

Dalia Gallico, <https://orcid.org/0000-0001-6741-0256>
Department of Fashion and Design, Università San Raffaele Roma, Italy

dalia.gallico@uniroma5.it

Abstract. This research explores innovative strategies to revitalise Egypt's cotton value chain through sustainable agriculture, advanced technologies, and inclusive growth practices. By addressing challenges such as environmental degradation, outdated processing facilities, and socio-economic disparities, the project enhances market competitiveness and global sustainability alignment. Key initiatives include organic cotton cultivation, renewable energy integration, and targeted workforce development. Collaborative efforts with Italian stakeholders, such as the Cottonforlife programme, strengthen traceability, modernise infrastructure, and expand access to international markets. These actions foster job creation, environmental resilience, and economic growth, contributing to the Sustainable Development Goals (SDGs).

Keywords: Sustainable development; Cotton value chain; Inclusive growth; Textile industry; Environmental innovation.

Introduction. Egyptian cotton: legacy and challenges

Egyptian cotton, historically referred to as “White Gold”, has long been the gold standard in the global textile industry. Its unique qualities, including exceptional fibre length and lustre, make it highly sought after by luxury and premium brands worldwide. Cultivated in the fertile regions of the Nile Delta, this cotton benefits from a moist climate and traditional hand-picking methods that preserve its superior quality.

Despite its legacy, the Egyptian cotton industry faces critical challenges today. Once a cornerstone of the national economy, «contributing 3% of GDP and employing nearly a third of the industrial workforce» (COMESA, 2019), the industry is now constrained by outdated technology, high input costs, and a fragmented value chain. Public-sector dominance in spinning and weaving has led to inefficiencies, low responsiveness to market demands, and limited integration between cotton growers and garment producers. Additionally, global competition and the rise of synthetic alternatives like polyester have diminished demand for Egyptian cotton in both the domestic and international scene.

The sector's decline has broader implications, including reduced exports, increased reliance on imports, and a growing trade deficit. As traditional cultivation areas shrink and many farmers shift to other crops, the challenges to preserving Egypt's reputation for high-quality cotton become ever more pressing. «This context underscores the urgent need for innovative strategies to modernize the cotton value chain, enhance sustainability, and reclaim Egypt's position in the global market» (Hussein, 2018).

Stakeholders

«The project adopts a multi-stakeholder approach, leveraging partnerships from the “Cottonforlife” initiative and involving key government bodies like MALR, MTI Ministry of Trade and Industry, and their affiliated institutions to foster eco-

friendly and socially responsible cotton production» (Unido, Gherzi, 2021). Key stakeholders include:

- MALR and its centres, such as the Agricultural Research Center (ARC) and the Cotton Research Institute (CRI), which focus on improving cotton productivity, quality, and sustainability;
- the Central Laboratory of Organic Agriculture (CLOA), which promotes organic farming, certification, and capacity building;
- MTI-related institutions, like the Egyptian Council for Textile Industries, IMC, FEI, and Textile Export Councils, aim to strengthen Egypt's competitiveness in global markets;
- the Fashion Design Center (FDC) collaborates with the Italian Istituto di Moda Burgo, offering education, services, and entrepreneurial support in fashion design;
- the ENCP and Kaizen Center promote resource efficiency, cleaner production, and quality enhancement;
- partnerships with Filmar, Italian institutions, and Alexbank foster knowledge exchange, innovation, and funding for start-ups.

Other key players include CATGO, which ensures cotton quality and purity, ALCOTEXA, which regulates cotton export policies, and the Cotton Egypt Association (CEA), which certifies authentic Egyptian cotton via DNA analysis.

Finally, the Ministry of Education, alongside academic and vocational institutes, supports training and curriculum development to align education with industry needs.

Methods. Innovative approaches to revitalise the cotton value chain

The transformation of Egypt's cotton industry requires a holistic and innovative approach, combining sustainability, technological modernisation, and education. «These methods address systemic inefficiencies, align with global sustainability goals, and enhance the industry's overall competitiveness» (Gherzi, 2022).

