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A Blockchain and Metaheuristic-Enabled Distributed Architecture for Smart Agricultural Analysis and Ledger Preservation Solution: A Collaborative Approach

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Abstract: Distributed forecasting of agriculture commodity prices has an attractive research perspective that delivers active breakthrough analysis of the rapid fluctuations in pricing forecasts for participating stakeholders without being manually dispatched lists. The increased use of an efficient forecasting mechanism for the agriculture information management of generated records and processing creates emerging challenges and limitations. These include new government mandates and regulations, the price of land for expansion, forecasting the growing demand for commodities, fluctuations in the global financial market, food security, and bio-based fuels. Building and deploying distributed dynamic scheduling, management, and monitoring systems of agricultural activities for commodity price forecasting and supply chains require a significant secure and efficient approach. Thus, this paper discusses a collaborative approach where two different folds are demonstrated to cover distinct aspects with different objectives. A metaheuristic-enabled genetic algorithm is designed to receive day-to-day agricultural production details and process and analyze forecast pricing from the records by scheduling, managing, and monitoring them in real-time. The blockchain hyperledger sawtooth distributed modular technology provides a secure communication channel between stakeholders, a private network, protects the forecasting ledger, adds and updates commodity prices, and preserves agricultural information and node transactions in the immutable ledger (IPFS). To accomplish this, we design, develop, and deploy two distinct smart contracts to register the system's actual stakeholders and allow for the addition of node transactions and exchanges. The second smart contract updates the forecasting commodity pricing ledger and distributes it to participating stakeholders while preserving detailed addresses in storage. The simulation results of the proposed collaborative approach deliver an efficient E-agriculture commodity price forecast with an accuracy of 95.3%. It also maintains ledger transparency, integrity, provenance, availability, and secure operational control and access of agricultural activities.

Keywords: blockchain; hyperledger sawtooth; metaheuristic; genetic algorithm; private network; smart agriculture

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1. Introduction

Artificial intelligence is commonly used in computer science and mathematics to explain the creation of machine learning to the learning process, manage transactions based on patterns of extraction, recognition, and classification, and improve dynamic monitoring and optimization mechanisms [1]. It is the concept, theory, and implementation of information systems (IS) that are capable of executing scheduled problems that require human intelligence. Examples include computer vision, cognitive correlation and perception, text-to-speech recognition and vice versa, making an intelligent business decision, and security protection [2]. However, machine learning (ML) is an emerging domain of information technology that is widely used to work on training machines that are designed to function like humans [3,4]. Geoffrey Hinton, a machine learning expert, defines ML as a 'type of AI that allows applicational software to become more accurate at predictive outcomes without being explicitly programmed to act on them.' Further, the algorithms of ML use heuristic records as one of the input variables to forecast new outcome values.

A metaheuristic is one of the most common approaches for scheduling, organizing, managing, and optimizing records, particularly those related to business [5]. Metaheuristic models were used to anticipate and organize information (processed records) from data in single, large enterprise records and a number of governmental transaction managements [6]. Metaheuristic techniques are more complex and diverse in nature, most probably depending on the range of data, especially genetic algorithms in the agriculture and food departments, and commodity price forecasting, especially agricultural commodities such as rice. Therefore, records management and optimization are still challenging aspects considered in the field of metaheuristic-ML, which are being developed in real-time [7,8].

The economy of every developing country depends on agricultural growth, demand, and supply [9]. As the food production that feeds the entire population is an insecure mechanism, economic growth is dependent on the link and interaction of all the internal country-relevant industries with each other [10]. However, as illustrated in Figure 1, Pakistan faced an inaccurate and insecure trail of food demand, supply, and future production forecasting of agricultural commodities. Pakistan is considered socially and economically affluent if and only if it has a strong future plan for expanding agriculture production and supplies. Most of the employment is generated while increasing the growth of agriculture. Another challenging perspective is the need to investigate the proper forecasting of commodities' supply and demand and future pricing according to the quality of production [11]. From a supply-chain point of view, the expansion of production to a stable economy needs to focus on the safe and secure exchange of agricultural information between stakeholders.

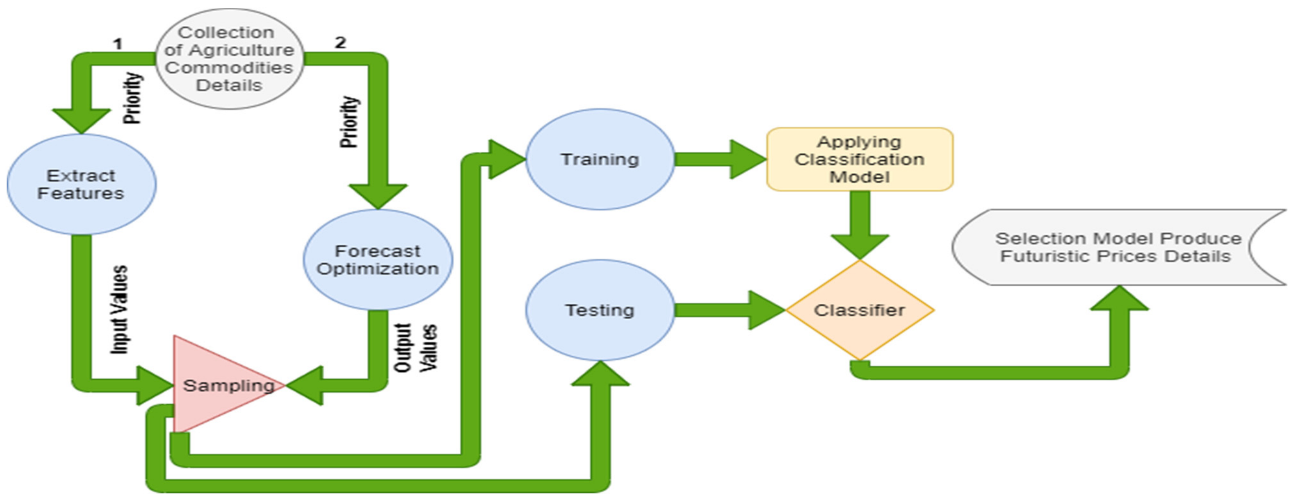

Figure 1. Current architecture for forecasting agriculture commodity prices.

Machine learning and mathematical optimization have been utilized in agriculture commodity forecasting to improve crop production and water wastage, predict food demand and supply-chain protocols, and continuous monitoring, schedule processing, information management, and record optimization [12,13]. The main objectives are to design standard production and reliable operational control mechanisms, maintain efficient forecasting, and maintain a secure way to search, reach, and serve society [14]. These two different approaches simply provide a sequential process of data collection, examination, analysis, and scheduling, and predict, manage, and optimize detailed records. Individuals, corporations, and businesses can distinguish accurate commodity price forecasting, as well as complete ledger scheduling, organization, management, and monitoring.

