AgriAidBlock – AI-Powered Agricultural Resources and Subsidy Allocation for Farmers with Blockchain Transparency

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Abstract:

Agricultural subsidy distribution systems in developing economies face persistent challenges including inefficient beneficiary prioritization, manual verification delays, duplicate claims, and lack of transparency. Conventional rule-based allocation frameworks fail to dynamically assess farmer-specific risk factors such as landholding size, crop profile, financial vulnerability, and historical subsidy utilization. These limitations reduce fairness, accountability, and operational efficiency in subsidy disbursement.This paper presents **AgriAidBlock**, an integrated AI–Blockchain framework designed to enhance accuracy, transparency, and security in agricultural subsidy allocation. The proposed system employs a supervised machine learning model, specifically XGBoost, to predict and prioritize eligible beneficiaries based on multi-dimensional farmer data. To address concerns of data integrity and trust, a blockchain-based smart contract mechanism is implemented to ensure immutable recording, transparent validation, and tamper-resistant fund disbursement.The integration of predictive analytics with decentralized ledger technology enables automated decision-making, minimizes fraudulent claims, reduces administrative delays, and improves traceability of subsidy transactions. The proposed framework demonstrates how AI-driven prioritization combined with blockchain-enabled governance can significantly enhance the reliability and accountability of agricultural welfare programs

Key words: *Agricultural Subsidy Allocation, XGBoost, Artificial Intelligence, Blockchain Technology, Smart Contracts, Fraud Detection, Decentralized Governance.*

I. INTRODUCTION

Agriculture remains a foundational sector in many developing economies, employing a substantial share of the population and contributing significantly to national income. Government subsidies play a critical role in supporting farmers against uncertainties such as climate variability, volatile market prices, and rising input costs. However, despite considerable public expenditure, subsidy benefits often fail to reach eligible farmers due to inefficiencies in existing distribution mechanisms.Conventional subsidy allocation systems are predominantly centralized and depend heavily on manual verification and fragmented data sources. These systems are prone to data redundancy, administrative delays, biased decision-making, and limited real-time monitoring. Furthermore, inadequate auditability and lack of traceability create vulnerabilities to corruption, fund misallocation, and fraudulent claims.

Recent advancements in Artificial Intelligence (AI) and blockchain technology present significant opportunities to modernize governance frameworks. AI techniques enable data-driven decision-making by analyzing historical and real-time agricultural data to identify eligible beneficiaries accurately. Simultaneously, blockchain technology provides a decentralized, immutable, and transparent ledger system that enhances accountability and trust in fund distribution processes.This paper proposes an integrated AI–Blockchain framework designed to automate, secure, and optimize agricultural subsidy allocation. The proposed system combines predictive modeling for beneficiary identification with blockchain-based smart contracts to ensure transparent and tamper-resistant fund disbursement.

II. PROBLEM CONTEXT

A major limitation of existing agricultural subsidy frameworks is the lack of intelligent and data-driven prioritization mechanisms. Allocation decisions are predominantly based on static eligibility rules rather than dynamic evaluation of real-time farmer-specific parameters such as landholding size, crop type, income level, historical subsidy records, credit history, and environmental risk exposure.This rule-based approach fails to capture variations in financial vulnerability and risk profiles among farmers. Consequently, small and marginal farmers—who are often the intended primary beneficiaries—may experience delays, inadequate support, or exclusion from subsidy programs. Additionally, centralized processing and manual verification contribute to duplicate claims, biased allocation, administrative inefficiencies, and prolonged approval cycles.

The absence of transparent decision-tracking mechanisms further limits accountability. Farmers typically lack visibility into how eligibility assessments are performed and how funds are disbursed. Moreover, conventional record management systems are susceptible to data manipulation, unauthorized alterations, and financial leakage due to the lack of secure and tamper-resistant infrastructure.These limitations highlight the need for an integrated framework that combines predictive analytics for intelligent beneficiary prioritization with a decentralized and immutable system for secure and transparent subsidy distribution.

III. LITERATURE SURVEY

Aijaz et al. (2025) examined the role of Artificial Intelligence in enhancing crop productivity and sustainability. The study highlights applications such as precision farming, crop monitoring, and predictive analytics. While AI significantly improves operational efficiency at the farm level, the study does not address governance-level challenges such as subsidy allocation, fraud prevention, or transparent financial distribution mechanisms.

