

SMART FERTILIZER AND WATER ADVISORY SYSTEM FOR SUSTAINABLE AGRICULTURE**Premnath .A**

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ABSTRACT

Fertilizer recommendation plays a vital role in improving agricultural productivity and ensuring sustainable farming practices. This study applies machine learning models, including Logistic Regression, Decision Tree, Naive Bayes, and Support Vector Machine (SVM), to recommend suitable fertilizers based on key parameters such as soil nutrients (Nitrogen, Phosphorus, Potassium), soil moisture, temperature, and humidity. After data preprocessing and feature selection, model performance is evaluated using accuracy-based metrics to identify the most effective prediction model. Results indicate that machine learning approaches provide more accurate and consistent fertilizer recommendations compared to traditional methods. The system integrates real-time environmental data and provides water level suggestions and fertilizer price estimation to support cost-effective decision-making. This research demonstrates the effectiveness of machine learning in precision agriculture and suggests future enhancements through advanced models and expanded real-time data integration.

Agriculture is a fundamental sector that supports food production, economic stability, and sustainable development. One of the most critical factors influencing crop productivity is the appropriate use of fertilizers. Selecting the correct fertilizer based on soil composition and environmental conditions is essential for improving crop yield, maintaining soil health, and reducing unnecessary agricultural expenses. However, farmers often rely on traditional knowledge or generalized recommendations, which may not accurately reflect real-time soil and climate conditions.

With the advancement of machine learning and web technologies, intelligent decision-support systems can be developed to provide precise, data-driven agricultural recommendations. This project presents a Fertilizer Recommendation System designed to assist farmers and agricultural

practitioners in selecting the most suitable fertilizer based on soil nutrient values such as Nitrogen (N), Phosphorus (P), and Potassium (K), along with environmental parameters including temperature, humidity, and moisture. The system integrates machine learning models with a web-based interface to provide accurate and practical recommendations.

The system enhances decision-making by automatically fetching environmental parameters such as temperature and humidity through API integration, ensuring real-time and location-relevant inputs. Based on the analyzed data, the system not only recommends the appropriate fertilizer but also suggests the required water level for crops according to weather and soil conditions. Additionally, it provides an estimated price of the recommended fertilizer, helping users make economically informed decisions.

The project is implemented using Python and Flask to create a web-based application where users can input soil and crop details through an interactive interface. Machine learning models trained on agricultural datasets are stored using serialization techniques and deployed within the system to generate predictions efficiently. The system processes user inputs, applies the trained model, and returns fertilizer recommendations along with supporting agricultural insight.

Key Words

1. Machine Learning in Agriculture
2. Fertilizer Recommendation System
3. Soil Nutrient Analysis (NPK Modelling)
4. Precision Agriculture Technology
5. Environmental Parameter Integration
6. Crop Yield Optimization
7. Smart Farming Decision Support
8. Sustainable Nutrient Management

LITERATURE REVIEW

Fertilizer recommendation has traditionally been based on generalized agricultural guidelines and expert knowledge. Conventional methods rely on soil testing and manual interpretation of nutrient levels such as Nitrogen (N), Phosphorus (P), and Potassium (K). While these methods provide useful insights, they often fail to consider complex relationships between soil properties, weather conditions, and crop requirements, leading to inefficient fertilizer usage. Recent research highlights the growing use of machine learning techniques to improve fertilizer recommendation accuracy. Commonly used models include:

- Linear Regression (LR): Used for predicting nutrient requirements based on soil parameters, but limited in handling complex and non-linear patterns.
- Decision Trees (DT): Capable of handling both categorical and numerical soil features, though prone to overfitting with large datasets.
- Random Forest (RF): An ensemble learning method that improves prediction stability and accuracy by combining multiple decision trees.
- Support Vector Machine (SVM): Effective in classification tasks such as recommending fertilizer categories based on soil composition.

ADVANTAGE

1. **Improved Accuracy:** Machine learning models provide precise fertilizer recommendations based on soil nutrients and crop requirements.
2. **Efficient Resource Utilization:** Prevents overuse or underuse of fertilizers, reducing cost and environmental impact.
3. **Data-Driven Decision Making:** Uses soil analysis and environmental data to support scientific agricultural practices.
4. **Adaptability:** Can incorporate real-time data such as weather conditions to provide dynamic recommendations.
5. **Sustainable Farming Support:** Helps maintain soil health and promotes eco-friendly agricultural practices.
6. **Automation:** Reduces dependency on manual interpretation of soil data and expert intervention.
7. **Scalability:** Can be applied to different crops, soil types, and geographic regions.

