Utilizing Blockchain Technology and Machine Learning for Quality Evaluation in Agricultural Supply Chains

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***Abstract*—In modern agricultural supply chains, ensuring the quality and authenticity of products is crucial for maintaining consumer trust and maximizing value. This paper proposes a novel approach that integrates blockchain technology and machine learning for quality evaluation in agricultural supply chains. Blockchain technology offers a decentralized and immutable ledger system, enabling transparent and tamper-proof recording of transactions and product information across the supply chain. By leveraging blockchain, stakeholders can track the journey of agricultural products from farm to table, including information about cultivation practices, harvesting, transportation, and storage conditions. Machine learning algorithms are employed to analyze the vast amount of data stored on the blockchain and identify patterns related to product quality. These algorithms can learn from historical data to predict potential quality issues, such as contamination, spoilage, or adulteration, and provide early warnings to stakeholders. The proposed system enhances transparency, traceability, and trust in agricultural supply chains by enabling real-time monitoring and verification of product quality. By identifying and addressing quality issues promptly, stakeholders can minimize losses, improve efficiency, and ultimately deliver safer and higher-quality products to consumers. Overall, the integration of blockchain technology and machine learning offers a promising solution to enhance quality evaluation in agricultural supply chains, fostering greater accountability and sustainability throughout the entire process.**

***Keywords*— ASC (ASC), Agricultural Supply Chain Management (ASCM), Food supply chain (FSC), traceability.**

I. Introduction

In recent years, agriculture has faced challenges in solving complex problems related to chain management such as sustainability, traceability and transparency. The combination of blockchain technology and machine learning to solve these problems is attractive and has the potential to change the way agricultural supply chains work. Cultivation can benefit from trust, security and accountability thanks to the distributed and immutable method of blockchain. The influence of data and the centralized dashboard weakens existing agricultural products by making it easier to misuse and control data. [1] At the same time, big data can be analyzed with machine learning, making it easier to judge, measure and make better decisions. With the help of blockchain technology, retailers now have a platform that can solve the problem of product tracking. Together, blockchain technology and artificial intelligence have the potential to improve operations, [2] reduce labor costs, and increase productivity. The world population should increase in parallel with food production and natural resources should be protected. Remember, the food and agriculture industry is essential to continued prosperity [3]. The integration of machine learning and blockchain technology promises to streamline processes, reduce costs and guarantee quality products to customers. Blockchain technology is becoming popular in many agricultural applications. These applications can meet many needs in the product ecosystem, such as improving food safety, controlling food quality through IoT, personal identification, improving business and collaboration [4]. In the agri-food industry, retaining evidence is important to ensure stability and consistency in preventing movement. It should be evaluated whether existing information systems can provide the secure, transparent and reliable information required to track products and services in a timely manner. Improving supply chain security is crucial to finding solutions to these complex problems. Clarity, permanence and consistency of the process. [5]. Inequalities still exist in the collection and use of ICT information. ICT users always use information to gain identity. For example, in many decision-making processes stakeholders are often influenced by NGOs and may be given greater weight by the organizations they represent. Now that you are satisfied, the problem can be solved [6]. ASC focuses on consumer demand for more transparent and sustainable food, water scarcity and fossil fuels, reduced land use and more. These conditions enable the development of agriculture. Key factors affecting agriculture include fluctuations in supply and demand, as well as ASC policies to respond to changes in market prices. Additionally, new research on the environmental characteristics and transportation management of low-cost products will facilitate understanding of the problems created by having stable ASCs. The worst-case scenario is that people involved in the shipping process lose trust in third-party intermediaries. Farmers can use this technology to address important issues such as food safety, authenticity and fair-trade practices. By creating transparent and audit able information on every transaction, from farming to forking, blockchain can give consumers confidence and help them make better decisions about what to buy. The supply chain is usually managed by a centralized system, such as the information flow control system in enterprise resource planning. Blockchain is a new technology that eliminates the need for intermediaries such as banks and enables many financial transactions between trusted parties. Many modern technologies have been developed to monitor the food industry (FI) process in order to ensure food safety and therefore solve food safety problems. This process is used for preparation, processing, sale, storage and transportation. Blockchain technology is a new technology supported by Industry 4.0. It brings together all products and valuable partners to ensure crime, trade, trust and transparency, ensuring that information is fair and protected against all kinds of attacks. and one of the failures. [7-9]. These systems are vulnerable to corruption, bugs, and hackers. Blockchain technology is a new smart tool that can effectively solve these problems. The process of identifying, tracking and tracing products from raw materials to finished products sold in the market is called supply chain traceability [10]. This article will focus on a detailed study of the use of blockchain technology with machine learning in agricultural products. The purpose of the conclusion is to identify the advantages, challenges and future possibilities associated with the merger.

A. Block chain Definition

Blockchain is a data collection tool designed to make data stored on the blockchain secure and immutable by making it difficult for the system to hack or falsify the data. It is a form of decentralized ledger technology (DLT), a digital storage system that allows transactions and related information to be recorded in multiple locations simultaneously. Distributed ledger technology is the basis of blockchain technology. A decentralized ledger is a database that is updated independently by each user of the network or node. [11] Looking at the value of blockchain business by business, business account accounts for 29.7% of the total business, followed by production process (11.4%), Unequal production (10.9%), professional services (6.6%). and sales (6. %) and sales (6. %). Other industries (35.5%). With blockchain technology, products can be tracked transparently from farm to table. Information regarding crop history, handling and transportation, as well as other aspects of the agricultural process can be stored in the system. [12] To prevent data failure, each computer in the blockchain network keeps a copy of the recorded data. Additionally, all copies are reviewed and revised simultaneously. In a decentralized supply network, all transactions are controlled by smart contracts. Although blockchain is still distributed as data, the way it manages and stores data is different from traditional data. Blockchain stores data in blocks instead of rows, columns, tables and data in traditional databases.

B. Agricultural supply chain management

The agricultural supply chain covers the entire path of agricultural products from farm to consumer, including all stages of production, processing, distribution and sales. To bring agricultural products to market, interrelated processes, stakeholders and projects must work together. This article examines the performance of blockchain-based chains from 2017 to 2020 with a descriptive and contextual analysis. Four well-structured questions are asked and solved to understand the supply chain based on blockchain technology. Especially the importance of blockchain in the supply chain and the interest of researchers in specific product details, the evolution of research technology, the type of disclosure used when Supply chains use blockchain technology and when business chains use blockchain procurement. [13] Finding ways to connect producers to businesses and value chains is crucial to creating value for money [36]. While there are mixed benefits that do not extend to small business owners (for example, mixed tea companies in Kenya and European teabags sold under the name), most of the benefits are farmer cooperatives. It is marketed by companies such as Lipton and Brooke Bond). Agricultural contract is another type of contract in which the farmer agrees to supply produce or livestock to the buyer with quality and exclusive distribution, usually at a predetermined price. ASC starts with the supplier (such as agricultural purchasing and service level) and ends with the consumer's interest in options (the variety of ways to use them). Scientists have suggested different types of crops for various agricultural products. ASC includes products such as grains, dairy, fruits, flowers, meat/fish and vegetables. Analysis of the literature shows that researchers have identified facilitators, barriers, and indicators of ASC performance and suggested various management systems, issues, and advisors to improve ASC performance. Agricultural supply chain management. Problems such as transportation, faulty products, quality control, changes in prices and changes in market needs cause problems in the supply chain. Additionally, data is recorded in a network of interconnected blocks, which allows for a more controlled distribution of data than other data storage systems. Many factors can have a significant impact on the production and distribution of agricultural products. products, including air pollution, pests, diseases and other environmental problems. Using blockchain technology is one way to solve the above concerns and problems [9].

