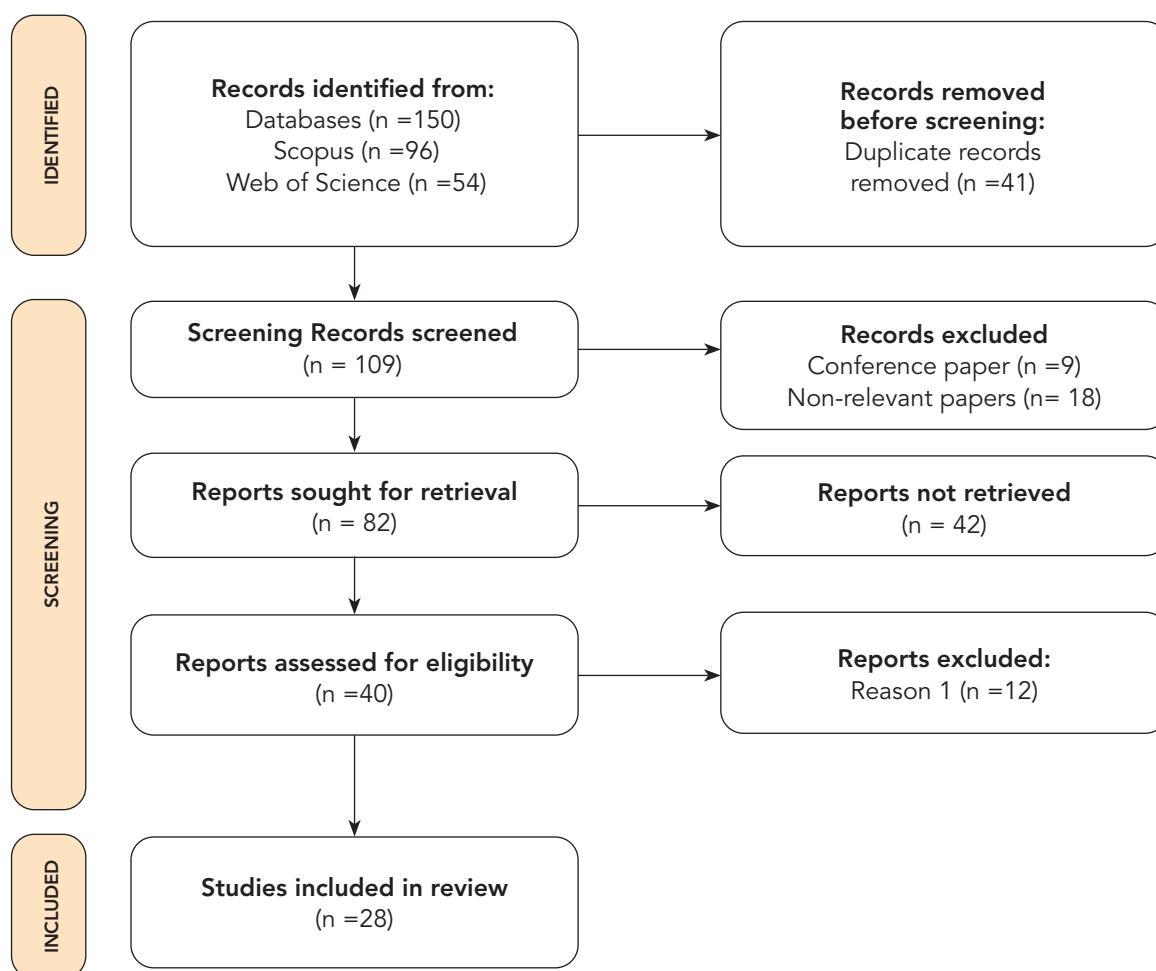
Figure 1 presents the PRISMA flowchart used for this review, illustrating the stages of identification, screening, eligibility, and inclusion. Data were processed in Microsoft Excel to extract, organize, and categorize information from the consulted databases. To that end, the studies were presented in spreadsheets to support comparative analysis and apply the eligibility criteria and organized systematically around the groups based on the categories selected from the research questions. These were classified into the following: “Technological In-

novations” and “Transformed Production Processes” and “Key Environmental Metrics” and “Barriers to Technology Adoption” and “Recent Sustainable Trends”. Furthermore, when it comes to environmental measurement, carbon footprint, water consumption, and life cycle analysis were incorporated.

