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Ensembled Learning-Based Smart Farming System for Price Prediction and Resource Optimization

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ABSTRACT: India's agriculture faces challenges like fluctuating crop prices, unpredictable weather, and limited access to modern resources. This project introduces a crop price prediction system using ensemble machine learning methods, including Decision Tree, Random Forest, and K-Nearest Neighbours (KNN), to forecast minimum and maximum crop prices based on historical data. A secondary dataset containing crop-specific threshold values helps determine fertilizer recommendations. If the predicted minimum price falls below the threshold, the system suggests a suitable fertilizer; otherwise, it displays relevant government schemes. A chatbot powered by Mistral AI provides real-time assistance on crops, fertilizers, and schemes. Farmers can log in to access price predictions and recommendations, while admins manage government scheme updates. The system ensures role-based access for secure and efficient management. By integrating machine learning with agricultural insights, this project empowers farmers with data-driven decision-making tools. It enhances productivity, profitability, and access to critical resources. Ultimately, this solution aims to improve the financial stability of farmers in an unpredictable agricultural market.

KEYWORDS: Crop Price Prediction, Ensemble Machine Learning, Fertilizer Recommendation, Government Schemes, Mistral AI Chatbot.

I. INTRODUCTION

Agriculture is the backbone of India's economy, but farmers face challenges such as fluctuating crop prices, unpredictable weather, and limited access to modern resources. Accurate price forecasting is crucial for helping farmers make informed decisions about cultivation and sales. This project introduces a crop price prediction system using ensemble machine learning techniques, including Decision Tree, Random Forest, and K-Nearest Neighbours (KNN). By analyzing historical price data, the system predicts minimum and maximum crop prices to improve decision-making. A secondary dataset with crop-specific threshold values helps determine whether to recommend fertilizers or display government schemes. If the predicted price falls below the threshold, a suitable fertilizer is suggested; otherwise, relevant government schemes are shown. A chatbot powered by Mistral AI assists farmers by providing instant information on crops, fertilizers, and schemes. Farmers can access personalized insights through a login system, while admins manage scheme updates. The system ensures secure role-based access for effective management. By integrating machine learning with agricultural insights, this project empowers farmers with data-driven tools to enhance productivity and profitability.

II. LITERATURE SURVEY

[1] Data-driven analysis of climate impact on tomato and apple prices using machine learning - S.Yoon, T.H. Kim, D. Sub kim. This study examines the impact of climate change on tomato and apple prices using machine learning. It analyzes historical climate data, including temperature, rainfall, and humidity, alongside market price trends. Machine learning algorithms identify patterns linking extreme weather events to price fluctuations. The research highlights the

need to integrate climate models with market analysis for better price forecasting. Findings help farmers and policymakers mitigate risks and enhance agricultural market resilience.

[2] Agricultural product price forecasting methods: A review - F. Sun, X. Meng, Y. Zhang, Y. Wang, H. Jiang, P. Liu. The system categorizes agricultural price forecasting methods into traditional statistical approaches and modern machine learning techniques. Traditional methods like time series analysis are simple but struggle with complex data patterns. Machine learning models, including neural networks and ensemble learning, better capture intricate relationships. The study emphasizes integrating external factors like weather and market trends for improved accuracy. It also highlights data quality challenges and the need for robust preprocessing techniques.

[3] Understanding deep learning(still) requires rethinking generalization - C. Shang, S. Bengio, B. Recht, O.Viyals. The system explores the challenges of deep learning generalization to unseen data, questioning traditional statistical theories. Despite being overparameterized, deep neural networks often perform well without overfitting, suggesting implicit regularization plays a key role. Optimization methods like stochastic gradient descent may encourage solutions that generalize effectively. The study also highlights the impact of model architecture and training complexity on performance. The authors emphasize the need for further research to establish a stronger theoretical foundation for deep learning generalization.

