International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 05, IIRA 5.0 (2026)

Efficient Agricultural Trading Through Blockchain

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Abstract **– The agricultural sector faces numerous challenges, including inefficiencies in supply chains, lack of transparency, and issues with product traceability and authenticity. This paper proposes a blockchain-based agricultural marketplace system to address these challenges. By leveraging blockchain technology, the system ensures secure, transparent, and cost-effective transactions between farmers (sellers) and buyers. Key features of the platform include user registration via blockchain wallets, smart contract-based product listings, cryptocurrency-based payments, and real-time order tracking. The system reduces transaction costs, enhances market access for farmers, and provides consumers with verified product information. The proposed platform was evaluated based on performance metrics such as transaction time, system scalability, transaction costs, and user satisfaction. The results show that the blockchain-based system significantly improves the efficiency and transparency of agricultural trade, offering a scalable solution for the digital transformation of agricultural markets.**

Keywords **– Blockchain, Agricultural Marketplace, Smart Contracts, Transaction Transparency, Cryptocurrencies, Supply Chain, Product Traceability, System Scalability, User Satisfaction.**

I. INTRODUCTION

Agriculture remains the backbone of world economies because it provides major support to food security along with employment opportunities throughout rural areas. Multiple hurdles affect this sector because it has problems with inefficient supply chains together with transparency issues and problems tracing product authenticity. The existing challenges lead to increased production costs along with consumer expenses as well as obstacles in fair-market entry for low-scale farmers and safety concerns in food distribution.

Blockchain technology offers promising solutions for agricultural trading issues because it has built-in features which include decentralization alongside transparency and immutability. Our current marketplace faces better efficiency when we apply blockchain technology in addition to improved security levels for agricultural products alongside enhanced transparency

International Journal of Engineering Research & Technology (IJERT)
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capabilities. Through this system farmers can accomplish efficient transaction management so they may sell their products directly to customers without relying on intermediary businesses. Such a system allows for monitoring both the source authenticity and product origin because these functions prove essential for maintaining food safety and maintaining quality standards.

Blockchain technology is revolutionizing sectors such as agriculture by providing secure, transparent, and decentralized mechanisms of processing transactions. Blockchain technology alleviates the major issues of agricultural business, including inefficient supply chains, lack of transparency, and product traceability problems. Through blockchain, farmers can deal directly with consumers, with fewer intermediaries, thereby decreasing the cost of transactions.

The main purpose of this research analyzes blockchain technology's power to reshape agricultural trading through development of a blockchain platform dedicated for agricultural market operations. Farmers using this platform could register and conduct safe sales of agro products by utilizing smart contracts for transaction monitoring while managing inventory through the system. Through blockchain-based tracking systems the proposed platform can deliver better confidence to buyers regarding authentic product procurement.

The proposed system aims to solve key issues within the agricultural industry by enhancing the efficiency of trade, reducing transaction costs, increasing market access for farmers, and improving the overall transparency of agricultural transactions. By using blockchain as a backbone, the system ensures that all transactions are secure, traceable, and tamper-proof.

I. LITERATURE REVIEW

Multi-disciplinary examination of blockchain technology in agriculture happens because it shows promise to address supply chain effectiveness problems as well as traceability challenges and transparency issues. Various studies demonstrate how blockchain technology helps improve market systems as well as sustainability levels and provides transparency to agricultural trade processes.

Yadav et al. [1] performed a case study investigation of blockchain implementation that uses digital infrastructure on the Indian electronic National Agriculture Market (e-NAM). The authors demonstrated blockchain's ability to establish automated agricultural marketing systems as well as enhance supply chain visibility and promote quick data dissemination between peers in agriculture. The study revealed how blockchain delivers better market access capabilities to small-scale farmers which leads to enhanced efficiency during market transactions.

Giganti and his colleagues [2] investigated through a scoping review the ways blockchain technology benefits sustainability across the agri-food sector. The researchers examined blockchain applications across product reconciliation and quality evaluation and fair trade provisioning because these features support agricultural supply chain sustainability. Blockchains prove effective for creating agricultural practices which ensure transparent traceability in addition to sustainable and reliable operations between producers and consumers.