This process was independently performed by every researcher, with disagreements resolved by consensus through discussion that

were, when necessary, subject to the intervention of another reviewer. Study selection criteria were relevance to research objectives. Although this analysis did not attempt to establish causal relationships, it relied on a quantitative synthesis that aimed to characterize the prevalence of variables identified from the reviewed literature. Dominant patterns and thematic concentrations were described using frequency-based graphs and descriptive statistics.

Figure 1
PRISMA Flow Chart



Note. Prepared by the authors using data from Scopus and Web of Science.

Forty-two records collected during the screening could not be retrieved for evaluation. The availability of these files was restricted by publisher paywalls or the absence of full texts. Since the full text was a necessary element for analyzing methodological quality, technological relevance, and environmental performance measures, these were removed from the analysis to ensure a consistent and transparent review. Subsequently, from this selection, after applying the filter, a total of 12 articles were excluded at the eligibility stage. These exclusions were determined based on explicit and predefined criteria: (i) the lack of a direct focus on the topic, (ii) the peripheral treatment of sustainability concepts without empirical or analytical evidence, (iii) the research's focus on different sectors, and (iv) the absence of clearly defined or measurable indicators.

Risk of bias

Potential bias in selection and analysis was considered as databases such as Scopus and Web of Science, and the search terms in the search equations, could influence the representativeness of the results. Similarly, publication bias, which arises from the greater visibility of positive findings, was acknowledged. To mitigate these risks, predefined inclusion criteria were applied, along with independent review processes and cross-checking of information.

Given the heterogeneity of designs across the retrieved literature (e.g., empirical studies, qualitative analyses, modeling-based contributions, and systematic reviews), quality appraisal was conducted using general and transparent criteria rather than a single design-specific scoring tool. More specifically, the evaluation con-

cerns the following issues: (i) clarity of research aims and context; (ii) sufficiency and transparency of approach (data sources, procedures, analytic steps); (iii) coherence between methods, results, and conclusions; (iv) the precise expression of environmental metrics or evaluation procedures (e.g., carbon/water footprint indicators, life cycle assessment assumptions, or operational efficiency measures); and (v) the disclosure of limitations and potential conflicts of interest when applicable.

Studies that provided inadequate methodological clarity, vague measurement methods, or were poorly aligned between proposed novelties and reported environmental outcomes were considered with more interpretive care on synthesis. As such, results were not evaluated by meta-analytic approach, and the review focuses on emergent themes that emerged through descriptive synthesis as well as on the differences in study quality on the strength and comparability of measured impact.

Contributions to the current state of the art

The results are presented in accordance with the research questions, thereby facilitating a systematic relationship with the stated objectives and ensuring consistency in the analysis process. The organization by thematic axes facilitates comparison between studies and the identification of the role of technological innovation in reducing the environmental footprint in the textile sector, ensuring an orderly interpretation of the evidence supported in Table 1, which summarizes the studies included for detailed analysis.

Table 1

Studies included in the research

Número	Título	Autores
1	Assessing Chinese Textile and Apparel Industry Business Sustainability: The Role of Organization Green Culture, Green Dynamic Capabilities, and Green Innovation in Relation to Environmental Orientation and Business Sustainability	Xiaoyi <i>et al.</i> (2023)