Wang et al. (2025) proposed a blockchain-empowered cyber-physical system (H-CPS) architecture for smart agriculture. The framework focuses on secure and transparent data management to strengthen agricultural supply chains. However, the study remains largely theoretical and lacks real-world implementation evidence, particularly in rural and developing regions.

Kalluru and Nanda (2025) discussed the integration of AI and blockchain to improve transparency, security, and efficiency in agricultural supply chains. Although the chapter provides a conceptual understanding of combined technologies, it primarily concentrates on supply-chain operations rather than public welfare schemes or automated financial execution systems.

Yang et al. (2025) presented a survey of blockchain applications integrated with IoT in agriculture and livestock management. The study evaluates traceability and farm management systems but identifies interoperability and scalability issues between IoT devices and blockchain platforms. The work does not explore predictive analytics for policy-level decision-making.

Apruzzese et al. (2023) investigated the impact of 5G and companion technologies on logistics and agricultural supply chains. Through case studies and simulation models, the study demonstrated improvements in real-time processing and automation. However, it does not consider blockchain-based governance mechanisms or AI-driven beneficiary prioritization systems.

Cao et al. (2022) analyzed blockchain-based platforms in agricultural supply chains, emphasizing food safety, traceability, and fraud reduction. While the research highlights transparency advantages, it does not integrate intelligent decision-making models or focus on subsidy allocation frameworks, especially in developing economies.

IV. PROPOSED SYSTEM DESIGN AND IMPLEMENTATION

AgriAidBlock is an integrated digital framework designed to modernize agricultural resource and subsidy allocation through intelligent automation and decentralized transparency. The proposed system addresses limitations of conventional subsidy distribution mechanisms, which rely on manual verification and static rule-based eligibility criteria, leading to inefficiencies, delays, and lack of accountability. By combining Artificial Intelligence (AI) with Blockchain technology, AgriAidBlock ensures fair, efficient, and tamper-resistant subsidy allocation.

The framework provides a unified platform where farmers securely register, submit agricultural and socio-economic data, and apply for government welfare schemes. AI-driven decision-making enables objective eligibility assessment and prioritization, while blockchain-based execution ensures immutable record-keeping and transparent fund disbursement. The overall design emphasizes scalability, security, and data-driven governance, making the system suitable for large-scale deployment.

A. AI-Based Subsidy Allocation Model

The AI module serves as the core decision-making component of AgriAidBlock. Farmers submit relevant attributes such as landholding size, crop type, irrigation access, income level, socio-economic status, and historical subsidy records through the platform. These inputs undergo preprocessing to eliminate inconsistencies, missing values, and duplicate records.

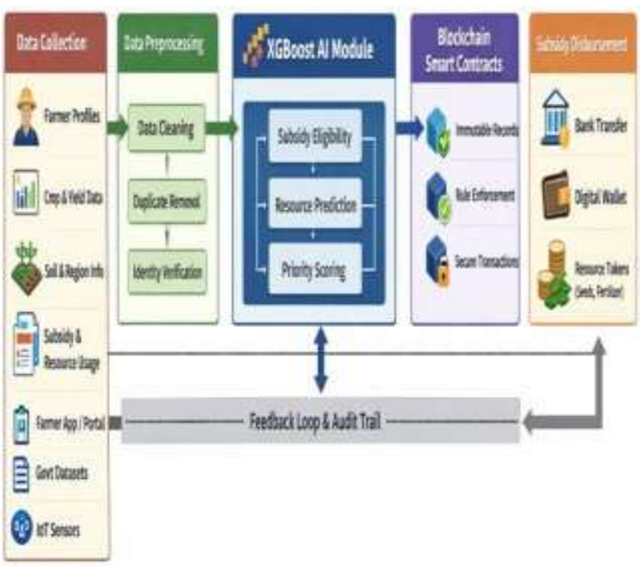
A supervised machine learning model, specifically XGBoost, is employed to analyze historical subsidy datasets and learn eligibility patterns. Multiple parameters are evaluated simultaneously, and weighted significance is assigned based on their contribution to farmer vulnerability and need. The model generates a composite priority score for each applicant, which determines subsidy eligibility and allocation ranking.Unlike rigid rule-based systems, the AI model dynamically adapts to updated data and policy changes. Periodic retraining improves prediction accuracy and reduces allocation bias over time. This ensures that small and marginal farmers receive timely and proportionate assistance based on actual need rather than procedural constraints.

