ABSTRACT

The decentralized traceability and direct marketing platform for agriculture supply chains. Globalized delivery of manufacturing and agricultural production offers renewed attention to the health, efficiency, and validation of many vital criteria in the food and agricultural supply chain. That numbers of food safety and corruption hazards have generated an enormous need of an efficient traceability solutions which acts as an essential quality managements tools ensuring to enough product’s safety within the agriculture supply chain. Block chain is the revolutionary technological method, which provides the ground-breaking result for commodity traceableness in agriculture and in food supply chains. Today's agricultural supplying chains are complicated ecosystems mixing several stakeholders making it difficult to validate several significant requirements mainly towards nation of first origin, crop growth phases, quality standards compliance, and yield monitoring. This paper proposes a strategy that levitates the block chain and conducts business operations effectively across the agricultural supply chain for tracking crop prices and traceability. The proposed framework solution discards the need for trusted centralized authority, intermediaries and offers records of the transactions, improving efficient science and safety with high integrity and reliability. All transactions are registered and then stored in block chain’s unchangeable ledger with linkages to a decentralized le network, thereby ensuring vary high degree of traceability and transparency in the supply chain ecosystem in a stable, reliable and in efficient manner.

Keywords: Decentralized, Traceability, Direct marketing, Agriculture, Supply chains, QR scanner.

INDEX

CHAPTER 1 – INTRODUCTION

To ensure product safety, handling the growth of farming products and effective management of logistics -chain in agricultural supply chain is censorious. That cover about food safety and the risk of contamination has renewed the prominence of tracing power across the supply chain Moreover, farming goods exchanged across multiple nations require accurate tracking and compliance with nation-specific regulations Tracing of goods in the agricultural field requires to gather, communicate and maintain critical data by specifically identifying the source, multiple data exchanges in the logistic network. High-spirited nature of data in the agricultural / food supply chain where products are manufactured, processed and sent through multiple intermediaries allows tracking and tracing difficult. Contamination of products and its public health consequences highlight traceability as the required policy instrument for tracking food quality and safety. The present traceability practice in the supply chain of agriculture is mainly affected by data fragmentation and centralized controls that are susceptible to both information modification and management. In case of contamination that identifies the source and isolates the product quickly from the supply chain. Today's supply chain is becoming really complex. At various stage multiple stakeholder are present. All these Stakeholder need to collaborate with each other in various direction for efficient and effective management. To deal with food scares and accidents, the food industry becoming more customer-oriented and need quicker response time. Good traceability mechanisms help reduce the manufacture and sale of dangerous or low quality goods, mitigating the risk for false ads, liability and recalls. Reducing the impacts of food safety. Improving food safety, and providing a means to verify food quality attribute are driving the development of traceability initiatives in agri-food system. The United Nation Food and Agriculture Organization (FAO) and the International Telecommunications Union (ITU) are continuing to work together to facilitate the use of innovation Information and communication technologies (ICTs) in agriculture. The importance of traceability has significantly increased with the globalization of the food industries. Therefore, the need for a reliable identification and tracking system is necessary to ensure the quality and safety of food which reaches the consumer. Block chain for Supply Chain is a natural fusion of two technologies, built for mutual or common ledge transactions. A supply chain often reflects a distribution of products through industries, and is also cross-border. Food provenance is one pf FSC's most difficult issue. This issue companies are facing today. A global supply chain network with asymmetric food regulation and multiple operating procedure between various countries makes end-to-end food tracking incidental to the food industry. Distributed ledger/Block chain is very important technology that can significantly impact the supply chain management. This paper shows the possibility of block chain technology using supply chain for both perishable product and manufacturing. In food supply chain firms are rapidly adopting block chain system. Example for retailers such as Carrefour indicates that block chain can be used to provide access to rich and details information about food product, which is used to reduce the uncertainty about quality and ingredient. Food safety has been an enormous concern in china over the last few years. As conventional agri-food logistic practices can no longer satisfy consumer demands, developing a traceability framework for agri-food supply is becoming increasingly urgent.

CHAPTER 2 – SYSTEM ANALYSIS

A. Existing system

There is no computerized system in place to trace the cost of agriculture. Agricultural products cannot be obtained by the farmer.72 percent of the population in India is dependent on the farming industry. Farmers get enormous quantities of crop manufacturing, but they have not got the correct price because they can survive the present circumstances. So they are suicide and nothing is done by the government. So we are attempting to fix this issue in the suggested scheme by tracing the cost of the agricultural product from farmer to client.

Disadvantages

1.Complexity in Implementation: Setting up decentralized systems can be intricate, demanding expertise and resources, making it challenging for smaller agricultural players.

2.Interoperability Issues: Ensuring compatibility among various decentralized platforms and technologies can be a hurdle, potentially leading to data silos and inefficiencies.

3.Scalability Constraints: Expanding a decentralized system to accommodate a growing number of users and transactions can be challenging, causing performance issues.

4.Security Risks: Decentralized systems are not immune to security threats like smart contract vulnerabilities and hacking, posing risks to data integrity and user trust.

B. Proposed System

In proposed system we are using a Block chain helps which helps in maintaining the integrity and transparency of the whole process right from inception of crop details. Blockchain helps in managing and tracing the crop information transparent distribution.

Advantages

1. Enhanced Transparency: Decentralized traceability allows consumers to track the journey of agricultural products from farm to table, fostering trust.

2. Reduced Fraud: Direct marketing eliminates intermediaries, reducing the risk of counterfeit goods and fraud in the supply chain.

3. Fair Pricing: Farmers receive a fair share of profits by selling directly to buyers, avoiding price manipulation by middlemen.

4. Efficient Logistics: Real-time data improves inventory management and logistics, reducing wastage and optimizing distribution.

CHAPTER 3 – FEASIBILITY STUDY

A. Technical Feasibility

This study is carried out to check the technical feasibility, that is, the technical requirements of the system. Any system developed must not have a high demand on the available technical resources. This will lead to high demands on the available technical resources. This will lead to high demands being placed on the client. The developed system must have a modest requirement, as only minimal or null changes are required for implementing this system.

B. Operational Feasibility

The proposed Blockchain-based system for managing hospital, donor, and patient data is highly feasible from an operational standpoint. The implementation of this decentralized solution aligns with the operational goals of healthcare institutions, such as ensuring data integrity, enhancing patient privacy, and improving system reliability. The automation of data handling using smart contracts minimizes manual interventions, thereby reducing errors and streamlining workflows for healthcare professionals and administrators. Moreover, the use of QR codes and digital signatures simplifies the verification process, making the system user-friendly for non-technical staff. Since Blockchain operates across a distributed network, it reduces dependency on a central server and ensures continuous availability even during hardware failures or cyberattacks. This robust and resilient framework enables seamless integration with existing hospital management systems and enhances trust among stakeholders. With proper training and onboarding, the transition to the new system can be smooth, making it operationally viable for day-to-day healthcare activities.

C. Economic Feasibility

This study is carried out to check the economic impact that the system will have on the organization. The amount of fund that the company can pour into the research and development of the system is limited. The expenditures must be justified. Thus, the developed system as well within the budget and this was achieved because most of the technologies used are freely available. Only the customized products had to be purchased.

CHAPTER 4 – SYSTEM REQUIREMENT SPECIFICATION DOCUMENT

A. Overview

The increasing complexity of the agricultural supply chain, combined with the need for food safety and traceability, has highlighted the importance of effective tracking systems to ensure product quality and reduce contamination risks. The fragmented data and centralized controls currently prevalent in the agricultural sector make it difficult to trace products accurately through the supply chain, which is essential for identifying contamination sources and quickly isolating affected products. The growing global demand for food safety, faster response times to food scares, and regulatory compliance across multiple nations has led to the adoption of innovative technologies, including blockchain. Blockchain offers a decentralized, secure system for tracking the movement of agricultural products, improving transparency and accountability across the supply chain. This technology helps mitigate risks associated with food safety, false advertising, and recalls by providing reliable, real-time data about food provenance. With companies like Carrefour adopting blockchain for food traceability, it is becoming increasingly essential for ensuring food quality and safety in the global market.

B. Modules Description

To develop a decentralized traceability for agriculture supply chains, you can break down the functionality into several modules for the different user roles: Buyer, Seller, and Admin. Here are the modules for each role:

1. System:

Buyer:

- **Register:** The buyer will register with their details like name, email, password, address, contact, so after that the buyer will login.
- **Login:** After registration the buyer will login with their details.
- **View Seller's Crop Information:** Once the sellers will add the details the buyer can view those details here.

- **Send Request to Seller:** If the buyer wants the details of crop then buyer will send request to seller.
- **View Seller Requests:** Displays responses from sellers to the buyer's requests.
- **Make Payment:** Once the seller accept the request for the crop the buyer has to pay the amount for that crop.
- **Logout:** Allows buyers to logout securely.

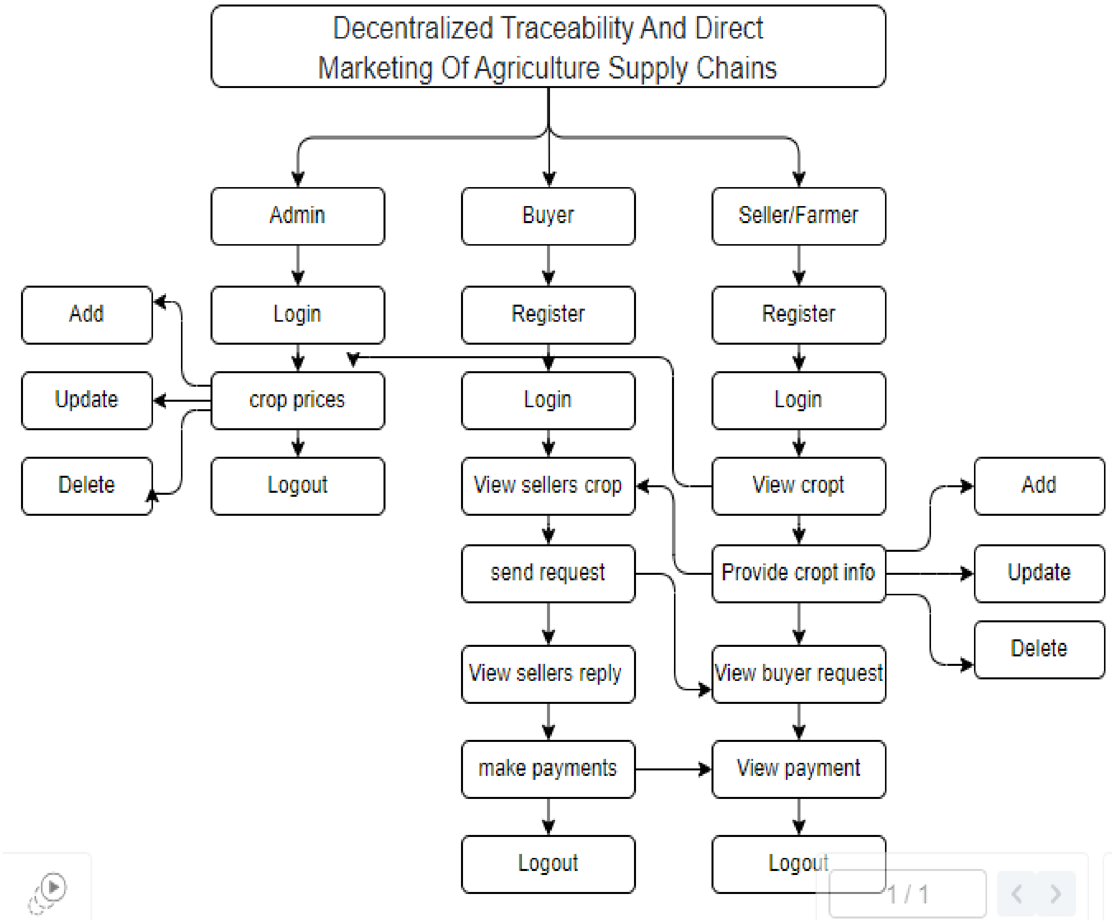
Seller:

- **Register:** The seller will register with their details like name, email, password, address, contact, so after that the seller will login.
- **Login:** After registration the seller will login with their details.
- **Provide Crop Information:** The seller will add there crop details like (crop name, crop category, and quantity and quality).
- **View Buyer Requests:** When the buyer will send the request for the crop, here the buyer will view and he/she has to accept the request.
- **View Payments:** Once the buyer will pay the amount for the crops. The seller can view the details of the payment.
- **Logout:** Allows sellers to logout securely.

Admin:

- **Login:** The admin will login with default email and password.
- **Crop price:** The admin is the person he/ she will add the crop price for each and every crop details with that crop name, category, maximum cost, minimum cost and quantity.
- **Logout:** Allows the admin to log out securely.

C. PROCESS FLOW:



D.SDLC Methodology

SOFTWARE DEVELOPMENT LIFE CYCLE

The meaning of Agile is swift or versatile. “Agile process model" refers to a software development approach based on iterative development. Agile methods break tasks into smaller iterations, or parts do not directly involve long term planning. The project scope and requirements are laid down at the beginning of the development process. Plans regarding the number of iterations, the duration and the scope of each iteration are clearly defined in advance. Each iteration is considered as a short time "frame" in the Agile process model, which typically lasts from one to four weeks. The division of the entire project into smaller parts helps to minimize the project risk and to reduce the overall project delivery time requirements. Each iteration involves a team working through a full software development life cycle including planning, requirements analysis, design, coding, and testing before a working product is demonstrated to the client.