[4] Source-sink relationships during grain filling in wheat in response to various temperature, water deficit, and nitrogen deficit regimes - L. Fang, P.C. Struik, C. Girousse, X.Yin, P. Martre. The study examines how environmental stress factors impact wheat growth, particularly during the grain-filling stage. It explores the source-sink relationship, where assimilates move from photosynthetic organs to developing grains, and how stressors like high temperature, water deficit, and nitrogen deficiency disrupt this process. The research finds that these stressors often interact, causing greater reductions in yield and grain quality than when acting alone. High temperatures accelerate senescence, water deficits hinder nutrient transport, and nitrogen deficiency affects protein synthesis. The study highlights the need for stress-resistant wheat varieties and integrated crop management to ensure stable yields under climate change conditions.

[5] Prediction of Crop Price Using Machine Learning Techniques: A case study on Paddy and Maize Price - S.S. Sahoo, S.K. Lenka and B.B. Mishra. The study explores crop price prediction using machine learning techniques, focusing on paddy and maize prices. It applies various algorithms to analyze historical price data and identify patterns influencing market fluctuations. The researchers highlight the effectiveness of machine learning in improving price forecasting accuracy compared to traditional statistical methods. The study emphasizes the importance of external factors like weather and market trends in price prediction. Overall, the findings provide insights to help farmers and policymakers make informed decisions for better market planning.

III. METHODOLOGY

3.1 ADMIN/FARMER LOGIN

The Admin/Farmer Login Module ensures secure, role-based access, dividing users into Farmers and Admins. Farmers access crop price predictions, market trends, fertilizer recommendations, and government schemes, while Admins manage backend functionalities like updating schemes and chatbot content. Built on Django's authentication system, it uses hashed passwords, session management, and RBAC to enforce access control. Farmers register and log in to view personalized dashboards, whereas Admins access a separate portal with content management privileges. Security measures include session monitoring, input validation, and restricted admin access. The database efficiently stores user roles and login sessions. The module integrates with crop price prediction, fertilizer recommendation, and chatbot support, offering a personalized experience. Farmers interact with a chatbot for real-time assistance, and Admins ensure data accuracy. This module enhances usability, security, and scalability, providing a seamless and protected user experience.

3.2 DATA INPUT AND PRICE PREDICTION

The crop price prediction module helps farmers navigate market fluctuations by forecasting prices based on location, crop type, and market trends. Developed using Django, it incorporates Pandas, NumPy, and Scikit-learn for data processing and machine learning. The system employs Decision Tree, Random Forest, and KNN regressors, using ensemble learning to enhance accuracy. Data preprocessing includes label encoding, handling missing values, and train-test splitting. Predictions are evaluated using Mean Absolute Error (MAE) and R^2 Score to ensure reliability. If

the predicted minimum price falls below a threshold, fertilizer recommendations are provided; otherwise, government schemes are suggested. The system integrates chatbot support via the Mistral API, offering real-time assistance to farmers. Secure authentication, session management, and input validation enhance platform security. Dynamic thresholding ensures flexible recommendations based on real-time market trends. This module empowers farmers with data-driven insights to optimize profitability and decision-making.

3.2.1 ENSEMBLED PREDICTION

All three models (Decision Tree, Random Forest, KNN) and combine their predictions to get a final, more stable result.

$$\hat{y}_{ensemble} = \frac{\hat{y}_{DT} + \hat{y}_{RF} + \hat{y}_{KNN}}{3}$$

- $\hat{y}_{DT}$ = Prediction from Decision Tree
- $\hat{y}_{RF}$ = Prediction from Random Forest
- $\hat{y}_{KNN}$ = Prediction from KNN

3.2.2 EVALUATION METRICS

1. MAE calculates the average absolute difference between the actual prices and the predicted prices. It gives a straightforward understanding of how much, on average, the model's predictions deviate from the actual crop prices.

$$MAE = \frac{1}{n} \sum_{i=1}^n |y_i - \hat{y}_i|$$

- y_i = Actual crop price for the i^{th} data point
- $\hat{y}_i$ = Predicted crop price for the i^{th} data point
- n = Total number of data points

