

# Harvestiq: An Integrated Ai-Powered Smart Agriculture Decision-Support and Marketplace Framework

M. Deebeka<sup>1</sup>, J. Preethi<sup>2</sup>, K. kaviyasree<sup>3</sup>, J.J.Jenifer<sup>4</sup>, S.S.Nandhini<sup>5</sup>

<sup>1,3,4,5</sup>Final Year AI & DS Student, Department of CSE Anna University Regional Campus, Coimbatore, India

<sup>2</sup>Assistant Professor (Selection Grade), Department of CSE Anna University Regional Campus, Coimbatore, India

## Abstract:

Agriculture faces increasing challenges due to climate variability, inappropriate crop selection, plant diseases, limited access to personalized agricultural guidance, and market-related uncertainties. This paper presents HarvestIQ, an integrated AI-driven smart agriculture platform designed to support farmers throughout the agricultural decision-making process. The proposed system combines machine learning-based crop recommendation, weather and location intelligence, CNN-based plant disease detection, a multilingual AI chatbot with voice assistance, and an intelligent buyer–seller marketplace within a unified platform. Crop recommendations are generated by analyzing soil parameters, weather conditions, season, and farm location, while real-time climate information supports crop and irrigation-related decisions. The disease detection module analyzes plant leaf images to identify diseases and provide relevant management guidance. The AI chatbot supports agricultural queries in Tamil and English, with voice-based responses to improve accessibility. In addition, the marketplace uses Government Mandi prices, road distance, transportation cost, crop quality, and buyer requirements to recommend suitable trading matches and estimate fair prices. By integrating climate-aware decision support, disease management, agricultural guidance, and market intelligence, HarvestIQ aims to provide a comprehensive, accessible, and data-driven framework for improving farm productivity, sustainability, and profitability.

**Index Terms** - Artificial Intelligence, Smart Agriculture, Crop Recommendation, Convolutional Neural Networks, Weather Intelligence, Location-Aware Farming, Multilingual Chatbot, Intelligent Agricultural Marketplace, Agricultural Decision Support.

## I. INTRODUCTION

Agriculture plays a vital role in economic development and food security; however, farmers face several challenges in making informed decisions regarding crop selection, farm management, plant disease control, agricultural guidance, and market trading. These decisions depend on multiple factors such as soil conditions, weather variations, geographical location, crop health, and market price fluctuations. Existing agricultural solutions often focus on individual tasks such as crop recommendation or disease detection, requiring farmers to use separate systems for different agricultural needs. This fragmented approach limits

the availability of integrated and personalized decision support [1], [2].

Recent advancements in Artificial Intelligence (AI), Machine Learning (ML), Deep Learning, Natural Language Processing (NLP), and location-based technologies have created new opportunities for data-driven agriculture. ML techniques can analyze agricultural and environmental parameters to recommend suitable crops, while Convolutional Neural Networks (CNNs) enable automated plant disease prediction from leaf images [2],[4]. Similarly, AI-based chatbots can provide farmers with agricultural guidance through natural language interaction, improving the accessibility of digital farming services [7], [9].

To address these challenges, this paper presents HarvestIQ, an integrated AI-driven smart agriculture platform consisting of four major components: AI-based Crop Recommendation, CNN-based Plant Disease Prediction, a Tamil–English Bilingual AI Chatbot, and an Intelligent Buyer–Seller Marketplace. The crop recommendation module analyzes soil, weather, and environmental conditions to identify suitable crops, while Farm Location Intelligence supports both current location and map-based selection of the actual farmland for personalized recommendations [1], [10], [13].

The system further integrates a CNN-based disease prediction module for identifying plant diseases from leaf images and providing relevant management guidance. The bilingual chatbot enables farmers to access agricultural assistance in Tamil and English, while the marketplace incorporates Government Mandi prices, location, road distance, transportation cost, crop quality, and quantity requirements to support intelligent buyer–seller matching and fair trading decisions [7], [10], [13], [14].

By integrating these modules into a unified platform, HarvestIQ aims to provide comprehensive, location-aware, and accessible agricultural decision support, covering the major stages from crop planning and disease management to farmer guidance and agricultural trading.



**Figure 1 : Agricultural field cultivation**

## **II. LITERATURE REVIEW**

### **A. AI-Based Crop Recommendation**

Machine Learning techniques have been widely applied to recommend suitable crops by analyzing agricultural and environmental parameters. Crop recommendation systems generally consider soil nutrients, pH, temperature, rainfall, and seasonal conditions to support crop selection. However, many existing approaches rely mainly on predefined datasets and do not provide complete decision support by combining environmental analysis with personalized farm-level information. HarvestIQ addresses this

through an AI-based crop recommendation approach that incorporates soil and environmental parameters for more informed crop suitability analysis [1], [5].

Location-aware agricultural systems improve decision-making by incorporating geographical information into farming analysis. However, existing applications often depend only on the user's current GPS location, which may not accurately represent the actual farmland. HarvestIQ addresses this limitation by supporting both current location detection and interactive map-based farm location selection, enabling recommendations based on the farmer's actual agricultural land. Location information can further support the retrieval and analysis of farm-specific environmental and geographical data [10], [13].

### **B. Plant Disease Prediction**

Deep learning has shown significant effectiveness in image-based classification, particularly through Convolutional Neural Networks (CNNs). Architectures such as MobileNet have established effective approaches for extracting visual features and performing image classification [2]–[5]. Based on these developments, HarvestIQ uses a CNN-based approach to process plant leaf images and predict disease classes, with the results integrated into the overall agricultural decision-support platform rather than operating as an isolated system.