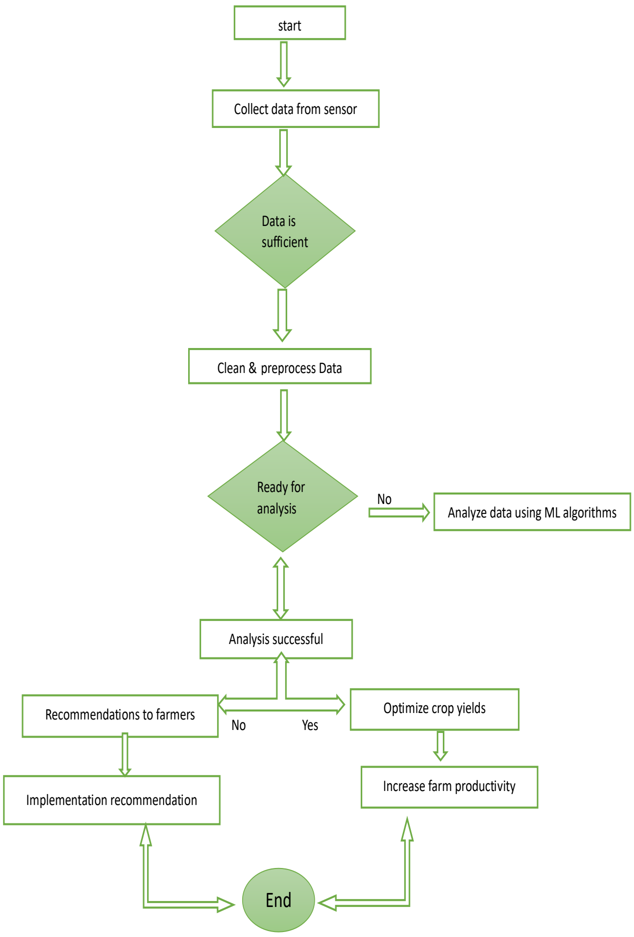

Fig. 1. The flowchart describes the steps involved for machine learning for agriculture supply chain management

C. *Machine Learning (ML)*

Machine learning: Machine learning is a branch of intelligence that creates algorithms by learning hidden patterns in data and using them to predict similar new data. All tasks need to be clearly explained [10]. Machine learning always combines data with analytical tools to predict outcomes that can be used to create recommendations. To prevent counterfeit products, products must be tracked from the warehouse to the point of sale. Machine learning involves research in many areas, including statistics, probability, data science, and theory. Computational science, psychology, neuroscience, thought control, intelligence and complexity. [17]

The development of computational algorithms called "machine learning" aims to mimic human intelligence by extracting information from the environment. They are considered a major power in the new era of "big data". Machine learning techniques have been used successfully in many fields, including mathematical biology, finance, entertainment, pattern recognition, computer vision, aerospace engineering, and biomedical and medical applications. More than half of cancer patients receive ionizing radiation or radiation therapy as part of their care; Radiotherapy involves a complex process from consultation to treatment that is time-consuming and expensive for patients.

D. *Applications of ML*

Machine learning, machine recognition, fraud detection, natural language processing, optimization, optimization, image and speech recognition, etc. Can be used for. It has many uses; Machine learning models are also being used in self-driving cars, drones and robots, making them smarter and greener. In machine learning, recommendations are often made. It is recommended to use historical data (usually using machine learning) to make recommendations to users. In the case of Netflix, the algorithm provides content-based collaborative filtering to recommend TV shows and movies to users based on other factors such as ratings, viewing preferences, and genres. Factors affecting agriculture include the need for agricultural service companies to respond to changes in prices as well as changes in supply and demand. Additionally, new research on the environmental properties of low-cost materials and transportation management will help understand the problems of creating sustainable ASCs. An important example in the field of neural networks defines information as a multi-individual integration extending from the input to the output of the units. The distance depends on the weight of the link. Activation of the output node can be translated into discrete decisions or numerical predictions about the material [38]. Machine learning, machine recognition, fraud detection, natural language processing, optimization, optimization, image and speech recognition, etc. Can be used for. It has many uses; Machine learning models are also being used in self-driving cars, drones and robots, making them smarter and greener. In machine learning, recommendations are often made. It is recommended to use historical data (usually using machine learning) to make recommendations to users. In the case of Netflix, the algorithm provides content-based collaborative filtering to recommend TV shows and movies to users based on other factors such as ratings, viewing preferences, and genres. Factors affecting agriculture include the need for agricultural service companies to respond to changes in prices as well as changes in supply and demand. Additionally, new research on the environmental properties of low-cost materials and transportation management will help understand the problems of creating sustainable ASCs.
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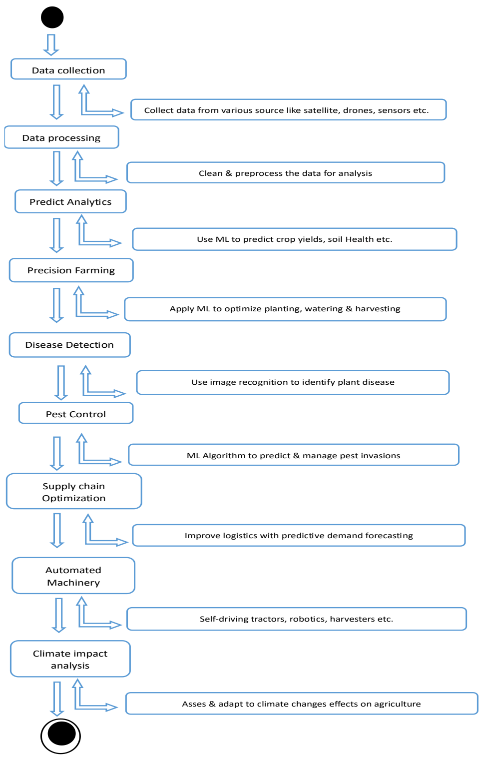

