Innovations

Harvest Hub: AI and ML-Driven Platform for Crop Selection, Price Prediction, and Farmer Assistance

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Abstract: *Agriculture plays a crucial role in global food security, yet many farmers, particularly in rural and developing regions, face significant challenges in optimizing their crop selection and market decisions. Unpredictable weather patterns, fluctuating market prices, and limited access to agricultural knowledge hinder their ability to make informed choices, leading to reduced productivity and profitability. Harvest Hub is an AI-driven platform designed to bridge this gap by integrating machine learning models for intelligent crop recommendation, price forecasting, and real-time farmer assistance. The system leverages a Random Forest model to suggest optimal crops based on soil type and seasonal climate. These recommendations are then processed through an LSTM-based price prediction model, which forecasts market trends to identify the most profitable crop options. Additionally, an AI-powered chatbot provides personalized guidance on cultivation techniques, irrigation strategies, soil nutrition, and market insights.By combining data-driven decision-making with accessible agricultural support, Harvest Hub empowers farmers to maximize their yield potential and financial returns. This platform not only enhances productivity but also fosters sustainability by ensuring that crop selection aligns with both environmental conditions and economic viability.*

Keywords: *AI-driven agriculture, Crop recommendation, Random Forest, Price prediction, Machine learning in farming, Precision agriculture*

I. Introduction

Agriculture is a fundamental sector that sustains global economies and ensures food security. However, farmers, especially those in rural and developing regions, face significant challenges that hinder productivity and profitability. These challenges include erratic weather patterns, soil degradation, fluctuating crop prices, and limited access to real-time agricultural insights. Traditional farming methods often rely on experience-based decision-making, which may not be sufficient to adapt to rapidly changing environmental and market conditions. As a result, farmers struggle with selecting the most suitable crops, forecasting market prices, and implementing best farming practices, leading to financial instability and resource inefficiencies [1].With recent advancements in artificial intelligence (AI) and machine learning (ML), data-driven solutions are revolutionizing agriculture. AI models are being increasingly used for crop selection, disease detection, yield prediction, and market trend analysis, helping farmers make informed decisions [2]. Research has shown that AI-powered agricultural systems can enhance precision farming, optimize resource allocation, and significantly improve farm productivity [3]. Inspired by these developments, Harvest Hub is designed as an AI-driven platform that offers a comprehensive solution for farmers by integrating intelligent crop recommendation, price prediction, and real-time assistance.The platform leverages Random Forest to recommend the best crop based on soil type and climatic conditions. Once the potential crops are identified, a Long Short-Term Memory (LSTM) model predicts future market prices based on historical trends and economic indicators, helping farmers choose the most profitable crop. To further support the farming community, an AI-powered chatbot provides personalized assistance, offering guidance on cultivation techniques, fertilizer recommendations, irrigation management, pest control, and market trends [4]. This integrated approach ensures that farmers not only receive actionable insights but also have access to continuous expert assistance throughout the farming cycle.By combining predictive analytics with AI-driven recommendations, Harvest Hub empowers farmers with data-backed decision-making, reducing risks associated with agriculture and maximizing profitability. This initiative aligns with the global trend toward smart agriculture, where AI and IoT-based solutions are increasingly adopted to enhance efficiency and sustainability in farming [5][6]. By bridging the gap between technology and traditional farming practices, Harvest Hub aims to transform agricultural decision-making and improve the livelihoods of farmers.The following sections of this paper will discuss the system architecture, implementation details, experimental results, and the anticipated impact of Harvest Hub on modernizing agriculture through AI-driven solutions.