### **C. Bilingual AI Chatbot**

AI chatbots provide agricultural guidance through natural language interaction and improve accessibility to digital farming services. Advances in semantic language representations and retrieval-augmented generation have enabled more context-aware responses to user queries [7], [9]. HarvestIQ extends this approach through a Tamil–English bilingual chatbot that handles queries related to crop recommendation, farm location, plant diseases, weather, and marketplace services. The system combines AI-based responses with local AI support to improve accessibility, particularly for users in low-connectivity environments [7], [9], [14].

### **D. Intelligent Buyer–Seller Marketplace**

Digital agricultural marketplaces can improve market access by connecting farmers and buyers; however, many platforms do not provide intelligent decision support for selecting suitable trading partners. Important trading factors such as market price, geographical distance, transportation cost, crop quality, and quantity requirements are often considered separately. HarvestIQ integrates these parameters to support intelligent buyer–seller matching and fair-price estimation, using Government Mandi price information and location-based transportation analysis to improve transparency and data-driven agricultural trading.

### **E. Research Gap**

Existing systems mainly focus on individual agricultural tasks and lack a unified platform that connects crop selection, plant disease prediction, multilingual farmer assistance, and intelligent agricultural trading. HarvestIQ addresses this gap by integrating these four core components into a single AI-driven agricultural decision-support framework, providing support from farm planning to crop marketing.

## **III. METHODOLOGY**

Based on the research gap identified from existing agricultural systems, HarvestIQ proposes an integrated AI-driven framework that combines AI-based crop recommendation, Farm Location Intelligence, CNN-based plant disease prediction, a Tamil–English bilingual chatbot, and an intelligent buyer–seller marketplace. The methodology is designed to provide continuous decision support from farm-level crop

planning to agricultural marketing. The overall workflow begins with user and farm data acquisition, followed by processing through specialized AI models and intelligent service modules. The outputs from these modules are presented through a unified application interface to support informed agricultural decision-making.

#### **A. Farm and Agricultural Data Acquisition**

The system collects agricultural information required for AI-based decision-making through the application interface. The crop recommendation module uses relevant parameters such as soil nutrient values, soil pH, temperature, rainfall, water-related conditions, and seasonal information. These parameters are structured as input features for the machine learning model.

HarvestIQ supports two approaches for obtaining geographical information. In Current Location mode, the system obtains the user's geographical coordinates through location services. In Farm Location mode, the farmer selects the actual farmland using an interactive map. The selected coordinates are processed using geocoding services to identify location-related information such as the district and taluk. This approach allows recommendations to be associated with the actual farmland rather than only the user's current position.

### **METHODOLOGY – HARVESTIQ**

| 1. DATA COLLECTION                                       | 2. DATA PREPROCESSING                            | 3. AI / ML PROCESSING                                               | 4. OUTPUT GENERATION                      | 5. DECISION SUPPORT                                                                                                        |
|----------------------------------------------------------|--------------------------------------------------|---------------------------------------------------------------------|-------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| Farmer Input Soil, NPK, pH Location, Crop Preferences    | Data Cleaning & Missing Value Handling           | Crop Recommendation Model (ML Classification)                       | Recommended Crops (Top Suggestions)       | Integrated Smart Farming Dashboard<br>• Crop Planning<br>• Disease Management<br>• Market Trading<br>• Reports & Analytics |
| Weather Data Temperature, Humidity, Rainfall, Wind, etc. | Normalization & Standardization                  | Disease Detection Model (CNN)                                       | Disease Prediction & Treatment Suggestion |                                                                                                                            |
| Leaf Image Captured via Camera / Gallery                 | Image Preprocessing Resize, Filter, Augmentation | AI Chatbot Engine NLP – Intent Detection, Response Generation       | Chatbot Response (Text / Voice)           |                                                                                                                            |
| Market Data Prices, Demand, Buyer Information            | Feature Extraction Weather, Soil, Location, etc. | Marketplace Matching Engine Buyer–Seller Matching, Price Estimation | Market Insights & Best Deals              |                                                                                                                            |



| 6. MODEL IMPROVEMENT (FEEDBACK LOOP)                                                         | FARMER DECISION MAKING                                                         | EXTERNAL INTEGRATIONS                    |
|----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|------------------------------------------|
| User Feedback & New Data → Model Retraining & Optimization → Improved Accuracy & Performance | Use recommendations, disease guidance, market insights and reports for action. | Weather • Maps • Geocoding • Market APIs |

## FINAL OUTPUTS

|                     |                   |                      |                           |                       |                     |                    |
|---------------------|-------------------|----------------------|---------------------------|-----------------------|---------------------|--------------------|
| Crop Recommendation | Disease Diagnosis | Treatment Suggestion | Yield & Profit Estimation | AI Chatbot Assistance | Marketplace Matches | Reports & Insights |
|---------------------|-------------------|----------------------|---------------------------|-----------------------|---------------------|--------------------|

**Table 1 : Methodology**

### B. AI-Based Crop Recommendation and Farm Location Intelligence

The collected agricultural and environmental parameters are processed by the crop recommendation engine. The system uses a trained Random Forest machine learning model to analyze the relationship between the input conditions and suitable crop classes.

Farm Location Intelligence is integrated into the recommendation workflow to provide geographical context. The location information obtained from GPS or map-based farm selection is used together with relevant agricultural inputs. Weather-related information is integrated through external services to support climate-aware analysis.

The model generates crop suitability predictions, which are ranked and presented to the farmer. The recommendation output can further include expected yield and estimated profitability, providing additional support beyond basic crop classification.