2. The R^2 Score tells how well the model explains the variability in the actual crop prices. It measures the proportion of the variance in the dependent variable (price) that is predictable from the independent variables (features like crop, state, market, etc.).

$$R^2 = 1 - \frac{SS_{res}}{SS_{tot}}$$

Where:

- $SS_{res} = \sum (y_i - \hat{y}_i)^2$ → Residual Sum of Squares (error between actual and predicted values)
- $SS_{tot} = \sum (y_i - \bar{y})^2$ → Total Sum of Squares (variance of actual values around the mean)

3.3 FERTILIZER RECOMMENDATION

The Fertilizer Recommendation Module enhances crop yield and profitability by providing targeted fertilizer suggestions based on real-time market conditions. It integrates with the crop price prediction system, using Decision Tree, Random Forest, and KNN models to compare predicted prices against predefined threshold values. If the predicted minimum price falls below the threshold, the system triggers crop-specific fertilizer recommendations. These thresholds are determined through historical market data, production costs, and profit margins. The recommendations ensure farmers apply the right fertilizers, preventing overuse or inefficiency. The threshold price is calculated as $ACP + (ACP \times \text{Desired Profit Margin } \%)$, where ACP includes seed, labor, irrigation, and input costs. This personalized approach optimizes soil health and yield while mitigating financial risks.

3.4 GOVERNMENT SCHEMES

The Government Schemes Module helps farmers access financial and technical support programs efficiently. It organizes schemes in a structured table, displaying names, descriptions, eligibility, and required documents. An admin panel allows authorized users to manage scheme data, ensuring accuracy and security. Farmers can view but not modify information. Integrated market analytics help farmers choose suitable schemes based on real-time trends.

Admins can monitor scheme effectiveness and update data as needed. The module promotes transparency, simplifies access to government aid, and empowers farmers with informed decision-making, bridging the gap between policies and agricultural development.

3.5 CHATBOT

The Chatbot Module provides farmers with instant, AI-driven support directly from the homepage. It answers queries on crop selection, pest control, market trends, and best farming practices, ensuring timely and informed decision-making. Integrated with Mistral AI, the chatbot understands natural language and delivers precise, contextually relevant responses. By offering real-time assistance, it reduces reliance on outdated sources and enhances farming efficiency. The chatbot helps farmers act promptly, improving productivity and minimizing risks. Its user-friendly interface ensures accessibility for all, regardless of digital literacy. Overall, it empowers farmers with expert-backed guidance, optimizing their agricultural decisions.

IV. SYSTEM ARCHITECTURE

A Software Architecture Diagram gives a top-down view of a system, showing its essential elements, relationships, and data flow. It features modules that process particular functionalities, interfaces that specify communication among components, and data flow paths that outline how information is processed. It can also reflect deployment information, indicating how components are spread over servers or cloud hosts. This diagram acts as a roadmap for developers and stakeholders, providing clarity, scalability, and streamlined system design while allowing collaboration and decision-making.

The Crop Price Prediction System architecture diagram is as shown in figure-1.