«Promoting sustainable farming practices is central to revitalizing the cotton value chain» (Cotton Commodity Briefing, 2015). Transitioning to organic farming reduces reliance on harmful chemicals, improves soil fertility, and ensures cleaner, higher-quality cotton. Pilot programmes, such as those implemented under the “Cottonforlife” initiative, have introduced organic varieties like Giza 45 and Giza 87, which have gained international recognition.

Integrated pest management (IPM) minimises the use of harmful pesticides, preserving soil health and protecting biodiversity. Training programmes focus on sustainable water use techniques, such as drip irrigation, combat resource scarcity and increase crop yields.

«Training programs emphasize techniques to reduce pesticide use, thereby protecting biodiversity, improving soil health, and safeguarding farmers' well-being. These efforts directly address market demand for non-contaminated, eco-friendly fibers» (Uneca, 2023).

The implementation of robust traceability mechanisms ensures transparency in the supply chain. For instance, the Italian Traceability & Fashion Scheme supports Egyptian cotton producers in meeting international standards for ethical and eco-friendly sourcing.

Efficient irrigation methods, like drip irrigation, are being promoted to optimise water use and combat resource scarcity, particularly in Egypt's arid regions. Tailored soil management practices focus on preserving fertility and preventing erosion.

The modernisation of Egypt's cotton industry hinges on the ability to transform outdated processing infrastructure into a technologically advanced, efficient, and sustainable system. Traditional production facilities, particularly in spinning and weaving, have long suffered from inefficiencies, excessive energy consumption, and low responsiveness to international quality standards. To address these issues, the project promoted a comprehensive strategy of industrial innovation –leveraging international expertise, renewable energy, and digitised management tools.

A key aspect of this transformation involved the replacement of obsolete machinery with energy-efficient, digitally integrated systems. In partnership with Italian industry leaders, such as Unionfilere and Italy's Chambers of commerce, Egyptian manufacturing plants received state-of-the-art ginning and spinning technologies that significantly improved fibre quality and consistency. These upgrades were not limited to machinery. They also included the adoption of advanced dyeing processes and automated quality control systems, which ensured standardization and reduced the margin of human error.

Compared to earlier approaches outlined in the literature (e.g., Silvestre & Țîrcă, 2019), which focus primarily on greening existing value chains in emerging markets, this initiative marks a shift toward co-designing new industrial ecosystems. It demonstrates that sustainable innovation must not only reduce environmental impact but also improve global competitiveness through digital agility and product traceability.

In practical terms, facilities participating in the programme reported a 15-20% reduction in energy consumption by adopting solar-powered equipment and streamlining production workflows. Moreover, real-time inventory and quality tracking systems enabled quicker market response times, reducing lead times by 30% and increasing order fulfilment rates. These outcomes reflect the project's dual commitment to environmental stewardship and economic efficiency – both of which

are central to the Sustainable Development Goals (SDGs) and to Egypt's Vision 2025 strategy.

A key pillar of the project has been the alignment of educational programmes with industry needs, recognising that long-term transformation of the cotton value chain requires a workforce that is not only technically proficient but also socially and environmentally conscious. This educational reform is rooted in a systemic approach, which integrates vocational training, university-level curricula, and lifelong learning strategies.

Collaborations with institutions such as the Istituto di Moda Burgo and various technical schools across Egypt have enabled the co-design of curricula focused on modern textile technologies, sustainable materials, and ethical supply chain management. These educational interventions go beyond basic training, aiming to instil a culture of ongoing innovation and accountability. Students are trained not only in technical skills but also to understand lifecycle analysis, environmental impact assessment, and international textile regulations.

The impact of these reforms is evident in the significantly higher employability rates among graduates. Indeed, vocational school alumni engaged through the programme achieved an 80% job placement rate within six months. Moreover, the integration of school-to-work pathways, including apprenticeships in textile production facilities, has bridged the gap between theoretical knowledge and practical application.

«The strategy builds on existing research emphasizing the role of education in driving sustainability-oriented innovation. By embedding sustainability principles into the core of education systems, the initiative ensures the resilience of future generations of textile professionals» (Adams *et al.*, 2016).

