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Block chain-Based Yield Loss Estimation and Crop Insurance Compensation

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Abstract

Crop insurance is an essential mechanism for protecting farmers against financial losses caused by crop failure. However, traditional crop insurance systems are often inefficient due to manual inspections, delayed claim settlement, lack of transparency, and dependence on weather-based indices that may not reflect actual crop damage. Although recent studies have explored the use of blockchain and smart contracts in agricultural insurance, most existing approaches rely on indirect indicators rather than real yield loss. This paper proposes a blockchain-based framework for yield loss estimation and automated crop insurance compensation. The proposed system integrates data from farmer records, IoT sensors, and satellite or drone imagery to estimate actual crop yield loss. A smart contract automatically triggers compensation when yield loss exceeds a predefined threshold, ensuring fast, transparent, and fair payouts without human intervention. Blockchain technology guarantees data immutability and trust among stakeholders. Simulation-based analysis shows that the proposed model reduces claim processing time, administrative costs, and disputes compared to traditional insurance systems. The results demonstrate that yield-based blockchain insurance offers a more accurate and farmer-centric solution for crop insurance claim settlement.

Keywords: *Crop insurance, Blockchain, Drone imagery, claim settlement*

Introduction

Agriculture plays a vital role in the economic stability of many countries, particularly in developing regions where a large population depends on farming for livelihood. Farmers frequently face yield losses due to uncertain weather conditions, pest attacks, diseases, and environmental changes. Crop insurance is designed to protect farmers from such losses, yet traditional insurance systems often suffer from delayed compensation, lack of transparency, and subjective loss assessment. Blockchain technology provides a decentralized and tamper-proof platform that can address these challenges by automating insurance processes and ensuring trust among stakeholders. While previous research has explored blockchain-based crop insurance and weather-indexed insurance models, limited work has focused on actual yield loss–based compensation integrated with smart contracts. This paper proposes a blockchain-enabled crop insurance framework that directly links yield loss estimation with automatic compensation, eliminating the need for intermediaries.

Existing crop insurance systems face several challenges as:

- Heavy dependence on manual field inspections
- Time-consuming claim settlement processes
- Lack of transparency and trust
- Weather-based indices that do not always reflect actual yield loss

Blockchain technology be used to automate crop insurance compensation based on actual crop yield loss while ensuring transparency, fairness, and efficiency.

Literature Review

Blockchain in Agriculture:

Previous studies show that blockchain improves transparency, data security, and traceability in agricultural systems. Blockchain has been applied to supply chain management, farmer data storage, and insurance record management [1],[7],[8],[9].

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IoT and Blockchain Integration:

Research published in IEEE Access [4],[10],[11] demonstrates that integrating IoT sensors with blockchain enables secure monitoring of agricultural data such as soil moisture, temperature, and humidity. However, these systems mainly focus on data integrity rather than insurance compensation.

Smart Contracts in Insurance:

Smart contracts automate insurance claims by executing predefined rules without human involvement. Existing research confirms reduced settlement time and administrative effort [3]12], but does not fully integrate agricultural yield loss estimation.

Weather-Indexed Crop Insurance:

Weather-indexed insurance models trigger compensation based on rainfall or temperature thresholds [3][5]. Although easy to implement, such models rely on indirect indicators and may fail to compensate farmers who suffer real yield loss without extreme weather events.

Literature survey shows that very few studies combines actual yield loss estimation, blockchain, and smart contract-based compensation in a single automated system.

Based on the literature review, the following gaps are identified:

- Limited use of actual yield loss data as insurance triggers[3],[5]
- Partial automation in existing blockchain insurance systems[1],[7]
- Lack of transparency for farmers to verify claim decisions[3],[9]
- Underuse of hybrid data sources such as IoT, satellite imagery, and farmer records[4],[10]

This research addresses these gaps by proposing a fully automated, yield-based blockchain insurance framework.

Proposed Methodology

Step 1: Data Collection

Yield-related data is collected from:

- Farmer records
- IoT sensors deployed in agricultural fields
- Satellite or drone imagery analysis

Step 2: Expected Yield Estimation

Expected yield is calculated using historical crop data, crop type, and environmental conditions.

Step 3: Actual Yield Comparison

Yield loss percentage is calculated using:

Yield Loss (%) = ((Expected Yield − Actual Yield) / Expected Yield) × 100

Step 4: Smart Contract Execution

If yield loss exceeds a predefined threshold (e.g., 30%), the smart contract automatically executes compensation.

Step 5: Blockchain Ledger

All yield data and transactions are stored on a decentralized blockchain ledger.

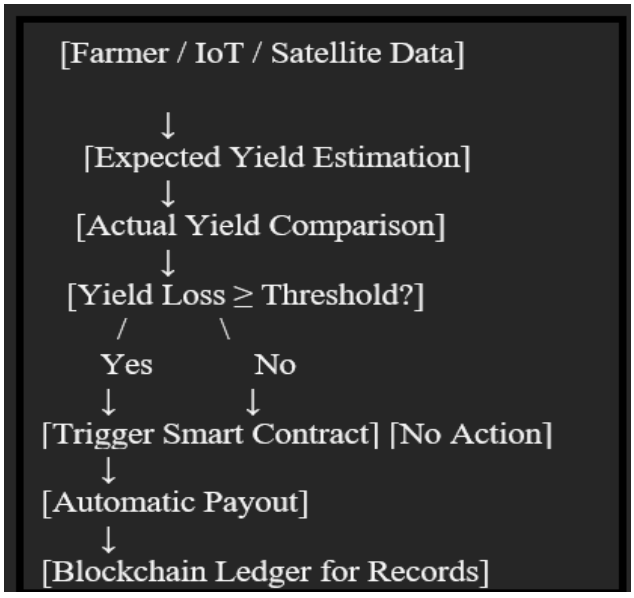

Figure 1: System Workflow of the Proposed Blockchain-Based Crop Insurance Framework

