Agri Forecast: A Review of Machine Learning Approaches for Crop Recommendation, Yield Prediction, Price Forecasting, and Fertilizer Recommendation

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***Abstract*—Agriculture plays a crucial role in the economy of developing countries like India and others. Farmers often face difficulties in selecting the appropriate crop, determining the required fertilizer, estimating crop yield, and predicting market prices. These uncertainties lead to financial loss and reduced agricultural productivity. To overcome these issues, intelligent decision-support systems based on machine learning can be utilized.**

This research proposes Agri-Forecast, a machine learning-based agricultural prediction system that integrates four major prediction models: Crop Recommendation, Fertilizer Recommendation, Crop Yield Prediction, and Crop Price Prediction. The system analyzes soil nutrients, environmental parameters, and historical agricultural data to provide accurate insights to farmers. Machine learning algorithms such as Decision Tree, Random Forest, Support Vector Machine and XGBoost are applied to develop predictive models. These models help farmers select suitable crops, apply the correct fertilizers, estimate crop production, and understand market price trends.

The proposed system aims to improve agricultural productivity, reduce risk, and support farmers in making data-driven farming decisions.

***Index Terms*—Smart Agriculture, Machine Learning in Agriculture, Crop Recommendation System, Fertilizer Recommendation Model, Crop Yield Prediction, Agricultural Price Forecasting, Precision Farming, Agricultural Data Analytics, Soil Nutrient Analysis, Agricultural Decision Support System, Sustainable Farming Technology**

I. INTRODUCTION

Agriculture plays a vital role in the economic development and food security of many countries, especially in developing nations where a large portion of the population depends on farming for their livelihood. Farmers face numerous challenges such as unpredictable climate conditions, soil nutrient imbalance, fluctuating market prices, and lack of accurate information regarding crop productivity. These challenges often lead to poor crop selection, inefficient fertilizer usage, and financial losses. Therefore, there is a growing need for intelligent systems that can assist farmers in making better agricultural decisions based on scientific analysis and data-driven insights.

With the advancement of modern technologies such as Machine Learning (ML), Artificial Intelligence (AI), and data analytics, it has become possible to analyze large volumes of agricultural data and extract useful information that can improve farming practices. Machine learning techniques can identify patterns in soil conditions, weather parameters, and crop performance, enabling predictive analysis and automated recommendations for farmers. These technologies play a significant role in the development of smart agriculture, where data is used to optimize crop production and improve farm management.

The proposed project, "Agri-Forecast: Nurturing the Harvest with Smarter Insights," aims to develop an intelligent agricultural prediction system that assists farmers in making informed decisions related to crop cultivation. The system integrates multiple machine learning models to analyze agricultural datasets and provide accurate recommendations and predictions. By combining various prediction modules into a single platform, the system helps farmers optimize crop production, improve soil health, and maximize profits.

The proposed system focuses on four major agricultural prediction tasks: crop recommendation, fertilizer recommendation, crop yield prediction, and crop price prediction. The crop recommendation model suggests the most suitable crop based on soil nutrients, temperature, humidity, rainfall, and pH level of the soil. The fertilizer recommendation model identifies nutrient deficiencies in the soil and recommends the appropriate fertilizer to improve soil fertility and crop growth. The yield prediction model estimates the expected crop production based on environmental and soil conditions, helping farmers plan their resources effectively. Additionally, the price prediction model analyzes historical market price data to forecast future crop prices, allowing farmers to make better marketing decisions. The system utilizes machine learning algorithms such as Random Forest, Decision Tree, Support Vector Machine, and other predictive models to analyze the dataset and generate accurate predictions. These models are trained using historical agricultural data to understand the relationship between environmental parameters and crop performance. Once trained, the models are integrated into a web-based platform where users can input relevant parameters and obtain real-time predictions and recommendations.

By integrating these predictive modules, the Agri-Forecast system aims to provide a comprehensive decision-support tool for farmers. The system helps reduce uncertainty in farming practices, promotes efficient resource utilization, and encourages sustainable agriculture.