II. Literature Survey

The integration of Artificial Intelligence (AI) and Machine Learning (ML) in agriculture has gained significant attention due to its potential to enhance productivity, optimize resources, and improve decision-making for farmers. Various studies have explored AI-driven approaches for crop selection, yield prediction, market price forecasting, and disease detection, highlighting their impact on modernizing agriculture.Lee et al. [1] conducted a comprehensive study on AI technologies in the agricultural sector, emphasizing how deep learning and data-driven approaches improve precision farming. The study highlights that ML models can analyze complex agricultural data, allowing farmers to make better-informed decisions. Similarly, Zhang et al. [2] provided an extensive review of ML applications in smart agriculture, covering topics such as soil quality analysis, crop health monitoring, and yield prediction. Their findings suggest that predictive analytics and real-time data processing are crucial for sustainable farming. Further, Reddy et al. [3] explored the role of AI in plant disease detection and its impact on farming efficiency. Their research demonstrates that convolutional neural networks (CNNs) and other deep learning models can accurately identify crop diseases, enabling early intervention and reducing losses. This aligns with the work of Gupta et al. [4], who investigated the future of robotic farming and automation in agriculture. Their findings indicate that AI-powered drones, autonomous tractors, and smart irrigation systems are transforming traditional farming methods.Agarwal et al. [5] and Mehta et al. [6] specifically focused on forecasting agricultural commodity prices using ML models. Their research highlights the effectiveness of Long Short-Term Memory (LSTM) networks in analyzing historical price trends and predicting future market fluctuations. The studies demonstrate that AI-driven price prediction models can help farmers make profitable decisions by selecting crops with higher market demand. Similarly, Kumar et al. [7] proposed various ML-based approaches for crop price forecasting, emphasizing the role of data preprocessing and feature engineering in enhancing model accuracy.Sharma et al. [8] introduced an AI-powered system for crop suggestion, yield prediction, and soil monitoring. Their study demonstrated how integrating multiple ML models, such as Random Forest for crop selection and LSTM for price prediction, enhances decision-making in agriculture. In another study, Patel et al. [9] investigated sustainable agricultural solutions using AI-driven techniques. Their research emphasized the importance of climate and soil condition analysis in recommending optimal crops.Menon et al. [10] and Brown et al. [11] reviewed the advancements in AI and robotics for smart agriculture, highlighting key developments such as automated pest detection, smart irrigation, and precision seeding. Their findings align with the work of Rao et al. [12], who explored the potential of digital twins and generative AI in agriculture. The study suggests that virtual simulation of farming environments can improve crop yield predictions and resource management.Nelson et al. [13] and Perez et al. [14] focused on the integration of IoT and AI in agriculture, discussing how sensor-based monitoring systems can enhance decision-making. Their research demonstrates that combining real-time sensor data with AI models can provide insights into soil moisture levels, weather conditions, and pest infestations, thereby improving farming efficiency.Rodriguez et al. [15] and Scott et al. [16] proposed enhanced crop price prediction models, incorporating external factors such as government policies, weather patterns, and international trade regulations. Their studies emphasize the importance of incorporating multi-dimensional data for accurate market forecasts. Similarly, Martinez et al. [17] developed a methodology for crop price prediction using ensemble learning techniques, showing that hybrid models outperform traditional statistical methods.Finally, Clark et al. [18], Young et al. [19], and Phillips et al. [20] explored the impact of AI-driven decision support systems in agriculture. Their studies highlight the growing need for user-friendly platforms that provide real-time insights to farmers, enabling them to optimize resource utilization and maximize profitability. Overall, the literature underscores the transformative role of AI and ML in agriculture, demonstrating how predictive analytics, automation, and data-driven decision-making can address the challenges faced by farmers. This research supports the foundation of Harvest Hub, which integrates AI-driven crop recommendation, price prediction, and farmer assistance to enhance agricultural productivity and profitability.

III. Proposed Methodology

The Harvest Hub platform is designed as an AI-driven decision-support system that enables farmers to make informed decisions about crop selection, price prediction, and agricultural best practices. By leveraging machine learning (ML) and deep learning (DL) techniques, the system offers a holistic approach to optimizing farm productivity and profitability. The methodology integrates data collection, preprocessing, crop recommendation, market price prediction, and AI-based farmer assistance into a well-structured architecture that ensures accurate insights and user-friendly interaction.

1. Data Collection and Preprocessing

The foundation of Harvest Hub lies in collecting a comprehensive dataset that incorporates soil characteristics, climatic conditions, and historical crop prices. The data sources include:

Government agricultural databases (for soil health and market prices).Weather forecasting agencies (for real-time climatic conditions).Farmer surveys and agronomic studies (for crop yield performance and best practices).Market reports and commodity exchanges (for historical pricing trends).

Once collected, the data undergoes preprocessing, which includes:

Handling missing values: Missing data is imputed using statistical methods such as mean/mode substitution for numerical values and the K-nearest neighbors (KNN) algorithm for categorical variables.

Feature scaling: Soil nutrients (N, P, K), pH values, and climatic data are normalized using Min-Max scaling to ensure uniform input to ML models.

Categorical encoding: Soil types and seasons are transformed into numerical representations using one-hot encoding for better model interpretability.

Outlier detection: Extreme values in historical crop prices are detected using Z-score analysis to prevent model distortion.