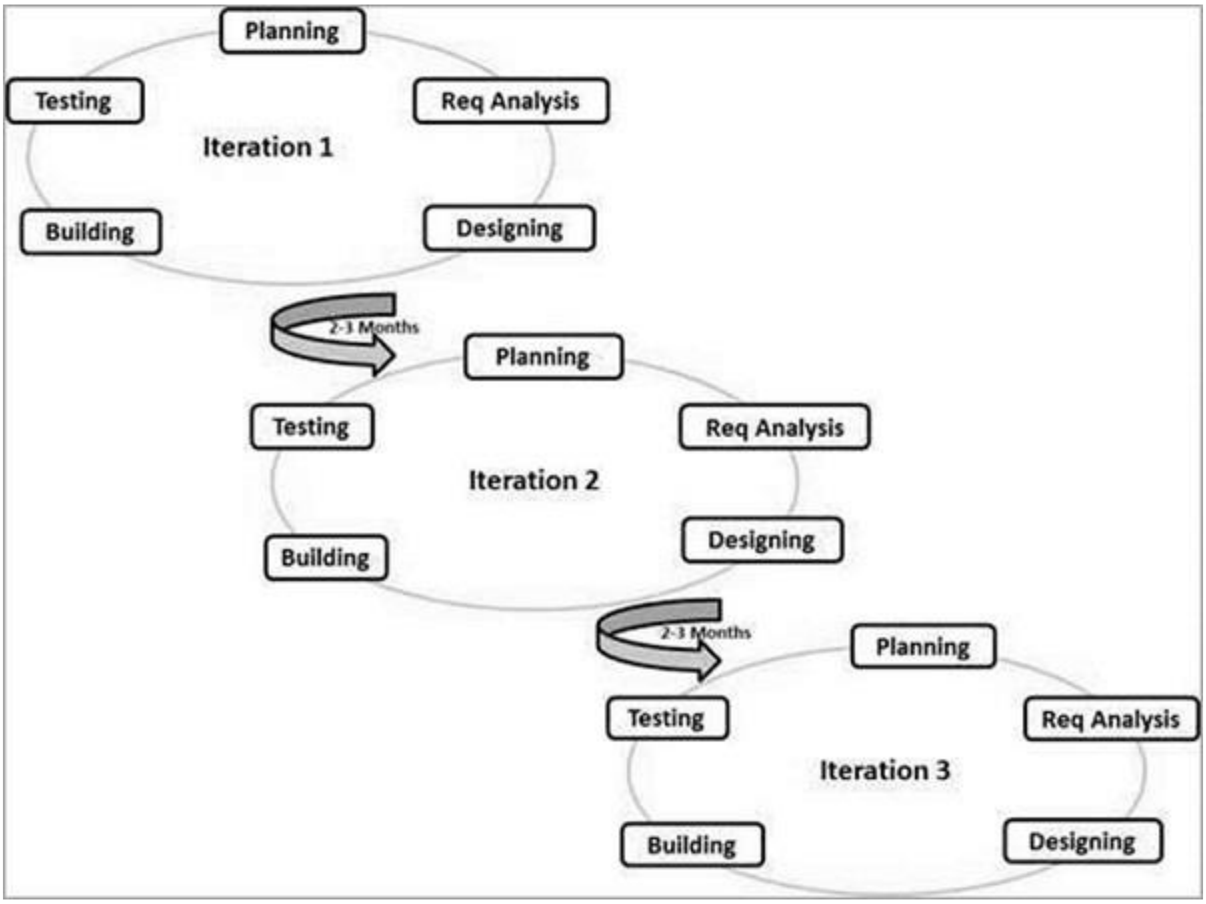
Actually, Agile model refers to a group of development processes. These processes share some basic characteristics but do have certain subtle differences among themselves. A few Agile SDLC models are given below: Crystal A tern Feature-driven development Scrum Extreme programming (XP) Lean development Unified process In the Agile model, the requirements are decomposed into many small parts that can be incrementally developed.

The Agile model adopts Iterative development. Each incremental part is developed over an iteration. Each iteration is intended to be small and easily manageable and that can be completed within a couple of weeks only. At a time one iteration is planned, developed and deployed to the customers. Long-term plans are not made.

Agile model is the combination of iterative and incremental process models. Steps involve in agile SDLC models are:

- Requirement gathering
- Requirement Analysis
- Design Coding
- Unit testing
- Acceptance testing

The time to complete an iteration is known as a Time Box. Time-box refers to the maximum amount of time needed to deliver an iteration to customers. So, the end date for an iteration does not change. Though the development team can decide to reduce the delivered functionality during a Time-box if necessary to deliver it on time. The central principle of the Agile model is the delivery of an increment to the customer after each Time-box.



Principles of Agile model:

- To establish close contact with the customer during development and to gain a clear understanding of various requirements, each Agile project usually includes a customer representative on the team. At the end of each iteration stakeholders and the customer representative review, the progress made and re-evaluate the requirements.
- Agile model relies on working software deployment rather than comprehensive documentation.
- Frequent delivery of incremental versions of the software to the customer representative in intervals of few weeks.
- Requirement change requests from the customer are encouraged and efficiently incorporated.

- It emphasizes on having efficient team members and enhancing communications among them is given more importance. It is realized that enhanced communication among the development team members can be achieved through face-to-face communication rather than through the exchange of formal documents.
- It is recommended that the development team size should be kept small (5 to 9 people) to help the team members meaningfully engage in face-to-face communication and have collaborative work environment.
- Agile development process usually deploys Pair Programming. In Pair programming, two programmers work together at one work-station. One does code while the other reviews the code as it is typed in. The two programmers switch their roles every hour or so.

Advantages:

- Working through Pair programming produce well written compact programs which has fewer errors as compared to programmers working alone.
- It reduces total development time of the whole project. Customer representatives get the idea of updated software products after each iteration. So, it is easy for him to change any requirement if needed.

Disadvantages:

- Due to lack of formal documents, it creates confusion and important decisions taken during different phases can be misinterpreted at any time by different team members.
- Due to the absence of proper documentation, when the project completes and the developers are assigned to another project, maintenance of the developed project can become a problem.

SOFTWARE DEVELOPMENT LIFE CYCLE – SDLC:

In our project we use waterfall model as our software development cycle because of its step-by-step procedure while implementing.

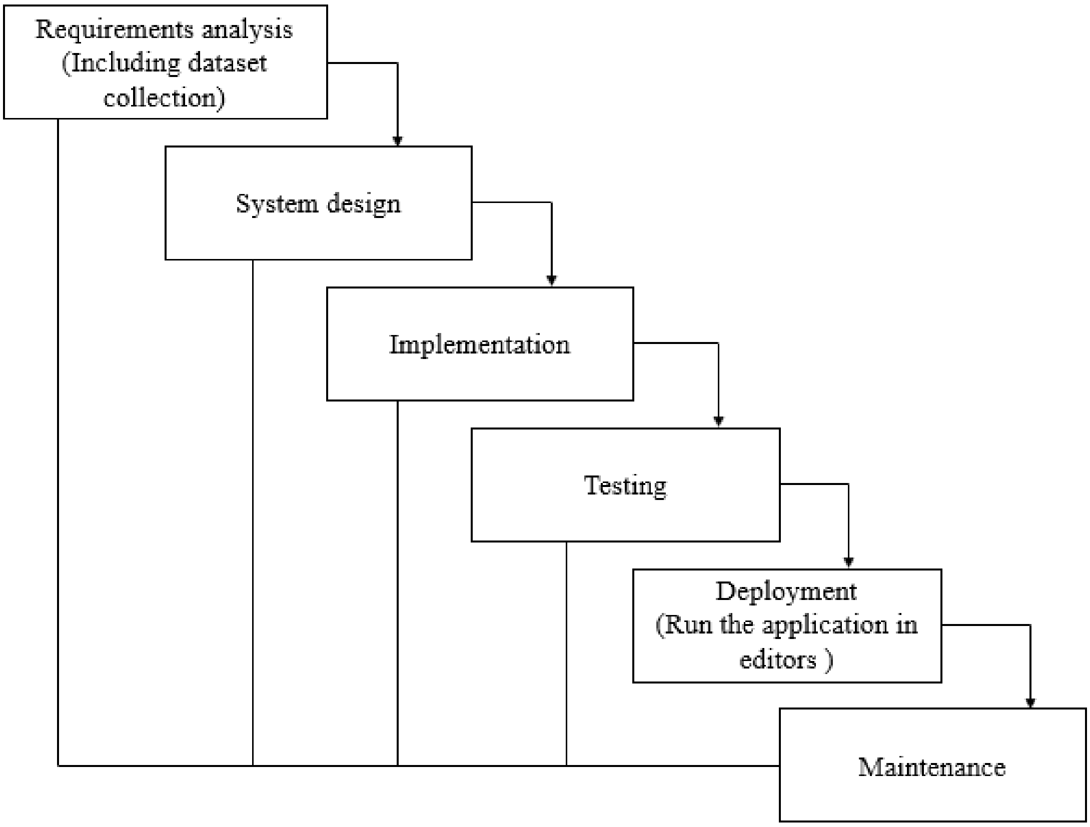


Fig: Waterfall Model

- **Requirement Gathering and analysis** − All possible requirements of the system to be developed are captured in this phase and documented in a requirement specification document.
- **System Design** − The requirement specifications from first phase are studied in this phase and the system design is prepared. This system design helps in specifying hardware and system requirements and helps in defining the overall system architecture.
- **Implementation** − With inputs from the system design, the system is first developed in small programs called units, which are integrated in the next phase. Each unit is developed and tested for its functionality, which is referred to as Unit Testing.

- **Integration and Testing** − All the units developed in the implementation phase are integrated into a system after testing of each unit. Post integration the entire system is tested for any faults and failures.
- **Deployment of system** − Once the functional and non-functional testing is done; the product is deployed in the customer environment or released into the market.
- **Maintenance** − There are some issues which come up in the client environment. To fix those issues, patches are released. Also, to enhance the product some better versions are released. Maintenance is done to deliver these changes in the customer environment.

E**. Software Requirements**

- Operating System : Windows 7/8/10
- Server-side Script : HTML, CSS, Bootstrap & JS
- Programming Language : Python
- Libraries : Flask, Pandas, Mysql.connector, Os, Smtplib, Numpy
- IDE/Workbench : PyCharm
- Technology : Python 3.6+
- Server Deployment : Xampp Server
- Database : MySQL

F. Hardware Requirements

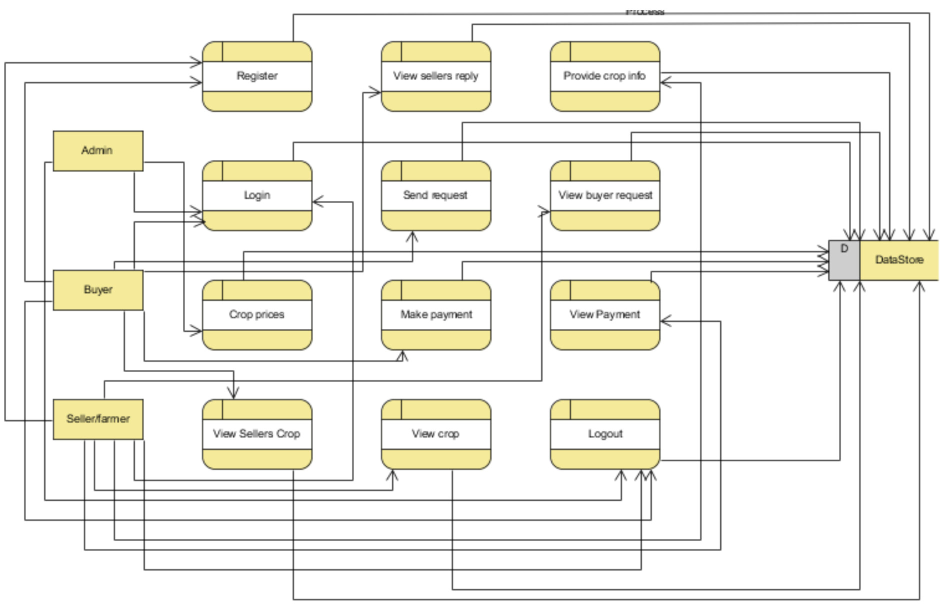
- Processor - I3/Intel Processor
- Hard Disk - 160GB
- Key Board - Standard Windows Keyboard
- Mouse - Two or Three Button Mouse
- Monitor - SVGA
- RAM - 8GB

CHAPTER 5 – SYSTEM DESIGN

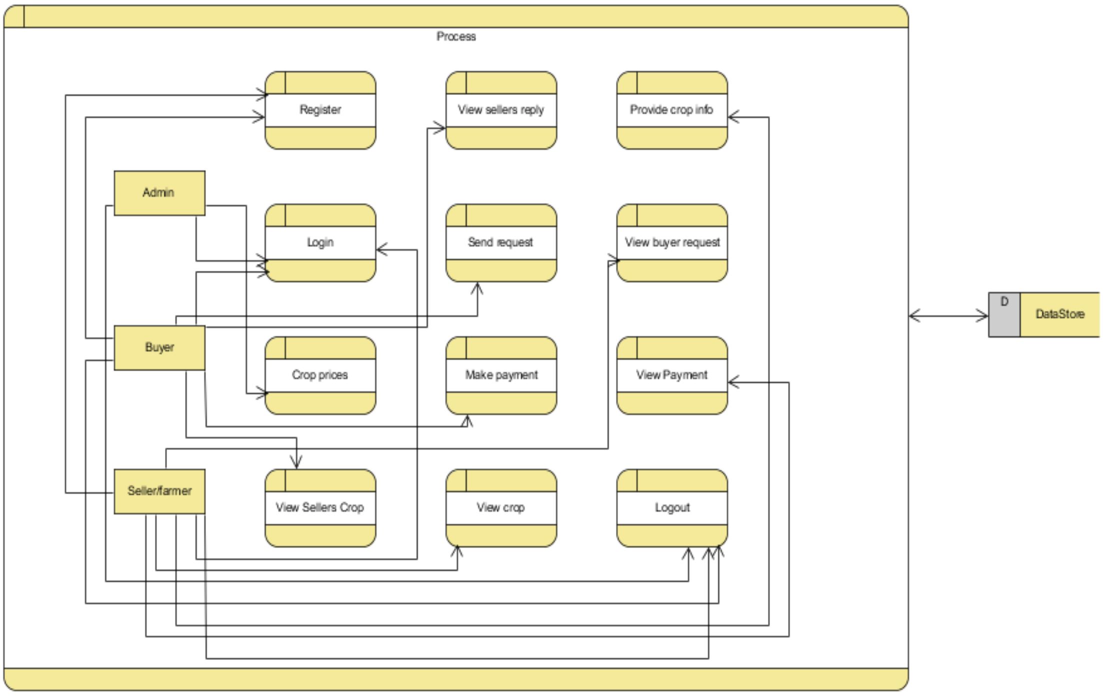
A. DFD

A Data Flow Diagram (DFD) is a traditional way to visualize the information flows within a system. A neat and clear DFD can depict a good amount of the system requirements graphically. It can be manual, automated, or a combination of both. It shows how information enters and leaves the system, what changes the information and where information is stored. The purpose of a DFD is to show the scope and boundaries of a system as a whole. It may be used as a communications tool between a systems analyst and any person who plays a part in the system that acts as the starting point for redesigning a system.

DFD 1 DIAGRAM:



DFD 2 DIAGRAM:



B. ER Diagram:

An Entity–relationship model (ER model) describes the structure of a database with the help of a diagram, which is known as Entity Relationship Diagram (ER Diagram). An ER model is a design or blueprint of a database that can later be implemented as a database. The main components of E-R model are: entity set and relationship set.

An ER diagram shows the relationship among entity sets. An entity set is a group of similar entities and these entities can have attributes. In terms of DBMS, an entity is a table or attribute of a table in database, so by showing relationship among tables and their attributes, ER diagram shows the complete logical structure of a database. Let’s have a look at a simple ER diagram to understand this concept.

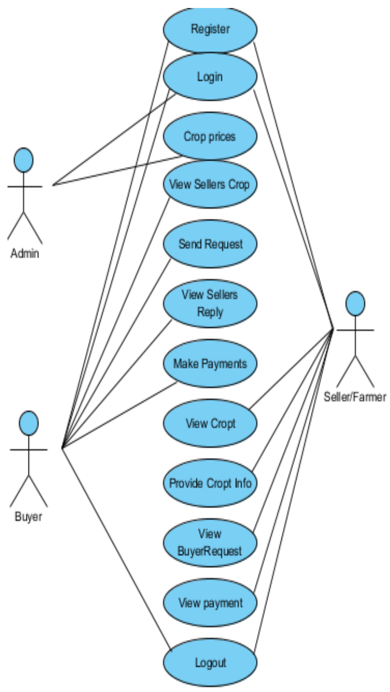
C. UML

- ✓ Uml stands for unified modelling language. Uml is a standardized general-purpose modelling language in the field of object-oriented software engineering. The standard is managed, and was created by, the object management group.

