Smart Soil Analysis & Crop Recommendation System

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Abstract

Agriculture plays a critical role in ensuring food security, yet farmers often face challenges in selecting the most suitable crops for their soil and climate. This research presents a Smart Soil Analysis & Crop Recommendation System that leverages sensor-based soil data and machine learning algorithms to provide accurate crop suggestions. The system measures key soil parameters such as pH, moisture, nitrogen, phosphorus, and potassium content, and integrates environmental factors like temperature and rainfall. Based on these inputs, predictive models analyze soil fertility and recommend optimal crops to maximize yield and sustainability. Experimental results demonstrate that the system can increase productivity and reduce resource wastage compared to traditional practices. This intelligent approach also empowers small-scale farmers by providing actionable insights in a user-friendly manner. The study concludes that combining IoT-enabled sensors with data-driven models enhances precision agriculture and contributes to sustainable farming practices.

Keywords: Soil Analysis, Crop Recommendation, IoT Sensors, Machine Learning, Precision Agriculture.

1. Introduction

Agriculture is the backbone of the economy in many countries, yet conventional farming methods often lead to suboptimal crop yields due to improper soil management and crop selection. Soil is the primary source of nutrients for plants, and its quality directly affects productivity. Modern technology enables real-time monitoring of soil conditions and provides data-driven recommendations for crop cultivation. A Smart Soil Analysis & Crop Recommendation System combines Internet of Things (IoT) sensors with machine learning techniques to analyze soil properties and recommend suitable crops. This research focuses on developing such a system to enhance agricultural efficiency, reduce input costs, and support sustainable farming. In addition to improving crop yields, a Smart Soil Analysis & Crop Recommendation System also addresses critical challenges faced by farmers, such as unpredictable weather, soil degradation, and inefficient use of fertilizers and water. By continuously monitoring soil parameters like pH, moisture, and nutrient levels, the system can detect deficiencies early and suggest corrective actions, preventing crop failure. Moreover, integrating historical soil data and environmental conditions with predictive analytics allows farmers to plan cropping patterns strategically over multiple seasons. This not only optimizes resource utilization but also promotes environmentally sustainable practices by reducing overuse of chemical fertilizers and minimizing soil erosion. Ultimately, such intelligent systems empower farmers to make informed decisions, increase productivity, and contribute to long-term food security and economic stability.

2. Review of Literature

The adoption of technology in agriculture has increased due to the need for precision farming and sustainable resource management. Several studies have focused on soil monitoring and crop recommendation using modern technologies. Ramesh and Kumar (2020) developed an IoT-based soil monitoring system that collects real-time data on soil moisture, pH, and nutrients, helping farmers detect deficiencies early, though it lacked predictive crop recommendations. Singh and Gupta (2019) used machine learning algorithms such as Decision Trees and Random Forest for crop prediction based on soil and environmental factors, but their study used a limited dataset and did not include real-time sensing. Patil and Sharma (2021) studied mobile applications that assist farmers in crop selection and fertilizer management, but these rely on manual data input, which may lead to inaccuracies. Earlier rule-based expert systems, such as those by Kaur and Arora (2018), provided structured recommendations but could not adapt to changing soil conditions. Zhang *et al*. (2020) suggested combining sensor data with predictive models for better soil fertility analysis, although full IoT integration was not implemented. Overall, existing systems face limitations such as limited sensor coverage, lack of large datasets, and absence of automated real-time crop recommendations. Therefore, there

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is a need for a comprehensive system that integrates IoT-based real-time soil sensing with machine learning to analyze nutrients (N, P, K), moisture, and pH, and provide accurate crop recommendations through a user-friendly interface. This research aims to develop a Smart Soil Analysis and Crop Recommendation System to improve crop yield and resource management. Swarm Optimization with Neural Networks for Effective Classification Techniques" by K. Kalyani (2021) introduces a hybrid EHBMO-NN model, combining Extended Honey Bee Mating Optimization with Artificial Neural Networks to improve classification accuracy and reduce training time. It uses HBMO to select optimal weights for neural network hidden layers, outperforming conventional methods on benchmark datasets. The accurate cancer classification is very important task for cancer treatment. Recently the informative genes are identified from the thousands of genes for correct cancer classification. The collection of microscopic Deoxyribo Nucleic Acid (DNA) microarray is attached in the solid surface. In this study, DNA microarray data is used for cancer classification. The accurate cancer classification is very important task for cancer treatment. Recently the informative genes are identified from the thousands of genes for correct cancer classification. The collection of microscopic Deoxyribo Nucleic Acid (DNA) microarray is attached in the solid surface. In this study, DNA microarray data is used for cancer classification (6).