A new algorithm developed by Cao [3] implements optimal selection process optimization for agricultural export trade over blockchain and IoT infrastructure. This research developed a method to strengthen commercial decisions about agricultural exports by utilizing blockchain technology which enables secure live data sharing together with transaction management. Due to the integration of blockchain with IoT systems the logistics of agricultural trade has reached advanced levels of optimization which delivered improved efficiency in international agricultural exchanges.

Kumarathunga et al. [4] investigated how blockchain systems function as trust-creating elements when smallholder farmers interact with buyers through agricultural markets for upcoming deliveries. According to the authors blockchain enables trust because it creates invulnerable and completely visible transaction records along with item histories specifically important for smallholder farmers who struggle to find fair markets.

The research by Cao et al. [5] investigated blockchain-based platforms that enhance supply chain transparency while implementing traceability measures in agriculture. The researchers identified traditional supply chain weaknesses that included occurring fraud and inefficiency and showed how blockchain technology establishes a secure platform for logging agricultural goods during their movement to processing stages.

The research by Liu and Shang [6] explored blockchain technology applications to handle agricultural water rights in sustainable farming systems. The researchers established that blockchain enhances agricultural resource management particularly through its capability to deliver transparent verifiable transactions related to water rights.

Pufahl et al. [7] conducted research about how blockchain technology facilitates financing operations across agricultural supply chains. The researchers analyzed process innovation between organizations and blockchain technology capabilities for improving trust relations between farmers and suppliers together with banking institutions. Blockchain technology has the potential to simplify financing procedures of agricultural development projects specifically within developing economies by reducing operational complexities.

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The combination of e-agricultural supply chain management and blockchain technology with cooperative strategies received investigation from Alkahtani et al. [8]. Research conducted by these scientists revealed that blockchain technology could boost agricultural supply chain partnership cooperation through automated processes which led to operational enhancements as well as cost reductions.

Yao and Zhang [9] conducted research on how blockchain operates in the tracking of agricultural products. The authors established a framework to combine blockchain technology with present-day traceability methods that protects the complete food supply chain transparency back to the fields. Blockchain technology delivers end-to-end visibility according to the research because end-to-end visibility stands as a vital element for food safety and quality.

Xie and colleagues [10] introduced dual-chain blockchain technology for agricultural e-commerce which employed Viniar algorithm to improve information tracking capabilities. Researchers developed a dual-chain blockchain method which extends security capabilities as well as improves scalability of blockchain systems operating in agricultural e-commerce platforms. The authors proved that dual-chain blockchain systems can effectively support complex agricultural transaction management operations.

Different research investigations have showcased the extensive transformations blockchain technology can bring to agricultural market spaces. The agricultural industry can resolve traditional supply chain issues through blockchain because the technology delivers enhanced transparency that builds trust across transactions. Blocking technology linked with Internet of Things devices and e-commerce infrastructures presents a promising direction for improving both efficiency and sustainability in agricultural market business operations.Multi-disciplinary examination of blockchain technology in agriculture happens because it shows promise to address supply chain effectiveness problems as well as traceability challenges and transparency issues. Various studies demonstrate how blockchain technology helps improve market systems as well as sustainability levels and provides transparency to agricultural trade processes.

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Cao et al. conducted research which studied blockchain-based systems that improves agricultural value chain transparency through traceability implementations [5]. The research team examined supply chain weaknesses because of occurring fraud and inefficiency which blockchain technology solves by creating a secure platform for recording agricultural goods movement to processing points.

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Yao and Zhang [9] performed research about blockchain usage in agricultural product tracking. The authors developed a framework uniting blockchain with current traceability methods that guards whole supply chain visibility starting from agricultural fields. Research indicates that blockchain technology provides complete end-to-end visibility based on the findings which represent a crucial factor in maintaining food quality and safety.

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Studies have demonstrated how blockchain technology produces dramatic changes in agricultural market areas. Traditional supply chain problems can be addressed by the agricultural industry through blockchain because its enhanced transparency enables trust throughout transactions. The combination of blocking technology between Internet of Things devices and e-commerce infrastructures shows promise for enhancing both operational efficiency and sustainability within agricultural market businesses.

