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Climate Change and Clothing: Challenges, Impacts and Sustainable Transitions in the Textile and Apparel Sector

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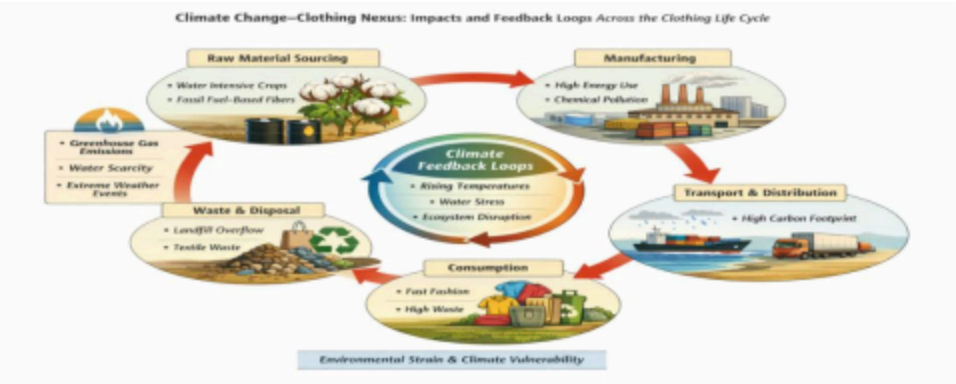
Abstract: ***Climate change has emerged as a defining challenge for the textile and apparel sector, influencing every stage of the clothing life cycle from raw material production to manufacturing, distribution, consumption and end-of-life disposal. The clothing industry is both a significant contributor to greenhouse gas emissions and a sector highly vulnerable to climate variability, resource scarcity and environmental regulations. Present paper examines the multifaceted relationship between climate change and clothing, highlighting impacts on natural and synthetic fibre sourcing, energy and water-intensive manufacturing processes, global supply chains, consumer behavior and waste management systems. It further explores regulatory frameworks, environmental standards and technological innovations shaping the transition towards sustainable clothing systems. Drawing on global literature, the paper emphasizes the need for circular economy approaches, indigenous and low-impact textile practices and responsible consumption to enhance climate resilience and reduce the environmental footprint of clothing. Thus climate-responsive transformation of the clothing sector is essential for achieving long-term sustainability and aligning with global climate and development goals.***

Key words: *Climate change, clothing industry, sustainable textiles, circular fashion, technological innovation*

Introduction– Climate change is reshaping ecological, economic and social systems across the globe, with profound implications for resource-dependent industries. The clothing and textile sector, recognized as one of the most environmentally intensive industries, is increasingly under scrutiny for its contribution to greenhouse gas emissions, water pollution, chemical use and solid waste generation (Niinimäki et al., 2020). At the same time, the industry is highly vulnerable to climate-induced disruptions such as water scarcity, extreme weather events, and supply chain instability. The global clothing industry accounts for approximately 8-10% of global carbon emissions and consumes vast quantities of water and energy (UNEP, 2023). Fast fashion business models, characterized by rapid production cycles and low-cost garments, have further intensified environmental pressures. As climate change accelerates, the need to transform clothing systems towards sustainability, resilience and climate responsibility has become imperative. This paper analyzes the impacts of climate change on the clothing industry and examines adaptive and mitigation strategies across the clothing life cycle, with particular emphasis on sustainable materials, cleaner production, consumer behavior and policy interventions.



2. Impact of Climate Change on Raw Material Sourcing- 2.1 Natural Fibres: The cultivation of natural fibres such as cotton, wool, linen, silk and jute is highly sensitive to climatic conditions. Changes in temperature, rainfall patterns and the frequency of extreme events such as droughts and floods directly affect fibre yield, quality and availability (FAO, 2020). Cotton, a water-intensive crop, faces increasing challenges in regions experiencing water scarcity and erratic monsoon patterns. Reduced water availability and soil degradation have led to declining productivity and increased production risks for farmers (WWF, 2021).

Similarly, wool production is influenced by climate-induced changes in grazing conditions, pasture quality and feed availability for sheep. Heat stress and extreme weather events negatively impact animal health, fibre quality and overall productivity (Henry et al., 2018). These vulnerabilities underscore the need for climate-resilient fibre production systems and diversification towards low-input natural fibres.