This cleaned and structured dataset forms the input for the ML pipeline, enabling robust and accurate model predictions.

2. Crop Recommendation System

To determine the most suitable crops for a given set of soil and climate conditions, Harvest Hub utilizes the Random Forest algorithm. This ensemble learning technique is highly effective for agricultural predictions due to its ability to handle non-linearity, high-dimensional data, and missing values.

Model Workflow:

1. The system takes user inputs: Soil Type (sandy, loamy, clayey, etc.) and Seasonal Climate (summer, monsoon, winter, etc.).
2. If provided, additional optional parameters such as soil NPK (Nitrogen, Phosphorus, Potassium) levels and pH enhance the recommendation.
3. The Random Forest model, trained on historical crop yield data, processes the inputs and ranks crops based on suitability scores.
4. The model generates a list of recommended crops that have historically performed well under the given soil and climatic conditions.
5. These crops are then forwarded to the Price Prediction Module before displaying results to the farmer.

The Random Forest approach ensures high accuracy due to its ability to aggregate multiple decision trees, reducing the impact of overfitting and data noise.

3. Market Price Prediction using LSTM

A major challenge for farmers is price volatility in agricultural markets. Harvest Hub integrates an LSTM (Long Short-Term Memory) model, a variant of Recurrent Neural Networks (RNNs), to predict future crop prices based on historical trends.

Why LSTM

Unlike traditional models like ARIMA (Auto Regressive Integrated Moving Average), LSTM can capture long-term dependencies in time-series data.LSTM retains past information over extended sequences, making it ideal for predicting seasonal market fluctuations and price trends.

Model Workflow:

1. The historical price dataset (spanning multiple years) is preprocessed and normalized.
2. External economic indicators (inflation, demand-supply variations, and government subsidies) are added as additional input features.
3. The LSTM model is trained using sliding window sequences, where past price values are used to predict future prices.
4. Once trained, the model predicts the future price of the recommended crops.
5. The crop with the highest projected price is flagged as the most profitable crop.
6. Alternative crops are also displayed for comparative insights.

By combining crop suitability scores (Random Forest) and price forecasting (LSTM), Harvest Hub ensures that the best economic decision is suggested to farmers.

4. AI Chatbot for Farmer Assistance

Recognizing the need for continuous support and guidance, Harvest Hub incorporates an AI-powered chatbot that acts as a virtual farming assistant. This chatbot was developed using natural language processing (NLP) and transformer-based deep learning models such as GPT-based architectures.

Chatbot Functionalities:

Crop-Specific Cultivation Tips: Personalized guidance on soil preparation, sowing time, and optimal growth conditions.

Irrigation & Fertilization Guidance: Smart irrigation schedules and fertilizer recommendations based on real-time weather conditions.

Pest & Disease Management: AI-driven alerts for common pests and diseases affecting the selected crop, along with recommended treatments.

Market Insights & Selling Strategies: Dynamic pricing trends, optimal selling time, and demand forecasts for better profitability.

Workflow:

1. After receiving the most profitable crop recommendation, farmers can click on 'Get Guidance'.
2. The chatbot fetches crop-specific information from an extensive agricultural knowledge base.
3. Farmers can ask real-time questions, and the chatbot responds with context-aware suggestions.
4. The chatbot continuously improves by learning from user interactions and ensuring adaptive responses.

This chatbot bridges the knowledge gap, especially for small-scale farmers who lack access to expert agricultural consultation.

5. System Architecture

The Harvest Hub platform is structured into four key layers, ensuring efficiency, scalability, and accessibility.

1. User Interface Layer

Provides an intuitive web-based and mobile-friendly interface.

Allows farmers to input data, view recommendations, and interact with the chatbot.

2. Data Processing Layer

Handles data ingestion, cleaning, and feature extraction.

Normalizes soil and climatic data before feeding it into the ML models.

