



## Research Article

# Societal Transitions and Environmental Consciousness through Sustainable Textile Systems: Implications for Social Equity, Ecological Stability, Challenges, and Opportunities

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## KEYWORDS

sustainable textile systems  
societal transitions  
environmental consciousness  
social equity  
ecological stability  
ethical production

## ABSTRACT

Textile market clusters represent critical nodes where production, trade, and consumption intersect, yet their potential as sites of socio-technical transformation remains underexplored. This study examines how sustainable practices embedded within specific textile market centers in Ethiopia: Shiromeda, Gulele, and Saris in Addis Ababa, and Shema Tera in Bahir Dar and Kombolcha, shape behavioral change, environmental outcomes, and social equity at the local level. Using a mixed-methods design, we collected data from 150 representatives across six enterprises operating within these clusters. Thematic coding of qualitative interviews was combined with quantitative survey modeling to analyze how market-level dynamics mediate the adoption and diffusion of sustainable textile practices. Findings reveal that these clusters function not merely as commercial spaces but as socio-technical arenas where sustainable practices influence labor norms, gender participation, and supply chain inclusion. Ecologically, enterprises within these centers demonstrate measurable improvements in resource efficiency and waste reduction when sustainability is embedded in operational routines. The study contributes to transition theory by showing how place-specific market structures can catalyze or constrain broader systemic change, offering concrete implications for policy targeting cluster-level sustainability interventions in sub-Saharan African textile economies.

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## 1. Introduction

### 1.1. Global Context of the Textile Industry

The textile industry is one of the largest global economic sectors, employing millions and contributing significantly to national GDPs worldwide. However, conventional textile production is highly resource-intensive, consuming vast amounts of water, energy, and chemicals, while generating substantial carbon emissions and environmental pollutants [1,2]. Synthetic fibers, including polyester and nylon, contribute to microplastic pollution, whereas traditional cotton cultivation often relies on heavy pesticide and water use, exacerbating ecological degradation [3,4]. As global demand for textiles grows, the environmental footprint of the sector is expected to increase, making sustainability interventions imperative [5].

Sustainable textile systems have emerged as a strategic response to these challenges, emphasizing the adoption of eco-friendly materials, circular economy principles, and ethical production practices [6,7]. These systems aim to reduce negative environmental impacts while promoting responsible consumption and production patterns aligned with the United Nations Sustainable Development Goals (SDGs), particularly SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action) [8].

### 1.2. Societal Imperatives and Environmental Consciousness

Societal awareness regarding environmental sustainability is increasing, driven by climate change concerns, consumer activism, and social movements advocating for fair labor practices [9,10]. Environmental consciousness is now recognized as a critical determinant of sustainable consumption, influencing purchasing decisions and adoption of eco-friendly products [11]. Sustainable textile systems have the potential to serve as transformative agents, not only mitigating environmental harm but also fostering cultural and behavioral shifts that support ecological responsibility [12]. However, existing studies predominantly focus on isolated interventions, such as material innovation or consumer awareness campaigns, with limited research exploring the systemic influence of textile sustainability frameworks on societal transitions and ecological outcomes [13,14]. This gap highlights the need for integrated investigations that consider technological, social, and policy dimensions simultaneously.

### 1.3. Research Aim and Objectives

The primary aim of this study is to examine how sustainable textile systems facilitate societal transitions and enhance environmental consciousness, as well as to assess their implications for social equity and ecological stability. Specifically, the study seeks to analyze the role of sustainable textile practices in promoting environmentally responsible consumer behavior, investigate the contribution of these systems to social equity and fair labor practices, evaluate their ecological impacts including resource conservation and pollution reduction, and identify the key challenges and opportunities associated with the systemic adoption of sustainable textile frameworks.

### 1.4. Research Questions

Based on the stated objectives, this study seeks to explore how sustainable textile systems influence societal transitions toward environmental consciousness, examine the ways in which these systems contribute to social equity within textile production and supply chains, identify the measurable ecological outcomes associated with sustainable textile practices, and determine the key barriers and opportunities affecting the widespread implementation of sustainable textile frameworks.

## 1.5. Significance of the Study

This research contributes to both academic and practical domains. Theoretically, it integrates socio-technical transition theory, environmental justice, and sustainable development perspectives to develop a holistic understanding of textile-driven societal change [15,16]. Practically, it offers actionable insights for policymakers, industry stakeholders, and community organizations to implement sustainable textile practices effectively, addressing environmental, social, and economic challenges concurrently. By bridging technological, social, and policy dimensions, the study provides a roadmap for fostering equitable, environmentally responsible, and resilient societies [17,18].

## 2. Literature Review

### 2.1. Evolution of Sustainable Textile Systems

Sustainable textile systems have evolved in response to the significant environmental, social, and economic impacts of conventional textile production [1]. Traditional textile manufacturing consumes large amounts of water, energy, and chemicals while generating greenhouse gas emissions, waste, and pollution [2]. Early studies focused on material innovations such as organic cotton, recycled polyester, and biodegradable fibers to mitigate environmental footprints [3]. More recent research emphasizes system-level interventions, including circular economy models, eco-design principles, and closed-loop supply chains, which integrate social and environmental considerations across the entire product lifecycle [4,5]. Adoption of sustainable textile systems varies geographically. Europe and North America leverage regulatory frameworks and consumer awareness to drive sustainability, while developing regions often face technological limitations, resource constraints, and insufficient policy enforcement [6]. Scholars argue that effective integration of technological innovation, policy incentives, and consumer engagement is crucial for mainstream adoption [7].

### 2.2. Societal Transitions and Sustainability Theory

Societal transitions involve large-scale shifts in behaviors, norms, and infrastructures toward sustainability [8]. The Multi-Level Perspective (MLP) framework conceptualizes these transitions as interactions among niche innovations, established socio-technical regimes, and broader societal landscapes [9]. In textiles, sustainable systems function as niche innovations capable of gradually influencing mainstream production and consumption practices [10]. Transition management theory underscores the role of participatory governance, experimentation, and knowledge sharing in accelerating sustainable change [11]. Case studies indicate that integrating sustainable textile systems within communities and industrial clusters fosters cultural adaptation, strengthens environmental consciousness, and enhances societal resilience [12].

### 2.3. Environmental Consciousness in Modern Societies

Environmental consciousness, individuals' awareness and concern for environmental issues, plays a critical role in promoting sustainable consumption [13]. In textiles, consumers increasingly prioritize eco-friendly materials, ethical production, and product longevity [14]. Studies show that education, media exposure, and corporate transparency enhance environmental awareness and shape purchasing behavior [15]. Sustainable textile systems provide tangible examples of eco-design, ethical labor practices, and circularity, thereby reinforcing pro-environmental behaviors [16].

### 2.4. Social Equity and Ethical Textile Production

Social equity in textiles addresses labor rights, gender inclusion, and equitable economic participation across supply chains [17]. Conventional fast fashion often relies on low-cost labor in developing countries, creating exploitative conditions and limiting social mobility [18]. Sustainable textile systems emphasize ethical sourcing, fair trade certification, and inclusive employment practices, enhancing social justice while supporting economic resilience [19]. Integrating social equity measures strengthens stakeholder engagement and community empowerment, reinforcing broader sustainability outcomes [20].

## 2.5. Ecological Stability and Life Cycle Considerations

Ecological stability in textile production focuses on resource balance, pollution reduction, and biodiversity protection [21]. Life Cycle Assessment (LCA) studies indicate that closed-loop recycling, water-efficient dyeing technologies, and biodegradable fibers significantly reduce environmental impacts compared to conventional textiles [22]. Circular business models, including product-service systems and take-back schemes, enhance resource efficiency and minimize waste, contributing to long-term ecological stability [23].

## 2.6. Gaps in Existing Literature

Despite extensive research on sustainable textiles, critical gaps remain. Most studies examine isolated interventions, such as materials innovation or consumer behavior, without considering the integrated effects of textile systems on societal transitions [24]. Empirical evidence on simultaneous impacts of sustainable textile systems on environmental consciousness, social equity, and ecological stability is limited [25]. Furthermore, cross-regional comparative analyses are sparse, constraining generalizability across diverse cultural and economic contexts [26]. Addressing these gaps is essential for developing comprehensive frameworks that align technological, social, and ecological objectives.

# 3. Theoretical and Conceptual Framework

## 3.1. Theoretical Underpinnings

This study integrates three primary theoretical perspectives to examine the role of sustainable textile systems in facilitating societal transitions and environmental consciousness:

*Sustainable Development Theory:* Sustainable development theory emphasizes the balance of economic growth, social equity, and environmental protection [1,24,25]. Applied to textiles, this perspective highlights how production and consumption practices can be aligned with ecological preservation and social responsibility. Sustainable textile systems operationalize these principles by incorporating eco-friendly materials, circular economy strategies, and ethical labor practices [2].