Blockchain-distributed ledger technology is currently enabling industries to secure their systems and real-time processes [13,15]. Food production-related demand–supply chain systems, in particular, must achieve transparency, integrity, provenance, traceability, and information accessibility via distributed applications (DAPP). In commodity forecasting, the blockchain can aid in the security, protection, and preservation of agricultural-related details and forecasting information in a distributed storage environment, allowing for a transparent analysis of the commodity price forecasting process [16]. However, blockchain hyperledger technology has been envisioned and widely adopted by various agricultural and industrial commodity forecasting systems to achieve secure food pricing forecasts, ledger transparency, system provenance, and immutable registration. AI and mathematical experts are shifting toward blockchain hyperledger technology because of its distributed, decentralized ledger preservation nature and protected private network channels with secure protocols. The benefits of applying these strategies to protect the system against a variety of malicious attacks are usually intended for central server-based systems and frameworks. The blockchain also enables the improvement of the distributed node defense abilities with the help of cryptographic hash re-encryption and NuCypher encryption functions, along with the deployment of intrusion detection. Substantially, the technology enables the deployment of firewall-enabled defense, an anti-disclosure model to detect malicious activities, and procedures and protocols to ensure system provenance, ledger integrity, transparency, and distributed trust within the forecasting architecture.

However, this paper addresses the collaborative approach of blockchain hyperledger sawtooth and metaheuristic-enabled modular architecture to analyze agricultural commodity prices and forecast the market fluctuations in terms of production, demand, and supply. In this paper, we proposed a novel and secure collaborative approach that provides complete data provenance, integrity, traceability, and assurance for performing distinct agricultural operations, for example, commodity forecasting. Therefore, it can create trust between the stakeholders while collecting details of records, registering, adding new transactions, updating ledgers, protecting preservation, and interpreting the information. This comprehensive package ensures the preservation of ledger privacy, and transactions are encrypted using a hash-based mechanism (SHA-256) for the entire event of nodes [16]. The main contributions to this paper are discussed as follows:

- This paper discusses the detailed design of a secure and novel blockchain-enabled architecture for precision agriculture that intelligently forecasts commodity prices. This architectural aim is to maintain communication between node transactions among stakeholders in a private network channel.
- We design and implement the process of day-to-day commodity pricing forecasting, such as capturing, examining, analyzing, scheduling, predicting, managing, and optimizing using a metaheuristic-based genetic algorithm.
- The reason for choosing the hyperledger sawtooth is that it is an open-source platform that provides a modular infrastructure with private communication protocols. In this paper, we adopt the customized nature of sawtooth with a PoET consensus policy and procedure for automating transactions in a proposed private channel.

- The smart contracts are created and deployed to automate events of agricultural node transactions, registration, adding new forecasting details, updating the ledger, and preserving detailed addresses in a protected manner.
- Finally, we examine, analyze, and document the evaluation of the proposed collaborative approach for secure transactions of agricultural commodity pricing and its relevant emerging challenges and limitations. We also mention a few descriptive solutions related to the distributed nature of the future objectives that have not yet been discussed.

The remainder of this paper is organized as follows: In Section 2, the agriculture supply chain, grain production, and demand for food forecasting and secure distribution with the preservation-related literature are discussed. Section 3 presents our proposed collaborative approach for agricultural commodity price forecasting and ledger security in distributed storage through the use of smart contracts. The experimental and simulation results of the proposed collaborative system and related state-of-the-art comparisons are discussed in Section 4, and we conclude our manuscript in Section 5.

2. Related Literature

In general, blockchain smart contracts and metaheuristics have been proven to have the capability to capture data, schedule processes, manage and organize distributed storage, and provide dynamic monitoring facilities [17]. It handles the process of system development that requires integrity and transparency and creates agricultural commodity forecasting and pricing-based records-keeping. Meanwhile, the collaborative method of metaheuristic-blockchain establishes a sturdy trustworthiness environment where the hyperledger sawtooth-enabled smart contracts create the necessary business rules and logic to automate adding new transactions and updating the ledger without interference and manipulation from any third party [18,19]. Internet of Things (IoT) devices, on the other hand, provide external technical support while collecting day-to-day production records from various sectors and assisting with forecasting. Moreover, this technology enables distributed real-time monitoring of a process by capturing and sending detailed records over the distributed permissioned blockchain network.

We analyzed various research articles to find current state-of-the-art developments in the domain of agriculture and commodity price forecasting. A few of them are discussed as follows, along with the research gaps and connectives (mentioned in Table 1).

Table 1. A literature review of blockchain, metaheuristic, and machine learning-enabled systems.

Research Method	Research Description	Research Limitations	Research Similarity and Difference
IoT-blockchain-enabled architecture of a provenance system for food industry 4.0 using advanced deep learning and optimization [20]	The authors of this paper proposed a hybrid model based on recurrent neural networks, genetic algorithms, and distributed ledger technology for secure IoT-blockchain information industry 4.0 in the food industry.	• Registration is limited to a certain number of users • Interoperability issue • Hash-encryption distributed node connectivity • Streamline automation of food security	• Blockchain distributed technology is used to prevent the transaction of IoT devices over a distributed network • Long-short term memory • Gated recurrent units

Table 1. *Cont.*

Research Method	Research Description	Research Limitations	Research Similarity and Difference
Forecasting the price of industry 4.0 and blockchain-enabled Bitcoin using deep learning [21]	This paper discussed the deep learning-enabled stacked denoising autoencoders method used to predict the prices of the food industry 4.0.	• It is less efficient in terms of ledger security issues. • The scope of data privacy • No encryption mechanism	• No blockchain distributed technology is used. • Absolute percentage error • Root-mean-squared error • Directional accuracy
E-Agricultural supply chain management: A framework coupled with blockchain effect and cooperative strategies [22]	The authors of this paper discussed the concept of advanced blockchain in digital marketing. A cooperative, sustainable, blockchain-enabled E-agriculture-based supply chain model was developed. The purpose of this paper was to maintain demand to determine shipments, prices, advertising costs, and the duty cycle of agricultural commodities.	• Predefine protection and consensus policies • No hyperledger was used • Preservation and scope of data issues • Cross-chaining limitations	• Elements of web design • Supply chain management • Design for digital marketing • Hash encryption • Blockchain re-encryption
Blockchain technology in agricultural supply chain operations [23]	This paper examined and analyzed the blockchain-enabled opportunities and benefits associated with the use of integration in supply chain and commodity production forecasting operations.	• Regulators and compliance-related challenges • Sustainable management limitations • Scalability, privacy, product provenance, and interoperability issues	• Smart contracts for social impacts • Cryptographic hash encryption • Agriculture supply chain-demand and circular economy inefficiency
An ensemble machine learning approach for forecasting credit risk of agricultural industry 4.0 [24]	The authors of this paper proposed a novel consortium ensemble ML technique to forecast the credit risk associated with small and medium-sized enterprises in the agriculture industry 4.0. The two main techniques utilized for forecasting were as follows: • Rotation Forecast • Logit Booting	• Security, privacy, and preservation of ledger-related issues • Scope limitations • Node connectivity and secure transaction delivery challenges	• No ledger encryption while exchanging information • Biases in sample selection and data collection • A few records cannot be adequate while using these approaches.
Collaborative approach: blockchain, IoT, and machine learning for enhancing security in intelligent manufacturing [25]	Integration of blockchain, IoT, and machine learning approaches were proposed to secure system transactions and manage day-to-day records to overcome tampering in stored datasets.	• Fault diagnoses prediction • IoT security and preservation issues • Automate smart contracts and streamline limitations • Data scope and preservation problems	• A quality control approach • Modeled for complex environments • Hyperledger fabric predefined protocols and policies are applied

3. Proposed Architecture

Figure 2 presents the proposed collaborative approach of the metaheuristic blockchain for commodity price prediction, information scheduling and management, distributed monitoring, and secure ledger preservation. The regression-based linear and logistic methods are used for efficient pricing forecasting to efficiently classify agricultural commodities and predict the future prices of individual products based on previous data. The forecast affects production and the nature of consumption drastically. In terms of the security and privacy of the proposed system, the cost-efficient process scheduling and optimization during the process of forecasting in the agriculture commodity distribution application is shown in Figure 2. This collaborative architecture demonstrates different aspects, such as forecasting, which requires more efficient resource distribution and classification during forecasting. However, to optimize the recorded data captured from different food and safety departments, the process of commodity production details services exchanged and stored through different network layers for efficient forecasting, as shown in Figure 2. In this architecture, we defined the overall scenario of data received in the process operation environment.