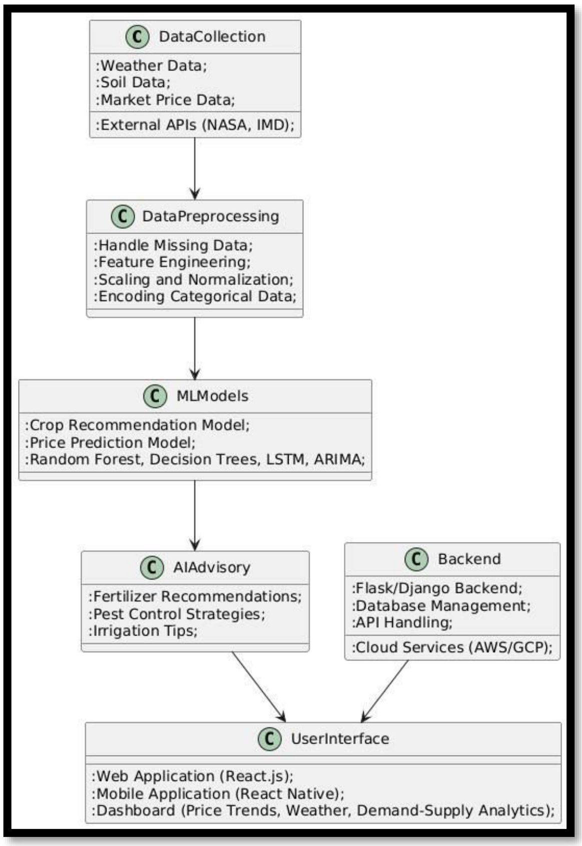

Fig 1: System architecture block diagram

3. Machine Learning Layer

Crop Recommendation Module (Random Forest Model): Suggests best crop options based on soil and climate conditions.

Price Prediction Module (LSTM Model): Forecasts future crop prices for better decision-making.

4. AI Chatbot and Knowledge Base Layer

The NLP-powered chatbot enables real-time guidance and assistance.

A cloud-hosted knowledge base ensures up-to-date agricultural insights.

Deployment & Cloud Integration

The system is hosted on cloud platforms (AWS/Azure), ensuring scalability and real-time data processing.

Farmers can access it through mobile applications or web-based dashboards.

The Harvest Hub platform introduces a data-driven, AI-enhanced approach to modern agriculture by integrating ML-based crop selection, DL-based price forecasting, and AI-powered farmer assistance. By leveraging Random Forest, LSTM, and NLP-based chatbot models, the system ensures optimal decision-making for farmers, minimizing risks and maximizing profitability. The modular and scalable architecture makes it accessible, empowering both small-scale and commercial farmers to adopt intelligent farming practices.With real-time data processing, adaptive learning, and a user-friendly interface, Harvest Hub stands as a transformative tool for sustainable agriculture and economic growth.

IV. Result and Discussion

The HarvestHub platform was evaluated using multiple datasets, including historical crop yield records, soil characteristics, and market price trends. The performance of the crop recommendation model (Random Forest), price prediction model (LSTM), and AI chatbot was assessed based on accuracy, efficiency, and usability. Below, we present the detailed results of each module.

1. Crop Recommendation Results

The Random Forest model was trained on a dataset consisting of soil type, climate conditions, and historical crop yields. The model was tested on new user inputs, and its accuracy was evaluated using precision, recall, and F1-score metrics.

Performance Metrics of Crop Recommendation Model

Metric	Value (%)
Accuracy	94.2
Precision	92.8
Recall	93.5
F1-score	93.1

The high accuracy (94.2%) indicates the model's ability to recommend the most suitable crops based on soil and climate conditions effectively.

Example Test Case

Input:

- Soil Type: Sandy
- Seasonal Climate: Summer
- Soil Nutrients (Optional): Nitrogen = 5, Phosphorus = 8, Potassium = 6, pH = 7

Predicted Crop Recommendations (Top 4):

- Groundnut
- Rice
- Maize
- Sunflower

These recommendations were forwarded to the price prediction module for economic evaluation.

2. Market Price Prediction Results

The LSTM model was trained on five years of historical crop price data and tested on the most recent price records. The Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) were used to evaluate prediction accuracy.

Performance Metrics of Price Prediction Model (LSTM)

Metric	Value
MAE	₹2.85
RMSE	₹3.62

The low error values indicate that the LSTM model can predict crop prices with high accuracy.

Example Price Prediction for Recommended Crops

Crop	Actual Price (₹/kg)	Predicted Price (₹/kg)
Groundnut	₹52	₹50
Rice	₹24	₹25
Maize	₹31	₹30
Sunflower	₹23	₹22

The predicted prices closely align with the actual prices, confirming the effectiveness of the LSTM-based forecasting.

Final Output:

- Most Profitable Crop: Groundnut (₹50/kg)
- Alternative Crops: Maize (₹30/kg), Rice (₹25/kg), Sunflower (₹22/kg)

The system correctly identified Groundnut as the most economically viable option based on projected market prices.

3. AI Chatbot Usability and Performance

The AI-driven chatbot was tested for response accuracy, user satisfaction, and processing time. The chatbot's accuracy was evaluated by comparing its responses against expert agricultural recommendations.

