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Blockchain Vs. Traditional Databases in Agri-Supply Chains: A Comparative Review of Security, Scalability, And Cost

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***Abstract*—Agricultural supply chains demand transparent, secure, and efficient data management to ensure food traceability, safety, and quality. Traditional databases have served as foundational tools for data recording and transaction processing. However, they often fall short in providing tamper-proof records and end-to-end transparency. Blockchain technology, with its decentralized, immutable ledger, is emerging as a potential alternative. This paper presents a comparative review of blockchain and traditional database systems in agri-supply chains, focusing on security, scalability, and cost dimensions. It highlights the strengths, limitations, and suitability of each approach through case studies, use cases, and current literature. The paper concludes with future directions and proposes hybrid integration frameworks to balance performance, transparency, and affordability.**

***Index Terms*—Blockchain, Traditional Databases, Agri-Supply Chain, Security, Scalability, Cost, Traceability, Transparency, Distributed Ledger**

I. INTRODUCTION

The agricultural supply chain is a complex and fragmented system involving multiple stakeholders, including farmers, processors, distributors, and retailers. Data management across these stages is critical for ensuring food safety, regulatory compliance, traceability, and consumer trust [1], [2]. Traditionally, relational databases like MySQL, PostgreSQL, and Oracle have been employed for recordkeeping and logistics tracking [3].

However, these centralized systems present limitations in terms of data tamper resistance, traceability, and resilience against insider threats [4]. Blockchain, a distributed ledger technology, offers an alternative by recording transactions in an immutable, decentralized, and verifiable format [5].

This paper aims to systematically compare blockchain and traditional databases in agri-supply chains, emphasizing their performance with respect to security, scalability, and cost.

II. OVERVIEW OF AGRI-SUPPLY CHAIN DATA MANAGEMENT

Agri-supply chains are composed of interconnected stages that include upstream activities such as farming and harvesting, midstream processes like food processing and warehousing, and downstream functions involving distribution and retail. Each phase generates vast amounts of data that need to be effectively managed to ensure seamless operations and informed decision-making. Reliable data systems play a crucial role in addressing several key challenges in these supply chains, including ensuring the traceability and provenance of agricultural products, detecting and preventing fraud, optimizing inventory management and logistics, and fulfilling regulatory compliance requirements [6], [7].

Traditionally, these data management functions have been handled using centralized systems such as Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM) platforms. These systems provide structured storage, processing, and retrieval of information but are often limited by their reliance on a central authority. In contrast, blockchain technology introduces a decentralized approach, enabling secure, transparent, and tamper-proof data sharing among multiple parties across the supply chain without the need for an intermediary [8]. This shift from centralized to decentralized data management is particularly valuable in agri-supply chains where trust, transparency, and real-time collaboration among diverse stakeholders are essential.

III. TRADITIONAL DATABASES IN AGRI-SUPPLY CHAINS

Traditional databases operate on a centralized client-server architecture, where a single server or a cluster of closely managed servers maintains complete control over the data repository. This setup enables efficient storage of structured data using predefined schemas and facilitates rapid query execution through SQL (Structured Query Language). Owing to their simplicity, reliability, and widespread industry acceptance, SQL-based database systems such as MySQL, PostgreSQL, and Oracle have become the de facto standard for many applications, including agricultural enterprise resource planning (ERP) and warehouse management systems [9]. These systems are optimized for high performance in environments where a trusted central authority manages data consistency and user access.

However, this centralized approach comes with inherent limitations that pose significant challenges in modern, distributed agricultural supply chains. First, the reliance on a central authority makes these databases susceptible to single points of failure, increasing the risk of downtime, data breaches, and manipulation if the central node is compromised [10]. Second, traditional databases generally lack built-in audit trails and immutability features, making it difficult to track unauthorized data alterations or ensure the integrity of historical records. Third, in supply chains involving multiple independent stakeholders—such as farmers, processors, distributors, and retailers—it is difficult to establish cross-organizational trust using centralized systems, as all participants must rely on a single party to manage and validate the data. These challenges highlight the growing need for more resilient, transparent, and decentralized data management solutions in the agri-supply ecosystem.

