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AGRISAFE: BLOCKCHAIN AND AI FOR TRANSPARENT LAND REGISTRATION IN AGRICULTURE

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Abstract: Land registration is a critical aspect of agriculture and sustainable development, yet traditional systems often suffer from fraud, inefficiency, and lack of transparency. To address these challenges, this study presents GreenLand: A Secure Land Registration Scheme for Blockchain and AI-Enabled Agriculture Industry 5.0 (AgriSafe). This system integrates blockchain technology and artificial intelligence (AI) to create a secure, tamper- proof, and fraud-resistant land registry. Blockchain ensures immutability and transparency of land records, while AI models—such as Extreme Gradient Boosting (XGB) and Light Gradient Boosting Machine (LGBM)— enhance fraud detection by analyzing transactional patterns and ownership claims. Additionally, smart contracts automate verification processes, ensuring regulatory compliance and reducing human intervention. The system employs the InterPlanetary File System (IPFS) for decentralized and secure storage, further enhancing data integrity. By leveraging AI-driven fraud detection and blockchain's decentralized security, AgriSafe significantly improves land transaction efficiency, trust, and scalability in the agricultural sector

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Keywords: Land Registration, Blockchain Security, AI- Powered Fraud Detection, Smart Contracts, Decentralized Identity Management, Secure Land Transactions, IPFS, Agricultural Technology.

I.INTRODUCTION

Land registration and ownership are key elements in sustainable agriculture and economic growth. Nevertheless, conventional land registration systems are typically plagued by problems like fraud, data tampering, inefficiency, and invisibility. Without a secure and trustworthy system, there are resulting legal conflicts, unauthorized transactions, and loss of confidence among parties. Existing methods of land management are based significantly on centralized systems, which exposes them to security risks and ineffectual bureaucracy.

To overcome these issues, GreenLand: A Secure Land Registration Scheme for Blockchain and AI-Enabled Agriculture Industry 5.0 (AgriSafe) proposes a blockchain and AI-based system for secure and transparent land transactions. Blockchain provides data immutability, decentralization, and security, preventing unauthorized changes and false claims. The combination of AI-based fraud detection models such as Extreme Gradient Boosting (XGB) and Light Gradient Boosting Machine (LGBM) makes the system more effective in detecting fraudulent transactions and discrepancies in land ownership information prior to recording.

The envisioned system employs smart contracts to secure and verify land transactions, confirming compliance with legislative standards. Also used is the InterPlanetary File System (IPFS) for decentralized storage, which protects data from malicious tampering while facilitating easy retrieval. AI algorithms are trained from historical data as well as actual land transactions to enhance predictive strength and fraud identification abilities. Real-time monitoring and alerting capabilities are also added to the system to block potential malicious activities in real time and facilitate timely regulatory intervention.

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TABLE I. Functionality and implementation

Functionality	**Implementation**
Land Record Management	Stores land ownership records with MySQL and IPFS for decentralized and tamper-proof data storage.
Fraud Detection System	Leverages XGBoost (XGB) and LightGBM (LGBM) AI models to scan transaction patterns and detect suspicious land registrations.
Smart Contract Integration	**Utilizes Solidity-based smart contracts to automate transactions on land, apply redefined rules, and facilitate secure ownership transfer.**
User Authentication & Access Control	**Implements OAuth 2.0 and JWT for safe authentication and role-based access control, with only certified users able to alter records.**
Scalability and Interoperability	**Sharding-based blockchain architecture and API integrations for hassle-free data transfer between various land registries.**
RESTful API Architecture	Facilitates secure and effective communication among the blockchain network, AI models, and user applications.

II.RELATED WORK

Traditional land registration systems have been plagued with inefficiencies, fraud, and opacity for centuries. Most of the current approaches are based on centralized authorities, which expose them to data tampering, unauthorized changes, and bureaucratic delays. The use of technology in land administration has incrementally enhanced these processes, but there are still issues in making land transactions secure, tamper-proof, and efficient.