- ✓ The goal is for uml to become a common language for creating models of object-oriented computer software. In its current form uml is comprised of two major components: a meta-model and a notation. In the future, some form of method or process may also be added to; or associated with, uml.
- ✓ The unified modelling language is a standard language for specifying, visualization, constructing and documenting the artefacts of software system, as well as for business modelling and other non-software systems.
- ✓ The uml represents a collection of best engineering practices that have proven successful in the modelling of large and complex systems.

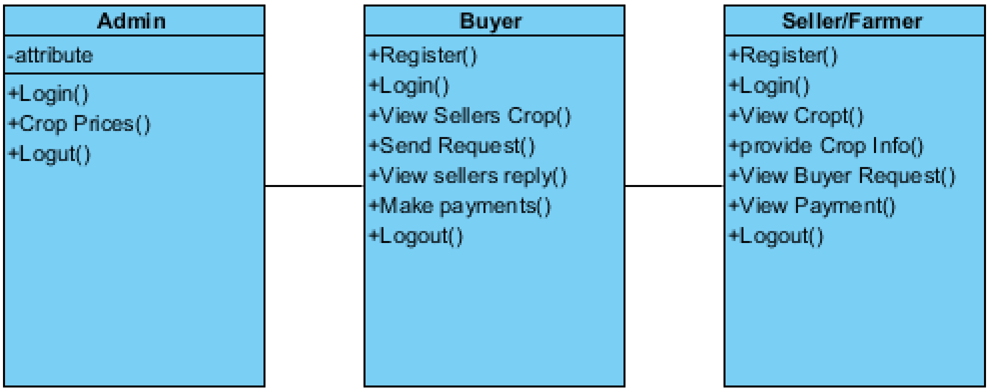
Use case diagram:

A use case diagram in the unified modeling language (uml) is a type of behavioral diagram defined by and created from a use-case analysis. Its purpose is to present a graphical overview of the functionality provided by a system in terms of actors, their goals (represented as use cases), and any dependencies between those use cases. The main purpose of a use case diagram is to show what system functions are performed for which actor. Roles of the actors in the system can be depicted.



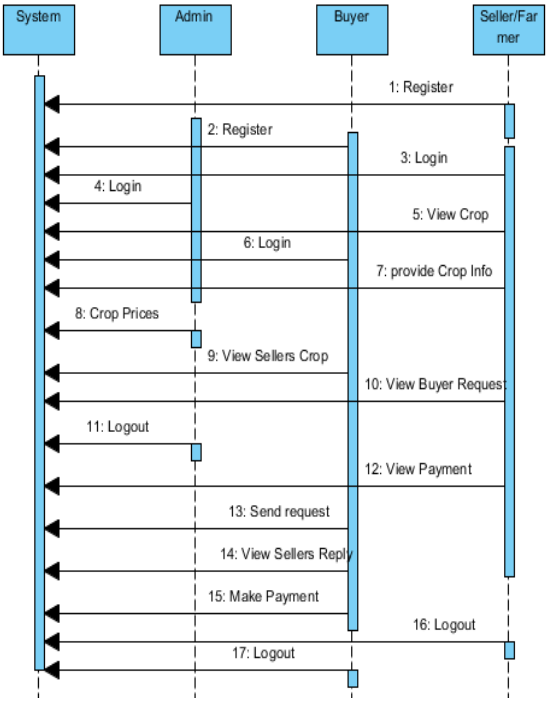
Class diagram:

In software engineering, a class diagram in the unified modeling language (uml) is a type of static structure diagram that describes the structure of a system by showing the system's classes, their attributes, operations (or methods), and the relationships among the classes. It explains which class contains information.



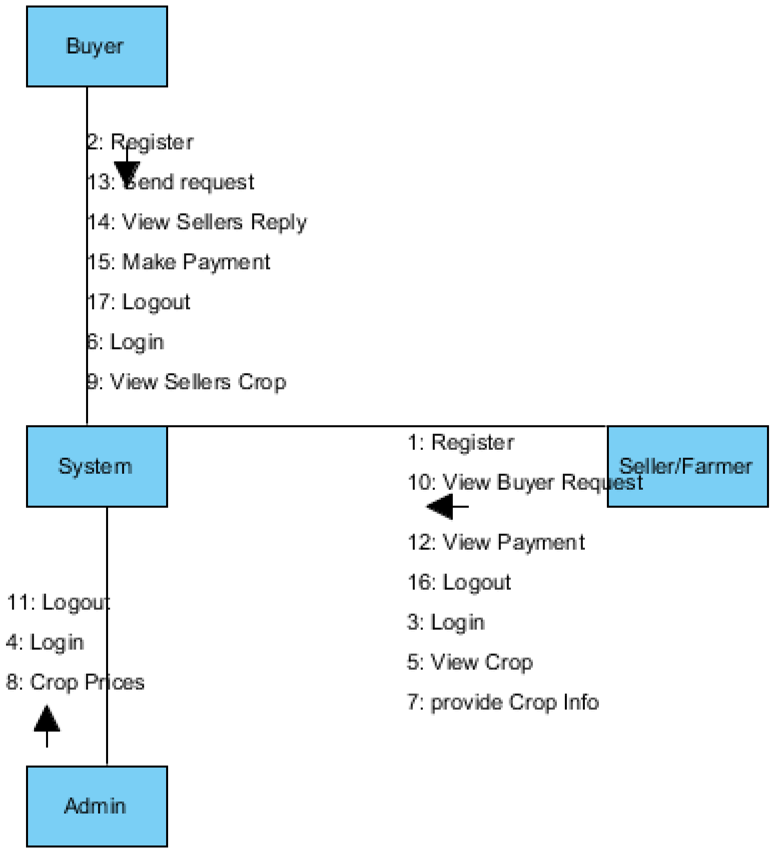
Sequence diagram:

A sequence diagram in unified modeling language (uml) is a kind of interaction diagram that shows how processes operate with one another and in what order. It is a construct of a message sequence chart. Sequence diagrams are sometimes called event diagrams, event scenarios, and timing diagrams.



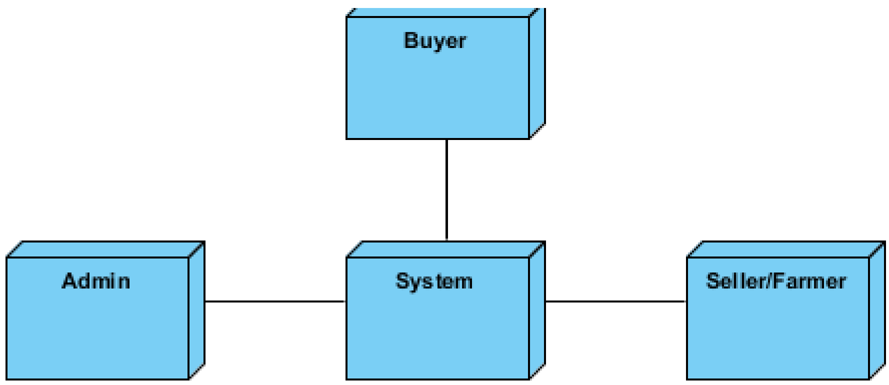
Collaboration diagram:

In collaboration diagram the method call sequence is indicated by some numbering technique as shown below. The number indicates how the methods are called one after another. We have taken the same order management system to describe the collaboration diagram. The method calls are similar to that of a sequence diagram. But the difference is that the sequence diagram does not describe the object organization whereas the collaboration diagram shows the object organization.



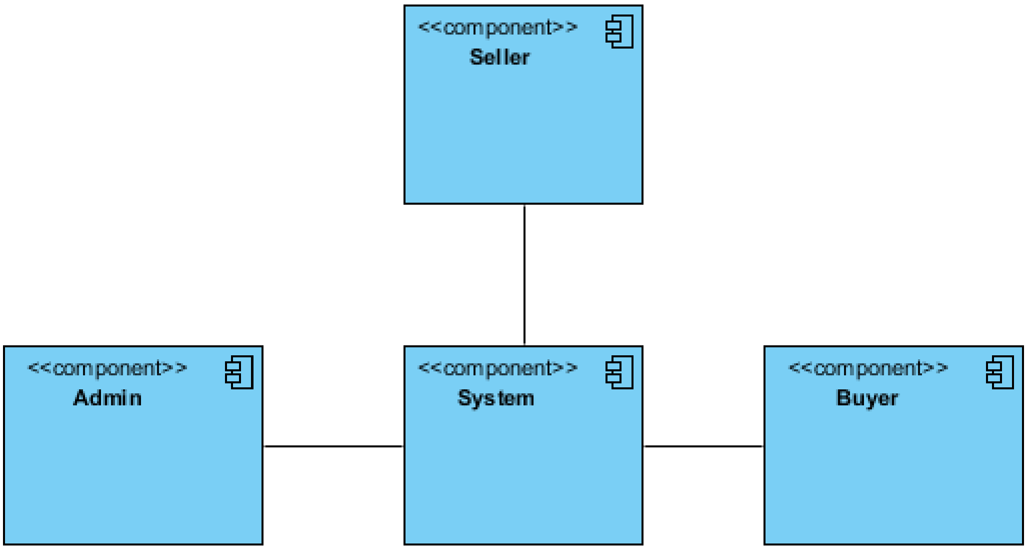
Deployment diagram:

Deployment diagram represents the deployment view of a system. It is related to the component diagram. Because the components are deployed using the deployment diagrams. A deployment diagram consists of nodes. Nodes are nothing but physical hard ware's used to deploy the application.



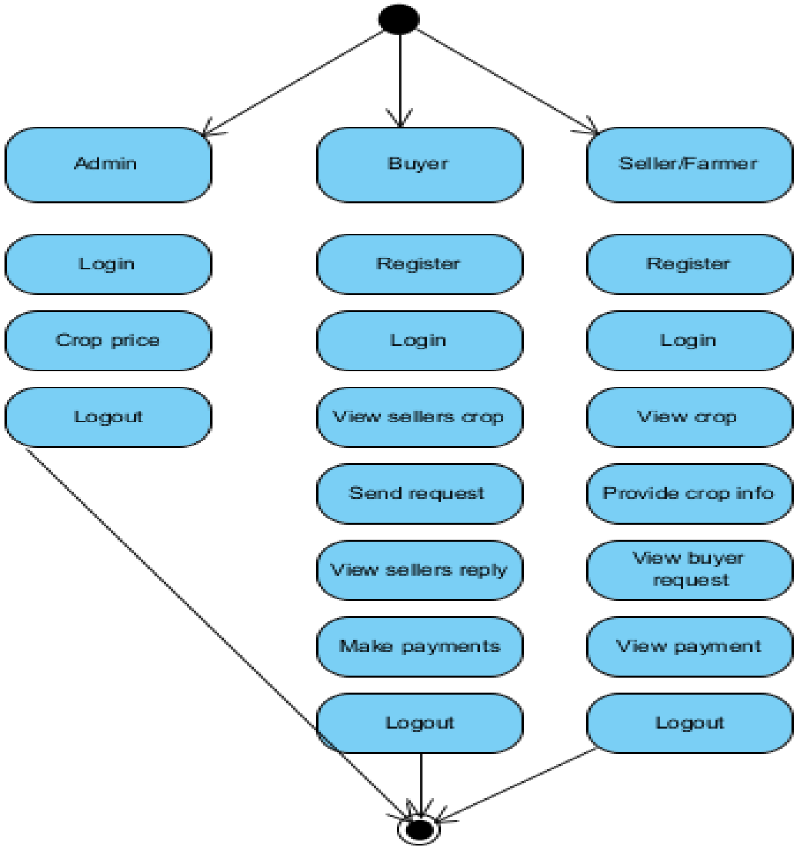
Component diagram:

Component diagrams are used to describe the physical artifacts of a system. This artifact includes files, executable, libraries etc. So the purpose of this diagram is different, component diagrams are used during the implementation phase of an application. But it is prepared well in advance to visualize the implementation details. Initially the system is designed using different uml diagrams and then when the artifacts are ready component diagrams are used to get an idea of the implementation.



Activity diagram:

Activity diagrams are graphical representations of workflows of stepwise activities and actions with support for choice, iteration and concurrency. In the unified modeling language, activity diagrams can be used to describe the business and operational step-by-step workflows of components in a system. An activity diagram shows the overall flow of control.



CHAPTER 6 - TECHNOLOGY DESCRIPTION

DECENTRALIZED TRACEAILITY AND DIRECT MARKETING OF AGRICULTURE SUPPLY CHAINS

The Agricultural Supply Chain Traceability System utilizes blockchain technology to enhance transparency, security, and accountability across the food supply chain. By leveraging a decentralized ledger, blockchain ensures the integrity and immutability of data, allowing for reliable tracking of agricultural products from production to consumption. Each transaction or movement of goods is recorded on the blockchain, providing a transparent and tamper-proof record of all activities. This system also incorporates data encryption techniques to protect sensitive information such as product origin, processing history, and quality attributes. Additionally, smart contracts can be used to automate certain aspects of the supply chain, such as verifying compliance with regulations or triggering alerts in the event of contamination. Blockchain's decentralized nature eliminates single points of failure, making the system more resilient to manipulation or corruption. With real-time data access and cross-border compatibility, the system enhances the ability to quickly trace food safety issues, reducing the impact of food scares and improving consumer trust in the global food market.

1. **Product Registration and Blockchain Storage Algorithm**

The product details, including type, origin, processing history, and associated documentation, are encrypted using secure encryption algorithms. A unique identifier (hash) is generated for the product and stored on the blockchain, ensuring its data is immutable. The product identifier is then associated with the relevant stakeholders, such as manufacturers and distributors. This registration ensures that the product can be traced securely through the entire supply chain.

2. **Supply Chain Tracking and Data Logging Algorithm**

As the product moves through different stages (e.g., transport, warehouse, processing), movement details are logged, encrypted, and recorded on the blockchain with a timestamp. This creates a transparent and immutable record of the product's journey through the supply chain, allowing real-time tracking. Each transaction in the supply chain is documented, ensuring the integrity and traceability of the product from farm to consumer.

3. **Contamination Detection and Isolation Algorithm**

When contamination is detected, an alert is triggered based on predefined conditions. Smart contracts are then used to automatically isolate the affected batch by updating its status on the blockchain. A notification is sent to all relevant stakeholders (e.g., manufacturers, distributors, regulatory bodies), preventing the contaminated product from progressing further in the supply chain. This system ensures quick isolation and containment of contaminated products.

4. **Smart Contract Automation for Regulatory Compliance**

Compliance conditions such as quality standards, health regulations, and packaging requirements are defined within smart contracts. These contracts automatically verify compliance at each stage of the supply chain. If a product fails to meet the criteria, the system triggers alerts and halts its movement. This automated compliance verification ensures that all products adhere to regulatory standards, reducing human error and maintaining product integrity.

5. **Audit and Reporting Algorithm**

All transaction logs related to product movements, compliance status, and contamination alerts are collected and compiled into audit reports. Using blockchain's immutable ledger, the system generates secure and tamper-proof reports that stakeholders, such as regulatory bodies and customers, can access in real-time. This audit mechanism ensures the transparency and authenticity of the product's journey, promoting accountability and trust in the supply chain.