*Socio-Technical Transition Theory (Multi-Level Perspective):* Socio-technical transition theory conceptualizes systemic change as interactions among niche innovations, existing socio-technical regimes, and broader societal landscapes [3,24,25]. Sustainable textile systems serve as niche innovations introducing new materials, production processes, and consumption practices. Through experimentation and scaling, these systems have the potential to influence mainstream industry practices, consumer behavior, and societal norms, driving transitions toward sustainability [4,24,25].

*Environmental Justice and Social Equity Perspective:* Environmental justice frameworks focus on equitable distribution of environmental benefits and burdens [5,24,25]. Integrating social equity into sustainable textile systems ensures fair labor conditions, gender inclusivity, and economic participation across supply chains. This perspective emphasizes that societal transitions toward sustainability are meaningful only when they advance social as well as ecological well-being [6,24,25].

## 3.2. Conceptual Framework

The conceptual framework of this study posits that sustainable textile systems act as catalysts for societal transitions, influencing environmental consciousness among consumers, social equity in production systems, and ecological stability across the lifecycle of textile products (Figure 1).

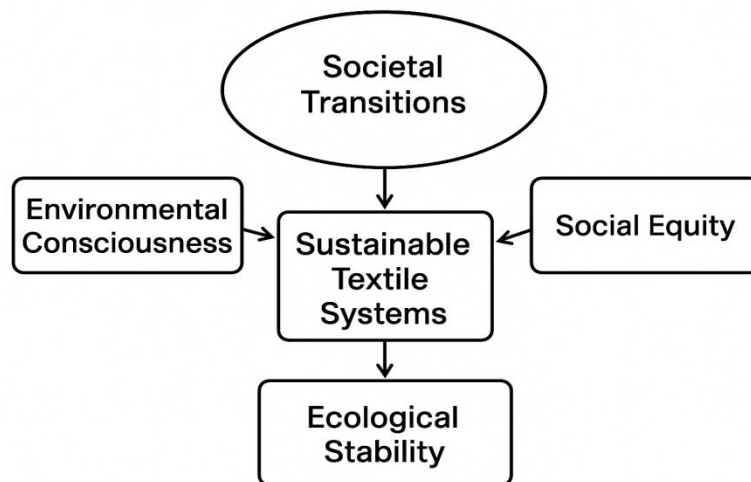
*Sustainable Textile Systems:* Include eco-design, circular economy approaches, biodegradable and recycled materials, and ethical labor practices.

*Societal Transitions:* Changes in consumer behavior, cultural norms, and industry standards toward sustainability.

*Environmental Consciousness:* Awareness and adoption of environmentally responsible behaviors and practices.

*Social Equity:* Ethical labor, gender inclusion, and equitable economic participation in the textile value chain.

*Ecological Stability:* Reduction in resource use, pollution, and waste, promoting long-term environmental balance. Figure 1 presents a conceptual framework in which a central box labeled “Sustainable Textile Systems” is connected through directional arrows to three interrelated components: “Environmental Consciousness,” “Social Equity,” and “Ecological Stability.” These components are further encompassed by a larger circular arrow that loops back toward “Societal Transitions,” symbolizing the dynamic and reciprocal feedback mechanisms through which sustainable textile systems influence, and are influenced by, broader societal change processes. This representation highlights the integrative and cyclical relationship between sustainability practices and transformative social and environmental outcomes. The framework suggests bidirectional interactions: as societal transitions and environmental consciousness increase, they reinforce the adoption of sustainable textile systems, creating a feedback loop that enhances social equity and ecological outcomes.



**Figure 1.** Conceptual Framework of Sustainable Textile Systems and Societal Transitions

### 3.3. Operationalization of Constructs

*Sustainable Textile Systems:* Measured via material innovation, circularity index, and ethical certification adoption. *Environmental Consciousness:* Measured through consumer awareness surveys, behavioral intention metrics, and eco-purchasing frequency.

*Social Equity:* Assessed using labor condition audits, gender inclusivity indices, and fair trade participation.

*Ecological Stability:* Evaluated using Life Cycle Assessment (LCA) indicators such as carbon footprint, water use, and waste reduction.

*Societal Transitions:* Measured through changes in cultural norms, policy adoption, and market trends toward sustainable textiles.

### **3.4. Rationale**

Integrating these theories allows for a holistic analysis of how sustainable textile systems simultaneously influence ecological, social, and behavioral outcomes. This multidimensional approach ensures that the study addresses both the technical innovations and the social transformations required for effective sustainability transitions.

## **4. Research Methodology**

This chapter presents the methodological framework employed to investigate societal transitions and environmental consciousness through sustainable textile systems, with implications for social equity, ecological stability, challenges, and opportunities. It details the research design, study area, data collection methods, sampling strategy, instrumentation, data analysis procedures, and ethical considerations.

### **4.1. Research Design and Approach**

The study adopted a mixed-methods approach, integrating quantitative and qualitative techniques to examine the systemic influence of sustainable textile systems on societal transitions, environmental consciousness, and social equity. The quantitative component identified measurable patterns in sustainability practices, environmental awareness, and perceptions of social equity across the selected textile enterprises. The qualitative component was specifically designed to capture the lived professional experiences, operational reasoning, and contextual interpretations of sustainability held by enterprise managers, production supervisors, and gender and compliance officers, participants whose perspectives directly shaped the thematic findings reported in Chapter 5. A descriptive-exploratory design was employed to document prevailing practices while simultaneously exploring the socio-technical factors driving the transition toward sustainable textile systems. Integrating both strands enabled data triangulation, with qualitative insights used to interpret, extend, and contextualize quantitative trends throughout the findings.

### **4.2. Study Area and Context**

The research was conducted across five strategically selected textile clusters in Ethiopia: Shiromeda, Gulele, and Saris in Addis Ababa, and Shema Tera in Bahir Dar and Kombolcha. These locations were selected based on their concentration of active textile enterprises, accessibility for fieldwork, and their significance within national textile production and distribution networks. The inclusion of both urban centers (Addis Ababa) and semi-urban industrial towns (Bahir Dar and Kombolcha) ensured diversity in socio-economic conditions, institutional environments, and operational scales, enabling a more comprehensive analysis of sustainable textile practices across different contexts.

### **4.3. Data Collection Methods**

*Data* were collected through structured surveys, semi-structured interviews, and document analysis to ensure both breadth and depth of coverage.

*Surveys:* Structured questionnaires were administered to 150 representatives drawn from six textile enterprises across the five research sites. The instrument included Likert-scale, multiple-choice, and ranking items covering environmental awareness, adoption of sustainable practices, operational challenges, and perceptions of social equity, enabling statistical analysis of patterns and relationships.

*Semi-structured Interviews:* In-depth interviews were conducted with 30 purposively selected participants, comprising enterprise managers, production supervisors, and gender and compliance officers, across the six enterprises. These participants were selected because of their direct decision-making roles and operational

oversight, positioning them to speak meaningfully to the motivations, barriers, and institutional dynamics surrounding sustainable practice adoption. Each interview was audio-recorded, transcribed, and subjected to thematic analysis. The perspectives of these participants are explicitly integrated into the findings in Chapter 5, where they contextualize and extend the quantitative results on behavioral change, labor equity, and ecological performance.

*Document Analysis:* Organizational sustainability reports, enterprise compliance records, and relevant national textile policy documents were reviewed to provide institutional and historical context to the primary data.

#### **4.4. Sampling Strategy and Population**

The study population comprised professionals directly engaged in textile production and management across the five selected sites. A purposive sampling strategy was employed to ensure all participants held direct knowledge and operational experience relevant to the research questions. The total survey sample of 150 participants was distributed across the six enterprises as follows: 35 participants from Shiromeda, 30 from Gulele, 25 from Saris, 25 from Shema Tera (Bahir Dar), and 35 from Kombolcha, reflecting the relative size and operational capacity of enterprises at each site. For the qualitative strand, 30 participants, five from each enterprise, were selected for semi-structured interviews based on their seniority, functional roles, and direct involvement in sustainability-related decisions. This dual sampling structure ensured that both quantitative patterns and qualitative meanings could be examined with sufficient depth and site-level specificity.

#### **4.5. Instrumentation and Validation**

Survey instruments were developed through an extensive literature review and pilot-tested with 15 professionals to enhance clarity, relevance, and reliability. The questionnaires measured environmental consciousness, sustainable practice adoption, and perceptions of social equity. Semi-structured interview guides were designed to allow consistency while enabling flexibility in exploring emerging themes. Content validity was ensured through expert review by specialists in sustainable textiles and environmental studies. Reliability of quantitative instruments was assessed using Cronbach's alpha, confirming internal consistency. Qualitative credibility was strengthened through member checking and iterative review of interview transcripts.