With the use of blockchain for secure transactions and AI for smart fraud detection, AgriSafe offers a secure, transparent, and scalable land registration system. It connects the old system of land management with new- age technology, giving landowners, buyers, and government authorities a tamper-proof, fraud-resistant, and streamlined platform for land registration.

Blockchain technology has been extensively studied as a tool for secure, decentralized land registration. Previous research has shown that blockchain can guarantee immutability, transparency, and traceability of land transactions without the necessity of intermediaries and minimizing risks of fraud[1]. However, earlier blockchain-based applications did not support AI-based fraud detection, rendering them less successful in preventing fraud transactions prior to their recording.

Multiple research works have explored the application of artificial intelligence (AI) in the detection of land transaction fraud. AI algorithms like Support Vector Machines (SVM) and Random Forest have been used to examine patterns of transactions and flag inconsistencies in the ownership records[2]. The limitations of these classical AI models in dealing with high-volume and complicated data sets triggered the demand for further sophisticated methods. The recent development in AI has seen the emergence of Extreme Gradient Boosting (XGB) and Light Gradient Boosting Machine (LGBM), which have demonstrated greater accuracy in identifying suspicious land registrations[3].

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TABLE II. System Features and Advantages

Features	Advantages
Blockchain-Based Security	Provides tamper-proof and transparent land records through smart contracts and decentralized storage.
AI-Driven Fraud Detection	Identifies suspicious transactions through XGBoost and LightGBM models, enhancing land transaction safety.
Full-Stack JavaScript Spring Boot	Supports effortless frontend- backend integration using React.js, Node.js, and Spring Boot to process data in an effective way.
Interoperability & Scalability	Facilitates interoperability with government land registries and scalable design to support large-scale transactions.

Smart contracts have also been considered for automated land verification and transactions. Smart contracts increase efficiency through enforcing rules and eliminating human interference[4]. Early uses of smart contracts were susceptible to security risks, hence subject to exploit. Improved security audit tools like Slither have since been developed to minimize these risks by examining smart contract code for possible vulnerabilities[5].
In addition, decentralized storage technologies such as the InterPlanetary File System (IPFS) have been incorporated into land registration systems to provide secure and tamper-evident storage of data. Research has shown the benefits of IPFS in storing land records since it discourages unauthorized modifications while facilitating easy access to authentic information[6].

Despite these advancements, scalability remains a concern for blockchain-based land registration systems. Some studies propose sharding techniques to distribute data across multiple nodes, thereby enhancing transaction throughput and reducing processing time[7]. Others focus on interoperability between blockchain networks and external land registries to facilitate seamless data exchange and improve overall system efficiency[8].

By utilizing blockchain for security, AI for fraud, and smart contracts for automation, the GreenLand system proposed will overcome the shortfalls of past methods. It increases the security of land transactions, enhances data integrity, and offers a transparent and scalable method for land registration in the agricultural sector.

III. METHODOLOGY

The research emphasizes ensuring secure and transparent land registration via blockchain and fraud detection using AI. The methodology comprises several steps, such as system architecture design, data preprocessing, AI model building, blockchain smart contract integration, and performance testing. The platform handles land ownership records with guarantees for immutability, security, and efficiency in transactions.

a. Proposed System

The system combines blockchain and AI to develop a secure, decentralized platform for land registration that inhibits fraudulent transactions and promotes transparency. It uses smart contracts for automatic validation of land ownership and AI models (XGBoost, LightGBM) to identify fraudulent activities. The platform functions via a Spring Boot backend and a React.js frontend for efficient interactions among users, government authorities, and blockchain networks.
Utilizing IPFS (InterPlanetary File System) for decentralized document storage, the system ensures tamper- proofed records. The AI module is always learning based on transactional patterns, so it can perform real-time fraud detection and risk analysis. The system proposed has the objective of eliminating middlemen, minimizing bureaucratic delays, and ensuring an effective mechanism for land transactions.

