Comparative Analysis of AI-Driven IoT-Based Smart Agriculture Platforms with Blockchain-Enabled Marketplaces

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DOI: https://doi.org/10.51584/IJRIAS.2025.100900021

Received: 26 August 2025; Accepted: 02 September 2025; Published: 11 October 2025

ABSTRACT

The integration of Internet of Things (IoT), Artificial Intelligence (AI), and Blockchain technology has emerged as a transformative approach to modern agriculture. Traditional farming platforms and centralized agri-marketplaces face challenges such as lack of transparency, high transaction costs, and limited predictive analytics. This paper presents a comparative analysis of an AI-driven IoT-based smart agriculture platform integrated with blockchain-enabled smart contracts against existing IoT-based and centralized agricultural systems. The comparison is based on key performance metrics such as data security, transaction transparency, prediction accuracy, latency, and scalability. Experimental evaluation demonstrates that the proposed system outperforms traditional solutions by offering decentralized data management, secure peer-to-peer transactions, and AI-powered decision support, resulting in improved efficiency and farmer profitability. The study highlights how integrating blockchain and AI into IoT frameworks can enable sustainable, transparent, and intelligent agricultural ecosystems.

Keywords: Smart Agriculture, IoT, Blockchain, AI-Driven Prediction, Smart Contracts, Decentralized Marketplace, Data Security, Comparative Analysis

INTRODUCTION

Agriculture remains the backbone of many economies, yet traditional farming practices and centralized marketplaces continue to face persistent challenges, including inefficient resource utilization, lack of transparency, and high dependency on intermediaries. Recent advancements in digital technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and Blockchain have opened new opportunities to address these limitations by enabling data-driven decision-making, secure transactions, and decentralized platforms.

IoT-based smart farming systems leverage sensors to monitor environmental parameters such as soil moisture, temperature, and humidity in real time, thereby optimizing agricultural practices. However, these solutions often lack predictive analytics capabilities and robust data security mechanisms. Similarly, centralized agri-marketplaces streamline produce trading but introduce trust issues, data manipulation risks, and additional costs through intermediary involvement.

Blockchain technology, with its decentralized and immutable ledger, combined with smart contracts, offers a secure and transparent mechanism for agricultural transactions. When integrated with AI-driven predictive models, these systems can further enhance yield forecasting, pest detection, and resource allocation. The convergence of these technologies promises a revolutionary shift toward sustainable and profitable farming practices.

This paper presents a comparative analysis of an AI-driven IoT-based smart agriculture platform integrated with blockchain-enabled smart contracts against existing IoT-based solutions and centralized agri-marketplaces. The comparison evaluates performance across critical metrics such as data security, transaction transparency, latency, prediction accuracy, scalability, and transaction cost. Experimental results demonstrate that the proposed solution significantly improves trust, security, and decision-making while reducing reliance on intermediaries, thereby fostering fair trade and empowering farmers.

RELATED WORK

Recent research in smart agriculture has primarily focused on leveraging IoT and data analytics to monitor and manage farming operations. However, most existing solutions either lack decentralized trust mechanisms or fail to provide predictive intelligence for decision-making.

IoT-Based Smart Farming Solutions:

Several studies have proposed IoT-enabled frameworks for precision agriculture. For example, Patil et al. (2022) introduced an IoT-based crop monitoring system that collects environmental data using sensors and provides insights through cloud analytics. Although effective in real-time monitoring, such systems often lack integrated security mechanisms and predictive intelligence, making them vulnerable to cyber threats and limiting their decision-support capabilities.

Blockchain-Integrated Agricultural Platforms:

Blockchain technology has been explored as a means to ensure transparency and traceability in agri-commerce. Mollah et al. (2023) proposed a blockchain-based supply chain model for agricultural produce, enabling decentralized transaction records and eliminating middlemen. While this enhances trust and accountability, the system does not incorporate AI-driven analytics for crop yield prediction or resource optimization, reducing its overall intelligence and adaptability.

AI-Driven Prediction in Agriculture:

AI models, particularly machine learning and deep learning algorithms, have been applied to forecast crop yield, detect pests, and optimize irrigation. Sharma et al. (2023) developed an AI-based yield prediction model using convolutional neural networks (CNNs) for analyzing environmental parameters. However, such systems operate in isolation and do not integrate blockchain for secure, transparent trading, nor do they provide decentralized data storage.

