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REVIEW ARTICLE

Tapestry of Crypto Cotton's Odyssey in the global textile industry: Blockchain-enabled traceability across the cotton value chain

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Abstract

Blockchain stands as one of the technological titans of our digital era, rapidly reshaping commerce and supply networks across the globe. Within this landscape, cotton cultivation and its vast textile ecosystem emerge as a critical frontier for innovation, where issues of authenticity, purity and ethical sourcing converge with the promise of decentralisation. This review offers a comprehensive global overview of cotton significance, contextualising its economic and cultural significance while mapping the sector's vulnerabilities to opacity, counterfeiting and unsustainable practices. The central hypothesis of this review is that cotton's global dominance in production and its pivotal role as the backbone of the textile industry make it imperative to integrate blockchain-enabled traceability from the agronomic phase of cultivation onward, thereby enhancing fibre quality, ensuring authenticity and fostering sustainable, trusted supply chains from farm to fashion. To evaluate this hypothesis, we conduct a structured review of peer-reviewed literature, patents and technical databases, triangulating insights from agronomy, supply chain management and financial technology. Whereas earlier reviews have focused narrowly on blockchain applications within the textile industry, this study uniquely integrates the agricultural foundation of cotton, highlightingthe importance of on-farm traceability and agronomic data, before extending the analysis to ginning, spinning and global textile trade. Our findings demonstrate that decentralised ledgers are not only strengthening traceability and reducing informational asymmetries, but also enabling equitable participation of farmers, enforcing sustainability standards. By critically examining both academic research and emerging real-world deployments, this paper establishes a forward-looking framework for the digital transformation of cotton supply chains, underscoring blockchain's potential to weave together ethical, transparent and sustainable textile futures.

Keywords: blockchain; cotton; decentralisation; digital agriculture; supply chain transparency; textile industry

Introduction

Cotton, often hailed as "white gold" for its luminous value and cultural resonance, stands unrivalled as the cornerstone of India's agrarian and industrial landscape (1–4). More than just a crop, it sustains millions of smallholder farming households, anchors rural economies and weaves together generations (5). Its unmatched versatility and commercial significance have rightly earned it the title of "King of Fibre Crops," a testament to its indispensable role in textiles, industry and daily life (6–10). Globally, cotton is acknowledged as the most extensively produced and utilized natural fibre, holding a significant position in the world economy with an estimated annual impact of $600 billion (11, 12). As the preeminent cash crop, cotton is the lifeblood of global textile value chains. Its natural fibers not only provide clothing for nations but also strengthen economies at all levels from massive industrial centres to the smallest rural homesteads, supporting the livelihoods of more than 100 million families and fuelling ambitions in manufacturing, commerce and agriculture (13).

Cotton also contributes substantially to the global food chain in addition to its role as a fibre crop. Approximately 65 % of cotton-derived products find their way into human and animal nutrition systems. This occurs directly, through cottonseed oil commonly used in cooking and processed foods and indirectly, through meat and milk from animals fed with cottonseed meal and ginning by-products (14, 15). Furthermore, cotton by-products are an exceptional source of nutrients. Cotton seeds are rich in protein, healthy fats, carbohydrates, dietary fibre and a variety of essential vitamins and minerals. The development of glandless cotton has further enhanced the potential for direct human consumption through plant-based protein products and fortified foods. Cottonseed oil, valued for its heart-healthy lipids and vitamin E, plays a vital role in the food industry. In addition, by-products such as cottonseed cake and bran support livestock nutrition, underscoring cotton's dual significance in sustainable agriculture and global food security (16, 17).

Therefore, this review synthesizes the global status of cotton cultivation and its dual significance in agriculture and industry, while critically examining how blockchain technology originating in digital finance has emerged as a transformative tool for this globally dominant crop. Given cotton's unparalleled role in sustaining economies and shaping the textile sector, the adoption of

blockchain in its supply chains marks a pivotal shift toward transparency, traceability and sustainable value creation. The urgency of this investigation stems from rising global concerns over textile counterfeiting, supply chain opacity and unsustainable practices, which directly impact farmer livelihoods, consumer confidence and climate goals. While earlier studies have primarily focused on blockchain applications within textile processing or trade, this study uniquely situates blockchain at the intersection of agronomic production thereby filling a critical knowledge gap. Accordingly, this review aims to consolidate existing knowledge on blockchain applications in the cotton value chain, identify key technological, economic and policy challenges and outline future directions to accelerate transparent, sustainable and digitally verifiable cotton systems.

Materials and Methods

Review approach

This study adopts a structured narrative review approach, suitable for emerging and multidisciplinary topics such as blockchain-enabled cotton traceability. While the approach is narrative in nature, key elements of transparency including search strategy, screening steps and inclusion criteria are explicitly reported to enhance replicability.

Literature search strategy

A structured search was conducted across leading scientific and technical databases including Scopus, Web of Science, Google Scholar, SpringerLink, ScienceDirect and IEEE Xplore. The search covered the period from January 2010 to July 2025 to capture the evolution of digital agriculture and early blockchain applications. Keywords included combinations of blockchain, distributed ledger, traceability, cotton, agriculture, fibre quality, supply chain transparency, digital farming and smart contracts. Grey literature, including industry reports, patents and government documents, was also screened to capture technological innovations not reported in peer-reviewed journals.