2	Business Model Innovation for Circular Economy in Fashion Industry: A Startups' Perspective	Ostermann <i>et al.</i> (2021)
3	Characterization of Atlantic Forest Tucum (<i>Bactris setosa</i> Mart.) Leaf Fibers: Aspects of Innovation, Waste Valorization and Sustainability	Flohr <i>et al.</i> (2024)
4	Circular Economy Solutions: The Role of Thermoplastic Waste in Material Innovation	Ochigüe <i>et al.</i> (2025)
5	Developing textile sustainability education in the curriculum: pedagogical approaches to material innovation in fashion	Wood <i>et al.</i> (2023)
6	Digitalization for a Sustainable Performance: Dual-Study Analysis of Digital Leadership, Circular Economy, and Technological Innovation	Khan <i>et al.</i> (2024)
7	Do Intelligent Manufacturing Concerns Promote Corporate Sustainability? Based on the Perspective of Green Innovation	Feng (2023)
8	Drivers and barriers of sustainability-oriented innovations in Brazilian denim treatment facilities: an expert-driven decision support	Brandão <i>et al.</i> (2025)
9	From Waste to Luxury Fashion at Elvis & Kresse: A Business Model for Sustainable and Social Innovation in the Circular Economy	Dominguez y Bhatti (2022)
10	How Circular Economy Innovation Can Backfire on the Environment: Quantifying the Rebound Effect of the Textiles and Clothing Sector	Yerushalmi y Saha (2025)
11	Immersive innovations for the communication of heritage, handcraft and sustainability	Cross <i>et al.</i> (2025)
12	Qualitative Analysis of Sustainability and Innovation Within the Luxury Business Sector	Grigorescu e Ion (2022)
13	Supplier-customer relationships for sustainability-led innovation in the textile industry	Dominidiato <i>et al.</i> (2024)
14	Sustainability Innovation in the Textile Industry: A Systematic Review	Harsanto <i>et al.</i> (2023)
15	Sustainability through lignin valorization: recent innovations and applications driving industrial transformation	Jiju <i>et al.</i> (2025)
16	Sustainability Values and Strategic Innovation in Sustainable Fashion MSMEs: the Dynamic Capabilities Perspective	Ceicyte-Pran-skune (2025)
17	Sustainability-Oriented Innovation in the Textile Manufacturing Industry: Pre-Consumer Waste Recovery and Circular Patterns	Butturi <i>et al.</i> (2025)
18	Where do professionals find sustainability and innovation value? Empirical tests of three sustainable design methods.	Faludi <i>et al.</i> (2020)
19	Evaluation of Circular and Integration Potentials of Innovation Ecosystems for Industrial Sustainability	Tolstykh <i>et al.</i> (2020)
20	Green HRM practices in textile sector of Pakistan and its impact on green innovation and environmental sustainability	Awais-e-Yazdan <i>et al.</i> (2024)
21	Green practices and economic performance: Mediating role of green innovation in Ethiopian leather, textile, and garment industries-An integrated PLS-SEM analysis	Nigatu <i>et al.</i> (2024)
22	Harnessing the multifaceted potential of mushrooms: sustainable development, health promotion, and industrial innovation	Lu <i>et al.</i> (2025)
23	How Does Corporate Sustainability Increase Financial Performance for Small- and Medium-Sized Fashion Companies: Roles of Organizational Values and Business Model Innovation	Yang y Jang (2020)

24	Managerial decisions and new product development in the circular economy model enterprise: absorptive capacity and a mediating role of strategic orientation	Stelmaszczyk <i>et al.</i> (2023)
25	Review the potential for regenerated protein fibres within a circular economy: Lessons from the past can inform sustainable innovation in the textiles industry	Stenton <i>et al.</i> (2021)
26	The relationship between sustainability practices and innovation strategies: the effect of the clusterization in the bop segment	Doliveira <i>et al.</i> (2018)
27	The Role of Agile Practices and Green Innovation on Environmental Sustainability Through Waste Reduction in Indian Garment Manufacturing	Nayeemunnisa y Padhy (2025)
28	Transformational leadership and radical innovation for sustainability: mediating role of knowledge management capability and moderating role of competitive intensity	Nabi (2023)

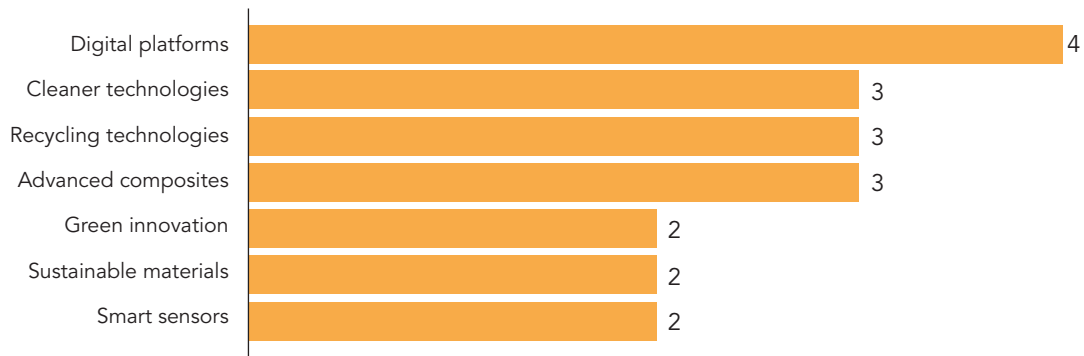
Note. Prepared by the authors based on data from Scopus and Web of Science.