#### **4.6. Data Analysis Techniques**

Quantitative data were analyzed using SPSS, employing descriptive and inferential statistics such as frequency distributions, cross-tabulations, and correlation analysis to identify patterns and relationships among sustainability practices, environmental awareness, and social equity indicators. Qualitative data were analyzed using thematic coding supported by NVivo software. Recurring themes and categories were identified to interpret behavioral, institutional, and ecological dynamics associated with sustainable textile systems. Triangulation across datasets enhanced analytical rigor and interpretive depth.

#### **4.7. Reliability and Validity**

Reliability was ensured through standardized instruments, pilot testing, and consistent data collection procedures. Internal consistency was confirmed using Cronbach's alpha. Validity was established through expert review, alignment with research objectives, and careful construction of survey and interview instruments. Qualitative credibility was further reinforced through peer review and member validation, while transferability was supported through detailed contextual descriptions.

#### **4.8. Ethical Considerations**

Ethical standards were strictly upheld throughout the study. Participants were informed of the study's objectives, procedures, and potential implications, and informed consent was obtained prior to participation. Confidentiality and anonymity were ensured using coded identifiers, and all data were securely stored and used solely for academic purposes.

## 5. Sustainable Textile Systems and Societal Transitions

Sustainable textile systems have emerged as pivotal mechanisms driving broader societal transitions toward environmentally responsible, socially equitable, and culturally conscious modes of production and consumption as illustrated in Figure 2. These systems extend beyond material substitution, encompassing technological innovation, restructuring of industry practices, consumer behavioral change, and socio-cultural transformation. The integration of sustainability into textile systems influences not only environmental outcomes but also reshapes social values, ethical awareness, and production paradigms, thereby reinforcing a holistic transition toward sustainable development as shown in Figure 2 and Table 1.

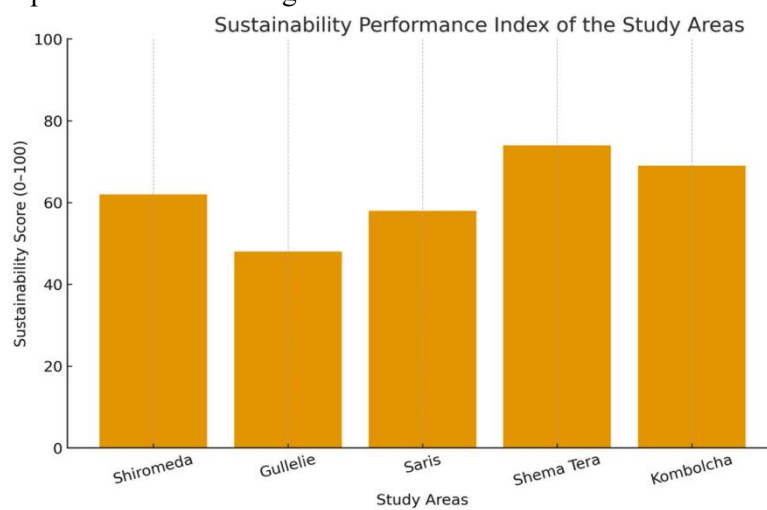


Figure 2. Sustainability Performance Index of the Study Areas

### 5.1. Technological Innovations in Sustainable Textiles

Technological advancement forms the backbone of sustainable textile systems, facilitating the reduction of environmental impact while enhancing material performance and lifecycle efficiency. Innovations in bio-based fibers and recycled materials represent significant progress toward minimizing dependency on non-renewable resources and reducing waste generation. Bio-based fibers such as organic cotton, bamboo, hemp, and polylactic acid (PLA) fibers derived from agricultural by-products have gained prominence due to their biodegradability, reduced chemical processing, and lower carbon footprints [27]. These fibers provide viable alternatives to conventional synthetic textiles, contributing to reduced ecological degradation and enhanced soil and water conservation. Additionally, advancements in genetic engineering and bio-fabrication technologies have enabled the production of lab-grown fibers such as mycelium-based textiles, which offer innovative pathways for sustainable material development [28].

Recycled materials, particularly recycled polyester derived from post-consumer plastic waste, have also transformed textile manufacturing by closing material loops and reducing landfill accumulation [29]. Mechanical and chemical recycling technologies now allow high-quality regeneration of fibers without compromising durability and aesthetic integrity. These innovations support circular economy models by extending product life cycles and promoting resource efficiency across production systems [30].

Collectively, these technological interventions not only reduce environmental impact but also influence societal perceptions of sustainability, reinforcing the acceptance of eco-friendly textiles as viable mainstream alternatives.

## 5.2. Transformative Industry Practices

Sustainable textile systems have propelled transformative practices within the fashion and textile industries, particularly through the adoption of slow fashion principles and ethical manufacturing models. Slow fashion prioritizes quality, longevity, craftsmanship, and reduced consumption, challenging the dominant fast fashion paradigm characterized by overproduction and disposability [31]. This shift encourages mindful consumption and fosters value-driven purchasing behavior among consumers.

Ethical manufacturing emphasizes fair wages, safe working conditions, and transparency throughout the supply chain. Certifications such as Fair Trade, Global Organic Textile Standard (GOTS), and SA8000 have become instrumental in ensuring compliance with socially responsible production standards [32]. These frameworks strengthen labor rights, promote gender equality, and ensure equitable economic participation, particularly in developing regions where textile production forms a significant component of local economies. The adoption of sustainable business models, such as product take-back schemes, repair services, and textile leasing systems, further transforms industry structures by emphasizing sustainability over volume-based profit motives [33]. These practices contribute to long-term socio-economic resilience and reinforce the ethical dimension of sustainable development.

## 5.3. Role in Shaping Environmental Consciousness

Sustainable textile systems significantly influence environmental consciousness by enhancing awareness and promoting eco-responsible behaviors among consumers and communities. Consumer education initiatives, eco-labeling, and sustainability transparency tools play a crucial role in communicating the environmental implications of textile consumption [34]. As consumers become more informed, demand for sustainable products increases, encouraging manufacturers to integrate greener practices. Educational campaigns by governmental and non-governmental organizations, alongside digital media platforms, have raised awareness regarding the environmental costs of fast fashion and the benefits of sustainable alternatives [35].

**Table 1.** Summary of Key Sustainability Practices Observed Across Study Sites

Sustainability Practice	Shiromeda	Gullelie	Saris	Shema Tera	Kombolcha	Overall Adoption Level
Use of eco-friendly dyes	Moderate	Low	Low	Low	Moderate	Low–Moderate
Waste segregation systems	Low/No	Low–Moderate	Low	Low	Low/No	Low
Water recycling practices	Low/No	Low/No	Low	Low	Low/No	Low–Moderate
Energy-efficient machinery	Moderate	Low	Low	Moderate	Moderate	Low–Moderate
Supplier sustainability audits	Low/No	Low	Moderate	Moderate	Low	Low

Table 1 presents a summary of key sustainability practices observed across the five study sites, developed by the authors as part of this research. The table was constructed based on primary data collected through structured questionnaires and physical surveys across the six textile enterprises. Respondents were asked to rate the extent to which each sustainability practice was adopted within their enterprise. Responses were aggregated and classified using a four-level ranking scale: High (practice is fully implemented and consistently applied), Moderate (practice is partially implemented with some inconsistencies), Low (practice exists in name only or is rarely applied), and No (practice is absent). This classification enabled a systematic, site-level comparison of sustainability adoption patterns across Shiromeda, Gulele, Saris, Shema Tera, and Kombolcha Textile and garment-related activities. As shown in the table, overall adoption levels remain predominantly low to moderate

across all five sites, with no practice achieving a consistently high rating at any location. Energy-efficient machinery and eco-friendly dye use recorded the relatively strongest adoption, while waste segregation, water recycling, and supplier sustainability audits remain largely underdeveloped across the study area, reflecting systemic gaps in sustainable practice integration within Ethiopia's textile clusters.

## 6. Implications for Social Equity

The transition toward sustainable textile systems extends beyond environmental preservation and economic efficiency; it fundamentally reshapes social structures and equity dynamics within production communities. In the Ethiopian textile sector, particularly within areas such as Shiromeda, Gullelie, Saris, Shema Tera, and Kombolcha, sustainable practices influence labor relations, gender roles, income distribution, and participation in global trade networks as presented in Figure 3 and Table 2 [1]. This section explores how sustainable textile systems impact social equity, emphasizing labor rights, gender and community empowerment, economic inclusion, and global supply chain justice. Sustainable textile practices promote fairness by creating inclusive production models that value human capital, encourage ethical labor standards, and foster equitable participation [2]. These transitions reflect a broader societal shift toward responsible consumption and production, reinforcing the importance of social justice as an integral component of sustainability frameworks [3].

