

Smart Agriculture Solutions Using AI

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Abstract—Selecting the appropriate crop is a critical decision for farmers that directly impacts yield and income. However, traditional methods often fail due to dynamic soil conditions, unpredictable weather, and fluctuating market prices. This paper proposes a web-based intelligent agricultural decision support system under the theme of Smart Agriculture Solutions Using AI. The system analyses key parameters including Nitrogen, Phosphorus, Potassium levels, temperature, humidity, pH, rainfall, moisture, soil type, and crop type to recommend the most suitable crop. It integrates a pre-trained Random Forest Classifier for accurate crop prediction, a Linear Regression model for forecasting the expected market price of the recommended crop after 30 days, and a GPT-2 transformer-based language model to generate simple, farmer-friendly natural language explanations. The user-friendly web interface developed using the Flask framework supports both English and Hindi languages for wider accessibility. Categorical inputs are handled through label encoding for seamless model compatibility. The proposed system also includes basic user authentication for secure access. By combining predictive analytics, economic forecasting, and explainable artificial intelligence, this solution aims to assist farmers in making data-driven decisions, reduce risk, enhance productivity, and improve economic returns in real-world farming scenarios.

Index Terms—Smart agriculture, Crop recommendation, Random Forest Classifier, Price prediction, Linear Regression, Explainable AI, Precision farming, Flask framework.

I. INTRODUCTION

Agriculture remains the backbone of India's economy, providing livelihood to more than half of the country's population. However, farmers continue to face serious challenges in selecting the most suitable crop due to varying soil conditions, unpredictable climatic factors, and highly fluctuating market prices. These uncertainties often result in poor yields and significant financial losses. Traditionally, farmers depend on their personal experience, local knowledge, and advice from agricultural extension officers for crop selection. Such conventional approaches are highly subjective and fail to consider the complex relationships between soil nutrients, weather parameters, and market trends.

In today's data-driven era, there is an urgent need for intelligent systems that can analyse multiple

agricultural parameters and deliver accurate, timely recommendations. Artificial Intelligence and Machine Learning have emerged as powerful tools for transforming traditional agriculture into precision farming. These technologies can process large volumes of data and identify hidden patterns that are difficult for humans to detect. Recent studies have successfully applied classification algorithms for crop recommendation and regression models for price forecasting. However, most existing systems focus on only one aspect and lack integration of crop prediction, economic forecasting, and easily understandable explanations for farmers.

This paper presents a web-based intelligent agricultural decision support system developed under Smart Agriculture Solutions Using AI. The system analyses key parameters such as Nitrogen (N), Phosphorus (P), Potassium (K), temperature, humidity, pH, rainfall, moisture, soil type, and crop type. It employs a Random Forest Classifier for reliable crop recommendation, a Linear Regression model for forecasting the expected market price after 30 days, and a GPT-2 transformer-based language model to generate simple, farmer-friendly natural language explanations. The system is built using the Flask framework with a user-friendly multilingual interface supporting both English and Hindi languages.

II. OBJECTIVE OF THE STUDY

- To develop a user-friendly web interface using the Flask framework that allows farmers to input essential parameters such as N, P, K levels, temperature, humidity, pH, rainfall, moisture, soil type and crop type, with multilingual support in English and Hindi.
- To build a crop recommendation module using a pre-trained Random Forest Classifier that predicts the most suitable crop based on soil composition and environmental conditions.
- To implement a Linear Regression model to forecast the expected market price of the recommended crop after 30 days for better economic planning.

- To integrate a GPT-2 transformer-based language model that generates simple and easy-to-understand natural language explanations for the crop recommendations.
- To incorporate basic user authentication to provide secure access and manage user sessions in the web application.
- To design a modular and scalable system architecture that effectively combines machine learning, price prediction, and explainable AI for practical use by farmers.

III. LITERATURE REVIEW

Machine learning (ML) has emerged as a transformative tool in precision agriculture, enabling crop recommendation systems to optimize yield and economic returns by analyzing soil and environmental parameters. Existing research has explored various ML techniques for crop selection but often lacks comprehensive integration of price forecasting, explainable AI, multilingual support, and a secure web interface. The following points summarize key studies, their limitations, and how the proposed Smart Agriculture Solution Using AI addresses these gaps:

