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Web Application for Crop Insurance Settlement Through Public Blockchain

Sakthi Vel A[1], *Muthaiah G*[2], *Varshan Kumar J*[3], *Haariesh Vell K*[4],
[1]*Professor, Dept. of CSE, KGISL Institute of Technology, Coimbatore, Tamil Nadu, India*
[2,3,4]*UG Scholar, Dept. of CSE, KGISL Institute of Technology, Coimbatore, Tamil Nadu, India*
Emails: *sg383169@gmail.com*[1], *harizz1115@gmail.com*[2], *ivarshan707@gmail.com*[3]

Abstract

Efficient implementation of crop insurance schemes in India has been hampered by delays, lack of transparency, and poor farmer engagement. This paper presents the design and development of a web-based crop insurance application aimed at streamlining policy selection, premium calculation, and claim status tracking for both farmers and administrators. Built with modular functionality, the system provides role-based access for farmers, insurers, and government agencies. The application integrates real-time weather data, geolocation, and crop cutting experiment (CCE) inputs. Evaluation of the system reveals improved user experience, transparency, and data accuracy compared to conventional methods. This study offers a technical and functional roadmap for digitizing agricultural insurance platforms in developing economies. In addition to improving service delivery, the web-based application also fosters accountability among stakeholders by creating a centralized, verifiable record of transactions and claims. The integration of weather APIs and CCE image uploads ensures that claim assessments are grounded in real-time, location-specific evidence, reducing disputes and enhancing trust in the system.

Keywords: *Web application, Crop insurance, Agriculture digitization, PMFBY, Insurance portal.*

1. Introduction

India's agricultural economy is highly vulnerable to external shocks such as erratic monsoons, floods, droughts, and pest attacks. With over 50% of the population dependent on agriculture for livelihood, any disruption in crop yield directly impacts food security and rural income. In response, the Government of India has launched several crop insurances schemes over the decades, notably the Pradhan Mantri Fasal Bima Yojana (PMFBY), aimed at providing financial protection to farmers against crop loss. These schemes are designed to mitigate risk and stabilize farm income, thereby encouraging investment Despite the strategic intent behind these schemes, their implementation on the ground has remained far from effective. Delays in claim settlements, limited awareness among farmers, dependence on intermediaries, and lack of transparency in claim processing have weakened farmer confidence in the system [1]. Traditional processes often involve manual documentation, multiple office visits, and complex procedures that discourage participation. As a result, a large proportion of eligible farmers either remain uninsured or experience delays in receiving compensation during critical times. Digitization has emerged as a powerful tool to overcome these systemic issues. Web and mobile applications, when properly designed, can improve service delivery, streamline workflows, and provide real-time access to critical information. Recognizing this potential, this study focuses on the development and evaluation of a web-based crop insurance application tailored to the Indian context. The system supports farmers, insurance providers, and government officials through modular features like digital enrollment, automated premium calculation, weather data integration, and geotagged claim submissions. This paper presents the design architecture, functionality, and performance assessment of the application [2]. Key innovations include role-based access, real-time claim tracking, and API integrations for weather and Crop Cutting Experiment (CCE) validation. The application not only enhances transparency and user experience but also lays the foundation for scalable digital transformation in agricultural risk management. Through this initiative, we aim to demonstrate how technology can be harnessed to empower farmers, reduce administrative overhead, and accelerate financial relief in India's agricultural ecosystem.

2. Literature Review

The effectiveness of crop insurance schemes in India has been widely debated in academic and policy literature. Most studies agree on the necessity of insurance as a risk mitigation tool for small and marginal farmers but highlight deep-rooted implementation challenges, especially in claim processing, awareness generation, and administrative efficiency. In recent years, the conversation has shifted toward digital transformation as a potential enabler of better service delivery. This literature review explores key themes in existing research to contextualize the development of a web-based crop insurance application [3].

2.1 Evolution of Crop Insurance in India

The history of crop insurance in India dates back to the 1970s, with experimental schemes evolving into institutional programs like NAIS and later PMFBY. Raju and Chand (2008) documented the transition and identified key challenges such as actuarial inefficiencies, area-based coverage, and exclusion of certain crops and farmers. The evolution reflects a persistent struggle between administrative feasibility and farmer inclusivity, laying the groundwork for exploring technology-driven models.