Problem	Description	Proposed ML Solution	Expected Benefit
Suboptimal Crop Selection	Farmers often lack guidance on which crops are best suited for soil type, climate, and location.	Crop Recommendation Model	Suggests the most suitable crops for specific conditions, optimizing land use and productivity.
Inefficient Resource Management	Fertilizer and input application is based on generalized guidelines, leading to waste and reduced efficiency.	Fertilizer Recommendation Model	Provides context-aware recommendations, ensuring precise nutrient utilization and sustainable farming.
Yield Uncertainty	Lack of predictive tools makes it difficult to estimate harvests, affecting planning and resource allocation.	Crop Yield Prediction Model	Predicts expected harvests using historical and environmental data, enabling informed decision-making.
Market Volatility & Limited Access	Farmers face unpredictable prices and limited access to real-time market data.	Crop Price Prediction Model	Forecasts future crop prices, empowering farmers to optimize selling strategies and maximize revenue.

Literature Review: A Comparative Analysis of Machine Learning Approach

The papers reviewed explore three primary applications of machine learning: crop selection, yield prediction, and fertilizer recommendation. This section provides a comparative analysis of the methodologies and findings presented in each study.

1. Artificial Intelligence in Agriculture: A Systematic Review of Crop Yield Prediction and Optimization

The article examines various ML and Deep Learning techniques to predict crop yield. The studies use data on soil, climate and other environmental variables to develop crop recommendation systems and predict yield, with the aim of optimizing agricultural practices and increasing productivity. KNN is employed as a flexible prediction approach. Machine (SVM) to suggest one of twenty-two different crops. The Random Forest model was identified as the best-performing one, with an impressive accuracy of 99.7%.

2. Crop Classification and Yield Prediction using Robust Machine Learning Models for Agricultural Sustainability

The article used a variety of different machine learning classification methods for crop analysis which include- Extra Tree Classifier (ETC), Logistic Regression (LR), Decision Tree (DT), Random Forest (RF), K-Nearest Neighbour (KNN), Gaussian Naïve Bayes (GNB) AND Support Vector Machine (SVM). The article even suggested the use of explainable AI (XAI). Extra Tree Classifier and Gaussian Naïve Bayes both had accuracy rates of 99.4% and 99.2%

respectively. However Random Forest Classifier, with 99.7% accuracy, was the most accurate.

3. Crop and Fertilizer Recommendation System Applying Machine Learning Classifiers
The article suggests the use of various machine learning algorithms like Logistic Regression, Naïve Bayes, Random Forest, Decision Tree and Support Vector Machine. The research examines three parameters: soil properties, type of soil and harvest data, which gives farmers information about suitable crops to grow according to the parameter

Sr No	Research Paper	Released Year	Authors	Research Gap
1.	Artificial Intelligence in Agriculture: A Systematic Review of Crop Yield Prediction and Optimization	April, 2025	a. Claudia R. Srepnik b. Eduardo Zamudio c. Laura I. Gimenez	a. Lack of outlier detection and use of data normalization techniques that cannot handle outliers properly. b. Highlights the importance of using more meaningful feature selection methods and other pre-processing tasks.
2.	Crop Classification and Yield Prediction using Robust Machine Learning Models for Agricultural Sustainability	October, 2024	a. Abid Badshah b. Basem Yousef Alkazemi c. Fakhrud Din d. Kamal Z. Zamli e. Muhammad Haris	a. Applied only on 22 crops. b. Yield forecast only for wheat.
3.	Crop and Fertilizer Recommendation System Applying Machine Learning Classifiers	2023	a. S. Iniyan b. M. Senthil Raja c. R. Srinivasan d. C. Santhanakrishnan e. Arvindam Srinivasan	a. Does not explicitly mention other impactful factors like pests, diseases, or specific microclimates within the region.