Processing Flow:

Agricultural Data + Farm Location + Weather Data → Feature Processing → ML Model → Crop Prediction → Ranking → Yield and Profit Output

### C. Plant Disease Prediction

The plant disease prediction module uses a trained CNN-based image classification model to identify diseases from uploaded plant leaf images. The input image is resized to the dimensions required by the model and converted into an appropriate numerical array. The image is then passed to the CNN, where convolutional layers extract disease-related visual features.

The model produces probability values for the supported disease classes. The class with the highest probability is selected as the final prediction. The predicted disease is subsequently mapped to the corresponding management or treatment guidance stored in the advisory layer.

This workflow enables farmers to obtain both disease identification and actionable information through a single prediction request.

Processing Flow:

Leaf Image → Resizing and Preprocessing → CNN Feature Extraction → Probability Classification → Disease Prediction → Treatment Guidance

### D. Tamil-English Bilingual AI Chatbot

The chatbot module enables users to interact with HarvestIQ using agricultural queries in Tamil and English. The user query is processed through language and intent analysis to determine the purpose of the request. Queries are categorized into relevant domains, including crop recommendation, plant disease, weather, farm location, marketplace services, and general agricultural guidance.

Based on the detected intent, the request is routed to the appropriate service or AI response component. Domain-specific queries can retrieve information from the relevant HarvestIQ modules, while complex or open-ended queries are processed using cloud-based LLM services. For selected low-connectivity scenarios, local AI support using Ollama is used.

The generated response is returned in the selected language. A Text-to-Speech component can convert the chatbot response into audio, providing voice-based assistance.

Processing Flow:

Tamil/English Query → Intent Processing → Service or AI Routing → Response Generation → Bilingual Text → Voice Output

### E. Intelligent Buyer–Seller Marketplace

The marketplace module processes crop listings submitted by farmers and purchasing requirements submitted by buyers. A farmer listing contains crop type, quantity, crop quality, farm location, and optional expected price. Buyer requirements include the required crop, quantity, budget, preferred quality, and buyer location.

The system first filters eligible matches based on crop and quantity compatibility. It then integrates Government Mandi price information as a market reference. The geographical locations of the farmer and buyer are used for road-distance analysis, and transportation costs are estimated based on the calculated distance.

The eligible candidates are evaluated using multiple factors, including market price, transportation cost, crop quality, quantity compatibility, buyer budget, and seller expectations. The resulting matches are ranked to identify suitable trading opportunities. The final output provides the recommended trading partner, estimated road distance, transportation cost, and fair-price suggestion.

Processing Flow:

Crop Listing + Buyer Requirement → Eligibility Filtering → Government Market Price Analysis → Road Distance Calculation → Transportation Cost Estimation → Multi-Factor Matching → Ranking → Recommended Match and Fair Price

### F. Unified Decision-Support Integration

The outputs of the five modules are delivered through a unified application architecture. The crop recommendation and Farm Location Intelligence components support crop planning, the CNN module supports crop-health assessment, the bilingual chatbot provides interactive agricultural guidance, and the marketplace supports informed agricultural trading.

The integrated methodology enables HarvestIQ to support multiple stages of the agricultural lifecycle through a single platform, connecting farm-level analysis, crop planning, disease management, farmer guidance, and market decision-making.

## IV. MODEL ARCHITECTURE

### 1. Machine Learning (Random Forest)

In this project, a Machine Learning-based crop recommendation model is used to analyse agricultural and environmental conditions and identify suitable crops for cultivation. The model processes input parameters such as soil nutrient values, soil pH, temperature, rainfall, water availability, and seasonal conditions. These parameters are converted into a structured feature vector and provided to the trained machine learning model developed using Random Forest.

Before generating a recommendation, the system combines the available agricultural inputs with farm-specific information and weather-related conditions. The trained model learns the relationship between different environmental conditions and crop suitability from the agricultural dataset. Based on the input features, it predicts and ranks the crops that are most suitable for the given conditions.

The crop recommendation architecture is enhanced by combining:

- Machine Learning → predicts suitable crops from agricultural features.
- Farm Location Intelligence → provides geographical context for the actual farmland.
- Weather Intelligence → incorporates temperature and rainfall information.

This integrated approach enables HarvestIQ to provide more personalised recommendations instead of

relying only on manually entered values. The output can further support yield estimation and profit estimation, helping farmers evaluate both crop suitability and potential economic return. The HarvestIQ report similarly describes this module as analysing farm location, soil properties, weather conditions, and seasonal factors to generate crop recommendations.

## 2. Convolutional Neural Network (CNN)

In addition to crop recommendation, the system uses a Convolutional Neural Network (CNN) to analyse plant leaf images and identify possible plant diseases. Before feeding the image into the model, the uploaded leaf image is resized to the required input dimensions, normalised, and converted into a numerical representation so that it can be processed consistently.

The CNN consists of multiple convolutional layers that automatically learn important visual characteristics from the leaf image. These features include colour variations, textures, spots, lesions, and other disease-related patterns. Activation functions such as ReLU allow the model to learn complex relationships, while pooling operations reduce the size of the feature maps and retain important visual information.

After feature extraction, the learned features are passed through the classification layers, which generate probability scores for the supported disease classes. The disease class with the highest confidence score is selected as the final prediction.

Unlike a basic image classification system, HarvestIQ also connects the predicted disease with an advisory component that provides relevant treatment or management guidance. The disease prediction process therefore provides both:

- CNN → identifies disease-related visual patterns from the leaf image.
- Advisory Mapping → converts the prediction into practical treatment guidance.

This architecture enables farmers to receive a disease prediction together with actionable agricultural support. The project report also identifies the CNN module as an image-classification component whose performance is supported by image preprocessing and normalisation.

