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Blockchain and machine learning driven agricultural transformation framework to enhance efficiency, transparency, and sustainability

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ABSTRACT

The agricultural sector is undergoing a transformative journey empowered by technological innovations. In this context, this research work endeavors to revolutionize the agricultural supply chain (ASC) by developing a comprehensive online platform that connects sellers, farmers, and customers. Through meticulous planning, design, and implementation, the system aims to streamline the process of buying and selling agricultural products, thereby fostering efficiency, transparency and accessibility. The key features include user registration, product management, order tracking, and blockchain-machine learning (ML) based transaction security. The proposed research work's success hinges on thorough testing and validation, ensuring its reliability and usability. By leveraging technology to bridge gaps in the agricultural ecosystem, this proposed work seeks to empower stakeholders and contribute to the sustainable growth of the agricultural industry. In the current agricultural landscape in India, traceability has been a significant challenge. The industry lacks a comprehensive system that provides visibility into the source and quality of produce. Our proposed system aims to address the shortcomings of the existing agricultural ecosystem by introducing a comprehensive solution powered by blockchain technology and advanced data processing techniques.

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1. INTRODUCTION

The agriculture industry, a cornerstone of India's economy, has long grappled with challenges ranging from traceability issues to inefficiencies in crop management and inadequate crop insurance systems. An innovative idea that seeks to use cutting-edge technologies to revolutionize the agricultural environment arises in response to these difficulties. This essay provides an insightful overview of this ambitious initiative, outlining its objectives, methodologies, and the significant influence it aspires to make. In the basic idea of this endeavor lies the recognition of the persistent problem of traceability within the agricultural supply chain (ASC). Farmers, retailers, and consumers often find themselves in a labyrinth of information asymmetry, hindering transparency and fostering inefficiencies. To address this issue, we have data sets to implement a blockchain-based traceability system. The blockchain, revered for its decentralized and immutable nature, promises to offer a seamless solution. This system envisions empowering stakeholders to trace the origin and journey of crops, providing an antidote to prevailing challenges of information asymmetry and lack of visibility. This lack of traceability has resulted in a multitude of problems, including food wastage, inefficiencies in the supply chain, and difficulties in ensuring the safety and quality of agricultural products. The absence of a robust traceability system has hindered the capacity for tracking the journey of agricultural products from the farm to the consumer, resulting in the loss of valuable information and contributing to the prevailing challenges in the industry.

Additionally, this research work sets its sights on revolutionizing the existing crop insurance paradigm. Historically, Indian farmers have faced obstacles in accessing transparent and timely crop insurance. Blockchain emerges as a beacon of hope in this domain, offering a decentralized and secure platform. Smart contracts, automated, and triggered by predefined conditions, become the linchpin of this transformation. Through this approach, the proposed work aims to streamline the crop insurance process, mitigating delays, and ensuring swift compensation for farmers when confronted with adversities. The marriage of deep learning (DL) techniques with agricultural practices forms another cornerstone of this initiative. Recognizing the need for timely and accurate crop disease detection and seed quality assessment, the proposed research work introduces a sophisticated model. Trained on vast datasets, this model becomes an invaluable tool for farmers. By allowing them to upload images for analysis, the system facilitates early detection of diseases and ensures the use of high-quality seeds, thus fortifying the foundations of successful cultivation. Transaction inefficiencies in business-to-consumer (B2B) dealings within the agriculture sector also come under the purview of this visionary research.

The implementation of a blockchain-machine learning (ML) prediction based transaction system seeks to dismantle traditional intermediaries, fostering secure, and efficient transactions. This not only expedites the process but also ensures that both farmers and retailers receive fair compensation, promoting a fairer and more equitable economic environment. Crop management, often a complex and multifaceted process, finds a novel solution through the implementation of blockchain. The proposed work envisions a comprehensive crop management system where vital information, including seed origin, planting dates, and harvest yields, is securely stored on the blockchain. This guarantees openness and is a useful instrument for controlling and keeping an eye on crops at every stage of their life. As this proposed work unfolds, it encapsulates a broader vision of fostering sustainability and trust within the agriculture industry. By providing end consumers with the ability to trace the journey of their food from seed to plate, the proposed work instills confidence and promotes sustainable farming practices.

The blockchain and ML prediction, with its inherent authenticity and transparency, emerges as the catalyst for ushering in a new era of trust and accountability. In conclusion, this proposed work emerges as a beacon of innovation, poised to propel the Indian agriculture industry into a future defined by transparency, efficiency, and sustainability. By seamlessly integrating blockchain, DL, and visionary methodologies, it not only addresses longstanding challenges but also lays the groundwork for a more resilient and modernized agricultural sector. As the sun rises on this technological renaissance, it carries the hope of a more promising and sustainable future for Indian agriculture.

