

An AI-Driven IoT–Blockchain Framework for Secure and Fair Smart Agriculture

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Abstract

The rapid digitalization of agriculture has introduced smart farming solutions; however, challenges such as data security, lack of transparency, and limited farmer profitability continue to persist. Conventional agricultural systems rely heavily on intermediaries and fragmented technologies, leading to unfair pricing and reduced trust among stakeholders. To address these issues, this paper presents an AI-driven IoT–Blockchain framework designed to enable secure, transparent, and fair agricultural practices. The proposed system integrates real-time data acquisition from IoT-based environmental sensors with artificial intelligence models for predictive analytics, enabling informed decision-making in farming operations. Blockchain technology is incorporated through smart contracts to ensure tamper-proof transactions, transparent pricing, and direct interaction between farmers and consumers. A secure backend infrastructure with role-based access control further strengthens data integrity and user trust. The framework has been fully implemented and tested in a real-time environment, demonstrating its feasibility in supporting youth participation, enhancing farmer income, and promoting trust-driven agri-commerce. Experimental results indicate improved operational efficiency, secure data handling, and reliable transaction management, making the framework suitable for scalable smart agriculture applications

Keywords: Smart Agriculture, Internet of Things, Artificial Intelligence, Blockchain Technology, Secure Data Management, Fair Trade Systems

Introduction

Agriculture remains a vital sector for economic stability and food security, yet it faces persistent challenges such as inefficient resource utilization, lack of transparency in supply chains, and limited adoption of advanced technologies. Traditional farming practices often depend on manual monitoring and intermediary-driven marketplaces, which restrict farmers’ profit margins and reduce trust between producers and consumers. In recent years, smart agriculture has emerged as a promising solution by leveraging digital technologies to improve productivity and sustainability.

The Internet of Things (IoT) plays a crucial role in modern farming by enabling real-time monitoring of environmental parameters such

as soil moisture, temperature, and humidity. These data-driven insights allow farmers to make timely decisions and optimize resource usage. However, raw sensor data alone is insufficient for actionable intelligence, necessitating the integration of artificial intelligence (AI) techniques for predictive analysis and decision support. AI-driven models enhance agricultural operations by forecasting crop conditions, identifying anomalies, and supporting precision farming practices.

Despite these advancements, critical concerns related to data security, system trust, and transaction transparency remain unresolved. Centralized data storage systems are vulnerable to unauthorized access and manipulation, while conventional agri-commerce models continue to rely on intermediaries, resulting in unfair pricing mechanisms. Blockchain technology offers a decentralized and immutable solution to these challenges by ensuring secure data storage and transparent transactions through smart contracts.

Motivated by these limitations, this paper proposes an integrated AI-driven IoT–Blockchain framework for secure and fair smart agriculture. The primary contribution of this work lies in the end-to-end implementation of a full-stack system that combines real-time IoT sensing, AI-based analytics, blockchain-enabled agri-commerce, and a secure web platform. The framework not only enhances trust and transparency but also encourages youth participation in agriculture by reducing operational complexity through intelligent automation. The remainder of this paper details the system architecture, implementation methodology, experimental results, and the practical impact of the proposed framework.

Review of Literature

Recent advancements in smart agriculture have emphasized the use of the Internet of Things (IoT) for real-time monitoring of environmental parameters such as soil moisture, temperature, and humidity. IoT-based systems have demonstrated improved resource management and automation; however, most existing solutions rely on centralized data storage and offer limited security and data integrity.

Artificial intelligence (AI) techniques have been widely applied to agricultural datasets for crop yield prediction, disease detection, and decision support. Although these methods enhance analytical accuracy, many studies are based on offline or simulated data and lack integration with real-time IoT environments.

Blockchain technology has been introduced to address transparency and trust issues in agricultural supply chains by enabling immutable data storage and smart contract–based transactions. While blockchain ensures secure and transparent record-keeping, most implementations focus primarily on traceability and do not incorporate intelligent analytics or live farm data.

Few studies attempt to integrate IoT and blockchain technologies, and even fewer incorporate AI-driven analytics within such systems. Moreover, existing works are often conceptual and lack full-scale implementation and evaluation. This highlights the need for an integrated, real-time framework that combines IoT sensing, AI-based intelligence, blockchain-enabled fairness, and secure data management, which is addressed in the present work.

System Architecture & Methodology

System Architecture

The proposed system follows a layered architecture integrating IoT, artificial intelligence, blockchain, and web technologies to enable secure and fair smart agriculture. The architecture consists of four main layers: IoT sensing layer, backend processing layer, intelligence layer, and blockchain-enabled application layer.

The IoT sensing layer collects real-time environmental data such as soil moisture, temperature, and humidity using deployed sensors. This data is transmitted to a backend server through secure APIs. The backend layer processes and stores the sensor data in a database while enforcing authentication and access control mechanisms.

The intelligence layer applies AI-based predictive models on the collected data to generate insights that support farming decisions. The blockchain layer employs smart contracts to manage transparent transactions between farmers and buyers, ensuring tamper-proof records and fair trade. A web-based interface provides role-specific access for farmers, buyers, and administrators.