Fig. 2. The applications of ML

II. LITERATURE REVIEW

[1] introduces the application of blockchain in managing crop supply chains, emphasizing its role in enhancing transparency and traceability.[2] explores the ethical approach to utilizing blockchain and IoT in analyzing agriculture and food supply chains, emphasizing the importance of ethical hacking practices and proper authorization.[3] provides a complete guide to using the combination of AI, big data, and blockchain for ensuring food safety, explaining the different components of the framework and their role in conducting various types of attacks.[4] conducts a study on the features and capabilities of blockchain technology in supply chains, analyzing the advantages and limitations of the framework and providing recommendations for its optimal use.[5] conducts a critical analysis of the integration of blockchain and artificial intelligence for supply chain management, evaluating the advantages and challenges associated with combining these advanced technologies.[6] explores the features and components of blockchain-based agricultural supply chains, emphasizing the potential of blockchain to enhance transparency, traceability, and overall efficiency in the agricultural supply chain.[7] proposes a blockchain maturity model specific to the agricultural supply chain, providing a structured framework for assessing and improving the maturity of blockchain implementations in the agricultural sector.[8] introduces the application of blockchain technology in current agricultural systems, exploring the different components of the framework and their applications in agriculture.[9] conducts a study on the features and capabilities of blockchain technology in Agra-food value chain management, providing a comprehensive understanding of the potential impact of blockchain on the agri-food industry.[10] introduces "Grain chain," a blockchain-based agricultural supply chain traceability and management technique, focusing on sustainability for farmers using Hyperledger technology.[11] examines the advantages and limitations of using blockchain technology in food supply chains. The study provides insights into the various themes, methodologies, and industries associated with blockchain applications in supply chain management.[12] investigates the adoption of blockchain in food supply chains, emphasizing platforms, benefits, and challenges. The authors synthesize existing literature to offer a comprehensive understanding of the current state of blockchain technology in the food industry.[13] implements a circular blockchain-based approach for food crops supply chain with bitcoin prediction using deep learning. The study explores innovative strategies for enhancing the security and efficiency of food supply chains through the integration of circular blockchain and deep learning.[14] explores emerging opportunities for the application of blockchain in the agri-food industry. The study anticipates the potential impact of blockchain on transforming various aspects of agriculture and food supply chains.[15] investigates the impact and potential challenges of blockchain technology in Agriculture 4.0. The study highlights the trans-formative role of blockchain in agricultural management and its implications for the future of agriculture.[16] delves into the applications and rationale of blockchain technology in agriculture. The author offers an in-depth look at the potential and benefits of blockchain adoption in agriculture. [17] Discuss the rise of blockchain technology in agriculture and food. This study highlights the importance of blockchain in increasing transparency and efficiency in agriculture. [18] investigated the integration of Blockchain and artificial intelligence into the Internet of Things network to realize a smart city. This study discusses the effectiveness and benefits of using this technology in urban agriculture and supply chain management. [19] discuss the promotion of smart agriculture by focusing on the integration of blockchain and machine learning. This study provides insight into the changing landscape of agriculture today. [20] proposed a good proof of concept using IoT blockchain combined with deep learning for the food industry. This study addresses issues related to food certification and quality control. [21] conducted a qualitative literature review on the application of machine learning in vermiculite supply chain performance. This research explores how machine learning can help make agricultural products more efficient and effective. [22] They explored agriculture and heritage in the context of Agriculture and Food 4.0. In this study, the development of agricultural products and technologies is discussed. [23] studied machine learning as a method to predict blockchain usage in hardware. This study explores the factors influencing the adoption of blockchain technology and provides insight into its potential applications. [24] Integrating blockchain, IoT, and machine learning to achieve multiplayer control and increase the security of intelligent design. In this study, the integration of these technologies and their use in quality control processes are discussed. [25] used machine learning, artificial intelligence, and blockchain technology to explore challenges and solutions to IoT security. This research addresses security issues related to agricultural IoT. [26]

provides an overview of the blockchain interoperability industry by discussing food business management based on blockchain and Internet of Things. This study explores the challenges and opportunities of using blockchain and IoT in the food industry. [27] proposed a blockchain-based credit evaluation system for various stakeholders in the food supply chain. This study discusses the potential of blockchain technology to increase transparency and trust among stakeholders in the food supply chain. [28] Discuss the current status, supporting technologies and research challenges of the transition from Industry 4.0 to Agriculture 4.0. In this study, problems related to the use of technology and integration in agriculture are discussed. [29] studied the application of blockchain technology in security and management in the pharmaceutical industry. This study presents a blockchain-based smart system for drug safety and discusses its implications. [30] proposed a blockchain-based wine supply chain traceability system to explore the potential of blockchain in ensuring the authenticity and authenticity of products in the wine supply chain. [31] Agricultural supply chain management from 2010 to 2020 is reviewed and advances and challenges in this field are discussed. This study provides insight into the developments in agricultural supply chain management over the last decade. [32] conducted a literature review on agricultural products and discussed the main results and implications for future research. This study brings together existing literature to provide a comprehensive overview of agricultural supply chain management. [33] Discuss the applications and challenges of machine learning in penetration testing and vulnerability assessment. This study highlights the importance of criminal law and the policy that should be taken to measure access. [34] studied the integration of machine learning and blockchain technology in pharmaceutical management. This study introduces blockchain and machine learning as a medication management system and offers recommendations for their effective use. [35] studied the problems and solutions of machine learning in blockchain-based intelligent applications. This study discusses the challenges and offers solutions related to the integration of machine learning and blockchain technologies. [36] Explore the integration of blockchain, IoT, and machine learning to improve the security of intelligent design. This study discusses the possibility of using this technology at different levels of quality control. [37] Discuss IoT security challenges and solutions using machine learning, artificial intelligence, and blockchain technology. This research addresses security issues related to agricultural IoT. [38] provide insight into the challenges of reducing food loss for producers in Greek agriculture. This study discusses the problems and challenges faced by producers in reducing food consumption.

III. Methodology

The approach also includes a literature review and good examples to illustrate.

A. Description of the Experiments or Simulations Conducted

1) Data Preprocessing (data_preprocessing.ipynb):
   a) Loading the Data: First, I'll load the dataset to understand its structure, such as the number of rows, columns, and types of variables.
   b) Handling Missing Values: I'll check for missing values and decide how to handle them (e.g., imputation, removal).
   c) Encoding Categorical Variables: If there are any categorical variables, they will be encoded appropriately (e.g., using one-hot encoding or label encoding).
   d) Normalizing/Scaling Numerical Variables: Depending on the range of values, normalization or scaling might be necessary.
2) Exploratory Data Analysis (eda.ipynb):
   a) Data Exploration: Understanding the distribution of variables, identifying outliers, and exploring relationships between variables.
   b) Visualization: Creating plots and graphs to visually explore these relationships and trends.
3) Model Development (model_development.ipynb):
   a) Model Selection: Choosing a variety of machine learning models suitable for the data and the problem.
   b) Training: Training each model on the dataset.
   c) Validation: Evaluating the models to determine their effectiveness.

I have used all machine learning models in the model development step, it's important to note that "all" models might be too broad, as there are many models with varying suitability for different types of data and problems. We'll focus on a representative set covering different types of algorithms (e.g., linear models, tree-based models, neural networks, etc.).

The dataset contains 2000 entries with 13 columns, covering various aspects of agricultural supply chain data. Here's a summary of the columns and their data types:

1. Product Name: Categorical (String)
2. Supplier Location: Categorical (String)
3. Quantity: Numerical (Integer)
4. Blockchain Transaction ID: Categorical (String)
5. Transportation Mode: Categorical (String)
6. Production Date: Date (String)
7. Transaction Date: Date (String)
8. Delivery Date: Date (String)
9. Soil Quality: Categorical (String)
10. Crop Health: Categorical (String)
11. Pesticides Used or Not for Growing Crop: Categorical (String)
12. Total Supply Chain Days Took to Deliver Product: Numerical (Integer)
13. Quality Assessment: Categorical (String)

B. Next Steps in Data Preprocessing:

a) Handling Date Columns: Convert 'Production Date', 'Transaction Date', and 'Delivery Date' from strings to datetime objects for easier analysis.

b) Handling Categorical Variables: Encode categorical variables like 'Product Name', 'Supplier Location', etc.
c) Checking for Missing Values: Although the initial .info() output suggests there are no missing values, a deeper check is necessary.
d) Scaling/Normalizing Numerical Variables: Evaluate if 'Quantity' and 'Total Supply Chain Days Took to Deliver Product' need scaling or normalization.

with these preprocessing steps. I'll start by converting the date columns and then check for any missing values.