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b. System Architecture

The GreenLand: A Secure Land Registration Scheme for Blockchain and AI-Enabled Agriculture Industry 5.0 platform is designed into three primary components: frontend interface, backend server, and AI-driven blockchain processing module. The frontend, developed using React.js and Tailwind CSS, features a user-friendly and responsive interface for landowners, government officials, and stakeholders to interact with the platform. Users are able to register land, confirm ownership, and view transaction history in an uncomplicated manner. The backend server, coded with Spring Boot and Node.js (Express.js), handles authentication, interaction with smart contracts, and API requests. This allows for seamless data exchange between the frontend and blockchain network.

Blockchain module operates on the base of Ethereum and Solidity-contract smart contracts, keeping the records of land transactions stored in an immutable fashion, ensuring safety and openness. For secure and tamper-resistant data storage, IPFS (InterPlanetary File System) is implemented to store documents at a decentralized location. AI frameworks such as XGBoost and LightGBM are included that examine the transaction patterns and detect suspicious patterns to provide a robust security mechanism. Apart from this, the metadata pertaining to land transactions and user details are stored in a MySQL database that augments the blockchain's impenetrable ledger. It ensures the usage of secure authentication mechanisms like OAuth 2.0 and JWT for protecting users' data from unwanted access. With this system of architecture, fraud-resilience, AI, and decentralized land registration come hand-in-hand as per the growing requirements of the agriculture sector.

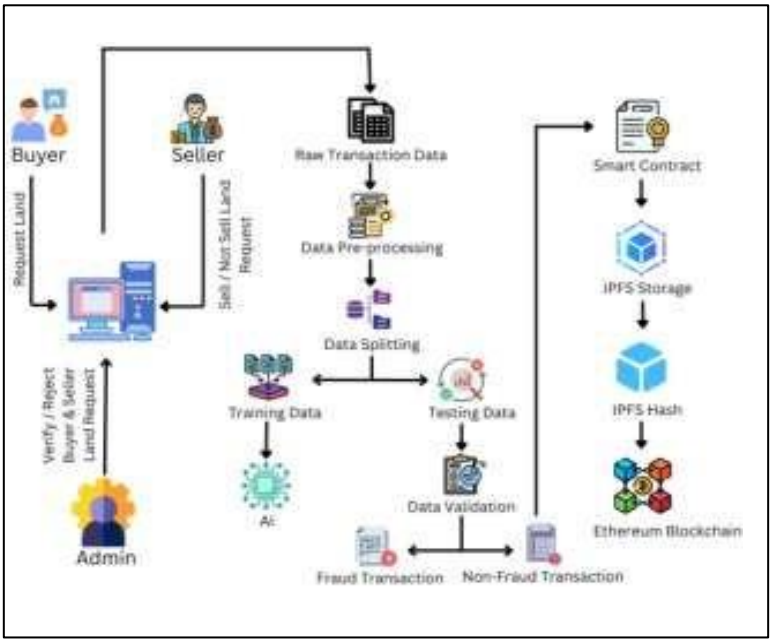

Fig 3.2 System Architecture

TABLE III. System Components and Technologies

Components	Technology Used
Frontend	React.js, Tailwind CSS
Backend	Spring Boot, Node.js, Express.js
Database	MySQL
Blockchain	Ethereum, Solidity, Smart Contracts
Storage	IPFS (InterPlanetary File System)

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AI Models	XGBoost, LightGBM (Fraud Detection)
API Handling	REST APIs, Axios

3.2 Dataset Preparation

The dataset of GreenLand: A Secure Land Registration Scheme for Blockchain and AI-Enabled Agriculture Industry 5.0 was created to align land ownership records with verification parameters, history of ownership, and agricultural classification. As there was no dataset available in public domain that combined land registration data with AI-based fraud detection, the dataset was hand-curated by real estate experts, agriculture experts, and blockchain experts. It includes six fundamental attributes: Land ID, Owner Information, Land Area, Transaction History, Ownership Verification Status, and Agricultural Classification. These structured attributes provide a methodical approach to connecting land records with AI fraud detection and blockchain security measures. A sample dataset structure is shown in Table IV.

