

Blockchain-Enabled Digital Land Registry with AI-Driven Validation for Agriculture 5.0

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Abstract— Reliable land ownership records are essential for sustainable agricultural development, yet conventional land registration systems often depend on centralized databases that are susceptible to unauthorized modifications, security threats, and inefficient verification processes. To overcome these limitations, this study presents a blockchain-enabled digital land registry integrated with Artificial Intelligence (AI) for Agriculture 5.0. The proposed framework employs blockchain technology to maintain transparent, decentralized, and immutable records of land transactions, while the InterPlanetary File System (IPFS) securely stores associated land documents in a distributed environment. Smart contracts automate the registration and ownership transfer process, ensuring accuracy and reducing manual intervention. To strengthen transaction validation, several machine learning models, including Logistic Regression, Random Forest, Support Vector Machine (SVM), XGBoost, and LightGBM, are evaluated for identifying fraudulent activities. Experimental analysis shows that the LightGBM model delivers the best performance with an accuracy of 99.35%, while a CNN2D-based deep learning model further improves the detection accuracy to 99.52%. A web-based application demonstrates the practical implementation of the proposed framework, enabling secure land registration, intelligent transaction validation, and efficient fraud prevention. The results indicate that the proposed approach offers a dependable and transparent solution for modern agricultural land management.

Keywords— Blockchain, Digital Land Registry, Agriculture 5.0, Artificial Intelligence, Smart Contracts, Ethereum, IPFS, Fraud Detection, Machine Learning, Land Management.

I. INTRODUCTION

The rapid advancement of digital technologies has transformed agricultural practices by improving productivity, resource utilization, and decision-making. Agriculture 5.0 encourages the integration of technologies such as Artificial Intelligence (AI), Blockchain, and the Internet of Things (IoT) to build intelligent and sustainable agricultural ecosystems [5]. Among these technologies, blockchain offers a decentralized and tamper-resistant platform for managing digital records, while AI supports intelligent analysis and automated decision-making. However, conventional land registration systems still face challenges such as unauthorized data modification, ownership disputes, and limited transparency because they rely on centralized databases. Integrating blockchain with AI provides a secure and reliable approach for protecting land ownership records, enhancing transparency, and supporting efficient digital land administration in Agriculture 5.0 [1], [10].

Traditional land registration systems often depend on centralized databases and manual verification procedures, making them vulnerable to fraud, unauthorized access, and administrative delays. These limitations reduce trust among landowners and government authorities while increasing the risk of duplicate registrations and ownership conflicts [2]. Blockchain technology addresses these challenges by storing transaction records in a distributed ledger where approved data cannot be altered without network consensus. In addition, Ethereum-based smart contracts automate ownership verification and land transfer according to predefined rules, reducing manual intervention and improving operational efficiency [3]. This decentralized approach strengthens transparency, accountability, and security in modern agricultural land management systems [13].

Although blockchain ensures secure record storage, it cannot determine whether every transaction submitted to the network is legitimate before validation. To overcome this limitation, the proposed framework integrates Artificial Intelligence (AI) to analyze transaction patterns and identify suspicious activities before approval [11]. Machine learning algorithms, including Logistic Regression, Random Forest, Support Vector Machine (SVM), XGBoost, and LightGBM, are employed to classify transactions using historical blockchain data. Their performance is evaluated to identify the most reliable model for secure transaction validation and fraud detection [15]. By combining AI with blockchain technology, the framework improves transaction reliability, minimizes fraudulent activities, and strengthens confidence in digital land registration for Agriculture 5.0 [5].

To further improve fraud detection, the proposed framework incorporates a two-dimensional Convolutional Neural Network (CNN2D) that automatically extracts meaningful features from transaction data. The deep learning model enhances classification performance by identifying complex relationships that may not be captured by conventional machine learning techniques [20]. The framework also utilizes the InterPlanetary File System (IPFS) to securely store land-related documents, while blockchain stores only the generated hash values to maintain data integrity and reduce storage requirements. Furthermore, Ethereum smart contracts automate land registration and ownership transfer, ensuring transparent and secure execution of every transaction without relying on intermediaries [3]. This integrated architecture provides an efficient and scalable solution for secure agricultural land administration [4].