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2.2 Synthetic Fibres- Synthetic fibres such as polyester, nylon and acrylic dominate global fibre production due to their low cost and versatility. However, these fibres are derived from petrochemicals, making their production highly dependent on fossil fuels and a major source of greenhouse gas emissions (Textile Exchange, 2022). In addition, synthetic textiles contribute to microplastic pollution during washing and disposal. In response to climate concerns, the industry is increasingly exploring recycled polyester, bio-based synthetics and alternative materials to reduce reliance on virgin fossil resources and lower carbon emissions (Shen et al., 2019).

3. Manufacturing and Production Challenges- 3.1 Energy Consumption and Carbon Emissions: Clothing manufacturing is an energy-intensive process, particularly in fibre production, spinning, weaving, knitting, dyeing and finishing operations. Many textile-producing regions rely heavily on coal-based energy, resulting in high carbon emissions (IEA, 2022). Climate change mitigation efforts are driving manufacturers to adopt renewable energy sources such as solar and wind power, along with energy-efficient machinery and process optimization.

3.2 Water Use and Pollution: Textile wet processing is one of the largest industrial consumers of freshwater and a major source of water pollution. Dyeing and finishing processes generate effluents containing salts, heavy metals and hazardous chemicals that contaminate water bodies if untreated (Kant, 2012). Climate-induced water scarcity further exacerbates these challenges, making efficient water management essential. Innovations such as waterless dyeing technologies, closed-loop water systems, digital printing and the use of natural and low-impact dyes are increasingly adopted to reduce water consumption and pollution loads (Karthik & Gopalakrishnan, 2019).

4. Transportation and Distribution Impacts- 4.1 Global Supply Chains and Emissions: The globalization of the clothing industry has resulted in complex supply chains spanning multiple countries. Raw materials, intermediate products and finished garments often travel long distances, leading to substantial carbon emissions from transportation (McKinsey & Company, 2020). Air freight, commonly used in fast fashion, has a significantly higher carbon footprint than sea or land transport.

4.2 Sustainable Logistics Practices: To reduce emissions, companies are increasingly localizing supply chains, optimizing logistics, consolidating shipments and shifting towards lower-emission transport modes such as shipping by sea or rail. The adoption of eco-friendly packaging and route optimization further contributes to emission reductions (UNEP, 2023).

5. Consumer Behavior and Market Trends- 5.1 Fast Fashion and Environmental Pressure: Fast fashion has transformed clothing consumption patterns by promoting frequent style changes and low-cost garments. This model drives excessive resource use, short garment lifespans and large volumes of textile waste (Fletcher & Tham, 2019). However, growing consumer awareness of climate change and environmental impacts is gradually shifting demand towards sustainable and ethically produced clothing.

5.2 Circular Fashion and Upcycling: Circular fashion emphasizes extending the life cycle of garments through reuse, repair, recycling and upcycling. Practices such as thrift shopping, clothing rental, resale platforms, and brand-led take-back programs are gaining popularity, reducing the demand for new production and associated emissions (Ellen MacArthur Foundation, 2017).

6. End-of-Life Disposal and Waste Management- 6.1 Textile Waste Challenges: A significant proportion of discarded clothing ends up in landfills or incinerators, where synthetic fibres may take hundreds of years to decompose (Niinimäki et al., 2020). Textile waste contributes to land and air pollution and represents a loss of valuable resources.

6.2 Biodegradable and Recyclable Textiles: The development of biodegradable, compostable, and recyclable textiles is critical for reducing end-of-life environmental impacts. Advances in fibre-to-fibre recycling technologies enable the conversion of old garments into new textiles, supporting circular economy objectives (Textile Exchange, 2022).

7. Environmental Regulations, Standards and Certifications- Governments and international organizations are implementing stricter environmental regulations to reduce the clothing industry's climate impact. These include restrictions on hazardous chemicals, mandates for wastewater treatment, carbon emission reporting and extended producer responsibility (EPR) schemes (UNEP, 2023).

Certifications such as the Global Organic Textile Standard (GOTS), OEKO-TEX Standard 100, and Fair Trade provide assurance regarding environmental and social compliance, encouraging transparency and accountability within the industry.