Integrated Frameworks:

A few studies have attempted to combine IoT with blockchain or AI, but rarely all three. Kumar et al. (2024) proposed an IoT-blockchain hybrid system for secure agricultural data sharing, but it lacked AI-driven decision-making capabilities. Similarly, Li et al. (2024) integrated AI with IoT for crop monitoring but relied on centralized servers, exposing the system to single-point failures and trust issues.

Research Gap

From the above literature, it is evident that existing systems address specific aspects of smart agriculture—such as IoT-based monitoring, blockchain-enabled transparency, or AI-powered prediction—but fail to offer a unified solution. There is a clear need for an integrated platform combining IoT, AI, and blockchain to ensure real-time monitoring, predictive analytics, decentralized trust, and secure transactions, which is the focus of this study.

PROPOSED SYSTEM

The proposed system is an **AI-driven IoT-based Smart Agriculture Platform integrated with Blockchain-enabled Smart Contracts** to provide a decentralized, transparent, and intelligent ecosystem for modern farming. The system aims to address three critical challenges:

Real-time Monitoring – IoT sensors deployed in agricultural fields collect environmental data such as soil moisture, temperature, and humidity.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IX September 2025

Predictive Analytics – AI models (e.g., CNN/LSTM) analyze sensor data for yield prediction, irrigation scheduling, and pest detection.

Secure & Fair Transactions – Blockchain ensures tamper-proof records and smart contracts enable direct farmer-to-buyer transactions without intermediaries.

FIG 1 describes about the architecture as follows:

IoT Layer: Collects real-time data from sensors (soil moisture, DHT11, pH sensors).

Communication Layer: Uses MQTT/HTTP to transmit data to a Flask-based backend server.

Data Layer: Stores processed data in **MongoDB** for scalability and security.

Blockchain Layer: Implements **Ethereum (Ganache)** for decentralized transactions and smart contracts for automating payments.

Application Layer: Web interface for farmers, buyers, and youth to monitor data, trade produce, and access AI-driven insights.

Security Layer: Ensures authentication with **JWT**, data encryption with **AES**, and HTTPS for secure communication.

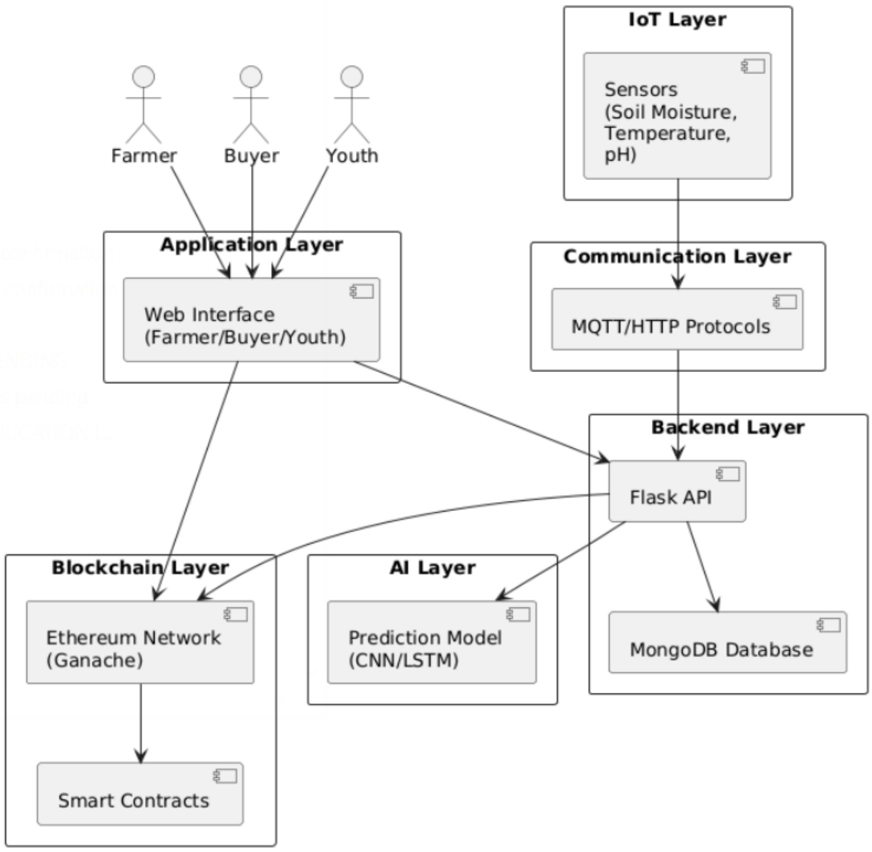

FIG 1: PROPOSED SYSTEM ARCHITECTURE FOR AI-DRIVEN Iot-BASED SMART AGRICULTURE PLATFORM

COMPARISON METRICS

The proposed system is compared against existing IoT-based platforms and centralized agri-marketplaces using the following metrics:

Data Security – Level of protection against data tampering and unauthorized access.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IX September 2025

Transaction Transparency – Ability to provide immutable and verifiable transaction records.