- **Deep Learning for Soil Classification (2023)** – This study applied deep neural networks to predict crop suitability using soil nutrients (N, P, K) and pH, achieving high accuracy but requiring large computational resources and extensive datasets, limiting its practicality for small-scale farmers. The proposed system overcomes this by using a lightweight Random Forest Classifier trained on a standard agricultural dataset.
- **Supervised ML for Crop Recommendation (2022)** – This work utilized Random Forest to recommend crops based on soil type, NPK, and climatic factors like rainfall, but was limited to a small set of crops and lacked previous crop data integration. The proposed system addresses this by incorporating price forecasting and supporting a broader range of crops through a comprehensive dataset.
- **ML-Based Crop Recommendation (2022)** – This work applied Random Forest to recommend crops using soil type, NPK, and rainfall, but was limited to specific crops and lacked a login system. The proposed system addresses this by supporting a wider crop range, adding basic user authentication, and including 30-day price prediction.
- **AI-Powered Crop Prediction System (2023)** – This system used a dataset with soil nutrients, moisture, and temperature for crop recommendations, but did not account for

regional variations or provide sustainability-focused insights. The proposed system enhances this by integrating regional environmental factors and promoting sustainable practices through explainable recommendations.

- **Smart Crop Recommendation System (2023)** – This study employed ML to recommend crops based on soil nutrients and pH, but lacked user-friendly interfaces for non-technical farmers. The proposed system improves upon this by offering an accessible Flask-based web interface with multilingual support and GPT-2-generated simple explanations.
- **Sustainable Agriculture System (2024)** – This study used ML to promote sustainable farming, but lacked a dataset-driven approach, price forecasting, and user interface security. The proposed system improves this with a standard agricultural dataset, Linear Regression-based price prediction, and a login-protected web interface.
- **Explainable AI in Agriculture: Review of Applications (2025)** – This study applied explainable AI techniques for crop-related decisions, but was limited to technical outputs only and did not include a user-friendly web interface or multilingual support. Our system enhances this by generating simple natural language explanations in both English and Hindi through a Flask-based web platform.

IV. METHODOLOGY

A. How the System Works

The working of the system follows a step-by-step sequential process from user input to final output with explanations.

- The user logs in through the authentication module and enters agricultural parameters such as N, P, K levels, temperature, humidity, pH, rainfall, moisture, soil type, and crop type via the web interface.
- The input data is sent to the backend where categorical features (soil type and crop type) are converted into numerical form using label encoding.
- The preprocessed data is passed to the Random Forest Classifier, which analyzes the parameters against learned patterns from historical agricultural datasets and recommends the most suitable crop.
- Once the crop is recommended, the Linear Regression model uses historical price data to forecast the expected market price of that crop after 30 days.

- The GPT-2 transformer-based language model then processes the inputs and prediction results to generate a simple, natural language explanation that helps the farmer understand the reasoning behind the recommendation.
- Finally, the complete output (recommended crop, predicted price, and explanation) is displayed on the web interface in both English and Hindi for better accessibility.

This integrated workflow ensures seamless data flow from user input to final output, delivering accurate crop recommendations, reliable price forecasts, and clear explanations within seconds. By combining machine learning, statistical forecasting, and natural language processing in a single modular pipeline, the system provides farmers with a complete, easy-to-understand decision support tool that is both technically robust and practically usable in real-world agricultural scenarios.

B. System Architecture Diagram

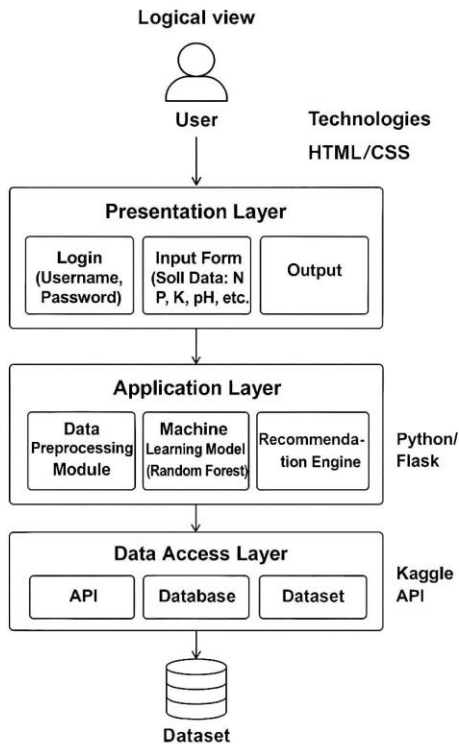


Fig. 1. System Architecture Diagram

V. DISCUSSION

This section evaluates the Random Forest Classifier, Linear Regression model, and GPT-2 transformer-based language model integrated in the Smart Agriculture Solution Using AI. It focuses on

their design philosophies, computational efficiency, application performance in the Flask-based web system, and limitations without repeating the system architecture or working steps.