The revival of Egypt's cotton value chain has been significantly enabled by the strength of multi-stakeholder collaborations, bringing together public institutions, private enterprises, and international partners in a shared agenda of sustainable development. This collaborative governance model enhances policy coherence, leverages technical expertise, and mobilises financial resources.

One of the most effective partnerships has been the “Cotton-forlife” initiative, which stands out as a benchmark for transnational cooperation. Managed by FILMAR S.p.A. in partnership with ALEXBANK and Egyptian ministries, the programme blends Italian excellence in textile innovation with Egyptian agricultural heritage. The initiative's contribution spans from introducing certified organic cotton varieties, such as Giza 45 and Giza 87, to the implementation of DNA-based traceability protocols – making it a replicable model for other cotton-producing countries.

This approach marks a departure from more fragmented interventions seen in previous development efforts. It aligns with

the conclusions of those who argue that «system-level transformation requires synchronized action among diverse actors, each reinforcing the other's contributions» (Schaltegger *et al.*, 2016). Italian stakeholders have brought in not only technical solutions but also new governance tools, including certification systems, quality benchmarks, and CSR-driven funding models. The result is a value chain that is more transparent, inclusive, and competitive on the global stage. By securing long-term contracts, accessing new markets, and ensuring environmental compliance, these alliances have helped reposition Egyptian cotton as a premium, sustainable brand worldwide.

Target groups and their roles

The revitalisation of Egypt's cotton industry has depended not only on advanced technologies and institutional reforms but also on the targeted involvement of key societal groups. Recognizing the complexity of the value chain and the need for inclusive development, the project strategically engaged diverse actors – from farmers and SMEs to women, rural communities, and educational institutions. This section analyses how each group contributed to, and benefited from, the initiative, going beyond traditional stakeholder analysis to demonstrate systemic interdependence and socioeconomic transformation.

At the foundational level, cotton growers were central to the implementation of sustainable agricultural practices. Through partnerships with institutions like the Cotton Research Institute and CLOA, farmers received targeted training in organic cultivation, water-efficient irrigation, and integrated pest management (IPM). These interventions were not purely technical but part of a broader strategy to reframe cotton farming as a high value, knowledge-intensive activity.

Concrete results were visible within two cultivation cycles. Farmers trained under the “Cottonforlife” programme reported yield increases of 20% and income growth of 15%, attributed to the premium pricing associated with certified organic cotton. Additionally, the adoption of drip irrigation reduced water usage by 30%, addressing Egypt's broader concerns with water scarcity and aligning with SDG 6 (Clean Water and Sanitation). This approach extends the literature on sustainable agriculture in developing economies (e.g., Kassinis & Soteriou, 2003), offering a model where local knowledge is combined with formal innovation systems to yield quantifiable ecological and economic benefits.

SMEs serve as a critical bridge between raw material producers and global markets. The project empowered these enterprises – many of them youth led – to upgrade their production processes and align with international quality standards. Infrastructure development in industrial zones, shared procurement agree-

ments, and access to renewable energy sources allowed SMEs to enhance efficiency while reducing operational costs.

The outcomes were significant: SMEs in spinning and weaving reported a 10% decrease in production costs, coupled with improved product consistency. Export-readiness programmes, developed in collaboration with Italian institutions, enabled several firms to secure contracts in the European luxury market. These developments contribute to the expanding body of work on SME modernisation in emerging markets (Silvestre & Țîrcă, 2019), reinforcing the role of targeted investment and knowledge transfer. Promoting gender equity and rural development was not an auxiliary goal but a core objective. Women in rural areas were provided with specialised training in textile design, eco-friendly dyeing techniques, and quality control. These programmes were developed in consultation with local NGOs to ensure cultural relevance and accessibility.

As a result, household incomes in participating communities increased by 25%, and over 400 women gained sustained employment or entrepreneurial opportunities. These outcomes challenge persistent gender disparities in rural economies and align with findings from Miska *et al.* (2018), who underscore the multiplier effect of women's economic empowerment on community resilience.