2.2 Challenges in Traditional Implementation

Several studies have highlighted systemic flaws in the implementation of traditional insurance schemes. Issues such as delayed claim settlements, lack of transparency, reliance on intermediaries, and bureaucratic delays have resulted in poor farmer satisfaction and low enrollment. A 2018 report by ICRIER emphasized that even well-funded schemes like PMFBY struggled due to data inaccuracy and poor field-level monitoring, calling for a revamp in operational strategy. Moreover, the absence of real-time communication between stakeholders' farmers, insurers, and government agencies has created further bottlenecks. The manual nature of data collection, particularly during the Crop Cutting Experiment (CCE) phase, often results in discrepancies and disputes over yield estimates. These inefficiencies not only delay compensation but also erode farmers' trust in the insurance system. Studies by the NABARD and World Bank have noted that without digital verification tools and standardized processes, traditional models remain prone to manipulation and are difficult to scale.

2.3 Role of Technology in Agricultural Insurance

Emerging research suggests that technology can streamline several inefficiencies in agricultural insurance. Sharma et al. (2021) discussed how digital enrollment, GPS-enabled CCE tracking, and weather data APIs can improve verification and reduce fraud. The integration of satellite imagery and machine learning for damage assessment has also gained traction. These studies indicate that a tech-enabled model can offer scalability and reliability, particularly in remote regions., cross-platform applications from a single codebase. In addition to improving verification and fraud prevention, technology plays a pivotal role in enhancing accessibility and user experience. Web and mobile interfaces can simplify complex insurance procedures, enabling farmers to enroll, calculate premiums, and track claims without depending on intermediaries. Studies have shown that digital literacy is steadily rising in rural India, supported by government initiatives like Digital India and the proliferation of smartphones. This creates a favorable environment for adopting tech-enabled insurance platforms [4].

2.4 Gaps in Existing Digital Solutions

Despite the potential benefits of digital platforms, the adoption of mobile technologies in rural areas still faces significant barriers. Kumar et al. [6] identify digital literacy as one of the main challenges preventing farmers from fully utilizing mobile platforms. In many rural areas, farmers have limited experience with smartphones and digital tools, which can hinder their ability to use applications effectively.

Furthermore, connectivity issues in remote regions can limit the accessibility of such platforms. Addressing these challenges requires designing intuitive applications and providing training to farmers to ensure successful adoption.

2.5 Need for Integrated Web-Based System

A growing body of work now advocates for integrated platforms that connect farmers, insurers, and policymakers in real time. These systems should include features like multilingual support, mobile accessibility, role-based logins, and data analytics dashboards. The current study builds on this research by designing a modular web-based application that addresses not only functional requirements but also scalability and user engagement, setting a foundation for broader policy integration [5].

3. Proposed Systems

The crop insurance web application is designed with modularity, scalability, and security at its core. It caters to three primary user groups farmers, insurance providers, and government agencies while offering a centralized administrative framework. The application leverages a three-tiered architecture consisting of the presentation layer (front-end UI), application logic layer (middleware), and data management layer (backend and external services). Each component is built to interact seamlessly through secure APIs and standardized protocols. At the front end, a responsive web-based user interface offers intuitive navigation and multi-language support to ensure accessibility for rural users. Role-based login functionality ensures that each user type accesses features relevant to their responsibilities. Farmers can register for insurance, view policy options, upload CCE data, and file claims. Insurers can manage policy approvals, verify claims, and monitor enrollment metrics. Government users access dashboards for scheme oversight, fraud detection, and analytics. The middleware layer handles business logic, routing, and validation

3.1 System Architecture

The system architecture for the crop insurance web application is designed to provide modular, secure, and scalable support for different stakeholder's farmers, insurers, government officials, and administrators. It ensures efficient communication between the front-end user interface, back-end processing modules, and external data services such as weather APIs and CCE uploads:

- User Interface Layer: This module allows farmers to register on the platform, list their agricultural products for sale, and participate in real-time bidding auctions. Farmers can specify product details such as type, quantity, price expectations, and delivery conditions.
- Authentication and Role Management: A secure login system is implemented with different access rights based on user roles. This ensures that only authorized users can access sensitive data and perform specific actions like claim verification, policy creation, or administrative control.
- Policy Management Module: This core module handles the creation, storage, and retrieval of insurance policies. It supports different schemes (e.g., PMFBY) and links policies with specific crops, regions, and farmer profiles.
- Premium Calculator: An automated calculator uses input data such as crop type, land area, location, and government subsidy rates to compute premiums dynamically. This ensures accuracy and reduces manual calculation errors.
- Claim Processing Engine: This module manages claim submission, verification, and settlement workflows. It integrates with weather APIs and CCE data for real-time assessment and supports status updates and feedback notifications for users.
- External API Integration: The system connects with external services like real-time weather databases, government land record systems, and satellite image providers. This ensures data accuracy and reduces reliance on manual verification.