## 3. Intent Detection and Large Language Model (LLM)

To provide interactive and accessible agricultural guidance, HarvestIQ incorporates a Bilingual AI Chatbot that supports both Tamil and English. The chatbot accepts user queries and processes them using Natural Language Processing techniques and intent-based routing. Before generating a response, the system analyses the user's query to identify the required agricultural service.

The chatbot can understand queries related to crop recommendation, plant diseases, weather conditions, farm location, marketplace services, and general farming guidance. Once the intent is identified, the request is directed to the appropriate module or AI service.

The chatbot architecture combines:

- Intent Detection → identifies the purpose of the user's query.
- Domain Routing → connects specific queries with the relevant HarvestIQ module.
- Cloud-based LLM → handles complex and open-ended agricultural questions.
- Local AI using Ollama → supports selected low-connectivity or offline scenarios.
- Text-to-Speech → converts the generated response into voice output.

This hybrid architecture combines structured agricultural service routing with generative AI capabilities. Instead of providing only fixed responses, the chatbot can deliver context-aware assistance based on the user's selected language and agricultural requirements.

## 4. Multi-Factor Matching Algorithm

HarvestIQ also incorporates an intelligent Buyer–Seller Marketplace Architecture to support transparent agricultural trading. The system processes information provided by both farmers and buyers and identifies suitable trading matches based on multiple economic and geographical factors.

The farmer provides details such as crop type, available quantity, crop quality, farm location, and expected selling price. Similarly, the buyer provides the required crop, quantity, preferred quality, budget, and location. These inputs are initially analysed to identify eligible matches based on crop compatibility and quantity requirements.

The marketplace architecture then combines multiple data sources and calculations:

- Government Mandi Price Data → provides a market reference for crop pricing.
- Location and Road Distance Analysis → determines the geographical distance between the farmer and buyer.
- Transportation Cost Estimation → calculates the expected logistics cost.
- Multi-Factor Matching → evaluates quality, quantity, market price, budget, distance, and seller expectations.

The eligible buyers or sellers are ranked according to the calculated matching criteria. The system then generates a recommended trading partner and a balanced fair-price estimate.

This approach enables the marketplace to combine market intelligence, geographical analysis, and multi-factor decision-making rather than simply connecting buyers and sellers based only on crop availability. The project report also defines the marketplace recommendation process around Government Mandi price, transportation cost, road distance, crop quality, and buyer budget.

## 5. Fair Price Estimation Algorithm

The above components are integrated into a unified HarvestIQ decision-support architecture. Each module processes a different type of agricultural input, while the backend coordinates communication between AI models, external services, and application data.

The complete system integrates:

- Crop Recommendation Model → supports crop selection.
- Farm Location Intelligence → provides farm-specific geographical context.
- CNN Disease Prediction Model → analyses plant leaf images.
- Bilingual AI Chatbot → provides Tamil and English agricultural guidance.
- Buyer–Seller Matching Engine → supports intelligent agricultural trading.

These components work together to provide a continuous decision-support process, from crop planning and farm analysis to plant disease management, agricultural guidance, and crop marketing. The modular design also allows the individual services to be updated independently without affecting the overall platform.

## A. System Architecture Overview

### 1. User Interface (Frontend)

The frontend of the HarvestIQ system provides a simple and interactive interface for farmers, buyers, and sellers to access the different smart farming services. Through this interface, farmers can enter soil and crop-related parameters, select their current location or actual farmland using an interactive map, upload plant leaf images, and interact with the AI chatbot using Tamil or English. The marketplace interface also allows farmers to create crop listings and enables buyers to provide their crop requirements, quantity,

quality, budget, and location details.

The interface is designed to present all major agricultural services through a unified platform, making the system easier to use without requiring technical knowledge. Users can access crop recommendations, disease predictions, weather-related information, chatbot assistance, and buyer–seller marketplace services from the same application.

## **2. Backend Server**

The backend of the system is developed using FastAPI and acts as the central communication layer between the frontend, AI models, external APIs, and database. When a user submits agricultural data, uploads a leaf image, sends a chatbot query, or accesses the marketplace, the backend receives the request and routes it to the appropriate processing module.

The backend also handles data validation, preprocessing, model inference, API communication, and response generation. Agricultural data is prepared for the crop recommendation model, while plant leaf images are resized and converted into the required format before CNN-based disease prediction. Similarly, chatbot queries and marketplace information are processed before being sent to their respective engines. The backend returns the processed results as structured responses, enabling efficient communication between all components of HarvestIQ.

## **3. Integrated AI and Machine Learning Engines**

The core component of HarvestIQ consists of four major intelligent engines: the Crop Recommendation Engine, Disease Detection Engine, AI Chatbot Engine, and Marketplace Engine. The Crop Recommendation Engine analyses soil parameters, farm location, weather conditions, and other agricultural information to predict suitable crops. It also supports yield and profit estimation to help farmers make informed cultivation decisions.

The Disease Detection Engine uses a Convolutional Neural Network (CNN) to analyse uploaded plant leaf images and identify possible diseases. The AI Chatbot Engine uses intent detection, Natural Language Processing, cloud-based LLM services, and local AI support to provide agricultural guidance in Tamil and English. The Marketplace Engine analyses buyer and seller information, crop quality, quantity, market prices, road distance, transportation cost, and budget to generate intelligent buyer–seller matches and fair-price recommendations. By integrating these specialised engines, HarvestIQ provides complete agricultural decision support through a single platform.