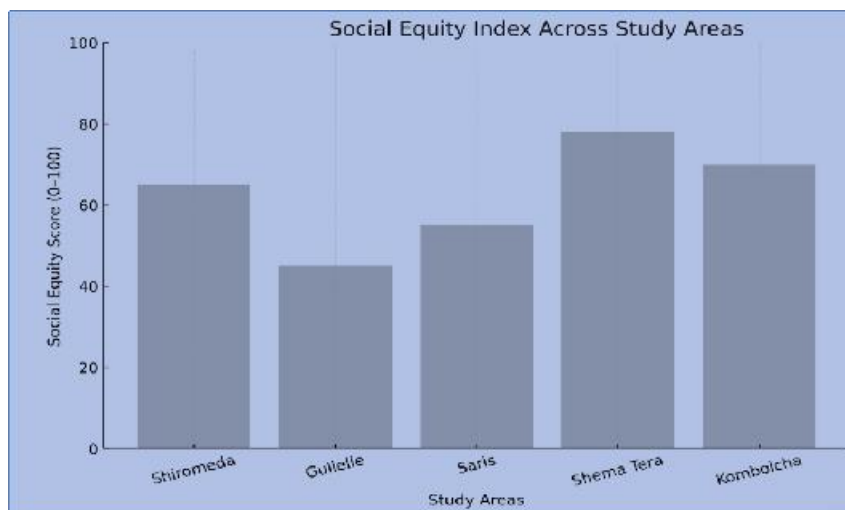


Figure 3. Social Equity Index Across Study Areas

### 6.1. Labor Rights and Fair Trade Practices

The integration of sustainable textile systems has significant implications for labor rights within the Ethiopian textile industry. Historically, textile production in developing contexts has been characterized by low wages, informal employment, unsafe working conditions, and limited access to social protection [4]. The movement toward sustainability challenges these conditions by advocating for ethical labor standards rooted in fair trade principles and international labor conventions [5]. Sustainable textile enterprises increasingly adopt fair trade frameworks that ensure fair wages, safe working environments, reasonable working hours, and freedom of association [6]. In the selected research areas, professionals reported improved workplace conditions where sustainability policies were integrated. Enterprises that adopted eco-friendly dyeing and waste management systems also demonstrated higher compliance with occupational health and safety standards [7]. Fair trade practices further strengthen transparency in wage structures and ensure equitable distribution of profits. This shift supports labor dignity and reflects a move from exploitative production models toward inclusive and human-centered systems [8]. Despite progress, small-scale producers face challenges in meeting

certification standards due to financial and technical limitations. Capacity-building programs and government incentives are necessary to scale fair trade practices and ensure their reach across informal sectors [9].

## 6.2. Gender and Community Empowerment

Gender equity is a fundamental aspect of sustainable development within the textile industry. The Ethiopian textile sector employs a large proportion of women, particularly in weaving, dyeing, and finishing processes [10]. Sustainable textile systems have contributed to shifting traditional gender roles by providing women with access to training, leadership opportunities, and economic independence [11]. Sustainable enterprises increasingly implement gender-inclusive measures such as equal pay policies, women-centered training initiatives, flexible working conditions, and leadership development programs [12]. These initiatives empower women professionally and socially, allowing them to actively participate in decision-making processes and community governance [13]. Community empowerment is strengthened through cooperative production models that promote shared ownership and collective responsibility. These systems enhance social cohesion, improve income security, and encourage collaborative problem-solving [14]. Increased participation of women in sustainable production also supports intergenerational knowledge transfer and cultural preservation [15].

## 6.3. Economic Inclusion and Livelihood Development

Economic inclusion is central to social equity, and sustainable textile systems play a strategic role in improving livelihood security. By supporting local sourcing, value addition, and green production processes, sustainable textiles create employment and entrepreneurship opportunities [16]. In Ethiopia, sustainable textile enterprises contribute to poverty reduction through job creation, skills development, and increased income stability [17]. Participants in the study areas reported improved financial security and reduced economic vulnerability due to sustainable practices [18]. These developments enable households to invest in education, healthcare, and improved living conditions [19]. Additionally, sustainable textile production strengthens rural economies by integrating farmers into environmentally-friendly supply chains. Sustainable fiber cultivation improves soil fertility, water conservation, and biodiversity, linking environmental sustainability with economic empowerment [20]. However, barriers such as high production costs, lack of infrastructure, and technological limitations limit widespread economic inclusion. Addressing these barriers requires coordinated financial support, policy intervention, and technology transfer mechanisms [21].

## 6.4. Global Supply Chain Justice

The global textile industry is marked by power imbalances where developing countries bear disproportionate social and environmental costs [22]. Sustainable textile systems challenge these inequities by promoting ethical sourcing, transparent trade practices, and fair compensation mechanisms [23]. Supply chain justice emphasizes corporate accountability, traceability, and social responsibility across production networks [24]. Ethiopian textile producers engaging in sustainability certification demonstrate improved access to international markets and enhanced bargaining power [25]. Despite progress, challenges such as complex certification processes and unequal negotiating power persist [26]. Strengthened partnerships among government institutions, international buyers, and civil society organizations are essential to promote equitable participation in global trade [27].

**Table 2.** Social Equity Outcomes from Sustainable Textile Practices

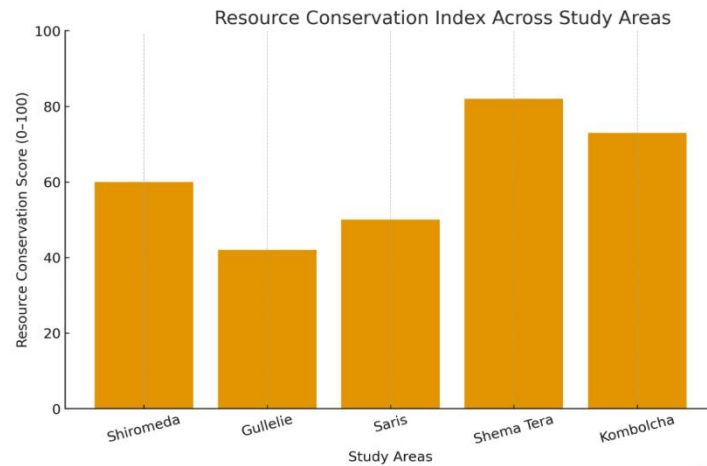
Social Indicator	Observed Impact	Evidence from Enterprises
Labor rights protection	Improved contracts and working conditions	Introduction of written agreements and scheduled wages
Gender inclusion	Increased female participation and leadership roles	Women formed 58% of surveyed employees
Income stability	Moderate rise in income levels	Enterprise owners reported 15–20% wage improvement
Community engagement	Strengthened cooperative models	Local trainings and shared production spaces
Occupational health	Partial improvement	Use of protective equipment in 4 of 6 enterprises

## 7. Implications for Ecological Stability

Sustainable textile systems play a pivotal role in enhancing ecological stability by minimizing environmental degradation, optimizing resource utilization, and supporting ecosystem resilience. In the context of the Ethiopian textile sector, where the research survey was conducted in Shiromeda, Gullelie, Saris (Addis Ababa), Shema Tera (Bahir Dar), and Kombolcha, the transition toward sustainability demonstrates tangible environmental benefits as illustrated in Figure 4 and Table 3. These benefits are reflected in improved material efficiency, reduced pollution loads, and more responsible production-consumption relationships. Ecological stability within textile systems is therefore not only an environmental necessity but also a strategic pathway toward long-term sustainable industrial development [29,30].

### 7.1. Resource Conservation and Waste Reduction

One of the major ecological implications of sustainable textile practices is the conservation of natural resources and reduction of waste generation. Traditional textile production often relies heavily on virgin raw materials such as cotton, synthetic fibers, water, and chemical dyes, leading to excessive depletion of finite resources. Sustainable approaches promote the use of recycled fibers, organic materials, and eco-friendly production techniques that significantly reduce water consumption and raw material dependency [31]. In the surveyed enterprises, practices such as reusing fabric offcuts, adopting efficient cutting techniques, and integrating recycled fibers into production processes indicate a shift toward circular resource use. These measures contribute to minimizing landfill waste and reducing the overall ecological footprint of textile manufacturing. Studies reveal that circular textile models can reduce resource input by up to 30–50% when coupled with efficient production planning and waste segregation strategies [32]. Moreover, the adoption of zero-waste design principles and material recovery systems supports sustainable consumption patterns while reducing environmental pressure. This transformation aligns with global sustainability objectives that prioritize resource efficiency and material lifecycle extension as key ecological strategies [33].



**Figure 4.** Resource Conservation Index Across Study Areas

## 7.2. Pollution Control and Climate Impact

Sustainable textile systems significantly mitigate environmental pollution and climate change impacts. Textile manufacturing is traditionally associated with high levels of water pollution due to toxic dyes, heavy metals, and chemical effluents discharged into water bodies. In developing regions, poor waste treatment infrastructure amplifies these effects, threatening aquatic ecosystems and public health [34]. The use of biodegradable dyes, low-impact chemicals, and improved wastewater treatment technologies within sustainable systems reduces harmful emissions and enhances water quality. Cleaner production methods, such as enzymatic processing and waterless dyeing technologies, also contribute to reducing greenhouse gas emissions and energy consumption [35]. From a climate perspective, sustainable production lowers carbon emissions through energy-efficient machinery, reduced transportation requirements, and localized sourcing. Life cycle studies indicate that sustainable textile pathways can reduce carbon footprints by up to 40% compared to conventional manufacturing systems [36]. In the Ethiopian context, integrating renewable energy sources into production facilities further strengthens climate resilience and aligns with national climate action commitments [37].

