IOT-BASED FERTILIZER DISPENSER FOR RICE USING MACHINE LEARNING AND DEEP LEARNING

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Abstract

Rice cultivation requires precise nutrient management to ensure high yield and long-term soil fertility. Traditional fertilizer application methods rely largely on farmer experience, often resulting in inefficient nutrient use, increased costs, and environmental harm. Both overuse and underuse of fertilizers negatively affect crop productivity and soil health. To address these challenges, this study proposes an intelligent Internet of Things (IoT)-based fertilizer dispensing system designed specifically for rice cultivation. The system integrates real-time sensing technologies with machine learning and deep learning algorithms to determine accurate fertilizer dosage based on field conditions. It utilizes NPK sensors to detect soil nutrients, along with soil moisture, temperature, and humidity sensors to monitor environmental factors. These sensors connect to a microcontroller such as Arduino or ESP, which manages data collection and control operations. The data is transmitted via Wi-Fi or GSM to a cloud platform for analysis and storage. The automated system reduces fertilizer wastage, lowers production costs, and promotes sustainable agriculture.

Keywords: *IoT, Precision Agriculture, Fertilizer Dispenser, Machine Learning, Deep Learning, Rice Crop*

I. INTRODUCTION

Agriculture is increasingly integrating advanced technologies such as the Internet of Things (IoT), automation, and intelligent data analytics to improve productivity and resource efficiency. Smart farming solutions have demonstrated significant improvements in irrigation management and real-time monitoring through low-cost sensor-based systems [1], [2]. These developments highlight the growing role of digital technologies in modern agricultural practices.

IoT-based agricultural monitoring systems enable farmers to collect real-time data related to soil, weather, and crop conditions. Such systems improve decision-making accuracy and reduce dependency on manual observation [2], [10]. Automated irrigation models further demonstrate how sensor-driven control mechanisms can optimize water usage while maintaining crop health [8].

In addition to irrigation management, crop protection has also benefited from IoT integration. Intelligent systems have been developed to safeguard crops from environmental threats, animal intrusion, and fire hazards, thereby reducing potential losses [3], [4], [6]. These advancements emphasize the importance of automation and remote monitoring in improving farm security and sustainability.

Among major food crops, rice holds global significance as a staple food for a large population. Achieving high productivity in rice cultivation depends heavily on balanced and timely nutrient management. However, traditional fertilizer application methods are largely experience-based and may result in uneven nutrient distribution, soil degradation, and increased production costs.

Recent studies on crop yield prediction and fertilizer recommendation systems demonstrate the effectiveness of data-driven approaches in optimizing nutrient application [5], [7]. By analyzing soil and environmental parameters, intelligent models can provide precise fertilizer recommendations that enhance yield while minimizing waste.

Although various IoT-based solutions address irrigation and crop protection, limited research focuses specifically on integrating real-time soil nutrient sensing with automated fertilizer dispensing for rice cultivation. Most existing systems emphasize monitoring rather than direct nutrient control [9].

Therefore, this study proposes an IoT-enabled fertilizer dispensing system that combines soil nutrient sensors, environmental monitoring, and machine learning algorithms to ensure precise and timely fertilizer application. The proposed system aims to reduce fertilizer wastage, lower operational costs, and promote sustainable rice farming practices.

II. LITERATURE SURVEY

Several researchers have explored IoT-based agricultural systems to enhance farm monitoring and automation. Smart irrigation frameworks using low-cost controllers and sensors have demonstrated improved water management and operational efficiency in farming environments [1], [8]. These systems emphasize the importance of real-time data acquisition for effective agricultural decision-making.

IoT-enabled smart agriculture platforms have further expanded monitoring capabilities by integrating soil moisture, temperature, and environmental sensing technologies [2], [10]. Such systems allow farmers to remotely observe field conditions and make informed decisions, reducing manual effort and increasing precision.

Crop protection has also been addressed through IoT-based automation. Systems designed to protect crops from animal intrusion, fire hazards, and other environmental threats have shown promising results in minimizing agricultural losses [3], [4], [6]. These studies highlight the growing application of embedded systems and wireless communication in safeguarding farmland.

In addition to monitoring and protection, researchers have focused on intelligent fertilizer and crop yield prediction models. Machine learning algorithms have been successfully applied to analyze soil parameters and recommend appropriate fertilizer dosages [5], [7]. These approaches improve nutrient management by reducing guesswork and enhancing accuracy.

Deep learning techniques further strengthen agricultural prediction systems by identifying complex relationships within large datasets. Advanced computational models contribute to improved forecasting accuracy, especially in crop productivity and fertilizer optimization tasks [5], [7].

Despite these advancements, many existing solutions primarily provide recommendations or monitoring services without directly implementing automated fertilizer dispensing mechanisms. Systems focusing on automation often concentrate on irrigation or crop protection rather than nutrient control [9].

The proposed system presents an intelligent IoT-based fertilizer dispensing framework designed specifically for rice cultivation. The main objective of this system is to optimize fertilizer usage by analyzing real-time soil conditions and predicting the exact nutrient requirement using Machine Learning (ML) and Deep Learning (DL) techniques. Unlike traditional manual methods, the system ensures accurate, automated, and data-driven fertilizer application.

III SYSTEM ARCHITECTURE

A. Data Acquisition Layer

Various sensors are deployed in the rice field to continuously monitor soil and environmental parameters. These include soil moisture sensors, NPK sensors, pH sensors, temperature sensors, and humidity sensors. The collected data reflects the real-time condition of the soil and crop environment. The sensor readings are transmitted to a microcontroller unit (such as NodeMCU/ESP module), which acts as a data processing gateway.