Based on the literature review, the emphasis on digital and green technology innovation solutions is clearly illustrated in Figure 2. Although a total of 28 studies were reviewed, the figures present lower totals, as each graph includes only those studies that explicitly address the corresponding thematic category. Consequently, a single study may appear in more than one category or may not be represented in all figures, depending on its scope

and classification criteria. The reviewed studies report that firms are increasingly adopting digital platforms and clean technologies, reflecting a strategic shift toward data-driven approaches to sustainability. Additionally, the prominence of recycling systems and advanced materials highlights a growing research interest in circular economy practices and the development of new materials for textile applications.

Figure 2

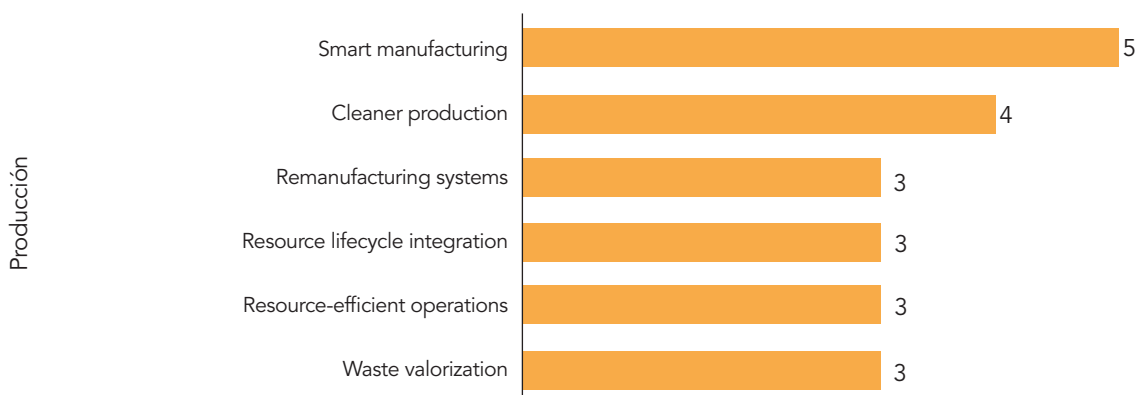
Technological innovations in the textile industry



Note. Prepared by the authors based on data from Scopus and Web of Science.

Given that technological innovation has brought about a significant transformation in textile production processes, studies highlight a shift towards smarter and cleaner manufactur-

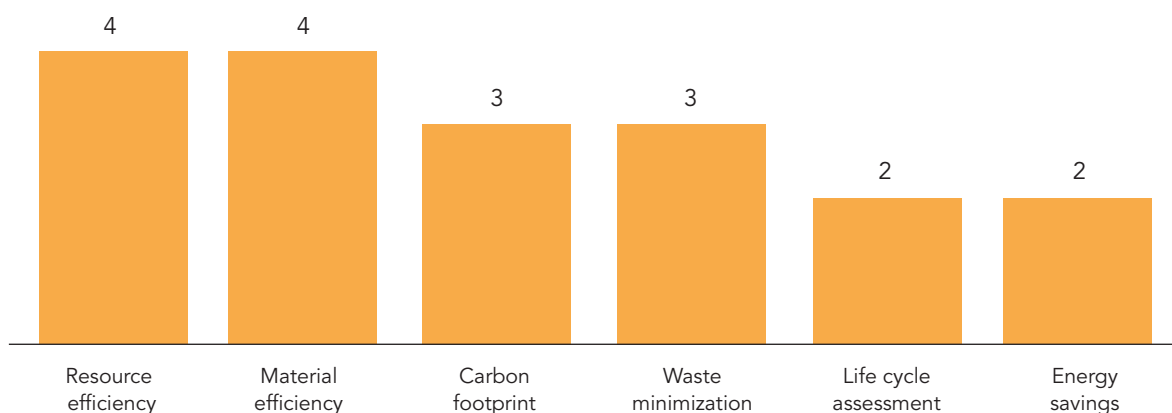
ing models. These changes indicate a growing integration between production efficiency and environmental sustainability goals, as illustrated in Figure 3.

Figure 3*Transformed production processes in the textile industry*

Note. Prepared by the authors based on data from Scopus and Web of Science.

The assessment of the textile industry's environmental performance focuses on efficiency-based indices, as shown in Figure 4. This pattern of repeated use of metrics relevant to resource and material efficiency is consistent with

an operational approach focused on minimizing inputs and outputs, while indicators based on footprints and life cycle modalities allow for a broader measurement of environmental impact.

