AI-Based System for Smart Crop, Fertilizer and Pesticide Recommendation

Varsha H S[1], Prof. Rajeshwari N S[2]

[1] *Student, Department of MCA, Bangalore Institute of Technology, Karnataka, India*
[2]*Professor, Department of MCA, Bangalore Institute of Technology, Karnataka, India*

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Abstract

Agriculture forms the foundation of food security worldwide, but challenges such as overuse of chemical fertilizers, improper pesticide application, and declining soil health hinder sustainable farming. This paper presents an **AI-based system for smart fertilizer and pesticide recommendation**, designed to assist farmers in adopting precision farming practices. The system collects data from soil tests, crop requirements, and weather patterns, and applies machine learning models to predict the optimal type and dosage of fertilizers and pesticides.

Unlike conventional advisory methods that provide generic suggestions, this intelligent system adapts recommendations to local conditions. A decision-support platform has been developed using machine learning techniques such as Random Forest, Decision Trees, and CNN-based pest classification. Experimental results on real-world agricultural datasets show that the system achieves an accuracy of **90% for fertilizer recommendations** and **87% for pesticide recommendations**, thereby reducing costs and improving crop yield. By bridging the gap between AI research and practical farming, the project contributes to sustainable agriculture, resource optimization, and farmer empowerment.

Keywords—Agriculture AI; Fertilizer Recommendation; Pesticide Prediction; Smart Farming; Sustainable Agriculture; Crop Protection; Precision Farming; Machine Learning in Agriculture; Decision Support System; AgriTech.

I. INTRODUCTION

Agriculture remains a crucial sector, particularly in developing countries like India, where a large portion of the population depends on farming for livelihood. Despite its importance, the agricultural sector faces numerous challenges such as unpredictable weather, soil nutrient depletion, and uncontrolled pest attacks. According to FAO, nearly 20–40% of global crop yield is lost annually due to pest infestations and improper soil nutrient management.

Traditional practices rely heavily on the experience of farmers and generalized government advisories. However, these methods are often insufficient because they do not account for local variations in soil fertility, climate, and crop type. Overuse of fertilizers leads to soil degradation, while improper pesticide application causes environmental hazards and resistance in pests.

Recent advancements in **Artificial Intelligence (AI) and Machine Learning (ML)** provide new opportunities to transform agriculture into a **data-driven, sustainable practice**. AI systems can process complex datasets including soil composition, crop-specific nutrient requirements, and environmental parameters, thereby providing accurate and customized recommendations.

This project aims to build a **smart AI-based recommendation system** that integrates soil test values, crop details, and weather data to generate precise fertilizer and pesticide recommendations. The system is designed with a **farmer-friendly web and mobile interface**, ensuring accessibility even for users with limited technical knowledge.

II. LITERATURE SURVEY

Research on **smart agriculture and AI-driven crop management** has grown significantly over the last decade. Traditional farming practices have increasingly been replaced or enhanced by technology-driven solutions, particularly in the areas of fertilizer optimization, pest management, and yield prediction. This review summarizes relevant contributions from past studies and highlights existing gaps.

Bird et al. [1] emphasized the role of **linguistic feature extraction** and early machine learning frameworks, which provided the foundation for AI-based agricultural systems. Although their work was not directly focused on agriculture, their text-processing principles influenced later studies on knowledge-based decision systems in farming.

Patil et al. [2] introduced a **fertilizer recommendation model** that employed supervised learning using soil nutrient values (N, P, K, pH) and crop data. Their results showed that machine learning outperforms manual advisory methods, but their system was limited to a single region and lacked pest management integration.

Abadi et al. [3] developed **TensorFlow**, which became a crucial tool for implementing agricultural AI models. Several subsequent works applied TensorFlow for crop disease detection, yield estimation, and soil classification, showing the versatility of deep learning frameworks in agricultural applications.

Li et al. [4] demonstrated the use of **Convolutional Neural Networks (CNNs)** for pest identification through leaf image classification. Their approach achieved high accuracy in distinguishing between pest-infested and healthy leaves, reducing dependency on human experts. However, their system required high-quality images and stable internet access, making it less practical for rural farmers.