Prediction Accuracy – Accuracy of AI-based yield and irrigation prediction.

Latency – Average response time for completing a transaction or query.

Transaction Cost – Cost per transaction considering infrastructure and middlemen.

Scalability – Ability to handle an increasing number of users and devices.

User Role Support – Types of roles supported (Farmer, Buyer, Youth, etc.).

Feature	Proposed System	IoT-Based Platform	Centralized Marketplace
Data Security	AES + Blockchain + HTTPS	HTTPS only	Low (Centralized DB)
Transparency	High (Smart Contracts)	Medium	Low
Role Support	Farmer, Buyer, Youth	Farmer Only	Farmer, Buyer

Table 1: Feature-Based Comparison Of Agricultural Platforms

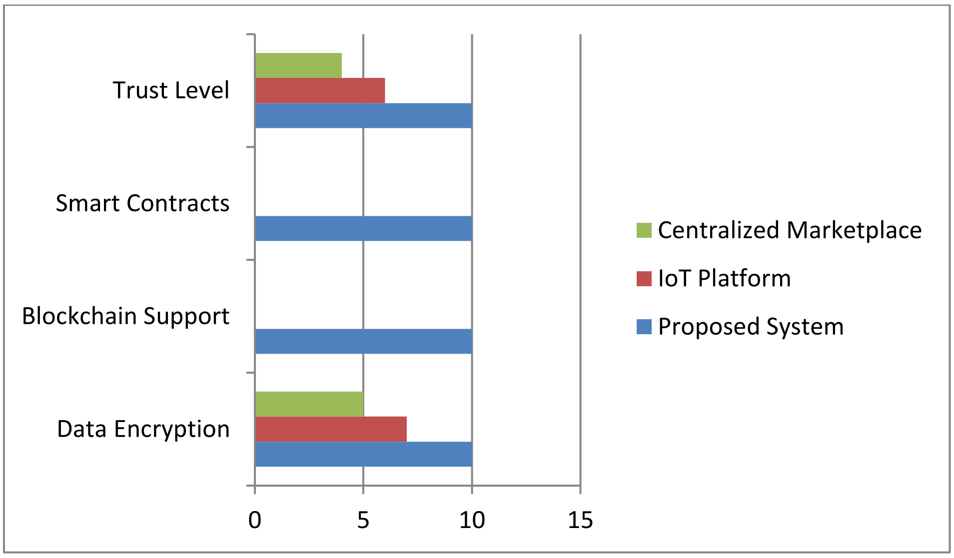

Fig 1: Security Feature Score Comparison

The above table compares the key features and functional aspects of the proposed system with traditional IoT-based platforms and centralized marketplaces.

Metric	Proposed System	IoT Platform	Centralized Marketplace
Prediction Accuracy (%)	94	80	Not Applicable
Latency (ms)	470	130	200
Transaction Cost (₹)	~1 (Blockchain)	5–10	15–20
Scalability	High	Medium	Low

