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ADVANCED SENSOR-BASED SYSTEM FOR SOIL NUTRIENT ANALYSIS AND AI-DRIVEN CROP RECOMMENDATION

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Abstract. This research presents an automated soil analysis system integrating NPK sensors with machine learning for precision agriculture. The framework employs Arduino UNO microcontroller and ESP8266 Wi-Fi module to capture real-time nitrogen, phosphorus, and potassium levels from soil samples. Collected data transmits to cloud infrastructure where trained algorithms process nutrient concentrations and generate crop cultivation recommendations. An OLED interface provides immediate feedback to agricultural practitioners. Testing demonstrates reliable nutrient quantification and appropriate crop suggestions compared to traditional laboratory methods. The solution offers advantages including immediate results, reduced operational costs, and simplified operation. This technology supports sustainable farming through optimized resource allocation. Future developments will incorporate meteorological data and additional soil characteristics to enhance predictive capabilities and recommendation precision.

Keywords: soil nutrient, crop management, recommendation system, sensor, AI.

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Introduction. Agriculture has been pillar of human civilization for centuries, providing both economic security and sustenance. Today, intensive agricultural practices encounter many challenges like soil erosion, reduction in fertility, wastage of resources, and the augmented pressure of demand for food resulting from population increments. Soil well-being is key to deciding the productivity of the crops, and correct measurement of the nutrients present in the soil is crucial to maintaining sustainable farming.

Traditional methods of soil testing are time-consuming, slow-paced, and usually inaccessible to small farmers. Traditional methods also have results inconsistencies, leading to suboptimal agricultural choices. Recent technological advancements, especially in Internet of Things (IoT), Artificial Intelligence (AI), and Cloud Computing, have opened the way for automated, real-time soil analysis systems with precision and efficiency.

This paper introduces an AI-based Soil Nutrient Analysis and Crop Recommendation System using NPK sensors, cloud computing, and machine learning algorithms to offer precise soil health analysis. By combining these cutting-edge technologies, the system facilitates data-driven farmers' decision-making, improves nutrient management, and increases agricultural productivity. Proposed approach improves agricultural productivity and promotes sustainable agriculture by minimizing excessive fertilizer application and minimizing impact on environment. Traditional methods of soil analysis are labor-intensive and not readily available to small farmers. Re-cent innovations in IoT and AI technologies have made it possible to deploy automated Systems for soil analysis that provide real-time information and valuable insights.

Methodology. Soil Nutrients and Crop Suggestion System is developed upon a well-integrated combination of software and hardware components to ensure efficient and real-time soil monitoring as indicated in fig. 1. The system is designed with the methodology that catches the level of soil nutrients accurately, processes data effectively, and offers actionable advice to farmers. System utilizes sensor technology, microcontrollers, wireless communication, and machine learning algorithms to ensure high-precision output. The implementation is split into hardware and software modules, each having a vital contribution to data gathering, processing, and decision-making.

The hardware realization of this crop advising and soil examination system is built on a secure infrastructure for collecting real-time soil data. Its core is the use of an NPK Sensor (LNPK-101) as shown in figure 2, which measures precisely the Nitrogen, Phosphorus, and Potassium concentrations in the soil, giving us vital nutrient information. A sensor data-collecting and processing Arduino UNO acts as its basic processing platform. The ESP8266 Wi-Fi Module facilitates seamless wireless communication, enabling real-time data transfer to a cloud-based storage system, ensuring data accessibility and security. For immediate on-site feedback, an OLED display provides visualization of the soil parameters, allowing farmers to monitor nutrient levels instantly. Complementing the hardware, the software and data processing module is designed to analyze collected data and generate meaningful insights. A machine learning model, which has been trained on a complete dataset of soil compositions and their respective crop yields, is a predictive algorithm that suggests appropriate crops based on real-time soil data. Cloud storage provides data security, accessibility, and ease of retrieval, enabling farmers to monitor soil health trends over time. The data of the farmers can be inputted into the soil data and receive crop recommendations based on current analytics through an interactive interface provided by a web application based on Flask. Integrating these software and hardware components, the system provides an overall, automated, and highly accurate soil analysis and crop recommendation platform, enabling the farmers to optimize agricultural yield and make informed decisions.