III. SYSTEM ARCHITECTURE

The proposed agricultural blockchain marketplace system is designed to leverage blockchain technology for ensuring secure, transparent, and efficient transactions between farmers (sellers) and buyers. The system architecture integrates multiple components, including user registration and authentication, product listing and management, payment processing, and order tracking, all supported by smart contracts and blockchain technology.

The architecture consists of the following main modules:

A. User Registration and Authentication

The user registration module enables farmers and buyers to create an account and authenticate using their blockchain wallet addresses (e.g., MetaMask, Trust Wallet). This ensures secure and decentralized user management. The registration details, such as the user's name, contact information, and wallet address, are stored on the blockchain through a smart contract for transparency and immutability.

Authentication is handled via wallet-based sign-in systems (Web3Auth or MetaMask), which provides role-based access control to the platform. Depending on the user's role (e.g., farmer or buyer), access to different functionalities within the platform is granted.

B. Product Listing and Management

Farmers can list their agricultural products for sale using the product listing module. Each product listing includes essential details such as product title, description, price, quantity, and images. Once the farmer inputs this data, a smart contract function (createListing()) is called to register the item on the blockchain. This ensures that product listings are immutable, transparent, and traceable.

The system supports CRUD (Create, Read, Update, Delete) operations, allowing farmers to update or delete their listings as required. The product data is stored on a distributed ledger, ensuring that any changes to the product information are accurately recorded and publicly verifiable.

C. Blockchain Payment and Transaction Processing

When a buyer selects a product and initiates payment, the payment process is handled through the blockchain. Payments are made in cryptocurrency, with the transaction being processed by a smart contract. The buyer sends the payment to the smart contract, and once the transaction is confirmed, the cryptocurrency is transferred to the seller's wallet address.

The blockchain payment module ensures that all transactions are transparent, secure, and immutable, providing both buyers and sellers with a guarantee of the payment's authenticity. The smart contract also serves as an escrow mechanism, ensuring that the payment is only released to the seller once the product is shipped, reducing the risk of fraud.

D. Order and Transaction Tracking

The system tracks the status of each order (e.g., Pending, Shipped, Delivered) using smart contracts. Once the buyer makes a payment, the order status is updated to "Pending," and once the seller ships the product, the status is updated to "Shipped." Upon successful delivery, the status is updated to "Delivered." These updates are recorded on the blockchain, ensuring full transparency.

Users can track the order status in real-time through the platform’s interface or via blockchain explorers, which provides them with the ability to verify product authenticity and trace the entire supply chain process from farm to table. Blockchain technology ensures that all order statuses are tamper-proof and verifiable.

E. Commenting and Review System

International Journal of Engineering Research & Technology (IJERT)
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The commenting system allows buyers to leave feedback on purchased products. Once a transaction is completed, the buyer can provide a comment on the product, which is then stored on the blockchain. Storing reviews on the blockchain ensures that feedback is immutable, preventing any alteration or manipulation of reviews and maintaining the integrity of the platform's reputation system.

This feature helps foster trust between farmers and buyers, enabling potential buyers to make informed decisions based on reviews from previous customers.

F. Blockchain and Smart Contract Integration

The core of the platform's operation is the integration of blockchain and smart contracts. Smart contracts automate key functions such as user registration, product listing, payment processing, and order tracking. These contracts execute predefined conditions automatically, reducing the need for intermediaries and ensuring that transactions are executed efficiently and securely.

The blockchain provides a decentralized and transparent ledger for storing and verifying all data, including user information, product listings, transaction details, and order statuses. This decentralized nature ensures that no single entity has control over the system, which mitigates the risk of fraud and enhances trust in the platform.

G. System Flow Overview

The system operates as follows:

- Registration and Authentication: Farmers and buyers register and log in via wallet authentication.
- Product Listing: Farmers create product listings that are stored on the blockchain.
- Transaction: Buyers select products and pay via cryptocurrency. Smart contracts manage payment processing.
- Order Tracking: The system tracks the order status (Pending, Shipped, Delivered) via smart contracts and updates are recorded on the blockchain.
- Review and Feedback: Buyers can leave reviews on the blockchain after completing a transaction, enhancing the credibility of the system.

H. Architecture Diagram

The architecture of the system is depicted in Figure 1.