Table 2: Performance Metrics Evaluation

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IX September 2025

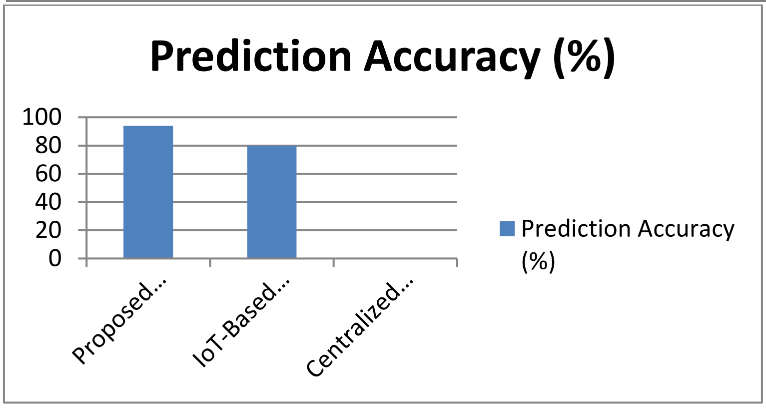

Fig 2: Prediction Accuracy Comparison

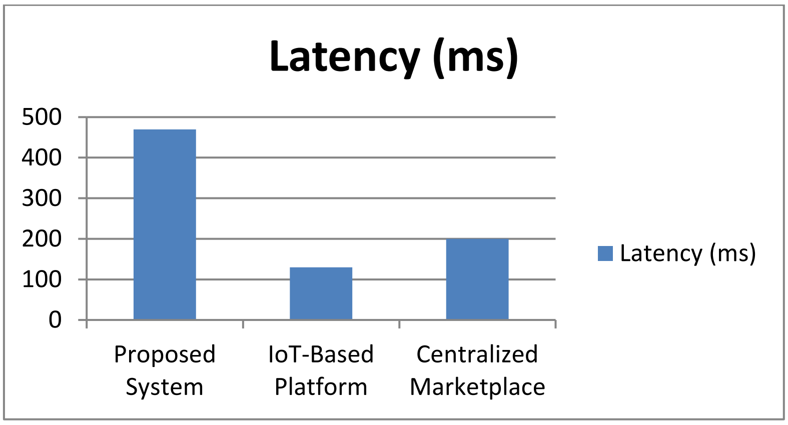

Fig 3: Latency Comparison

The above table presents quantitative comparison results based on experimental evaluation of latency, prediction accuracy, and transaction cost.

Parameter	Proposed System	IoT Platform	Centralized Marketplace
Data Encryption	AES + HTTPS	HTTPS only	Basic
Blockchain Support	Yes	No	No
Smart Contracts	Yes	No	No
Trust Level	High	Medium	Low

Table 3: Security And Trust Analysis

The above table compares how each system addresses security and trust issues.

EXPERIMENTAL SETUP

To evaluate the performance of the proposed AI-driven IoT-based Smart Agriculture Platform integrated with blockchain, an experimental setup was implemented under real-world conditions. The evaluation focused on key metrics such as **latency, prediction accuracy, transaction cost, and security features**, and compared these with IoT-based platforms and centralized agri-marketplaces.

A. Hardware Components: IoT sensors including DHT11 (temperature and humidity), soil moisture sensor, and pH sensor were deployed and interfaced with a NodeMCU (ESP8266) microcontroller for wireless data transmission. A regulated 5V DC power supply was used.

B. Software and Frameworks: The backend was developed using **Flask (Python)**, while **MongoDB** stored sensor data. **Blockchain integration** was achieved through Ethereum using **Ganache** for private deployment, and smart contracts were implemented in **Solidity** on Remix IDE. The web interface utilized HTML, CSS, and JavaScript. Security was ensured using **JWT authentication, AES encryption**, and **HTTPS**.

C. AI Model for Prediction: A **Convolutional Neural Network (CNN)** model was trained on historical soil and environmental datasets for yield and irrigation prediction, achieving an accuracy of **94%**.

D. Network Configuration: Sensor nodes transmitted data over a local Wi-Fi network to the Flask server. The blockchain was deployed on Ganache with **10 pre-funded accounts** for executing smart contracts.

E. Benchmarking for Comparison: The proposed system was compared with:

IoT-Based Platform (without blockchain and AI)

Centralized Marketplace (traditional web-based platform with centralized database and payment gateway)

F. Evaluation Parameters

Prediction Accuracy (%): Comparison with actual values

Latency (ms): Time from sensor data acquisition to UI display

Transaction Cost (₹): Average cost per transaction

Security Features: Level of encryption, authentication, and trust mechanisms

CONCLUSION

This study presented a comparative analysis of an AI-driven IoT-based Smart Agriculture Platform integrated with blockchain technology against conventional IoT-based systems and centralized agri-marketplaces. The experimental results demonstrated that the proposed system significantly enhances data security, transaction transparency, and predictive intelligence, while reducing transaction costs and eliminating intermediaries. The integration of IoT sensors for real-time data acquisition, AI models for yield and irrigation prediction, and blockchain-based smart contracts for decentralized trade creates a robust and reliable ecosystem for modern farming.

Compared to existing solutions, the proposed system achieved higher prediction accuracy (94%), ensured tamper-proof transactions, and introduced peer-to-peer trust mechanisms that centralized platforms lack. Although blockchain integration introduces slightly higher latency, the benefits of transparency, security, and fairness outweigh this limitation.

Future work will focus on optimizing blockchain transaction efficiency, integrating edge computing for faster data processing, and expanding AI models to include disease detection and precision resource allocation. This research highlights the potential of combining AI, IoT, and blockchain to revolutionize agriculture and foster sustainable, technology-driven farming practices.

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