The proposed blockchain-enabled digital land registry combines blockchain, AI, IPFS, and smart contracts to establish a secure platform for agricultural land management. A web-based application enables users to register land, submit ownership transfer requests, and verify transaction status through a transparent interface. AI-based validation identifies suspicious transactions before approval, while blockchain permanently records verified transactions to ensure accountability and traceability throughout the registration process [10]. Experimental evaluation demonstrates that intelligent machine learning and deep learning models significantly improve fraud detection and strengthen the reliability of digital land registration systems [15]. Therefore, the proposed framework

provides a secure, transparent, and scalable solution that supports digital governance and advances the objectives of Agriculture 5.0 [5].

II. RELATED WORK

Nakamoto et al., [2008] [1] introduced Bitcoin as the first decentralized digital currency that operates without the involvement of a central authority. The proposed system uses blockchain technology to record transactions in a distributed ledger, ensuring transparency and preventing unauthorized modifications. The study explained how cryptographic techniques and the Proof-of-Work consensus mechanism secure transaction records and eliminate the problem of double spending. Every transaction is verified by participating nodes before being permanently added to the blockchain, making the ledger highly reliable and tamper-resistant. The decentralized architecture also removes dependence on trusted third parties, increasing system security and transparency. This work established the foundation for modern blockchain applications beyond cryptocurrency. Today, the concepts introduced in this research are widely adopted in areas such as digital identity, healthcare, supply chain management, and secure land registration, where data integrity and trust are essential.

Zheng et al., [2017] [5] presented a comprehensive overview of blockchain technology by explaining its architecture, operating principles, consensus mechanisms, and practical applications. The authors described how blockchain enables decentralized data management while maintaining transparency, traceability, and security across distributed networks. The study discussed different consensus algorithms, including Proof-of-Work and Proof-of-Stake, and analyzed their strengths and limitations in various environments. In addition, the authors highlighted the growing use of blockchain in finance, healthcare, supply chain management, and government services. They emphasized that blockchain improves data integrity by preventing unauthorized modifications and maintaining permanent transaction records. The paper also identified several research challenges, including scalability, privacy, and energy consumption. This survey provides valuable insights into blockchain technology and serves as an important reference for researchers developing secure digital systems based on decentralized architectures.

Wood et al., [2014] [3] introduced Ethereum as a decentralized blockchain platform capable of executing programmable smart contracts and

decentralized applications. Unlike earlier blockchain systems that mainly supported cryptocurrency transactions, Ethereum provided a flexible environment where developers could create applications with customized business logic. The study explained the role of the Ethereum Virtual Machine (EVM), which executes smart contracts securely across all participating nodes. Smart contracts automatically enforce predefined rules without requiring third-party intervention, improving transparency and reducing operational costs. The platform also supports secure storage of transaction records while maintaining decentralization and immutability. Ethereum has become one of the most widely adopted blockchain platforms for developing applications in finance, healthcare, supply chain management, and digital governance. The concepts presented in this work continue to support research on secure land registration and automated transaction management using blockchain technology.

Ke et al., [2017] [15] proposed LightGBM, a highly efficient gradient boosting framework designed to improve the speed and accuracy of machine learning models. The authors introduced innovative techniques such as Gradient-based One-Side Sampling (GOSS) and Exclusive Feature Bundling (EFB), which significantly reduce computational complexity while maintaining predictive performance. The framework efficiently handles large-scale datasets and high-dimensional features, making it suitable for classification, regression, and ranking tasks. The study demonstrated that LightGBM requires less memory and shorter training time compared with many traditional boosting algorithms. Experimental results showed that the proposed model consistently achieved high prediction accuracy across multiple benchmark datasets. Due to its computational efficiency and scalability, LightGBM has become widely used in fraud detection, financial analytics, healthcare, and cybersecurity. This work provides an effective solution for developing intelligent prediction systems using large transactional datasets.