8. Technological Innovations for Climate-Responsive Clothing- 8.1 Sustainable Materials: Advances in material science are driving the development of sustainable alternatives, including fibres

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derived from agricultural residues, bio-based polymers, regenerated cellulose fibres and lab-grown leather (Shen et al., 2019). These materials offer opportunities to reduce carbon emissions and resource use.

8.2 Smart Textiles: Smart textiles capable of responding to environmental conditions or monitoring wearer health represent an emerging frontier. While these innovations offer functional benefits, their overall environmental footprint must be carefully evaluated to ensure alignment with sustainability goals (Stoppa & Chiolerio, 2014).

9. Socio-Economic and Livelihood Implications of Climate-Responsive Clothing- Climate change driven transitions in the clothing sector have significant socio-economic implications, particularly for smallholder farmers, artisans and garment workers in developing countries. Climate-resilient fibre cultivation, promotion of handloom and craft-based production and localized value chains can generate sustainable livelihoods while reducing carbon footprints. Community-based textile systems anchored in natural fibres and indigenous skills provide income diversification, strengthen rural economies and enhance adaptive capacity to climate shocks (FAO, 2020; Fletcher, 2014).

Women play a central role in clothing production across the value chain from fibre processing and weaving to garment construction and retail. Climate-responsive clothing systems that emphasize skill development, safe working conditions and fair wages contribute to gender equity and social sustainability. Supporting women-led textile enterprises and cooperatives also aligns climate action with inclusive development goals.

10. Role of Education and Capacity Building- Education and training are critical for enabling the clothing sector to respond effectively to climate change. Textile and Community Science education programs must integrate climate literacy, sustainable design principles, life cycle thinking and circular economy concepts. Experiential learning approaches, such as living labs, industry-academia collaboration and community internships, equip learners with practical skills to design low-impact and climate-resilient clothing systems. Capacity building across the value chain including farmers, artisans, factory workers, designers and consumers is essential for scaling sustainable practices. Extension services, digital platforms, and participatory training models can accelerate the adoption of climate-smart technologies and sustainable consumption behaviors.

11. Policy Pathways for Climate-Resilient Clothing Systems: Effective policy interventions are vital for driving systemic change in the clothing industry. Governments can promote climate-resilient clothing systems through incentives for renewable energy use, sustainable fibre cultivation, eco-friendly processing technologies and circular business models. Regulatory measures such as extended producer

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responsibility (EPR), carbon disclosure requirements and bans on hazardous chemicals encourage accountability and transparency. Public procurement policies that prioritize sustainable textiles such as uniforms and institutional clothing can create stable markets for low-carbon products. Alignment of national textile policies with climate action plans and Sustainable Development Goals further strengthens the role of the clothing sector in climate mitigation and adaptation (UNEP, 2023).

12. Future Directions and Research Needs- Despite growing momentum towards sustainable clothing, several gaps remain. Further research is required to quantify the climate impacts of emerging materials, evaluate the scalability of biodegradable textiles and assess the socio-environmental trade-offs of smart textiles. Strengthening data availability through life cycle assessment and climate risk analysis will support evidence-based decision-making. Future clothing systems must balance innovation with equity, ensuring that climate solutions do not marginalize small producers or exacerbate social inequalities. Integrating indigenous knowledge with scientific and technological advancements offers promising pathways for resilient and inclusive clothing futures.

13. Conclusion- Climate change and clothing are intricately linked through complex production, consumption and disposal systems. While the clothing industry significantly contributes to climate change, it also holds immense potential to be part of the solution. Transforming clothing systems through sustainable materials, cleaner production, circular economy approaches, responsible consumption and supportive policies is essential for reducing environmental impacts. By embracing climate-responsive strategies, technological innovation and community-centered approaches, the clothing industry can enhance resilience, protect livelihoods and contribute meaningfully to global climate action. Sustainable clothing is no longer a niche concern but a critical component of climate change mitigation and adaptation in the 21st century.

Figure 3: Circular Fashion Model for Climate Mitigation
(Design for durability, repair, reuse, recycling, and waste reduction)
Figure 4: Socio-Economic Co-benefits of Sustainable Clothing
(Linkages between climate action, livelihoods, gender equity, cultural preservation, and rural development)

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