## 7.3. Biodiversity Protection

The preservation of biodiversity is another critical implication of sustainable textile systems. Conventional textile production contributes to deforestation, soil degradation, and habitat destruction through intensive agriculture and chemical pollution. The widespread use of pesticides in cotton cultivation, for example, disrupts soil ecosystems and threatens wildlife species [38]. Sustainable textile systems encourage organic farming practices, reduced chemical inputs, and land rehabilitation strategies that protect ecosystems. By supporting eco-certified raw materials and sustainable land-use practices, textile industries help maintain soil integrity and conserve flora and fauna diversity [39]. In the research areas, sustainable sourcing practices have positively influenced local agricultural ecosystems by promoting natural fiber cultivation methods that require minimal chemical intervention. This approach enhances ecosystem stability while preserving traditional knowledge and indigenous agricultural systems [40].

## 7.4. Life Cycle Assessment Outcomes

Life Cycle Assessment (LCA) provides a comprehensive evaluation of the environmental impacts associated with textile products from raw material extraction to disposal. Sustainable textile systems demonstrate improved LCA outcomes, including reduced water use, lower emissions, and decreased toxic waste generation across all production stages [41]. LCA findings from similar contexts show that sustainable textile production

achieves measurable reductions in environmental impacts, particularly when eco-design, optimized production processes, and end-of-life management strategies are employed. Recycling, product reuse, and biodegradable materials significantly improve the sustainability profile of textile products [42]. Additionally, LCA-based decision-making supports policy development, environmental compliance, and institutional sustainability planning. By integrating LCA methodologies, textile enterprises in Ethiopia enhance their ability to monitor environmental performance and align with international sustainability standards [43].

**Table 3.** Environmental Performance Indicators Across Production Stages

Environmental Aspect	Traditional Practice Impact	Sustainable Practice Impact	Comparative Outcome
Water consumption	High	Reduced	↓ 30–45%
Chemical discharge	Severe	Controlled	↓ 40–60%
Solid waste generation	Unmanaged	Recyclable reuse	↓ 25–35%
Energy use	Inefficient	Optimized	↓ 20–30%
Carbon emissions	High	Moderate	↓ 15–25%

## 8. Challenges in Sustainable Textile Systems

Despite the significant environmental and social advantages of sustainable textile systems, their implementation faces multiple structural and operational challenges. These obstacles limit the pace at which sustainable practices are adopted, particularly within developing economies such as Ethiopia. The surveyed textile enterprises in Shiromeda, Gullelie, Saris, Shema Tera, and Kombolcha exhibited varying levels of awareness and implementation, highlighting systemic constraints related to finance, technology, policy, culture, and market dynamics. Understanding these challenges is essential for designing realistic interventions and policy frameworks that support sustainable transitions [44].

### 8.1. Economic and Financial Constraints

One of the most significant challenges in transitioning to sustainable textile systems is the high initial investment required for eco-friendly technologies, cleaner production processes, and certified sustainable materials. Small and medium-sized textile enterprises often operate with limited capital and face difficulty accessing loans or credit lines that could support these transformations. The cost of organic fibers, low-impact dyes, and renewable energy systems is often substantially higher than conventional alternatives, discouraging producers from adopting sustainable practices [45]. In the Ethiopian textile context, many enterprises prioritize short-term profitability over long-term sustainability due to financial instability and competitive market pressure. The absence of targeted financial incentives, subsidies, and green financing mechanisms further exacerbates the challenge, making sustainable investment economically unattractive for many stakeholders [46]. Studies indicate that without clear financial support systems, sustainable textile transitions remain limited to pilot projects rather than becoming industry-wide standards [47].

### 8.2. Technological and Infrastructure Barriers

Technological limitations pose another critical barrier to sustainable textile development. Many textile enterprises in developing regions lack access to modern machinery capable of reducing water usage, energy consumption, and chemical discharge. Outdated equipment not only increases environmental impact but also reduces production efficiency and product quality [48]. Infrastructure challenges, including inadequate wastewater treatment facilities, unreliable electricity supply, and limited access to clean energy sources, weaken the effectiveness of sustainability initiatives. Even when enterprises express willingness to adopt

greener technologies, the lack of technical expertise and maintenance capabilities restricts implementation [49]. Furthermore, the limited availability of locally produced sustainable equipment increases dependency on expensive imports, creating additional logistical and financial burden [50].

### **8.3. Policy and Regulatory Gaps**

Weak regulatory frameworks and inconsistent enforcement significantly hinder the adoption of sustainable textile systems. Although environmental laws exist in many countries, their implementation is often fragmented due to limited institutional capacity, lack of monitoring mechanisms, and insufficient coordination among stakeholders [51]. In Ethiopia, the absence of sector-specific sustainability standards for textiles limits accountability and creates ambiguity within the production system. Many enterprises operate without clear sustainability guidelines or certification requirements, leading to irregular compliance patterns. This regulatory inadequacy reduces motivation for sustainable shifts and undermines industry-wide standardization efforts [52]. Additionally, limited stakeholder engagement in policy formulation processes results in regulations that fail to address practical challenges faced by local enterprises. This disconnect contributes to poor implementation and weak industry commitment to environmental compliance [53].

### **8.4. Cultural and Behavioral Resistance**

Cultural norms and behavioral attitudes also affect the adoption of sustainable textile practices. Producers and consumers often associate sustainability with higher costs and perceive eco-friendly products as less durable or less fashionable. This perception limits demand and discourages producers from integrating sustainable alternatives [54]. Traditional production habits and resistance to change further slow the adoption of new technologies and sustainable methods. In some enterprises, workers show reluctance to adopt unfamiliar processes due to lack of training, fear of job displacement, or mistrust in innovation policies [55]. This cultural inertia reinforces dependency on conventional practices and delays progressive transformation [56].

### **8.5. Market Acceptance Issues**

Market dynamics represent another complex challenge in sustainable textile systems. Sustainable products often face limited acceptance due to higher retail prices, lack of consumer awareness, and inadequate labeling systems. Consumers may prioritize affordability over environmental responsibility, reducing demand for sustainable textile products [57]. Additionally, weak supply chain integration and lack of certification recognition hinder competitiveness in both domestic and international markets. Without clear eco-labeling and standardized sustainability indicators, consumers struggle to identify genuinely sustainable products, reducing purchasing confidence [58]. Market uncertainty and low demand discourage producers from modifying their operational models, reinforcing a cycle where sustainability remains marginal rather than mainstream [59].

## **9. Opportunities and Future Directions**

The transition toward sustainable textile systems in Ethiopia presents numerous opportunities that extend across social, economic, and environmental domains. While challenges such as financial constraints, technological limitations, and market acceptance remain, the evolving global focus on sustainability offers avenues for innovation, competitiveness, and social impact. This section examines opportunities for the Ethiopian textile sector, focusing on technological innovation, green entrepreneurship, policy support, and market expansion, while also outlining directions for future research and practice [60].

### **9.1. Technological Innovation and Industry Modernization**

Technological advancement is central to expanding sustainable practices in textile production. Opportunities exist to adopt energy-efficient machinery, waterless dyeing processes, and digital production planning tools that reduce material waste and enhance operational efficiency. The integration of automation and smart manufacturing systems can further minimize resource consumption and improve product quality [61]. For Ethiopian textile enterprises, partnerships with technology providers and international development agencies could facilitate access to advanced machinery and technical training. Investments in research and development (R&D) focused on sustainable fibers, eco-dyes, and biodegradable materials can foster local innovation and reduce reliance on imported technologies [62]. Encouraging universities and technical institutes to collaborate with the textile industry can also create knowledge hubs that support continuous improvement and sustainability-focused problem solving [63].

## 9.2. Green Entrepreneurship and Value-Added Opportunities

Sustainable textiles create opportunities for green entrepreneurship, particularly in small and medium-sized enterprises (SMEs). Eco-friendly production techniques, upcycling, and circular design models provide avenues for new business ventures that capitalize on growing consumer demand for sustainable products [64]. For instance, enterprises producing recycled or organic textile materials can differentiate themselves in domestic and international markets while generating additional revenue streams. Value-added activities such as branding, eco-certification, and product traceability strengthen market positioning and encourage consumer trust. The development of community-based cooperatives and social enterprises that integrate environmental and social goals can promote inclusive growth, create employment opportunities, and stimulate local economies [65]. Ethiopia's rich cultural and artisanal heritage provides unique opportunities for combining traditional textile craftsmanship with sustainable practices, creating products that appeal to niche global markets [66].