CHAPTER 7 - TESTING & DEBUGGING TECHNIQUES

A. Unit Testing:

Purpose: Unit testing ensures that individual components of the system function as expected in isolation. It helps detect errors early by verifying that each function or method behaves as intended.

Tools: Common unit testing tools include **JUnit** for Java, **pytest** for Python, and **Mocha** for JavaScript. These tools automate test execution and provide feedback on code correctness.

Examples:

- Testing a function that calculates the sum of two numbers to ensure it returns the correct result.
- Verifying a function that processes user data and handles invalid input correctly.

1. Integration Testing:

Purpose: Integration testing verifies if different modules or components of the system work together as intended. It ensures that interactions between various parts of the system function properly.

Tools: Tools like **Postman** and **SoapUI** are commonly used for API integration testing, while **JUnit** or **Spring Test** are used for testing integrated systems in Java-based applications.

Examples:

- Testing how the user registration API interacts with the database when creating a new user.
- Verifying that the payment gateway successfully processes transactions within the system.

Model Evaluation Testing:

Purpose: Model evaluation testing assesses the performance of machine learning models by using metrics such as accuracy, precision, recall, and F1-score. It helps determine how well the model performs on unseen data.

B. Debugging:

Purpose: Debugging identifies and resolves issues or bugs in the code, ensuring the software functions as expected. It is essential for locating and fixing errors to improve code quality and reliability.

Tools: Debugging tools like **Visual Studio Code Debugger**, **GDB** for C/C++, and **Chrome DevTools** for JavaScript help step through code and inspect variables to diagnose problems.

Examples:

- Using **GDB** to track down a segmentation fault in a C++ program.
- Utilizing **Visual Studio Code Debugger** to fix a JavaScript function that returns an incorrect value.

Boundary Testing:

Purpose: Boundary testing focuses on verifying how the system behaves at the edge of input ranges. It ensures that edge cases, such as maximum and minimum values, are handled correctly.

Tools: Tools like **JUnit** for Java and **pytest** for Python can be used to test boundary conditions, ensuring that the system responds correctly to extreme inputs.

Examples:

- Testing a form to ensure it accepts ages within the valid range.

- Verifying that a function handling prices correctly processes the minimum and maximum allowable values.

Real-Time Data Testing (Deployment Testing):

Purpose: Real-time data testing evaluates how the system handles live or streaming data, ensuring that it performs efficiently in real-world scenarios with continuous data flow.

Tools: Tools like **Apache Kafka** and **StreamSets** facilitate real-time data testing. **JMeter** is also useful for simulating real-time data loads and measuring system performance.

Examples:

- Testing a recommendation system to ensure it can process new user interactions in real-time.
- Evaluating the performance of a live chat system when handling multiple concurrent messages.

User Interface (UI) Testing:

Purpose: UI testing ensures that the user interface works as expected, with elements like buttons, forms, and menus responding correctly to user actions.

Tools: Tools such as **Selenium** for web applications and **Appium** for mobile apps automate UI testing. **Cypress** is another tool for frontend testing in modern web applications.

Examples:

- Testing a button click to ensure it triggers the correct action in a web app.
- Verifying that an error message is displayed correctly in a mobile app when incorrect input is entered.

Performance Testing:

Purpose: Performance testing evaluates the system's ability to perform under various conditions, measuring aspects like speed, responsiveness, and scalability.

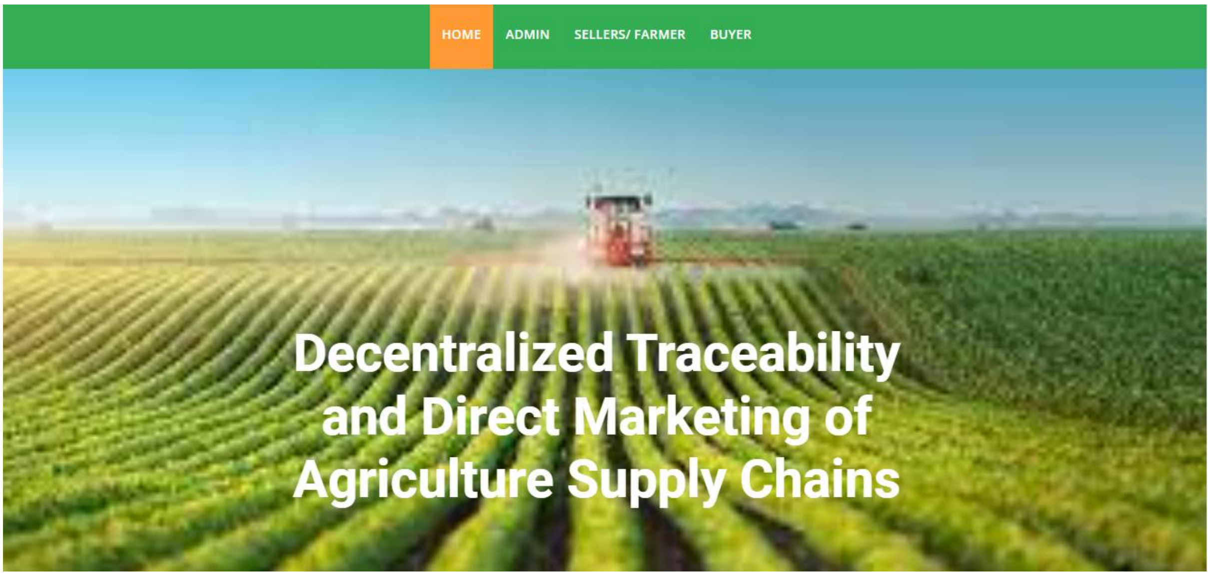
Tools: Tools like **JMeter**, **LoadRunner**, and **Gatling** are used to simulate user load and assess the system’s ability to handle varying traffic and transaction volumes.

Examples:

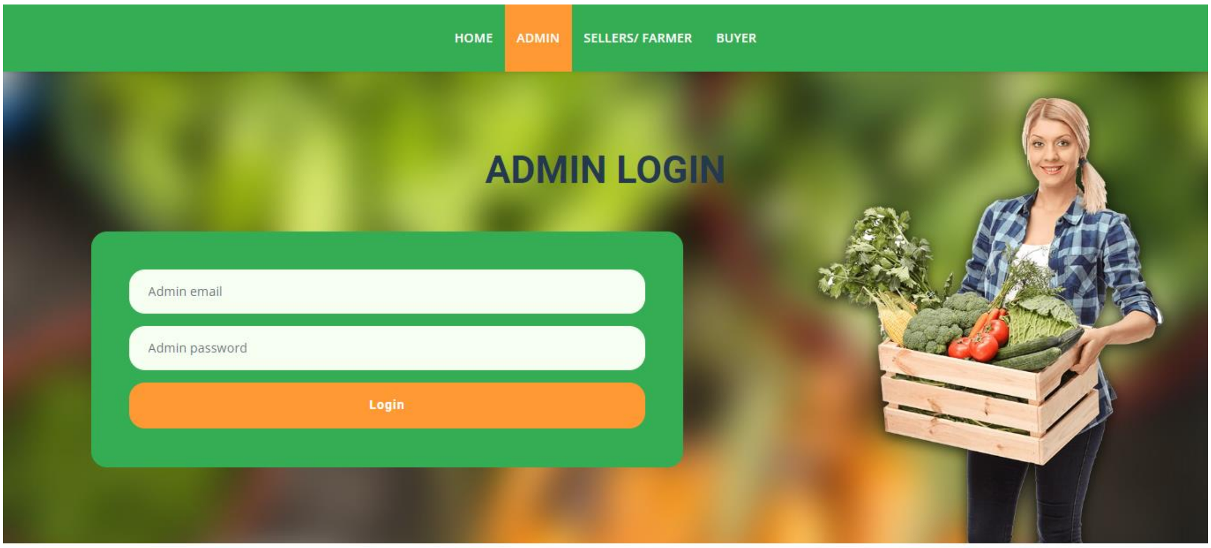
- Testing how a website performs when handling 1,000 concurrent users.
- Evaluating the response time of an API under heavy traffic to ensure it meets performance benchmarks.

CHAPTER 8 – OUTPUT SCREENS

Home Page: Decentralized Traceability and Direct Marketing of Agriculture Supply Chains home page.

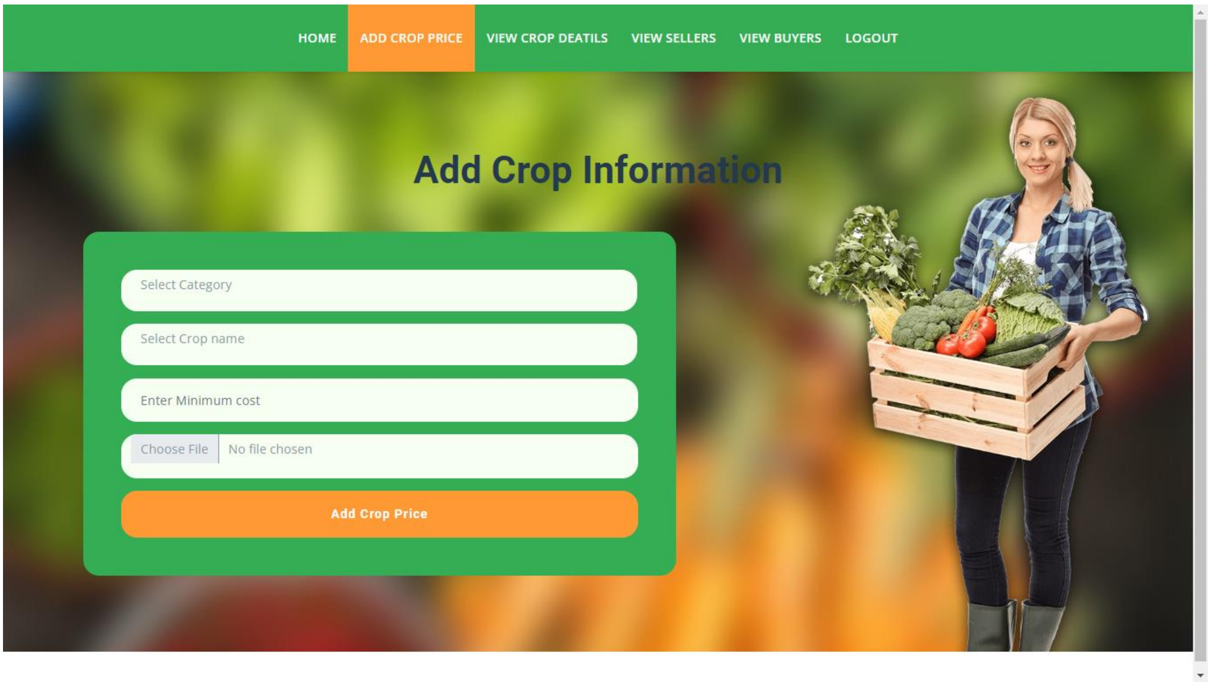


Admin Login page: The admin will login with default email and password.

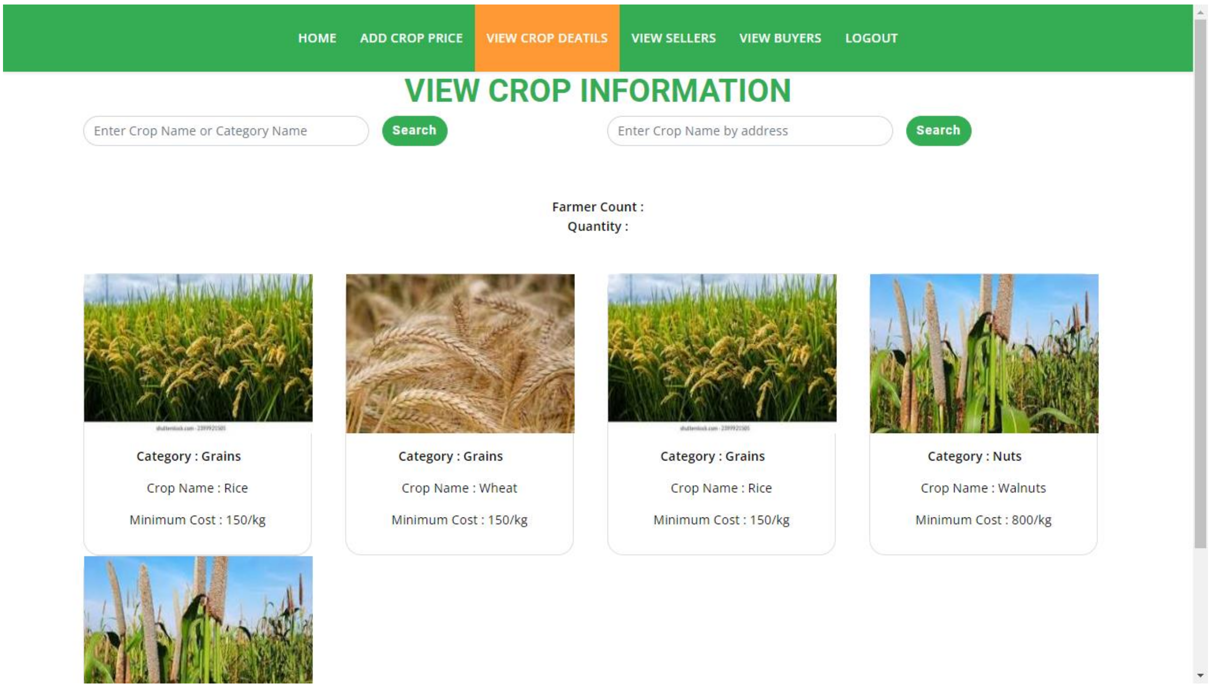


Admin home page: After login the admin will enter into home page.

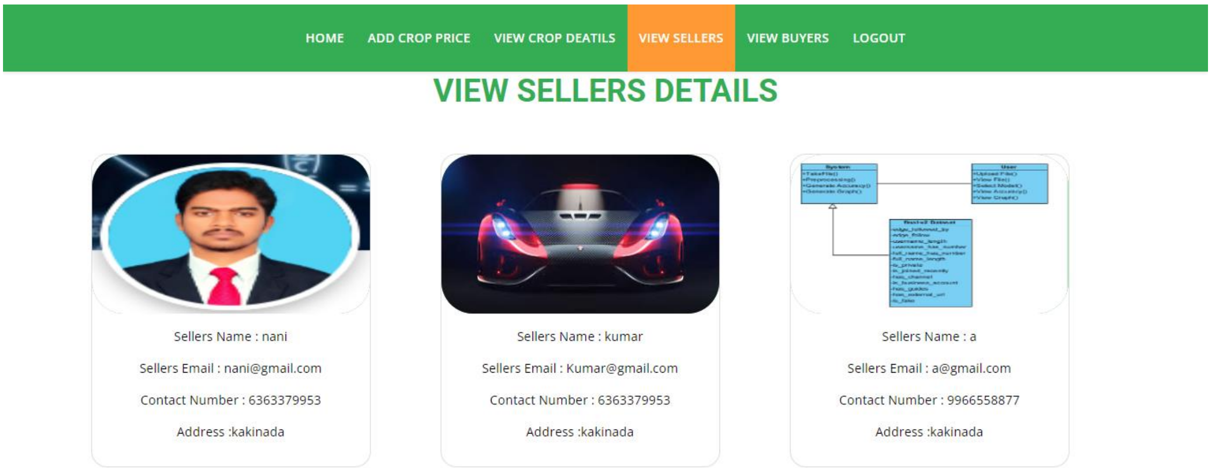
Add crop price: Here the admin can add the crop details, categories, and cost need to enter here.