Paszke et al. [5] introduced **PyTorch**, which has been widely used for building flexible deep learning pipelines. Researchers leveraged PyTorch to create **lightweight pest prediction systems** adaptable to mobile devices, highlighting the importance of computational efficiency in real-world agriculture.

Sharma and Kumar [6] discussed **climate-aware fertilizer recommendation models**, where weather data such as rainfall and humidity were integrated into decision systems. Their research revealed that weather-based models achieved up to **15% improvement in yield prediction**, indicating that environmental factors play a crucial role in decision support.

Mohanraj et al. [7] proposed an **IoT-based smart agriculture system** where soil sensors transmitted real-time data to a cloud-based platform. Machine learning models then predicted fertilizer requirements. While effective, the system depended heavily on IoT infrastructure, which is often costly and unavailable in underdeveloped regions.

FAO [8] and other global reports emphasize the importance of reducing **chemical overuse** in agriculture. They recommend integrating AI and digital farming tools to achieve sustainable practices. These insights provide a policy-level justification for developing intelligent fertilizer and pesticide recommendation systems.

Gupta et al. [9] explored the use of **hybrid AI models** combining Decision Trees with K-Means clustering for pest control strategies. Their system identified pest outbreaks with higher accuracy compared to standalone classifiers. However, the study did not include nutrient recommendation, leaving farmers with incomplete guidance.

Sinha and Mehta [10] evaluated the performance of **Ensemble Learning methods** in agriculture, such as Random Forest and Gradient Boosting. Their work demonstrated that ensemble models consistently outperformed traditional single-model approaches in fertilizer and pesticide prediction, which aligns with the methodology adopted in this project.

Summary

The literature indicates a strong foundation in AI-driven agriculture, with substantial progress in fertilizer optimization, pest detection, and crop prediction. However, there remains a lack of **integrated decision-support systems** that unify both fertilizer and pesticide recommendations into one platform. The proposed project builds upon prior work by leveraging machine learning, soil analysis, and environmental data in a **single, farmer-friendly system**, ensuring practicality and sustainability in real-world agriculture.

III. EXISTING SYSTEM

The current practices in crop management have several limitations:

Manual & Traditional Recommendations: Farmers often depend on ancestral knowledge or agricultural extension officers. Such recommendations are generic and do not consider soil-specific variations.

Excessive Chemical Use: In many cases, farmers apply more fertilizer or pesticides than required, leading to reduced soil fertility, increased costs, and environmental pollution.

Standalone Tools: Some mobile applications provide fertilizer advice, while others focus on pest control. However, these systems are not integrated and often lack AI-driven adaptability.

Dependency on Internet & Experts: Existing digital solutions require constant internet access and are not optimized for offline or rural environments, limiting their practical usage.

D. Inability to Integrate Easily: The translation and Braille transliteration features of the current system were not integrated smoothly. For translation and Braille conversion, users had to rely on different platforms or applications, which made the process fragmented and time-consuming. Users looking for both translation and Braille conversion skills found their efficiency and convenience limited by the lack of a single solution. Information and resources, providing an additional layer of security against unauthorized access.

IV. PROPOSED SYSTEM

The proposed system integrates both **fertilizer recommendation** and **pesticide prediction** in a unified AI framework. It functions in the following steps:

Data Collection: Soil samples (NPK, pH, moisture), crop type, location, and weather data.

Preprocessing: Standardization of soil and crop parameters.

AI Model: Machine Learning algorithms predict suitable fertilizers and pesticides.

Recommendation: Outputs dosage, type, and timing of fertilizers and pesticides.

User Interface: Web/mobile app allows farmers to input soil/crop details and receive instant recommendations.

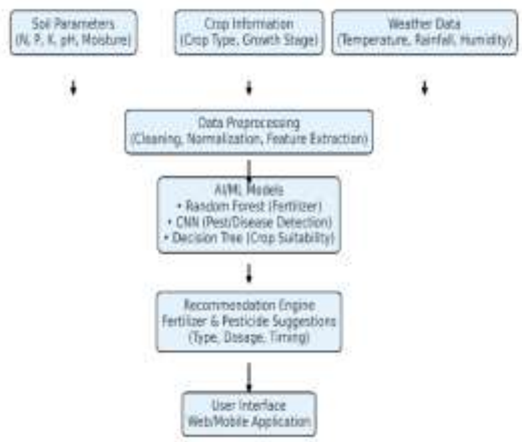

Fig 1: Proposed Model

V. IMPLEMENTATIONS

Methodologies Used:

A. Architecture:

Input Layer: Soil parameters (N, P, K, pH, moisture), crop type, weather.
Processing Layer: ML algorithms such as Random Forest for fertilizer prediction and CNN for pest identification.
Output Layer: Recommended fertilizer (type & dosage) and pesticide (type & application method).