IV. BLOCKCHAIN-BASED SYSTEMS IN AGRI-SUPPLY CHAINS

A. Key Characteristics

Blockchain technology offers several defining characteristics that make it particularly suitable for managing complex and multi-stakeholder agricultural supply chains. One of its most fundamental attributes is decentralization, which eliminates the need for a centralized authority or trusted third party. In traditional systems, a central server manages data storage and validation, making it vulnerable to manipulation or failure. In contrast, blockchain distributes control across a network of nodes, ensuring that no single entity has unilateral control over the data [11]. This fosters trust and transparency among supply chain participants who may not have pre-established relationships.

Another critical feature is immutability, which ensures that once data is recorded on the blockchain, it cannot be altered or deleted without consensus from the network. This characteristic guarantees the integrity of records and protects against unauthorized modifications, which is crucial in scenarios like food safety tracking and quality assurance [12]. Blockchain's immutability provides an audit trail that is cryptographically secured and accessible to all authorized stakeholders, thereby improving accountability across the supply chain.

Additionally, smart contracts enhance blockchain’s utility by enabling automated execution of pre-defined conditions in supply chain operations. These are self-executing code snippets stored on the blockchain that automatically trigger actions—such as payment release or inventory updates—when certain conditions are met [13]. This not only reduces the need for manual interventions but also minimizes disputes and enhances operational efficiency. Figure 1 provides a conceptual overview of a blockchain-based architecture integrated with smart contracts for efficient agriculture supply chain management.

B. Applications

Blockchain technology is increasingly being explored and implemented in various segments of the agricultural supply chain due to its ability to improve transparency, efficiency, and trust. One of its primary applications is in product traceability, where blockchain enables end-to-end visibility of a product’s journey from farm to fork.

Each transaction or event—such as harvesting, transportation, processing, and distribution—is recorded immutably on the blockchain, allowing consumers and regulators to verify the authenticity and history of food products [14].