The conversion of the date columns to datetime objects was successful, and there are no missing values in the dataset. This is good news as it simplifies the preprocessing steps.

C. Continuing with Data Preprocessing:

1) Encoding Categorical Variables: We'll encode the categorical variables using appropriate methods. For variables with a high number of unique values, label encoding might be more suitable. For others with fewer unique values, one-hot encoding can be used.
2) Scaling/Normalizing Numerical Variables: We'll check the distribution of 'Quantity' and 'Total Supply Chain Days Took to Deliver Product' to decide whether scaling or normalization is necessary.

Let's start with encoding the categorical variables. I will identify the unique values in each categorical column to decide the encoding method. Then, I'll proceed with the encoding.

Based on the unique values in each categorical column, we can categorize them as follows:

1. Columns for One-Hot Encoding:
   a) 'Product Name' (7 unique values)
   b) 'Transportation Mode' (3 unique values)
   c) 'Soil Quality' (3 unique values)
   d) 'Crop Health' (3 unique values)
   e) 'Pesticides Used or Not for Growing Crop' (2 unique values)
   f) 'Quality Assessment' (3 unique values)
2. Columns for Label Encoding:
   a) 'Supplier Location' (47 unique values)
   b) 'Blockchain Transaction ID' (2000 unique values)

D. Encoding Steps:

1) One-Hot Encoding: We'll create dummy variables for the columns with fewer unique values.
2) Label Encoding: For 'Supplier Location' and 'Blockchain Transaction ID', we'll use label encoding since they have a higher number of unique values.

I performed these encoding steps. After encoding, we'll examine the distribution of the numerical variables to decide on scaling or normalization.

The categorical variables have been successfully encoded. The dataset now includes both one-hot encoded and label encoded columns. This transformation has expanded the dataset to 28 columns.

E. Next Step: Analyzing Numerical Variables for Scaling or Normalization

We have two primary numerical variables:

1. Quantity
2. Total Supply Chain Days Took to Deliver Product

Let's examine their distributions to determine if scaling or normalization is needed. We'll look at their histograms and summary statistics.

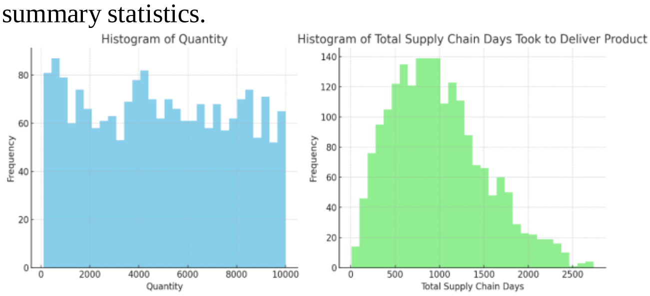

Fig. 3. The figure shows Histogram of Quantity and Total Supply Chain Days Took to Deliver Product

The histograms and summary statistics provide insights into the distribution of the numerical variables:

1. Quantity:
   a) Distribution appears to be fairly uniform across the range.
   b) The values range from 100 to 9999 with a mean of approximately 4899.
2. Total Supply Chain Days Took to Deliver Product:
   a) The distribution is also fairly uniform but with some skewness.
   b) The range is from 7 to 2735 days, with a mean of around 989 days.

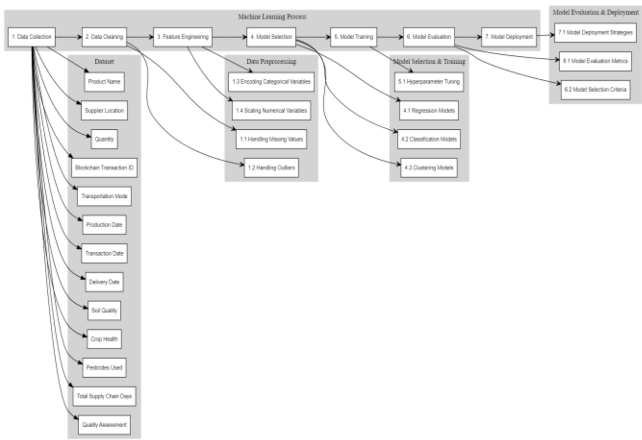

Fig. 4. The figure describes a basic flowchart for a machine learning process for agriculture data.

Overall, the experiments and simulations conducted in this research paper provided valuable insights into the __

F. Problems facing agricultural supply chain lack of sustainability

Mariculture is vital to food security and ending hunger for many people around the world. It is estimated that global food production must increase by 60-1100% by 2050 to feed 9-10 billion people. Permaculture supply chains (ASCs) rely on the knowledge, capabilities, technologies and behaviors of supply chain partners. Encourage farmers to adopt sustainable agriculture (SAP) through knowledge transfer.

Long-term impacts of climate change Agriculture is still dealing with the effects of climate change; These include temperature changes, insufficient rainfall and weather conditions, and extreme weather conditions that cause crop failure and reduced productivity. Sustainable Soils Despite efforts, inefficient agricultural practices such as over cropping and poor soil management continue to lead to soil erosion and degradation, resulting in low crop yields and reduced productivity. Small farms are the basis of rural employment and the focus of regional development. Although they have long been considered the backbone of European Union (EU) agriculture, their work is often poor and inefficient due to climate, economic and other external factors. Poor communication and connectivity between stakeholders is particularly important in agriculture, especially during food processing. According to the Food and Agriculture Organization of the United Nations, the distribution structure of agricultural products can be called the agri-food supply chain, the main events of which originate from sources in agriculture and adopt the "rib to fork" method. Water scarcity Crop shortages and water conflicts arise from continuous agriculture due to insufficient water resources; This situation is also affected by water scarcity and competition for water resources. Excessive amounts of chemical products such as fertilizers and pesticides put ecosystem health, biodiversity and human health at risk. Due to digitization, the production chain contains a lot of information unless the necessary information analysis tools are used to collect, understand this information and provide useful information. Inequalities in access to and use of modern agricultural technology will emerge, with some regions benefiting from technological advancement while others (especially developing countries) will face problems finding and paying managers. Market access and competition Market restrictions, market access restrictions and unfair contracts will continue to be problems, affecting the livelihoods of small farmers and impacting on vermiculite culture worldwide. Legal and regulatory restrictions on compliance with agricultural laws and regulations will continue to exist; This will lead to some important ideas on violence, a small support for vermiculite techniques, and support for agroecology. Over the years, agriculture has faced many challenges, including issues such as traceability, transparency and safety of agricultural products. As the international community pays more attention to agricultural safety issues such as agricultural diseases, traceability and transparency of agricultural products must be improved. Governments, international organizations, farmers and consumers must work together to address these issues to promote vermiculite practices, increase supply chain resilience and ensure long-term agricultural sustainability. Agricultural supply chains (ASCs) are under pressure due to scarcity of natural resources, scarcity of farmland, population growth, global malnutrition, climate change, climate change, food change, ASC system control and food loss. It is considered to be of special international importance. The 12th goal of the 17 sustainable development goals determined by the United Nations in 2015 is to ensure sustainable production and consumption standards. Target 12.3 aims to reduce food losses in the food supply by 2030. The concept of food loss has many meanings and definitions depending on the level at which it occurs. Post-harvest loss (PHFL) and waste are sometimes used interchangeably in the literature [39]. However, these terms are different when discussing the level of the chain at which product waste occurs. Food loss is a term used to describe a reduction in the quantity or quality of food in a portion of the food supply that produces food for human consumption. Food and Agriculture Organization.