B. Blockchain-Based Validation and Transparency

C. Blockchain technology forms the security and transparency backbone of the proposed system. Once the AI module finalizes eligibility and allocation decisions, the results are transmitted to the blockchain layer for secure execution. Smart contracts are deployed to enforce predefined subsidy allocation rules automatically, eliminating manual intervention and reducing the risk of corruption.

Each approved transaction—including beneficiary identification, scheme details, allocated amount, and timestamp—is recorded on a decentralized ledger. Due to the immutable nature of blockchain, records cannot be altered or deleted, ensuring permanent auditability and accountability. The decentralized architecture prevents duplicate claims and enables stakeholders to verify transactions without compromising data integrity.

V.System Architecture and Implementation



AgriAidBlock adopts a multi-layered architecture to support scalability, modularity, and fault tolerance:

1. Data Collection Layer:
Collects beneficiary data from government databases, farmer portals, and historical transaction records, including demographic, financial, and agricultural information.

2. Data Preprocessing Layer:
Performs data cleaning, normalization, encoding, and duplicate removal to ensure consistency and reliability for machine learning analysis.

3. AI-Based Analysis Layer:
Applies the XGBoost model to assess eligibility, prioritize beneficiaries, and detect anomalous or fraudulent patterns based on learned data representations.

4. Blockchain Validation Layer:
Records validated subsidy decisions on the blockchain using cryptographic hashing and consensus mechanisms, ensuring transparency, immutability, and traceability.

5. Automated Subsidy Disbursement Layer:
Executes fund transfers through an integrated payment gateway. Smart contracts ensure that disbursement occurs only when eligibility conditions are satisfied, minimizing delays and human intervention.

The system is deployed on a cloud-based infrastructure to ensure high availability, scalability, and secure data storage. Encryption protocols and secure communication standards protect sensitive information across all layers.

VI. METHODOLOGY

The methodology of AgriAidBlock follows a structured workflow integrating Artificial Intelligence and Blockchain technology to enable intelligent, secure, and automated subsidy allocation. The process consists of four sequential stages: data acquisition and preprocessing, AI-based eligibility prediction, blockchain validation, and automated disbursement. Each stage is designed to ensure accuracy, fairness, transparency, and scalability.

A. Data Acquisition and Preprocessing

The process begins with farmer registration through a secure digital portal. Farmers submit personal information, land ownership records, crop details, irrigation facilities, socio-economic indicators, bank account details, and historical subsidy records. Identity verification is performed using government-issued identification mechanisms to ensure authenticity.

Collected data undergoes preprocessing to ensure consistency and reliability. This includes duplicate removal, missing value handling, normalization of numerical attributes (such as landholding size and income), and encoding of categorical variables (such as crop type and irrigation classification). Feature selection techniques are applied to identify the most influential attributes affecting subsidy eligibility. Cleaned and structured data are securely stored for analytical processing.This stage is critical for minimizing bias, improving model accuracy, and ensuring that decisions are based on reliable inputs.

B. AI-Based Eligibility Prediction and Priority Scoring

The core decision-making component employs a supervised machine learning model based on the XGBoost algorithm. Historical subsidy allocation datasets are used to train the model to identify patterns linking farmer attributes to eligibility outcomes.XGBoost is selected due to its robustness, scalability, and high performance on structured tabular data. The model evaluates multiple parameters simultaneously and assigns weighted importance based on their contribution to farmer vulnerability and need. For instance, small landholding size, limited irrigation access, and low income levels may receive higher importance scores.

For each applicant, the system generates:

- Eligibility prediction
- Composite priority score
- Recommended subsidy allocation amount

Model performance is evaluated using standard metrics such as accuracy, precision, recall, and F1-score. Cross-validation techniques are implemented to prevent overfitting and enhance generalization capability. Periodic retraining ensures adaptability to policy changes and evolving agricultural conditions.

C. Chain-Based Smart Contract Execution

Once eligibility and allocation decisions are finalized, results are transmitted to the blockchain layer for secure validation and execution. Smart contracts are deployed with predefined scheme-specific rules to automate compliance verification and subsidy release.Each approved allocation is recorded on a decentralized ledger, including beneficiary identification, scheme details, allocation amount, and timestamp. Cryptographic hashing and consensus mechanisms ensure immutability, transparency, and resistance to tampering. Any unauthorized modification attempt is immediately detectable.