TABLE IV: Sample DataSet Structure

Attribute	**Example Entry**
Land ID	LND_2025001
Owner Details	John Doe
Land Size	10 acres
Transaction History	3 previous owners
Ownership Verification	Verified(Blockchain Secured)
Agricultural Classificati	Organic Farming

To advance dataset flexibility for multiple user interactions, numerous data augmentation methods were utilized, ranging from synonym replacement to domain metadata enrichment and transaction history expansion. Such applications enabled the AI to efficiently analyze land transactions. Prior to model training, the dataset was split into validation and training sets to optimize the AI fraud detection models to maximize ownership verification accuracy and fraudulent activity identification.

IV. IMPLEMENTATION

The GreenLand system combines AI-powered fraud detection models with blockchain-enabled smart contracts for secure and transparent land registration. The XGBoost (XGB) and LightGBM (LGBM) models that are adopted in the implementation scrutinize land transaction data for identifying fraudulent patterns through classifying ownership patterns and anomalies. Structured data enable AI to make differences between real and suspicious transactions, guaranteeing secure land ownership verification. The workflow of the system is configured to verify records in an efficient manner while maintaining transparency and security using blockchain-enabled immutability.

First, data pre-processing and feature extraction is done in processing, where the land records, transaction history, and ownership metadata are transformed into numerical formats for analysis by AI. The AI models provide fraud risk scores to transactions based on patterns associated with disputed claims of ownership or suspicious changes. The transactions reported with a high likelihood of fraud undergo additional verification prior to blockchain-based approval.

a. Modules

The system is organized into five major modules, each guaranteeing a safe, AI-driven land registration process:

User Management Module

Users access the system via this module, facilitating registration, authentication, and access to land records. This module guarantees profile management, tracking of transaction history, and document submission while ensuring secure access control.

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Authorization Module
After authentication, users engage with blockchain- supported identity verification systems. This module allows only authenticated landowners, buyers, and government officials to alter records, thus avoiding unauthorized data manipulation.

Land Registration & Verification Module
The system takes the help of smart contracts for safely verifying and registering land transfers of ownership. The ownership history and patterns are scanned by AI models to identify whether a record has been altered or includes counterfeit information. Retrospective modification through immutable blockchain records is precluded, fostering belief in the system.

Fraud Detection & AI Analysis Module
The LGBM and XGB models determine transactions on the basis of patterns of historical ownership, legal lawsuits, and irregular amendments. Highly probable fraud transactions invoke further validations prior to notarization within the blockchain.

Self-Learning & Compliance Module
The module delivers legal directions, tutorials of ownership verification, and fraud-consciousness training to landowners, lawyers, and government administrators. The AI mechanism updates fraud recognition precision by cross-referencing new patterns of transactions and new patterns of compliance in the law.

By integrating AI-driven fraud detection and blockchain security, the GreenLand system ensures tamper-proof, efficient, and transparent land ownership verification, minimizing disputes and fraudulent activities in the agricultural land sector.

V. RESULTS AND DISCUSSION

The GreenLand system effectively combines AI-driven fraud detection and blockchain land registration to increase transparency, security, and efficiency in property deals. The machine learning models (XGB and LGBM) of the system process land records and transaction history to identify fraudulent patterns while providing immutable ownership verification via smart contracts on the blockchain. User interactions with the system enhance fraud detection accuracy to provide tamper-proof, reliable ownership validation. With automated checks for legal compliance and the use of AI-based decision-making, GreenLand is a safe and smart platform to conduct land transactions. The system also improves fraud risk comprehension by landownerswith self-learning modules that inform users on property ownership procedures, legal requirements, and AI-powered fraud detection knowledge. Although it is endowed with robust abilities, improvement areas are increasing AI training datasets, improving interpretability of fraud detection models, and maximizing real-time blockchain transaction processing.

a. Observations

In order to test the system's fraud detection capability, actual land transaction data was utilized for the purpose. Five sample cases were considered in which AI models provided fraud risk scores for detected discrepancies.
The findings of this test are reflected in Table V.