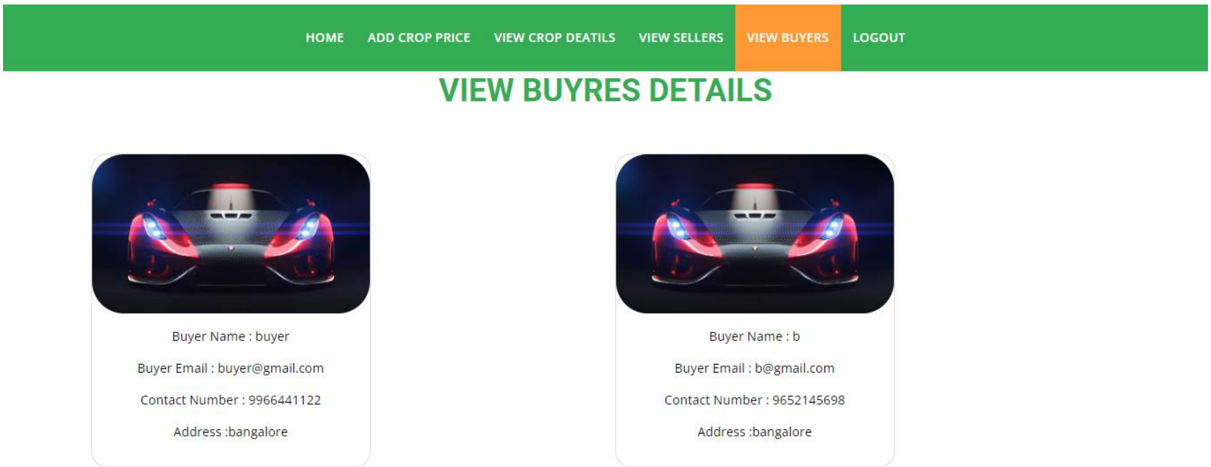
View crop details: Once the sellers/farmers will add the crop details then the admin can view those details.



View sellers: Admin can view all the sellers' details after their registration.



View buyers: Admin can view all the buyers' details after their registration.

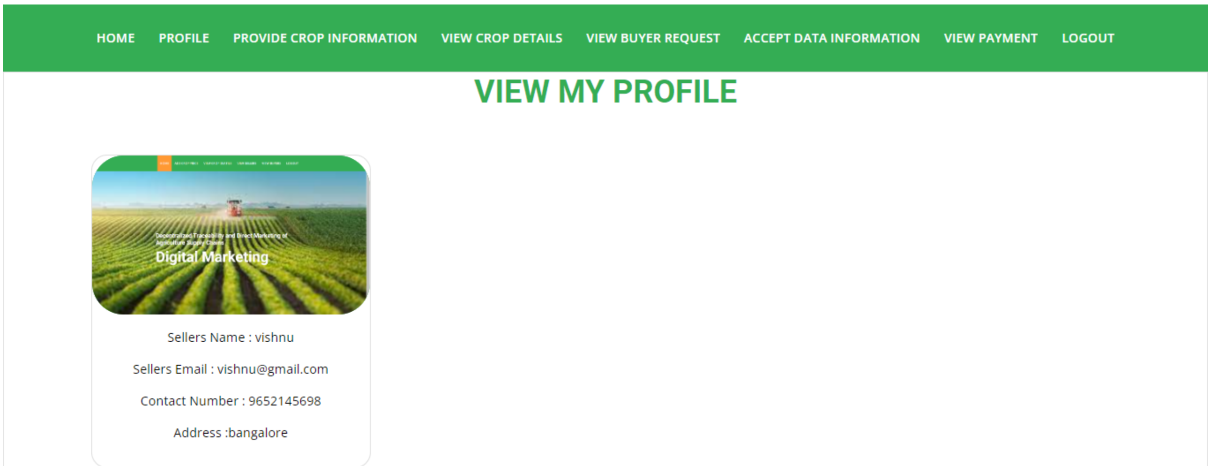


Seller's registration page: The seller will register with their details like name, email, password, address, contact, so after that the seller will login.

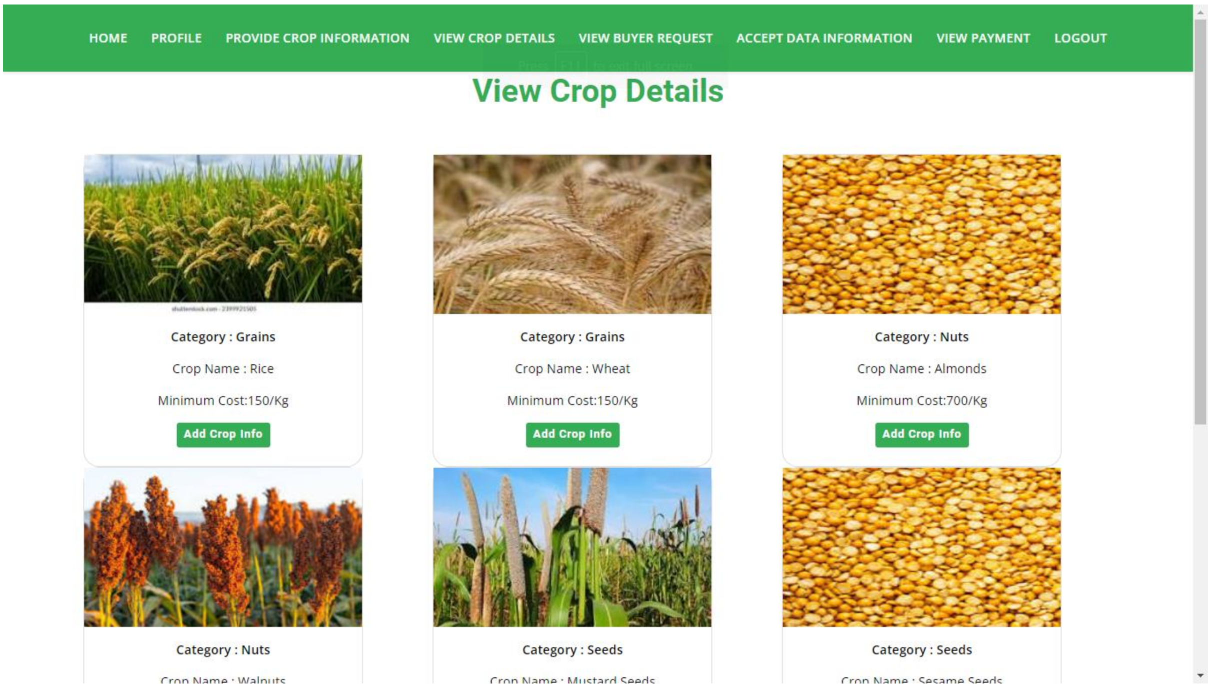
Seller's login page: After registration the seller will login with their details.

Sellers home page: After Login the will enter into home page.

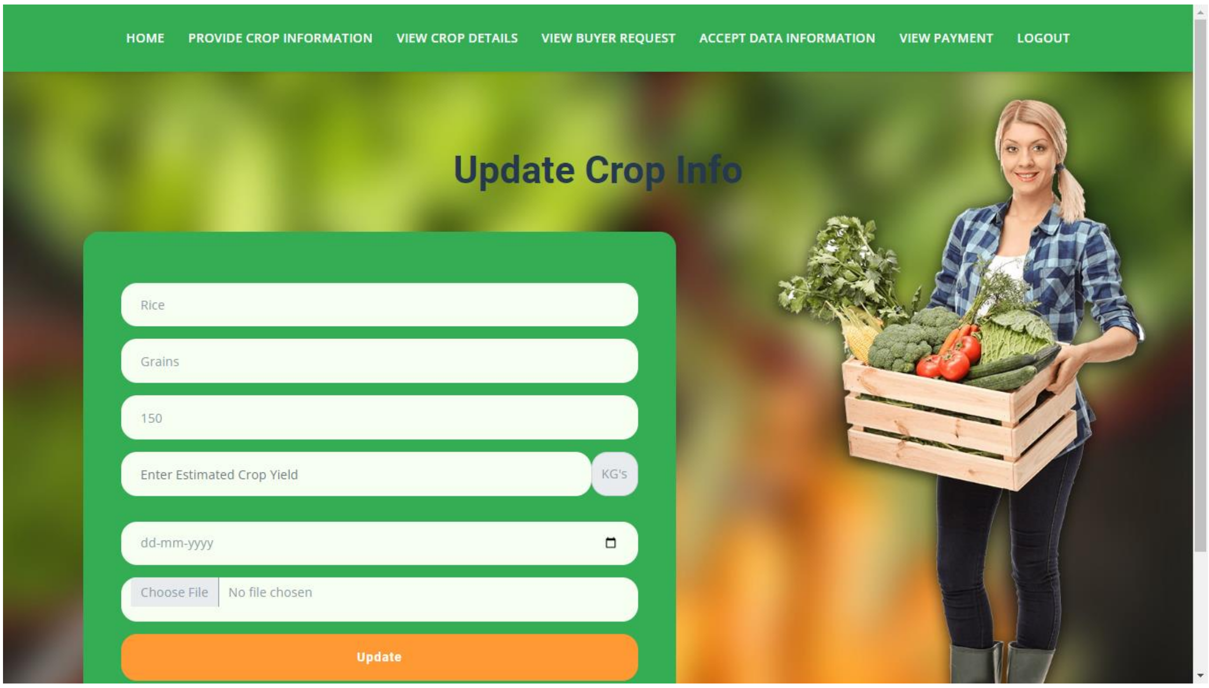
View profile: Here the seller can view the their profile.



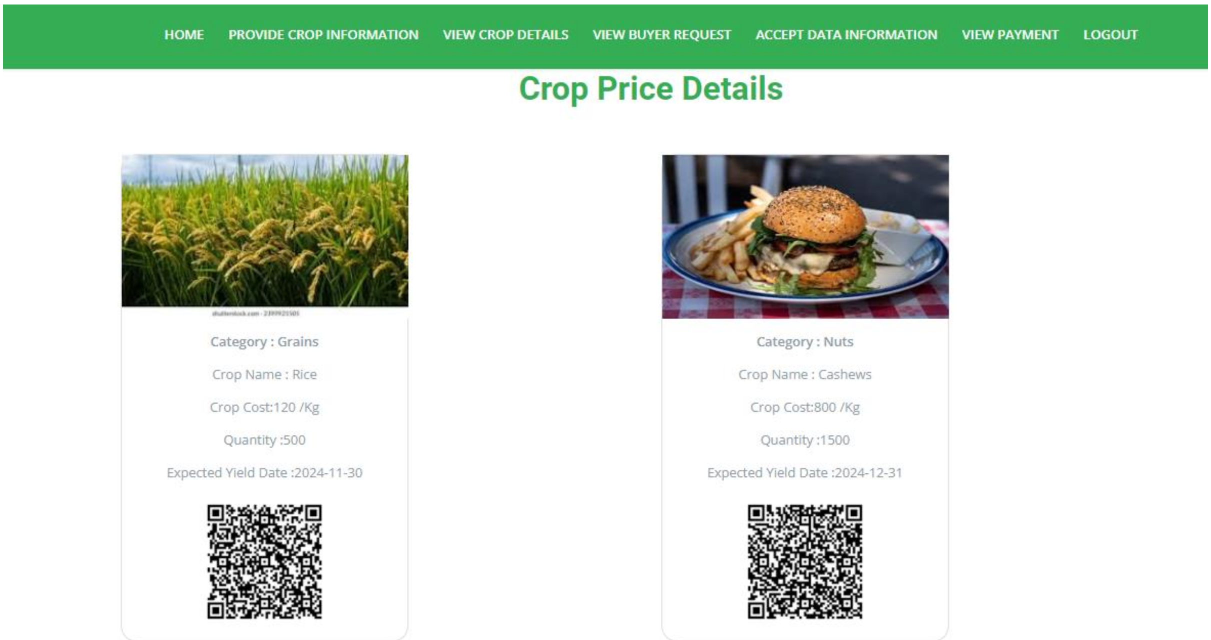
View crop details: Sellers will view the details of the crop and they need to update details.



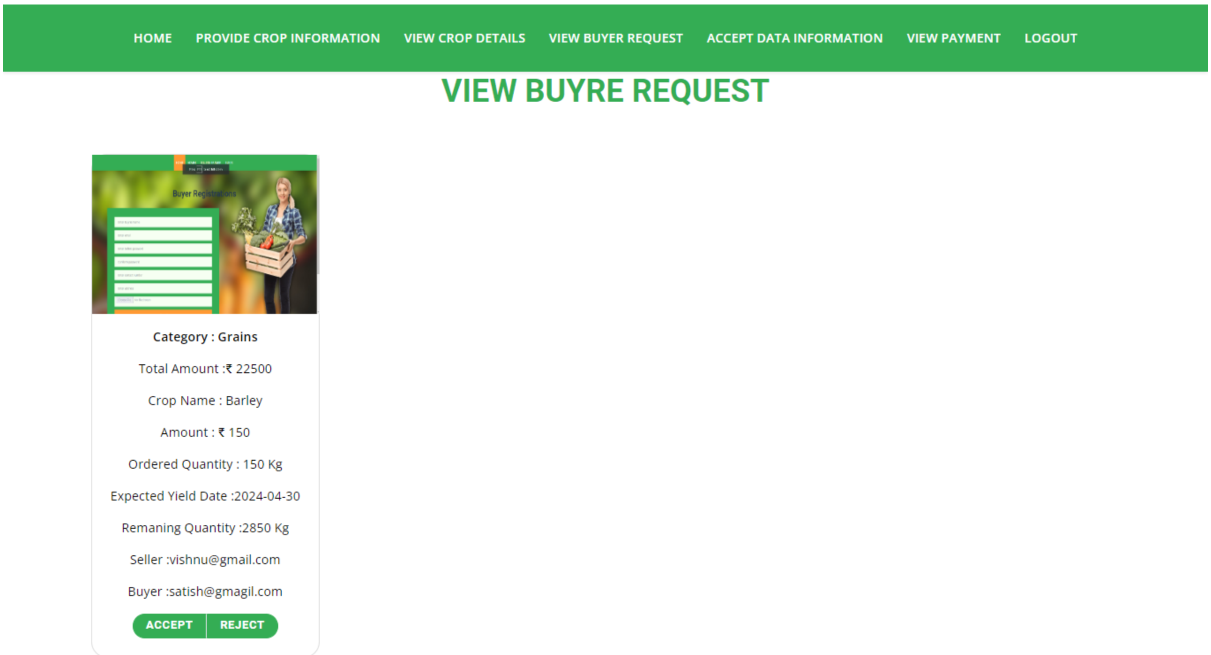
Update crop details: Here the sellers are going to add how much quantity of crop they will grow and when yield will come.



View crop price details: After adding details we can see here with QR code.