The organization of the papers is as follows: section 1 presents the introduction about the agriculture industry and blockchain. In section 2, describes the old methods and recent research works related to blockchain and ML algorithms and implementation in the agriculture by providing authenticity and transparency. Section 3 presents the design and implementation of blockchain and ML agricultural transformation framework. In section 4, describes the result and discussion of the proposed research work. Finally, the summary of the agricultural transformation framework to enhance efficiency, transparency and sustainability using blockchain and ML driven is concluded.

2. RELATED RESEARCH WORK OF BLOCKCHAIN AND MACHINE LEARNING AGRICULTURAL TRANSFORMATION FRAMEWORK

According to Shahid *et al.* [1], the study and analysis demonstrates that the distributed, verifiable, and immutable requirements were satisfied by the footrail blockchain. Because of the complex procedure and limited server capacity, the system performs poorly while handling transactions pertaining to the breadth and depth aspects. Nevertheless, because every transaction is locally kept, verified, and immutable in each node, the system has access and precision benefits. Singh *et al.* [2] presented a comparative analysis of the previous proposed works based on blockchain. The benefits and negative marks of the past works are recorded at the top of the priority list while growing such frameworks. Further, we have talked about different agreement instruments for the framework and inspected conceivable security assaults and their answers. They have fostered a calculated system of food safety traceability system (FSTS) utilizing blockchain innovation that covers all perspectives.

An automated approach was proposed for accurately detecting and classifying diseases from a supplied photograph by Haridasan *et al.* [3]. The proposed framework for the acknowledgment of rice plant sicknesses takes on a personal computer (PC) vision-based approach that utilizes the strategies of picture handling, artificial intelligence (AI), and profound getting the hang of, diminishing the dependence on customary techniques. An integration of a support vector machine (SVM) classifier and convolutional neural networks (CNN) are used to recognize and classify specific varieties of paddy plant diseases Bosona and Gebresenbet [4]. This paper introduced the consequences of concentrate on recognizability frameworks inside agri-food supply chains (AFSCs) that coordinate arising blockchain technology, a blockchain technology-based framework renders detectability information effectively open and unchanging. A blockchain technology-based computerized recognizability framework likewise empowers one to create and execute a decentralized, changeless, straightforward, versatile, and dependable framework in which the robotization of cycles works with the checking of constant information and dynamic cycles. Harakannanavar *et al.* [5] suggested model makes use of preprocessing contour tracing, histogram equalization (HE), K-means clustering, and RGB to grayscale conversion among other computer vision techniques.

Principle component analysis, gray-level co-occurrence matrix (GLCM), and discrete wavelet transform are three descriptors that are used to extract relevant features from leaf samples. ML techniques like SVM, k-nearest neighbors (K-NN), and CNN are employed to differentiate between leaves that are infected and those that are not. Eventually, by extracting important characteristics through fusion approaches, the model can be further refined and tested with additional dataset leaf samples. With great success, the system has used blockchain technology and ML algorithms to the healthcare industry [6]. Throughput, transaction response time, latency, and other performance metrics were used in a number of tests to test the functionality of our system. Our system's simulation findings indicate that it performs admirably. With the use of this method, pharmaceutical businesses may significantly boost their revenue and solve the issue of counterfeit medications.

The AI is the field that bridges the gap between different application industries and information and communication technology (ICT) [7]. AI algorithms facilitate decision making. The two top performances in the field are ML and DL. With its layers and optimizers, DL functions similarly to the neural structure of the human brain, assisting in the development of a dependable model with increased accuracy. The image processing methods used in the work [8] are designed to separate and recognize rice grains. Based on the results obtained, it can be stated that analyzing grain quality based on size may be done effectively by using an image processing technique. The suggested method's primary advantage is that it produces better outcomes than manual or conventional procedures while requiring the least amount of time and money. The goal of this work's expansion is to create a system that can identify rice grains according to each criteria, hence improving rice quality. Such a method ought to be less expensive and require less time for quality analysis.

Kamilaries *et al.* [9] explores the transformative potential of blockchain in the agricultural and food supply chain. While blockchain promises transparency, challenges like technical issues and the need for regulatory frameworks hinder adoption. Kshetri *et al.* [10] discussed proposed work evaluates ongoing initiatives and highlights the complex landscape of blockchain in agriculture. Addressing challenges in fair compensation for farmers, the paper proposes blockchain in Indian sugarcane farming. Algorithms and flowcharts outline the SugarChain system, providing secure and transparent frameworks for user registration, login, and transactions, aiming to empower farmers and eliminate intermediaries [11] focusing on safety and quality in globalized agriculture, the paper employs Ethereum blockchain and smart contracts for soybean traceability. Smart contracts govern interactions, ensuring transparent, efficient, and secure transactions. Challenges remain, but the solution aims to address complexities in ASCs.