II. PROPOSED SYSTEM

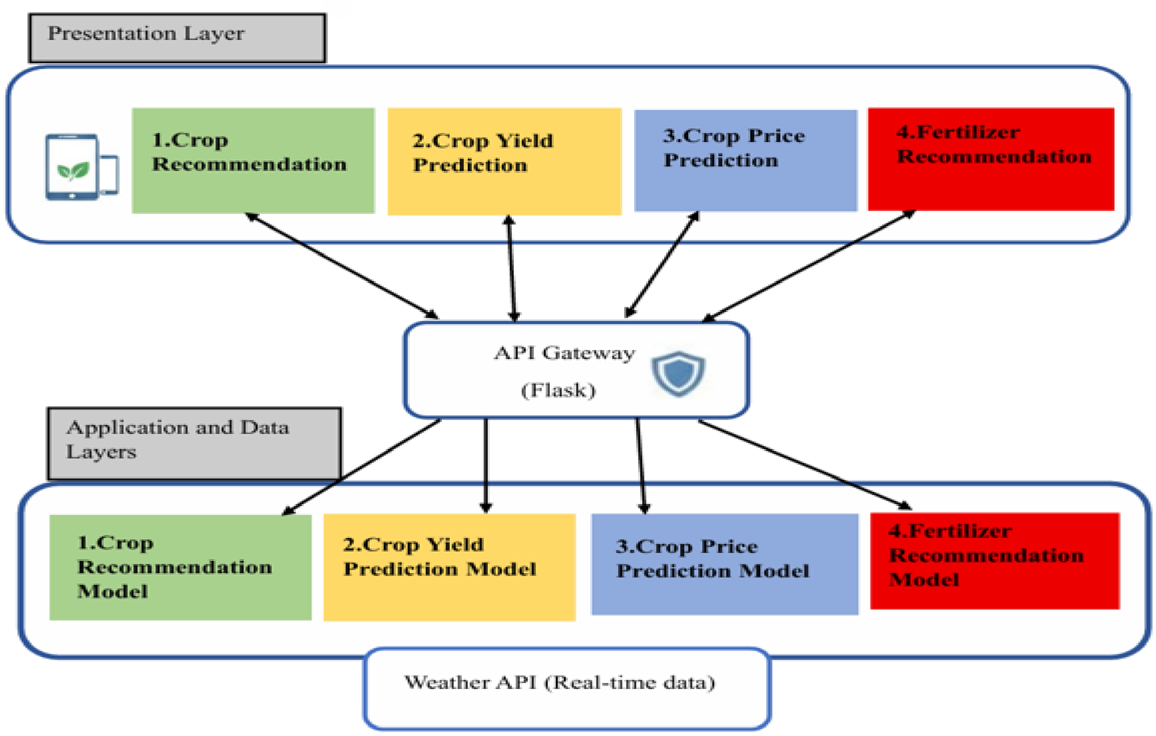

Fig. System Architecture

The proposed system Agri-Forecast is a machine learning–based agricultural prediction platform designed to assist farmers in making intelligent farming decisions. The system integrates multiple prediction modules including crop recommendation, fertilizer recommendation, crop yield prediction, and crop price prediction to improve agricultural productivity and profitability.

Traditional farming systems depend on manual observation and farmer experience for selecting crops and fertilizers. These methods are often inaccurate and cannot analyse large volumes of environmental and historical agricultural data. The proposed system overcomes these limitations by applying machine learning algorithms to analyse soil, climate, and market data to generate accurate predictions.

The system takes various agricultural parameters such as soil nutrients (Nitrogen, Phosphorus, Potassium), soil pH, temperature, humidity, and rainfall as inputs. These parameters are used to train machine learning models which identify patterns between environmental conditions and crop productivity. Based on this analysis, the system recommends suitable crops, fertilizers, predicts yield production, and forecasts market prices.

III. WORKING OF THE PROPOSED SYSTEM

The proposed system operates by integrating multiple machine learning models into a unified agricultural decision-support platform. Initially, agricultural datasets containing soil nutrients, environmental conditions, crop yield data, and historical market prices are collected. These datasets are pre-processed to remove inconsistencies and improve data quality. After preprocessing, the data is used to train machine learning models capable of learning relationships between soil conditions, weather patterns, and crop performance. Once trained, the models are deployed into a web-based application where users can input field parameters. Based on the provided input values, the system processes the data through the trained models and generates predictions. The crop recommendation module suggests the best crop for cultivation, while the fertilizer recommendation module identifies the appropriate fertilizers needed to maintain soil fertility. Additionally, the yield prediction model estimates the potential crop output, and the price prediction model forecasts market prices to assist farmers in selling their produce at the right time.

By integrating these four modules, the system provides a complete agricultural forecasting solution that supports efficient farm management and improves productivity.

Modules of the Proposed System:

The proposed Agri-Forecast system consists of four major modules:

1. Crop Recommendation Module

This module predicts the most suitable crop for cultivation based on soil and environmental conditions.