## **4. Knowledge, Data and External Integration**

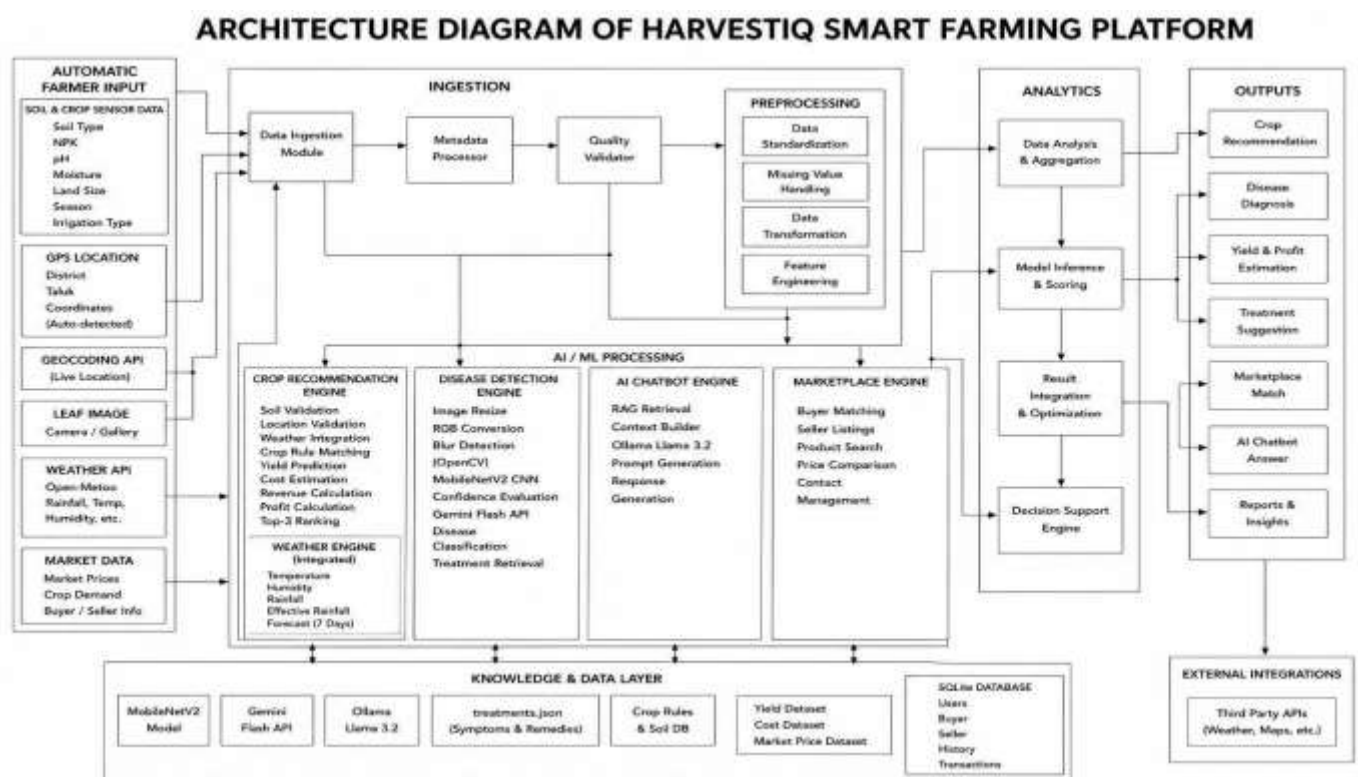
To support the intelligent processing modules, HarvestIQ uses a knowledge and data layer containing the Scikit-learn crop recommendation model, CNN disease detection model, crop and soil information, disease symptoms and treatment data, yield and cost datasets, and market-price information. Application data such as user details, farm information, crop listings, buyer requirements, chat history, and recommendation results are stored in the database.

The system also integrates external services to obtain dynamic information. Open-Meteo provides weather-related data, while map and geocoding services support current-location detection and farm location selection. Government Mandi market data is used for price comparison, and routing services support distance and transportation-cost estimation. Cloud-based AI services and Ollama are used to enhance chatbot responses. These integrations enable HarvestIQ to combine AI predictions with real-time weather, location, market, and agricultural information.

## **5. Result Visualisation**

After the processing is completed, the results are displayed through the HarvestIQ interface in a clear and understandable format. For crop recommendation, the system presents suitable crops based on the given agricultural, weather, and location-related conditions. The disease detection module displays the predicted plant disease along with confidence information and relevant treatment guidance.

The chatbot provides agricultural responses in the selected Tamil or English language, while the marketplace displays suitable buyer or seller matches, market-price information, transportation costs, and fair-price recommendations. Yield and profit estimation results can also be presented to support crop-planning decisions. This integrated result visualisation allows farmers to access different AI-driven insights through a single application and supports decision-making from crop selection and disease management to agricultural marketing.



**Figure 2 : Architecture**

## B. IMPLEMENTATION DETAILS

### A. Quantitative Performance

Table 1 summarises the implementation components and technologies used in HarvestIQ. Unlike a single-model classification system, HarvestIQ integrates multiple Artificial Intelligence, Machine Learning, Deep Learning, and API-based modules. Therefore, the system performance is evaluated using module-specific measures rather than a single overall accuracy value.

The crop recommendation component uses machine learning to analyse soil and environmental parameters for identifying suitable crops. The plant disease detection module uses a Convolutional Neural Network (CNN) for plant leaf image classification. The chatbot combines Natural Language Processing, intent detection, and Large Language Models to provide agricultural assistance, while the marketplace uses multi-factor matching and price estimation for buyer–seller recommendations [1], [2], [3].

**B. Qualitative Analysis**

The qualitative performance of HarvestIQ is evaluated based on the practical relevance and usefulness of the generated outputs. The crop recommendation module produces suitable crop suggestions by analysing agricultural parameters along with farm location and weather-related conditions. Location-based agricultural systems and machine learning techniques can improve the relevance of recommendations by incorporating geographical and environmental context [4], [5].