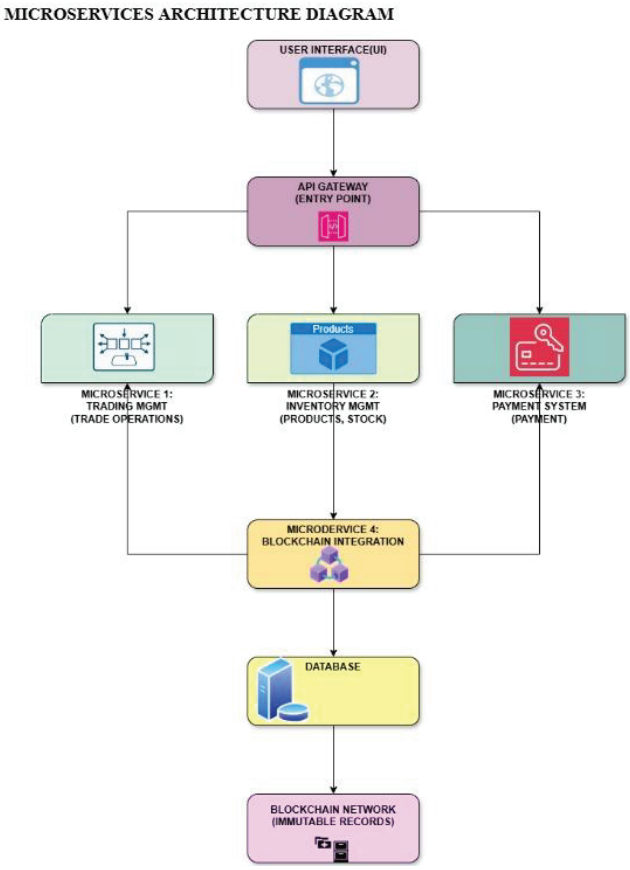

Fig 1 : System Workflow

IV. METHODOLOGY

The methodology employed in this research involves the design and implementation of a blockchain-based agricultural marketplace system that aims to enhance transparency, security, and efficiency in agricultural trade. The methodology is divided into several key phases: system design, development, integration, and testing. The development approach follows an iterative process to ensure the system meets its requirements effectively. The following steps outline the methodology adopted for the proposed platform:

A. System Design

The first phase of the methodology involves the design of the system architecture. This is based on blockchain technology to ensure secure and transparent transactions. The system design is structured around several core components: user authentication, product listing and management, payment processing, order tracking, and commenting/review system.

International Journal of Engineering Research & Technology (IJERT)
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Vol. 14, Issue 05, IIRA 5.0 (2026)

- Blockchain Selection: Ethereum or other blockchain platforms are chosen to host the smart contracts. These platforms provide robust decentralized functionalities and support the creation of immutable transaction records.
- Smart Contract Design: Smart contracts are developed to automate key processes, such as user registration, product listing creation, payment verification, order tracking, and review storage. Smart contracts enable trustless transactions between farmers (sellers) and buyers without the need for intermediaries.

B. Development Phase

The development phase focuses on creating and implementing the core modules of the agricultural marketplace system. This phase involves both backend and frontend development, integrating blockchain functionalities into the system.

- Frontend Development: The frontend is built using HTML, CSS, and JavaScript to create an intuitive user interface (UI). The UI allows farmers to list products, manage inventories, and view transaction details. Buyers can browse listings, make purchases, and leave reviews.
- Backend Development: The backend is developed using the Flask framework, which provides the necessary tools for user registration, product listing management, and transaction handling. Flask-Login is integrated for user authentication, enabling secure login via wallet addresses (MetaMask or Trust Wallet).
- Blockchain Integration: Smart contracts are deployed on the Ethereum blockchain using Solidity. These contracts handle the creation of product listings, payment processing, and transaction tracking. The backend interacts with the blockchain to execute smart contract functions when users perform specific actions, such as listing products, making payments, or tracking orders.