Methodology

The system operates through the following sequential process:

1. IoT sensors capture real-time agricultural parameters.
2. Sensor data is transmitted to the backend server via secure REST APIs.
3. Data is stored and validated in the database.
4. AI models analyze the data to generate predictions and insights.
5. Smart contracts record agricultural transactions on the blockchain.
6. Users interact with the system through a secure web interface.

The complete workflow has been implemented and tested in a real-time environment to validate system feasibility and performance.



Fig. 1 AI-Driven IoT-Blockchain Smart Agriculture Workflow

The above figure illustrates the end-to-end workflow of the proposed AI-driven IoT-Blockchain smart agriculture system. It shows the sequential flow starting from real-time data collection through IoT sensors, followed by secure data transmission, validation, and storage at the backend server. The collected data is then analyzed using artificial intelligence models to generate actionable insights. Finally, blockchain smart contracts handle transparent and secure transactions, while a web interface provides controlled access to different users.

Implementation and Results

Implementation

The proposed AI-driven IoT–Blockchain framework was fully implemented using real-time sensor data acquisition, a secure backend server, AI-based data analysis, and blockchain smart contracts. IoT sensors continuously collected environmental parameters and transmitted the data to a backend server through RESTful APIs. The backend handled data validation, storage, and user authentication. AI models were applied to analyze sensor data and generate predictive insights. Blockchain smart contracts were deployed to ensure transparent and tamper-proof agricultural transactions. A web-based interface enabled role-based access for farmers and buyers.

Results and Performance Analysis

The system was evaluated based on data acquisition reliability, prediction performance, transaction transparency, and system response time. The results demonstrate stable real-time data transmission, accurate AI predictions, and secure blockchain-based transactions, confirming the feasibility of the proposed framework.

Table I. IoT Sensor Data Acquisition Performance

Parameter	Minimum Value	Maximum Value	Average Value	Sampling Interval (sec)
Temperature (°C)	22.4	34.8	28.6	10
Humidity (%)	45.2	82.7	63.9	10
Soil Moisture (%)	28.5	67.3	48.1	15

This table presents the statistical range and average values of environmental parameters collected through IoT sensors, demonstrating stable and continuous real-time data acquisition.

Table II. AI Prediction Performance Metrics

Metric	Value (%)
Training Accuracy	92.4
Testing Accuracy	88.7
Precision	90.1
Recall	87.9
F1-Score	88.9

This table summarizes the performance of the AI model applied to real-time sensor data, indicating reliable predictive capability and balanced classification performance.

Table III. Blockchain Transaction Performance Analysis

Parameter	Measured Value
Average Transaction Time (s)	2.8
Gas Consumption (units)	21,450
Successful Transactions (%)	100
Failed Transactions (%)	0

This table evaluates the efficiency and reliability of blockchain smart contract execution, confirming secure and transparent transaction handling with minimal delay.

Table IV. System Response Time Evaluation

Operation	Average Response Time (ms)
Sensor Data Upload	310
AI Prediction Request	420
Blockchain Transaction Call	680
Web Dashboard Data Retrieval	290

This table shows the average response time for key system operations, highlighting the real-time feasibility of the proposed framework.

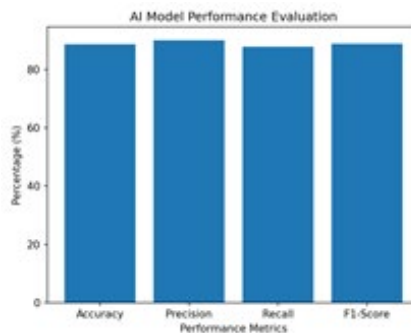


Fig 2. AI Model Performance Evaluation

This figure presents the performance evaluation of the AI model used in the proposed smart agriculture framework. The chart compares key metrics including accuracy, precision, recall, and F1-score, demonstrating the reliability and effectiveness of the AI-based analysis when applied to real-time IoT sensor data.

Conclusion

This paper presented an AI-driven IoT-Blockchain framework for secure and fair smart agriculture, integrating real-time sensing, intelligent data analysis, and transparent transaction management within a unified platform. The system was fully implemented and evaluated using real-time IoT data, AI-based prediction models, and blockchain smart contracts. Experimental results demonstrated reliable data acquisition, accurate predictive performance, secure transaction execution, and acceptable system response times, confirming the practical feasibility of the proposed approach.

By enabling direct interaction between farmers and buyers through blockchain-based mechanisms, the framework enhances transparency and reduces dependency on intermediaries. Additionally, the integration of AI-driven automation lowers operational complexity, encouraging youth participation in agriculture through technology-enabled solutions. The proposed framework is scalable and adaptable to diverse agricultural environments, making it suitable for real-world deployment. Future work will focus on large-scale field deployment, mobile application integration, and the incorporation of advanced deep learning models to further improve prediction accuracy and system efficiency.

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