For plant disease detection, the CNN analyses uploaded leaf images and identifies disease-related visual patterns. Deep learning-based image classification has demonstrated its ability to automatically learn discriminative features from agricultural images without requiring manual feature extraction [6], [7]. The system returns the predicted disease together with relevant treatment guidance.

The bilingual AI chatbot provides agricultural guidance through Tamil and English interactions. NLP and LLM-based conversational systems enable users to ask agricultural questions using natural language and receive context-aware responses [8], [9]. The buyer–seller marketplace combines crop availability, quality, quantity, market prices, distance, and transportation cost to generate economically relevant recommendations.

**C. System Performance and Comparison**

HarvestIQ differs from conventional agricultural applications by integrating multiple intelligent services into a unified decision-support platform. Existing approaches often address crop recommendation, plant disease detection, agricultural advisory, or agricultural marketing as separate systems [1], [4], [6]. In contrast, HarvestIQ integrates Farm Location Intelligence, machine learning-based crop recommendation, CNN-based disease detection, bilingual AI assistance, and buyer–seller marketplace services.

The modular backend architecture allows the individual services to communicate through API-based interfaces. FastAPI supports efficient backend service development and structured communication between application modules, while REST-based APIs enable independent integration of AI models and external services [10]. External weather, location, routing, and market data are combined with model predictions to generate more context-aware recommendations.

This integrated approach provides an end-to-end agricultural support workflow, beginning with farm analysis and crop selection and extending to disease management, AI-based guidance, yield and profit estimation, and agricultural marketing.

**D. Limitations and Future Directions**

Several limitations of the current implementation should be acknowledged. The quality of crop recommendations depends on the availability and accuracy of agricultural and environmental input data. Similarly, the performance of the CNN-based disease detection module depends on the diversity of the training dataset and the quality of uploaded plant images [6], [7].

The system also depends on external services for weather information, geographical processing, market prices, and routing. Internet connectivity or temporary API failures may therefore affect the availability of certain real-time services. The marketplace recommendations also depend on the availability of sufficient buyer and seller data.

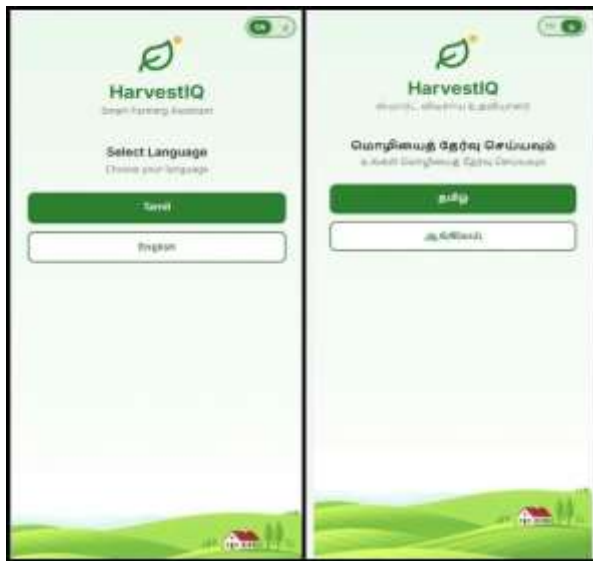
Future work can incorporate larger and more geographically diverse agricultural datasets, advanced ensemble learning algorithms for crop recommendation, and improved deep learning architectures for disease prediction. Future versions can also include crop-price forecasting, demand–supply analysis,

additional regional languages, improved offline AI support, and continuous learning from user interactions [4], [6], [8].

**Table 2 : Implementation Details and System Configuration**

| Component                       | Technology Used          |
|---------------------------------|--------------------------|
| Programming Language            | Python 3.11              |
| Frontend                        | Next.js 14               |
| Backend API                     | FastAPI + Python         |
| Secondary Backend / API Gateway | Express.js               |
| Machine Learning                | Scikit-Learn             |
| Crop Recommendation             | Random Forest Model      |
| Disease Detection Model         | CNN                      |
| Deep Learning Framework         | TensorFlow / Keras       |
| AI Chatbot                      | OpenRouter API / LLM     |
| Local AI Support                | Ollama                   |
| Database                        | PostgreSQL 16            |
| Vector Search                   | pgvector                 |
| Cache                           | Redis 7                  |
| Map Technology                  | Leaflet + OpenStreetMap  |
| Geocoding                       | Nominatim API            |
| Weather Integration             | Open-Meteo API           |
| Market Price Data               | AGMARKNET / Data.gov.in  |
| Distance & Routing              | OpenRouteService API     |
| Voice Processing                | Browser / Web Speech API |
| Multilingual Support            | English and Tamil        |
| Data Communication              | REST API / JSON          |
| Authentication                  | JWT + Google OAuth       |

Overall, the implementation demonstrates that HarvestIQ can integrate multiple AI-driven agricultural services within a single software platform. The system provides crop recommendations, disease predictions, weather-aware guidance, multilingual AI assistance, yield and profit estimation, and transparent buyer–seller matching. By combining these functions through a unified backend architecture, HarvestIQ aims to support farmers in making more informed, location-aware, and economically beneficial decisions.