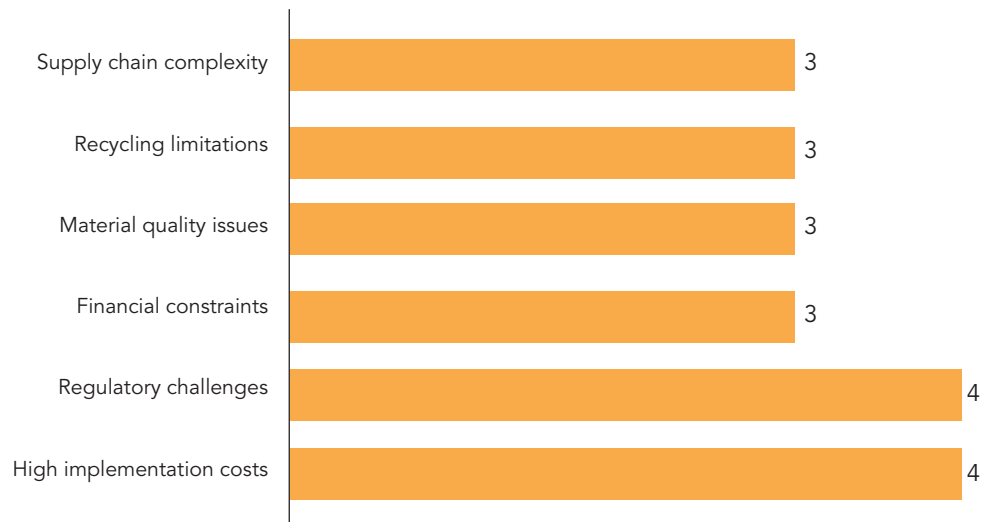
Figure 4*Key environmental metrics in the textile industry*

Note. Prepared by the authors based on data from Scopus and Web of Science.

Figure 5 presents a general view of the main challenges hindering sustainable technologies adoption in the textile industry. The results suggest that two broad layers of economic and regulatory constraints become central, along

with the structural (material, recycling systems and supply chain complexity) ones. These barriers underscore the distance between the technology available and implementing at scale efficiently.

Figure 5
Barriers to technology adoption in the textile industry

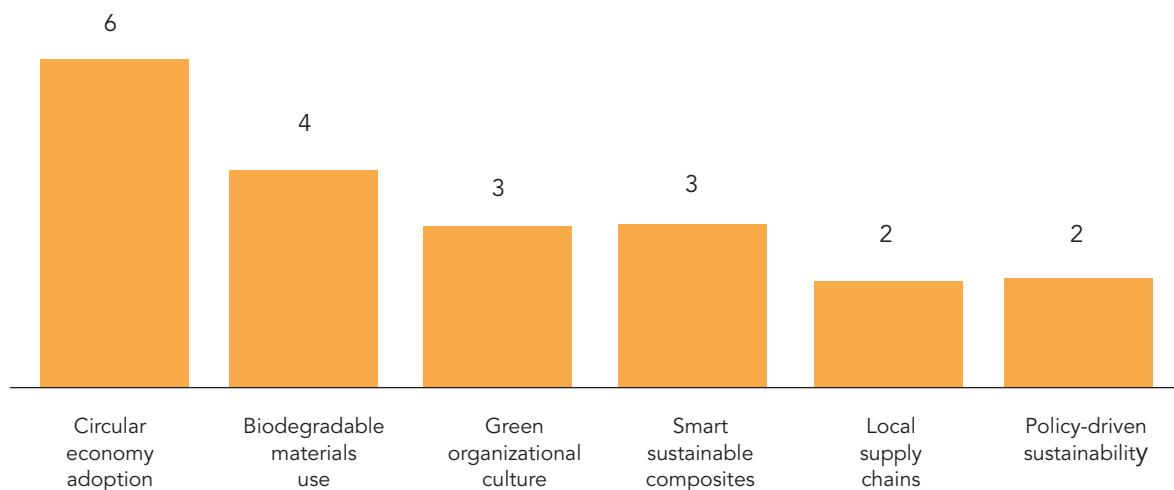


Note. Prepared by the authors based on data from Scopus and Web of Science.

Sustainable trends in the textile sector are being guided more by circular economic considerations. Trends are biodegradable materials, environment-focused corporate cultures, a

localized supply chain, supplemented by policy frameworks, pointing to a multifaceted view of sustainability beyond the technology, consistent with the results presented in Figure 6.