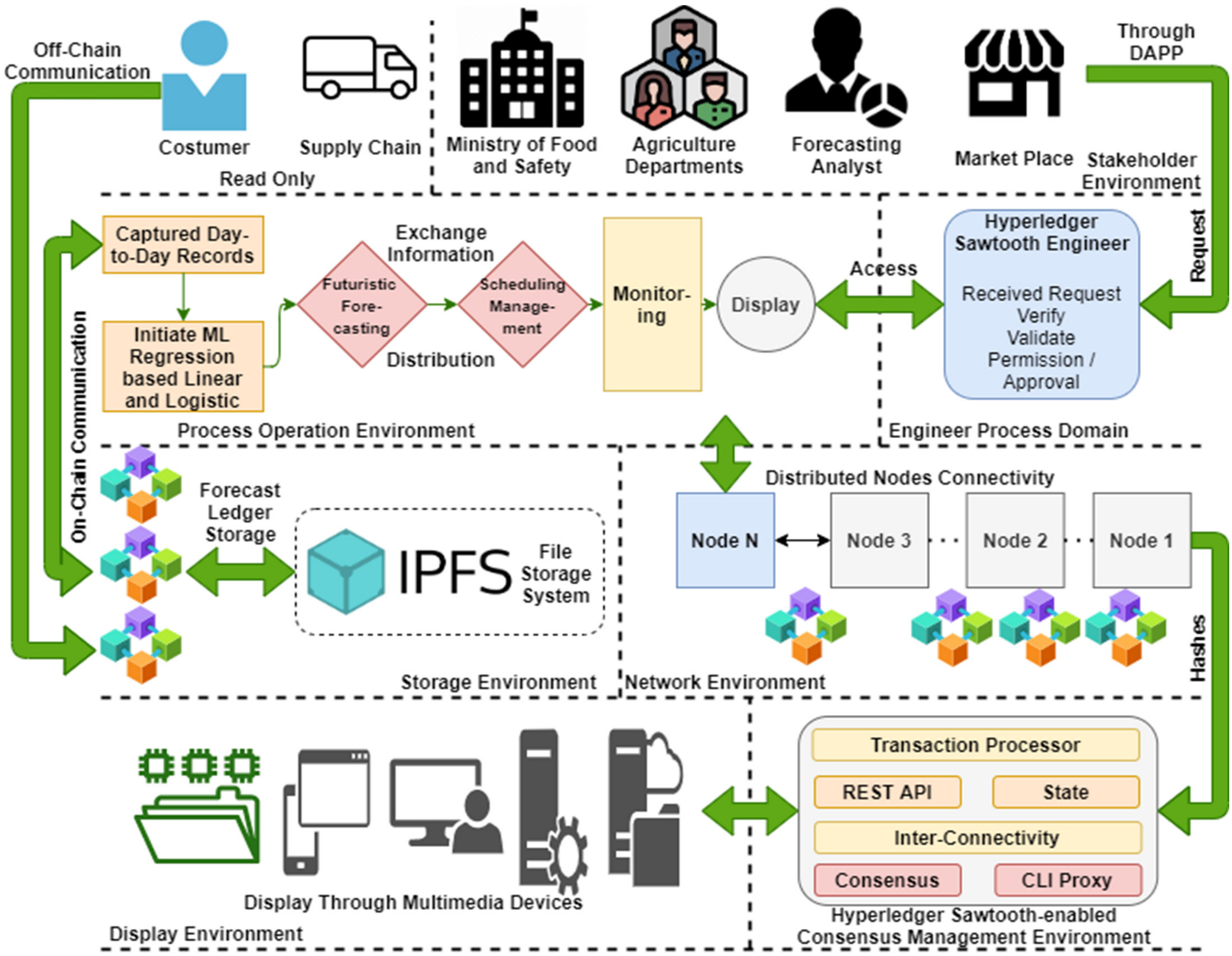

Figure 2. The proposed collaborative architecture of metaheuristic-blockchain hyperledger sawtooth.

In this architecture, we defined the overall scenario of data received in the process operation environment and started forecasting with process scheduling, information management, organization, and monitoring of the preserved ledger using metaheuristic-enabled genetic algorithms and regression-based linear and logistic methods. All initial data generated by departments are stored in the immutable distributed Interplanatery File Storage (IPFS). Through the edge nodes, participating stakeholders make a request for read-only purposes or information exchange directly, as shown in Figure 2 (stakeholder environment). The on-chain and off-chain gateways manage the agricultural commodity-related transactions and the access control of storage to retain information and exchanges. In this regard, stakeholders request the blockchain hyperledger sawtooth engineer in a dynamic time for various product pricing forecasting-related services. The number of forecasting task schedules for the process and management of outputs is organized in such a way that it can be preserved securely in the distributed ledger storage system. This procedure takes a short time frame (evaluate delay) to complete the process of execution. The relationship between the agricultural nodes' transactions on the network environment can obtain permission from the hyperledger sawtooth engineer for further processing after validation, whereas the storage environment can only store and exchange the executed transaction via off-chain communication. The cost of delay is measured continuously while the system continuously generates a forecast of commodities and exchanges such information among stakeholders (using Quality-of-Services parameter, where serverless delay = 80 ms tuned). However, the optimization of individual commodity price forecasts becomes prioritized by the utilization of the product, which is mentioned in Figure 2, and then the task is executed individually and in parallel in an efficient way.

The process of this collaborative approach is categorized into capturing, examining, analyzing, scheduling, managing, predicting, organizing, optimizing, and monitoring the network layers. For instance, we evaluate delays between events of execution, prediction accuracy, efficient network transmission, dynamic control of process scheduling, etc. In addition, the proposed collaborative approach is computed effectively while exchanging forecasting-related information, and details are transmitted among stakeholders in the distributed permissioned private network. The agenda of this proposed approach is achieved with the deployment of smart contracts, resulting in a satisfactory schedule process of forecasting and management in a secure distributed manner, while sharing the commodity price information through the defined on-chain and off-chain communication protocols, as shown in Figure 2. Several internal resources are crucial that need to be calculated, such as node interconnectivity, state of hyperledger, one-to-one communication or broadcast, REST API, hashes, consensus, CLI proxy, and processor transaction evaluation. The hyperledger sawtooth engineer manages all the records of transactions and adds detailed addresses to the storage. Therefore, this engineer tackles redundancy in the event of transaction preservation in the ledger before verifying and validating node delivery, as shown in Figure 2.