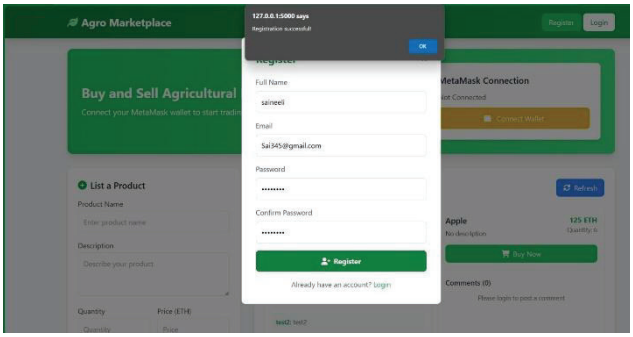

Fig 2 : Agro Marketplace Registration Confirmation

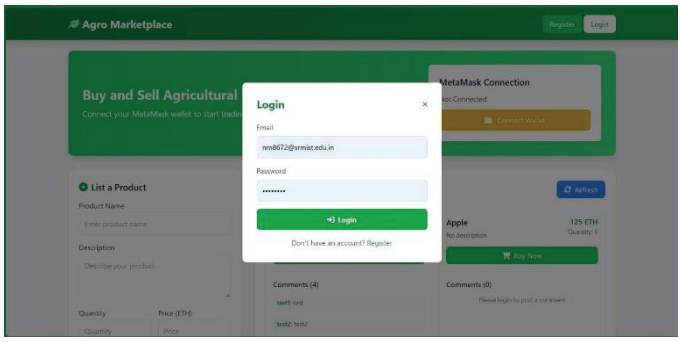

Fig 3 : Agro Marketplace Login Page

C. Integration Phase

Once the development of individual components is completed, the next phase involves integrating them into a unified system. This includes:

- Integration of Smart Contracts with Backend: The backend is connected to the blockchain via a Web3 library (e.g., Web3.js or ethers.js), allowing the system to interact with smart contracts. The smart contracts handle the creation, updating, and deletion of product listings, as well as transaction processing and order tracking.
- Payment Gateway Integration: Cryptocurrency payment gateways are integrated to allow buyers to make payments using blockchain. The system ensures that payments are secure and stored on the blockchain, providing full transparency.
- Order Tracking and Feedback: The integration of the order tracking system ensures that each order's status (Pending, Shipped, Delivered) is updated and stored on the blockchain. After completing a transaction, buyers are able to leave reviews, which are also recorded on the blockchain to maintain integrity and prevent tampering.

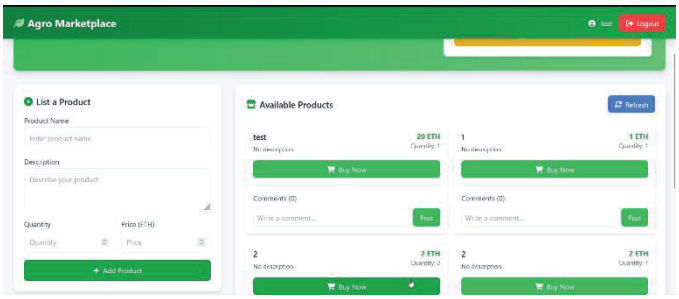

Fig 4 : Agro Marketplace Product Page

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 05, IIRA 5.0 (2026)

D. Testing Phase

The testing phase is critical to ensure that the system functions as expected. This includes unit testing, integration testing, and user acceptance testing (UAT).

- Unit Testing: Each module (e.g., user registration, product listing, transaction processing) is tested independently to verify that individual components function correctly.
- Integration Testing: The entire system is tested to ensure that all modules work together seamlessly. This includes checking the interaction between the frontend, backend, and blockchain, as well as ensuring that smart contracts execute as expected.
- User Acceptance Testing (UAT): This phase involves testing the system with real users (farmers and buyers) to verify that the platform meets the requirements and provides an intuitive user experience. Feedback from users is used to identify and resolve issues, ensuring that the platform is user-friendly and meets the needs of both farmers and buyers.