Screening and selection process

The screening and selection process consisted of four steps. First, all records were identified from the sources mentioned. Second, duplicate entries were removed manually. Third, title and abstract screening was performed to remove papers irrelevant to blockchain or cotton and agriculture. Fourth, a full-text review was conducted to include only studies discussing blockchain use-cases in cotton, agriculture, textile supply chains, data transparency, or traceability. A total of 148 records were initially identified. After removing duplicates, 112 records remained. Following title and abstract screening, 54 studies were retained and ultimately 37 full-text articles were included for synthesis.

Inclusion criteria

Studies were included if they discussed blockchain, distributed ledger, or digital traceability, addressed cotton, agriculture, or textile supply chains, provided conceptual, empirical, or technical insights, were published in English and appeared in journals, conferences, patents, or credible reports.

Exclusion criteria

Studies were excluded if they focused only on non-agricultural sectors without relevance to traceability, lacked sufficient methodological or conceptual information, were duplicates, or had inaccessible full texts.

Data extraction

Data extracted from each included study comprised publication year, country or region, study type, blockchain platform used, cotton or fibre supply chain stage addressed and reported challenges and outcomes.

Analytical framework

A manual thematic analysis was conducted, with themes developed inductively from the content of the papers. No software such as NVivo or Zotero was used; coding was performed manually by the author.

Patent integration

Blockchain-related agricultural patents were screened from publicly available patent databases. Insights from patents were compared with academic findings to identify technological gaps, highlight real-world implementations and strengthen the discussion on innovation pathways.

Replicability statement

Although this study does not claim to be a full PRISMA systematic review, major components of transparency including database selection, search strings, screening steps and inclusion rules are provided to support replicability.

Results and Discussion

Cotton's global significance and India's dominance

In the realm of cultivated land, India stands as the world's largest producer of cotton, with an astounding 11.8 million hectares devoted to this vital commodity. With such a vast area under cultivation, India not only leads the world in cotton production but also plays a pivotal role in the textile and agricultural industries, both of which underpin rural livelihoods and national economic activity. Closely following India, the United States (3.35 million ha) and China (2.9 million ha) also dedicate significant land resources to cotton production (18). However, India's unparalleled commitment to cotton farming, far surpassing that of any other country, is underscored by these rankings, which firmly establish its status as the global leader in cotton cultivation by area. Fig. 1 depicts the exceptional prominence of cotton cultivation across major producing nations, alongside the global distribution of cotton-growing land.

In terms of output, however, China emerges as the world leader for 2024–2025, producing 31.75 million bales by leveraging high-input systems and advanced agronomic practices that achieve a remarkable 2384 kg ha^{-1}, setting the global benchmark for yield efficiency. India, despite having the largest cultivation area, ranks second with 25.0 million bales, while Brazil, a rapidly emerging powerhouse, produces 17.0 million bales at a strong productivity level of 1879 kg ha^{-1} (18). Conversely, although cultivating a comparatively smaller area, Australia records the second-highest productivity worldwide (1960 kg ha^{-1}), reflecting a strategic emphasis on technological innovation and resource efficiency. Fig. 2 provides a comparative visualization of global cotton production (in million bales) and productivity (kg ha^{-1}) during the 2024–2025 season, clearly illustrating disparities in yield efficiency and shifting dynamics among top producers.