Blockchain Framework for Crop Insurance

The proposed framework includes:

- Farmers: Register crop and yield information

- Oracles: Provide verified data to blockchain
- Smart Contracts: Encode compensation logic
- Insurance Providers: Define policy rules
- Blockchain Ledger: Stores immutable records

Smart contract logic:
IF (yield_loss ≥ threshold)
THEN payout = compensation_rate × loss_amount
Yield Loss Estimation Model:
Example:

- Expected Yield: 100 quintals/acre
- Actual Yield: 60 quintals/acre

Yield Loss = ((100−60)/100) × 100=40%
Since 40% exceeds the threshold, compensation is triggered automatically.
Integration of Blockchain with Risk Compensation

- Yield data is transmitted via oracles
- Smart contracts evaluate loss conditions
- Compensation is transferred to the farmer's digital wallet

The benefits of this model is it is fully automated process, having immutable and verifiable records, faster payouts and reduced disputes.

Results

This section discusses the performance of the proposed blockchain-based crop insurance system using simulation-based analysis. The evaluation focuses on yield estimation accuracy, claim processing time, and administrative cost reduction, as illustrated in figure 2 to figure 4.
Figure 2 compares the yield loss estimation accuracy of weather-based insurance models with the proposed yield-based approach. The proposed system achieves higher accuracy as it directly utilizes actual crop yield data.

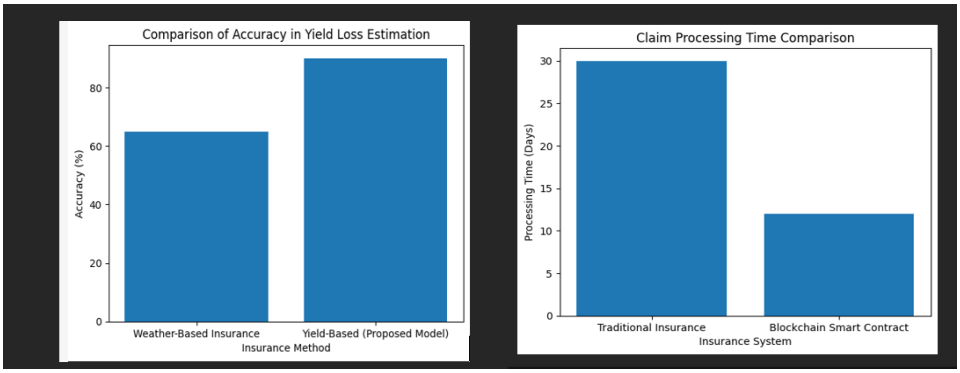

Figure 2: Yield Loss Estimation Accuracy **Figure 3:** Claim Processing Time Comparison

Figure 3 shows a comparison of claim processing time between traditional insurance systems and the proposed blockchain-based approach, where smart contract automation significantly reduces settlement time. Figure 4 presents a comparison of administrative costs between traditional crop insurance systems and the proposed blockchain-based model. Traditional insurance systems incur higher costs due to agent involvement and manual inspections, whereas blockchain-based automation significantly reduces administrative overhead.

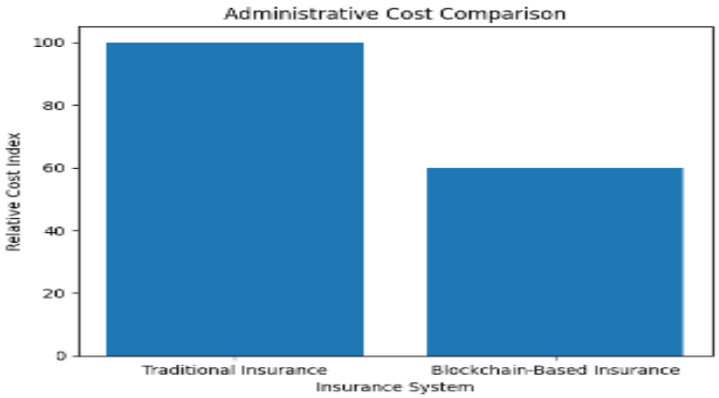

Figure 4: Administrative Cost Comparison between Traditional and Blockchain-Based Insurance Systems

Simulation results indicate:

- 50% reduction in claim processing time
- Improved transparency for farmers
- Lower administrative and operational costs

Table 1: Comparison of existing vs Proposed crop insurance model

Feature	Traditional Insurance	Weather-Based Models	Proposed Model
Trigger Mechanism	Manual inspection	Weather index	Actual yield loss
Automation	Low	Partial	Full
Transparency	Low	Medium	High
Compensation Speed	Slow	Moderate	Fast
Farmer Trust	Low	Medium	High

Conclusion

This research presents a blockchain-based crop insurance framework that uses actual yield loss estimation to trigger automated compensation. Unlike traditional and weather-indexed models, the proposed system ensures transparency, fairness, and timely payouts. By integrating blockchain, smart contracts, IoT, and yield estimation, the system provides a scalable and farmer-centric insurance solution. This paper proposes a yield-based blockchain crop insurance model which integrates IoT, satellite imagery, and farmer data, automates compensation using smart contracts, improves transparency and farmer trust and reduces cost, delay, and disputes.

The future work could be **p**ilot implementation on real that integrates with government crop insurance schemes.

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We also acknowledge the contribution of the broader research community in the fields of blockchain technology, smart contracts, and agricultural risk management, whose published works greatly assisted in shaping the direction of this study.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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