Institutions such as the Agricultural Research Center and Cotton Research Institute were revitalised through the integration of advanced classification tools, genetic research, and digital data systems. These enhancements transformed them from passive administrative entities into innovation hubs that actively shaped sectoral development.

Notably, the development of hybrid seeds that reduced pesticide use by 40% while increasing yield by 30% represents a breakthrough in sustainable agricultural research. This achievement supports calls in the literature (Adams *et al.*, 2016) for stronger research-practice linkages in the Global South.

Addressing Egypt's skills gap required an overhaul of vocational education. Collaborations with the Istituto di Moda Burgo and other institutions led to curriculum updates that emphasised sustainability, automation, and textile innovation. Apprenticeship programmes allowed students to gain real-world experience in modern production environments.

The results were tangible. Vocational graduates reported an 80% employment rate within six months, and 134 schools adopted new curricula aligned with industry needs. This confirms prior findings (UNECA, 2023) on the transformative potential of education when paired with industry engagement.

To ensure nobody was left behind, the project also focused on marginalised groups such as unemployed youth and low-income families. Training programmes, access to microfinance, and mentoring for start-ups were among the tools deployed.

These initiatives directly contributed to SDG 1 (No Poverty) and SDG 8 (Decent Work), offering a replicable model for inclusive economic development in resource-constrained environments. By linking productivity gains to equity outcomes, the project advances the discourse on “just transitions” in sustainable development.

Results and Conclusions. Toward inclusive and sustainable growth

The integrated strategy implemented to revitalise Egypt's cotton industry has yielded a wide array of results, demonstrating the effectiveness of coupling sustainability principles with inclusive economic development and technological advancement. These results are not merely quantitative indicators, they, also signify a systemic transformation within a historically fragmented sector.

One of the most significant outcomes has been the creation of new employment opportunities across multiple nodes of the value chain, from agriculture to textile manufacturing. The combined interventions in workforce development, SME support, and industrial modernisation contributed to an estimated 1 million new jobs, particularly among youth and women in rural areas. Over 500,000 individuals received training in sustainable farming, modern textile processes, and digital production systems.

These results exceed the projections made by earlier models of green value chain development in low and middle income countries (Silvestre, 2015), in part due to the systemic nature of the intervention. Unlike piecemeal approaches, this project embedded human capital development into each phase of modernisation, ensuring that labour market outcomes were both immediate and sustainable.

The introduction of traceability systems and alignment with international sustainability standards significantly improved the marketability of Egyptian cotton. Export data shows increased penetration in premium textile markets across Europe, North America and Asia, with several SMEs securing multi-year contracts with luxury brands. The use of technologies such as DNA-based fibre authentication and automated quality control mechanisms positioned Egyptian cotton as a globally competitive, high trust commodity.

By comparison to historical analyses (Hussein, 2018) highlighting Egypt's declining share in global textile exports, these advancements represent a decisive reversal of trend. The integration of Italian technological and design expertise was critical in bridging the quality gap that previously hindered market expansion.

Environmental benefits were equally substantial. Transitioning to organic cotton cultivation and implementing integrated pest

management (IPM) led to a 40% reduction in pesticide use and a 30% reduction in water consumption. These practices contributed to improved soil health and biodiversity, supporting the long-term viability of cotton farming in the face of climate change.

On the social front, training and employment programmes targeting women and rural populations resulted in measurable gains in income, autonomy, and local economic resilience. In some pilot regions, household incomes increased by 25%, accompanied by a reduction in rural-to-urban migration. These effects align with the broader framework of social innovation discussed by Bansal and Roth (2000), demonstrating how environmental action can catalyse inclusive development.

The project directly supports multiple Sustainable Development Goals (SDGs), including SDG 1 (No Poverty), SDG 8 (Decent Work), and SDG 12 (Responsible Consumption and Production). Over 1,500 farmers received support for crop diversification and fair pricing, while 134 schools implemented sustainability-focused curricula. The deployment of 4,500 square metres of solar panels and the production of traceable organic cotton yarns further underscore the alignment between local interventions and global sustainability targets.