Figure 6
Recent sustainable trends in the textile industry



Note. Prepared by the authors based on data from Scopus and Web of Science.

This classification provides a detailed survey summarizing the advancements reported in literature and identifies the chances and difficulties that lie ahead for a change which will see textile industries in more sustainable and technologically advanced form.

Results and Discussion

The discussion has been arranged in such a way that the integration of the findings from technological innovation research for reducing the environmental impact in the textile industry has been considered. First, the article presents an analysis to compare the findings with past publications and to identify commonalities and differences among the literature. A conceptual model based on the obtained findings is in the next part. This section also provides the development of theoretical, policy and practical implications.

Analysis of the results

Textile sector technology innovations are mostly tied to digital transformation and quest for sustainable solutions. Notably, a significant portion of digital platforms have been found, in addition to technology in the areas of environmental efficiency, recycling, and advanced material development, validating the role of green innovation in this sector. These findings have been related to studies highlighting the value of organizational culture and dynamic capabilities for achieving corporate sustainability (Xiaoyi *et al.*, 2023) and to studies indicating contextual barriers to sustainable innovation (Brandão *et al.*, 2025). As for changing the production process, there is evidence that there is a change of course toward smart and sustainable practices, with a strategy to optimize resources and reduce environmental impacts. Clearly evidence of the growing integration of digital technology in industrial automation and new advanced manufacturing, with cleaner manufacturing methods and waste recovery strategies emerges.

As such, these findings are congruent with the literature exploring the circular economy

and the use of recycled materials in the manufacturing of high-performance innovative products (Ochigue *et al.*, 2025); they are congruent with literature focusing on “sustainable innovation in production processes” (Harsanto *et al.*, 2023), i.e., the use of the circular economy and recycled materials in generating high-performance innovation. Key environmental metrics are focused on practices which maximize resource use, reduce waste and support life-cycle assessment. The metrics indicate alignment with efficiency and sustainability-focused strategies, a major component of the circular economy, and educational innovations that intend to embed sustainable materials and techniques within vocational training. This points to the importance of integrating technological innovation and social training for sustainable models of production in the textile industry (Ostermann *et al.*, 2021; Wood *et al.*, 2023).

Not only are barriers to technological adoption identified; alternative materials (especially sustainable fibers) for production (Flohr *et al.*, 2024) and the way in which innovation and sustainability interact (Grigorescu & Ion, 2022) are also important areas for consideration. Furthermore, structural and financial barriers to the transition to sustainable practices exist. This text addresses factors related to high implementation costs and regulatory barriers, financing issues, and challenges linked to materials and recycling.

These findings from this systematic review suggest that the advancements of sustainability technologies in the textile sector are not universally progressive or sustainably adopted. These factors digital platform technologies, smart manufacturing technologies, cleaner production technologies and so forth are emerging as dominant strategies but have not been embraced in all regions of the world and whether to use them is contingent on contextual aspects of implementation and use. Hence, existing technological initiatives would not help with supporting systemic, holistic environmental transformation given embedded context on an organizational and strategic level. Therefore, the impact on innovation appears to be deter-

mined by firms' internal capabilities, culture, governance framework, sustainability desire and policies on alignment of sustainability aspiration versus implementation of the same, organizational policy.

In comparative analysis, these findings also support previous studies that say sustainability-oriented innovation is the best use when learning, culture and policy change in a company at industry level are required along with technological advancement. But what is clear in this review is also a persistent disconnect between technological development and production, from cost mechanisms and regulatory precarity to supply chain complexity.

The confirmed sustainable development trends reflect the consolidation of the circular economy and the adoption of digital traceability solutions, with an increasing emphasis on value chain transparency and emissions reduction—not only are they desirable components but also fundamental imperatives of sustainability. Also noted are practices of a green organizational culture, recycling, waste recovery and biodegradable and smart materials use. These orientations are consistent with research focusing on the role of smart manufacturing in promoting corporate sustainability (Feng, 2023) and with findings on the importance of strategic preferences concerning strategic values of fashion SMEs (Ceicyte-Pranskune, 2025).

Comparison of Results with Other Studies

The results of this study complement other works on technological innovation and sustainability related to the textile sector. In line with Mansi *et al.* (2025), the findings demonstrate how clean technologies, green chemistry, and life cycle assessment can reduce environmental impacts and provide an approach to the textile sector that enables a more detailed analysis of production processes, environmental indica-

tors, and adoption barriers. Similarly, the convergence with Timbayo *et al.* (2025) describes the contribution of digitalization to sustainability and modernization; however, the current study expands this perspective to digital platforms applied within production systems and environmental management, rather than focusing on e-commerce applications.