Jangir *et al.* [12] proposes an Ethereum blockchain-based framework for managing blockchain driven agricultural transformation framework to enhance efficiency, transparency, and sustainability the pharmaceutical supply chain, addressing transparency and trust issues. Smart contracts manage various processes, enhancing user privacy, quality management, and preventing deal repudiation. The framework aims to offer a more efficient and trustworthy pharmaceutical supply chain. Blockchain technology in current agricultural systems [13]. The paper explores blockchain applications in agriculture, emphasizing transparency, traceability, and efficiency. It covers technical aspects, applications, and challenges, showcasing blockchain's potential in enhancing the food supply chain.

The post-COVID-19 scenario illustrates the effective application of blockchain in agriculture. Remote sensing and precision agriculture technologies by Yang [14]. This article discusses crop disease diagnosis using precision agriculture and remote sensing technologies, using imagery to map cotton root rot. Practical guidelines benefit various stakeholders by offering insights into disease control and enhancing agricultural practices plant disease detection by imaging sensor [15]. The article emphasizes practical guidelines for stakeholders in agriculture, utilizing imaging sensors for plant disease detection. Technology integration increases productivity and supports the objectives of sustainable precision farming. Plant disease detection and classification [16].

The comprehensive analysis focuses on techniques for plant disease detection in India. Covering various aspects of data processing and model utilization, the study aims to improve agricultural practices, benefitting farmers and contributing to food security [17]. The report examines propels in crop disease identification with unmanned aerial vehicles (UAVs) and profound learning calculations. It accentuates the meaning of sensors and picture handling, characterizes existing exploration, and assesses the exhibition of AI and profound learning strategies. The difficulties, amazing open doors, and exploration headings of UAV-based remote detecting for rural sickness location are examined. Blockchain has been used to identify the blockchain driven agricultural transformation framework to enhance efficiency, transparency and sustainability and track product provenance by capturing information on product ownership, material processing, and material movements as the product flows across the supply chain [18].

Blockchain is a distributed ledger that operates independently of a central authority and makes it possible to create an unchangeable, decentralized log of transactions that can be tracked down and verified [19] and designed a blockchain-based ASC framework to provide product traceability, which guarantees decentralized security for the agri-food tracing data in ASCs. And to assurance the quality of food, a blockchain-based framework to guarantee the agri-food safety with product traceability in ASC systems. The blockchain technology [20]–[22] is agriculture and food supply chain, blockchain technology, which allows for immutable and decentralize transactions. Technologies like blockchain, internet of things, big data, and AI, to secure data, transactions, financial transactions in agriculture supply chain and transparency. The accurate disease management using DL techniques [23], [24] which manage disease and to help farmer needs. Using image processing, transactions, image classifiers and presented Blockchain in agriculture provide many opportunities to improve the sector [25].

The expanded utilization of versatile broadband gadgets, savvy matrices, huge information examination and man-made brainpower give apparatuses to creating shrewd cultivating frameworks. Supply-chain model facilitating seeds certification process, monitoring and supervision of the grain process, provenance and as optional interactions with regulatory bodies, logistics and financial services the three level blockchain reference infrastructure and a blockchain-enabled supply chain supporting [26] five information channels with nine participants and smart contracts. Blockchain-enabled supply chain model for a smart crop production framework. The blockchain based online ecommerce system [27], [28] in which farmers will be able to upload and sell their products to processor companies or distributors. Profound support learning is an AI and ML consciousness class in which shrewd robots can gain from their activities similarly individuals also.

3. METHOD

This proposed research work aims to address the shortcomings of the existing agricultural ecosystem by introducing a comprehensive solution powered by blockchain and ML prediction technology and advanced data processing techniques.

– Blockchain-enabled traceability: the proposed system introduces a blockchain-based traceability system that records the entire journey of agricultural products. Every transaction, from seed origin to the final product, is securely and immutably stored on the blockchain, providing stakeholders with a transparent and traceable supply chain.
– Blockchain-based transaction system: to streamline transactions between farmers and retailers, the proposed system incorporates a blockchain-based transaction mechanism. This system eliminates intermediaries, reducing transaction costs and delays. It ensures secure and efficient business-to-business (B2B) transactions, promoting fairness in compensation for agricultural products.
– Comprehensive crop management: with the use of blockchain technology, the suggested system offers a comprehensive crop management system that securely stores and manages crop lifecycle information. This gives farmer useful information about how to manage their crops, which helps them make wise decisions and make the best use of their resources.
– Integration of advanced technologies: advanced technologies such as DL and image processing are integrated into the proposed system. This allows for early detection of crop diseases, assessment of seed quality, and overall improvement in crop health management. Farmers can leverage these tools for proactive measures and timely interventions.
– Enhanced transparency and trust: by enabling end consumers to trace the origin and production of agricultural products, the proposed system aims to enhance transparency and build trust in the food supply chain. This transparency encourages sustainable farming practices and fosters a stronger connection between producers and consumers. In summary, the proposed system envisions a transformative shift in the agriculture industry, addressing the current challenges through blockchain technology, advanced data processing, and a holistic approach to crop management and traceability.