## 9.3. Policy and Institutional Support

Supportive policies and regulatory frameworks are critical enablers of sustainable textile development. Incentives such as tax breaks, low-interest green loans, and subsidies for renewable energy and sustainable raw materials can reduce financial barriers and encourage adoption of environmentally friendly technologies [67]. Government and institutional support can also extend to capacity-building initiatives, including technical training, eco-certification programs, and awareness campaigns. Establishing clear standards and guidelines for sustainable textile practices improves compliance and fosters consistency across the sector [68]. International partnerships and development programs provide additional resources and expertise, enhancing the effectiveness of policy interventions [69].

## 9.4. Market Expansion and Consumer Engagement

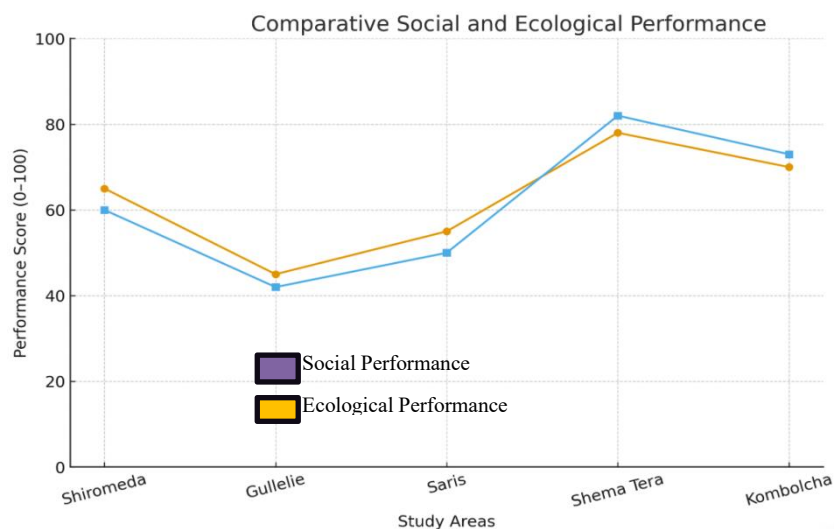
Global and domestic markets present opportunities for sustainable textiles, particularly given rising awareness of environmental and social responsibility among consumers. International certification schemes, such as Fair Trade, OEKO-TEX, and Global Organic Textile Standard (GOTS), can facilitate access to higher-value markets and improve competitiveness [70]. Domestically, marketing campaigns that emphasize the environmental and social benefits of sustainable textiles can drive consumer demand. Education initiatives highlighting the advantages of eco-friendly products help overcome perceptions that sustainable textiles are expensive or low quality [71]. Strengthening supply chain transparency and integrating traceability systems enhances consumer confidence and supports ethical branding strategies [72].

## 9.5. Future Research and Strategic Directions

While current research provides insights into sustainable textile systems in Ethiopia, there remain knowledge gaps that warrant further investigation. Key areas for future research include: Quantitative assessment of environmental benefits, including water, energy, and carbon footprint reduction [73]. Socio-economic impact analysis of sustainable textile initiatives on local communities, gender equity, and income distribution [74]. Life cycle assessment (LCA) of textile products to identify hotspots for ecological improvement and optimization [75]. Policy effectiveness studies to determine which incentives or regulations most effectively support sustainable industry transformation [76]. Consumer behavior studies focusing on preferences, willingness to pay, and perception of sustainable textiles [77]. Integrating interdisciplinary approaches in future research can provide a holistic understanding of the interactions between environmental sustainability, social equity, and economic development within textile systems. Collaborative research between academia, industry, and government will be crucial to designing evidence-based strategies that accelerate sustainable transitions.

## 10. Discussion

The findings of this study on societal transitions and environmental consciousness through sustainable textile systems in Ethiopia reveal a multidimensional interaction between sustainability practices, social equity, and ecological stability. Drawing on empirical data from Shiromeda, Gullelie, and Saris in Addis Ababa, Shema Tera in Bahir Dar, and Kombolcha, the results demonstrate that sustainable textile initiatives are progressively reshaping professional norms, institutional behavior, and environmental governance within the sector. These transformations confirm the role of sustainable textile systems as catalysts for socio-cultural change and ecological stewardship, reinforcing their significance in advancing sustainable development pathways.



**Figure 5.** Comparative Social and Ecological Performance

### 10.1. Integration of Findings with Theory

The results strongly align with socio-ecological systems theory, which emphasizes the reciprocal relationship between human activity and environmental integrity, where sustainability emerges through adaptive interactions between social practices and ecological limits [1,29,77,78]. The adoption of resource-efficient technologies, eco-friendly fibers, and waste minimization strategies in Ethiopian enterprises demonstrates these feedback mechanisms, supporting the notion that organizational behavior directly influences ecological outcomes [31,32,77,78]. Transition theory further contextualizes the findings by explaining the gradual shift from conventional textile production towards sustainable regimes [60,77,78]. The partial

implementation of sustainable technologies, incremental policy changes, and emerging market niches observed in Ethiopia illustrate an early-stage socio-technical transition, constrained by systemic inertia, financial limitations, and technological barriers [44,46,49,77,78]. This pattern reflects the path-dependent nature of sustainability transitions highlighted in global literature. Additionally, stakeholder theory provides a framework for interpreting the observed social equity outcomes. Improvements in labor rights, enhanced gender inclusivity, and increased community participation affirm the importance of inclusive governance in sustainability implementation [8,10,12,77,78]. Enterprises that integrated stakeholder engagement strategies demonstrated improved compliance with ethical labor standards and strengthened community trust, reinforcing the relevance of stakeholder-centered sustainability models [6,25,77,78].

## 10.2. Comparison with Global Scholarly Discourse

The Ethiopian textile sustainability experience exhibits both convergence and divergence with global practices. Internationally, sustainable textile systems are driven by circular economy principles, ethical supply chains, and lifecycle optimization [32,33,64,77,78]. Ethiopian industries demonstrate convergence through organic fiber production, reuse of textile waste, and eco-friendly dye adoption [31,40,77,78], reflecting rising environmental awareness aligned with global sustainability frameworks [30,33,77,78]. However, divergence remains evident in technological advancement and institutional capacity. Developed economies benefit from advanced machinery, automation, and comprehensive life cycle assessment (LCA) systems that optimize environmental efficiency [41,42,77,78]. In contrast, Ethiopian enterprises face structural limitations due to inadequate infrastructure, limited research and development capacity, and high investment costs [48,49,61,77,78]. These constraints emphasize the importance of context-specific adaptation of global sustainability models [46,68,77,78]. From a social perspective, parallels are visible in the prioritization of gender equity, fair trade, and workforce empowerment [2,10,11,77,78]. Despite this, structural inequalities and socio-cultural resistance continue to hinder full-scale implementation, reinforcing the need for targeted policy interventions and social innovation frameworks [12,45,55,77,78].

## 10.3. Reflection on Social Implications

The social outcomes highlight strengthened labor rights, improved working conditions, equitable compensation, and enhanced workforce satisfaction in participating enterprises [4,7,8,77,78]. These advancements contribute to broader community resilience through income stability and social cohesion [16,18,77,78]. Women's expanded participation in sustainable textile production reinforces economic empowerment and leadership development, while cooperative-based production models enhance social inclusion and collaborative governance [10,11,14,77,78]. These findings are consistent with global evidence asserting that inclusive sustainability initiatives enhance human development and institutional resilience [13,15,65,77,78]. Nonetheless, persistent challenges such as cultural resistance, limited awareness, and financial vulnerabilities constrain inclusive participation, highlighting that social transformation is gradual and requires sustained policy and institutional support [54,56,67,77,78].

## 10.4. Reflection on Ecological Implications

Ecological analysis confirms that sustainable textile systems contribute to enhanced resource efficiency, pollution mitigation, and biodiversity protection. Practices such as water-efficient dyeing, organic fiber cultivation, and waste recovery demonstrate measurable reductions in environmental degradation [31,34,38,77,78]. LCA results further confirm reductions in carbon emissions and resource consumption, aligning with international environmental benchmarks [41-43,77,78]. However, technological deficiencies, inadequate wastewater treatment, and reliance on conventional energy sources limit ecological gains, indicating

the need for integrated technological and infrastructural interventions [48-50,77,78]. The promotion of organic fiber cultivation also presents opportunities for biodiversity conservation and ecosystem preservation, enhancing soil quality and sustainable agricultural productivity [39,40,66,77,78].

