

Smart Fertilizer Recommendation System

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Abstract

Efficient fertilizer management is critical for enhancing crop yield, ensuring sustainable agricultural practices, and minimizing environmental impact. This paper presents a web-based application that leverages machine learning techniques to predict the most suitable fertilizer type based on real-time agricultural parameters. The system integrates multiple models, including ExtraTrees, CatBoost, Decision Trees, Linear Discriminant Analysis, and Gradient Boosting, to analyze factors such as temperature, humidity, soil moisture, nutrient levels (nitrogen, phosphorus, potassium), soil type, and crop variety. The application provides accurate fertilizer recommendations tailored to specific conditions, enabling farmers and agricultural professionals to make informed decisions. Additionally, the platform offers user and admin interfaces for data input, feedback management, and access to fertilizer store information. Experimental results demonstrate the effectiveness of the proposed system in optimizing fertilizer use, improving crop productivity, and supporting sustainable farming. This work contributes to precision agriculture by combining data-driven insights with user-friendly technology to promote resource conservation and environmental sustainability.

Keywords: ExtraTrees, CatBoost, Decision Trees, Linear Discriminant Analysis, Fertilizer Recommendation, Gradient Boosting

1. INTRODUCTION

Agriculture plays a pivotal role in sustaining human life and supporting economies worldwide. With the global population continuously rising and the demand for food increasing correspondingly, enhancing agricultural productivity has become a critical challenge. Fertilizers are among the most important inputs in modern agriculture, supplying essential nutrients that promote healthy plant growth and maximize crop yields. These substances, whether chemical or organic, provide vital macronutrients such as nitrogen, phosphorus, and potassium, as well as micronutrients like iron, zinc, and manganese. These nutrients are indispensable for various physiological and biochemical processes within plants, including photosynthesis, nutrient uptake, and disease resistance. However, the effectiveness of fertilizers depends heavily on their appropriate selection and application, which must be tailored to specific soil conditions, crop types, and environmental factors.

Despite their benefits, improper fertilizer use is a widespread issue that can lead to significant problems. Over-application of fertilizers often results in nutrient runoff and leaching, which contaminate water bodies and contribute to

environmental issues such as eutrophication and soil degradation. Conversely, under-application can cause nutrient deficiencies, leading to poor plant growth and reduced yields. The challenge lies in accurately identifying the right type and quantity of fertilizer that meets the unique needs of a given agricultural setting. Traditional methods for fertilizer recommendation, including soil testing and expert consultations, are often time-consuming, costly, and inaccessible to many farmers, particularly in developing regions. Furthermore, these methods may not fully account for dynamic environmental variables such as temperature, humidity, and soil moisture, which significantly influence nutrient availability and crop requirements.

The rapid advancement of digital technologies and machine learning offers promising solutions to these challenges. Machine learning algorithms can analyze complex datasets containing multiple variables and uncover intricate relationships that are difficult to detect through conventional approaches. By integrating real-time environmental data, soil nutrient levels, crop types, and other relevant factors, machine learning models can generate precise and context-specific fertilizer recommendations. Such data-driven approaches enable more efficient nutrient management,

reduce resource wastage, and promote sustainable agricultural practices. This project aims to harness these technological advancements by developing a web-based application that predicts the most suitable fertilizer type based on comprehensive agricultural data inputs.

The proposed system incorporates multiple machine learning models, including ExtraTrees, CatBoost, Decision Trees, Linear Discriminant Analysis, and Gradient Boosting, to enhance prediction accuracy and robustness. These models collectively analyze inputs such as temperature, humidity, soil moisture, nitrogen, phosphorus, potassium levels, soil type, and crop variety to recommend the optimal fertilizer. By leveraging the strengths of diverse algorithms, the system mitigates the limitations of any single model and provides reliable recommendations tailored to specific conditions. This approach not only improves fertilizer selection but also supports precision agriculture by enabling farmers to make informed, data-driven decisions.