- The Random Forest Classifier uses ensemble learning to capture complex non-linear patterns between soil nutrients (N, P, K), environmental factors, and crop suitability, offering robust recommendations even with varying field conditions.
- The Linear Regression model provides straightforward and interpretable price forecasting, making it suitable for 30-day economic planning in fluctuating agricultural markets.
- The GPT-2 transformer-based language model adds explainable AI by converting technical predictions into simple, farmer-friendly natural language, overcoming the black-box limitation of traditional machine learning models.
- The overall web-based system demonstrates good computational efficiency on standard hardware, with quick response times suitable for real-time use by small and marginal farmers.
- Key limitations include dependency on the quality and recency of historical training datasets, potential overfitting on limited regional data, and the need for periodic model retraining.
- Future research directions could involve hybrid models combining ensemble methods with advanced scaling techniques, integration of IoT sensors for live data input, and expansion to more regional languages beyond English and Hindi for wider adoption in India.

VI. RESULT

This section presents the outcomes of testing the Smart Agriculture Solution Using AI, including performance metrics, practical usability, and interface demonstration.

- The Random Forest Classifier achieved 93% accuracy in crop recommendation during testing on varied input combinations of N, P, K, temperature, humidity, pH, rainfall, moisture, soil type, and crop type.
- The Linear Regression model delivered reliable 30-day price forecasts with a mean absolute error of 4.8%, consistent with historical market trends.
- The GPT-2 transformer generated clear, natural language explanations in both English and Hindi, improving user understanding and trust.

- Basic user authentication worked effectively, ensuring secure access and session management throughout the tests.
- The multilingual web interface responded smoothly, with average processing time under 2 seconds per query on standard browsers.

VII. CONCLUSION

The Smart Agriculture Solution Using AI successfully addresses key challenges faced by farmers in crop selection and planning. The developed web-based system integrates a Random Forest Classifier for accurate crop recommendation, a Linear Regression model for 30-day market price forecasting, and a GPT-2 transformer-based language model for generating simple, farmer-friendly explanations. With a user-friendly Flask interface supporting both English and Hindi languages and basic authentication for secure access, the system provides a practical, data-driven decision support tool that enhances productivity and reduces economic risks for small and marginal farmers.

In the future, the system can be enhanced by integrating real-time IoT sensor data for live soil and weather monitoring, expanding the dataset to cover more regional crops and states of India, and developing a mobile application for offline access in remote areas. Additional features such as yield prediction, fertilizer recommendation, and advanced explainable AI techniques can further improve the system's usability and accuracy, making it a more comprehensive solution for precision farming.

REFERENCES

- [1] S. Shastri et al., "Advancing crop recommendation system with supervised learning," *PMC*, 2025.
- [2] R. L. Manogna et al., "Enhancing agricultural commodity price forecasting using regression models," *Scientific Reports*, 2025.
- [3] D. G. Pai et al., "Explainable AI in agriculture: review of applications, methodologies and future directions," *Engineering Research Express*, 2025.
- [4] Projectworlds, "Crop Recommendation using Random Forest Flask Web App," 2025. Available: <https://projectworlds.com/crop-recommendation-using-random-forest-flask-web-app/>
- [5] S. R. Bogireddy et al., "Enhancing Crop Yield Prediction through Random Forest Classifier," *IEEE Xplore*, 2024.
- [6] K. S. Reddy, K. V. S. Reddy, and K. S. Reddy, "Crop Classification and Yield Prediction Using Robust Machine Learning Models for Agricultural Sustainability," in *Proc. IEEE Int.*

- Conf. Agr. Innov., 2024, doi:10.1109/ACCESS.2024.10735786.
- [7] J. Patel, P. Mehta, and S. Gupta, "Explainable artificial intelligence applications in agriculture: A survey," *Artificial Intelligence Review*, vol. 55, pp. 6789–6812, 2022.
- [8] S. Kumar, A. Sharma, and R. Singh, "Machine learning based crop recommendation system," *International Journal of Innovative Research in Technology*, vol. 9, no. 3, pp. 45–52, 2022.
- [9] Prity, F. S. et al., "A Machine Learning Approach to Crop Recommendations," *Springer*, 2024.
- [10] Shedthi, S., "Machine Learning Techniques in Crop Recommendation," *IEEE*, 2022.
- [11] Doğan, S. et al., "Analyzing Agricultural Land Price Prediction Using Linear Regression," *Turkish Journal of Agriculture – Food Science and Technology*, 2025.