Krizhevsky et al., [2012] [20] introduced a deep Convolutional Neural Network (CNN) architecture that significantly improved image classification performance on the ImageNet dataset. The proposed model demonstrated the ability of deep learning to automatically extract meaningful features from raw input data without relying on manual feature engineering. The study incorporated multiple convolutional and pooling layers to capture complex patterns and hierarchical representations, resulting in superior classification accuracy. The authors also utilized Graphics Processing Units (GPUs) to

accelerate the training process and enable efficient learning from large datasets. The success of this architecture established CNNs as one of the most influential deep learning models for pattern recognition. Although initially developed for image analysis, CNN-based approaches are now widely applied to structured datasets, fraud detection, medical diagnosis, and intelligent decision-support systems because of their strong feature learning capabilities.

III. DATASET DETAILS

The dataset used in this study is the Ethereum Fraud Detection Dataset, which contains blockchain transaction records collected from Ethereum-based financial activities. It includes several transaction-related attributes such as sender and receiver addresses, transaction values, gas usage, block information, contract interactions, and other blockchain features that help characterize each transaction. Every record is labeled as either fraudulent or legitimate, allowing the dataset to be used for supervised machine learning and deep learning tasks. The dataset is organized in a structured tabular format, making it suitable for data preprocessing, visualization, and predictive analysis. Since blockchain transactions generate large volumes of data, the dataset provides sufficient diversity for identifying normal and suspicious transaction patterns. It serves as the primary source for training and evaluating fraud detection models within the proposed blockchain-enabled land registry framework. Using this dataset enables the system to validate land transactions more accurately and improve the security of digital land ownership verification.

Before training the machine learning models, the dataset undergoes several preprocessing steps to improve data quality and prediction performance. Initially, duplicate and incomplete records are identified and removed to ensure consistency throughout the dataset. Missing values are handled using appropriate preprocessing techniques, while irrelevant attributes that do not contribute to fraud detection are excluded from the analysis. Numerical features are normalized to maintain a common scale, allowing different algorithms to learn more effectively without being influenced by variations in feature ranges. The processed dataset is then divided into training and testing subsets, where 70% of the records are used for model training and the remaining 30% are reserved for performance evaluation. This data partition enables the proposed models to learn transaction behavior from historical records while validating their ability to classify

previously unseen blockchain transactions accurately. Proper dataset preparation significantly contributes to reliable fraud detection and overall system performance.

IV. PROPOSED METHODOLOGY

The proposed system provides a secure and intelligent approach for managing digital land registration by integrating blockchain technology with machine learning-based fraud detection. Initially, users such as buyers and sellers register and log in to the system through a secure authentication process. When a buyer submits a land transaction request, the related transaction details are uploaded to the InterPlanetary File System (IPFS), while the generated IPFS hash is permanently stored on the Ethereum blockchain using smart contracts. This combination ensures that transaction records remain tamper-resistant, transparent, and easily verifiable. Before fraud detection, the transaction dataset undergoes preprocessing, where missing values are handled, categorical attributes are converted into numerical form, and relevant features are selected using the ANOVA feature selection technique. The processed data is then divided into training and testing sets to build reliable prediction models.

After preprocessing, multiple machine learning algorithms, including Logistic Regression, Support Vector Machine (SVM), Random Forest, XGBoost, and LightGBM, are trained and evaluated using the prepared dataset. Their performance is measured using evaluation metrics such as accuracy, precision, recall, F1-score, confusion matrix, and ROC curve. Among all the tested models, LightGBM achieves the highest prediction accuracy and is selected as the final model for fraud detection. Whenever a new land transaction is uploaded, the trained model predicts whether the transaction is legitimate or fraudulent before it is forwarded to the seller for approval. Based on the prediction results, the seller can accept or reject the request, and the final decision is securely recorded on the blockchain. This integrated methodology enhances transaction security, improves fraud detection accuracy, and provides a transparent and trustworthy digital land registration system.