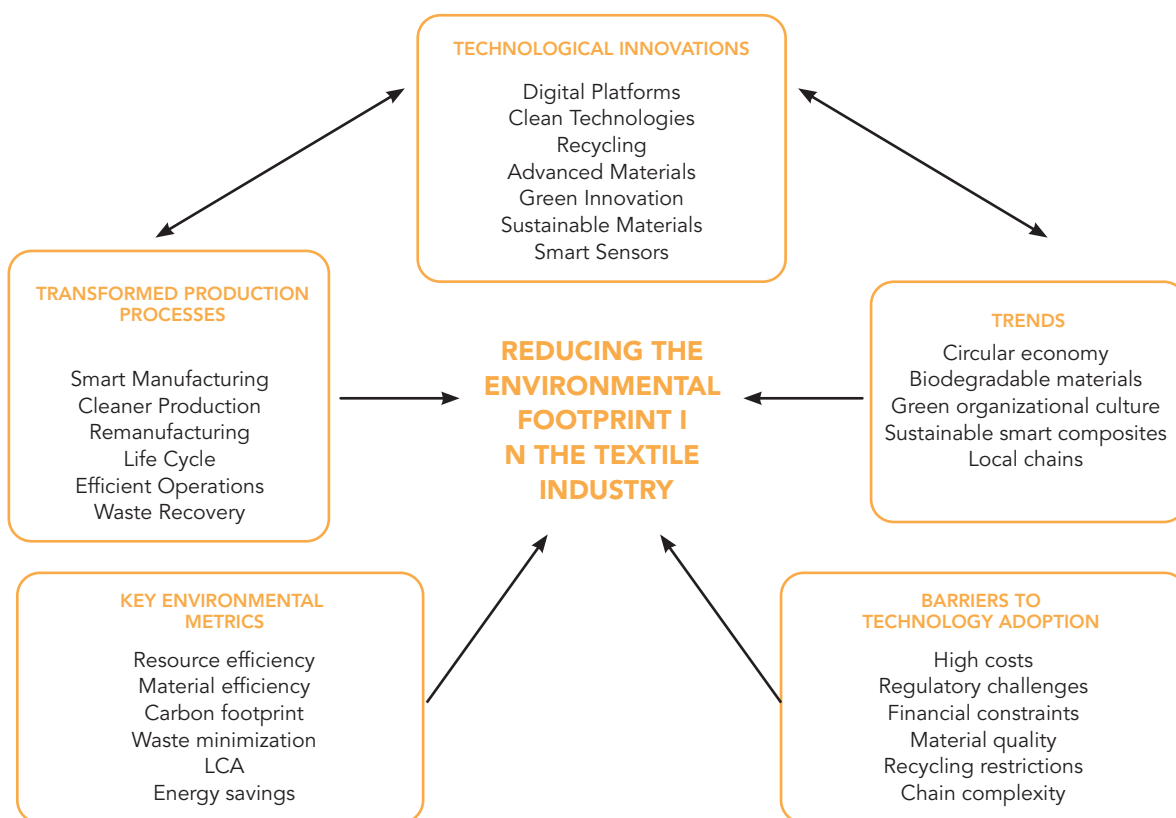
Authors such as Sellappa (2025) and Nourin *et al.* (2025) emphasized that sustainability practices play a crucial role in their work. This is in line with findings for circular economy models. However, while the studies focus on artisanal models, this research investigates a holistic technology perspective to understand the present state of dynamics and potential barriers for their adoption, like the newly emerging paradigms of Industry 5.0 discussed by Sonar *et al.* (2025) which covers digitalization and traceability, and the resiliency of supply chains.

Proposed Conceptual Framework

The next section offers a five-axis framework, influenced by some of the ideas of the previous sections. Figure 7 conceptualizes the objective of the study as the systematic analysis of technological innovations aimed at mitigating the environmental impacts of the textile industry within a multidimensional context encompassing technological, productive, environmental, and organizational dimensions. Rather than implying a direct reduction of the environmental footprint, the framework frames sustainability improvement as a systemic process informed by transformed production processes, environmental performance metrics, adoption barriers, and emerging trends identified in the literature. This perspective highlights how structural constraints and enabling conditions shape technological change and supports the formulation of more coherent and comprehensive policy and managerial approaches toward more responsible textile production models.