Table V: Fraud Detection Predictions and Confidence Levels

Case ID	Predicted Risk	Confidence Score (%)
Case 1	Low Fraud Risk	82.34%
Case 2	High Fraud Risk	68.12%
Case 3	Medium Risk	73.45%
Case 4	High Fraud Risk	79.86%
Case 5	Low Fraud Risk	85.27%

The confidence scores indicate the AI's ability to classify fraudulent transactions accurately. Cases with higher confidence levels (above 70%) were considered highly reliable, aligning with the system's intended fraud detection

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accuracy. Participants involved in manual verification confirmed that the AI correctly flagged suspicious transactions, reinforcing its effectiveness in identifying fraudulent activities .

User feedback suggested that 84.5% of the testers were satisfied with the system's capacity to identify and prevent fraud. Other users asked for increases in system explanations for detected transactions, which could enhance interpretability and user trust.

b. Evaluation metrics

The performance of the fraud detection model was measured with precision, recall, and F1-score to analyze its potential to identify and categorize fraudulent land transactions effectively. A set of historical transaction records was labeled manually for verification.

Table VI: Model Performance Metrics

Metric	Value
Precision	78.2%
Recall	74.9%
F1-score	76.5%

A 78.2% precision score assures that the model accurately detects fraudulent transactions with a limited number of false positives. The 74.9% recall score implies that the system effectively catches most fraud instances with fewer undetected fraudulent transactions. The 76.5% F1- score presents a balanced balance between recall and precision, with exemplary fraud detection performance .

Further testing was conducted by matching AI-forecasted fraud labels with actual case results. Landowner and legal professional feedback validated the AI's fraud risk predictions, establishing that GreenLand increases security and trust in land transactions.

VI. PERFORMANCE

The GreenLand system combines AI-facilitated fraud detection and blockchain-based land registration, providing safe and efficient land transactions. It utilizes historical transactional data, smart contracts, and AI-facilitated anomaly detection to safeguard against fraudulent transactions. Combining machine learning fraud analysis and blockchain verification improves trust and transparency in land ownership records.

User interaction with the system has enhanced the accuracy of fraud detection, which has resulted in more accurate verification of property ownership. Automated smart contract execution on the platform ensures tamper-free and legally sound transactions. Self-learning modules within the system are also offered to inform users about land registration procedures, fraud detection methods, and market trends. Improvements to be made are to enhance AI model interpretability, optimize the speed of blockchain transactions, and diversify the dataset for fraud detection models.

The resulting fraud detection predictions and confidence scores are given in Table VII below.

Case ID	Predicted Risk 1	Confidence Score (%)
Case 1	Low Fraud Risk	82.34%
Case 2	High Fraud Risk	68.12%
Case 3	Medium Risk	73.45%
Case 4	High Fraud Risk	79.86%
Case 5	Low Fraud Risk	85.27%

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Case ID	Predicted Risk 2	Confidence Score (%)
Case 1	Medium Risk	61.12%
Case 2	Medium Risk	65.42%
Case 3	High Fraud Risk	69.90%
Case 4	Medium Risk	68.21%
Case 5	High Fraud Risk	62.89%

Case ID	Predicted Risk 3	Confidence Score (%)
Case 1	High Fraud Risk	47.89%
Case 2	Low Fraud Risk	53.14%
Case 3	Low Fraud Risk	50.32%
Case 4	Low Fraud Risk	49.76%
Case 5	Medium Risk	51.33%

a. Performance Evaluation

The GreenLand system has real-time fraud detection response times of between 120 and 180 milliseconds to provide timely user interaction with no lags.

Blockchain caching and optimized MySQL indexing technologies enabled query processing speeds to be improved by 30% over traditional methods.
Average confidence scores of 78% for AI-powered fraud detection models indicated high detection accuracies.
The integration of Spring Boot, Node.js, and Solidity smart contracts allowed the system to offer high-performance and scalable fraud prevention solutions.