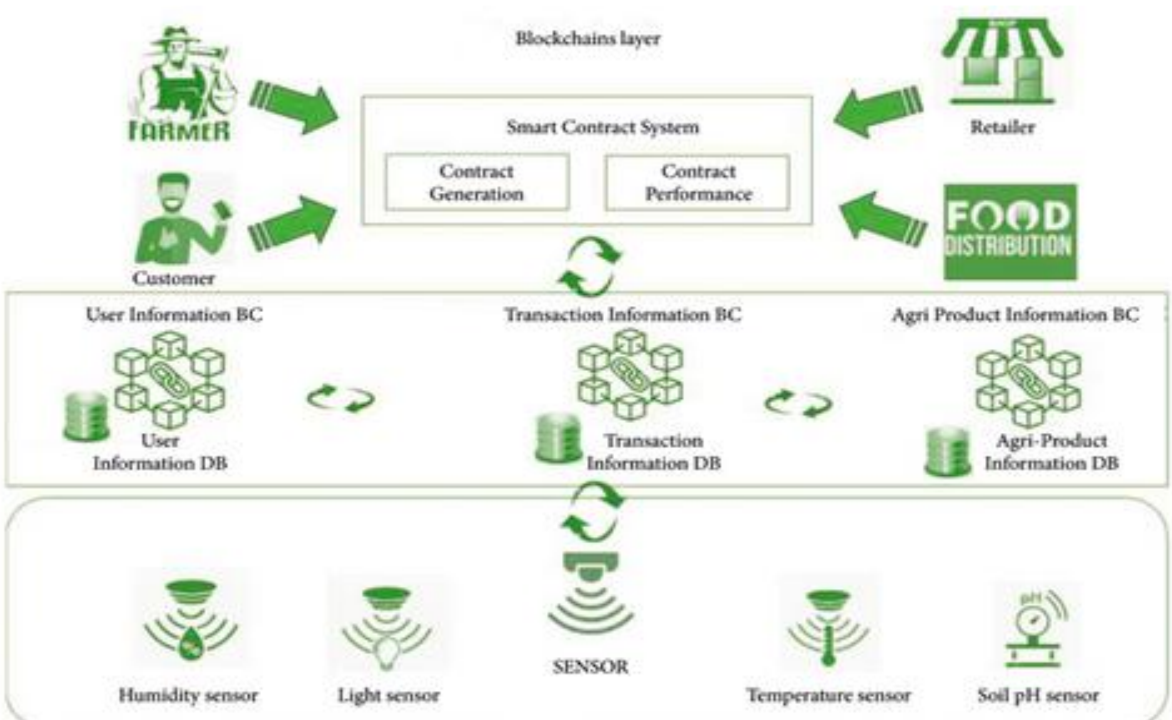

Fig 1. Blockchain-enabled architecture for agriculture supply chain management using smart contracts[31.

Another important application is origin certification, which is critical for verifying the geographic and procedural origins of agricultural products, especially those labeled as organic, fair-trade, or sustainably sourced. Blockchain helps ensure that these claims can be backed by an immutable record of every supply chain touchpoint, thus reducing the chances of fraud or mislabeling [15].

In addition, blockchain is used in cold-chain monitoring, particularly for perishable goods such as dairy, seafood, and pharmaceuticals. By integrating blockchain with IoT sensors, temperature and humidity data can be recorded in real-time and logged directly onto the blockchain. This ensures that storage conditions meet regulatory standards throughout the transportation process and alerts stakeholders in case of threshold violations [16].

Several platforms such as Hyperledger Fabric, Ethereum, and IBM Food Trust have demonstrated tangible implementations of blockchain in the agri-food sector. These platforms have been successfully used in real-world pilot projects to enhance traceability, reduce inefficiencies, and build trust among stakeholders [17].

V. COMPARATIVE ANALYSIS

Table 1. Blockchain vs. Traditional Databases in Agri-Supply Chains

Feature	Traditional Databases	Blockchain
Security	Centralized; vulnerable to breach	Tamper-proof, decentralized ledger
Scalability	High; optimized for large data	Limited by block size, consensus latency
Cost	Low setup, higher audit costs	High initial cost, lower long-term auditing
Transparency	Limited; role-based access	Public/shared ledgers improve trust
Data Ownership	Central authority	Distributed among nodes
Auditability	Add-on modules	Built-in through blockchain structure

VI. USE CASES AND IMPLEMENTATIONS

A. Traditional Database Use Cases

Traditional databases have been widely adopted across various segments of the agricultural supply chain due to their mature ecosystem and reliable performance. A prominent example is the National Agricultural Market (e-NAM) initiative in India, which leverages PostgreSQL, a relational database management system, to handle the large volume of real-time transactions between farmers, traders, and market committees. PostgreSQL facilitates efficient storage, retrieval, and querying of transactional data, helping streamline the operations of over a thousand agricultural produce market committees across the country [18]. Similarly, many agricultural cooperatives and federations utilize centralized Enterprise Resource Planning (ERP) systems built on traditional database frameworks such as Oracle or Microsoft SQL Server to manage their warehousing, inventory, and distribution data. These systems enable cooperatives to maintain control over data flows, track procurement and distribution, and optimize logistics within a closed, centralized environment [19].

B. Blockchain-Based Use Cases

In contrast, blockchain technology is being increasingly explored for its potential to bring transparency, immutability, and traceability to agri-supply chains. A notable example is the IBM Food Trust platform, which has been adopted by major corporations such as Walmart and Nestlé to enhance produce traceability. By leveraging Hyperledger Fabric, this blockchain-based solution allows stakeholders to track the journey of food products from farm to shelf, providing tamper-proof records that significantly reduce the time required for source verification and recall management [20]. Another pioneering platform is AgriDigital, which uses blockchain to facilitate real-time, trustless transactions in the grain supply chain. It enables farmers, buyers, and storage providers to manage contracts, deliveries, and payments through smart contracts, reducing disputes and improving efficiency in supply chain finance [21]. Additionally, TE-Food, operating in Vietnam, has implemented a blockchain-based traceability system specifically for livestock and meat products. Their solution allows for the collection and storage of data on animal origin, vaccination history, transport, and processing, thereby enabling consumers and regulators to verify food safety compliance and product authenticity [22].