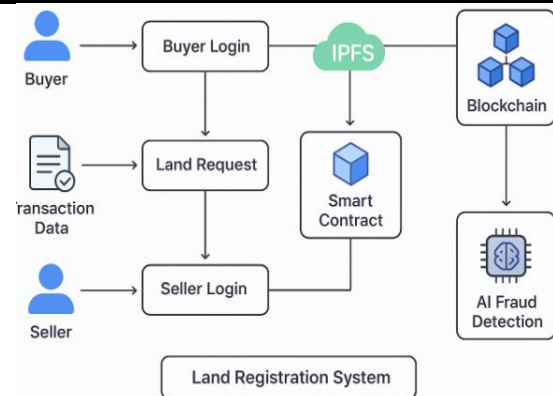


Figure [1]: Land Registration Framework

Figure [1] shows the workflow of the proposed blockchain-based land registration system. The buyer logs into the system and submits a land request with the required transaction details. The transaction data is stored securely in IPFS, while the corresponding hash value is recorded on the blockchain through smart contracts. The seller reviews the request, and the AI-based fraud detection module analyzes the transaction to identify fraudulent activities. Based on the prediction result, the seller approves or rejects the request. This framework ensures secure storage, transparent transactions, and reliable land ownership verification.

V. RESULT AND DISCUSSION

The experimental results demonstrate the effectiveness of the proposed blockchain-enabled digital land registration framework in providing secure transaction management and accurate fraud detection. The Ethereum fraud detection dataset was first preprocessed by handling missing values, converting categorical attributes into numerical form, and selecting the most relevant features for model training. The processed dataset was then divided into training and testing sets to evaluate the performance of different machine learning algorithms. Logistic Regression, Support Vector Machine (SVM), Random Forest, XGBoost, and LightGBM were trained and compared using evaluation metrics such as accuracy, precision, recall, F1-score, confusion matrix, and ROC curve. Among the machine learning models, LightGBM achieved the highest accuracy of 99.35%, demonstrating its ability to identify fraudulent blockchain transactions with high reliability. To further improve prediction performance, a CNN2D-based deep learning model was implemented, which increased the overall accuracy to 99.52%. The developed web application also validated the

practical implementation of the proposed framework by enabling secure land registration, transparent transaction processing, real-time fraud detection, and reliable ownership verification through Blockchain, IPFS, and Artificial Intelligence.

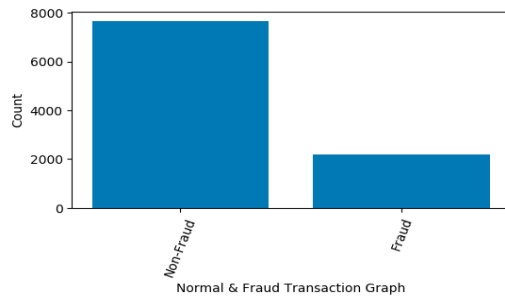


Figure [2]: Fraud and Non-Fraud Transaction Distribution

Figure [2] shows the distribution of fraudulent and non-fraudulent transactions in the Ethereum fraud detection dataset. The graph indicates that non-fraud transactions are significantly higher than fraud transactions. This visualization helps understand the dataset distribution and supports the development of effective fraud detection models.