3.1. Data collection and preparation

The data collection for the agricultural frame work is first Initiation in this research work, the procedure for collecting and preparation are mentioned as follows:

– Collecting the diverse dataset of high-resolution images for seeds and leaves, including various quality parameters and disease symptoms. Ensure the dataset covers a wide range of crop types (maize, rice, beans, channa, and wheat) and includes both healthy and diseased samples. Pre-process the images to standardize size, color, and orientation, and augment the dataset to increase its diversity and robustness;
– To begin, the data collection process for the seed quality and leaf disease detection research work involves sourcing a comprehensive dataset of high-resolution images. These images must encompass a wide array of quality parameters for seeds, such as size, color, and texture variations, as well as a diverse range of disease symptoms exhibited on leaves. It is crucial to include samples from multiple crop types, including maize, rice, beans, channa, and wheat, to ensure the model's applicability across different agricultural contexts. Moreover, the dataset should consist of both healthy and diseased samples to enable the model to accurately differentiate between the two;
– Once the images are collected, pre-processing is essential to standardize them for analysis. This step involves resizing images to a uniform size, adjusting color balance, and ensuring consistent orientation to eliminate any potential biases. Additionally, data augmentation techniques are applied to the dataset to increase its diversity and robustness. Augmentation methods such as rotation, flipping, and scaling help the model generalize better to unseen data and improve its performance in real-world scenarios. Overall, this meticulous data collection and pre-processing stage lays the foundation for the subsequent development and training of the CNN models for seed quality and leaf disease detection; and
– The diversity and quality of the dataset are paramount to the success of the proposed research work objectives, as they directly impact the model's ability to accurately identify seed quality parameters and detect leaf diseases. By ensuring the dataset covers a wide range of crops, quality parameters, and disease symptoms, the resulting models will be more robust and applicable across various agricultural settings. Additionally, the pre-processing steps standardize the images and augment the dataset, enhancing the model's ability to generalize and make accurate predictions. This meticulous approach to data collection and preparation is essential for developing a reliable and effective system for seed quality assessment and leaf disease detection in agriculture.

3.2. Seed quality detection module

For the YOLOv5 implementation of the seed quality detection module, the initial step involves data pre-processing to ensure that the seed images are suitable for analysis. This includes resizing the images to a standard size and adjusting the color balance to enhance features relevant to quality assessment, such as size, color, and texture. Additionally, data augmentation techniques are applied to the dataset to increase its diversity and improve the model's ability to generalize to unseen data.

– Once the pre-processing is complete, the next step is to select the YOLOv5 architecture for the model. YOLOv5 is a state-of-the-art object detection model known for its speed and accuracy, making it well-suited for the task of seed quality assessment. The model is then trained on the pre-processed seed dataset using transfer learning, which allows the model to leverage pre-trained weights to accelerate the training process and improve performance.
– After training, the model is validated using a separate test dataset to evaluate its performance. Any necessary fine-tuning is done to improve the model's accuracy and reliability in detecting seed quality parameters. Once the model has been validated and fine-tuned, it is implemented into the system for automated seed quality assessment. This involves integrating the model with the system's backend to process uploaded seed images and provide quality assessment reports to users.
– Finally, the system is deployed, allowing users to upload seed images for automated quality assessment. Continuous evaluation of the system's performance in real-world scenarios is conducted, collecting feedback to further refine the model and improve the system's overall effectiveness. This iterative process of training, validation, implementation, and deployment ensures that the YOLOv5-based seed quality detection module provides accurate and reliable results, ultimately enhancing agricultural productivity and sustainability.

3.3. Leaf disease detection module

The different methods for the detection of leaf disease are mentioned as follows:

– Pre-processing: preprocess leaf images to highlight disease symptoms and enhance image clarity. This may include resizing images, adjusting brightness and contrast, and applying filters to enhance disease-related patterns.

– Model selection: choose a CNN architecture suitable for image classification tasks, particularly for identifying plant diseases. Common architectures for this task include visual geometry group (VGG), ResNet, Inception, or MobileNet, depending on the complexity and computational resources available.
– Training: train the selected CNN model on the pre-processed leaf dataset. Utilize transfer learning by initializing the model with weights from a pre-trained model (e.g., ImageNet) to improve efficiency and performance. Fine-tune the model on the leaf dataset to adapt it to the specific characteristics of plant diseases.
– Validation and refinement: validate the trained model using a separate test dataset to evaluate its performance. Refine the model by adjusting hyper parameters and architecture as necessary to achieve high accuracy and reliability in disease detection.
– Implementation: implement the trained CNN model into the system for automated leaf disease detection. Integrate the model with the system's backend to process uploaded leaf images and provide disease detection reports.
– Deployment and evaluation: deploy the system with the integrated leaf disease detection model, allowing users to upload leaf images for automated disease detection. Continuously evaluate the system's performance in real-world scenarios, collecting feedback to further refine the model, and improve the system's overall effectiveness. Integrate the trained model into the system for automated leaf disease detection.