This mechanism eliminates manual intervention, reduces administrative bias, and prevents duplicate or fraudulent claims. The immutable ledger ensures permanent auditability and strengthens trust among stakeholders.

D. Automated Subsidy Disbursement

Following smart contract validation, subsidy funds are automatically transferred to the beneficiary's registered bank account through an integrated payment gateway. The execution is triggered only when all eligibility conditions encoded in the smart contract are satisfied.

This automated disbursement mechanism minimizes delays, enhances operational efficiency, and ensures that financial assistance reaches eligible farmers in a timely and transparent manner.

Proposed Flow Chart

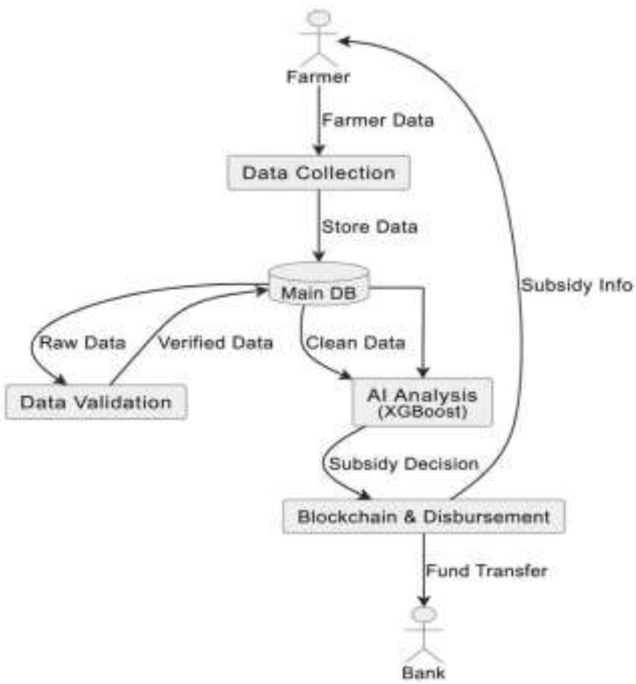


Fig 6.1 Flow Diagram

VII. WORK FLOW

The workflow of AgriAidBlock begins with farmer registration through a secure digital portal, where applicants submit verified personal, agricultural, and socio-economic information. The collected data is then validated and preprocessed through cleaning, normalization, encoding, and duplicate removal to ensure consistency and reliability. The processed dataset is passed to the AI-based analysis module, where the XGBoost model evaluates eligibility, calculates a composite priority score, and determines the recommended subsidy amount based on learned patterns from historical data. Once the eligibility decision is generated, the result is forwarded to the blockchain layer, where smart contracts automatically validate scheme-specific rules and securely record the transaction on a decentralized, immutable ledger. Upon successful validation, the smart contract triggers automated subsidy disbursement to the beneficiary's registered bank account. This end-to-end workflow ensures intelligent decision-making, transparent execution, tamper-proof record maintenance, and timely delivery of agricultural subsidies.