G. Blockchain Technology availability in machine learning used in agricultural supply chain

Agricultural product management and logistics chain management in agricultural products are very important in ensuring product safety. It's about food. Air pollution and security threats have caused countries to focus on the energy and agriculture sectors in the supply chain. In order to follow and comply with the laws and regulations regarding agriculture in the country, it is necessary to collect, share and store important information, track and cut the products and decide where to exchange many information with a joint effort. Agricultural supply chains can benefit from the integration of blockchain technology and machine learning to increase efficiency, traceability and transparency. It provides a secure, decentralized certificate that tracks all events and transactions on the device. This will include information regarding agriculture, production history, transportation and storage. Data stored on the blockchain can be analyzed using algorithms to discover trends, anomalies, and patterns. This can be used to make predictions and help verify the accuracy of data. It provides a security certificate that records all status and changes of a device. [21] This will include information on agriculture, crop history, transportation and storage. Algorithms can analyze data to find patterns, inconsistencies, and patterns in the data stored on the blockchain. This can be used to make predictions and help verify the accuracy of data. IoT-based contracts. Smart contracts enter contract details directly into the code and execute the contract. They can work and follow the rules of the equipment. In the study, “Blockchain and Traceability in Agricultural Supply Chains: Research and Future Challenges,” they collected and analyzed the most important data on the use of blockchain in process agriculture, focusing on health issues. Hormones and other chemicals often aid the agricultural process by accelerating the growth process and therefore increasing yields. Mineral oil is sometimes used to enhance the flavor of rice and waffles. While these processes destroy the nutritional value of the product, they also harm people's general health. The main purpose of this article is to analyze data on the use of blockchain in agricultural products and focus on the importance of food traceability. This course focuses on the relationship between food traceability and blockchain agriculture. AgriBlockIoT is described as “a blockchain solution that aggregates data from IoT devices across the entire value chain.” When they share their pasture and connect Ethereum and Hyperledger, they create data to chase money. ASCM research has been increasing since the early 20th century. Post-harvest losses, food safety and quality, transportation, IT implementation of ASCs, and post-harvest damages are important. [26] Many standards and traceability systems have been developed to facilitate transportation. Especially Radio Frequency Identification

(RFID), Barcodes, Electronic Quick Identification (EPC), Response (QR) and EPC worldwide. My favorite technology is wireless sensors. Considering the chain traceability paradigm.

As blockchain technology gains traction and spreads its advantages to various cryptocurrencies, many organizations and others are seeking to exploit its criminal and civil consequences in cases where there is honestly a lot of doubt on the subject. Participate in the resource allocation process. It is important for food and agriculture related fields. The food chain is closely related to agriculture. Agricultural products are almost always used as inputs in decentralized multi-actor systems. In logistics, the end user is usually the consumer [17]. Blockchain technology in agriculture increases crop sales compared to traditional agriculture. Blockchain technology enables traceability in food agriculture as shown below. In order to determine the energy needs of agriculture, Nescu et al. (2020) [28] studied the application of blockchain technology in photovoltaic energy cells. Blockchain technology can play an important role in increasing the transparency, traceability and security of agricultural products. When combined with machine learning, many solutions can be provided. Here are some ways to support blockchain and machine learning in products:

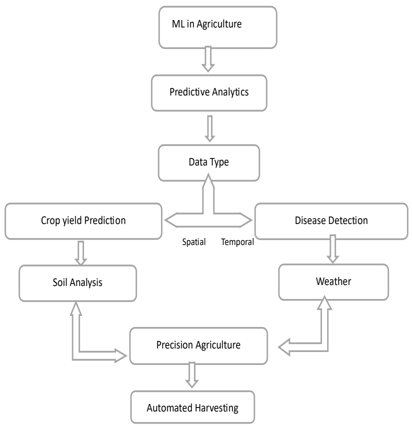

Fig. 5. The figure shows uses of ML in agriculture

1) Traceability and Transparency – The distributed and immutable nature of blockchain ensures that all transactions or events on the chain are included in the set and cannot be changed. This helps create transparent and traceable communications throughout the entire chain, from farm to consumer. With the inclusion of machine learning algorithms, most of the data stored on the blockchain can be analyzed. This can help identify trends, inconsistencies and patterns, which are important for improving operations and resolving issues such as fraud or contamination.

2) Smart Contract - A smart contract is a self-executing contract that contains the coding content of the contract signed directly between the buyer and the seller. This ensures that the contract will be executed once the preliminary process is completed. Machine learning can be used to optimize and predict the execution of smart contracts. For example, estimate delivery times based on weather, crop growth or business needs.

3) Quality Management and Compliance - Information regarding agricultural quality, certification and compliance can be securely stored on the blockchain. Machine learning algorithms can analyze this data to identify patterns, predict compliance issues, and provide insights for continuous improvement.

4) Supply Chain Optimization - Real-time data on the blockchain can help identify bottlenecks and inefficiencies by providing a clear view of the entire supply chain. Algorithms analyze historical and real-time data to improve delivery processes, predict demand and improve overall performance.

5) Forecast for Crop Management - Information about crop health, weather and agriculture can be stored securely on the blockchain. By applying machine learning algorithms to this data, disease outbreaks can be predicted, irrigation schedules can be optimized, and overall crop management can be performed.

6) Business and Payment - Business and payment on blockchain can improve business between different parties in the supply chain. Machine learning algorithms can analyze business data to identify patterns and assess creditworthiness, thus improving the financial process in the supply chain.

In the next section of this paper, we will discuss Results and analysis.

IV. RESULTS AND ANALYSIS

A. Dataset Overview

The dataset contains information on various aspects of the agricultural supply chain, including product names, supplier locations, quantities, blockchain transaction IDs, transportation modes, production dates, transaction dates, delivery dates, soil quality, crop health, pesticide usage, total supply chain days, and product quality assessments.

B. Exploratory Data Analysis (EDA) and Visualizations -

To gain insights into the dataset, we conducted an exploratory data analysis. Here are some key visualizations:

Product Distribution: Showing the frequency of different agricultural products in the supply chain.

Supplier Location Distribution: Illustrating the geographical spread of suppliers.

Transportation Mode Analysis: Displaying the modes of transportation used in the supply chain.

Soil Quality vs. Product Quality: Investigating the relationship between soil quality and the assessed quality of agricultural products.

Supply Chain Duration: Analyzing the total days taken for supply chain processes.

Crop Health and Pesticide Usage: Examining the impact of pesticides on crop health.

Quality Assessment Distribution: Showing the distribution of product quality assessments.