EXISTING SYSTEM

Traditional fertilizer recommendation methods rely on manual soil testing, generalized agricultural guidelines, and expert judgment. These approaches typically consider basic soil nutrients such as Nitrogen (N), Phosphorus (P), and Potassium (K) without analyzing complex relationships between soil properties, crop requirements, and environmental conditions. As a result, farmers may apply excessive or insufficient fertilizers, leading to reduced crop yield, increased cost, and soil degradation. Manual interpretation of soil data can also produce inconsistent recommendations.

Limitations:

- **Low Accuracy:** Traditional methods cannot effectively capture complex and non-linear relationships between soil nutrients, crop type, and environmental factors.
- **Time-Consuming:** Requires manual soil analysis and expert consultation.
- **Lack of Adaptability:** Unable to adjust recommendations based on changing weather and soil conditions.
- **Resource Inefficiency:** May lead to overuse or underuse of fertilizers.
- **Human Bias:** Recommendations depend heavily on subjective judgment and experience.

Due to these limitations, machine learning-based fertilizer recommendation systems are essential for improving accuracy, efficiency, and sustainability in modern agriculture.

.PROPOSED SYSTEM

The proposed system leverages machine learning (ML) algorithms to recommend suitable fertilizers accurately by analyzing key agricultural parameters such as soil nutrients, moisture level, temperature, humidity, and crop type. Unlike traditional methods, ML models can capture complex relationships between soil properties and crop requirements, adapt to environmental changes, and automate the recommendation process

Key Features:

- **Data Preprocessing:** Handles missing values, noise removal, and feature selection to improve prediction accuracy.

- ML Models Used: Logistic Regression, Decision Tree, Naive Bayes, and Support Vector Machine (SVM) for accurate fertilizer classification.
- Performance Evaluation: Uses accuracy score and model comparison techniques to select the best-performing algorithm.
- Real-Time Environmental Integration: Fetches temperature and humidity data using API services for dynamic recommendations.
- Water Level Recommendation: Suggests suitable irrigation levels based on soil and weather conditions.
- Automation & Efficiency: Reduces manual analysis, eliminates human bias, and provides instant recommendations.

MEHODOLOGY.

1. Data Collection: An agricultural dataset is collected containing soil nutrients such as Nitrogen (N), Phosphorus (P), Potassium (K), soil moisture, temperature, humidity, crop type, and fertilizer labels.
2. Data Preprocessing: The dataset is cleaned by handling missing values, removing noise, encoding categorical features, and normalizing data to improve model performance.
3. Feature Selection: Important parameters that significantly influence fertilizer recommendation are identified based on soil and environmental conditions.
4. Model Selection & Training: Machine learning classification algorithms including Logistic Regression, Decision Tree, Naive Bayes, and Support Vector Machine (SVM) are implemented using an 80–20 train-test split.
5. Model Evaluation: The performance of each model is evaluated using accuracy score, and the best-performing model is selected for deployment.
6. Prediction & Deployment: The trained model is deployed as a web-based application using Python and Flask to provide real-time fertilizer and water level recommendations based on user input.

MODULE FUNCTION

The Fertilizer Recommendation System is designed using a modular architecture where each module performs a specific function in the overall workflow. This modular design improves system organization, scalability, and maintainability

1. Data Collection Module

This module handles the collection of agricultural data required for training and prediction. The dataset includes important soil and environmental parameters such as Nitrogen (N), Phosphorus (P), Potassium (K), temperature, humidity, moisture, and fertilizer type. The dataset is stored in CSV format and used for training machine learning models.

2. Data Preprocessing Module

The preprocessing module prepares the dataset for machine learning by cleaning and transforming the data. It handles tasks such as removing inconsistencies, converting categorical values into numerical format, and preparing feature variables and target labels. Proper preprocessing ensures

that the models learn effectively and produce accurate predictions.

3. Machine Learning Model Training Module

This module is responsible for training classification algorithms using the prepared dataset. Multiple machine learning models such as Logistic Regression, Decision Tree, Naive Bayes, and Support Vector Machine (SVM) are trained and evaluated. The best-performing model is selected based on accuracy and performance metrics.