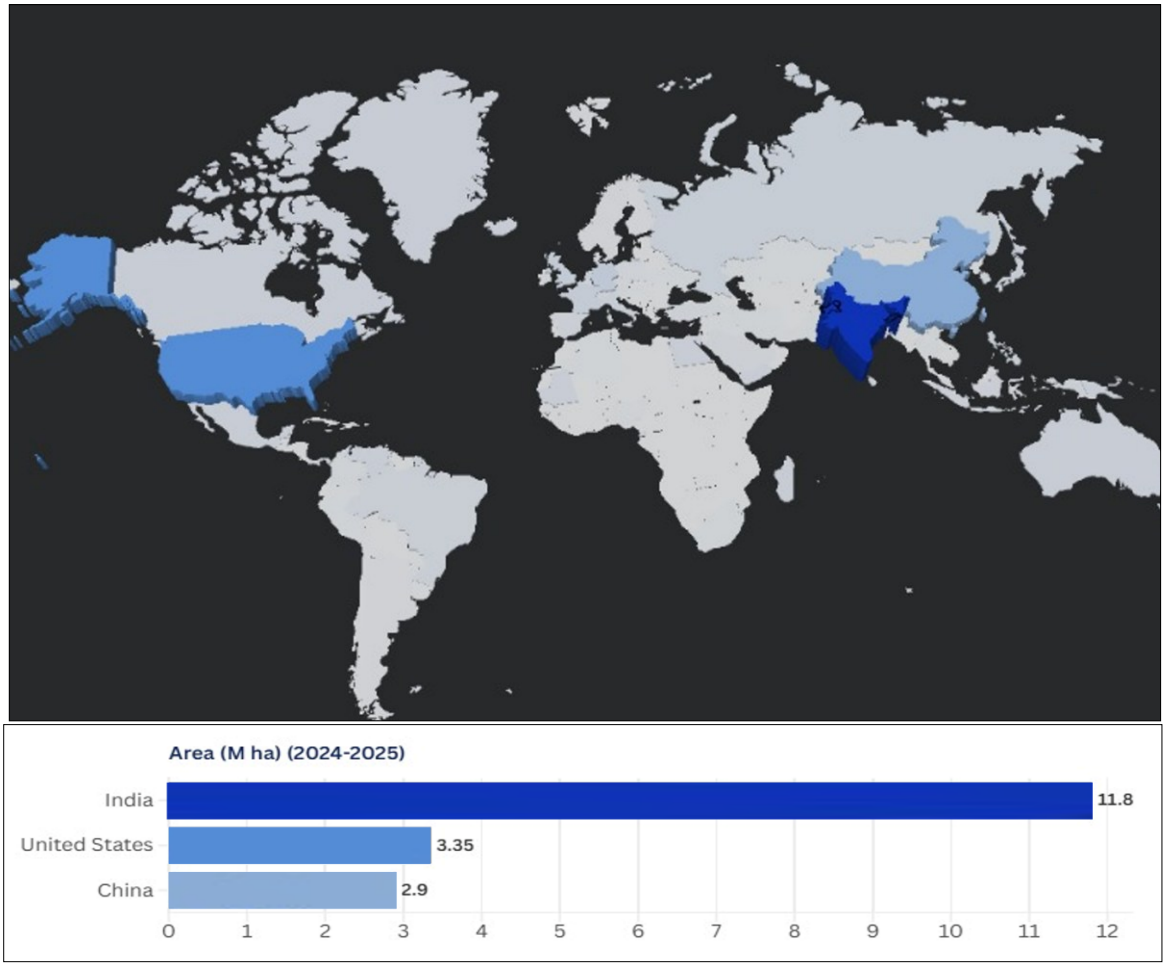

Fig. 1. Global footprint of cotton cultivation: Leading nations and area distribution (2024–25). Data from: (ICAR-AICRP, 2025).

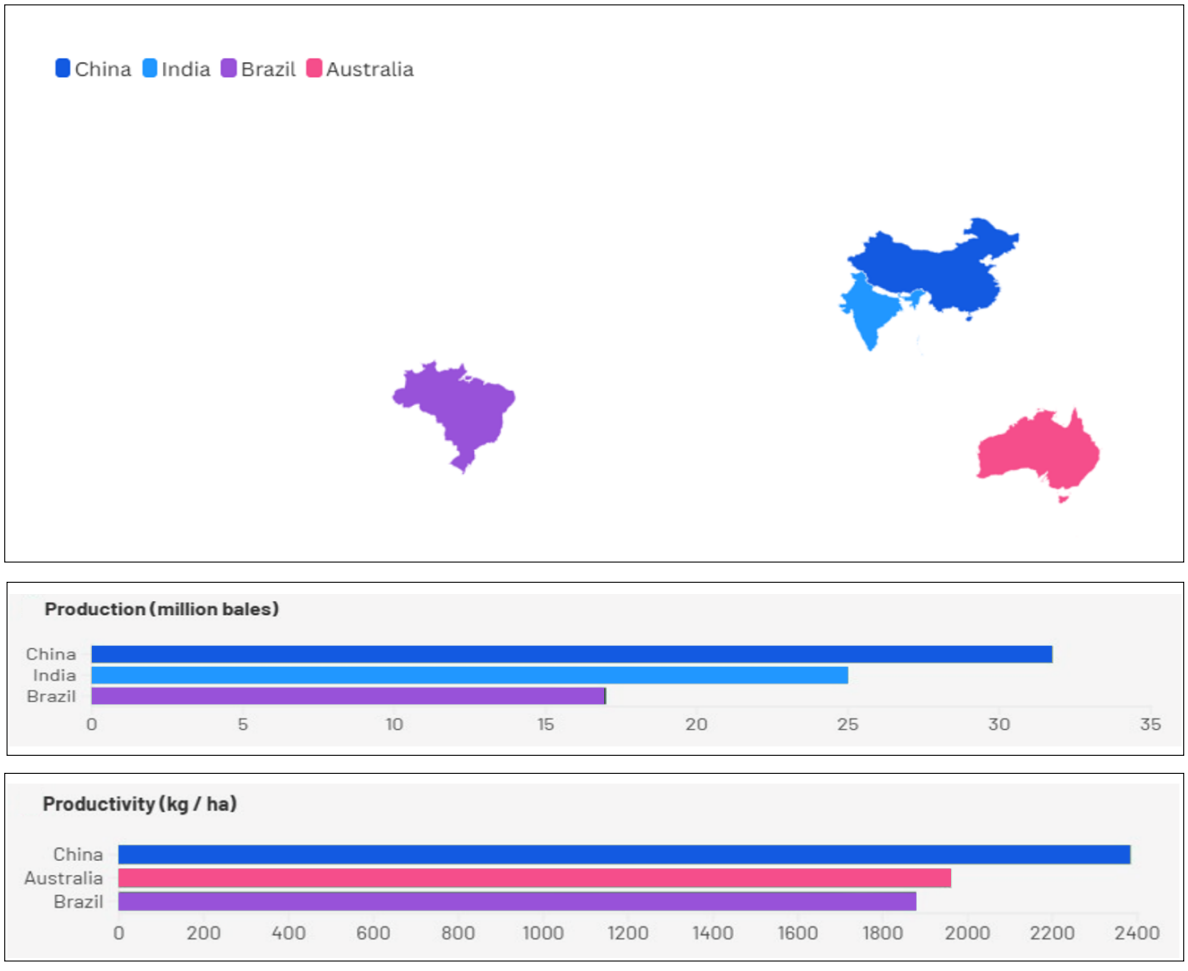

Fig. 2. Comparative overview of global cotton production and productivity among leading countries (2024–25). Data from: (ICAR-AICRP, 2025).