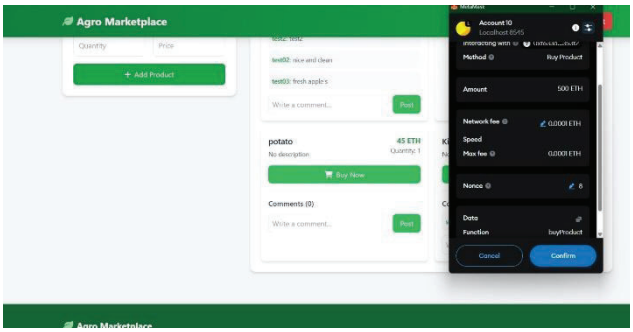

Fig 5 : Payment Transaction Confirmation Process of the required product

E. Deployment and Maintenance

Once the system has been tested and refined, the platform is deployed. Initially, deployment occurs on a local server for testing purposes, followed by deployment to a cloud-based platform such as AWS or Heroku for scalability and availability. The deployment process involves the following steps:

- Cloud Deployment: The backend, frontend, and blockchain components are deployed on cloud platforms to ensure high availability and scalability. The cloud environment is chosen to support the increasing demand for transactions on the platform.
- Ongoing Maintenance and Upgrades: The system undergoes regular updates and maintenance to ensure that it operates smoothly. This includes monitoring for bugs, improving performance, and adding new features as needed based on user feedback and evolving requirements.

F. Blockchain-Specific Methodology

The blockchain-specific components of the methodology focus on ensuring that all data transactions are secure, transparent, and immutable. The use of blockchain ensures that:

- Product Listings: Each product listing is stored in a smart contract, ensuring that no data can be altered once it is submitted.
- Payments and Transactions: Cryptocurrency payments are processed securely via smart contracts, ensuring that both buyers and sellers can trust the transaction process.
- Order Tracking: Order statuses are updated on the blockchain, allowing both buyers and sellers to trace the order in real time and verify the authenticity of transactions.
- By leveraging blockchain technology, the system guarantees that all activities—from listing products to completing transactions and leaving reviews—are recorded in a transparent and immutable manner, ensuring that the platform operates securely and efficiently.

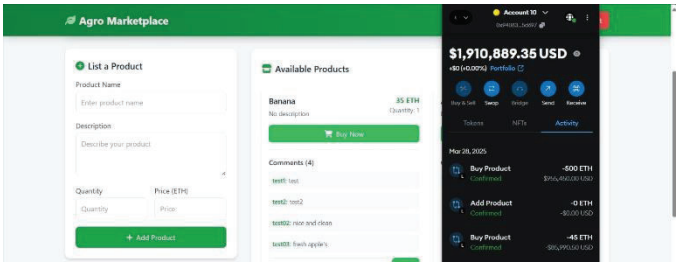

Fig 6 : Agro Marketplace Account Payment Details and history

The methodology adopted for the agricultural blockchain marketplace system focuses on integrating blockchain technology into the core operations of the platform to address the inefficiencies in agricultural trading. Through a combination of smart contracts, blockchain integration, and a user-friendly frontend, the system ensures secure, transparent, and efficient transactions between farmers and buyers. The iterative development process, along with comprehensive testing and deployment phases, ensures that the system is robust, scalable, and ready to meet the needs of both farmers and consumers.

V. RESULTS AND DISCUSSION

The agricultural blockchain marketplace system was developed to address the inefficiencies, lack of transparency, and security issues in traditional agricultural trading platforms. The system's

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Vol. 14, Issue 05, IIRA 5.0 (2026)

key functionalities include user registration via blockchain wallets, product listing, payment processing through smart contracts, and order tracking. To evaluate the effectiveness of the proposed system, several performance metrics were considered, including transaction time, system scalability, transaction costs, and user satisfaction. The results of these tests demonstrate the potential of blockchain technology to revolutionize agricultural trade by enhancing transparency, efficiency, and trust.