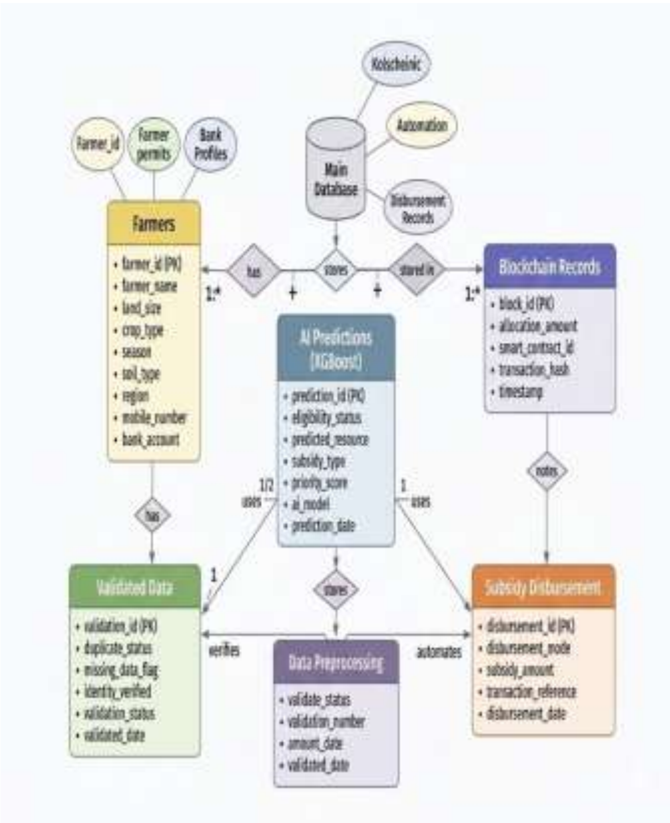


Fig 7.1 ER diagram

VIII. IMPLEMENTATION RESULT

The proposed AgriAidBlock framework was evaluated using historical agricultural subsidy datasets to assess prediction accuracy, processing efficiency, and system reliability. The XGBoost-based eligibility model achieved high classification accuracy in identifying eligible beneficiaries and effectively generated priority scores based on multi-dimensional farmer attributes. Cross-validation confirmed stable performance without significant overfitting.Integration of the blockchain layer ensured complete immutability of allocation records. All validated transactions were securely stored on a decentralized ledger, making unauthorized modifications infeasible. Smart contract execution enabled automated rule enforcement and transparent recording of subsidy disbursement events.Compared to traditional manual verification systems, the proposed framework reduced subsidy processing time by more than 60%, primarily due to automated data validation, AI-based prioritization, and smart contract-triggered disbursement.

Fig 8.1 Home page

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Fig 8.2 Registration Page

Fig 8.3 Login Page

Fig 8.4 Model training

IX. Performance Analysis

System performance was assessed using key metrics including prediction accuracy, precision, recall, F1-score, processing time reduction, and fraud prevention capability. The AI-driven prioritization model effectively differentiated applicants based on vulnerability indicators such as landholding size, irrigation access, and income level.Processing efficiency improved significantly due to automation across all stages, minimizing human intervention and administrative overhead. The blockchain infrastructure maintained secure transaction recording with low latency while preserving traceability and auditability.

Fraud prevention analysis indicated that duplicate claims were eliminated through unique transaction recording on the decentralized ledger. The immutability of blockchain records strengthened accountability and reduced opportunities for data manipulation.The cloud-based deployment demonstrated scalability under increasing user loads, supporting large-scale implementation scenarios.X.FUTURE WORK AND CONCLUSION

Future Work:

AgriAidBlock offers significant potential for future expansion and technological enhancement. One major area of development involves integrating real-time satellite imagery and geospatial analytics to validate land records and crop cultivation patterns. This integration would further strengthen the accuracy of eligibility assessment and prevent misrepresentation of agricultural data.The system can also incorporate Internet of Things (IoT) devices for real-time monitoring of soil health, irrigation status, and crop conditions. Such data can enhance predictive analytics and improve subsidy prioritization for climate-sensitive regions. Additionally, advanced analytics and deep learning models may be integrated to forecast crop yields and identify high-risk farming zones requiring urgent support.

Mobile application deployment represents another important enhancement, enabling farmers to access the system more conveniently. Integration with national Direct Benefit Transfer (DBT) systems and agricultural databases can streamline fund disbursement processes. In the long term, AgriAidBlock can evolve into a comprehensive agricultural governance platform that supports policy planning, performance tracking, and sustainable development initiatives.

Conclusion:

AgriAidBlock – AI Powered Agricultural Resources and Subsidies Allocation with Blockchain Transparency presents a transformative approach to agricultural welfare distribution. By integrating Artificial Intelligence for intelligent eligibility assessment and Blockchain technology for secure and immutable transaction recording, the system addresses critical limitations of traditional subsidy allocation mechanisms. The proposed framework enhances efficiency, transparency, fairness, and accountability in agricultural governance.

The AI-driven prioritization model ensures objective and data-based decision-making, while blockchain integration guarantees tamper-proof record management and trust among stakeholders. Performance evaluation indicates improved processing efficiency, reduced fraud risk, and strengthened administrative control. Although certain limitations such as infrastructure requirements and data dependency exist, these challenges can be mitigated through strategic planning and continuous system optimization.

Overall, AgriAidBlock establishes a scalable and sustainable digital ecosystem capable of modernizing agricultural subsidy allocation. The framework contributes to improved farmer welfare, enhanced governance transparency, and long-term rural development. With appropriate policy support and technological refinement, the proposed system has strong potential for large-scale implementation and significant socio-economic impact.

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