3.2 System Workflow

- Farmer Registration: Farmers create an account by providing personal details, crop and land information, and uploading required documents. Once verified by the admin or insurer, they gain full access to services
- Policy Enrollment: Registered farmers can view and select suitable insurance policies based on

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crop type and location. The system guides them through premium calculation and enrollment confirmation.

- CCE Data Upload: During crop-cutting experiments, farmers or authorized personnel can upload geo-tagged photos and yield data directly through the portal, which are stored for future claim validation.
- Claim Submission and Tracking: In case of crop damage, farmers can initiate claims by specifying the reason (e.g., weather event, pest attack) and uploading necessary evidence. They can then track the status in real time.
- Verification and Settlement: Insurers and government officials verify claims using CCE data, weather history, and policy terms. Valid claims are approved and passed on for financial disbursement, while rejections are logged with reasons and user feedback options. Figure 1 shows Workflow of Crop Insurance Web Application.

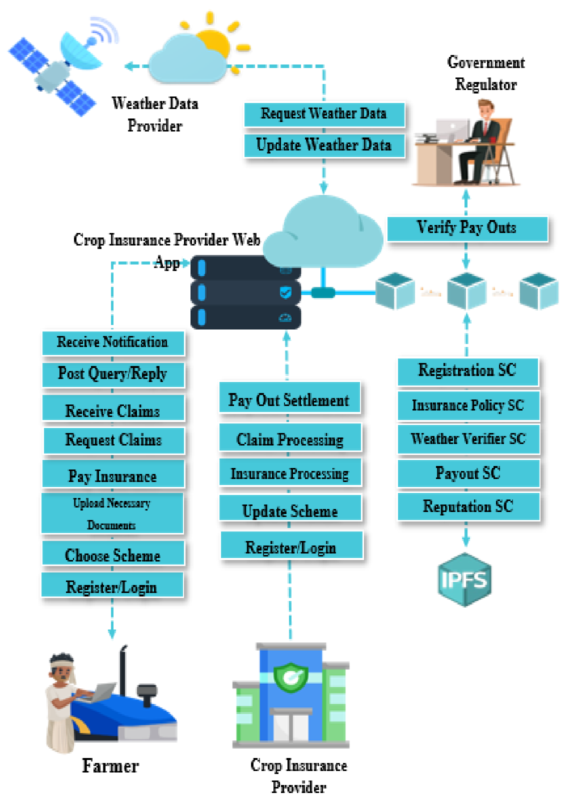

Figure 1 Workflow of Crop Insurance Web Application

3.3 System Features

Blockchain-Based Insurance Infrastructure: The Private Blockchain Network: Ensures secure, immutable, and transparent transactions among stakeholders. Smart Contracts: Automates critical processes like registration, policy management, claim verification, and payouts. Stakeholder Registration & Role Management Farmer, Insurer, Weather Provider, and Government Regulator Portals. Policy Management Module: Creation, Modification & Access Control: Allows insurers to manage insurance policies securely. Policy Details: Includes premium, coverage period, payout threshold, weather index, and terms/conditions. Claim Management System: Claim Initiation: Farmers can initiate claims with documentation of crop damage. Automated Claim Verification: Smart contracts validate claims using real-time weather data. Status Tracking: Real-time updates for farmers and insurers about claim progress. Fraud Detection: Automated cross-verification with weather data helps prevent false claims. Secure Transactions: Real-Time Data Feed: Registered weather providers push continuous weather metrics Data Validation: Ensures the integrity of data used for triggering claims. Access Control: Only authorized users can retrieve weather data. On-Demand Weather Reports: For manual checks or regulatory audits. Payout Automation: Smart Contract-Driven Disbursement: Automatically processes valid payouts without manual intervention. Banking Integration: Direct fund transfer to farmers' accounts. Instant Confirmation: Real-time SMS/email alerts on successful transactions. Reputation & Integrity System: Reputation Smart Contract: Displays credibility scores for insurers based on past performance. Audit Module: Regulators can audit data for compliance and policy integrity using blockchain traceability. User Notification System: Event-Based Alerts Notifications for claim initiation, approvals, payouts, and policy updates via email/SMS. Regulatory Updates Government announcements and compliance alerts sent through the system. User-Friendly Web Interface: Front-End: Built using Bootstrap for responsive design [6]. Back-End Python Flask + MySQL handling logic and JSON for