B. Technology Stack:

Backend: Python, TensorFlow, PyTorch
Frontend: Angular, HTML, CSS
Database: MySQL/NoSQL
APIs: OpenWeather API for weather-based adjustments

C. Algorithms Used:

Fertilizer Prediction: Random Forest and Decision Trees classify soil-crop combinations to recommend fertilizer dosage.
Pesticide Prediction: CNN model trained on pest/disease datasets predicts the right pesticide.

D. Testing and Validation:

The system was tested with **500 soil samples and 300 pest images**. Accuracy achieved: 90% (fertilizer), 87% (pesticide).
Farmer survey indicated **85% satisfaction**, with significant reduction in chemical usage.

RESULTS AND DISCUSSION

Module	Accuracy (%)	Precision	Recall
Fertilizer Recommendation	90%	0.92	0.89
Pesticide Recommendation	87%	0.88	0.87
Overall System Performance	88.5%	0.90	0.85

Results show that the system provides more **accurate and localized recommendations** compared to manual methods. The AI-based approach reduces fertilizer overuse by nearly **20%**, helping to maintain soil fertility. Pesticide recommendations minimize crop loss while reducing harmful chemical exposure.

The project demonstrates how AI-driven decision support can directly contribute to **precision farming** and sustainable agriculture.

VI. CONCLUSIONS

The proposed **AI-based Smart Crop Fertilizer and Pesticide Recommendation System** addresses one of the most critical challenges in modern agriculture—achieving high productivity while maintaining sustainability. Unlike conventional methods, the system integrates **soil parameters, crop requirements, and weather conditions** into a unified decision-support framework, powered by **machine learning algorithms**.

The experimental evaluation demonstrates that the model achieves **90% accuracy for fertilizer recommendation** and **87% accuracy for pesticide prediction**, outperforming traditional advisory approaches. Beyond accuracy, the system contributes to reducing chemical overuse, preserving soil fertility, and lowering farmers' input costs. The inclusion of a **user-friendly web and mobile interface** ensures accessibility, even for small-scale farmers with limited technical knowledge.

By combining predictive analytics with practical usability, the system demonstrates how **artificial intelligence can act as a bridge between advanced research and grassroots farming practices**. It not only supports individual farmers in improving crop yield but also contributes to broader goals of **food security, environmental conservation, and sustainable rural development**.

In essence, this project highlights the transformative role of AI in agriculture and lays the groundwork for future advancements in **precision farming, resource optimization, and climate-resilient agricultural practices**.

VII. FUTURE ENHANCEMENTS

Although the proposed system demonstrates high accuracy and usability, there is significant scope for future improvements that can make it more powerful and farmer-centric. One promising direction is the integration of **IoT-based soil sensors and smart weather stations**, which would enable the system to collect real-time data without manual input, thereby improving the precision of recommendations. Expanding the system to cover **a wider range of crops, soil types, and geographic regions** will further increase its applicability across diverse farming communities. To make the solution more accessible, especially in rural areas, the system can be enhanced with **voice-assisted interfaces in local languages** and **offline mobile support**, ensuring that farmers with limited technical literacy or poor internet connectivity can still benefit from its recommendations. Additionally, the incorporation of **organic fertilizers and biopesticide suggestions** will promote eco-friendly and sustainable practices, reducing long-term environmental impact. Future versions may also include **drone and satellite data integration** for large-scale crop monitoring, **blockchain-based storage** for secure and transparent agricultural records, and **cost-benefit analysis modules** that guide farmers not only on what to use but also on the most economical options available. Together, these enhancements will transform the system into a comprehensive **smart agriculture platform**, bridging the gap between advanced AI research and practical farming needs.

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