3.4. System integration and deployment

Develop a unified framework that integrates the seed quality and leaf disease detection modules into a single system. Design a user-friendly interface that allows farmers and agronomists to easily upload seed and leaf images for analysis. Implement a backend system that processes uploaded images using the trained CNN models and provides detailed reports on seed quality and disease status. Deploy the system on a scalable platform to ensure its accessibility and usability for a wide range of users.

3.5. Evaluation and improvement

Continuously evaluate the performance of the system in real-world scenarios, collecting feedback from users and stakeholders. Monitor key metrics such as accuracy, speed, and user satisfaction to identify areas for improvement. Incorporate feedback and insights gained from the evaluation process to enhance the system's performance and usability over time.

3.6. Documentation and knowledge sharing

Document the entire methodology, including dataset preparation, model selection, training, and system deployment. Share the findings, insights, and best practices through publications, presentations, and workshops to contribute to the broader agricultural research community. Provide comprehensive documentation and support materials for users to effectively utilize the system for seed quality assessment and leaf disease detection in their agricultural practices.

3.7. Design of machine learning model

To fabricate a machine inclining model, it comprises of two stage specifically testing and preparing stage were the model is first prepared and an information is given to test the model which is known as the test information. Figure 1 presents the framework design of AI model. The model comprises of a few picture handling steps, for example, picture obtaining, picture pre-handling, division, include extraction, and SVM classifier to order the infections. The unhealthy leaf picture is gained utilizing the camera, the picture is procured from a specific uniform distance with adequate lighting for learning and grouping. The example pictures of the unhealthy leaves are gathered and are utilized in preparing the framework. To prepare and to test the framework, infected leaf pictures and less solid pictures are taken. The pictures will be put away in some standard arrangement. The background of the picture ought to appropriately stand out from the shade of the leaves. The leaf sickness dataset is made with both a high contrast setting. Dark foundation pictures are used for illness identification on leaves in light of the fact that, as per an examination research, they yield unrivaled outcomes.

3.8. Implementation of agricultural transformation framework using blockchain and machine learning model

Figure 1 presents the development modules such as seller registration, seller login, add seeds, view seeds, delete seeds, and view seeds order. These modules empower sellers to register on the platform, manage their inventory of seeds, track orders, and maintain seamless communication with buyers. Similarly, farmers are provided with modules including farmer registration, farmer login, purchase seed, add crop, view crop, delete crop, view seeds order, and view crop order.

These functionalities enable farmers to register, purchase seeds, list their crops for sale, manage crop inventory, and monitor orders placed for their products. Customers, on the other hand, are facilitated with modules like customer registration, customer login, purchase crop, and view crop order. These functionalities empower customers to register, purchase crops from farmers, and track their crop orders efficiently. In addition to user-specific modules, our proposed work incorporates a blockchain server, which serves as a secure and transparent ledger for recording all transactions. This ensures data integrity, security, and transparency in all interactions within the platform.