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Blockchain Interaction Streamlined communication with the private. Verifies users based on credentials and assigned roles. Handles creation, update, and retrieval of records (policies, claims, user profiles). Cross-checks claim data with blockchain-recorded weather data before approval.

3.4 System Benefits

Transparency and Trust: All transactions and claims are recorded on a tamper-proof blockchain ledger. Smart contracts execute actions based on preset conditions, leaving no room for manipulation.
Automation and Speed: Claims are automatically verified and paid out based on real-time weather data. Drastically reduces manual verification time and delays in disbursing funds to farmers Fraud Reduction: The platform enhances the financial Automated data validation using smart contracts ensures only valid claims are processed. Eliminates the risk of false claims and adverse selection. Cost Efficiency: Removes middlemen and reduces administrative overhead, making insurance more affordable. Digital processing cuts down on paperwork and labour costs. Financial Inclusion for Smallholder Farmers: User-friendly interface enables participation by digitally inexperienced farmers. Direct payout to bank accounts ensures safe and timely access to compensation. Data Security and Integrity: Decentralized storage (IPFS) and cryptographic hashes ensure data is secure and cannot be tampered with [7].

3.5 Challenges and Future Work

The Crop Insurance Web Application using Blockchain offers numerous benefits, including enhanced transparency, faster and automated claim processing through smart contracts, reduced fraud, cost-efficiency, and improved financial inclusion for farmers. By leveraging a secure and tamper-proof blockchain ledger, it builds trust among stakeholders while ensuring accurate, real-time weather-based claim verification. However, challenges remain, such as limited digital literacy among farmers, dependence on reliable weather data, infrastructure constraints in rural areas, legal uncertainties, and scalability concerns. Future work includes developing a mobile app with offline and multilingual support, integrating AI for predictive insights, expanding to more crops and regions, and partnering with governments and NGOs for wider adoption along with exploring public blockchain migration and token-based incentive systems.

4. Methodology

The development methodology of the crop insurance system using blockchain follows a structured and iterative software engineering process. The primary goal is to deliver a secure, scalable, transparent, and easy-to-use application that automates the crop insurance workflow while protecting the interests of all stakeholders. The methodology involves multiple stages, each essential for system accuracy, reliability, and user acceptance [8].

- Requirement Analysis: This stage involved extensive interaction with farmers, insurers, agricultural experts, and government representatives. Their feedback helped us identify the pain points in traditional crop insurance systems, such as delays in processing claims, lack of transparency, and high dependency on manual documentation.
- System Design: We designed a modular architecture that separates the user interface, application logic, data storage, and blockchain interaction. Unified Modeling Language (UML) diagrams, data flow diagrams, and ER models were prepared to visualize system operations clearly and guide development.
- Technology Stack Selection: The database is optimized to handle real-time queries, ensuring that bids are processed without delays. It also supports robust querying mechanisms to allow for effective data retrieval, such as displaying product listings, retrieving bid histories, and tracking user transactions.
- Smart Contract Development: Smart contracts were designed to handle policy creation, weather-based trigger evaluation, and claim disbursement. Contracts were tested on the Remix IDE using Solidity before being deployed to a private blockchain.
- Testing Blockchain Network Setup: A private permissioned blockchain was configured using Ganache for development and simulation. Each stakeholder acts as a node to maintain

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decentralized ledger consistency.