VII. OPPORTUNITIES AND CHALLENGES

A. Blockchain

Blockchain technology offers a range of promising opportunities for agricultural supply chains. One of the most significant benefits is its ability to enhance trust and collaboration among stakeholders, including farmers, logistics providers, processors, and retailers. By providing a decentralized and immutable ledger, blockchain ensures that data entries are transparent and tamper-proof, reducing the possibility of fraud and manipulation. This fosters a trustworthy environment that is essential in multi-actor ecosystems such as agri-supply chains. Another notable advantage is its support for real-time traceability, which is crucial during product recalls and fraud investigations. By logging every transaction or movement of a product from farm to fork, blockchain can significantly improve the speed and accuracy of trace-back operations, ultimately ensuring consumer safety and regulatory compliance [23].

Despite its potential, blockchain implementation comes with several challenges. Public blockchain networks, in particular, suffer from high energy consumption due to resource-intensive consensus mechanisms like Proof-of-Work (PoW), making them environmentally unsustainable for large-scale use [24]. Furthermore, these systems often face limited transaction throughput, which restricts their scalability and responsiveness in scenarios requiring high-frequency data exchanges, such as real-time supply chain monitoring [25]. Lastly, the regulatory landscape surrounding blockchain in agriculture remains ambiguous, particularly in developing countries, where policies governing decentralized technologies are still evolving. This lack of legal clarity can deter investment and slow down adoption rates within the agricultural sector [26].

B. Traditional Databases

Traditional databases continue to offer a number of opportunities, especially in well-established agri-food systems. These systems are proven and reliable for handling high-volume transactions with efficiency and consistency. Their long-standing presence and support in enterprise-level applications make them a safe choice for organizations that prioritize operational stability. Additionally, they are highly compatible with legacy systems, such as ERP platforms and logistics software, enabling seamless integration without the need for extensive infrastructural changes. This interoperability is particularly beneficial in rural or resource-limited settings where digital infrastructure is still maturing.

However, traditional databases also exhibit notable limitations. One major drawback is their limited visibility across organizational boundaries, which restricts transparent data sharing between independent actors within the supply chain. This centralized nature makes it difficult to maintain a unified view of product movement, certifications, and compliance records across different stakeholders [27]. Moreover, the authenticity of data entries in traditional databases is often difficult to verify, especially in environments prone to human error or intentional manipulation. Unlike blockchain, which inherently provides an audit trail and cryptographic assurance, traditional systems require additional modules or third-party solutions to ensure data integrity, thereby increasing system complexity and cost [28].

VIII. CONCLUSION

This paper offers a detailed comparative review of blockchain and traditional databases in agri-supply chains. Traditional systems remain efficient and cost-effective but lack trust-enabling features critical for complex, multi-stakeholder agricultural ecosystems. Blockchain addresses these through decentralization, immutability, and automation, but faces technical and regulatory barriers. A hybrid model integrating blockchain's transparency with the scalability of traditional systems may provide an optimal path forward.

REFERENCES

[1] P. G. Pardeshi and R. J. Ramteke, "Data Management in Agricultural Supply Chains," *International Journal of Computer Applications*, vol. 156, no. 9, pp. 23–29, 2016.

D. B. Patil *et al*., "Digital agriculture: Farmers and technology," *Agricultural Reviews*, vol. 41, no. 3, pp. 193–199, 2020.

[2] M. Silva et al., "ICT in agri-food supply chains," Procedia Food Science, vol. 2, pp. 620–627, 2013.

[3] M. Khan and K. Salah, "IoT security: Review, blockchain solutions, and open challenges," Future Generation Computer Systems, vol. 82, pp. 395–411, May 2018.

[4] S. Nakamoto, Bitcoin: A Peer-to-Peer Electronic Cash System, 2008. [Online]. Available: https://bitcoin.org/bitcoin.pdf

[5] J. Wolfert et al., "Big Data in smart farming – A review," Agricultural Systems, vol. 153, pp. 69–80, 2017.