3.1. Problem Description and Notation

In this context, the linear classification of agriculture commodity forecasting initially classifies different commodities and predicts their future prices based on a predictor function that is linear in nature. For this purpose, we need to combine weight with the value of a commodity-dependent variable. Further, nonlinear operations for future predictions regarding commodities prices can be involved in the entire process.

$$Linear = [X\ (features)] + Weight\ (w),\ Y\ (classification) \tag{1}$$

$$Link\ Function = Calculate\ Gradients \tag{2}$$

$$Compute\ Cost = Analysis\ (Link\ Function). \tag{3}$$

In Equation (1), the linear equation associates an individual feature with a connected weight. The reason behind this equation is to call it logistic regression, which is a more generalized linear model. The link function provides a data converter platform, where we can define the range of parameters, such as (0,1) for computing efficient cost and dependencies, as elaborated in Equation (2), whereas Equation (3) demonstrates the link function, which is an activation function, and 'a' is the defined value as follows:

After this linear process of commodity classification, logistic regression is applied to the range of two dependent variables (A and B). Therefore, A is defined as a matrix of values with an '*n*' number of features extracted in the '*i*th' iteration. Similarly, B is defined as a vector with dependent features of 'm.' According to the gathered values of agricultural commodities, we create a customized weight matrix, which is as follows:

$$Linear\ (l) = w_0 + w_1 * a_1 + w_2 * a_2 + \ldots + w_n * a_n \quad (4)$$

The link function is calculated after the multiplication of randomly generated features for forecast prices:

$$Link\ Function\ (LF) = \left[\frac{1}{(1+e^a)}\right] \quad (5)$$

However, the cost of the '*i*th' iteration of the price prediction is calculated as:

$$Cost\ (c) = (1-n)\sum_{j=1}^{j=n} LF' \log(LF) + \left(1 - LF'\right) * \log(1 - LF) \quad (6)$$

After this whole process, we calculate the derivation of the calculated cost of LF' with the updated weight for efficient future prediction of commodity prices:

$$Gradients\ (g) = \sum_{j=1}^{j=n} \left(LF' - LF\right) * mj \quad (7)$$

$$Update\ Weight\ \left(w'\right) = wj - (a * g) \quad (8)$$

The main objective of using the linear-logistic regression method is to create a linear boundary-based classification and decision system that separates two classes based on conditional probability:

$$Probablity\ (P) = \left(LF' = 1\ |a; w\right) \quad (9)$$

We initiate the future prediction of classification by tuning the decision boundary of '+' features, where '1' and '0' are classified as factors related to the class-based decision boundary, and therefore, the equation is:

$$Probablity\ (P) = \left(LF' = 0\ |a; w\right) \quad (10)$$

Logistic regression evaluates the probability of commodity prices for a particular set of defined data points, such as agricultural-related crop production information, belonging to either class '0,' equal to the previous predictive class, or class '1,' equal to the current predictive class. The value of a and w is changed in every classification phase to obtain an accurate price forecast of each commodity efficiently. We evaluate a set of values obtained from negative (−ve) to positive (+ve) infinity according to the previous and current prices in the linear model. For this purpose, we narrow down the score to a range of (0,1) as the probability (for prediction).

The exponent of the activation function is justified as the probability, which is always '>0.' The limit of this linear-logistic regression is set at values less than 1, for the purpose of dividing the value in the numerator by the value of '>1.'

3.2. The Development and Deployment of Smart Contracts

In this paper, we design, create, and deploy different smart contracts for secure stakeholders' registration, adding nodes of new transactions, efficient update ledger, and protected preservation, as shown in Table 2. Contract 1 (secureStkRegister() and addRecord()) is designed to initiate the registration of new participants. The blockchain hyperledger sawtooth engineer is the responsible person who registers stakeholders after detailed verification and validation. The purpose of this contract is to maintain a platform for the secure and smooth exchange and broadcast of agricultural information directly among participating stakeholders. The function of secureStkRegister() of the contract is implemented to aggregate and run commodity price forecasting information and management, where the engineer manages each transaction execution, logs executions and management, and records addresses accordingly, as mentioned in the defined consensus policy [26,27]. This contract also records additional information for privacy purposes, such as stkID(), stkName(), stkRole(), rRecords(), forecastInfo(), addNewNodeTran(), exchangeInfo(), timestamp, system [execution], and other activities.

Table 2. Pseudocode of smart contracts implementation.

```
Contract #1: Stakeholder Registration and Exchange New Node Transactions Registration
System Initialization: Blockchain Hyperledger Sawtooth Engineer Initiate Agriculture System
Data Collection: Day-to-Day Records Captured from Agriculture Commodity Department
                 Received Records from Production and Supply Chain Sectors
                 Captured Data from Agriculture R&D Department
                 Partial Data Collection from Reginal State
                 Add Individual Transaction Addresses
Input Variables: file.[type].txt
                 int main():

                 stakeholder ID
                 stkID();
                 stakeholder name
                 stkName();
                 stakeholder role
                 stkRole();
                 stakeholder access details
                 stkAccDetails();
                 received records
                 rRecords();
                 forecast information
                 forecastInfo();
                 add new node transactions
                 addNewNodeTran();
                 exchange information
                 exchangeInfo();

Process:         Blockchain Hyperledger Sawtooth timestamp,
                 system [execution];
                 Metaheuristic-Blockchain-Based Stakeholder Registration and Add New Transaction Contracts
                 Add overall transaction after verification and validation by Engineer and Record Addresses
if               file.[type].txt
                 int main(): Metaheuristic-Blockchain Sawtooth Engineer is == true;
                 then, if    records of participating stakeholder are not in the stored data
                 then,       add new records
                             change state of distributed ledger;
                             counter + 1 after registration;
                             similarly, exchange information after adds new record details;
                             Sawtooth Engineer is the only responsible person who managed addresses of all the transactions
                             Engineer also manages stkID(), stkName(), stkRole(), stkAccDetails(), rRecords(), forecastInfo(),
addNewNodeTran(),exchangeInfo(), timestamp, system [execution];
                 else        all the executed transactions verified, analysis error, update state, and trace individually
                             terminate;
else             all the executed transactions verified, analysis error, update state, and trace individually
                             terminate;
```

Table 2. *Cont.*

Output: secureStkRegister(); addRecord();
Contract #2: Update Event of Node Transactions and Preservation in the Distributed Storage
System Initialization: Blockchain Hyperledger Sawtooth Engineer Initiate Agriculture System
Data Collection: Day-to-Day Records Captured from Agriculture Commodity Department Received Records from Production and Supply Chain Sectors Captured Data from Agriculture R&D Department Partial Data Collection from Reginal State Maintain Update Ledger and Record Addresses

Input Variables: file.[type].txt
int main():
 	
receive records for add new ledger
receiveRANLedger();
update ledger
updateLedger();
hash encrypted
hashEncrypted();
preserve records
preserveRec();

Process: **Blockchain Hyperledger Sawtooth** timestamp system [Execution]; Metaheuristic-Blockchain-Based Update Ledger and Preservation Contracts Add update forecast related ledger in the distributed secure storage and protected preservation Records individual transaction and Addresses
if file.[type].txt int main(): updateLedger() is = = true; **then, if** add new transactions are not in the stored details **then,** add update transaction counter + 1 = for every update ledger and preservation; change state in every update; Sawtooth Engineer is the only responsible person who handle all the update transaction and tackle addresses and records; Engineer also records extra activities such as, receiveRANLedger(), updateLedger(), hashEncrypted(),preserveRec(), timestamp, system [execution]; **else** all the executed transactions verified, analysis error, update the state, and trace individually terminate;
else all the executed transactions verified, analysis error, update the state, and trace individually terminate;
Output: updateRecord(); securePreservation();

The addRecord () function is used to provide an automated service of events for node transaction execution and management in a distributed network, as well as to directly broadcast new information to stakeholders [28,29]. This function calculates the size of the transaction and the party who initiated the transaction; moreover, it calculates the changes in the hash after the new transaction occurs, as shown in Figure 3.