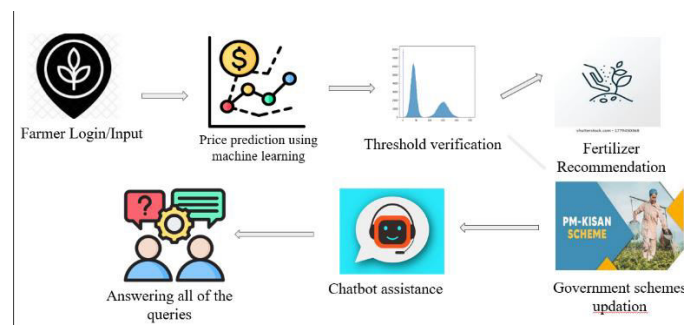


Figure -1: Architecture of the System

The system diagram illustrates the Crop Price Prediction and Recommendation System, designed to empower farmers with accurate price forecasts, fertilizer suggestions, and government scheme information. The process begins with Farmer Login/Input, where farmers enter crop details and location. The system then performs Price Prediction Using Machine Learning, utilizing ensemble algorithms like Decision Tree, Random Forest, and K-Nearest Neighbors (KNN) to analyze historical data and predict crop prices. Once predictions are generated, the Threshold Verification step compares the predicted minimum price against a predefined crop-specific threshold to assess market conditions. If the predicted price falls below this threshold, the Fertilizer Recommendation module is activated, suggesting suitable fertilizers to enhance yield. Additionally, the Government Schemes Updation module, managed by the admin, ensures that farmers have access to the latest financial support programs like PM-Kisan. To enhance usability, the system features Chatbot Assistance powered by Mistral AI, providing real-time responses to farmer queries related to crops, fertilizers, price predictions, and schemes. The chatbot also guides users to the relevant modules, ensuring seamless navigation. This integration of machine learning, dynamic thresholds, and real-time assistance enables farmers to make informed decisions. By combining price prediction, fertilizer recommendations, and government support, the system enhances agricultural profitability. The chatbot ensures that farmers receive accurate information efficiently, improving accessibility. Overall, the system offers a comprehensive solution for modernizing agricultural decision-making.

V. EXISTING SYSTEM

The existing agricultural price prediction system relies on Long Short-Term Memory (LSTM) models, which capture historical price patterns but fail to consider external factors like climate, policies, and trade dynamics. This limitation reduces prediction accuracy and effectiveness. The system focuses only on tomato and apple prices, making it less applicable to farmers growing other crops. Additionally, it lacks real-time market trend analysis, which is essential for farmers to make timely decisions. Without real-time data, farmers may miss profitable opportunities or fail to mitigate price drops. The absence of personalized recommendations further limits its usefulness, as farming decisions depend on factors like farm size, resources, and regional climate. A one-size-fits-all approach does not provide effective guidance on crop selection and management. The system's reliance on a single algorithm reduces adaptability to changing agricultural markets. Using multiple algorithms or hybrid models could improve accuracy and flexibility. The lack of interactive features prevents farmers from inputting real-time data and receiving customized feedback. An interactive system would enhance usability and provide tailored insights for better decision-making. To improve, the system should incorporate diverse crops, real-time data, and interactive tools. Expanding its capabilities would help farmers maximize profitability and manage risks effectively.

VI. PROPOSED SYSTEM

The proposed system is an advanced agricultural tool designed to assist farmers in making informed decisions about crop pricing and fertilizer recommendations. It integrates machine learning-based crop price prediction with a dynamic threshold mechanism to enhance agricultural planning and productivity. The core of the system is a machine learning model trained to predict crop prices per kilogram based on historical market trends and real-time data. This model considers multiple factors, including seasonal variations, demand-supply patterns, and geographical conditions. To improve decision-making, the system introduces a dynamic threshold for each crop to determine whether intervention is needed. If the predicted minimum price of a crop falls below its specific threshold, an automated recommendation process is triggered. The fertilizer recommendation module is seamlessly linked with the price prediction model. If a crop's predicted price is lower than its threshold, a 'Fertilizer' button appears, directing the user to a dedicated recommendation page. This module utilizes a dataset that maps specific crops to optimal fertilizers, ensuring data-driven recommendations tailored to farmers' needs. Additionally, the system accounts for soil health, weather conditions, and government agricultural schemes. By integrating these factors, it provides a holistic approach to improving farm productivity. The interactive nature of the system allows farmers to receive real-time guidance for better decision-making. This approach helps maximize profitability and efficiency in farming practices.