C. Visualizations

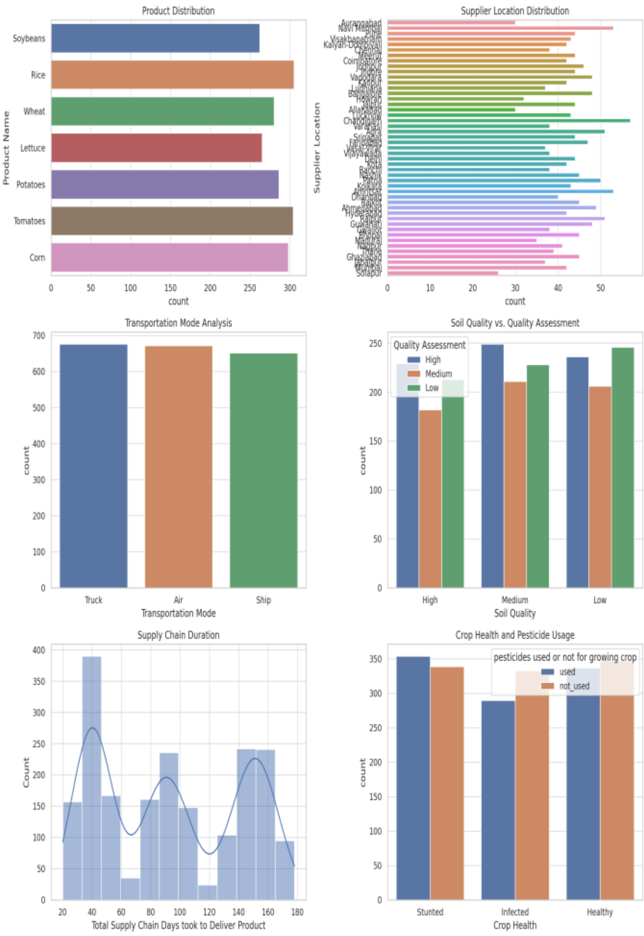

Fig. 6. The figure shows EDA(Exploratory Data Analysis) visualizations

Later we Encode categorical variables to numeric for correlation calculation

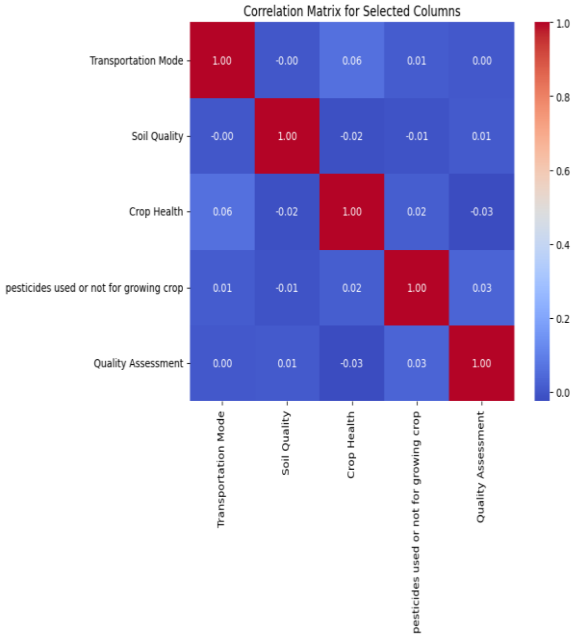

Fig. 7. Shows correlation matrix for the selected columns ‘Transportation Mode', 'Soil Quality', 'Crop Health', 'pesticides used or not for growing crop','Quality Assessment'