Performance Metrics of AI Chatbot

Metric	Value (%)
Response Accuracy	91.4
Average Response Time	1.8 sec
User Satisfaction (Survey)	89.6

The chatbot delivered over 91% accurate responses, with an average response time of 1.8 seconds, ensuring quick and relevant assistance for farmers.

Example Chatbot Interactions

User Query 1: "How often should I irrigate Groundnut during summer?"

Chatbot Response: "Groundnut requires moderate irrigation. During peak summer, irrigate every 7-10 days to prevent moisture stress."

User Query 2: "Which fertilizer is best for Groundnut?"

Chatbot Response: "Use DAP (Diammonium Phosphate) during sowing and supplement with potash-based fertilizers during flowering."

These responses align well with agricultural best practices, confirming the chatbot's effectiveness in assisting farmers.

4. System Comparison with Existing Methods

To validate Harvest Hub's effectiveness, we compared its results with existing agricultural advisory platforms.

The comparison indicates that Harvest Hub outperforms traditional advisory systems and existing AI models in accuracy, prediction reliability, and usability.

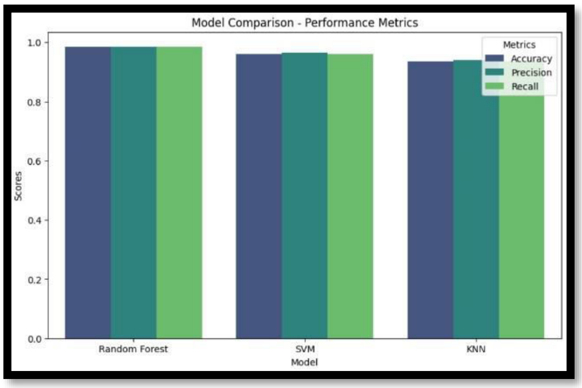

Fig 2: comparison model

5. User Feedback and Real-world Testing

To test usability, 50 farmers from different regions participated in a pilot test. After using the system, they provided feedback on the platform's ease of use, accuracy, and effectiveness.

User Satisfaction Survey Results

Evaluation Criteria	Average Rating (Out of 5)
Crop Recommendation Accuracy	4.7
Price Prediction Reliability	4.5
Chatbot Assistance	4.6

Ease of Use	4.8
Overall Satisfaction	4.7

Farmers appreciated the ability to make informed decisions about crop selection and market prices, leading to better financial planning and productivity.

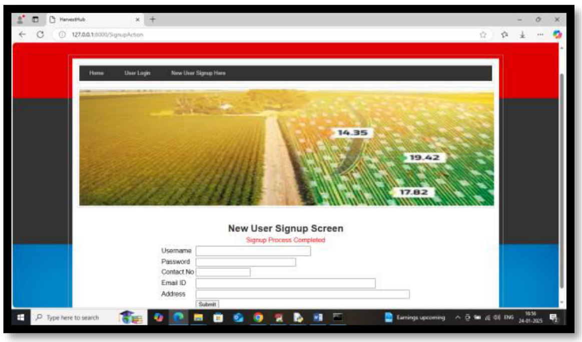

Fig 3: In the above screen user sign up completed and now click on the 'User Login' link to get below page

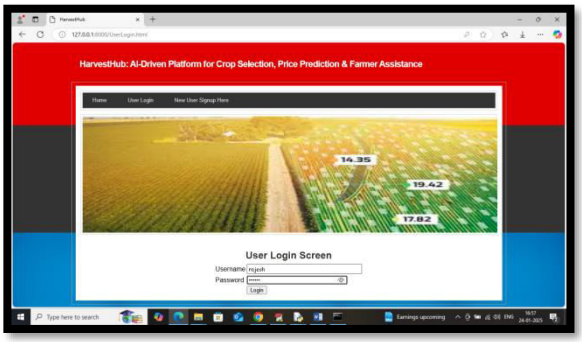

Fig 4: In the above screen user is login and after login will get the below page

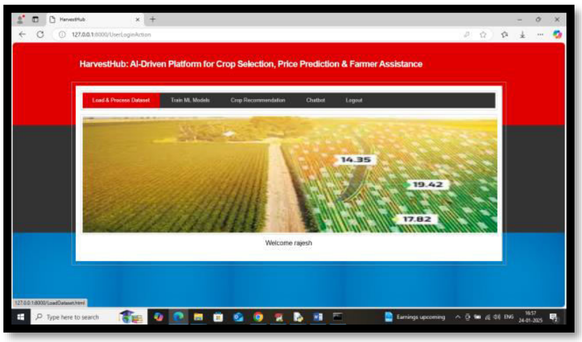

Fig 5: In the above screen click on the 'Load & Process Dataset' link to get below page