The model takes the following input parameters:

- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Soil pH
- Temperature
- Rainfall

Machine learning algorithms such as Decision Tree Classifier, Random Forest Classifier are used to train the model. These algorithms analyse historical agricultural datasets to determine which crop performs best under specific environmental conditions. Among these two algorithms Random Forest Classifier had the highest accuracy rate of 93% on both training and testing data. This proved that the model is ‘generalized’. On the other hand, the Decision Tree Classifier had an accuracy rate of 92% on the testing data.

The output of this module is the recommended crop that is most suitable for the given soil and weather conditions.

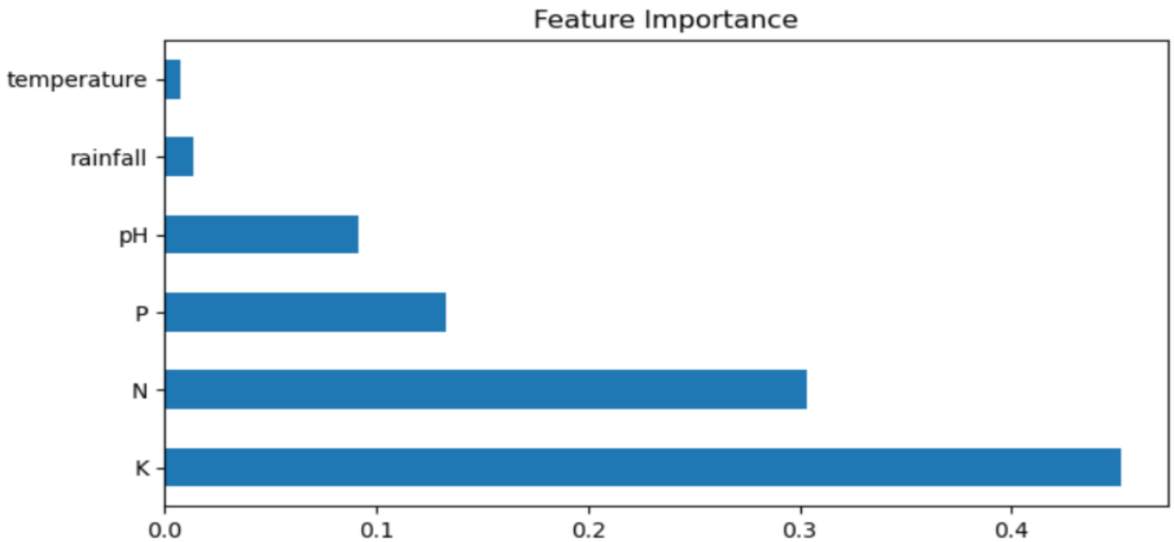

Fig. Feature Importance of various features available in the data.

2. Fertilizer Recommendation Module
The fertilizer recommendation module helps farmers select the most appropriate fertilizer for the recommended crop and soil condition.
The model uses the following input features:

- Soil nutrient values (N, P, K)
- Carbon
- Soil pH level
- Temperature
- Moisture
- Rainfall
- Crop type

The machine learning model analyses the nutrient requirements of crops and recommends fertilizers that can improve soil fertility and crop productivity. Algorithms such as Decision Tree Classifier, XGB Classifier and Random Forest Classifier were used. Among these the XGB Classifier proved to have the maximum accuracy rate of 95% on training data and 91% on testing data.