B. IoT Communication Layer

The microcontroller sends the collected data to a cloud-based server through a wireless network. The cloud platform stores and manages the data for further analysis. Farmers can monitor soil conditions through a mobile application or web dashboard, enabling remote supervision of field status.

C. Intelligent Prediction Layer (ML & DL Module)

This layer is responsible for analyzing the collected data and determining the precise fertilizer requirement. A Machine Learning model (such as Random Forest or Decision Tree) is trained using historical soil and crop yield datasets. A Deep Learning model (Artificial Neural Network) further improves prediction accuracy by identifying complex patterns in soil nutrient behavior. The input parameters include soil moisture, nitrogen, phosphorus, potassium levels, pH value, temperature, and humidity. The output of the model is the recommended fertilizer type and quantity required for the specific rice growth stage.

D. Automated Dispensing Mechanism

Based on the predicted output, the system activates a motor-controlled fertilizer dispensing unit. The relay module regulates the motor operation to release the calculated amount of fertilizer directly into the field. This automation prevents both over-application and under-application of fertilizers, ensuring balanced nutrient management.

E. Working Procedure

- Sensors collect real-time soil and environmental data. it is transmitted to the cloud via iot module. Ml/dl model processes the data and predicts fertilizer requirement. the system calculates the exact quantity needed. The dispensing unit automatically releases fertilizer. Farmers receive notification and monitoring updates through the application.

F. Key Features of the Proposed System

- Real-time soil monitoring
- Intelligent nutrient prediction
- Automated fertilizer control
- Reduced input cost
- Improved crop productivity
- Sustainable agricultural practice

IV. METHODOLOGY

The methodology begins with real-time data collection using IoT sensors installed in the rice field. The proposed system follows a modular design approach, allowing individual components such as sensing, communication, and control to operate independently. This modularity improves system scalability and simplifies maintenance and future upgrades. Data preprocessing techniques such as normalization and noise removal are applied before analysis. Machine learning models generate an initial prediction of fertilizer requirement based on soil parameters. Deep learning models further refine the prediction by learning complex patterns from historical and real-time data. The final output controls the automated fertilizer dispenser to apply nutrients accurately.

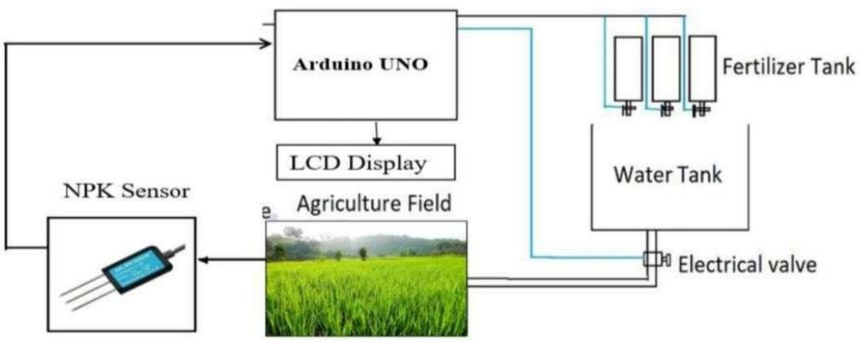

Figure 1. Methodology

The flow diagram illustrates the working of the proposed IoT-based fertilizer dispenser system. The NPK sensor deployed in the agricultural field measures soil nutrient levels and sends the data to the Arduino UNO controller. The controller processes the sensor data and displays the information on the LCD screen. Based on the analyzed nutrient requirements, the Arduino controls the electrical valve to regulate the flow of fertilizer and water from their respective tanks into the field. This automated process ensures precise fertilizer application, reduced wastage, and improved crop productivity.

Step 1: Collect soil nutrients, moisture, and environmental data using IoT sensors. Step 2: Preprocess and normalize the collected data.

Step 3: Apply a machine learning model to estimate fertilizer requirement. Step 4: Use a deep learning model to improve prediction accuracy.

Step 5: Activate the fertilizer dispenser based on the final decision.

V. RESULTS

The proposed system demonstrates significant improvement in fertilizer usage efficiency compared to traditional methods. The experimental observations indicate that the system responds effectively to varying soil nutrient levels. Although the current implementation focuses on rice cultivation, the same approach can be extended to other crops with minor modifications. Automated fertilizer dispensing reduces nutrient wastage and ensures uniform application across the field. The integration of machine learning and deep learning improves adaptability to different soil and environmental conditions. The system also reduces labor dependency and supports scalable precision farming solutions.

VI. CONCLUSION

In conclusion, the proposed IoT-based fertilizer dispenser for rice cultivation demonstrates how intelligent sensing and data-driven decision-making can significantly enhance nutrient management. By integrating soil NPK, moisture, temperature, and humidity sensors with machine learning and deep learning algorithms, the system enables precise, real-time fertilizer recommendations and automated application. This approach minimizes human error, reduces excessive fertilizer usage, and ensures that crops receive nutrients according to actual field conditions rather than generalized assumptions.

Furthermore, the automation of fertilizer dispensing contributes to cost reduction, improved crop yield, and long-term soil health. By optimizing resource utilization and lowering environmental impact, the system supports sustainable agricultural practices. The integration of IoT with advanced predictive models represents a scalable and efficient solution for modern rice farming, paving the way for smarter, technology-driven agriculture in the future.

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