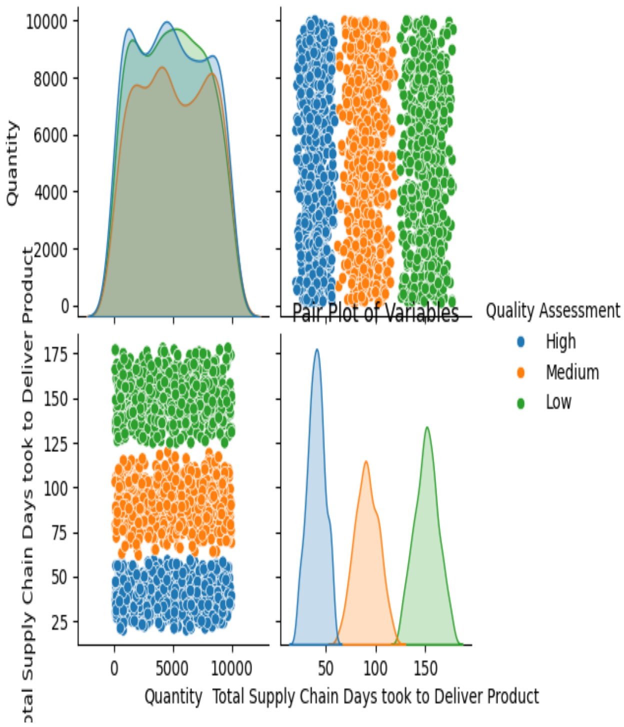

Fig. 8. Shows Pair plot for Total supply chain Days took to Deliver Product

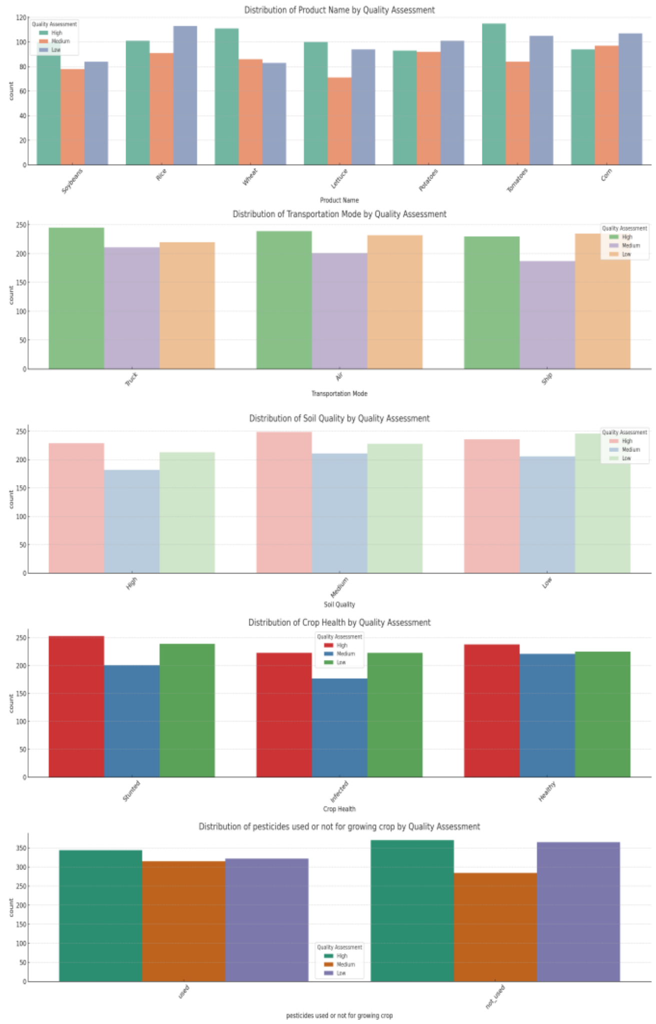

Fig. 9. Shows Distribution of
Bar plots for categorical variables

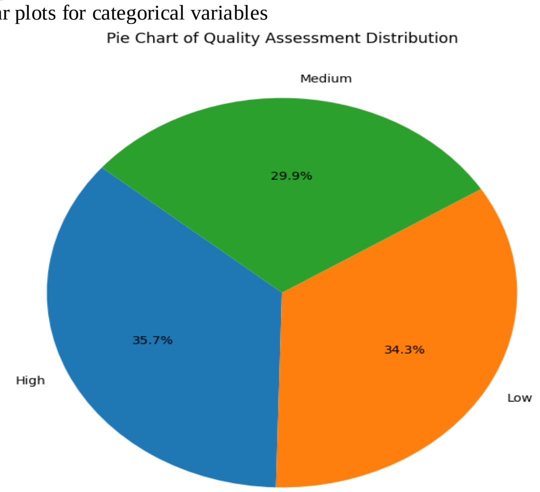

Fig. 10. Shows Pie Chart of Quality Assessment Distribution

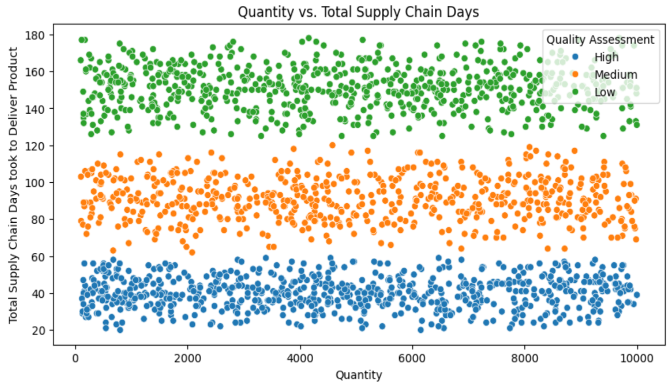

Fig. 11. Shows Total Supply Chain Days took to Deliver Product

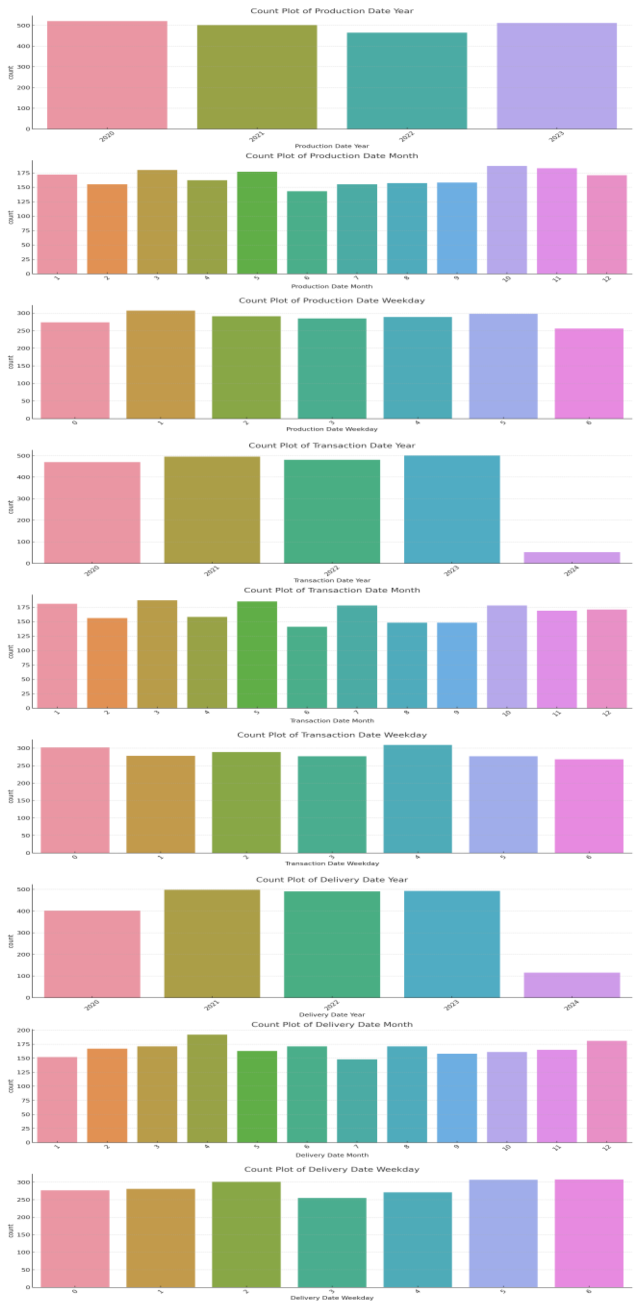

Fig. 12. Shows The count plots for each extracted date feature

D. *Performance metrics using machine learning*

TABLE I.
THIS TABLE PROVIDES A CONCISE OVERVIEW OF EACH MODEL'S PERFORMANCE:

Model	*Precision (Avg)*	*Recall (Avg)*	*F1-Score (Avg)*	*Accuracy (%)*
Logistic Regression	0.941	0.941	0.941	94.33
Decision Tree	1.000	1.000	1.000	100.00
Random Forest	1.000	1.000	1.000	100.00
Support Vector Machine	0.274	0.379	0.308	40.17
K-Nearest Neighbors	0.339	0.345	0.336	35.50
Gaussian Naive Bayes	1.000	1.000	1.000	100.00

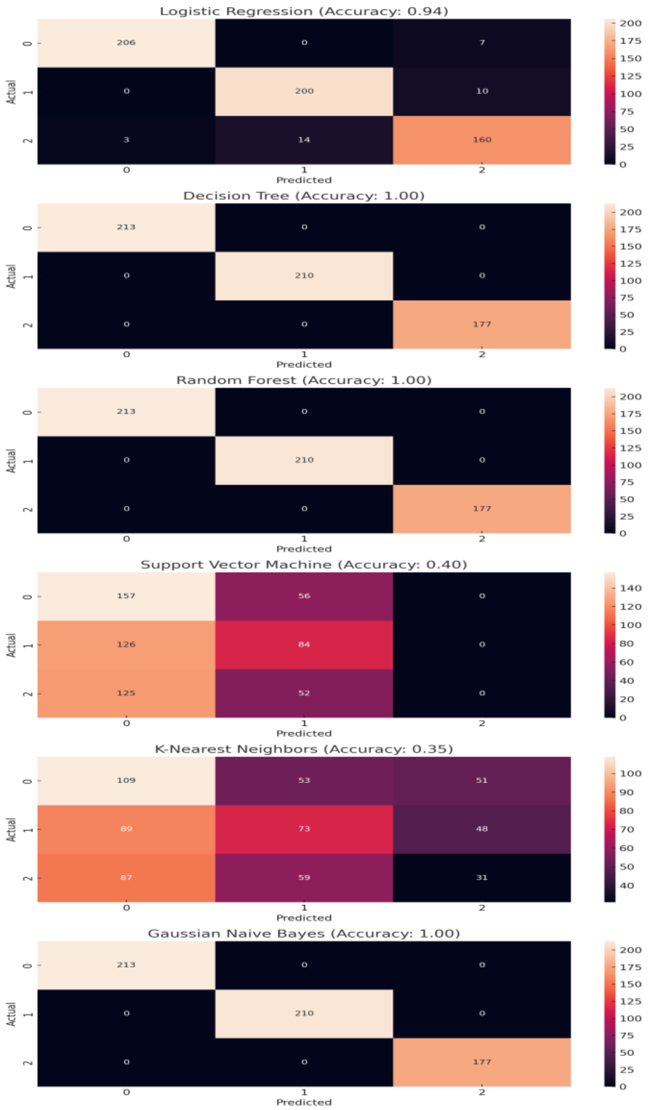

Fig. 13. Shows confusion matrices for ML Models

E. *Performance metrics using Deep learning*

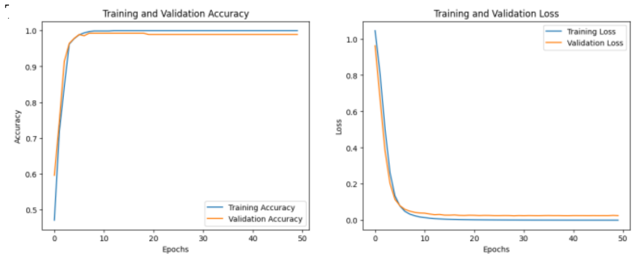

Fig. 14. Shows Model Training and Validation Accuracy and Losses

V. COMPARISON, PROS, AND CONS

A. *Comparison of applications of blockchain technology and machine learning in the agricultural chain*

TABLE II.