As the world's largest cotton cultivator by area and a perennial leader in production, India's supremacy in the cotton sector is indisputable. Its extensive output not only sustains a robust domestic textile industry but also underpins foreign trade, thereby stabilizing global supply chains. Within India's cotton landscape during the 2024–2025 season, regional diversity is striking. Maharashtra leads in area with 40.84 lakh ha, followed by Gujarat (23.92 lakh ha) and Telangana (17.82 lakh ha). In terms of production, Maharashtra (84.80 lakh bales) and Gujarat (84.01 lakh bales) dominate, with Telangana contributing 48.95 lakh bales. In productivity, Gujarat excels with 597 kg ha^{-1} followed by Odisha (544 kg ha^{-1}) and Rajasthan (524 kg ha^{-1}) (18). These regional distinctions, whether in land use, fiber output, or yield efficiency emphasize the dynamic and multifaceted role of India within the global cotton value chain. Fig. 3 captures these state-level disparities and portrays India's overall influence in the cotton sector for 2024–2025.

Cotton's central role in the textile industry

Cotton continues to be the premier natural fiber in the textile sector, contributing significantly to global trade, employment and production. Across the world, cotton sustains over 100 million households in 75 countries, particularly in lower-income regions (19). By 2032, the global cotton textile market is projected to expand from its 2024 valuation of USD 1837.27 billion to USD 3611.95 billion (20). The fibre's softness, breathability, biodegradability and versatility in clothing, home textiles and industrial products make it indispensable. In 2024, cotton accounted for approximately 39.3 % of the textile industry's total revenue, more than any other single fiber (21). The economic contribution of cotton was valued at USD 0.39 billion in 2023 and is projected to rise steadily to USD 0.62 billion by 2033.