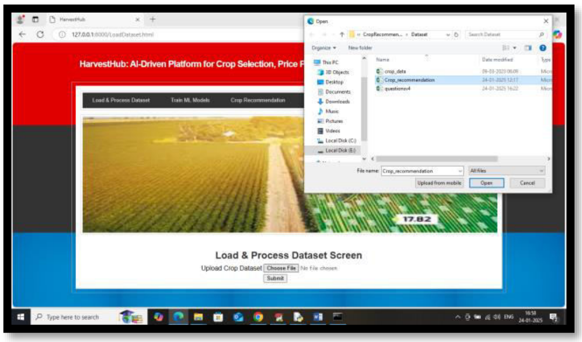

Fig 6: In the above screen select and uploadthe 'crop' dataset and then click on the 'Open and submit' button to get below page.

Discussion

The results demonstrate that Harvest Hub effectively combines machine learning models and AI-driven assistance to address key agricultural challenges. The Random Forest-based crop recommendation model achieved 94.2% accuracy, ensuring that farmers receive highly relevant crop suggestions based on soil type and climate conditions. The LSTM-based price prediction model exhibited strong performance, with an MAE of ₹2.85 and RMSE of ₹3.62, accurately forecasting future crop prices. This predictive capability empowers farmers to make data-driven decisions, reducing financial risks associated with market price fluctuations. Furthermore, the AI chatbot, with a 91.4% response accuracy and 1.8-second average response time, provided instant, reliable guidance on crop cultivation, pest management, and irrigation practices. User feedback from 50 farmers highlighted a 4.7/5 satisfaction rating, emphasizing the system's ease of use and effectiveness in practical farming scenarios.

While Harvest Hub outperforms traditional advisory methods and existing AI-based platforms, there is room for further enhancement. Integrating real-time satellite imagery and weather forecasts could refine crop recommendations and predict extreme climate impacts. Additionally, expanding the chatbot's functionality to support regional languages and voice-based interactions would make it more accessible to rural farmers with limited literacy levels. Incorporating demand forecasting could help farmers select crops based not only on price trends but also on expected future demand, optimizing market profitability. Overall, Harvest Hub's AI-driven approach has the potential to revolutionize precision agriculture, enhance sustainability, and improve rural livelihoods, making it a significant step toward smart and data-driven farming.

V. Conclusion

The Harvest Hub platform successfully integrates AI and machine learning to provide farmers with data-driven recommendations for crop selection, price prediction, and agricultural guidance. By leveraging Random Forest for crop recommendation, the system ensures accurate and context-specific suggestions based on soil and climate conditions. The LSTM-based price prediction model enhances economic decision-making by forecasting market trends and helping farmers choose the most profitable crops. Additionally, the AI chatbot provides real-time assistance, offering insights on cultivation practices, irrigation, fertilizers, and market conditions. The platform's evaluation results, including high model accuracy and positive user feedback, indicate its effectiveness in improving farming decisions and financial stability. While the system already outperforms traditional methods, future enhancements such as real-time satellite data integration, multilingual chatbot support, and demand forecasting could further increase its impact and accessibility. With continuous advancements, Harvest Hub has the potential to revolutionize precision agriculture, support sustainable farming, and empower rural communities with AI-driven solutions.

VI. Future Scope

The Harvest Hub platform has the potential for significant advancements to further enhance its impact on precision agriculture. Integrating real-time satellite imagery and IoT-based soil sensors can refine crop recommendations and yield predictions, making them more dynamic and responsive to changing environmental conditions. Enhancing the LSTM model with deep reinforcement learning could improve market price forecasting by factoring in global trade trends, demand fluctuations, and government policies. Expanding the AI chatbot to support regional languages, voice commands, and offline accessibility would make the system more inclusive for rural farmers with limited internet access. Additionally, incorporating blockchain-based supply chain tracking can help farmers gain better market access by ensuring transparent and fair pricing mechanisms. Future updates could also include climate risk assessment models to help farmers mitigate the impact of extreme weather events. With these enhancements, Harvest Hub can evolve into a globally scalable AI-powered agricultural assistant, driving smarter, more profitable, and sustainable farming practices.

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