THIS TABLE PROVIDES AN OVERVIEW; THE ACTUAL SUITABILITY OF EACH TECHNOLOGY DEPENDS ON THE SPECIFIC USE CASE, CONTEXT OF USE AND OBJECTIVES OF THE AGRICULTURAL EQUIPMENT.

Criteria	*Block-chain Technology*	*Machine Learning*
Data Transparency	Provide certificates and non-transferable transactions to increase traceability .	Data models are analyzed to provide insight, but transparency may depend on the explanatory power of the model. .
Traceability	Ensure end-to-end traceability of agricultural products to reduce fraud and ensure quality.	The sample profile can be verified to track the origin and quality of the product, but does not provide the same level of tamper-proof traceability.
Smart Contracts	Leverage self-executing contracts to automate processes and manage recommendations.	There is no smart contract for a single tax, but decisions can be made based on learning patterns.
Decentralization	Running a decentralized network reduces the risk of a single failure.	Centralized or decentralized depending on usage, but usually in a centralized model for education.
Security	Encryption technology is used to ensure the security of transactions and data integrity	Security is based on the effectiveness of algorithm use and protection against attacks..
Real-time Monitoring	Provide instant updates about connected devices and changes	Instant maintenance can be provided based on continuous learning of input data.
Data Ownership and Control	Allow participants to manage their profiles while maintaining privacy	Depending on the model and data storage, data ownership and control may be centralized.
Scalability	There may be scalability issues, especially in public blockchain networks	Scalability can be achieved through distribution and networking, but challenges will remain.
Costs	Startup cost will be high but ongoing operating	Costs will vary depending on the complexity of the

	costs will be lower.	machine learning model and the procedures required.
Decision Support	The main goal is to make information fair and transparent in the business world	Analyze data to make decisions to help manage crops, logistics and resource allocation.

B. Discussion of pros and cons

TABLE III.
THIS ARTICLE PROVIDES A BRIEF OVERVIEW OF THE PROS AND CONS OF INTEGRATING BLOCKCHAIN TECHNOLOGY AND MACHINE LEARNING INTO THE AGRICULTURAL SECTOR. IT IS IMPORTANT TO REMEMBER THAT THE SUCCESS OF SUCH A PROCESS DEPENDS ON CAREFUL PLANNING, EFFECTIVE IMPLEMENTATION AND REGULAR MAINTENANCE AND ADJUSTMENTS TO RESOLVE PROBLEMS AS THEY ARISE..

Aspect	Strengths
Block-chain Technology	- Transparency: Enhances visibility across the supply chain. - Security: Immutable blocks ensure data integrity. - Traceability: Enables tracking of products from farm to table. - - Decentralized management: Reduce the risk of a single failure.
Machine Learning Techniques	- Predictive Analytics: Improves demand forecasting and resource planning. - Optimization: Enhances efficiency in resource allocation. - Automation: Streamlines tasks such as crop monitoring and pest control. - Continuous Improvement: ML models can adapt to changing conditions.
Integration of Both Technologies	- Synergy: Combined strengths of blockchain and ML enhance supply chain efficiency. - Fraud Prevention: Blockchain's security combined with ML anomaly detection reduces fraud risk. - Real-time Insights: ML provides real-time analysis of blockchain data.
Overall Considerations	- Market Competitiveness: Early adoption can provide a competitive edge. - Sustainability: Potential for reduced waste and improved sustainability.

C. Limitations of the study

1) *Limitations of this study*:
   a) Scope and Generalization:
   b) This study focuses on a specific issue that may limit the generalization of findings to various agricultural fields.

2) *Data availability and quality:*
   a) The effectiveness of machine learning models depends on the availability and quality of data, which may cause problems in implementation.
   b) problem solving.

   c) Security Concerns:
   d) Although blockchain is praised for its security features, threats and vulnerabilities are not widely discussed and can affect data integrity.

3) *Integration Complexity*:

This study will not address the complexity of integration that leads to the integration of blockchain and machine learning technologies.

D. Suggestions for Future Research:

1) Context-Specific Studies:

a) Future research should delve into context-specific applications to enhance the practical relevance of proposed solutions across diverse agricultural environments.

2) Long-term Impact Assessment:

a) Conducting longitudinal studies will provide insights into the long-term impact, sustainability, and scalability of blockchain and machine learning implementations.

b) Enhanced Security Protocols:

c) Future research should focus on developing enhanced security protocols to address evolving threats and vulnerabilities in agricultural supply chain data.

3) Practical Implementation Frameworks:

a) Develop frameworks and guidelines for the seamless implementation of blockchain and machine learning in diverse agricultural settings.

b) Interdisciplinary Approaches:

c) Foster interdisciplinary collaborations to ensure holistic approaches that address the diverse challenges and requirements of the agricultural sector.

4) User Acceptance Studies:

a) Investigate factors influencing the acceptance and adoption of blockchain and machine learning technologies among stakeholders.

b) Robust Data Management:

c) Develop robust data management strategies to enhance the accuracy and reliability of machine learning models in the agricultural supply chain.

5) Exploration of Emerging Technologies:

a) Explore the integration of emerging technologies like edge computing and advanced sensors with blockchain and machine learning.

6) Comparative Analysis:

a) Conduct comparative analyses of different blockchain platforms and machine learning algorithms to identify the most suitable combinations for specific agricultural supply chain scenarios.

7) Stakeholder Education:

a) Develop educational programs to enhance stakeholder understanding, fostering an informed and collaborative ecosystem.

VI. CONCLUSION

Finally, integrating blockchain technology and machine learning into agricultural products shows the potential to transform the industry. With the collaboration of these technologies, we can create better and more sustainable agriculture and solve important problems such as transparency, traceability and efficiency. The use of blockchain technology ensures transparency and security of collected data, provides reliable business information and increases the trust of participants. This transparency is necessary to solve food safety, evidence and compliance issues. Additionally, the nature of blockchain reduces dependence on central authorities, supporting greater freedom and a stronger supply chain. Instead, machine learning enables agriculture to gain analytical and predictive capabilities. Machine learning algorithms can analyze large amounts of data to provide recommendations on resource usage, demand forecasting and crop performance. With predictive analytics, stakeholders can reduce risk, make informed decisions and streamline processes; anything can improve the overall product. Blockchain and machine learning work together to create a powerful synergy. Machine learning takes this data and turns it into intelligence; Blockchain forms the basis for transparent and secure information. Smart contracts are an important part of blockchain technology that can process and execute contracts, eliminating the need for intermediaries and reducing transaction delays.

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