The web application is designed with a user-centric approach, featuring separate interfaces for farmers and administrators. Farmers can register and log in to input their agricultural data and receive real-time fertilizer recommendations. They can also access information about local fertilizer stores and share feedback on the system's performance. Administrators have the ability to manage user accounts, monitor and respond to feedback, and update fertilizer store information to ensure the platform remains relevant and useful. This dual-interface design facilitates smooth management and continuous improvement of the system while enhancing user engagement and satisfaction.

By providing accurate and timely fertilizer recommendations, the system addresses several critical issues in modern agriculture. It helps optimize fertilizer use, thereby improving crop yields and profitability for farmers. It also contributes to environmental sustainability by minimizing nutrient runoff and conserving soil health. Moreover, the application democratizes access to expert agronomic advice, empowering farmers with limited resources or technical knowledge to implement best practices. The integration of multiple machine learning models ensures that the system remains adaptable to varying agricultural scenarios, making it a versatile tool for diverse farming contexts.

This paper presents the conceptualization, development, and evaluation of the fertilizer prediction web application. It details the data collection process, feature selection, model training, and system implementation. Experimental results demonstrate the effectiveness of the proposed approach in generating accurate fertilizer recommendations and highlight its potential to support sustainable farming practices. Through this work, we aim to contribute to the growing field of precision agriculture by providing a practical, scalable solution that enhances fertilizer management and promotes resource conservation.

II.RELATED WORK

Smart Crop and Fertilizer Prediction System, Authors: C.P. Wickramasinghe, P.L.N. Lakshitha, H.P.H.S. Hemapriya, Anuradha Jayakody, P.G.N.S. Ranasinghe

This paper proposes a smart solution to assist Sri Lankan farmers in selecting the most suitable crops based on the nutrient content of the soil and to provide an optimized fertilizer plan. The system uses a tool embedded with sensors to analyze soil fertility and is paired with a cross-platform mobile application to suggest crops and fertilizer usage. The study addresses the gap in scientific knowledge among farmers and aims to enhance agricultural productivity while preventing soil degradation. Validation of sensor data against laboratory results demonstrated accuracy in detecting Nitrogen (N), Phosphorus (P), and Potassium (K) levels.[1]

IoT Based Smart Soil Fertilizer Monitoring and ML Based Crop Recommendation System, Authors: Md. Delwar Hossain, Mohammad Abul Kashem, Shabnom Mustary,

This paper introduces an IoT-based soil monitoring and machine learning-based crop recommendation system aimed at improving agricultural productivity. The system uses various sensors to collect real-time data on soil nutrients (N, P, K), temperature, moisture, humidity, and pH. These data are transmitted wirelessly to a cloud database and analyzed using machine learning algorithms like Decision Tree, Random Forest, and SVM. Based on the collected parameters and past data, the system recommends the most suitable crops for the specific soil conditions. This approach reduces excessive fertilizer use, supports informed decision-making,

and enhances crop yield, contributing to national agricultural growth.[2]

Portable Device for Supporting Fertilizer Recommendation System in Smart Agriculture, Authors: Rara Widya Paramartha Hapsari, Mochammad Zen Samsono Hadi, Prima Kristalina,

This paper presents a portable IoT-based device developed to support fertilizer recommendations in smart agriculture. The system incorporates sensors to measure soil parameters such as temperature, humidity, conductivity, pH, and nutrient levels (N, P, K), along with GPS for location tracking. Data is transmitted via LoRa to a cloud server, where a Decision Tree algorithm analyzes it to recommend suitable fertilizers. The web-based platform allows users to access real-time soil condition reports and recommendations. Experimental results show the system's high precision in detecting soil parameters and a 90% accuracy rate in fertilizer prediction, offering an efficient and environment-friendly solution for modern farming.[3]

Smart Irrigation System By Recommending Crop And Fertilizers, Authors: Sunilkumar A, A. Arokiaraj Jovith