View buyer request: When buyer will request for the crop here sellers need to accept or reject for their crop



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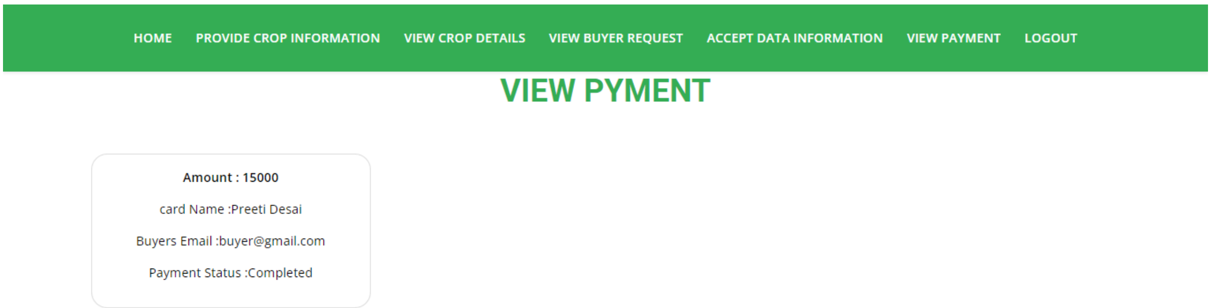
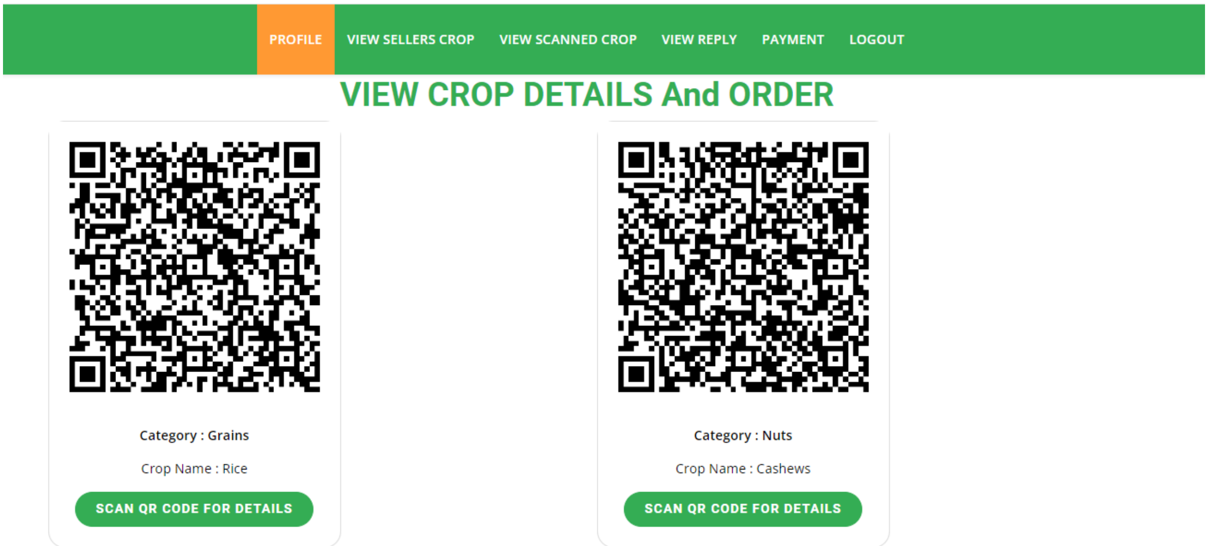
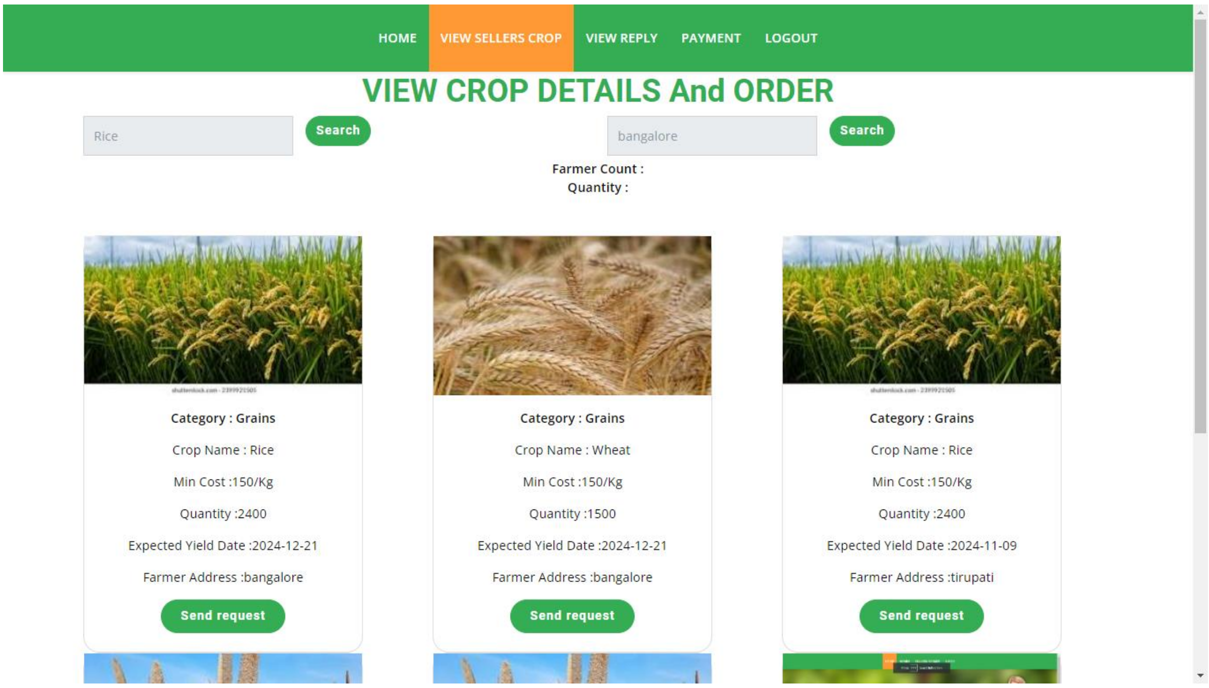
View payment: When the buyer will pay the amount for the crop the sellers will view the data.



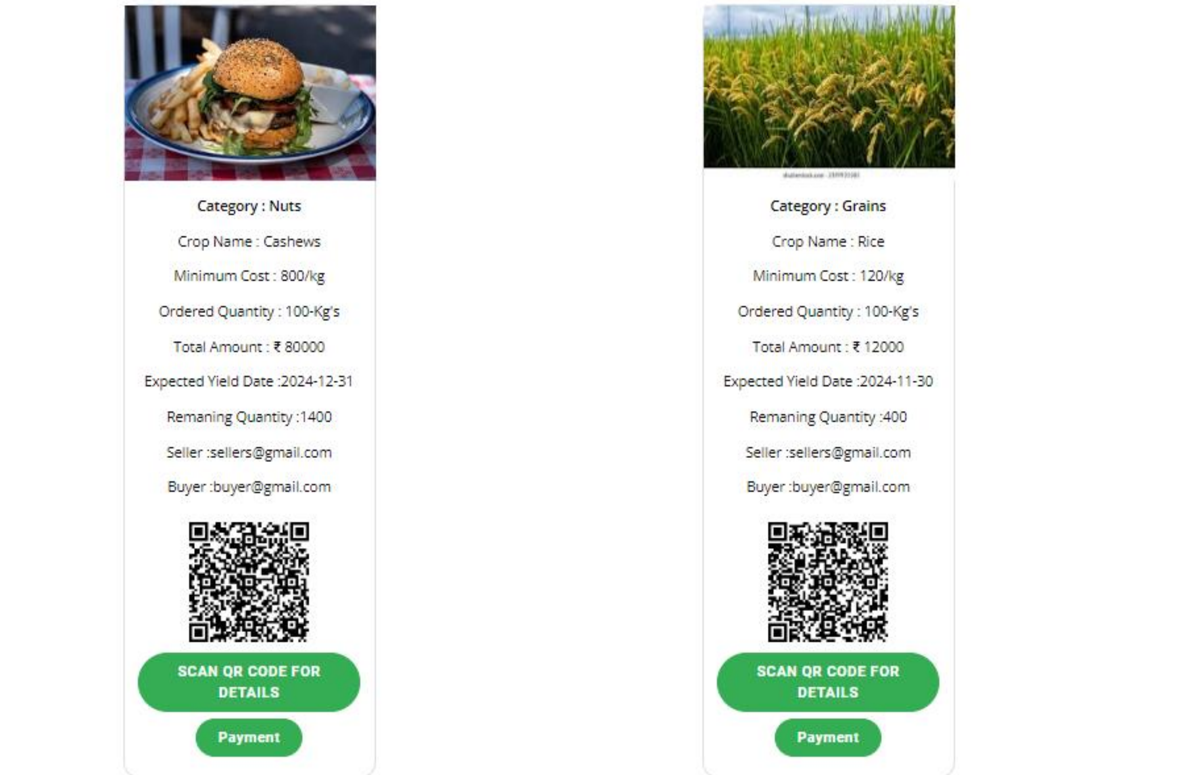
View crop details: Here the buyer can only view the QR code for the crop when they will scan and they can buy



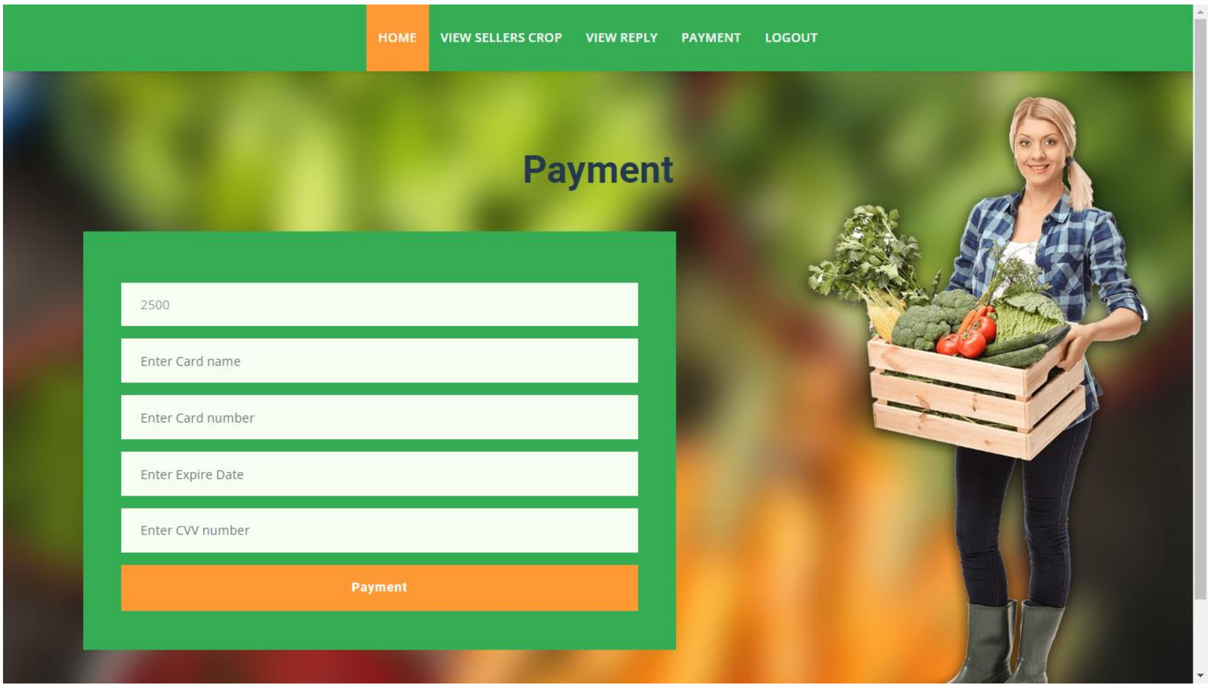
View Scanned Crop Details: After scan only the buyers can view this details and they need to send request for the crop how much he/she need of particular crop.

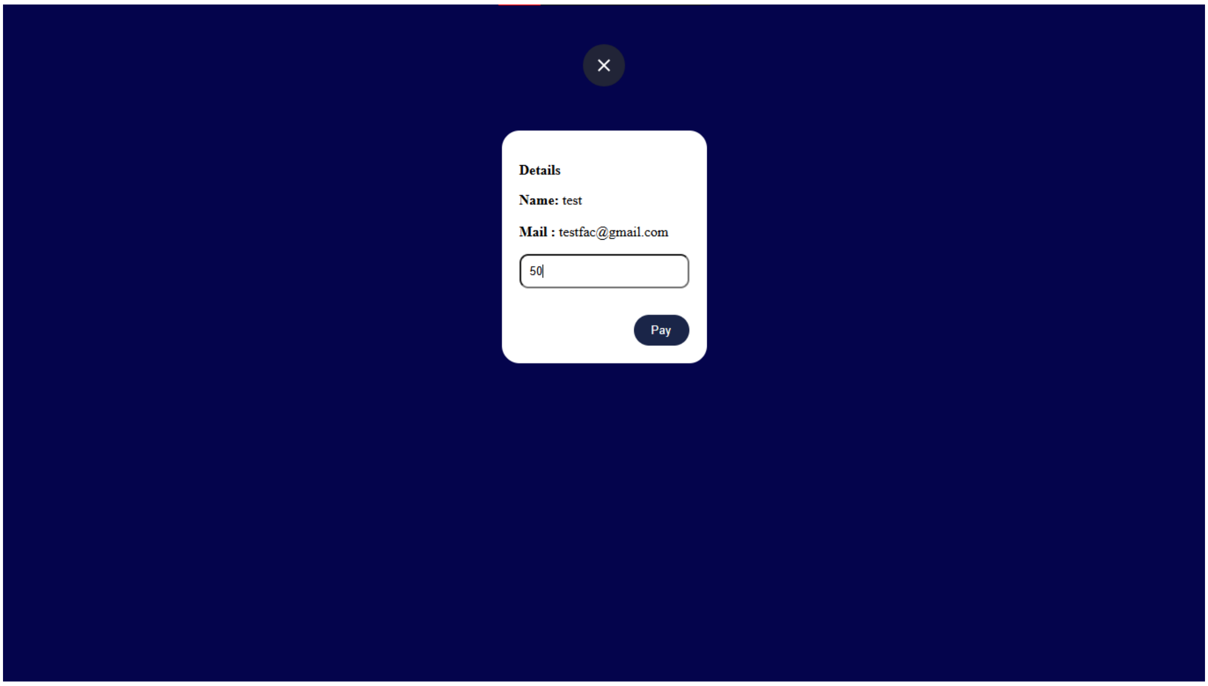


View reply: Here the buyers can view the response for the sellers. After accepting they need to pay the amount after scanning the QR code.



Payment: After scan the QR code Buyer will pay amount, by giving the details like account details.