3. Existing System

Traditional agriculture mainly relies on farmers' experience and manual soil testing for crop selection. Farmers usually test soil using kits or laboratory analysis to measure parameters such as pH, moisture, and basic nutrient levels, but this process is often time-consuming, costly, and not easily accessible to small-scale farmers, leading to delays in crop planting decisions. Some early automated approaches used rule-based expert systems that recommend crops based on predefined rules related to soil type or nutrient levels; however, these systems cannot adapt to changing environmental conditions like rainfall, temperature, or seasonal variations. In recent years, mobile and web-based applications have been introduced to help farmers select crops by manually entering data such as soil pH, temperature, and location, but these systems depend heavily on manual input and may produce inaccurate results without real-time monitoring. Sensor-based monitoring systems using IoT technology have also been developed to measure parameters like soil moisture, temperature, and pH, providing real-time data for better irrigation and fertilization decisions. However, most of these systems focus on limited parameters and often ignore essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K), lack predictive analytics for crop recommendation, and do not provide integrated actionable insights. Overall, existing systems suffer from fragmented data collection, limited accuracy due to manual input and insufficient sensor coverage, lack of predictive intelligence for optimized crop selection, and limited accessibility for small-scale farmers.

4. Proposed System

The proposed Smart Soil Analysis & Crop Recommendation System is designed to overcome the limitations of existing agricultural methods by integrating IoT-based soil monitoring with machine learning algorithms to provide intelligent crop recommendations. The system collects real-time soil data using IoT sensors that measure parameters such as pH, moisture, nitrogen (N), phosphorus (P), potassium (K), temperature, and humidity, with sensors placed at different points in the field to ensure accurate soil condition monitoring and wireless transmission of data to a central server. The collected data is then processed through a data processing module that filters noise, normalizes values, handles missing data, and stores both current and historical soil and environmental information in a database for long-term analysis. A machine learning–based recommendation engine uses predictive algorithms such as Decision Tree, Random Forest, or Support Vector Machine (SVM) to analyze soil parameters and compare them with historical data and optimal crop growth conditions to recommend the most suitable crops based on soil fertility, environmental factors, and expected yield. These recommendations are delivered to farmers through a user-friendly web or mobile interface that displays soil health reports, suitable crops, fertilizer requirements, irrigation schedules, and alerts for nutrient deficiencies or unfavorable environmental conditions. In operation, sensors continuously collect soil parameters, the data is cleaned and stored, the machine learning model predicts suitable crops for current soil and climate conditions, and the system provides actionable recommendations and alerts to farmers, enabling timely decisions. Key features of the system include real-time monitoring of soil parameters, multi-parameter analysis of pH, moisture, NPK nutrients, temperature, and humidity, predictive crop recommendation using machine learning, optimization of irrigation and fertilization to reduce resource wastage, and an accessible interface that allows farmers to easily monitor soil conditions and receive recommendations, ultimately improving crop yield and resource efficiency.

5. Experimental Result

The proposed Smart Soil Analysis & Crop Recommendation System was implemented and tested in selected agricultural fields to evaluate its effectiveness in both soil analysis and crop recommendation. Multiple soil samples were collected from different locations, and IoT sensors measured key parameters such as pH, moisture, nitrogen (N), phosphorus (P), potassium (K), temperature, and humidity. These data points were processed using a Random Forest machine learning model, which analyzed the soil fertility and environmental conditions to recommend the most suitable crops for each field.

The system's recommendations were compared with the suggestions provided by expert agronomists. Results indicated a high correlation, with a match accuracy of nearly 100% for all tested samples. For example, soil with a pH of 6.5, moisture 32%, and NPK values of 45, 20, and 150 ppm was accurately recommended for maize, while slightly acidic soil with a pH of 5.8 was suggested for rice, consistent with expert guidance. These results demonstrate the reliability of the proposed system in real-world conditions.

Further field trials were conducted to compare traditional farming methods with the system's recommendations. The experiments revealed that using the proposed system led to an 18% increase in crop yield, while simultaneously reducing fertilizer usage by 13% and water consumption by 12%. This indicates that the system not only improves productivity but also promotes sustainable resource management. Farmers also reported that the system's real-time alerts for soil nutrient deficiencies and environmental changes allowed them to take timely corrective actions, further enhancing crop performance.

In terms of performance, the system delivered soil parameter

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updates every 15 minutes, ensuring real-time decision-making. Overall, the experiments confirmed that the Smart Soil Analysis & Crop Recommendation System is effective in providing accurate, actionable recommendations, improving yield, and optimizing the use of fertilizers and water. This validates its potential as a valuable tool for precision agriculture and sustainable farming practices.

6. Conclusion

The Smart Soil Analysis & Crop Recommendation System presented in this research demonstrates a significant advancement in precision agriculture by combining IoT-based soil monitoring with machine learning algorithms. The system effectively measures key soil parameters such as pH, moisture, nitrogen, phosphorus, potassium, and environmental factors like temperature and humidity, providing real-time data that supports informed decision-making. Experimental results indicate that the system delivers crop recommendations with high accuracy, closely matching expert agronomist guidance, while also improving crop yield by up to 18% and reducing resource usage, including fertilizers and water. By offering actionable insights through a user-friendly interface, the system empowers farmers to optimize crop selection, reduce costs, and adopt sustainable agricultural practices. Overall, this research confirms that integrating intelligent soil analysis with predictive modeling can enhance agricultural productivity, support environmentally responsible farming, and contribute to long-term food security. Future work could extend the system by incorporating weather forecasting, pest and disease detection, and cloud-based analytics for broader scalability and automation.

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