This paper introduces a smart irrigation system that enhances precision agriculture by recommending optimal crops and fertilizers. The system uses the Light Gradient Boosting Machine (LGBM) algorithm to analyze historical crop yields and soil data, considering variables like pH, nutrients, and weather. For fertilizer prediction, a Random Forest algorithm is used to determine the appropriate type and quantity of fertilizer needed based on input parameters. The combined use of these machine learning models enables efficient and sustainable farming by providing accurate, data-driven recommendations for both crop selection and fertilizer application.[4]

IOT-Enabled Smart Crop Recommendation System Using Machine Learning, Authors: Saranya S S, Dharani A S, Kavitha M N, Selya Dharsnee M, Pragatheeswari E, Selya Varsnee M.

This paper proposes an IoT-enabled crop recommendation system using machine learning techniques to enhance agricultural productivity. By collecting real-time soil data

using sensors like FC-28, DHT11, and JXBS-3001, the system analyzes factors such as moisture, temperature, humidity, and NPK levels. Machine learning algorithms including SVM, KNN, Random Forest, and Decision Tree are employed to recommend suitable crops and fertilizers based on soil quality and location. This solution aims to empower farmers with data-driven, sustainable farming decisions that improve yield and resource efficiency.[5]

Smart Soil Monitoring System With Crop and Fertilizer Recommendation Features, Authors: Gourab Saha, Shabbir Hoshen Suvo, Farhan Tanjim Tonmoy, Jiad Bin Asad, Mohammed Thushar Imran, AKM Abdul Malek Azad.

This paper introduces a cost-effective and portable IoT-based smart soil monitoring system that measures nitrogen, phosphorus, potassium, pH, moisture, temperature, and humidity to recommend crops and fertilizers. The system uses a cloud platform and machine learning algorithms to analyze soil quality and provide accurate suggestions. With a user-friendly interface and wireless capability, the device supports real-time decision-making in agriculture. The solution aims to empower farmers—especially in developing regions—by improving crop yields and reducing misuse of fertilizers through data-driven insights.[6]

Agricultural Crop and Fertilizer Recommendations based on Various Parameters, Authors: B Mahalakshmi, V Sakthivel, B Sumitha Devi, S Swetha.

This paper presents a machine learning-based system designed to assist farmers—particularly in Tamil Nadu—by recommending appropriate crops and fertilizers based on various environmental and seasonal parameters. The system leverages data mining and techniques such as Linear Regression, Support Vector Regression, and ANFIS to analyze soil type, water availability, productivity, and seasonal patterns. The goal is to help farmers, especially new and inexperienced ones, make informed agricultural decisions despite unpredictable climate conditions, thereby boosting crop yield and ensuring sustainable farming practices.[7]

Smart Crop and Fertilizer Prediction System, Authors: C.P. Wickramasinghe, P.L.N. Lakshitha, H.P.H.S. Hemapriya, Anuradha Jayakody, P.G.N.S. Ranasinghe.

This study introduces a smart system designed to assist Sri Lankan farmers by recommending the most suitable crops and fertilizer plans based on the fertility of their soil. The system uses sensors to measure essential soil nutrients like nitrogen, phosphorus, and potassium, and employs a cross-platform mobile application to deliver personalized crop and fertilizer suggestions. By comparing sensor results with lab tests, the researchers confirmed the reliability of their system, aiming to reduce fertilizer misuse, increase productivity, and promote sustainable agriculture practices.[8]

Crop Recommendation System For Intelligent Smart Farming Technology, Authors: Vagisha Vagisha, E. Rajesh, Prasant Johri,

This paper presents a smart farming solution that uses IoT and machine learning to recommend suitable crops based on soil and environmental data. Leveraging sensors, 5G connectivity, and data analytics, the system monitors soil parameters such as pH, moisture, and nutrient content, and suggests crops using algorithms like Random Forest, XGBoost, and SVM. The model achieved an impressive accuracy of 99.09% with Random Forest, significantly improving decision-making for farmers. This approach reduces excessive fertilizer usage, enhances crop productivity, and promotes sustainable agriculture by enabling remote, real-time soil monitoring.[9]