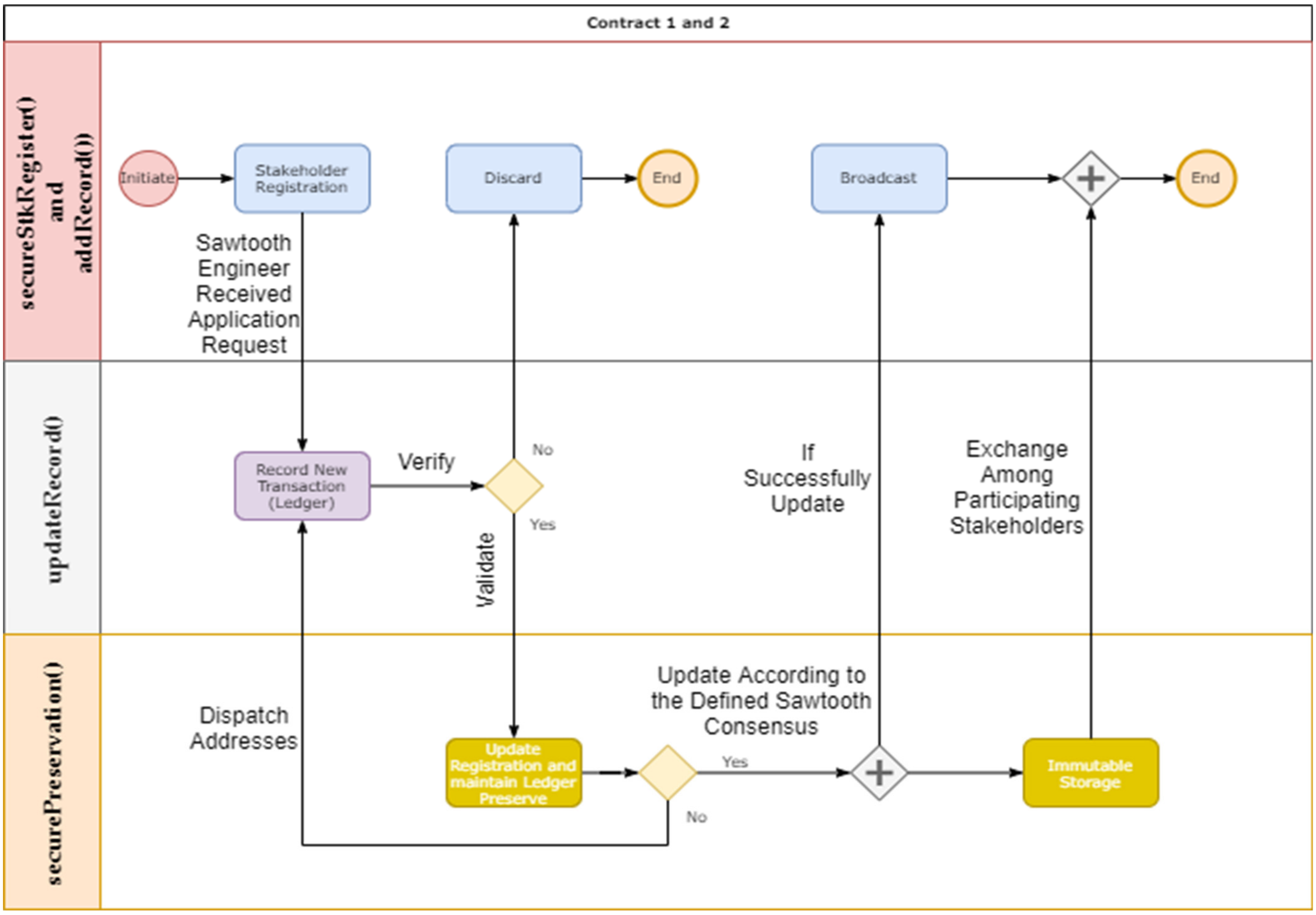

Figure 3. Activities (1) of the deployed smart contracts.

After the completion of the addRecord process, contract 2 is initiated, which aims to update the ledger and preserve the overall executional transactions (updateRecord() and securePreservation()). The function updateRecord() is implemented to record all the updates that occur after the permission of all the consensus according to the sawtooth-defined policies [30–32]. The update ledger is only possible when data transactions have already been recorded in the ledger previously. This function also adds more relevant details, including receiveRANLedger(), updateLedger(), hashEncrypted(), preserveRec(), timestamp, system [execution], and other related activities, which are performed. Finally, the securePreservation() function is designed and implemented to protect the ledger, exchange information in a decentralized distributed on-chain and off-chain network architecture, and store the ledger for long-term practice. The sawtooth engineer is the responsible person who collects units of transactions, integrates units after verification and node validation, protects information, and preserves it in the distributed storage with an immutable nature [33–35], as mentioned in Contract 2 and Figure 4.

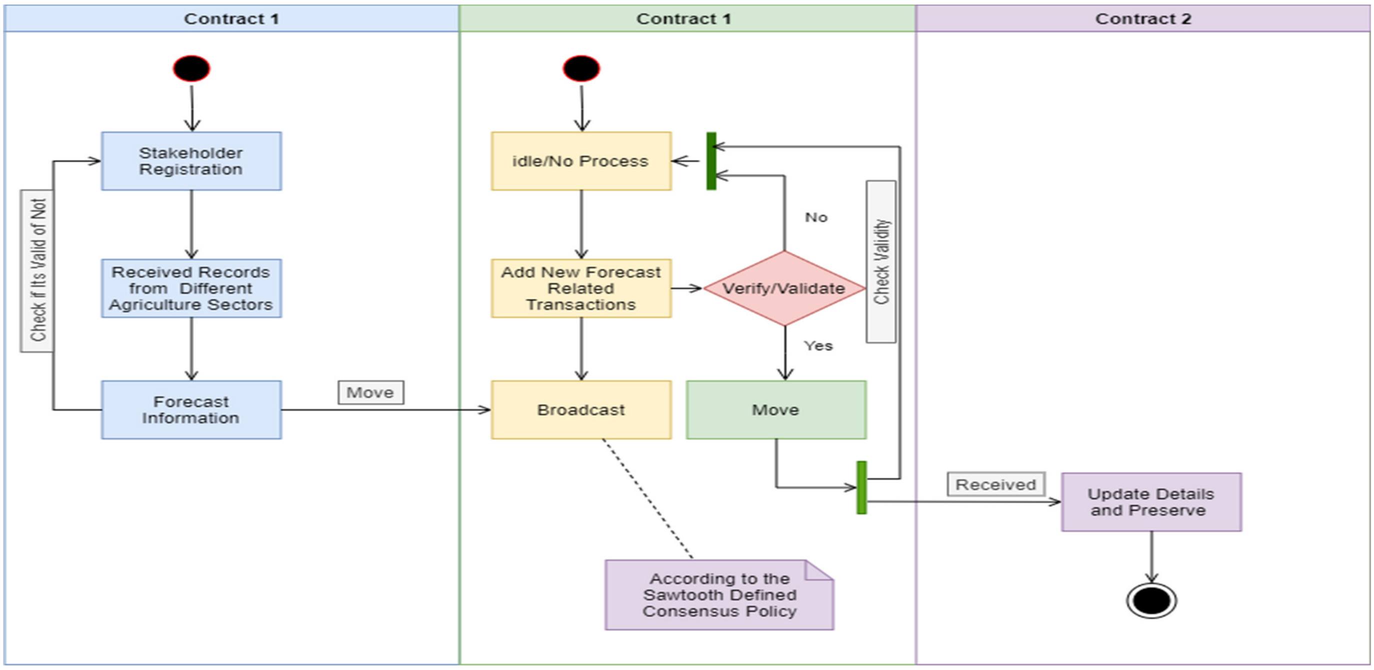

Figure 4. Activities (2) of the deployed smart contracts.