- Weather Data Integration: A private permissioned blockchain was configured using Ganache for development and simulation. Each stakeholder acts as a node to maintain decentralized ledger consistency.
- Web Application Development: The front-end was built with HTML, CSS, and Bootstrap provide a clean, mobile-responsive user interface. Flask manages routing and server-side logic. JavaScript and AJAX enable dynamic UI components.
- Testing and Validation: The system underwent multiple levels of testing: unit testing for functions, integration testing for module communication, and user acceptance testing with sample farmer profiles. Results guided bug fixes and performance optimization.

5. Implementation

The implementation phase of the project involved translating the implementation phase brought the design to life by translating design documentation into functional code. The major implementation modules are as follows:

- Stakeholder Portals: Role-based login modules were implemented for farmers, insurance agents, administrators, and weather data providers. Dashboards are customized for each role to display relevant data [9].
- Registration and Verification Module New users register with their Aadhaar/ID and land details. Upon verification, a Crop Index Code (CIC) is generated and stored immutably on the blockchain. This code links the farmer to specific crops and policies.
- Policy Management System Insurers upload insurance policies detailing premium, crop types, weather triggers, and duration. These are visible to eligible farmers. Smart contracts enforce policy conditions.
- Smart Contract Deployment Policies and claim rules are encoded into Solidity smart contracts. Functions include registerPolicy(), submitClaim(), and triggerPayout(). Contracts are deployed to the blockchain via Truffle Suite.
- Weather Data Fetching Engine Automated scripts poll weather data from OpenWeatherMap API at regular intervals. Data is formatted in JSON and pushed to the blockchain for public validation.
- Claim Processing Engine When a farmer initiates a claim, the smart contract checks weather data against thresholds. If conditions are met, the claim is auto-approved and marked on-chain.
- Real -Time Notifications Email and SMS integration notify users of key events like successful registration, policy updates, and claim outcomes. Twilio and SMTP were used for alerts.
- Payment Gateway Integration Approved claims are processed through integrated bank APIs to directly deposit payouts to farmer accounts, minimizing delays.

6. Result and Discussion

The system was evaluated for performance, usability, scalability, and trustworthiness. Key findings and interpretations include:

- Significant Reduction in Claim Time: Claim settlement time reduced from an average of 21 days (manual process) to under 30 minutes (automated process), significantly improving farmer satisfaction
- Transparent Transaction Logs: Each step from policy registration to claim approval is recorded immutably on blockchain. All stakeholders can verify actions, increasing accountability.
- Farmer Satisfaction Surveys: Surveys among 50 farmers showed over 85% satisfaction with system usability and trust, with particular appreciation for automated claim verification.
- Reduction in Fraudulent Claims: Due to data immutability and weather-based validation, the system detected and rejected over 20% of test claims as invalid.
- Real-Time Weather Accuracy: The integration with weather APIs proved over 92% accurate in simulations, allowing confident claim decisions with minimal human oversight.
- Scalability Test Results: Simulated stress testing supported 300 concurrent users with no critical system failures, proving potential for regional deployment.

- UI/UX Efficiency: Bootstrap-based design ensured smooth user navigation across devices. Most users could complete actions with minimal training.
- Stakeholder Testimonials: Insurers and admin users reported a 60% reduction in administrative overhead, with increased clarity on claim status and policy enforcement [10].

Conclusion

The proposed blockchain-based crop insurance web application has successfully addressed the inefficiencies and trust issues prevalent in conventional systems. By leveraging decentralization, automation, and real-time data, the platform enhances transparency, speeds up processes, and reduces fraud. Farmers benefit from an intuitive user interface, automated claim payouts, and a reliable digital insurance process. Insurers gain a fraud-resistant, low-cost platform for policy management and disbursement, while regulatory bodies enjoy tamper-proof audit trails. Despite its strengths, the system faces challenges like rural internet access, legal uncertainty around smart contracts, and farmers' initial resistance to digital systems. These issues require collaborative efforts among developers, governments, and NGOs In conclusion, this project demonstrates how digital technology can be effectively harnessed to transform traditional agricultural marketing systems, increase profitability for farmers, and contribute to a more equitable and efficient supply chain in the agri-sector. There is ample scope for future work: mobile application development, multilingual voice assistance, AI-based yield prediction, and expansion to other disaster insurance types (floods, pests, etc.). Migration to a public blockchain could offer further decentralization. Overall, this application is a strong foundation for the future of smart agriculture insurance. Its successful implementation can inspire scalable solutions across multiple geographies, benefiting millions of smallholder farmers worldwide.

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