Intelligent Decision Support System for Smart Agriculture, Authors: Kanchan Rufus Dabre, Hezal Rahul Lopes, Silviya Simpson D'monte

This paper proposes a fuzzy inference-based intelligent decision support system for smart agriculture, integrated with IoT technology. The system considers environmental parameters such as moisture, temperature, soil pH, nutrient levels, and pest activity to automate irrigation and recommend fertilizers and pesticides tailored to individual crops. It also incorporates geographic and climatic data to generate region-specific suggestions. The model aims to improve precision farming, conserve water, reduce chemical overuse, and ultimately increase both the quality and quantity of crop yields, contributing to sustainable agricultural development in India.[10]

III. METHODOLOGY

The methodology for the fertilizer prediction web application involves collecting and preprocessing agricultural data, selecting relevant features, training multiple machine learning models, evaluating their performance, and integrating the best models into a user-friendly web platform. The system uses environmental and soil parameters as inputs to generate accurate fertilizer recommendations, and it continuously improves through user feedback and updated data.

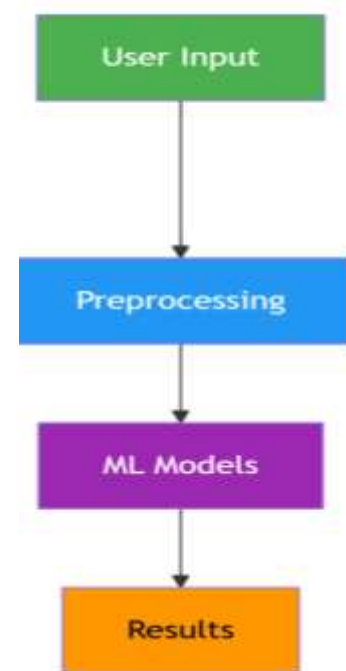


Fig 1. Proposed Methodology

1. Data Collection and Preprocessing

The process begins with the collection of diverse agricultural data, including soil nutrient levels (nitrogen, phosphorus, potassium), temperature, humidity, soil moisture, soil type, and crop type. These data are sourced from agricultural databases, research studies, and field sensors. Preprocessing steps such as handling missing values, normalizing numerical data, and encoding categorical variables ensure the dataset is clean and suitable for machine learning.

2. Feature Selection

To enhance model performance and interpretability, feature selection techniques are applied. Methods like correlation analysis and feature importance ranking help identify the most influential factors affecting fertilizer choice, reducing dimensionality and focusing the model on the most relevant inputs.

3. Model Training and Evaluation

Multiple machine learning algorithms—including ExtraTrees, CatBoost, Decision Trees, Linear Discriminant Analysis, and Gradient Boosting—are trained using the preprocessed data. The dataset is split into training and testing sets, and cross-validation is used to ensure robustness. Model performance is evaluated using metrics such as accuracy, precision, and recall, and the best-performing models are selected for deployment.

4. System Integration and Web Application Development

The selected models are integrated into a web application using frameworks like Flask or Django. The application features intuitive interfaces for both users and administrators, allowing users to input real-time agricultural data and receive fertilizer recommendations. Additional features include user feedback, registration, and access to fertilizer store information.

5. Continuous Improvement

The system is designed for ongoing enhancement. User feedback and new data collected through the application are periodically used to retrain and update the models, ensuring that recommendations remain accurate and relevant as agricultural practices and conditions evolve.

IV. TECHNOLOGIES USED

The fertilizer prediction web application leverages a combination of advanced technologies spanning machine learning, web development, and data acquisition to deliver accurate and user-friendly fertilizer recommendations.