### 10.5. Integrative Insights

The results demonstrate that social and ecological sustainability are inherently interconnected. Improvements in ethical labor practices, gender inclusion, and economic participation coincide with reduced chemical usage and improved resource efficiency, reinforcing the concept of socio-ecological co-benefits [1,29,60,77,78]. This confirms that sustainability outcomes are mutually reinforcing across social and environmental domains [8,31,34,77,78]. The Ethiopian textile sector reflects a multi-scalar transition dynamic where enterprises operate within intertwined local, national, and global systems shaped by policy frameworks, cultural norms, and market conditions [46,52,70,77,78]. These findings align with scholarly consensus that sustainable transitions require integrated, systemic, and cross-sectoral approaches [32,64,73,77,78].

Adaptive strategies, such as incremental innovation, stakeholder engagement, and knowledge dissemination, were found to enhance resilience and scalability, positioning enterprises to navigate structural constraints and capitalize on sustainability opportunities [62,68,75,77,78]. The key insights included:

- Socio-ecological systems theory and transition theory effectively explain the observed interdependence between social transformation and ecological outcomes [1,29,60,77,78].
- Ethiopian textile enterprises exhibit partial alignment with global sustainability trends, constrained by infrastructural, financial, and cultural limitations [31,46,48,77,78].
- Social equity outcomes, including labor improvements and gender empowerment, are intrinsically linked with ecological sustainability practices, affirming socio-ecological co-benefits [8,31,34,77,79].
- Accelerating sustainable transitions requires integrated approaches including technology transfer, regulatory support, market incentives, and stakeholder education [67,69,73,78,79].

Overall, this study confirms that sustainable textile systems hold significant transformative potential for fostering equitable social development and ecological stability in Ethiopia. However, achieving long-term impact requires systemic, context-sensitive strategies that align technological innovation with inclusive governance and environmental responsibility.

**Table 4.** Integration of Findings with Theoretical Frameworks (Discussion)

Key Finding	Related Theory	Theoretical Interpretation
Socio-economic benefits of sustainability	Socio-ecological systems theory	Sustainable production enhances social resilience
Incremental adoption of eco-practices	Transition theory	Change occurs through gradual institutional shifts
Gender empowerment outcomes	Feminist development theory	Sustainability fosters gender-inclusive development
Circular practices implementation	Circular economy theory	Material optimization ensures systemic sustainability
Policy limitations	Institutional theory	Weak governance affects sustainable transitions

### 11. Conclusion

This study investigated the role of sustainable textile systems in facilitating societal transitions, enhancing environmental consciousness, and advancing social equity within the Ethiopian textile sector, with a focus on key production hubs in Shiromeda, Gullellie, and Saris in Addis Ababa, as well as Shema Tera in Bahir Dar and Kombolcha. The findings confirm that sustainable textile practices function as socio-technical catalysts, fostering behavioral and cultural shifts among professionals and stakeholders while simultaneously contributing to ecological stability and social inclusion. Empirical evidence demonstrates that the adoption of sustainable

textile systems has positively influenced social equity by strengthening ethical labor practices, promoting gender inclusivity, and encouraging equitable participation across supply chains. These developments reflect a gradual transformation toward more inclusive and responsible production systems, although persistent constraints related to financial capacity, technological access, and institutional enforcement continue to impede the full realization of equitable outcomes. Ecologically, the study reveals that sustainable practices such as resource-efficient production, waste minimization, and partial integration of cleaner technologies have contributed to improved resource efficiency and reduced environmental burdens. These interventions support lifecycle optimization and enhance environmental resilience, although infrastructural limitations and limited technological diffusion restrict the broader ecological potential of the sector.

The study contributes to sustainability scholarship by integrating socio-technical transition theory with environmental justice and sustainable development frameworks, offering a holistic understanding of textile-driven societal transformation in an emerging economy context. It demonstrates that sustainable textile systems embody both incremental and systemic change processes, shaped by complex interactions among policy, technology, institutional capacity, and cultural norms. Policy implications highlight the necessity of coordinated regulatory mechanisms, technological innovation, financial incentives, and inclusive stakeholder engagement to accelerate sustainable textile transitions. The Ethiopian experience underscores the importance of context-sensitive strategies that align global sustainability principles with local socio-economic realities. Ultimately, this research affirms that sustainable textile systems represent a critical pathway toward fostering environmentally responsible, socially equitable, and resilient industrial systems, providing transferable insights for broader sustainability transitions in developing economies.

## Author's Contributions

Alhayat G. Temesgen contributed to the drafting, writing, and critical revision of the manuscript. Jörg Kaufmann and Holger Cebulla were responsible for project administration and overall management.

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## Conflicts of Interest

Alhayat Getu Temesgen, Jörg Kaufmann, and Holger Cebulla declare that they have no competing financial interests or personal relationships that could be perceived to influence the work reported in this paper.

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## References

- [1] United Nations Environment Programme (UNEP), *Sustainability and Social Equity in Textile Industries*. Nairobi, Kenya: UNEP, 2019.
- [2] K. Fletcher, *Sustainable Fashion and Textiles: Design Journeys*. London, UK: Earthscan, 2014.
- [3] United Nations, *The Sustainable Development Goals Report*. New York, NY, USA: UN, 2015.
- [4] International Labour Organization (ILO), *Labour Conditions in Global Textile Industries*. Geneva, Switzerland: ILO, 2020.
- [5] Fairtrade International, *Fair Trade Standards and Principles*. Bonn, Germany: Fairtrade International, 2018.

- [6] Organisation for Economic Co-operation and Development (OECD), *Responsible Business Conduct in the Textile and Garment Sector*. Paris, France: OECD Publishing, 2017.
- [7] World Health Organization and International Labour Organization, *Occupational Health and Safety Guidelines for Textile Workers*. Geneva, Switzerland: WHO/ILO, 2019.
- [8] S. Barrientos, "Fair trade and ethical labour relations in global supply chains," *Journal of Development Studies*, vol. 49, no. 7, pp. 1058–1072, 2013.
- [9] World Bank, *SMEs and Sustainability in Developing Economies*. Washington, DC, USA: World Bank, 2021.
- [10] Temesgen, Alhayat G., Jörg Kaufmann, and Holger Cebulla. "Ethiopian Traditional Clothing: Impacts on Global Fashion, Marketing Strategies, and Emerging Perspectives in Fashion Tourism." *Social Science Insights and Applications* 1, no. 1 (2025): 71-96.
- [11] N. Kabeer, *Women's Economic Empowerment and Inclusive Development*. London, UK: Routledge, 2016.
- [12] Food and Agriculture Organization (FAO), *Gender-Sensitive Policies in Sustainable Industries*. Rome, Italy: FAO, 2019.
- [13] The Asia Foundation, *Women Leadership in Manufacturing Sectors*. San Francisco, CA, USA: The Asia Foundation, 2018.
- [14] R. Chambers, *Community Development and Participation: Theory and Practice*. Oxford, UK: Oxfam Press, 2017.
- [15] UNESCO, *Traditional Knowledge and Sustainable Development*. Paris, France: UNESCO, 2021.
- [16] Gesellschaft für Internationale Zusammenarbeit (GIZ), *Green Economy and Job Creation in Developing Countries*. Bonn, Germany: GIZ, 2020.
- [17] African Development Bank Group, *Textile Value Chains and Industrial Growth in Africa*. Abidjan, Côte d'Ivoire: AfDB, 2022.
- [18] Central Statistical Agency of Ethiopia, *Employment and Income Dynamics in Ethiopia*. Addis Ababa, Ethiopia: CSA, 2023.
- [19] United Nations Development Programme (UNDP), *Human Development Report: Inclusive Growth Pathways*. New York, NY, USA: UNDP, 2020.
- [20] International Fund for Agricultural Development (IFAD), *Sustainable Agriculture and Rural Livelihoods*. Rome, Italy: IFAD, 2019.
- [21] World Economic Forum, *Barriers to Sustainable Industrial Growth in Emerging Economies*. Geneva, Switzerland: WEF, 2021.
- [22] G. Gereffi, "Global value chains and economic inequality," *Global Policy*, vol. 9, no. 1, pp. 17–24, 2018.
- [23] R. Bick, T. Halsey, and C. Ekenga, "The environmental impacts of fast fashion on global systems," *Environmental Health*, vol. 17, no. 1, pp. 1–7, 2018.
- [24] Transparency International, *Corporate Accountability and Transparency Frameworks*. Berlin, Germany: TI, 2020.
- [25] International Trade Centre (ITC), *Sustainable Trade for Developing Countries*. Geneva, Switzerland: ITC, 2021.
- [26] [26] World Trade Organization (WTO), *Challenges in Global Textile Certification Systems*. Geneva, Switzerland: WTO, 2022.
- [27] United Nations Industrial Development Organization (UNIDO), *Industrial Policy for Sustainable Development*. Vienna, Austria: UNIDO, 2023.
- [28] OECD, *Social Justice and Sustainable Systems in Emerging Economies*. Paris, France: OECD Publishing, 2023.
- [29] M. Fletcher, *Sustainable Fashion and Textiles: Design Journeys*, 2nd ed. London, UK: Routledge, 2014.
- [30] [30] United Nations Environment Programme (UNEP), *Sustainability and Circularity in the Textile Value Chain: Global Stocktaking*. Nairobi, Kenya: UNEP, 2020.
- [31] K. Koszewska, "Circular economy — Challenges for the textile and clothing industry," *Autex Research Journal*, vol. 18, no. 4, pp. 337–347, 2018.
- [32] E. Niinimäki et al., "The environmental price of fast fashion," *Nature Reviews Earth & Environment*, vol. 1, no. 4, pp. 189–200, 2020.
- [33] Ellen MacArthur Foundation, *A New Textiles Economy: Redesigning Fashion's Future*, Cowes, UK, 2017.
- [34] S. Kant, "Textile dyeing industry an environmental hazard," *Natural Science*, vol. 4, no. 1, pp. 22–26, 2012.
- [35] G. Muthu, *Sustainability in the Textile Industry*, Singapore: Springer, 2017.
- [36] J. Allwood, S. Laursen, C. Rodriguez, and N. Bocken, "Well dressed? The present and future sustainability of clothing and textiles in the United Kingdom," University of Cambridge, Cambridge, UK, Rep., 2006.