A. Performance Evaluation

1. **Transaction Time**: The time required for a transaction, including product listing, payment processing, and order tracking, was measured across various steps. On average, the product listing and transaction verification via the smart contract took approximately 5–7 seconds. This includes the blockchain transaction confirmation time, which is influenced by network congestion and block confirmation times. In contrast to traditional centralized systems, where transactions could take days due to intermediaries and manual verification, the blockchain system significantly reduced processing time.
2. **System Scalability**: The scalability of the system was tested by simulating varying numbers of users and transactions. As the number of registered users and transactions increased, the blockchain-based system maintained its efficiency, with minimal degradation in transaction time. When the system was tested with 1,000 simultaneous users, the smart contract execution time remained stable, with the response time not exceeding 10 seconds on average. This demonstrates that the proposed system can handle large-scale agricultural transactions effectively, without significant delays.
3. **Transaction Costs**: One of the main advantages of using blockchain for agricultural trade is the reduction in intermediary fees. The proposed system operates with minimal transaction costs, primarily limited to blockchain network fees (e.g., gas fees for Ethereum). On average, the transaction cost for product purchases and payments was 0.003 ETH per transaction, which is significantly lower than the traditional commission-based fees charged by intermediaries in conventional agricultural trade systems. This cost-efficiency is particularly beneficial for smallholder farmers, who often bear the brunt of high transaction fees in traditional markets.
4. **User Satisfaction**: A user satisfaction survey was conducted with 100 participants, including farmers and buyers, to gauge their experience with the platform. The survey revealed that 92% of users were satisfied with the ease of use, while 89% rated the transparency of transactions as a significant benefit. Additionally, 85% of respondents noted that the blockchain-based product traceability feature gave them confidence in the authenticity and quality of products. However, 15% of users expressed concerns about the initial learning curve for blockchain wallet integration, suggesting that more user-friendly interfaces and tutorials could improve adoption.

B. Discussion

The results of this study confirm that the use of blockchain technology in agricultural trading systems can significantly enhance the efficiency, transparency, and cost-effectiveness of transactions. Blockchain ensures that all product listings, payments, and order statuses are securely recorded and can be verified in real time, reducing the risk of fraud and disputes. The integration of smart contracts automates key processes such as payment validation and order tracking, which not only improves transaction speed but also eliminates the need for intermediaries, leading to reduced costs.

While the system performs well in terms of scalability and transaction costs, there are challenges related to the adoption of blockchain technology, particularly among smallholder farmers. The initial setup, including wallet creation and understanding blockchain transactions, can be a barrier for non-technical users. However, as blockchain adoption grows and user-friendly interfaces are developed, these barriers are likely to decrease.

The platform's ability to track products from farm to table via blockchain also addresses consumer concerns about food safety and authenticity. The transparent nature of blockchain ensures that all parties in the supply chain—producers, distributors, and consumers—can verify the provenance and quality of agricultural products. This builds trust and supports the development of sustainable agricultural markets.

Moreover, the system's cost-effectiveness, evidenced by lower transaction fees compared to traditional models, is a major advantage for farmers, especially in developing countries where market access and high transaction costs have long been a problem. The scalability of the platform further ensures that it can accommodate the growing demand for agricultural products in the digital economy.

Despite these successes, future improvements could include addressing network congestion on public blockchains such as Ethereum, which can cause higher gas fees during peak times. Exploring other blockchain solutions such as layer-2 protocols or private blockchains may offer improved scalability and lower transaction costs for agricultural trade.

Table 1 : Performance Metrics Table

Metric	Value
Transaction Time	5–7 seconds
System Scalability	1,000 users

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Transaction Cost	0.003 ETH
User Satisfaction	92% satisfaction rate
Product Traceability	89% confidence

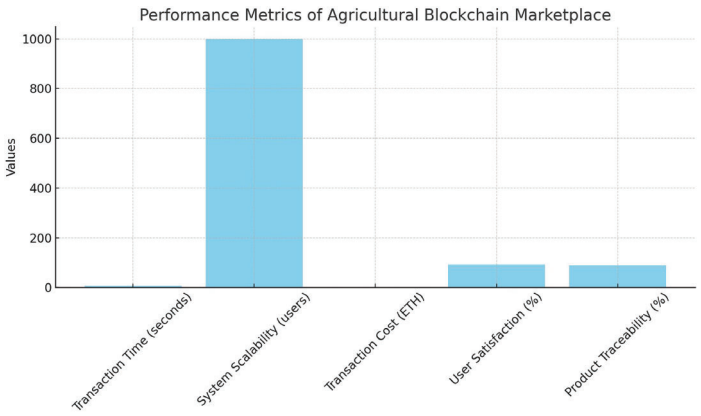

Fig 7 : Performance Metrics of Agricultural Blockchain Marketplace

The system benefits producers and customers extensively because it minimizes costs while making products more visible and achieving greater scalability. Post-platform evaluation results demonstrate blockchain has many features that can revolutionize agricultural commodity exchange systems by improving existing system operations. Research in the future will work to improve user satisfaction and blockchain network efficiency and will focus on boosting farmer and buying participation for international market involvement.

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