4. Model Serialization Module

After training, the selected machine learning model is saved using serialization techniques. The trained models are stored as .pkl files, which allows the system to load and use them directly during prediction without retraining. This improves efficiency and reduces processing time

5. API Integration Module

This module integrates external services to automatically fetch real-time environmental data such as temperature and humidity. By using live environmental conditions instead of manual input, the system provides more accurate and practical fertilizer recommendations.

6. Prediction and Recommendation Module

This is the core functional module of the system. It receives user inputs from the web interface, loads the trained machine learning model, and predicts the most suitable fertilizer. In addition to fertilizer prediction, the module also:

- Suggests the appropriate water level for crops based on fertilizer type and weather conditions
- Recommends the estimated price of the fertilizer for cost planning

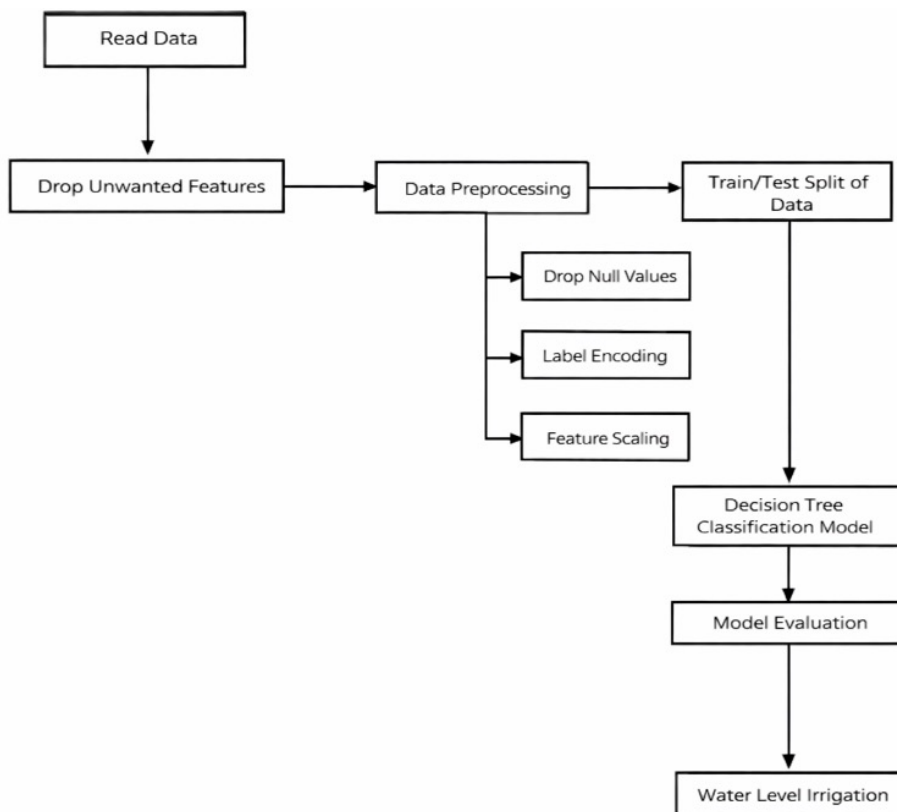
7. Web Application Interface Module

The user interface is developed using HTML, CSS, and Flask. This module allows users to enter soil and crop parameters through web forms and view prediction results in an easy-to-understand format. It connects the frontend with the backend machine learning system.

8. Result Display Module

This module presents the output generated by the prediction system. The recommended fertilizer, water requirement, and estimated price are displayed clearly to the user through the web interface.

SYSTEM FLOW DIAGRAM



TABLE

Nitrogen (N)	Phosphorus (P)	Potassium (K)	Soil Moisture (%)	Temperature (°C)	Humidity (%)	Crop Type	Soil Type	Recommended Fertilizer	Water Level (mm)	Estimated Price (₹)
90	42	43	60	26	80	Rice	Clay	Urea	120	550
60	55	50	45	30	65	Wheat	Loamy	DAP	80	1350
75	35	30	50	28	70	Maize	Sandy	NPK 10-26-26	90	1200
40	60	20	35	32	60	Cotton	Black Soil	Super Phosphate	70	700
85	40	45	65	27	85	Sugarcane	Clay	Urea	140	550
55	50	60	48	29	68	Tomato	Loamy	NPK 20-20-20	85	1100
30	25	25	40	31	55	Groundnut	Sandy	Potash Fertilizer	75	900
70	48	38	58	26	78	Paddy	Clay	DAP	115	1350

CONCLUSION

The Fertilizer Recommendation System developed in this project leverages machine learning and data-driven analysis to enhance modern agricultural practices. By analyzing soil composition, crop type, and environmental factors, the system provides accurate and efficient fertilizer recommendations that can improve crop yield, reduce waste, and promote sustainable farming.