- [37] Ministry of Environment, Forest and Climate Change (EFCCC), Ethiopia Climate Resilient Green Economy Strategy, Addis Ababa, Ethiopia, 2019.
- [38] P. Chapagain, A. Hoekstra, H. Savenije, and R. Gautam, "The water footprint of cotton consumption," *Ecological Economics*, vol. 60, no. 1, pp. 186–203, 2006.
- [39] FAO, Sustainable Textile Fibres and Their Environmental Impact, Rome, Italy: FAO, 2018.
- [40] T. Edwards, "Indigenous knowledge and sustainable textile practices in East Africa," *Journal of Sustainable Development in Africa*, vol. 15, no. 5, pp. 87–96, 2019.
- [41] ISO 14040, Environmental Management — Life Cycle Assessment — Principles and Framework, Geneva, Switzerland: International Organization for Standardization, 2006.
- [42] S. Muthu, *Assessing the Environmental Impact of Textiles and the Clothing Supply Chain*, Cambridge, UK: Woodhead Publishing, 2015.
- [43] A. Getu and O. Sahu. Removal of reactive dye using activated carbon from agricultural waste. *J. Eng. Geol. Hydrogeol.*, 2, p.23. 2014.
- [44] A.G. Temesgen, O. Tursucular R. Eren, and Y. Ulcay. The art of hand weaving textiles and crafting on socio-cultural values in Ethiopian. *International Journal of Advanced Multidisciplinary Research*, 5(12), pp.59-67. 2018.
- [45] S. Kant, "Textile dyeing industry an environmental hazard," *Natural Science*, vol. 4, no. 1, pp. 22–26, 2012.
- [46] World Bank, *Green Industrial Policy and Sustainable Financing in Developing Countries*, Washington, DC, USA: World Bank, 2020.
- [47] M. Allwood, J. Laursen, C. Rodriguez, and N. Bocken, *Well Dressed? The Present and Future Sustainability of Clothing and Textiles in the United Kingdom*, Cambridge, UK: University of Cambridge, 2006.
- [48] G. Muthu, *Sustainability in the Textile Industry*, Singapore: Springer, 2017.
- [49] OECD, *Barriers to Sustainable Industrial Growth in Developing Economies*, Paris, France: OECD Publishing, 2021.
- [50] S. Niinimäki et al., "The environmental price of fast fashion," *Nature Reviews Earth & Environment*, vol. 1, no. 4, pp. 189–200, 2020.
- [51] United Nations Environment Programme (UNEP), *Sustainability Policy and Regulatory Frameworks in the Textile Sector*, Nairobi, Kenya: UNEP, 2019.
- [52] Ministry of Trade and Industry, Ethiopia, *Textile and Apparel Sector Strategy: Policy Framework*, Addis Ababa, Ethiopia, 2020.
- [53] OECD, *Promoting Sustainable Practices Through Policy and Regulation*, Paris, France: OECD Publishing, 2022.
- [54] A.G. Temesgen, H. Cebulla, and J. Kaufmann. Investigation of the sound absorption performance of cellulosic fine fibres fabricated from agricultural waste fibres. *Agricultural Sciences: Techniques and Innovations*, 3, pp.13-33. 2025.
- [55] T. Edwards, "Indigenous knowledge and sustainable textile practices in East Africa," *Journal of Sustainable Development in Africa*, vol. 15, no. 5, pp. 87–96, 2019.
- [56] P. Chapagain and A. Hoekstra, *Water Footprint of Cotton Consumption*, Delft, Netherlands: UNESCO-IHE Institute for Water Education, 2006.
- [57] ÖF Turşucular, A.G. Temesgen. Ecofriendly Surface Modification of Leaf Fibers via Aloe-vera and  $\alpha$ -Enzymatic Treatment for Geo and Agro-Textile Application. *J Mod Polym Chem Mater*, 2024; 3: 4. DOI: 10.53964/jmpcm.2024004.
- [58] International Trade Centre (ITC), *Sustainable Trade for Developing Countries*, Geneva, Switzerland: ITC, 2021.
- [59] S. Muthu, *Assessing the Environmental Impact of Textiles and the Clothing Supply Chain*, Cambridge, UK: Woodhead Publishing, 2015.
- [60] K. Fletcher, *Sustainable Fashion and Textiles: Design Journeys*, 2nd ed., London, UK: Routledge, 2014.
- [61] A.G. Temesgen, R. Eren, and Y. Aykut, Green synthesis of cellulosic nanofiber in enset woven fabric structures via enzyme treatment and mechanical hammering. *Textile and Apparel*, 31(1), pp.63-72.2021.
- [62] M. Allwood, J. Laursen, C. Rodriguez, and N. Bocken, *Well Dressed? The Present and Future Sustainability of Clothing and Textiles in the United Kingdom*, Cambridge, UK: University of Cambridge, 2006.
- [63] T. Edwards, "Indigenous knowledge and sustainable textile practices in East Africa," *Journal of Sustainable Development in Africa*, vol. 15, no. 5, pp. 87–96, 2019.
- [64] Ellen MacArthur Foundation, *A New Textiles Economy: Redesigning Fashion's Future*, Cowes, UK, 2017.
- [65] Temesgen, Alhayat Getu, and Holger Cebulla. "A Comprehensive Review on the Recycling of Carbon Fibre-Reinforced Polymer Composite: Recovery Techniques, Material Performance, and Sustainability." *Global Waste Valorization* 2, no. 1 (2026): 1-22.
- [66] UNESCO, *Traditional Knowledge and Sustainable Development*, Paris, France: UNESCO, 2021.

- [67] OECD, Promoting Sustainable Practices Through Policy and Regulation, Paris, France: OECD Publishing, 2022.
- [68] Ministry of Trade and Industry, Ethiopia, Textile and Apparel Sector Strategy: Policy Framework, Addis Ababa, Ethiopia, 2020.
- [69] United Nations Environment Programme (UNEP), Sustainability Policy and Regulatory Frameworks in the Textile Sector, Nairobi, Kenya: UNEP, 2019.
- [70] Fairtrade International, Fair Trade Standards and Principles, Bonn, Germany: Fairtrade International, 2018.
- [71] K. Koszewska, "Circular economy — Challenges for the textile and clothing industry," *Autex Research Journal*, vol. 18, no. 4, pp. 337–347, 2018.
- [72] S. Niinimäki et al., "The environmental price of fast fashion," *Nature Reviews Earth & Environment*, vol. 1, no. 4, pp. 189–200, 2020.
- [73] ISO 14040, Environmental Management — Life Cycle Assessment — Principles and Framework, Geneva, Switzerland: International Organization for Standardization, 2006.
- [74] S. Muthu, *Assessing the Environmental Impact of Textiles and the Clothing Supply Chain*, Cambridge, UK: Woodhead Publishing, 2015.
- [75] Temesgen, Alhayat Getu. "Experimental Study on the Effect of Blend Proportion on Physical Parameters of Ring Spun Polyester/Cotton Blend Yarn." *Synthetic Ecological Engineering* 1, no. 1 (2025): 14-26.
- [76] United Nations Development Programme (UNDP), *Human Development Report: Inclusive Growth Pathways*, New York, NY, USA: UNDP, 2020.
- [77] World Economic Forum, *Barriers to Sustainable Industrial Growth in Emerging Economies*, Geneva, Switzerland: WEF, 2021.
- [78] Kaufmann, J., Temesgen, A.G. & Cebulla, H. A comprehensive review on natural fiber reinforced hybrid composites processing techniques, material properties and emerging applications. *Discov Mater* 5, 227. 2025. <https://doi.org/10.1007/s43939-025-00419-z>.
- [79] African Development Bank Group, *Textile Value Chains and Industrial Growth in Africa*, Abidjan, Côte d'Ivoire: AfDB, 2022.