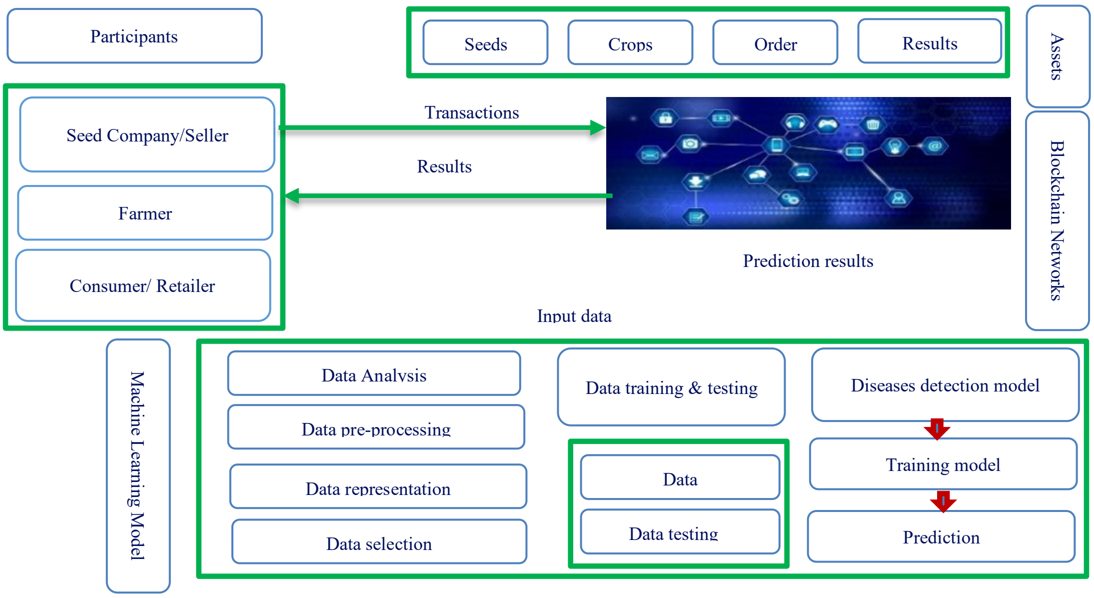

Figure 1. The proposed research work system architecture

3.8.1 Data pre-processing step

A data framework's "stream" of information is addressed graphically by an information stream outline (ISO). Information handling (organized plan) perception is one more use for ISOs. Information things travel through an interior interaction on a ISO from an outside information source or inner information store to an outer information sink or inward information store. With respect to planning, requesting, and whether cycles will run in equal or consecutive request, a ISO offers no data. Thus, it contrasts fundamentally from a flowchart, which portrays the progression of control through a calculation and tells the peruser what moves will be made, when they will happen, and in what request. In any case, a flowchart doesn't determine the kinds of information that will be placed into and yield from the framework, where they will start from, go to, or be put away. These subtleties are shown on a ISO.

Figure 2 shows the level zero data flow diagram from the blockchain model depicts the overall picture of the stakeholders in the agriculture sector. Figure 3 shows the level 1 data flow diagram from the blockchain model depicts the overall picture of the farmer and seed seller in the agriculture sector and their transactions. Figure 4 shows the level 2 data flow diagram from the blockchain model depicts the overall picture of the stakeholders in the agriculture sector, the connection with the blockchain server and the relationship of farmer and the consumer. Figure 5 shows the data flow diagram from the ML model depicts the working of a ML model that is used for seed and leaf disease analysis used in the agriculture sector.

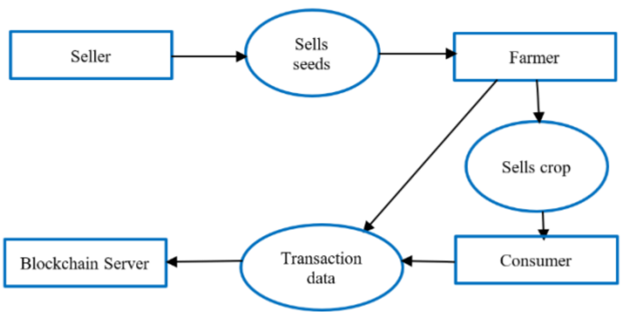

Figure 2. The level zero dataflow diagram for blockchain

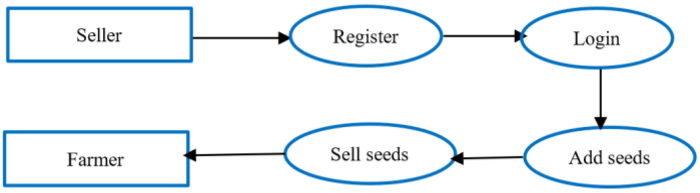

Figure 3. The level 1 dataflow diagram for blockchain

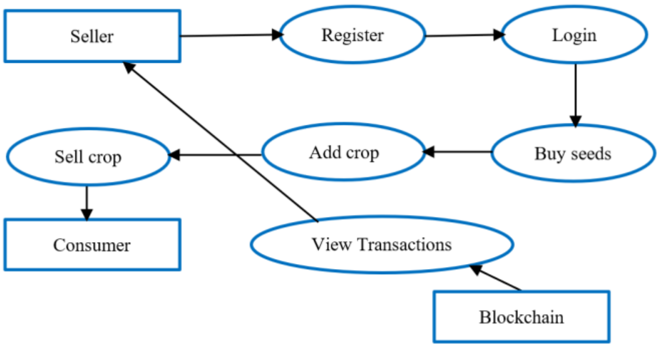

Figure 4. The level 2 dataflow diagram for blockchain

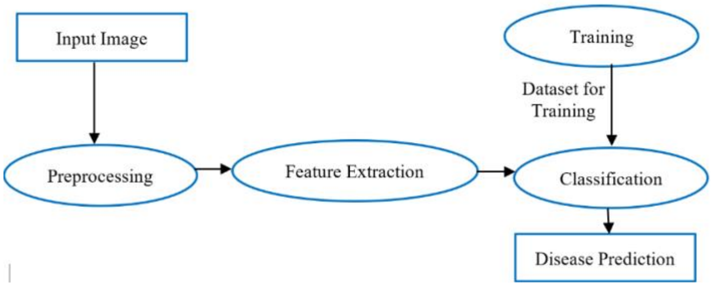

Figure 5. The data flow diagram for seed analysis and leaf disease prediction

Table 1 exhibits the typical gas charge utilization of the between authoritative shrewd agreement. addItem(), buyItem() and createParticipant() capabilities consume gas expenses as these capabilities impact the condition of the blockchain by making and changing the data connected with another thing and member. Figure 5 shows how much apple utilized on the off chance that an item is moved from a rancher to a client. To list his produce available to be purchased, the rancher utilizes the addItem() capability. Other closely involved individuals call the buyItem() capability, which changes the item's proprietorship. The overall apple cost of 1,48,056 Wei is negligible in contrast with the advantages that blockchain and smart contracts bring, such as transparency, immutability and automation.