4. Simulations, Results, and Discussion

In this context, we elaborate on components of the metaheuristic-enabled genetic algorithm for the development of agricultural commodity price forecasting-related information scheduling, management, monitoring, and optimization, as shown in Figure 5. For this purpose, a genetic algorithm's encoder is designed to represent a cluster to formulate a complete system. For forecasting ledger optimization, genetic genes are trained to model that paradigm of memory-time in which commodity price tasks can be scheduled to be broadcast and managed in the newly added ledger structure. However, the crucial aspect to organizing is the fixed length of the genomes of the population, which is unable to expand while scheduling transactions over a distributed blockchain permissioned network. A genetic chromosome contains a number of genes that are similar in nature, whereas each chromosome represents a task of scheduling, managing, organizing, and optimizing the process. The size of an individual task is distinct, so we use a fixed length of node size, which is up to 2–4 MB. The number of agricultural commodity price forecasting-related services is analyzed and validated to validate the demand for forecasting privacy solutions, which is not substantial, at 4 MB/transaction.

The function of the relative size of nodes is defined according to local maxima and minima. The ledger analysis ranges from a threshold, which is either an open interval or a non-open interval, during the process of future commodity price prediction, such as 'f(a) >= threshold' (a non-open interval) or 'f(a) = threshold' (an open interval). For ledger maintenance and transmission, we designate a range of thresholds into three different categories while broadcasting or exchanging newly added forecast details over the network, such as initial, normal, and final stages, whereas initials start from 1 to 29 ms, which means less priority. If the records pass through the normal range (30–59 ms), then schedule this process as an average priority. If it is above 60 ms, give high priority to dispatching forecasting-related transactions directly.

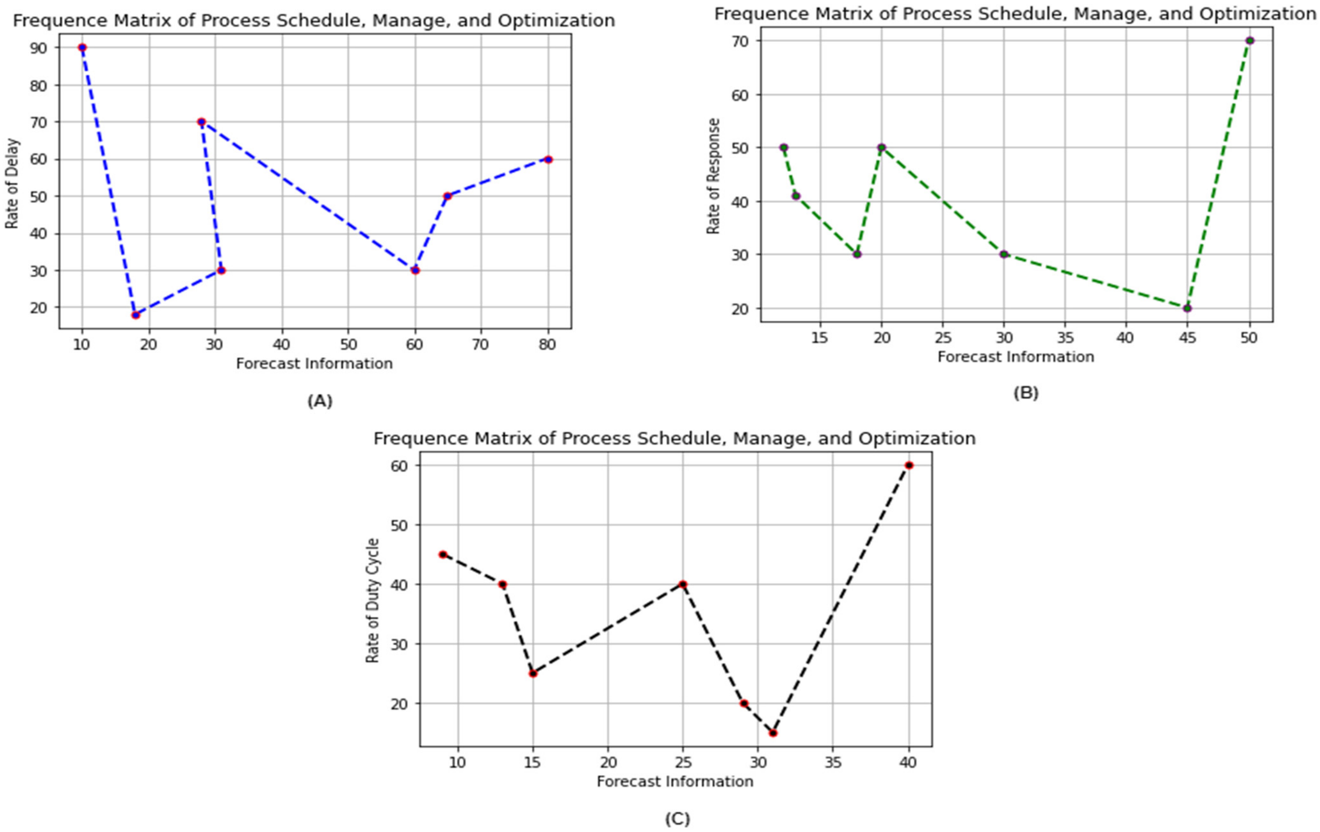

Figure 5. The simulation results of the frequency matrix of commodity price forecasting and classification: (**A**) the rate of delay between forecasting information using the linear-logistic regression (ML) method, (**B**) the rate of response between forecasting information, and (**C**) the rate of duty cycle between commodity classification and price forecast information.

With the use of a metaheuristic-enabled genetic algorithm, we examined and analyzed the dynamic commodity price forecasting problem with the initial gene pool of 480 in the complete population, whereas a stopping looping termination = 150 and is set at a single point of failure in the complete optimization process. A tournament selection genetic mechanism is used to regenerate or recombine a chosen symbol in the shape of crossover and mutation and make optimization, as shown in Figure 6. The randomly generated genes are chosen and mutated by using the strategy of one-point mutation, where 0 becomes 1 and vice versa. By toggling random bits, the system optimized the size of node transactions with a probability of 0.0001 to forecast a task or process and tuned the stopping point at a minimum of 80 loops with 110 executions simultaneously.