1. Machine Learning Algorithms:

The core of the system is built upon several supervised machine learning algorithms, including ExtraTrees, CatBoost, Decision Trees, Linear Discriminant Analysis, and Gradient

Boosting. These algorithms are chosen for their effectiveness in handling classification tasks with complex, multi-dimensional agricultural data. In related systems, other algorithms such as Random Forest, Support Vector Machines (SVM), Logistic Regression, and Naive Bayes have also demonstrated high accuracy and robustness in fertilizer and crop prediction tasks. Ensemble approaches, which combine multiple algorithms, are often used to further enhance prediction reliability and precision.

2. Programming Languages and Libraries:

Python is the primary programming language used due to its extensive ecosystem for machine learning and data science. Key libraries include scikit-learn for implementing ML algorithms, pandas and NumPy for data manipulation, and matplotlib or seaborn for data visualization.

3. Web Development Frameworks:

The web application backend is commonly developed using Flask or Django, lightweight and powerful Python-based web frameworks that facilitate rapid development and easy integration with machine learning models. The frontend may utilize HTML, CSS, JavaScript, and frameworks like Bootstrap to create a responsive and intuitive user interface.

4. Data Acquisition:

To enable real-time, context-specific recommendations, the system can accept data from users. These users collect parameters such as soil moisture, temperature, humidity, and nutrient levels, which are then fed into the prediction models. This integration allows for dynamic, location-aware recommendations and supports precision agriculture practices.

5. Database Management:

A relational database management system (such as MySQL or PostgreSQL) or a NoSQL database (like MongoDB) is used to store user information, feedback, historical agricultural data, and fertilizer store details. This ensures secure and efficient data retrieval for both users and administrators.

6. Deployment and Scalability:

The application can be deployed on cloud platforms such as AWS, Azure, or Google Cloud, enabling scalability, high availability, and secure access for users across different regions.

By combining these technologies, the fertilizer prediction web application delivers robust, data-driven recommendations, supports real-time user interaction, and contributes to sustainable and efficient agricultural practices.

V Result

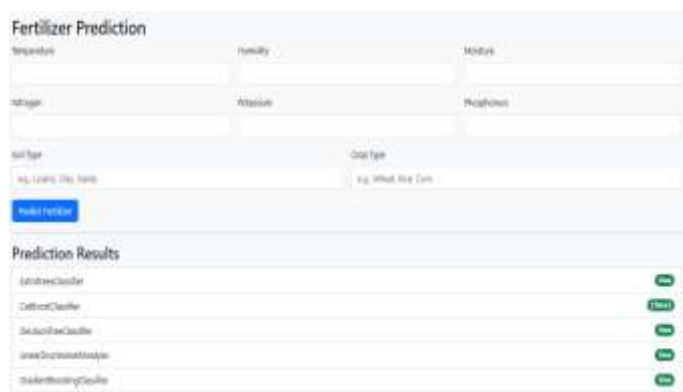
Prediction page



The screenshot shows a web form titled "Fertilizer Prediction". It contains input fields for Temperature (25), Humidity (55), Moisture (55), Nitrogen (20), Potassium (5), and Phosphorus (5). There are also dropdown menus for Soil Type (Sandy) and Crop Type (Rice). A "Predict Fertilizer" button is at the bottom.

User input parameters to predict fertilizer in this page.

Result page



The screenshot shows the same "Fertilizer Prediction" form, but with a "Prediction Results" section at the bottom. It lists four categories: Nitrogen Classifier, Potassium Classifier, Phosphorus Classifier, and Soil Classifier, each with a "View" button.

Fertilizer predicted is displaying in this page.

VI. CONCLUSION

In summary, the developed AI-powered skincare recommendation system successfully combines deep learning, computer vision, and web technologies to deliver accurate skin type classification and tailored product suggestions, addressing the limitations of traditional, subjective skincare assessments. By utilizing the MobileNetV2 architecture and a curated product database, the platform offers a user-friendly, accessible, and efficient solution that empowers individuals to make informed

decisions about their skin health. This integration of advanced technology into personal care not only enhances the effectiveness of skincare routines but also democratizes access to expert guidance, paving the way for future innovations in personalized healthcare and wellness.

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