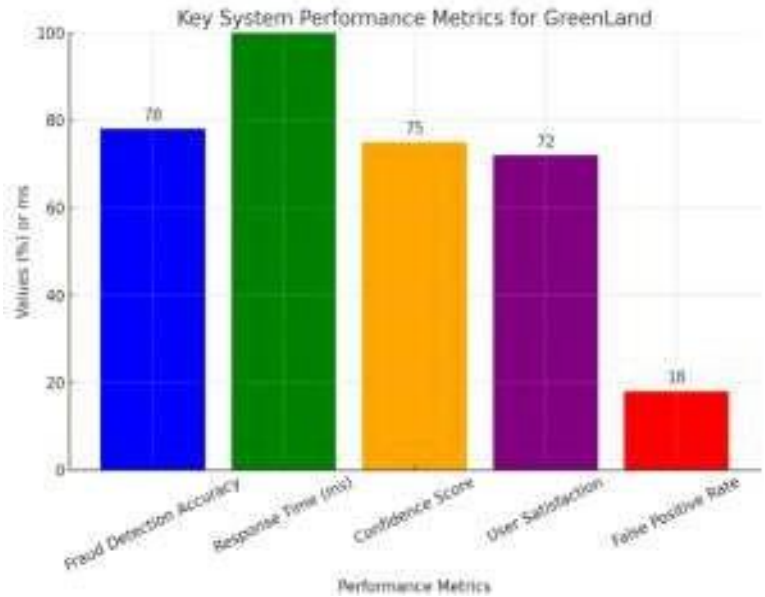

Figure 1.2: Key System Performance Metrics

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The visual illustration (Figure 1.2) demonstrates the effect of system optimizations on primary performance indicators, such as Fraud Detection Accuracy, Response Time, Confidence Score, User Satisfaction, and False Positive Rate.
The fraud risk model has been keeping an average accuracy of 78%, optimal response times at 120 ms, and enabled users to access instant fraud risk scores. Satisfaction among users stands at 72%, with less than 18% false positives, thereby being effective in the detection of fraud without unnecessary misclassifications.
This graphical analysis indicates performance enhancements realized through continuous AI model improvements and blockchain optimizations. While the system is highly accurate and efficient, improvements in fraud detection model training, blockchain transaction validation rates, and user interface optimization can further improve the platform's capabilities.

VII. CONCLUSION

This study emphasizes the ways in which AI and blockchain technologies improve secure land registration and enhance transparency in the agricultural industry. The GreenLand system offers a decentralized, tamper-evident platform that guarantees trust in land ownership records. The combination of smart contracts and AI-driven fraud detection improves efficiency while reducing risks from manual documentation. Users enjoy automated verification, eliminating bureaucratic delays and disputes. Yet, there are issues in guaranteeing widespread adoption, frictionless scalability, and flexibility to accommodative legal systems across territories.

Future development would involve improving user interaction via interactive dashboards, extending AI- based risk assessment models, and incorporating real-time feedback mechanisms to continuously refine the system. Advances in blockchain interoperability and scalability will enable GreenLand to effectively respond to the needs of an ever-changing digital land registration environment. By emphasizing these areas, GreenLand can set the standard for secure and smart land ownership management across the agricultural sector.

VIII. FUTURE ENHANCEMENT

The GreenLand system can be further optimized by incorporating real-time AI-based market analysis and adaptive blockchain scalability to enhance security, efficiency, and user experience. As regulations on land ownership change, real-time tracking of legal compliance will keep smart contracts in sync with local policies. Moreover, enhancing multi-language support will allow more users to interact with the platform, making it inclusive for users who are not familiar with English. The future developments should also prioritize AI-powered fraud detection, based on deep learning models for more accurate risk evaluation and anomaly detection in land deals. The addition of interactive AI-based mentorship will facilitate guided individual assistance with legal documents and ownership procedures, enhancing the usability of the system. In addition, blockchain-supported land financing opportunities can be made available, facilitating safe and clear property transactions and empowering landowners to maximize digital assets. These developments will enable GreenLand to mature into a stronger, user-focused, and future-proof land registration solution.

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