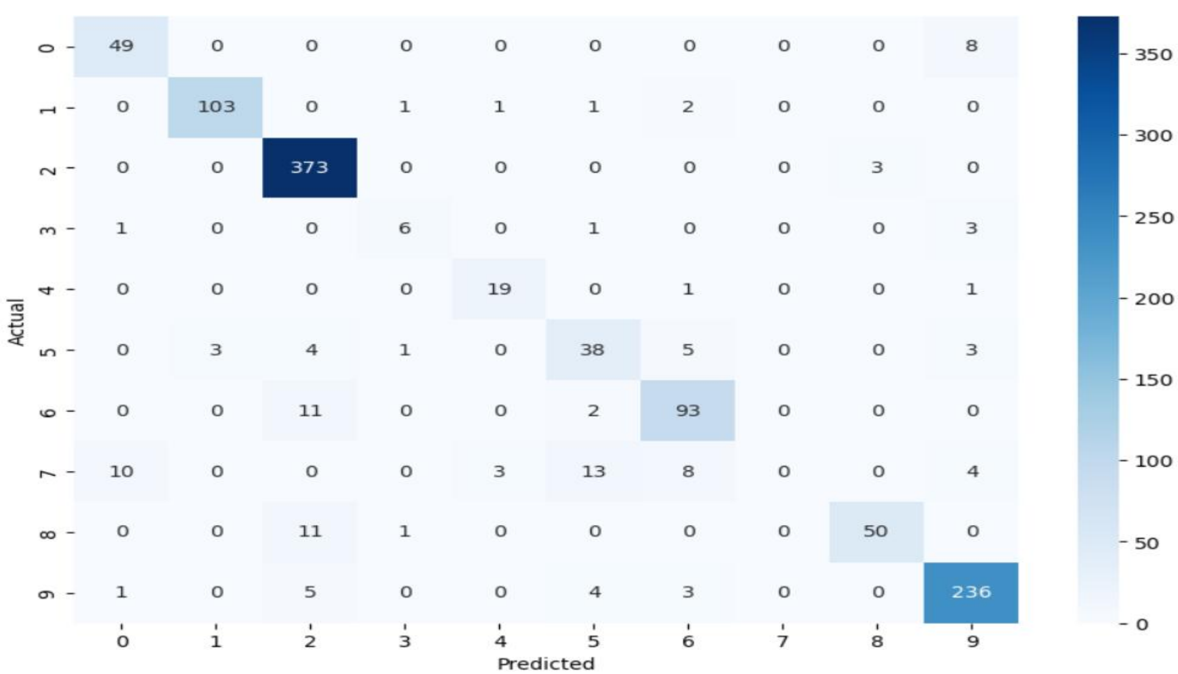

Fig. Confusion Matrix of the model

3. Crop Yield Prediction Module

Crop yield prediction is an important feature that helps farmers estimate the amount of crop production before harvesting.

This model uses:

- Soil nutrient values (N, P, K)
- Soil PH
- Rainfall
- Temperature
- Area in hectares
- Production in tones
- State
- Crop Type

Machine learning regression techniques such as Random Forest Regressor and XGB Regressor are applied to estimate the expected crop production. Among these two Random Forest Classifier proved to have higher metrics value for both training and testing data. It had a R2 score of 99% on the training data and 98% on testing data. Other metrics like MAE, MSE and RMSE were also less than zero for both training and testing dataset.

Fig. Metrics Report for the final model

```
Metric      | Training Set      | Testing Set
----------------------------------------------
MAE         | 0.0643            | 0.1736
MSE         | 0.0300            | 0.2321
RMSE        | 0.1733            | 0.4818
R-Squared   | 0.9983            | 0.9873
```

4. Crop Price Prediction Module

The crop price prediction module forecasts the future market price of agricultural products.

The model uses historical market data such as:

- Crop type
- State
- District
- Market
- Date

The model is trained to predict the price for 25 crop types which include apple, banana, bitter-guard, bottle-guard, cabbage, cauliflower, cucumber, garlic, ginger, green-chilly, gur, lemon, maize, mustard, onion, paddy, pomegranate, pumpkin, potato, radish, rice, soyabean, tomato and wheat.

Algorithms like Random Forest Regressor, XGB Regressor and Cat Boost Regressor were used. Among these Random Forest Regressor proved have higher metrics rate for both training and testing data. It had R2 score of 99% on training data and 94% on testing data. While XGB Regressor and Cat Boost Regressor had R2 score of 85% and 93% respectively.

	district_Encoded	market_Encoded	commodity_name_Encoded	state_Encoded	Year	Month	Day_of_Month
340397	24.431027	16.169685	9.870444	91.697605	2019	10	18
267317	77.415107	64.278502	10.973035	104.494759	2019	8	17
734838	116.973423	141.181382	1195.503887	104.494759	2021	3	27
203338	131.644981	111.152257	1195.503887	104.494759	2019	7	31
187167	132.088387	132.088387	56.883810	104.494759	2019	7	31

```
Ytest[0:5]
```

```
340397     6.8
267317     9.4
734838    74.0
203338    71.9
187167    59.0
Name: modal_price_Winsorized, dtype: float64
```

```
user_input1=[77.415107,64.278502,10.973035,104.494759,2014,8,17]
```

```
feature_names=Xtrain.columns
user_input_df1=pd.DataFrame([user_input1], columns=feature_names)
```

```
prediction=rf.predict(user_input_df1)
print(prediction)
```

```
[9.4185]
```