**Figure 3 : Home Page**



**Figure 4 : Dashboard Page**

## C. DISCUSSION

The results of this study demonstrate that Artificial Intelligence and Machine Learning can be effectively integrated to provide comprehensive agricultural decision support through the HarvestIQ platform. The effectiveness of the system depends on the availability of reliable agricultural data, including soil parameters, weather conditions, farm location information, plant leaf images, and market data. The crop recommendation module analyses these agricultural and environmental factors to identify suitable crops, while the integration of Farm Location Intelligence and weather information improves the contextual relevance of the recommendations. The CNN-based disease detection module plays an important role in analysing plant leaf images and identifying disease-related visual patterns. Proper preprocessing, including image resizing and normalisation, helps ensure that the input images are suitable for reliable prediction. The bilingual AI chatbot further improves accessibility by allowing farmers to obtain agricultural guidance through Tamil and English text or voice interactions. The marketplace component extends the system beyond crop management by considering crop quantity, quality, market price, road distance, transportation cost, buyer budget, and seller expectations to generate suitable matches and fair-price recommendations. Despite providing an integrated approach, the system has certain limitations. The performance of crop recommendation and disease detection depends on the quality and diversity of the available datasets and user inputs. Inaccurate agricultural parameters or poor-quality leaf images may affect the reliability of the generated results. In addition, some features depend on external services for real-time weather, location, market-price, and routing information, which may be affected by internet connectivity or API availability. The marketplace recommendations also become more effective as the number of active buyers, sellers, and crop listings increases. These limitations can be addressed in future work by using larger and more diverse datasets, improving the AI models, incorporating crop-price forecasting and demand analysis, and expanding multilingual and offline support. Overall, the integration of AI-based crop recommendation, Farm Location Intelligence, CNN-based disease prediction, a bilingual chatbot, and an intelligent marketplace shows promising potential for supporting farmers from crop planning and management to agricultural marketing through a unified smart farming platform.