VII. RESULT

The dataset consists of various attributes such as 'State_Name', 'District_Name', 'Market', 'Commodity', 'Variety', 'Grade', 'Min_Price', 'Max_Price', 'Modal_Price', and 'Date', which are essential for crop price prediction. To integrate this dataset with the existing prediction module, preprocessing is necessary, including converting the 'Date' column into a datetime format and extracting relevant features, encoding categorical variables, handling missing values, and normalizing numerical data if required. The prediction model, utilizing Decision Tree, Random Forest, and KNN algorithms, needs to be trained on the processed data, ensuring a proper train-test split for reliable results. The trained model will predict crop prices based on historical trends while maintaining logical constraints to prevent inconsistencies in minimum and maximum price values. The system then compares the predicted minimum price with a predefined threshold specific to each crop, triggering either a 'Fertilizer' button if the price falls below the threshold or a 'Government Schemes' button otherwise. This approach ensures farmers receive appropriate recommendations based on market trends and their crop's expected profitability.

VIII. CROP PRICE PREDICTION

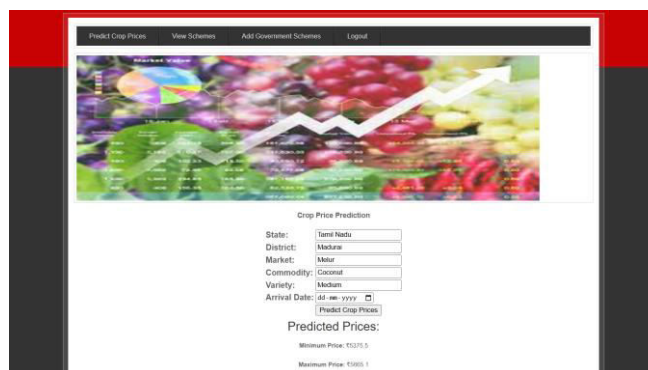


Figure 2.Crop Price Prediction

Farmers can access this module to predict crop prices by providing essential details such as State, District, Market, Commodity, Variety, and Arrival Date. The system employs an ensemble learning approach, integrating Decision Tree, Random Forest, and K-Nearest Neighbors (KNN) algorithms to ensure accurate price predictions. Based on historical data and market trends, the model forecasts the minimum and maximum prices for the selected crop, enabling farmers to make informed decisions. If the predicted minimum price falls below a predefined threshold, the system suggests a suitable fertilizer recommendation to enhance productivity. However, if the predicted price is above the threshold, farmers can explore available government schemes for financial support. This mechanism ensures that farmers receive timely insights into market fluctuations and necessary interventions for better yield and profitability. By providing data-driven recommendations, the system aids in efficient farm management and economic stability. The user-friendly interface simplifies the prediction process, making it accessible to all farmers. Through advanced machine learning techniques, the platform helps bridge the gap between market dynamics and agricultural planning.

IX. FUTURE ENHANCEMENT

Integrating IoT sensors for real-time soil health and weather monitoring can significantly enhance the accuracy of crop and fertilizer recommendations, ensuring that farmers receive precise guidance based on actual field conditions. Implementing blockchain technology can provide secure and transparent transactions, helping farmers get fair prices for their produce by reducing middlemen interference and preventing fraud. Expanding the AI-powered chatbot to support multiple regional languages will improve accessibility, allowing farmers from diverse linguistic backgrounds across India to receive expert agricultural advice in their preferred language. These advancements will further strengthen the system's impact, promoting efficiency, fairness, and inclusivity in the agricultural sector.

X. CONCLUSION

This AI-powered agricultural system provides farmers with accurate price forecasts, crop recommendations, and fertilizer suggestions, along with access to government schemes. These insights enable farmers to make well-informed decisions that enhance their productivity and profitability. By leveraging predictive analytics, the system optimizes resource usage, minimizing the wastage of water, fertilizers, and labor while improving overall efficiency. Real-time price predictions help farmers strategically plan their sales, reducing losses caused by market fluctuations and price instability. Additionally, the AI-powered chatbot offers instant expert guidance on farming practices, pest control, and market trends, making agricultural knowledge more accessible. By boosting farm profitability, reducing crop losses, and promoting sustainable practices, this system significantly contributes to India's agricultural and economic growth.

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