Fig. Prediction Snapshot

IV. METHODOLOGIES AND MODELS

The papers reviewed showcase a variety of machine learning methodologies. The common approach involves using classification models for crop selection and regression models for yield prediction. Key models discussed include:

- Random Forest: A widely used ensemble model that consistently performed well in both classification and regression tasks. One study reported a 93% accuracy for crop recommendation and an R^2 score of 0.98 for yield prediction using this model.
- XGB Boost: Used for both crop recommendation and fertilizer recommendation, as it can identify similarities between farm features.
- Cat Boost Regressor: A regressor that showed high R2 score (993%) in crop price prediction.

The papers also highlighted the importance of data preprocessing and feature engineering. Some studies, such as the one by Badshah et al., employed techniques like Multivariate Imputation by Chained Equations (MICE) to handle data limitations and predict future yields from incomplete datasets. Furthermore, the need for transparency in ML models was addressed through the use of Explainable AI (XAI) approaches, such as Feature Importance and Local Interpretable Model-Agnostic Explanations (LIME), to make the model decisions comprehensible to farmers and stakeholders.

ADVANTAGES OF THE PROPOSED SYSTEM:

1. Improved Crop Selection

The system analyses important agricultural parameters such as soil nutrients (Nitrogen, Phosphorus, Potassium), soil pH, temperature, humidity, and rainfall to recommend the most suitable crop for cultivation. This helps farmers select crops that are best suited to the environmental conditions of their land, thereby increasing the chances of successful crop growth and higher productivity.

2. Efficient Fertilizer Usage

The fertilizer recommendation module identifies nutrient deficiencies in soil and suggests the appropriate type of fertilizer required for optimal crop growth. This helps farmers avoid inappropriate fertilizer usage, which not only reduces input costs but also prevents soil degradation and environmental pollution.

3. Accurate Yield Prediction

The yield prediction model estimates the expected crop production based on historical data and environmental parameters. This enables farmers to plan harvesting, storage, and transportation in advance. Accurate yield estimation also helps farmers make better financial decisions and manage resources more efficiently.

4. Market Price Forecasting

The price prediction model analyses historical market price trends and predicts the future price of crops. This helps farmers decide the best time to sell their produce in order to maximize profit. By understanding market trends, farmers can avoid selling crops at low prices during market fluctuations.

5. Data-Driven Decision Making

Traditional farming methods often rely on intuition and experience. In contrast, the proposed system uses machine learning algorithms and data analysis to provide scientifically supported recommendations. This enables farmers to make informed decisions based on reliable data.

6. Increased Agricultural Productivity

By combining crop recommendation, fertilizer optimization, yield prediction, and price forecasting, the system helps farmers improve overall farm productivity. Selecting the right crop and managing soil nutrients effectively leads to better crop growth and increased agricultural output.

7. Cost Reduction in Farming

The system helps farmers reduce unnecessary expenses related to fertilizers, crop failures, and poor market decisions. Proper crop selection and fertilizer management lead to efficient resource utilization and lower farming costs.

8. Sustainable Farming Practices

The model promotes environmentally sustainable agriculture by preventing excessive fertilizer usage and encouraging soil health management. Sustainable practices ensure long-term agricultural productivity and environmental protection.

9. User-Friendly Web-Based System
The system is implemented using a web-based interface, allowing farmers or agricultural experts to easily input field parameters and receive recommendations. The interface simplifies the interaction with machine learning models and makes advanced technology accessible to farmers.

10. Integrated Agricultural Forecasting Platform
Unlike many existing systems that focus on a single task, the proposed system integrates four important agricultural prediction modules in one platform:

- Crop Recommendation
- Fertilizer Recommendation
- Yield Prediction
- Price Prediction

This integrated approach provides comprehensive agricultural insights, helping farmers make better farming and marketing decisions.

FUTURE WORK:
Although the proposed Agri-Forecast system provides intelligent recommendations for crop selection, fertilizer usage, crop yield estimation, and market price prediction, several improvements can be implemented in the future to enhance the system's performance, scalability, and usability.