Table 1. Costs of supply chain smart contract functions (Wei)

Function	Execution fee
addItem()	21,768 Wei
queryItem()	0 Wei
buyItem()	31,572 Wei
createParticipants()	110,017 Wei
queryParticipants()	0 Wei

4. RESULTS AND DISCUSSION

The system ensures secure, transparent, and efficient management of seed transactions, crop management, and customer purchases. The successful implementation of blockchain in the simulation environment suggests that the system could significantly improve real-world agricultural operations, promoting transparency, efficiency, and trust among all stakeholders.

– Purchase trends: we observed various patterns in purchasing behavior across different demographic groups. There were noticeable trends in the types of products purchased and the frequency of transactions
– User engagement: the level of user engagement varied among different user categories, including sellers, farmers, and customers. The implementation of the system led to a notable increase in user engagement among sellers, farmers, and customers. The user-friendly interface and intuitive design facilitated seamless interactions, resulting in higher levels of participation and activity within the platform. Some users interacted more frequently with the platform, while others were less active.
– Platform utilization: the extent to which users utilized different features of the platform differed. Certain functionalities, such as adding and viewing seeds or crops, were more popular among users.
– Streamlined transactions: one of the primary objectives of the proposed research work is to streamline transactions within the agricultural value chain. The system effectively facilitated buying and selling activities, reducing complexities and inefficiencies associated with traditional methods. As a result, users reported smoother and more efficient transaction processes.
– Improved transparency: transparency in agricultural transactions is crucial for fostering trust and accountability among stakeholders. The system's integration of blockchain technology ensured transparent and tamper-proof record-keeping, allowing users to access real-time information on transactions and product origins. This transparency was widely appreciated by users and contributed to greater confidence in system.
– Optimized resource management: effective resource management is essential for maximizing agricultural productivity and sustainability. The system provided users with valuable insights and tools for managing resources more effectively, such as crop selection, seed procurement, and inventory management. By optimizing resource allocation and utilization, users were able to achieve better outcomes and maximize their agricultural yield.
– Data-driven decision making: data analytics capabilities embedded within the system empowered users to make informed decisions based on real-time insights and trends. By leveraging data analytics tools, users gained valuable intelligence on market demand, pricing trends, and consumer preferences, enabling them to adapt their strategies and offerings accordingly.
– Feedback and suggestions: we collected feedback from users regarding their experience with the platform. Suggestions for improvements and additional features were provided by users, which can be valuable for future iterations of the attributes.
– Overall performance: the proposed work achieved its objectives of facilitating transactions between sellers, farmers, and customers. While there were areas for improvement identified, the overall performance of the platform was satisfactory.
– Future considerations: based on the results and feedback obtained, there are opportunities for enhancing the platform further. Future iterations may focus on addressing user concerns, improving user experience, and expanding the platform's capabilities. By presenting these results in simple terms, we aim to provide a clear understanding of the objective outcomes and insights gained from the implementation phase.

Figure 6 shows the home page of the web application as blockchain agriculture, which has separate login for customer, farmer and seller for transaction purpose. Figure 7 shows the leaf disease prediction module opening from a button on the web application linking to this ML model that predicts leaf diseases and detects healthy and diseased leaves and remedies for diseased leaves. Figure 8 shows the Seed quality analysis module opening from a button on the web application linking to this ML model that seed quality and detects healthy and diseased seeds for farmer to buy.