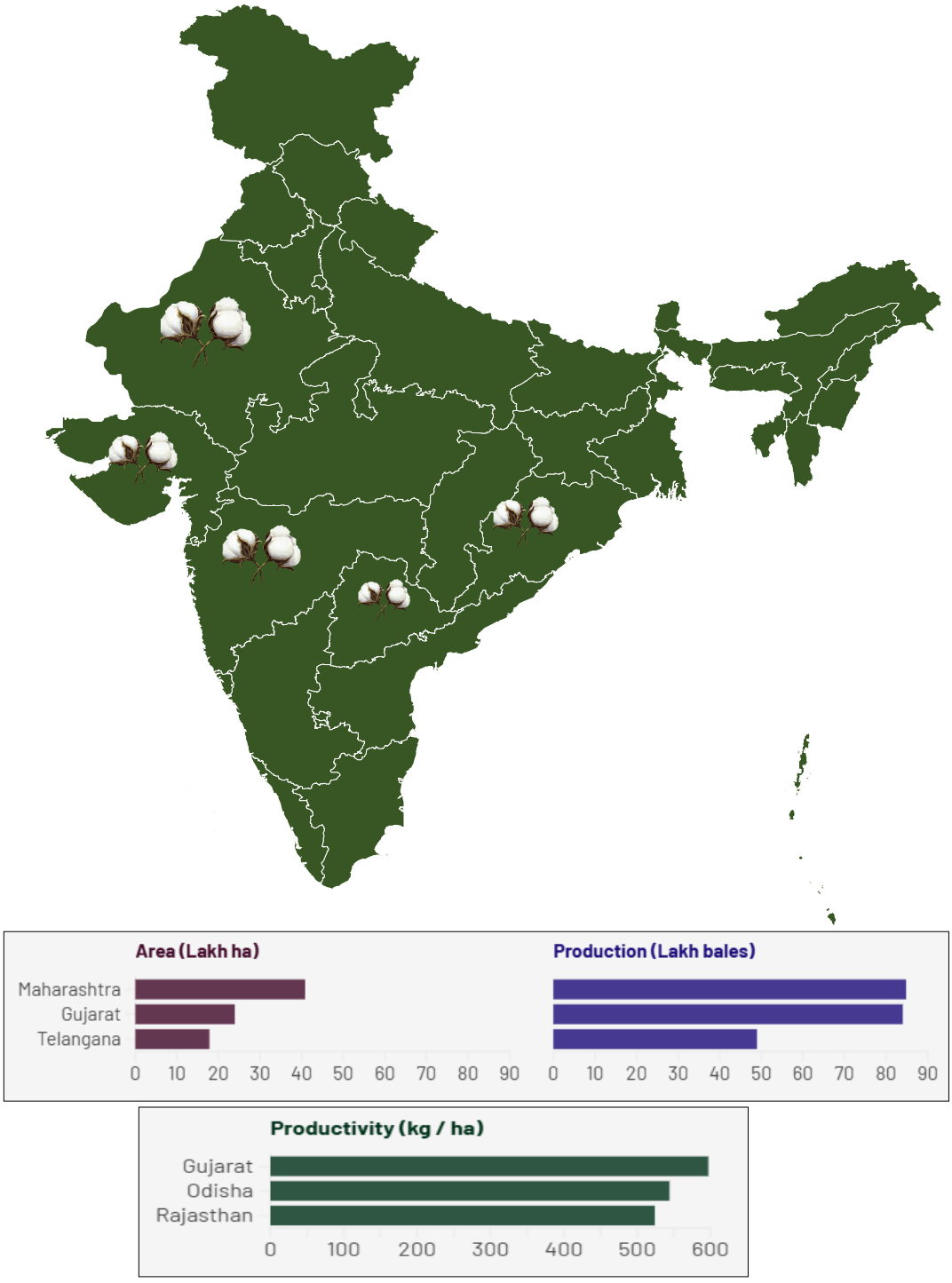

Fig. 3. Cotton powerhouses of India: Area, production and productivity share of thetop 3 states (2024–25). Data from: (ICAR-AICRP, 2025).

By contrast, the market for synthetic fibers grew from USD 0.46 billion in 2023 to USD 0.66 billion in 2033, driven largely by their versatility and affordability. Other natural fibers, such as wool and silk, contributed smaller shares to the global textile market, though their costs also rose considerably (21). Fig. 4 illustrates the proportionate contributions of cotton, synthetics and other fibers to overall textile market growth between 2023 and 2033. A testament to its exceptional economic, nutritional and cultural importance, cotton remains a global treasure linking farms, households, factories and markets. Given its immense impact, it is imperative to safeguard every link in the cotton supply chain: from seed to shirt and from farm to fork. Strengthening this unparalleled chain through transparency, technology and traceability is not only strategically vital in an era of volatility and disruption, but also essential for ensuring resilience, sustainability and responsible management of a resource that sustains civilizations worldwide.

Due to the enormous size and complexity of the cotton industry, traditional supply chain management techniques are becoming less effective at guaranteeing transparency accountability and reliability at every turn (22, 23). Contemporary digital technology must be incorporated as norms for sustainability, ethical sourcing and quality control escalate. Among these, blockchain technology holds legitimate revolutionary potential. Blockchain has the potential to completely reinvent the way cotton is grown, processed and traded around the world by offering an unchangeable digital ledger for tracking every movement and transaction along the cotton value chain, from farm to spinning mill, dye house, clothing factory and finally the retailer. Through transparency, traceability guarantees product quality and safety while enhancing profitability (24). By using blockchain technology, the industry can guarantee that each bale of cotton is tracked transparently and that its journey is verified, providing unmatched advantages in terms of sustainability, efficiency, quality and trust (25–28)

The evolution of blockchain from cryptocurrency to cotton cultivation

The concept of blockchain was first introduced in 2008 by Satoshi Nakamoto as the foundational infrastructure for Bitcoin, envisioned as an open, transparent and decentralised ledger (29, 30). At its core, blockchain is a distributed digital ledger that records time-stamped transactions across a peer-to-peer (P2P) network, enabling independent and transparent verification without the need for centralised authority. Each verified block is cryptographically linked to its predecessor using a unique hash, timestamp and transaction record, thereby forming a tamper-evident chain. The first block in the chain, known as the genesis block, has no parent, making any retroactive alteration of data easily detectable (31–42). While blockchain was initially created as a secure, peer-to-peer record of cryptocurrency transactions, its capacity to guarantee transparency, immutability and trust quickly attracted broader interest. Recognised as a tool to enhance confidence, streamline processes and combat fraud, blockchain began expanding beyond financial services into a wide array of domains (43). Over the past decade, blockchain has evolved into a cross-sectoral technology, with applications in governance, healthcare, logistics and most critically, global food and agricultural supply chains (44).

In 2017, Walmart, a leading global food manufacturer, implemented blockchain technology to track pork products in China, which resulted in significant improvements in traceability and transparency. This innovation lowered the traceability time from days to just seconds, enabling real-time transparency at every stage, from farm to processor to retail and established a new international standard for the integrity of the food supply chain. Following this historic trial, there has been a surge in interest in using blockchain technology in agriculture for a variety of purposes, such as food safety and certification, index-based crop insurance, supply chain automation and smart contracts to confirm the legitimacy of inputs and product origin. Blockchain is now enhancing traceability, transparency and trust across agro-based value chains, livestock and crops by dismantling conventional information silos and lowering fraud (45).

The welspun egyptian cotton scandal

In 2016, the textile giant Welspun was embroiled in controversy when it was discovered that around 750000 “Egyptian cotton” sheets and pillowcases sold at major retailers, including Target and Walmart, were in fact made with inferior cotton not sourced from Egypt. Welspun endured a huge financial loss (more than $700 million in market value), an industry-wide assessment and the unravelling of commercial ties with significant purchasers as a result. Systemic flaws in cotton supply chains were exposed by the incident, as suppliers, occasionally located several levels away, might purposefully or inadvertently mislabel the sources of cotton. It was discovered that conventional paper-based certificates were extremely susceptible to manipulation and fabrication (46, 47).