1. Integration of Real-Time Weather Data
In the current system, predictions are primarily based on historical datasets. In the future, the system can be integrated with real-time weather APIs to obtain live temperature, humidity, and rainfall data. This will allow the model to provide more accurate crop recommendations and yield predictions based on current environmental conditions.

2. Expansion of Crop Dataset
The present model supports a limited number of crops based on the available dataset. Future work can involve expanding the dataset to include more regional and seasonal crops, enabling the system to support farmers from different geographical regions and agricultural practices.

3. Use of Deep Learning Techniques
Currently, traditional machine learning algorithms such as Random Forest, Decision Tree, or Support Vector Machines are used. In the future, deep learning models such as Artificial Neural Networks (ANN) and Long Short-Term Memory (LSTM) can be implemented to improve prediction accuracy, especially for time-series data such as crop price forecasting.

4. Mobile Application Development
To make the system more accessible for farmers, a mobile application can be developed. This application would allow farmers to easily input soil and environmental parameters using smartphones and receive instant recommendations and predictions directly in the field.

5. Integration with IoT Sensors
The system can be enhanced by integrating Internet of Things (IoT) sensors in agricultural fields to automatically collect soil moisture, temperature, humidity, and nutrient levels. This will eliminate manual data entry and improve the reliability of the predictions.

6. Multilingual Support
To ensure usability for farmers from different regions, the system can be enhanced with multilingual support, allowing farmers to interact with the platform in their local languages.

7. Disease Detection and Pest Prediction
Future versions of the system can include crop disease detection and pest prediction modules using image processing and machine learning techniques. This will help farmers identify plant diseases at an early stage and take preventive actions.

8. Market Demand Analysis
The price prediction module can be further improved by integrating market demand analysis and supply chain data, which will help farmers make better decisions regarding crop selection and selling time.

V. CONCLUSION

In recent years, the convergence of machine learning (ML) techniques with agricultural decision-making has offered substantial promise across multiple domains: crop recommendation, yield prediction, price forecasting, and fertilizer recommendation. The reviewed literature shows that supervised learning algorithms (e.g., Random Forest, Support Vector Machine, Naïve Bayes), ensemble methods, and increasingly deep-learning frameworks (such as Long Short-Term Memory networks and convolutional architectures) have been successfully applied to agronomic datasets and remote-sensing/ IoT inputs to improve prediction accuracy and operational decision support. For instance, for yield prediction the incorporation of soil, climatic, vegetation index and remote-sensing derived features has improved performance markedly. However, the review also highlights persistent challenges:

- Data limitations: many models rely on relatively small, region-specific datasets, which limits generalizability and induces overfitting risks.
- Feature heterogeneity and pre-processing: agricultural systems involve a wide variety of variables (soil chemistry, weather, remote sensing, market dynamics), often with missing/unbalanced data or noisy inputs.
- Algorithm interpretability and farmer-friendly deployment: while high-accuracy black-box models exist, they are less transparent and harder to trust in real-world agronomic advisory contexts.
- Scalability across regions and crops: methods that work well in one agro-ecological zone often do not generalize without adaptation, limiting wider adoption.
- Integration of modules: For maximum benefit, crop recommendation, yield forecasting, price prediction and fertilizer advice should be integrated end-to-end, yet many studies still treat them separately.

Looking forward, future research directions include:

- Building large multi-region open datasets combining soil, weather, remote sensing, management and market variables.
- Incorporating hybrid models that combine domain knowledge (crop-growth models) with data-driven ML/DL methods to improve robustness.
- Emphasizing explainability, model-fairness, and user-interface design to ensure adoption by farmers, agronomists and policy-makers.
- Real-time/ streaming data integration (IoT sensors, satellite feeds, market feeds) enabling dynamic advisory systems rather than static models.
- Cross-task frameworks that seamlessly tie together crop choice, fertiliser dosage, expected yield and market price forecasting—thus supporting holistic decision making and sustainability.

In conclusion, machine-learning enabled "agri-forecasting" systems hold significant potential to enhance productivity, profitability and sustainability in agriculture. Yet, to fully realise their promise, research must move beyond accuracy benchmarks to address dataset scale, generalizability, interpretability and deployment in real agrarian contexts.

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