XGBoost Accuracy : 99.3227226549272
XGBoost Precision : 99.34715394128673
XGBoost Recall : 98.71661967781486
XGBoost FSCORE : 99.82751157567495

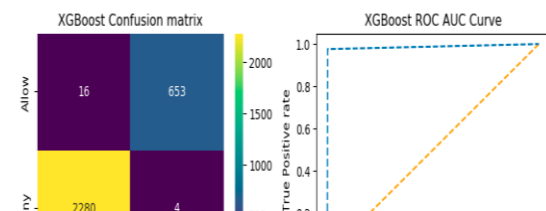


Figure [3]: XGBoost Model Performance

Figure [3] shows the performance evaluation of the XGBoost model on the Ethereum fraud detection dataset. The model achieved an accuracy of approximately 99.32%, with high precision, recall, and F1-score values. The results indicate that XGBoost effectively identifies fraudulent and non-fraudulent blockchain transactions, providing accurate and reliable fraud detection.

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[LightGBM] [Info] Number of positive: 1518, number of negative: 5378
[LightGBM] [Warning] Auto-choosing col-wise multi-threading, the overhead of testing was 0.008894 seconds.
You can set 'force_col_wise=true' to remove the overhead.
[LightGBM] [Info] Total Bins 3738
[LightGBM] [Info] Number of data points in the train set: 6888, number of used features: 17
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.219222 -> initscore=-1.270287
[LightGBM] [Info] Start training from score -1.270287
LightGBM Accuracy : 99.35650652218083
LightGBM Precision : 99.42306189772825
LightGBM Recall : 98.73851189557879
LightGBM FSCORE : 99.87564856624368
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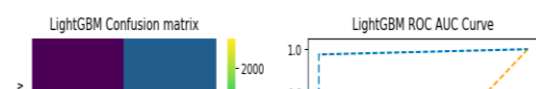


Figure [4]: LightGBM Model Performance

Figure [4] shows the performance evaluation of the LightGBM model on the Ethereum fraud detection dataset. The model achieved an accuracy of approximately 99.35%, along with high precision, recall, and F1-score values. The results indicate that LightGBM provides highly accurate and reliable classification of fraudulent and non-fraudulent blockchain transactions, making it the best-performing machine learning model in the proposed system.

Extension CNN2D Accuracy : 99.52598585844904
Extension CNN2D Precision : 99.69538729329852
Extension CNN2D Recall : 98.95366218236174
Extension CNN2D FSCORE : 99.31852737824747

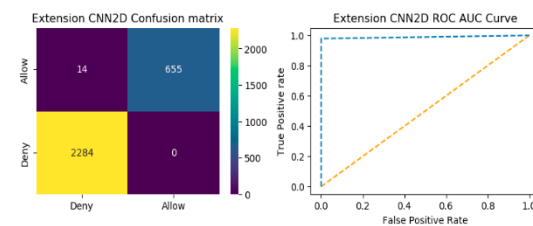


Figure [5]: CNN2D Model Performance

Figure [5] shows the performance evaluation of the CNN2D model on the Ethereum fraud detection dataset. The model achieved an accuracy of approximately 99.52%, with high precision, recall, and F1-score values. The results demonstrate that the CNN2D model accurately classifies fraudulent and non-fraudulent blockchain transactions, providing the highest prediction performance among all the evaluated models.

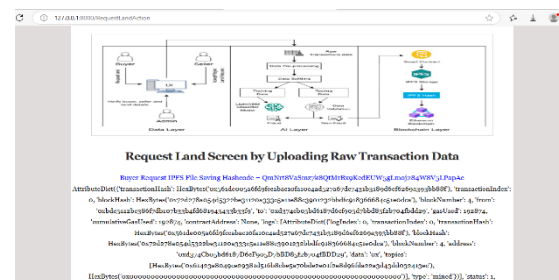


Figure [6]: Land Transaction Request and Blockchain Storage

Figure [6] shows the land transaction request process in the proposed system. The buyer uploads the transaction details, which are securely stored in the InterPlanetary File System (IPFS). The generated IPFS hash and transaction information are then recorded on the Ethereum blockchain through smart contracts. This process ensures secure storage, data integrity, and transparent verification of land transactions.