World’s first use of blockchain in the cotton textile industry

The Seam (USA) was the first company in the world to employ blockchain technology in the cotton and textile industry. Using IBM’s Hyperledger Fabric as the basis, The Seam and IBM Hyperledger Fabric announced in January 2017 a revolutionary blockchain consortium for the global cotton industry. The objective was to provide safe, unchangeable record-keeping from field to fabric to increase traceability and transparency in the cotton supply chain (48). In alignment with this pioneering effort, several other international blockchain-based consortiums and collaborations

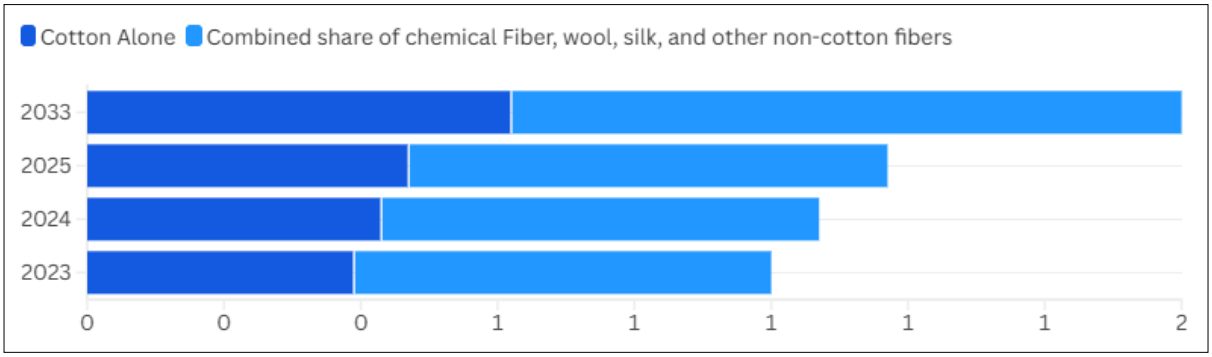

Fig. 4. Cotton’s consistent contribution to global textile revenue (2023–2033). Data from: Grand view research, 2024.

have emerged over the past decade. These initiatives, spanning from the United States to Austria and Europe, focus on strengthening cotton's end-to-end visibility, product authenticity and sustainability assurance. Table 1 provides an overview of key international blockchain consortiums and collaborations in cotton supply chains, highlighting their projects and primary objectives (49).

Blockchain in agronomic phase of cotton cultivation: From sowing to harvest

Cotton's contribution to the textile industry is not only vast but foundational. Given its central role, the assurance of quality cannot begin at the spinning mill or the factory floor; it must originate in the agronomic phase, from sowing to harvest, where fiber quality is determined. Every input and practice like seed variety, sowing date, fertilizer application, irrigation schedules, pest and disease management, shapes the eventual strength, fineness and durability of cotton fiber. Embedding this on-farm data into blockchain systems ensures that quality is not only measured at the end of the supply chain but transparently traceable back to its agricultural origins. This elevates blockchain from a post-production auditing tool to a seed-to-shirt quality assurance mechanism, thereby reinforcing sustainability, authenticity and farmer accountability within the global cotton economy.

From sowing onwards, the integration of agronomic data into blockchain allows precise recording of every management practice, creating a digital fingerprint of each cotton crop. When fertilizer applications, irrigation events and pest control measures are immutably logged, the resulting fiber can be directly linked to its cultivation history. This deepens consumer trust, empowers farmers with verified data and enhances compliance with sustainability standards. Beyond record-keeping, blockchain enhances cotton farming practices by securely and transparently managing pest and disease data gathered through unmanned aerial vehicles (UAVs). Advanced tools such as federated learning and blockchain sharding safeguard data privacy, while reputation-based consensus mechanisms protect against malicious inputs. This integration reduces computational burden, accelerates training cycles and supports precise, efficient, incremental diagnosis of multiple cotton diseases. By improving scalability, robustness and real-time processing, blockchain provides stakeholders with reliable, high-quality data essential for sustainable cotton production and superior crop management.

Beyond conceptual models, farm-level validation of blockchain in cotton remains limited. A notable pilot from the Cauvery Delta region of Tamil Nadu (Annamalai University) by Sudhakar et al. demonstrated a simulated blockchain-based traceability system for the cultivation-to-harvest phase of cotton. Using a hybrid cotton field as a testbed, agronomic operations, weather data and crop observations were digitally recorded, geo-tagged and linked to QR codes, enabling plot-level chronological traceability. The study showed that even low-cost, off-chain digital tools can operationalize blockchain principles under smallholder conditions (50).

Blockchain in the post-agronomic phase: From ginning to the global consumer

Once cotton leaves the farm, blockchain continues its odyssey through every subsequent transformation, from ginning, spinning and weaving to garment manufacturing, retailing and final purchase. Each conversion point functions as a verified digital checkpoint where the original on-farm record is seamlessly extended through encrypted smart contracts. A smart contract is a self-executing digital agreement that automatically validates and records transactions once predefined conditions are met, ensuring transparency and eliminating the need for intermediaries (51–53). At the ginning stage, the system authenticates the fiber's provenance, ensuring that organic or sustainable claims remain unbroken. During yarn and fabric manufacturing, batch-specific digital identities (Traceability Units) record details such as blending ratios, dyeing chemicals, energy consumption and emission footprints. These data are continuously verified through smart contracts that monitor compliance with sustainability standards and instantly flag any deviations, creating a self-auditing ecosystem. When apparel manufacturers tag each finished product with QR-encoded blockchain data, consumers can trace the entire journey from the exact field of cultivation to the retail shelf, through a simple smartphone scan. This transparent digital continuum enhances trust in organic and ethically sourced cotton, prevents counterfeit labelling and promotes responsible trade practices (27). This sequential transformation from cotton fibre to the end customer is depicted in Fig. 5.