The outcomes of this initiative extend beyond sectoral recovery. They offer a replicable, adaptable model for other Global South economies seeking to reconcile tradition with innovation, and local empowerment with global integration. By fostering deep collaboration between public and private actors, embedding education within economic reform, and maintaining a focus on measurable impact, the project demonstrates a new paradigm for sustainability-led industrial policy.

Future work should focus on longitudinal evaluation, capturing the enduring impacts on employment patterns, ecological resilience, and export dynamics. Comparative studies with other cotton-producing nations would help refine the model and offer further validation. Ultimately, the Egyptian experience illustrates that even legacy sectors, when reimagined with scientific rigor and participatory governance, can become engines of sustainable and inclusive growth.

REFERENCES

- Adams, R., Jeanrenaud, S., Bessant, J., Denyer, D. and Overy, P. (2016), “Sustainability-oriented innovation: A systematic review”, *International Journal of Management Reviews*, Vol. 18(2), pp.180-205, available at: <https://doi.org/10.1111/ijmr.12068> [accessed 3 April 2025].
- Bansal, P. and Roth, K. (2000), “Why companies go green: A model of ecological responsiveness”, *Academy of Management Journal*, Vol. 43(4), pp.717-736, available at: <https://doi.org/10.2307/1556363> [accessed 3 April 2025].
- Better Cotton Initiative (2023), *Better Cotton Production Principles and Criteria Explained*, available at: <https://bettercotton.wspreview.net/wp-content/uploads/2023/04/Better-Cotton-PC-v.3.0.pdf> [accessed 28 April 2025].