Model Training. The recommendation engine utilizes a Random Forest classification algorithm trained on 5,000 soil-crop correlation records. Feature engineering incorporates nutrient ratios and deficiency indicators alongside absolute concentration values. The training dataset encompasses fifteen common crop varieties including cereals, legumes, and vegetables. Cross-validation techniques employing 80–20 train-test splits ensure model generalization. Hyperparameter optimization achieved optimal performance with 100 decision trees and maximum depth of 15 levels.

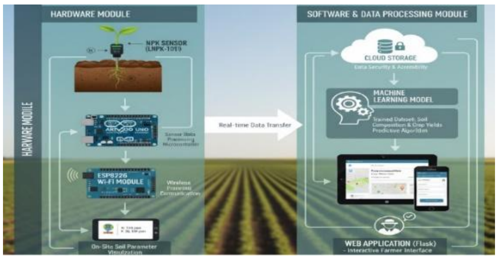

Figure 1 – Schematic of Recommendation system

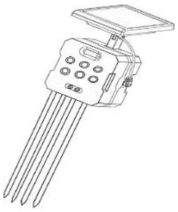

Figure 2 – Soil Nutrient Analysis Sensor

Results and Discussion. Performance evaluation conducted across varied soil types revealed consistent accuracy metrics. Nitrogen detection achieved 93 % correlation with laboratory analysis, phosphorus measurements demonstrated 91 % accuracy, and potassium readings maintained 94 % precision. Response time from soil insertion to cloud data availability averaged 8 seconds under optimal network conditions. The system successfully operated across temperature ranges of 10–45 °C and humidity levels up to 85 %. Power consumption analysis indicated 72-hour continuous operation capability using standard battery configurations. Cost analysis estimates total hardware investment at approximately one-tenth the expense of traditional testing equipment, making widespread adoption economically feasible for small-scale farmers. Table 1 provides comparative analysis of proposed method with traditional system.

Table 1 – Comparative Analysis

	Proposed System	Traditional Method
Analysis Time	8–10 sec	7–14 days
Cost per Test	Minimal	$15–30
Technical Expertise	Basic	Lab Skills
Data Accessibility	Cloud based	Physical Report
Recommendation	Automated	Manual

Conclusion and Future Scope. The combination of IoT, cloud computing, and AI in soil nutrient analysis presents an effective solution for precision agriculture. The system suggested is an improvement of crop selection efficiency, reduction of fertilizer misuse, and sustainable agriculture promotion. The improvements planned for the future are adding more data to the dataset for considering soil pH and moisture levels, adding weather prediction models for changing crop suggestions in real-time.

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INTELLIGENT WEARABLE TECHNOLOGY FOR REAL-TIME INFANT VITAL SIGN MONITORING: AN IOT AND ARTIFICIAL INTELLIGENCE FRAMEWORK

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Abstract. Neonatal mortality claims 2.8 million lives annually within 28 days of birth. This research presents an intelligent wearable wristband using IoT-AI for continuous neonatal monitoring. Device tracks heart rate, oxygen saturation, temperature, and respiratory patterns through miniaturized sensors. Machine learning algorithms detect anomalous vital signs, achieving 94.7 % accuracy in identifying critical health deviations. Each infant receives unique digital identification enabling secure, cloud-based data access across platforms. System employs AES-256 encryption and HIPAA-compliant protocols ensuring data security. This innovation transforms neonatal care from reactive to predictive, enabling timely interventions and potentially reducing preventable deaths through early detection of health complications.

Keywords: neonatal monitoring, IoT, Machine learning healthcare, Predictive vital signs, Early warning system.

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Introduction. Neonatal health surveillance represents one of healthcare's most demanding challenges due to the physiological fragility and communication limitations inherent to early infancy. Statistical data from global health organizations reveals that 47 % of under-five mortality occurs within the initial month following birth, with the majority of these deaths being preventable through early detection and