Table 1. Global blockchain consortiums and pilot Projects in cotton traceability

Blockchain Consortium	Blockchain Project	Description
AURA Consortium	AURA	Formed through a partnership between LVMH, ConsenSys and Microsoft Azure, the AURA Consortium drives industry-wide collaboration to implement blockchain for product traceability and authenticity. Leading brands including Prada and Cartier have joined the consortium. The project aims to enhance customer confidence by tracking products from raw material sourcing to point of sale.
HUGO BOSS	Tracey	Hugo Boss has collaborated with ASTRATUM to develop Tracey, a blockchain-based platform that monitors products throughout the supply chain. The platform ensures authenticity and provides verifiable product information to stakeholders.
C&A Foundation	Organic Cotton Blockchain Pilot	Led by Bext360, this pilot traces organic cotton from farms through the ginning process with plans to expand tracking to consumers. The platform securely integrates supply chain data while using complementary technologies such as machine vision, artificial intelligence and on-product markers to validate the information. Participants include C&A Foundation, Fashion for Good, Organic Cotton Accelerator and brands such as Kering, Zalando and C&A.
Armedangels	Retraced Solution	Several brands, including Armedangels, Boyish and CANO, have piloted Retraced's blockchain solution. Using Oracle Hyperledger Fabric and QR/NFC technologies, the platform tracks products across the supply chain, providing full transparency and traceability for stakeholders.
Lenzing AG	Fiber-to-Retail Traceability	Lenzing AG, in collaboration with Schneider and Armedangels, has explored blockchain applications to create fiber-to-retail traceability. The initiative aims to ensure end-to-end transparency and verifiable tracking from fiber production to retail distribution.

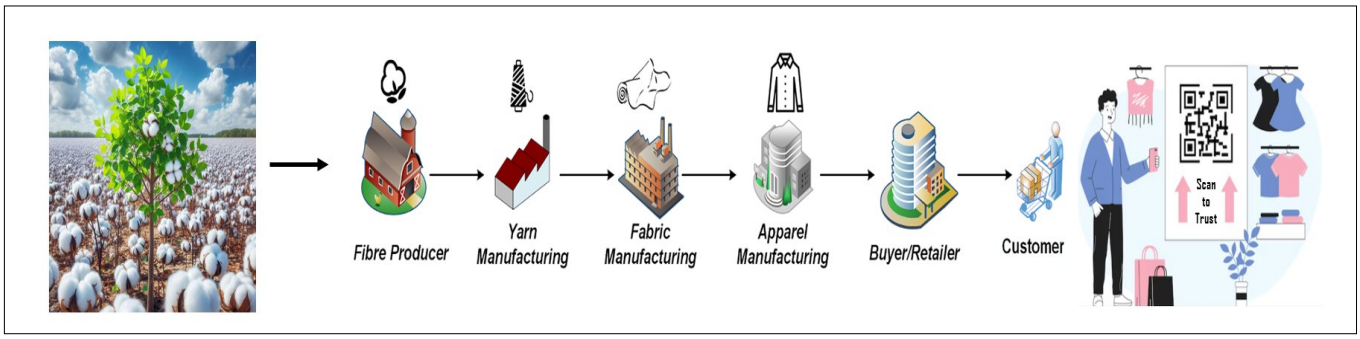

Fig. 5. Blockchain-enabled cotton supply chain, showing authenticated traceability from farm to the global consumer.

Overall prospects of blockchain in the textile industry

Blockchain technology is rapidly emerging as a transformative force in the cotton and textile industry, effectively addressing the persistent challenge of "information silos." By providing a decentralized, tamper-proof digital ledger, blockchain ensures that every stage of the cotton value chain from sowing and harvest to ginning, spinning, manufacturing and retail, is securely recorded and verifiable. This unprecedented level of transparency virtually eliminates the risk of fraud, adulteration and misrepresentation, while enhancing traceability and accountability across global supply chains (54). Beyond traceability, blockchain empowers farmers and stakeholders with accurate, real-time field-level data, optimizes certification and compliance workflows and integrates seamlessly with internet of things (IoT)and radio frequency identification (RFID) technologies to enable automated monitoring and quality assurance.

The implications for the textile industry are profound. Blockchain not only safeguards product authenticity but also strengthens sustainability, ethical sourcing and consumer trust by providing an immutable record of cotton's journey from seed to shirt. By enabling real-time quality tracking and data-driven decision-making, it reduces operational risks, increases efficiency and supports resilient supply chains in a highly globalized and complex industry. Furthermore, the fusion of blockchain with emerging technologies such as big data analytics, artificial intelligence (AI) and smart sensors positions the textile sector for a truly digital, sustainable and accountable future. In this context, blockchain represents more than a technological tool, it is a strategic enabler that redefines trust, quality and transparency in the global cotton-textile ecosystem. To enhance conceptual clarity and readability, the key opportunities, existing constraints and corresponding solutions for blockchain adoption in the cotton-textile sector are summarized in Table 2.