Details
Name: test
Mail : testfac@gmail.com
50
Pay

CHAPTER 9 -CODE

SELLER:

```
def Sellers():
    if request.method == "POST":
        sname = request.form['sname']
        semail = request.form['semail']
        password = request.form['password']
        password1 = request.form['Con_Password']
        contact = request.form['mobile']
        address = request.form['address']
        myfile = request.files['myfile']
        filename = myfile.filename
        hashedpassword = hashlib.md5(password.encode())
        hashpassword = hashedpassword.hexdigest()

        if password == password1:
            print(password)
            sql="select * from sellers where semail='%s' and password='%s'"%(semail,hashpassword)
            mycursor.execute(sql)
            data=mycursor.fetchall()
            print(data)
            if data==[]:
                path=os.path.join("static/profiles/", filename)
                myfile.save(path)
                profilepath = "static/profiles/"+filename
            print(sname, semail, password, address)
```

```
        sql = "insert into sellers(sname,semail,password,contact,address,profile)values(%s,%s,%s,%s,%s,%s)"
        val = (sname, semail, hashpassword , contact, address,profilepath)
        mycursor.execute(sql, val)
        mydb.commit()
        return render_template('sellerslog.html')
    else:
        flash('Details already Exist',"warning")
        return render_template('sellers.html')
```

BUYER:

```
@app.route("/Buyers", methods=["POST", "GET"])
def Buyers():
if request.method == "POST":
bname = request.form['bname']
bemail = request.form['bemail']
password = request.form['password']
password1 = request.form['Con_Password']
contact = request.form['mobile']
address = request.form['address']
myfile = request.files['myfile']
filename = myfile.filename
if password == password1:
hashedpassword = hashlib.md5(password.encode())
hashpassword = hashedpassword.hexdigest()
sql="select * from buyers where bemail='%s' and password='%s'"%(bemail,hashpassword)
mycursor.execute(sql)
data=mycursor.fetchall()
```

```
print(data)
if data==[]:
path=os.path.join("static/profiles/", filename)
myfile.save(path)
profilepath = "static/profiles/"+filename
print(bname, bemail, password, address)
sql = "insert into buyers(bname,bemail,password,contact,address,profile)values(%s,%s,%s,%s,%s,%s)"
val = (bname, bemail, hashpassword, contact, address,profilepath)
mycursor.execute(sql, val)
mydb.commit()
return render_template('buyerslog.html')
else:
flash('Details already Exist',"warning")
return render_template('buyres.html')
else:
flash('password not matched')
return render_template('buyres.html')
return render_template('buyres.html')
```

CHAPTER 10 – CONCLUSION

The convergence of decentralized traceability and direct marketing is a transformative force in agriculture supply chains. It promotes transparency and trust while empowering farmers through direct consumer connections, reducing reliance on middlemen and increasing profitability. For consumers, this means heightened confidence in food safety and quality through traceability. Additionally, the streamlined supply chains contribute to environmental sustainability by minimizing food miles. This holistic approach aligns economic interests with environmental responsibility, making it a pivotal advancement in agriculture that benefits all stakeholders

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Decentralized Traceability and Direct Marketing of Agriculture Supply Chains

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ABSTRACT— With the increased complexity of agricultural systems and the growing number of stakeholders in particular, ongoing food safety and transparency across the supply chains of agriculture are paramount. It is becoming more and more difficult to keep track of where food originates from, its quality, and its progress as crops move through the supply chains as agricultural systems become more complex. While I am simply just an ardent learner of new and emerging technology, I am currently excited about the transformational potential of blockchain for food safety and transparency. Blockchain has the potential to allow for decentralized traceability. All crop-related activities (i.e., sowing, harvesting, etc.) can securely and immutably be recorded and stored in a ledger. This establishes trust between farmers, sellers, and consumers without the need of any intermediaries or governing body.

The platform I am proposing is to use blockchain for not just tracking the prices of crops or the stages of crop growth, but also, to provide farmers a platform to sell their products, and therefore increase their profit while decreasing dependence on third parties. Each crop will have QR code scanners that will contain an entire product history, such as the origin of the product, health quality checks, and any evidence of compliance with safety regulation. This form of transparency will improve food safety, decrease corruption, and improve the overall reliability and efficiency throughout the supply chain. The intricacies of this approach show a visionary and pragmatic model that the agricultural supply chains could use by providing trust, accountability, and the ability to navigate the complexities of every stage of the food journey.

***Keywords:** Blockchain, Decentralized system, Agricultural supply chain, Traceability, Direct marketing, Food safety, Crop monitoring, Transparency, QR code scanning, Quality assurance, Farmer empowerment, Secure transactions, Origin tracking, Operational efficiency, Supply chain reliability.*

I. INTRODUCTION

In today's increasingly connected and interdependent world, food safety and transparency in agricultural supply chains are essential. As food networks expand and involve more people, seeing the source, quality, and path of a crop from its origin to consumers becomes more complicated and difficult. Traditional food supply chains cannot provide real-time, tamper-proof information all the way through the supply chain. However, blockchain technology can enable decentralized, secure, and transparent record-keeping that documents a crop's journey, from planting to harvesting to distribution. The ultimate benefit of blockchain technology in food supply chains and agricultural networks is to create greater trust between producers, distributors, and consumers without needing a centralized authority or intermediary. Additionally, blockchain platforms could help farmers by increasing direct sales opportunities and return on investment while decreasing reliance on middlemen. QR codes and scanners put consumer access to product details and histories, such as source verification and quality assurance data, at their fingertips. Blockchain technology could serve as a proactive strategy to expand transparency and safety, while increasing efficacy and accountability.

SCOPE OF THE STUDY

This study examines the potential of blockchain technology to improve transparency, traceability, and effectiveness in the supply chain in agriculture. It aims to overcome key challenges including identifying a crop's origin, maintaining the quality of crops, and tracking food safety from production through to consumption. The study illustrates how decentralized record-keeping can eliminate the need for intermediaries, allowing farmers to sell directly to consumers and retailers. It also examines the use of QR code scanners as a way for end-users to immediately have access to an entire history of the product for the purpose of trusting consumers and making educated buying decisions. The platform aims to make agriculture's supply chain more credible, increase farming power, decrease corruption, and increase the effectiveness of the supply chain. Each application intends to validate the system, despite focusing on agricultural crops; this could be used in the future for livestock and fisheries.

PROBLEM STATEMENT

In today's agricultural markets, globalized trading and increased scale have made ensuring food product transparency, traceability, and safety a difficult endeavour. The supply chain processes are fragmented, prone to error, and populated with intermediaries, resulting in data tampering, trust erosion, fraud, inefficiencies, and diminished profits for farmers. From the consumers' perspective, they can only see so far in understanding the origins, handling, and quality of their food purchases. Centralized systems are limited in providing "real-time" tracking to multiple stakeholders at once, and most lack a system that is tamper-proof at each stage of the journey of the agricultural product. Industry stakeholders can face food fraud, corruption, and inefficiency in their operations because we are unable to provide a secure, decentralized, and transparent means of tracking each leg of the journey of the agricultural product from the moment of planting, to harvesting, delivery, empowering the farmers, and building trust with consumers to reduce harm and improve efficiency and dependability for primary producers in the food supply chain.

II. LITERATURE SURVEY

Nowadays, food quality and safety are more important than ever. Food traceability has become a major focus in managing agricultural supply chains. [1]

Aung & Chang (2014) and Bosona & Gebresenbet (2013), traceability means being able to follow a food item from the farm where it was grown all the way to the plate where it is eaten. It is essential not only for identifying the source of contamination if something goes wrong but also for maintaining consumer trust. [2]

Hobbs (2006), traditional traceability systems rely heavily on paperwork and manual procedures, which are slow, prone to errors, and simple to manipulate. Blockchain technology offers a new and promising solution to this problem. With blockchain, every event in the food supply chain is recorded securely and permanently.[3]

It creates a tamper-proof history of the product's journey, making the entire process transparent and trustworthy (Mao et al., 2018). [4]

According to Opara & Mazaud (2001), blockchain stores crucial information such as the date and location of the crop's cultivation, the manner in which it was processed, stored, and transported, and even the certifications it possesses. A major benefit of using blockchain is that it improves the speed and accuracy of food tracking. [5]

Instead of spending days trying to trace the source of contaminated food, companies can find it within minutes by simply scanning a QR code linked to the blockchain record (Dabbene & Gay, 2011). [6]

According to Storoy, Thakur, & Olsen (2013), guidelines for establishing effective blockchain-based traceability systems are also provided by frameworks like TraceFood. When blockchain is combined with the Internet of Things (IoT), it also plays a significant role. IoT devices such as sensors can automatically collect and send real-time data about temperature, humidity, and other storage conditions. [7]

This reduces human error and ensures that food quality is monitored throughout the supply chain (Khan & Salah, 2018). However, IoT device security is a challenge as well, and blockchain makes data sharing safer by providing a secure environment. Blockchain is already being used by some businesses to track food in real time. [8]

According to Lucas (2018), Walmart, for instance, uses blockchain to track leafy greens, reducing the amount of time required to trace the origin of produce from seven days to a few seconds. Because customers can verify where their food comes from, blockchain not only ensures food safety but also increases brand loyalty. [9]

Meeuw, 2016 Smart contracts, which run on blockchain platforms like Ethereum, are another exciting development. They can automate payments between farmers and buyers, making transactions faster, more secure, and reducing the chances of disputes. [10]

Bogner, Chanson (2016) Blockchain is being investigated for a wide range of applications outside of agriculture, including. [11]

AI security (Salah et al., 2019) and even the fight against fake videos. Blockchain's biggest advantage is that it removes the need for trust between parties. [12]

Hasan and Salah (2019) investigated the potential application of blockchain technology to the fight against contemporary digital threats, particularly deep fake videos. They talked about how the immutability and transparency of blockchain could help verify the authenticity of video content in their 2019 paper, which was published in IEEE Access and was titled "Combating Deep fake Videos Using Blockchain and Smart Contracts." [13]

Instead, trust is placed in the technology itself (Beck et al., 2016). According to Peck (2017), blockchain could change the world by making systems more open, secure, and reliable. 14]

In the fight against counterfeits, blockchain-based product ownership management systems (POMS) are also becoming popular (Toyoda et al., 2017). [15]

In conclusion, blockchain is revolutionizing food supply chains by improving traceability, food safety, and efficiency. As a student, learning about how technology like blockchain can solve real-world problems is truly inspiring. [16]

III. PROJECT FLOW

The diagram illustrates the operational flow of a blockchain-enabled agricultural platform that involves three major actors (Seller, User and Admin). The flow starts with an access to the system through registration (signing up). The user, once logged in, is able to see the details about the seller and crops available. The user completes the process by sending purchase requests to sellers and making payments through a safe transaction interface. On the seller's side, the seller logs in to upload or provide crop details, including crop type, quantity, pricing, and harvesting information. The seller can also view requests from buyers and can confirm payments received. This direct communication from buyers to sellers is designed to eliminate middlemen and assure higher margins for the farmer.

The Admin, once logged in, performs a supervisory role where pricing for crop transactions is monitored and managed to ensure fair practice in the platform. Everything can be tracked by the Admin regarding crop pricing so that there is equity for all actors on the platform. Each actor and their function - user, seller or admin - are clearly defined and have a log out function.

The integration of blockchain in this system captures every actors' actions in a tamper-proof design which strengthens users trust, transparency and accountability on the platform - thanks to blockchain. The system enables secure log in, requests sent directly, payment to seller visibility, and provides both the consumer and supplier with more control and efficiency.

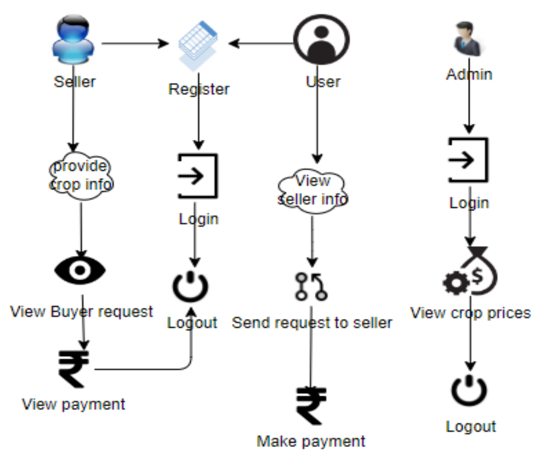

Figure 1 Project Flow Diagram

IV. METHODOLOGY

The approach to the method for the proposed blockchain-based agricultural platform will create a transparent, secure, and decentralised supply chain ecosystem that interacts with three different stakeholders: admin, sellers (in this case farmers), and users (also known as buyers). The method starts with the registration phase, where users and sellers are able to create a registered account, with their related information and farmer information. After creating an account registration, they will log in into their account and be able see and interact with the system accordingly to their registration role. After logging into the sellers' account, they will have to input certain selling information related to crops, including, crop type, quantity, price, and time of harvest. All registered crop information will be stored on the blockchain which means the information is immutable and traceable. After logging into a user's account, users can view the various crops or sellers available, be able to search for sellers based on information in their public profile, and send a request for a selected seller and or crop. Once a request is approved, a user can then make payment for the crop and the transaction will be recorded, ensuring authenticity. The admin of this agricultural platform will oversee and regulate the system, regulating crop prices and recording all activities undertaken throughout the system to ensure fairness throughout. Furthermore, each crop will provide a QR code, showing the history of each crop on its blockchain. Therefore, the consumer will able to scan the QR code and read/see the complete history of that crop from the farm to delivery. The method of the blockchain based agricultural supply chain is structured towards allowing the users and sellers to correspond directly, minimizing the role of intermediaries. All transactions will completely transparent and accountable, and with a clear immutability sign off from the blockchain, the agricultural supply chain will become efficient and trusted.

V. IMPLEMENTATION

A. Dataset

This dataset was built to accurately mimic the real-world experience of agricultural supply chain factors, focusing on supporting traceability and allowing for direct marketing functionality. It contains information over each part of the crop lifecycle, from cultivation to delivery. The dataset consists of key elements such as the farm identification, crop type, date of planting and harvesting, fertilizer and pesticide usage, details about packaging, transportation tracking, and price records on the market. Each crop item will have a unique id, or QR code applied to it that includes all the information to provide full traceability, from farm to fork.

Beyond just the core agricultural data, the level of detail includes timestamps, GPS location coordinates, logs of buyer-seller transactions, logs of storage conditions, and quality assurance certifications. All of the information is structured in a format that is suitable for blockchain; this means each entry is trusted, secure, immutable, and tamper-proof. For purposes of development and validation, data can be obtained from reputable sources such as the Food and Agriculture Organization (FAO), government databases on agriculture, or open-source repositories on supply chains. To simulate real-world aspects of the world and to test the performance of the system, synthetic data can be generated that resembles empirical patterns. This dataset is significant in the demonstration.

B. QR Code Integration:

QR Code Integration is critical in creating a transparent and traceable blockchain-based agricultural supply chain system. Each crop or product entry is tied to a unique QR code that links to its data stored on the Blockchain. The QR code represents a digital tag that holds important information such as crop type, breeding zone, cultivation and harvesting date, use of fertilizer and pesticides, packaging process, and transport history. When a consumer, buyer, or responsible authority scans their QR code, the entire life cycle of the product and transaction history is retrieved and shown in a readable format. This builds trust and accountability by allowing end users to confirm the authenticity, quality, and safety compliance of the food item that they are purchasing. Farmers and sellers can simply query the QR code, share verified data in a more efficient manner without the need for a longer explanation or third-party trust verification. QR codes will bridge the producer-consumer gap and provide real-time accessibility to immutable records stored on the blockchain to create a more transparent, secure, and efficient agricultural supply chain.