The implementation of a Decision Tree Classifier ensures high accuracy and interpretability, making it easier for farmers to understand and trust the recommendations. The Flask-based web application provides a user-friendly interface, allowing users to input soil and crop data and receive real-time predictions.

Compared to traditional methods that rely on generalized fertilizer guidelines or laboratory soil testing, this system is:

1. **Faster** – Delivers instant recommendations without requiring expensive and time-consuming soil testing.
2. **More Accurate** – Uses real-world agricultural datasets to train a machine learning model that tailors recommendations to specific conditions.
3. **Cost-Effective** – Reduces fertilizer waste, lowers input costs, and enhances crop productivity.
4. **Sustainable** – Promotes responsible fertilizer usage, minimizing environmental impact and preventing soil degradation.

Overall, this system represents a significant step forward in precision agriculture, enabling farmers to make informed, data-driven decisions that maximize yield while preserving soil health.

FUTURE ENHANCEMENTS

While the current system provides valuable insights for fertilizer application, there are several areas for future improvement and expansion.

1. Integration with IoT Sensors for Real-Time Monitoring

Currently, the system requires manual input of soil and environmental parameters. Future versions could integrate IoT-based soil sensors to:

- Automatically collect real-time data on soil moisture, temperature, and nutrient levels.
- Enhance prediction accuracy by continuously updating the dataset with live agricultural data.
- Send real-time alerts to farmers regarding nutrient deficiencies or fertilizer imbalances.

2. Expansion to Deep Learning Models

The current system uses a Decision Tree Classifier, which provides high interpretability. However, future enhancements could explore deep learning approaches like Convolutional Neural Networks (CNNs) or Recurrent Neural Networks (RNNs) for:

- More complex feature extraction from multi-dimensional soil datasets.
- Higher accuracy through adaptive learning as more data is collected over time.
- Integration of weather forecasting models to adjust fertilizer recommendations based on seasonal variations.

3. Mobile Application Development

Developing a mobile-friendly version of the application could:

- Enable offline functionality, allowing farmers to use the system in remote areas with limited

internet access.

- Include GPS-based soil mapping, helping farmers analyze specific regions of their land for different fertilizer needs.
- Improve adoption rates by making the technology more accessible on mobile devices.

4. Multi-Language Support for Wider Adoption

Many farmers, especially in rural areas, may not be proficient in English. Future versions of the system could:

- Support multiple regional languages, ensuring wider accessibility.
- Include voice-based inputs and responses, helping farmers interact with the system more easily.

5. Integration with Government Agricultural Databases

Collaboration with agricultural research centers and government agencies could provide:

- Access to updated soil fertility data from different regions.
- Better compliance with government policies on sustainable farming practices.
- Subsidy or policy recommendations alongside fertilizer suggestions.

6. Expansion to Global Agricultural Practices

Currently, the system is trained on a specific dataset that may be relevant to a particular region. Future work should:

- Expand the dataset to include soil and crop information from different climatic zones.
- Enable region-specific customization, allowing farmers from different countries to receive localized fertilizer recommendations.

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- "Soil Fertility and Crop Productivity: A Machine Learning Perspective" – International Journal of Agricultural Research.

Websites & Online Sources

1. Kaggle

<https://www.kaggle.com>

Useful for agricultural soil and crop datasets.

2. UCI Machine Learning Repository

<https://archive.ics.uci.edu/ml/index.php>

Provides structured machine learning datasets.

3. Scikit-learn Documentation

<https://scikit-learn.org/stable/documentation.html>

Reference for using machine learning models like Decision Trees.

4. Flask Official Documentation

<https://flask.palletsprojects.com/>

Helps build the web interface for your system.

5. GeeksforGeeks

<https://www.geeksforgeeks.org/>

Used to understand programming concepts, preprocessing, ML implementation.

6. W3Schools

<https://www.w3schools.com/>

Useful for building and styling your web interface (HTML/CSS).