Figure 7

Conceptual framework for technological innovation in the textile industry



Implications

The results have research value in three main categories: theoretical, public policy, and practical. First, at the theoretical level, the applicability of comprehensive analytical models is reiterated. It is in line with the second area referred to as well, according to which it offers input for designing strategies and incentive mechanisms to overcome financial barriers and promote adoption of technologies by businesses with a lower environmental impact, so that it can be relevant for those charged with forming public policies.

The third key thing is that the results are practical, as they encourage the use of platforms that manage the ecological footprint, connecting production technologies to recycling systems and

advanced materials. Nevertheless, this shift for responsible production must go together with a sustainable organizational culture including the creation of new capabilities and measures. Like this, it would be equally relevant to reflect on economic and structural obstacles because understanding these process hindrances in the transformation stages would help organizations to take sound decision-making strategies and understand dynamics that need further attention. The sector is challenged by adopting new technologies necessitating interdisciplinary perspectives which may be achieved by the effective integration of stakeholders.

Conclusions

Technology innovation, which has increasingly become the enabler in an increasingly

modernized textile industry, is the biggest vehicle for making the textile sector more responsible. But barriers social, regulatory and organizational stand in the way. Sustainability should mean not just new, powerful tools to make tech more efficient, but the ability to fit into the reality of complex production systems. Consequently, the adoption of emerging technologies can only become sustainable if a system-level framework is established that encompasses technical solutions, governance mechanisms, business strategies and collaboration processes driven by sector actors.

Thus, innovation is deemed to develop an integrated approach that alters commercial models. Therefore, it is important to construct theoretical and practical paradigms that can make possible a mixed vision which enables the emergence of circular, resilient, and transparent production models. Such models should not only be sustainable development-based but also harmonious with productive activity. Thus, organizations must develop practices which integrate technological innovation and social responsibility in order to become globally competitive in the future.

Both methodological and scope limitations of this study need to be cautiously considered. Methodologically, the research employs a systematic documentary analysis of academic and technical literature, a methodology that at its core is not conducive to the potential confirmation of findings with observable data in the context of a producing environment. Such an obsession with secondary sources places a greater exposure to prejudice in the acquisition and placement of the evidence and the type of information, which is produced may not be standardized, reliable or that other resources are comparable for. The variety of methodological approaches in the works discussed in the review also reduces the possibility of being able to formulate a firm generalization of the ability of technological innovations to be effective in the textile industry, thereby making the findings less robust.

The findings are limited by the lack of long-term studies in which the sustainability of the transformations is measured. The environmen-

tal metrics that were analyzed do not consider all potential dimensions included in the search equation, such as social impacts or indirect impacts on global value chains. Additionally, the barriers to technological adoption seen may vary according to geographic, economic, and regulatory factors, limiting the external validity of the results. Additionally, barriers to technology adoption can vary depending on the context. While this does not invalidate the contributions of this study, it does limit the external validity of the results. This highlights the need for future research.

Further study would benefit from further empirical analysis, such as case studies, longitudinal designs, and comparative analyses, to enrich the evidence on implementation in heterogeneous production contexts. Second, it should place a priority on developing more integrated environmental assessment frameworks in which sustainability assessments might be compared on technical, social, and economic grounds. Novel trends such as circular economy practices and digital traceability systems will need to be considered from the perspective of Industry 5.0 to understand their role in value chains and long-term competitiveness. Similarly, it would be helpful for the public and business decision-making process to explore the constraints imposed on technology adoption to frame applicable models.

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Author Declaration - CRediT Taxonomy

Autores Authors	Contributions
Sebastián Cardona-Acevedo	Conceptualization, formal analysis, research, methodology, visualization, writing – original draft, writing – revision and editing.
Alejandro Valencia-Arias	Conceptualization, supervision, validation, project management, fundraising, writing – revision and editing.
Jackeline Valencia	Data curation, formal analysis, research, validation, visualization, writing – review and editing.

Statement on the use of artificial intelligence

The authors **DECLARE** that, in the preparation of the article titled: “Emerging Technologies to Optimize Environmental Sustainability in the Textile Industry: A Systematic Review,” artificial intelligence (AI) was used to assist in the preparation of the manuscript. The authors declare that they reviewed and validated the content and assume full responsibility for the final version of the article.