Figure 6. The home page of the model

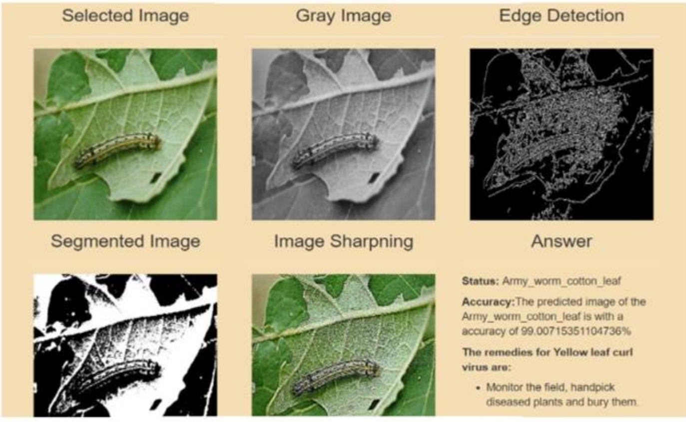

Figure 7. The leaf disease prediction

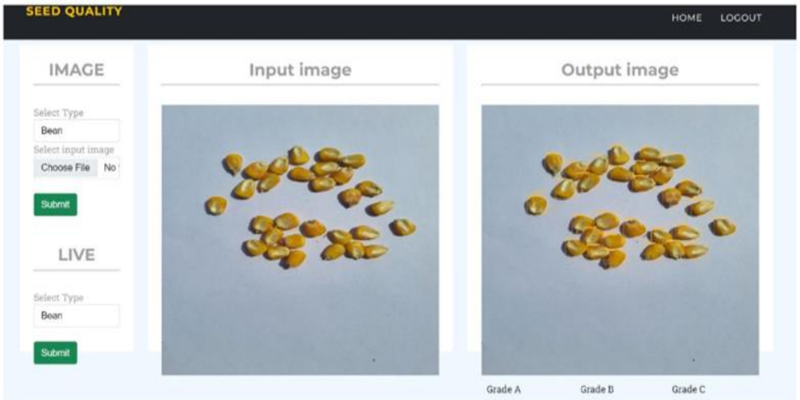

Figure 8. The seed quality analysis

Figure 9 shows how much crop-apple utilized if it transported from a farmer to customer. To list this produce available to be purchased, the farmer utilizes the addItem(). Other interested parties call the buyItem(), which changes the item's proprietorship. The complete apple cost of 148,056 Wei is negligible in contrast with the advantages that blockchain and smart contracts agreements bring, like transparency, immutability and automation.

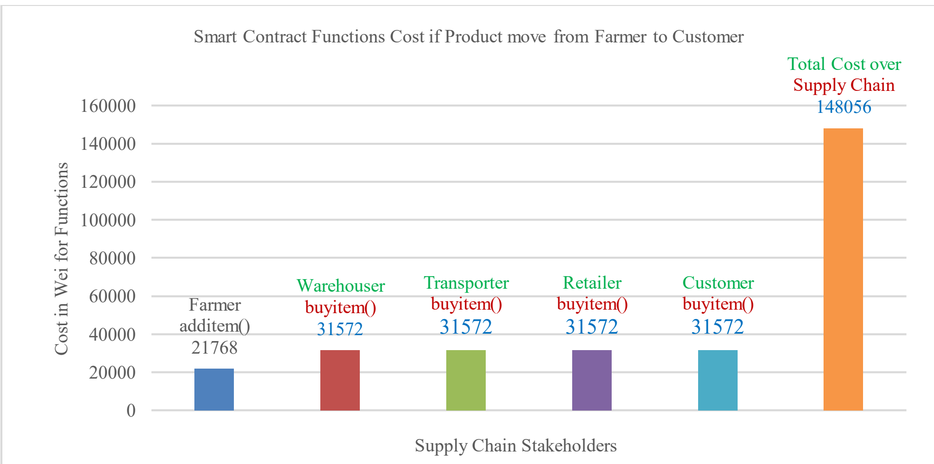

Figure 9. The total cost supply chain from farmer to customer product movement

5. CONCLUSION

While our proposed research work marks a significant milestone in modernizing agricultural practices, there exists a vast scope for future enhancements and expansions. Firstly, continuous refinement and optimization of our blockchain-based supply chain management system are essential to accommodate evolving industry standards and regulatory requirements. This entails further research into scalability solutions to handle increasing transaction volumes and ensure seamless interoperability with existing agricultural infrastructures. Moreover, future iterations of our proposed work can explore the integration of internet of things devices for enhanced data collection and monitoring capabilities. By deploying sensors and actuators in agricultural fields, farmers can gather real-time data on soil moisture levels, temperature, and crop health, enabling precise irrigation and fertilization strategies. Additionally, the incorporation of drones and satellite imagery can provide comprehensive aerial surveillance, facilitating crop monitoring and pest detection on a larger scale. Furthermore, extending our proposed research work's reach to encompass agricultural financing and insurance services presents a promising avenue for future development. By integrating financial instruments and risk management tools into our platform, we can offer farmers access to affordable credit, insurance coverage, and commodity trading options, thereby safeguarding their livelihoods and promoting economic resilience. In conclusion, the future holds immense potential for further innovation and expansion in agricultural technology, and this research work lays a solid foundation for continued advancements in this crucial sector.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
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C : **C**onceptualization	I : **I**nvestigation	Vi : **Vi**sualization
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So : **So**ftware	D : **D**ata Curation	P : **P**roject administration
Va : **Va**lidation	O : Writing - **O**riginal Draft	Fu : **Fu**nding acquisition
Fo : **Fo**rmal analysis	E : Writing - Review & **E**diting	

CONFLICT OF INTEREST STATEMENT

No conflict of interest.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

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