4.1. Comparison with Other State-of-the-Art Systems

In this paper, we compared and evaluated the differences between our proposed collaborative approach and other state-of-the-art methods for analysis. Yadav et al. proposed a blockchain-enabled system that achieves sustainable food security for the region of India [36]. This system provided a solution for food supply chain trackability and privacy. The distributed application of the proposed system provides a secure platform for registering stakeholders over the public permissionless network. However, the collaborative nature of this system investigates the agriculture supply-chain, integrated MCDM, total interpretative structure, market trails, and evaluation used of fuzzy-cross impact matrix multiplication-applied classification. The system is secure and protects the ledger using blockchain-distributed technology, but the drawback is that it uses a predefined hash-encrypted strategy with a public blockchain network with defined consensus policies and a digital signature strategy.

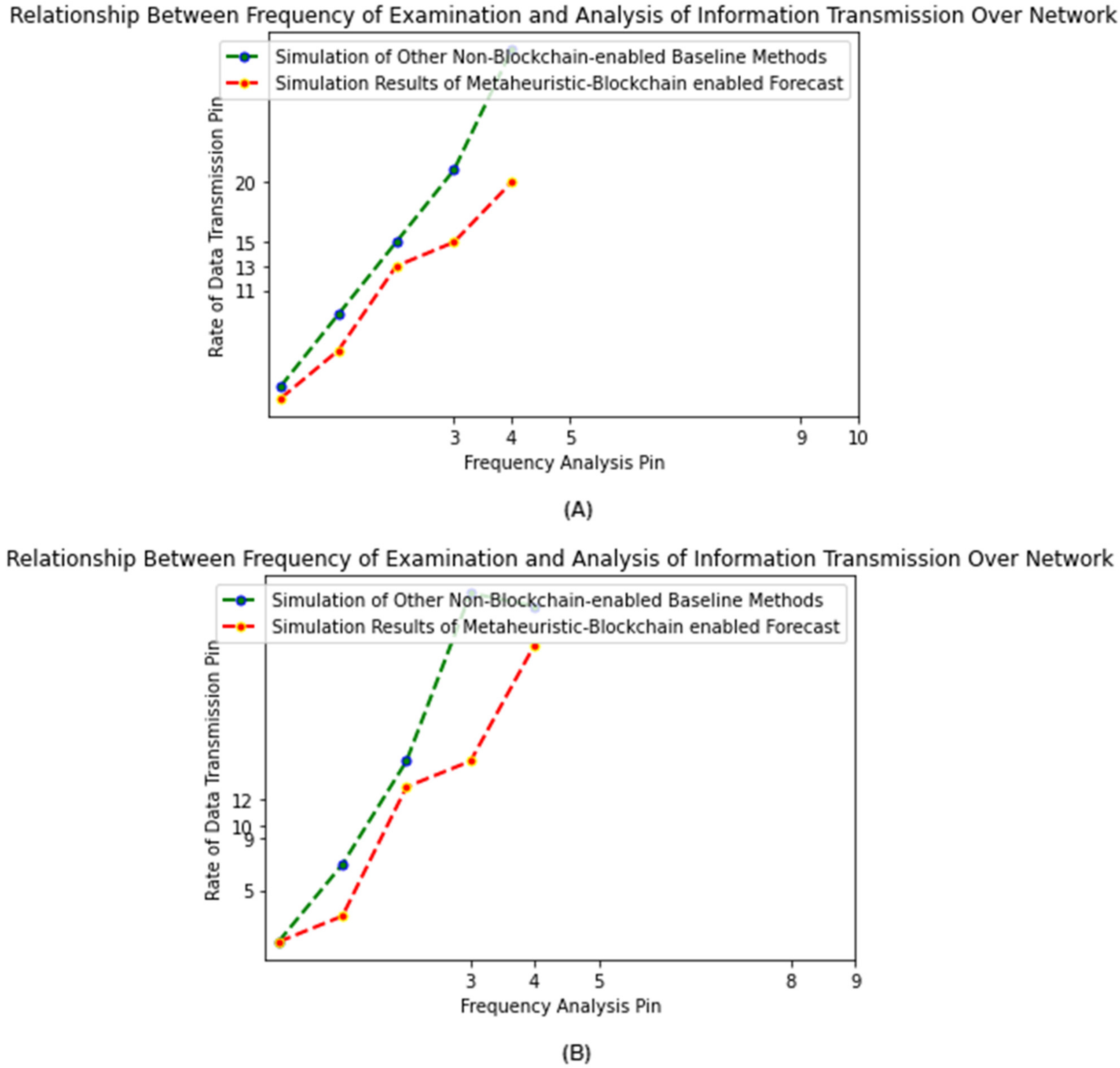

Figure 6. Simulation results of the relationship between frequency of examination and analysis of forecast information transmission over permissioned blockchain private network. (**A**) The simulation of other non-blockchain and metaheuristic-blockchain-enabled solution (1), and (**B**) the simulation of other blockchain (Ethereum) and metaheuristic-blockchain-enabled solution (2).

We examine, analyze, and evaluate various proposed methods; some of the well-known and related works are discussed as follows (shown in Table 3):

Table 3. Comparison table.

Method of Other State-of-the-Art Research	Matrix Analysis	Comparison with Our Proposed System
Netizens' behavior analysis: A blockchain-based esports framework for TPB, sustainable agriculture, and machine learning collaborative approach [37]. This proposed system used: • ReddiExtractoR • RStudio • Analysis Verasity • Blockchain • ML-based Predictive analysis strategy	The evaluation of this proposed method conducted through a general matrix is discussed as follows: Classification: Not applicable Prediction: Predictive analysis Security: Blockchain Information Protection: Pre-defined Network: Public System Accuracy: Not applicable Transaction Efficiency: Not applicable Storage: Cloud Node size: Not applicable Transaction Batch: Not applicable	The proposed collaborative approach of ML-Metaheuristic and Blockchain Hyperledger Sawtooth-enabled architecture is designed for agricultural commodity price forecasting. The matrix of evaluation is briefly discussed as follows: Classification: Linear classification Prediction: Logistic forecasting Security: Blockchain Hyperledger Sawtooth Information Protection: Hash Re-Encryption SHA-256 Network: Private permissioned architecture System Accuracy: The proposed collaborative approach's simulations demonstrate a system accuracy of 95.3 percent; it evaluates agricultural commodity forecasting and assists commodity classifiers in examining ledgers in a linear classification manner. Transaction Efficiency: Variable (depend on dynamic nature of execution) Storage: IPFS Node size: 2−4 MB Transaction Batch: 2 batches Therefore, the ledger optimization = 0.33 (33%), cost function (loss) = 0.3 (3%), transmission power = −12 dBm, jitter = 29 ms, delay = 80 ms, throughput = 130-bytes, duty-cycle and delivery = 0.17 (17%), and calculate variable response.
The forecast price and analysis: A factor of sustainable development of agriculture [38]. This system only focused on sugar production and sustainability. For this reason, it used different tools and techniques such as: • Machine Learning-based Predictive model • Auto-regression • Boc-cox transform • Blockchain • Integrated moving average strategy	The matrix is shown as: Classification: Linear Prediction: ML-auto-regression Security: Blockchain Information Protection: Pre-defined Network: Public System Accuracy: Not applicable Transaction Efficiency: Not applicable Storage: Cloud (Third party) Node size: pre-defined block size Transaction Batch: Not applicable	
Blockchain and the resurrection of consumer sovereignty in a sustainable food economy [39]. The investigation of this review is categorized as follows: • Sole end • Production robustness • A self-evident agricultural system required • Secure delivery of product among stakeholders • Sustainable privacy and security	The matrix of this system is discussed as follows: Classification: Not provided Prediction: Simple predictive approach used Security: Blockchain Information Protection: SHA-256 Network: Public System Accuracy: Not applicable Transaction Efficiency: Not applicable Storage: Cloud Node size: pre-defined block size Transaction Batch: Not applicable	
A Blockchain-enabled system to enhance environmental and agricultural sustainability: A systematic review, research agenda, and opportunities [40]. In this paper, the authors investigated different perspectives on sustainable security and privacy in agricultural growth and production. Some of the matrices are discussed as follows: • Meta-analysis protocols • Blockchain distributed technology • Bibliometric analysis	The evaluation matrix of the proposed systems is discussed as follows: Classification: ML-enabled classification methods are used for different purposes Prediction: Regression Security: Blockchain Information Protection: Network: Permissionless System Accuracy: Not defined Transaction Efficiency: not applicable Storage: Cloud Node size: pre-defined Transaction Batch: Not applicable	