Barriers in blockchain adoption within cotton-textile supply chains

Technical barriers

Despite its promise of transparency and efficiency, blockchain adoption in the cotton-textile industry is hindered by the sector's highly fragmented and multi-tiered structure. Millions of smallholder farmers, local ginners and regional processors operate with limited digital literacy, weak connectivity and inconsistent record-keeping, resulting in poor-quality data inputs that undermine blockchain's immutability. The absence of standardized data formats and interoperable identifiers across global value chains further complicates platform integration. Several international pilots such as the Walmart-BM Food Trust trial in cotton-based apparel, early RFID-blockchain pilots in Bangladesh and India's decentralized ginning traceability prototypes, reported limited scalability due to data inconsistency and device-level failures, demonstrating that blockchain is only as reliable as the data it receives.

Economic barriers

The high upfront cost of digital infrastructure, IoT tagging, cloud

Table 2. Opportunities, constraints and potential solutions for blockchain adoption in the cotton-textile industry

Opportunities	Constraints	Potential Solutions
End-to-end traceability and transparency across the cotton value chain	High initial implementation costs and limited digital infrastructure in rural areas	Public–private investment models; subsidized digital infrastructure; phased implementation strategies
Strong authentication of fibre origin and prevention of fraud, adulteration and mislabelling	Lack of technical expertise among farmers, ginners and small-scale processors	Capacity-building programs; user-friendly mobile interfaces; standardized training modules
Improved sustainability monitoring and ethical compliance verification	Fragmented data standards and interoperability issues among supply chain actors	Development of unified data standards; open source blockchain frameworks; regulatory harmonization
Automated data capture through IoT, RFID and smart sensors	Limited connectivity, especially in remote production clusters	Satellite-based communication; low-power IoT networks; infrastructure modernization
Enhanced certification workflows and reduced administrative burden	Concerns related to data privacy, ownership and reluctance to share sensitive operational data	Robust data-governance frameworks; permissioned blockchain models; stakeholder agreements
Strengthened consumer trust through verifiable "seed-to-shirt" product histories	Integration challenges with legacy enterprise systems used by mills and brands	API-based integration layers; middleware platforms; gradual system transition pathways
Data-driven decision-making and real-time quality assurance	Variability in adoption readiness across supply chain tiers	Pilot demonstrations; incentive-based adoption schemes; cluster-level digital hubs

storage and workforce training remains prohibitive for small and medium enterprises in developing economies. Many cotton-producing regions lack affordable access to digital devices or stable internet, restricting participation in blockchain-based traceability.

Organizational barriers

Resistance from intermediaries and supply-chain actors continues to be a major challenge. Traders, brokers and certain processing units often fear that blockchain will expose price manipulation, informal contracts, or inventory opacity, reducing their informational advantage. Poor coordination between farmers, ginners, spinners, brands and certifiers weakens multi-stakeholder participation.

Regulatory barriers

International cotton trade and sustainability claims are governed by diverse certification schemes such as the Better Cotton Initiative (BCI), the Global Organic Textile Standard (GOTS) and Fairtrade International (Fairtrade). Regulatory regimes for data protection and ledger liability also differ across jurisdictions, creating ambiguity over cross-border data sharing and liability. Regulatory uncertainty and inconsistent standards hinder the transition of pilots to scalable, cross-border deployments.

Future directions

While blockchain delivers substantial benefits to cotton supply chains by enhancing traceability, authenticity and transparency, its true potential will only be realized when integrated with complementary technologies. Big Data analytics, AI, IoT, remote sensing tools and secure digital identity systems along with advanced smart contract architectures, can collectively strengthen data accuracy, automation and end-to-end verification. Looking ahead, future research must explore how these technologies, in synergy with blockchain, can accelerate cotton's transition toward a fully digitized, resilient and sustainable value chain. At the same time, several structural gaps must guide future research. Establishing interoperability standards is essential to enable seamless data exchange across digital platforms, sectors and countries. Rigorous cost–benefit assessments for smallholder farmers are needed to ensure inclusivity and economic feasibility for the world's primary cotton producers.

Conclusion

This review confirms the central hypothesis that integrating blockchain-enabled traceability from the agronomic phase of cotton cultivation through to the textile value chain can decisively enhance fiber quality, authenticity and sustainability. Evidence demonstrates blockchain's ability to dismantle information silos, mitigate counterfeiting and create end-to-end transparency from seed to shirt, thereby strengthening farmer empowerment, sustainability compliance and consumer trust. However, its large-scale adoption is constrained by fragmented supply chains, digital illiteracy, high infrastructural costs and regulatory inconsistencies, which must be addressed to move beyond pilot projects. Overall, blockchain emerges not merely as a technological tool but as a transformative enabler for building resilient, transparent and sustainable cotton-textile ecosystems, especially when integrated with complementary technologies such as Big Data, AI and IoT

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Authors' contributions

PS provided visionary guidance, introduced the research domain and critically revised the manuscript.

TP conceptualized, structured and drafted the manuscript. Both the authors read and approved the manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare no competing interests, financial or otherwise, that could influence the content or interpretation of this work.

Ethical issues: None

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