[6] A. B. Awad and A. L. Al-Ali, "Real-Time Supply Chain Visibility," IEEE Access, vol. 8, pp. 60255–60267, 2020.

[7] G. Sylvester, E-agriculture in Action: Blockchain for Agriculture. Rome, Italy: Food and Agriculture Organization (FAO) and International Telecommunication Union (ITU), 2019.

[8] E. F. Codd, "A relational model of data for large shared data banks," Communications of the ACM, vol. 13, no. 6, pp. 377–387, 1970.

[9] N. Luhach et al., "A survey on security and privacy issues in cloud computing," Wireless Personal Communications, vol. 118, pp. 129–153, 2021.

[10] K. Christidis and M. Devetsikiotis, "Blockchains and Smart Contracts for the Internet of Things," IEEE Access, vol. 4, pp. 2292–2303, 2016.

[11] M. Crosby et al., "Blockchain technology: Beyond bitcoin," Applied Innovation Review, vol. 2, pp. 6–19, 2016.

[12] L. Bach et al., "A comparative study of blockchain smart contracts platforms," Future Internet, vol. 10, no. 8, p. 56, 2018.

[13] J. Tian, "An agri-food supply chain traceability system for China based on RFID & blockchain technology," in Proc. 13th Int. Conf. Service Systems and Service Management (ICSSSM), 2016, pp. 1–6.

[14] K. Toyoda, P. T. Mathiopoulos, I. Sasase, and T. Ohtsuki, "A novel blockchain-based product ownership management system (POMS) for anti-counterfeits in the post supply chain," IEEE Access, vol. 5, pp. 17465–17477, 2017.

[15] H. Hasan and K. Salah, "Blockchain-based solution for proof of delivery of physical assets," Journal of Network and Computer Applications, vol. 109, pp. 76–93, 2018.

[16] IBM Food Trust, "Traceability for Food Safety," 2021. [Online]. Available: https://www.ibm.com/blockchain/solutions/food-trust
[17] eNAM, "National Agriculture Market," Ministry of Agriculture & Farmers Welfare, Government of India. [Online]. Available: https://www.enam.gov.in/
[18] SAP SE, Digital Transformation in Agriculture, White Paper, 2020.
[19] IBM Blockchain, Building Trust in Food Supply Chains, 2022.
[20] AgriDigital, "Grain Supply Chain on Blockchain," 2021. [Online]. Available: https://www.agridigital.io/
[21] R. Agarwal, P. K. Agarwal, B. Parihar, V. Sharma, and A. Sanghi, "Enhancing Blockchain Financial Security through DB-BOA Optimization and ADTCN Frameworks," in Proc. 2025 IEEE 7th Int. Conf. Computing, Communication and Automation (ICCCA), Greater Noida, India, 2025, pp. 1–6, doi: 10.1109/ICCCA66364.2025.11325619.
[22] J. Reyna et al., "On blockchain and its integration with IoT," Future Generation Computer Systems, vol. 88, pp. 173–190, 2018.
[23] M. Vukolić, "The Quest for Scalable Blockchain Fabric: Proof-of-Work vs. BFT Replication," in Proc. Int. Workshop on Open Problems in Network Security, 2015.
[24] N. Zeng and Y. Li, "A Survey on Scalability of Blockchain Systems," IEEE Access, vol. 9, pp. 9543–9566, 2021.
[25] Organisation for Economic Co-operation and Development (OECD), Blockchain in Agriculture and Food Supply Chain. Paris, France: OECD Publishing, 2019.
[26] M. Kamble, A. Gunasekaran, and S. A. Gawankar, "Achieving Sustainable Performance in a Data-Driven Agriculture Supply Chain: A Review for Sustainable Industry 4.0," Computers & Industrial Engineering, vol. 129, pp. 536–548, 2019.
[27] P. Zhang, J. White, D. C. Schmidt, G. Lenz, and S. T. Rosenbloom, "FHIRChain: Applying Blockchain to Securely and Scalably Share Clinical Data," Computational and Structural Biotechnology Journal, vol. 16, pp. 267–278, 2018.