4.2. Solutions to Blockchain-Metaheuristic-Enabled Challenges, Issues, and Limitations

This section discusses the proposed blockchain-distributed ledger technology-enabled hyperledger sawtooth solution for agriculture commodity pricing forecasting and management in distributed storage with protected ledger transactions, as well as the limitations and challenges associated with DAPPs. In this regard, we have extracted and highlighted the agricultural production-related issues, supply–demand analysis, forecasting, and commodity pricing fluctuation examination, and their related solutions are discussed as follows:

1. In this proposed collaborative approach of the blockchain-metaheuristic, there are a few significant assumptions and motivations regarding the utilization of hyperledger sawtooth-enabled permissioned private networks to protect complex commodity forecasting information, including secure data capturing (day-to-day market analysis), data scheduling, data processing, distributed information management, dynamic monitoring, and gratifying individual types of records [39,40]. All these records can be preserved on distributed immutable storage (IPFS) with the secure protocol of hyperledger preservation. However, there are two main hyperledger connectivity, communication, and preservation solutions. One is on-chain communication: automated transactions deliver and preserve information because of smart contracts. Therefore, the off-chain is based on a non-direct channel of information preservation and retrieval, not vice versa. The hyperledger services are available for every connected stakeholder. Substantially, it assesses the rate of utilized agricultural services and preservation details. Agricultural data, particularly commodity forecasts and price information, are more sensitive. Therefore, the data optimization and computation must be stored and analyzed against each other. Therefore, every aspect of the preserved records must be checked by analyzing them through the blockchain serverless hash-based (SHA-256)-protected environment. Most importantly, the complex structure of critical commodity forecasting information is because of the size of node transactions in the network. The nature of such preserved records may create inaccuracies in terms of security and privacy in the distributed ledger environment. Moreover, the duplication and redundant information of the proposed collaborative approach in the storage creates more complexity for the analysis of individual transactions, which also consumes additional costs for every event of node transactions. By this, they have a direct impact on the business rules of deployed smart contracts' performance by means of efficiency and streamlined automation.
2. In the decentralized distributed blockchain network environment, the cross-chain platform allows distinct nodes of different blockchains to connect with each other for the purpose of direct communication [40,41]. The cross-chain blockchain platform includes agricultural participating stakeholders, stakeholders' devices registration and management, a food department, a commodity forecasting center, and a price list dispatch department. Through this act, the platform provides an efficient enterprise services delivery architecture, where the agricultural commodity prices are forecast in a better way with the secure exchange of information delivery among participating stakeholders via DAPP. Individuals and multiple stakeholders of different agriculture departments of this distributed blockchain network can interact, interconnect, share records, organize, and manage agriculture services and data utilization, and conduct meaningful exchanges in the supply chain. The existing centralized application of the agriculture supply chain and services delivery platform is based on server architectural solutions. On the other hand, the blockchain smart contracts and metaheuristics enable systems to ensure and allow serverless transactions over a private permissioned network among participating stakeholders.
3. The metaheuristic-blockchain hyperledger sawtooth-enabled agriculture commodity price forecasting and privacy solution is gaining demand as a proficient and hash-protected solution for each sector of agriculture [40,42]. In developing countries, the existing agricultural environment is unable to provide the quality-of-service delivery and security required. There is no other way to connect different nodes of different platforms for communication. Therefore, the system faces an untrustworthy and unreliable nature of service delivery, management, and optimization solutions. In addition, the current system is also unable to provide transaction scalability, because

of the size of the node, and its overall dependency on the significant rate of data storage is another challenging aspect. However, the continuous process of blockchain-enabled commodity forecasting data collection and preservation-related transactions is passed through the permissioned serverless network environment. The overall scenario maintains ledger transparency, efficient delivery, secure exchange services, and flexible node size, which is inherently low-latency, reduces time, and sacrifices scalability for privacy.

4. The competent authority for food and livestock management needs to focus on the process of commodity-related information, such as data collection, examination, and analysis. The difference is because of the policies and procedures of blockchain agriculture. According to the metaheuristic-blockchain hyperledger sawtooth, the proposed collaborative approach handles secure agriculture service delivery, commodity price forecasting, evaluation of supply–demand relations, scheduling and managing of the process, and real-time monitoring facilities with protected preservation [41,42]. The ministry of agriculture and food safety needs to be concerned about collaborating with the other state-of-the-art food manufacturing enterprises, providers of security and privacy, and third-party distributed preservation solutions for secure communication and transmission. The proposed collaborative distributed application evaluates real-time forecasting to analyze the difference and formulate new authority digital signatures, consensus approvals, policies and procedures, and objectives.

5. Conclusions

This section discusses agriculture commodity price forecasting and privacy security-related challenges in the current centralized system of developing countries. We investigated the various kinds of solutions to relevant problems and analyzed different types of approaches, tools, and techniques, but we did not find a specific one that performs the overall task at once. Thus, the collaborative approach was proposed to analyze the day-to-day transactions of commodity forecasting, scheduling, and management, as well as ledger protection and preservation. This collaborative nature of the proposed system is dependent on two different folds, such as metaheuristics and blockchain-distributed ledger technology. For the process of data collection and optimization, we used a metaheuristic-enabled genetic algorithm to schedule processes and efficiently optimize records. These organized records were then shifted to machine learning-enabled regression-based linear and logistic methods for forecasting future commodity prices and production rates. The collaborative approach manages the predictive ledger in the distributed immutable storage using the blockchain hyperledger sawtooth via a private permissioned network architecture by utilizing these methods.

The main objectives and priority of this proposed system are to maintain secure agricultural forecasting events and node transactions in the distributed, decentralized network first. However, the smart contracts are designed, created, and deployed to automate the stakeholder registration, and the metaheuristic-blockchain enables the adding of new ledgers, updating details of added records, and preservation in immutable storage and distributed provenance. Deployment of the proposed metaheuristic-blockchain-based real-time commodity forecast system deals with the collaborative node transaction execution, registered ledger security, and privacy solutions involved in the current system, which creates limitations. The hyperledger sawtooth is utilized, which provides more efficient transaction delivery on the private network with an increased rate of transparency, integrity, and robust performance in data collection, examination, analysis, scheduling, prediction, management, monitoring, and preservation. Thus, we have also provided solutions to well-known challenges that emerge while implementing the proposed metaheuristic-blockchain-based collaborative approach. The deployment of emerging challenges is the primary focus of our future research.

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