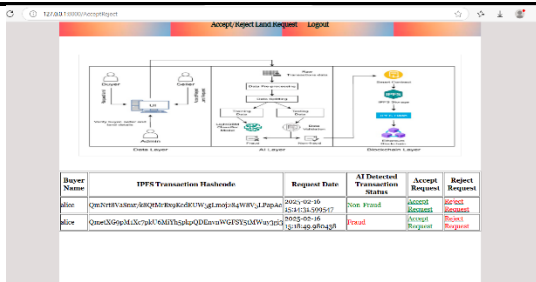


Figure [7]: Land Request Verification and Approval

Figure [7] shows the land request verification process performed by the seller. The AI module first analyzes each transaction and classifies it as Fraud or Non-Fraud. Based on the prediction result, the seller can accept or reject the land request. This process enhances transaction security and supports transparent decision-making in the proposed land registration system.

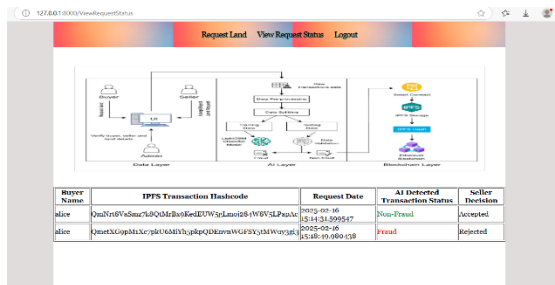


Figure [8]: Land Request Status

Figure [8] shows the final status of land transaction requests after AI-based validation and seller verification. The table displays the IPFS transaction hash, request date, detected transaction status, and the seller's final decision. Legitimate transactions are accepted, while fraudulent transactions are rejected, ensuring secure and transparent land registration.

DISCUSSION

The findings of this study indicate that integrating Blockchain technology with Artificial Intelligence provides a reliable solution for secure digital land registration and fraud prevention. Blockchain ensures that land ownership records and transaction details remain decentralized, transparent, and resistant to unauthorized modification, while IPFS securely stores transaction documents without increasing blockchain storage requirements. The comparative evaluation of different machine learning models shows that advanced ensemble algorithms outperform conventional classification techniques for blockchain fraud detection. LightGBM achieved the best performance among the machine learning models because of its efficient feature learning capability and ability to process large transactional datasets. Furthermore, the

CNN2D model produced the highest prediction accuracy by automatically extracting complex transaction patterns that are difficult to identify using traditional algorithms. Proper data preprocessing and feature selection also played an important role in improving model performance and reducing computational complexity. The web-based implementation demonstrates that the proposed framework can effectively support buyers and sellers by providing secure transaction validation and intelligent fraud detection. Overall, the proposed system offers a scalable, transparent, and trustworthy approach for modern agricultural land management and supports the objectives of Agriculture 5.0.

VI. CONCLUSION

The proposed Blockchain-Enabled Digital Land Registry with AI-Driven Validation for Agriculture 5.0 presents a secure and efficient approach for managing digital land registration and preventing fraudulent transactions. By integrating Blockchain, the InterPlanetary File System (IPFS), smart contracts, and Artificial Intelligence, the framework ensures transparent transaction processing, secure document storage, and reliable ownership verification. Blockchain protects transaction records from unauthorized modification, while IPFS enables decentralized storage of land-related documents. The comparative analysis of different machine learning algorithms demonstrates that LightGBM achieved the best performance among the traditional models, whereas the CNN2D model further improved fraud detection with an accuracy of 99.52%. The developed web-based application successfully supports buyers and sellers by providing secure transaction requests, AI-based validation, and transparent approval mechanisms. Overall, the proposed framework offers a scalable, reliable, and intelligent solution for modern land registration, supporting the objectives of Agriculture 5.0 through enhanced security, transparency, and trust in digital land management.

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