C. Smote Method

SMOTE (Synthetic Minority Over-sampling Technique) is a very effective method that can solve the class imbalance problem often found in datasets, especially in cases of machine learning classification tasks, when we have a scenario with obviously fewer instances in one class (typically the minority class), it is unclear which models will be biased towards the majority class and which will not base on the amount of classes, at best, these models would yield poor performance in predicting the minority class. SMOTE tackles the issue of class imbalance and rare event prediction by implementing methods to generate synthetic examples of the minority class instead of replicating already existing instances in the dataset. SMOTE uses a sampled data point from the minority class to determine their k-nearest neighbours, and thus it generates synthetic instances along the line segments joining the sampled point and its k-nearest neighbours to either multiply the instance along the k-nearest neighbours, or simply create synthetic examples and so on. This process has the effect of enlarging the feature space as unique, diverse and thoughtful examples of the underrepresented classes are now available for the classifier to learn by during training. By balancing the datasets with SMOTE synthetic examples, the model will become more accurately fit and generalized to make predictions and classify the instances to correspond to applications including fraud detection, disease diagnosis, and in rare event prediction as illustrated in previous examples. It is obvious that SMOTE is often effective in addressing the class imbalance problem but, these techniques must be used in conjunction with adequate validation techniques to limit overfitting so the model learns the relevant relationships within the data and differentiate between the synthetic samples and validation noise not yielding to superior performance.

D. Select K best Method

SelectKBest is a feature selection technique commonly used across machine learning applications to select the most pertinent features independent of the dataset. It uses a statistical test to score each feature, and SelectKBest will select the k features that have the highest scores. This technique reduces the number of features in a dataset, reducing dimensionality—and by minimizing the number of features included, SelectKBest minimizes overfitting, reduces computational cost, and typically yields better performing models. SelectKBest can utilize various scoring functions, depending on the type of data—certain scoring functions are appropriate for classification problems with categorical variables, such as chi-square. Others are appropriate for regression predictions with continuous variables like regression. Since SelectKBest only uses the features in the dataset that contribute most to the model's predictive power, it simplifies model building by eliminating irrelevant features and resulting in a more interpretable model. A large potential benefit of SelectKBest is that could be utilized at the pre-processing stage of a machine learning pipeline. During pre-processing, developers can filter out irrelevant features that are creating noise resulting in a decreased model performance, and utilize SelectKBest to quickly discard correlated, indistinguishable features that fail to add robustness to the data, otherwise could compromise the model's proficiency.

E. Model Instruction

1. SHA-256

The diagram illustrates the SHA-256 algorithm process as a step-by-step transformation of input data into a secure 256-bit hash value. The process begins with **padding the input**, where the original message is extended to ensure its length is a multiple of 512 bits. This is done by adding a '1' bit, followed by several '0' bits, and finally appending the original message length in 64-bit binary format. Next is **message breaking**, where the padded message is divided into 512-bit blocks, each of which will be processed independently. The third step involves setting up the **initial hash values**, a set of eight 32-bit constants derived from the square roots of the first eight prime numbers. These serve as the starting values for the hashing computation. In the fourth stage, **each block undergoes 64 rounds of processing**, where various bitwise operations (like AND, OR, XOR) and modular additions are applied using a set of predefined constants. These operations update internal working variables that reflect the ongoing transformation of the message. Finally, in the **hash calculation step**, the updated values from each block are combined to generate the final 256-bit hash output. This output acts as a secure, tamper-proof digital fingerprint of the input data.

Figure 2 SHA-256

2. Block Chain Technology

The diagram shows the basic template of a blockchain and illustrates the way blocks are interconnected through cryptographic hashes. The three parts to each block are: the current block's hash, the hash of the previous block, and the data, which is usually the transaction data. Each block's hash is created from the contents of each block and is essentially a unique digital fingerprint. By including the hash of the previous block, each block is effectively attached to the previous block, forming an unalterable time-stamped and sequential chain. For instance, block 2 contains a hash of Block 2, the hash of Block 1 and transaction data, just like Block 3 contains a hash of Block 2. This structure gives blockchain its immutability—if there was an alteration to any of the contents of a previous block, then the hash would change; and therefore, the following blocks would also be no longer valid. This trustworthiness of blockchain technology is important—all you would have to do is recalculate all of the hashes of the blocks that came after it, which is practically impossible. The diagram in each case reveals that blockchain technology includes integrity, transparency and security from the hash and their connection to each other.

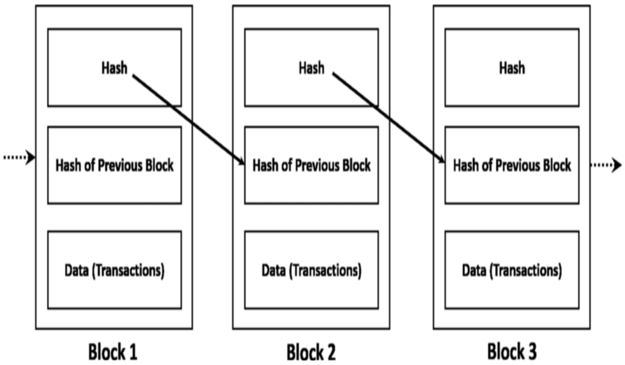

Figure *2* Block Chain Technology

V. RESULTS

Home Page: A platform on the blockchain that makes direct marketing and decentralized traceability in agricultural supply chains possible.

Figure 2 Home Page

Admin Login page: The administrator will use the default email and password to log in.

Figure 3 Admin Login Page

Admin home page: After logging in, the admin is redirected to the homepage where they can manage products, monitor transactions, and oversee the entire agricultural supply chain system.

Figure 4 Admin home page

Add crop price: The administrator can enter crop information, categories, and costs here.

Figure 5 Add crop price Page

View crop details: The administrator will be able to view the crop details once the sellers and farmers have added them.

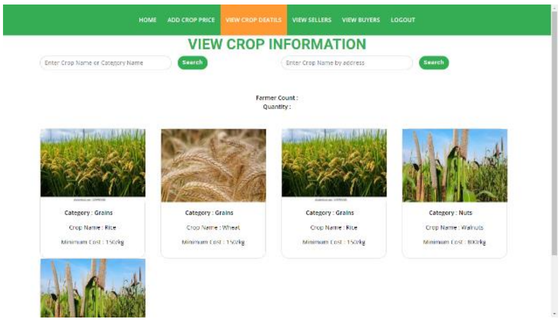

Figure 5 view crop details

View sellers: Admin can view all the sellers' details after their registration.

Figure 6 View sellers

View buyers: Admin can view all the buyers' details after their registration.

Figure 8 View buyers

Seller's registration page: The seller will register with their details like name, email, password, address, contact, so after that the seller will login.

Figure 8 Seller's registration page

Seller's login page: After registration the seller will login with their details.

Figure 9 Seller's login page

Sellers home page: After Login the will enter into home page.

Figure 10 Sellers home page

View profile: Here the seller can view their profile.

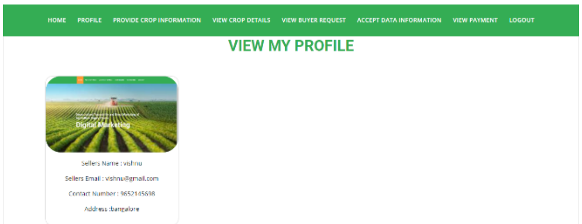

Figure 11 View profile

View crop details: Sellers will view the details of the crop and they need to update details.

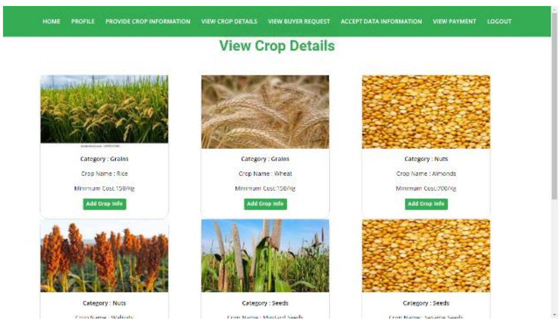

Figure 12 View crop details

Update crop details: Here the sellers are going to add how much quantity of crop they will grow and when yield will come.

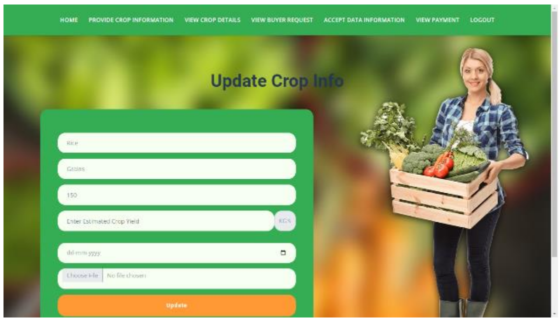

Figure 13 Update crop details

View crop price details: After adding details we can see here with QR code.

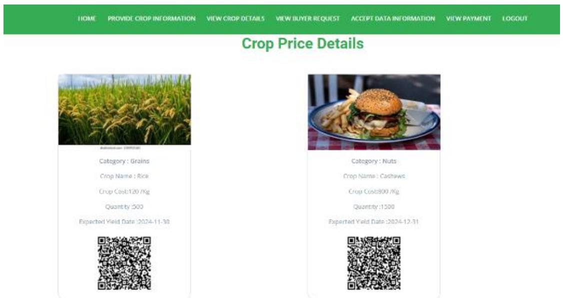

Figure 14 View crop price details

View buyer request: When buyer will request for the crop here sellers need to accept or reject for their crop

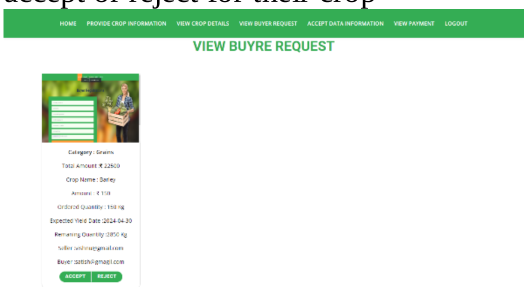

Figure 15 View buyer request

View payment: When the buyer will pay the amount for the crop the sellers will view the data.

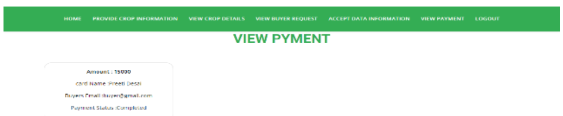

Figure 16 View Payment

View crop details: Here the buyer can only view the QR code for the crop when they will scan and they can buy

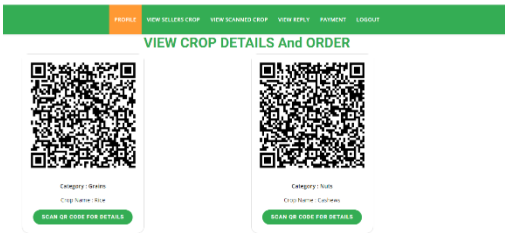

Figure 17 View crop details

View Scanned Crop Details: After scan only, the buyers can view this detail and they need to send request for the crop how much he/she need of particular crop.

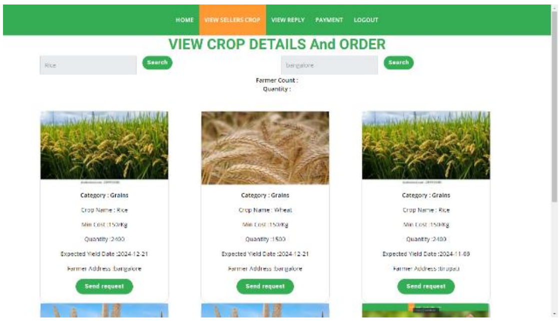

Figure 18 View Scanned Crop Details

View reply: Here the buyers can view the response for the sellers. After accepting they need to pay the amount after scanning the QR code.

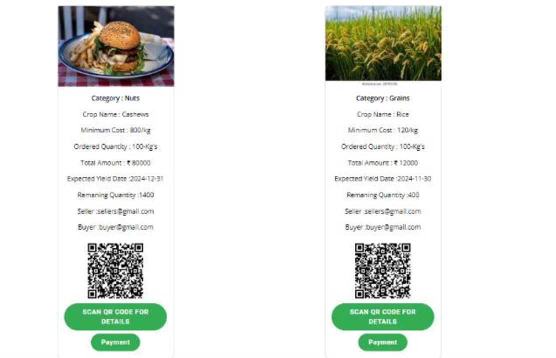

Figure 19 View reply

Payment: After scan the QR code Buyer will pay amount, by giving the details like account details.

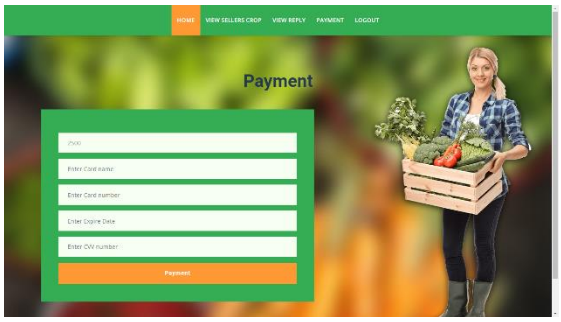

Figure 20 Payment

VI. CONCLUSION

The introduction of decentralized tracing and direct marketing systems in agriculture is a revolutionary step forward, providing transparency from farmer to consumer, and empowering farmers to actively engage their customers. By decreasing the mediating parties, farmers can enjoy better prices while engaging with durable customers. For an agricultural student who is interested in sustainability, it is encouraging to see how this approach supports consumer confidence, and gives consumers the ability to see the source of their food and verify some quality and safety standards. Better transparency and tracking can reinforce the trustworthiness of the food system.

In addition, the environmental benefits are just as important. Improved transparency and shorting of the supply chain will allow the sustainability movement to further diminish food miles, which is a big contributor to a carbon footprint. The whole notion embodies how technology and smart systems can catalyse positive social change, both economically or ecologically. For students like me who are interested in agriculture, sustainability and business innovation, this can inform real and positive change. It's a working model that integrates economic growth with a concern for the environment, ultimately leading to a smarter, more equitable, and sustainable agricultural sector.

VII. FUTURE WORK

In the future, the system can use deeper integrations of blockchain technology that further secure food traceability and prevent tampering with data. Building mobile-friendly platforms will also allow even the smallest of farmers in rural areas to readily use these systems to directly sell their product. Using IoT-sensors to automate data collection for information about food quality, location, and environmental data would make for a better, more efficient system for farmers and consumers. Adopting these technologies will also require some digital literacy training and onboarding for farmers. Partnering with cooperatives and local governments would also provide richer outreach and opportunity for scalability with a broader patient base. Through the use of smart contracts, it is also possible to make payments and agreements between farmers and consumers openly and transparently while minimizing delays and disputes. Finally, additional studies can focus on measuring longer term effects of the system on the economic and environmental impact that will produce relevant guidance for systems policy and broader implementation. As a student can ultimately grow these technological trends to positively influence rural development, sustainable agriculture and global food security.

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