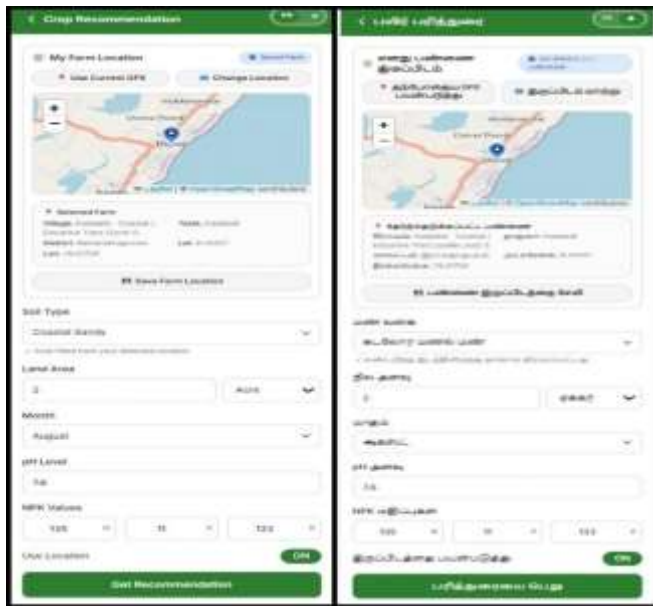


Figure 5 : Farm location intelligence

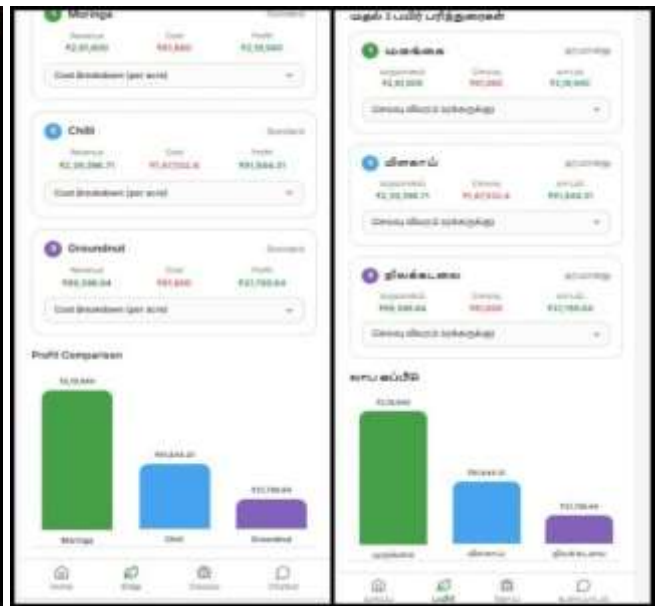


Figure 6 : Crop Recommendation

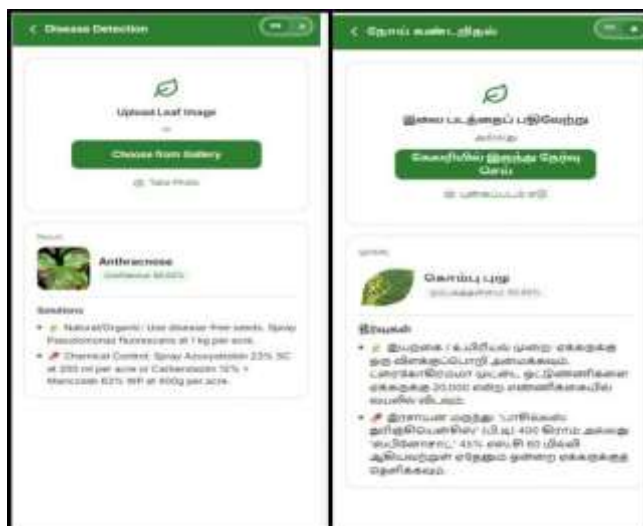


Figure 7 : Disease Prediction

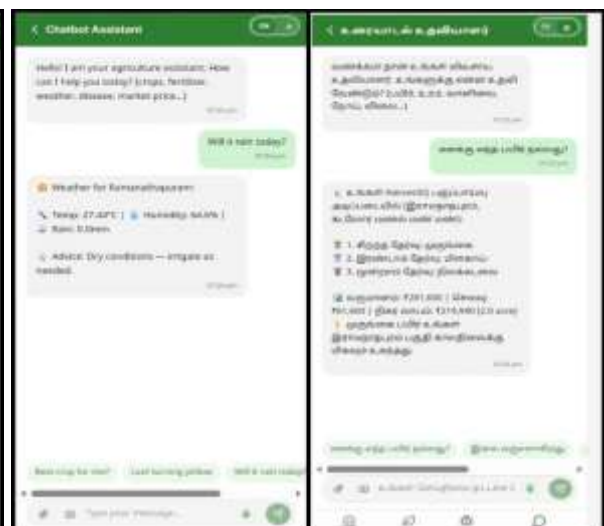


Figure 8 : Chatbot Assistant

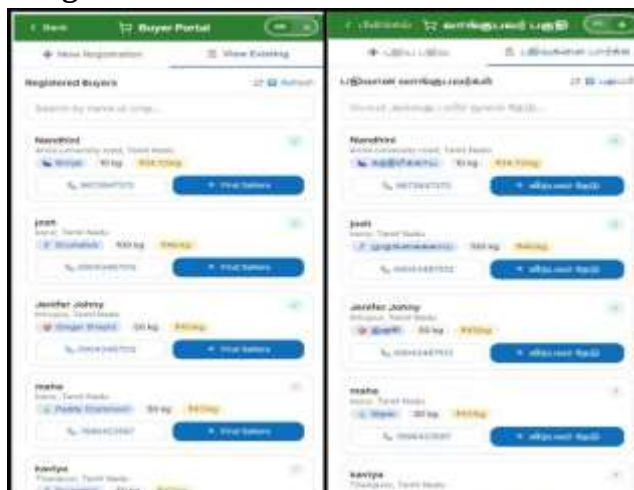


Figure 9 : Buyer Portal

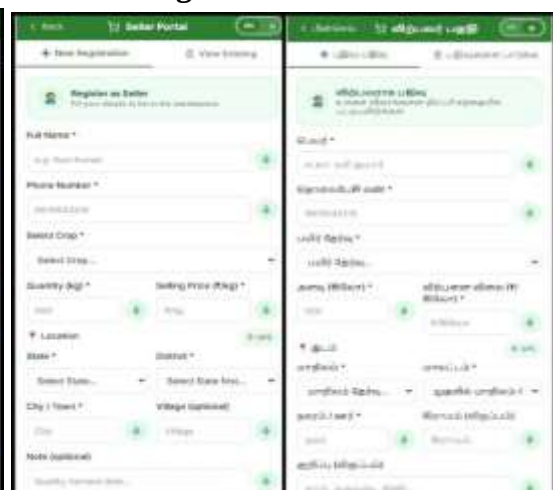


Figure 10 : Seller Portal

## V. CONCLUSION

This paper has described the design and implementation of HarvestIQ, an AI-driven smart farming platform developed to support farmers throughout different stages of agricultural decision-making. The core contribution of the proposed system is the integration of Farm Location Intelligence, AI-based crop recommendation, CNN-based plant disease detection, a bilingual AI chatbot with voice assistance, and an intelligent buyer–seller marketplace within a unified platform. The Farm Location Intelligence module enables farmers to select their actual farmland and obtain location-specific information, while the crop recommendation system analyses soil properties, weather conditions, seasonal factors, and other agricultural inputs to suggest suitable crops. The system further estimates crop yield and uses Government Mandi prices, transportation cost, and production cost information to provide revenue and profit-related insights. The final crop recommendations are ranked according to agricultural suitability, expected yield, market conditions, profitability, and weather compatibility, allowing farmers to make more informed cultivation decisions.

The integration of multiple AI and data-driven services addresses an important challenge in modern agriculture: farmers often require separate systems for crop planning, disease management, agricultural guidance, and market access. HarvestIQ combines these services into a single platform. The CNN-based disease detection module enables farmers to upload plant leaf images and receive disease predictions with treatment recommendations, while the bilingual AI chatbot improves accessibility by providing agricultural guidance in both Tamil and English through text and voice interaction. The buyer–seller marketplace further supports farmers by considering crop quantity, quality, Government Mandi prices, road distance, transportation cost, buyer demand, and seller expectations to recommend suitable trading partners and fair prices. The FastAPI-based backend integrates the AI models and external services through a modular architecture, enabling structured communication and future scalability. Overall, HarvestIQ provides a comprehensive digital decision-support platform that helps farmers from farm analysis and crop selection to disease management, profit estimation, agricultural guidance, and market access.

### 1. Crop Recommendation Model

$$C = f(X)$$

where:

- $C$  = Predicted suitable crop
- $X$  = Agricultural input features such as soil, weather, and location data
- $f$  = Machine Learning prediction model

### 2. Convolution Operation (CNN Core)

$$S(i, j) = (I * K)(i, j)$$

where:

- $I$  = Input plant leaf image
- $K$  = Convolution kernel
- $S(i, j)$  = Extracted feature map

### 3. ReLU Activation Function

$$f(x) = \max(0, x)$$

### 4. Softmax Function (Disease Classification)

$$\sigma(z_i) = \frac{e^{z_i}}{\sum_{j=1}^K e^{z_j}}$$

## 5. Profit Calculation Model

Revenue = Yield  $\times$  Government Market Price

Estimated Profit = Revenue – Transportation Cost – Production Cost

## 6. Buyer–Seller Matching Model

Match Score =  $f(Q, L, P, T, B)$

where:

- $Q$ = Crop quantity and quality compatibility
- $L$ = Location compatibility
- $P$ = Market price compatibility
- $T$ = Transportation cost
- $B$ = Buyer budget and seller expectations

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