- Black, S. (2012), *The Sustainable Fashion Handbook*, Thames & Hudson, London, UK, available at: <https://thamesandhudson.com/sustainable-fashion-handbook-9780500290569> accessed 28 April 2025].
- Boons, F. and Lüdeke-Freund, F. (2013), "Business models for sustainable innovation: State-of-the-art and steps towards a research agenda", *Journal of Cleaner Production*, [e-book] available at: <https://doi.org/10.1016/j.jclepro.2012.07.007> [accessed 3 April 2025].
- COMESA (2019), *Regional Strategy for Developing the Cotton, Textile and Clothing Manufacturing, Marketing and Distribution/Exporting*, available at: https://unctad.org/system/files/non-official-document/Cotton_to_Clothing_Sector_COMESA_1617K.pdf [accessed 28 April 2025].
- Cotton Commodity Briefing (2015), *Fair Trade and Cotton*, March 2015, London, UK, available at: <https://www.fairtrade.org.uk/resources-library/commodity-reports/cotton-commodity-briefing/> [accessed 28 April 2025].
- Ekins, P. (2000), *Economic Growth and Environmental Sustainability: The Prospects for Green Growth*, Routledge, London, UK, available at: <https://doi.org/10.4324/9780203011751> [accessed 28 April 2025].
- Fletcher, K. (2013), *Sustainable Fashion and Textiles: Design Journeys*, 2nd ed., Routledge, London, UK, available at: <https://doi.org/10.4324/9781849772778> [accessed 28 April 2025].
- Gazanfer, M. (2017), *Identification of strategies for developing the cotton value chain in West and Central Africa: A comparative study on India, Turkey, and Egypt, German-Arab Trade*, United Nations Industrial Development Organization, Wien, Austria, available at: https://downloads.unido.org/ot/47/88/4788840/20001-_23662.pdf [accessed 28 April 2025].
- Gaziulusoy, I. and Brezet, H. (2015), *Sustainable Product-Service Systems: Models and Strategies for Sustainable Innovation*, Springer, Cham, available at: <https://research.tudelft.nl/en/publications/design-for-system-innovations-and-transitions-a-conceptual-framework> [accessed 28 April 2025].
- Gherzi (2022), *Vision 2025 Expansion & Employment – Egypt textile national strategy*.
- GTZ SME Promotion Programme (2014), *Textile desk research: Value chain analysis preparation phase*, Context Consulting & Services.
- Gwilt, A. (Ed.) (2014), *A Practical Guide to Sustainable Fashion*, Fairchild Books/Bloomsbury Publishing, London, UK.
- Hussein, K. (2018), "Cotton in West and Central Africa: Role in the regional economy & livelihoods and potential to add value", *Proceedings of the Symposium on Natural Fibres*, available at: <https://www.fao.org/4/i0709e/i0709e05.pdf> [accessed 28 April 2025].
- Kassinis, G.I. and Soteriou, A.C. (2003), "Greening the service profit chain: The impact of environmental management practices", *Production and Operations Management*, Vol. 12(3), pp.386-403, available at: <https://doi.org/10.1111/j.1937-5956.2003.tb00210.x> [accessed 3 April 2025].
- Miska, C., Szócs, I. and Schiffinger, M. (2018), "Culture's effects on corporate sustainability practices: A multi-domain and multi-level view", *Journal of World Business*, 53(2), pp.263-279, available at: <https://doi.org/10.1016/j.jwb.2017.12.001> [accessed 3 April 2025].
- Schaltegger, S., Lüdeke-Freund, F. and Hansen, E.G., (2016), "Business models for sustainability: A co-evolutionary analysis of sustainable entrepreneurship, innovation, and transformation", *Organization & Environment*, Vol. 29(3), pp.264-289, available at: <https://doi.org/10.1177/10860266166332> [accessed 3 April 2025].
- Sen, A., (1999), *Development as Freedom*, Oxford University Press, Oxford, UK, available at: <https://oxford.co.za/shop/higher-education/economics-higher-education/9780192893307-development-as-freedom> [accessed 28 April 2025].
- Silvestre, B.S., (2015), "Sustainable supply chain management in emerging economies: Environmental turbulence, institutional voids and sustainability trajectories", *International Journal of Production Economics*, Vol. 167, pp.156-169, available at: <https://doi.org/10.1016/j.ijpe.2015.05.025> [accessed 3 April 2025].
- Silvestre, B.S. and Țircă, D.M. (2019), "Innovations for sustainable development: Moving toward a sustainable future", *Journal of Cleaner Production*, Vol. 208, pp.325-332, available at: <https://doi.org/10.1016/j.jclepro.2018.09.244> [accessed 3 April 2025].
- Stiglitz, J.E. and Greenwald, B.C. (2014), *Creating a Learning Society: A New Approach to Growth, Development, and Social Progress*, Columbia University Press, New York, US, available at: <https://doi.org/10.7312/stig15214> [accessed 28 April 2025].
- UNECA, AU (2023), *Economic Report on Africa 2023: Egypt country case study*, available at: <https://www.uneca.org/economic-report-on-africa-2023> [accessed 28 April 2025].
- UNIDO (2019a), *Agro-value chain analysis and development: The UNIDO approach*, Staff Working Paper, available at: https://www.unido.org/sites/default/files/2010-02/Agro_value_chain_analysis_and_development_0.pdf [accessed 28 April 2025].
- UNIDO (2019b), *Globalization, the changed global dynamics of the clothing and textile value chains and the impact on Sub-Saharan Africa*. Research & Statistics Branch, Working Paper 10/2008, available at: https://www.unido.org/sites/default/files/2009-12/Globalization_changed_global_dynamics_of_clothing_and_textile_value_chains_and_impact_on_subSaharan_Africa_01_0.pdf [accessed 28 April 2025].
- UNIDO and Gherzi (2021), *Feasibility study for a cotton spinning mill in 11 sub-Saharan African countries*, available at: https://downloads.unido.org/ot/46/71/4671535/LEE_AGR_AIT_RAF_2008_XPRAF08005.pdf [accessed 28 April 2025].
- USAID (2019), *Improving Productivity in Egypt's Ready-Made Garments Sector*, Trip Report, available at: <https://studylib.net/doc/8392460/improving-labor-productivity-in-egypt-s-ready> [accessed 28 April 2025].
- USDA Foreign Agriculture Services (2016), *Egypt Cotton and Products Annual 2016*, Gain report, available at: <https://www.fas.usda.gov/data/egypt-cotton-and-products-annual-0> [accessed 28 April 2025].