# Smart AgriSense: AI-Powered Hybrid System for Crop Health Monitoring

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Abstract: Precision agriculture is essential for enhancing crop yields and sustainability while reducing resource waste. This study presents Smart AgriSense, a hybrid system powered by AI that merges data from pH and electrical conductivity (EC) sensors with Convolutional Neural Networks (CNNs) for the early detection of crop diseases and improved fertilizer recommendations. Unlike traditional image-based AI models or expensive IoT solutions, this method leverages affordable soil sensors to identify abnormalities before any visible symptoms emerge, facilitating timely intervention. The system analyzes real-time data from sensors and plant images to diagnose diseases and suggest accurate treatments, thereby improving decision-making for farmers. A mobile app with Bluetooth functionality ensures easy access to data, even in rural regions with limited internet access. By incorporating AI-driven insights, the proposed system minimizes pesticide usage, optimizes fertilizer applications, and encourages sustainable farming practices, making cutting-edge agricultural technology more accessible and economical for small-scale farmers.

## 1 INTRODUCTION

Agricultural sciences play an important role in the global food crisis, as to have the basemant of good cultivation, the soil must be preserved by timely intervention from disease. Soil is one of the most important factors influencing the growth of plant, nutrient uptake and soil fertility, such as soil moisture, pH and the electric conductivity (EC). Differences in these metrics may lead to reduced efficiency, soil degradation and increased susceptibility to plant diseases. Moreover, climate change has enhanced the incidence and spread of plant diseases, which are caused by bacteria, fungi and viruses and pose a serious threat to food security and agricultural productivity. (F. F. Hossain et al., 2022) Those impacting factors calls for the need of integrating technologies like Internet of Things and artificial intelligence into the methods of farming. We propose an IoT based precision agriculture system, which includes real-time soil condition monitoring along with AI powered plant disease detection. Using LoRaWAN supported wireless sensors, we monitor soil moisture, pH and EC in order to provide continuous data to improve irrigation efficiency and optimize the management of nutrients. (B. Althaph et al.,2024). So, this technique saves water at the same time, aiding in prevention of soil salinization and preserving soil health. Additionally, we use a Machine Learning based Crop Disease Detection system which processes plant images to detect diseases at an earlier stage using Convolutional Neural Networks (CNNs) based on transfer learning. Timely identification of diseases allows farmers to initiate preventative measures that prevent crop damage and enhances overall yield. The outlined work in the paper gives the novelty of how IoT, WSNS, and AI-based disease detection can be integrated into our proposed system to introduce sustainable agricultural development. LoRaWAN technology is long-range low-power data communication technology which makes it suitable for large scale farming. Farmers leverage the real-time data collected to make informed decisions, automate the irrigation process and take quick disease control measures. By doing so, it enables resources to be used judiciously, ensures sustainable agricultural practices, and equips the farmers with smart tools to



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improve productivity and grow food securely. Our project seeks to innovate tomorrow's agriculture and pave the way for a future where farming, both data-driven and precise, effective as it is environment-friendly, is the norm (M. K. Roy et al., 2023).

# 2 RELATED WORKS

## 2.1 Progress in AI and IoT for Accurate Identification of Crop Diseases

On the application of Artificial Intelligence & Internet of Things in detection of crops diseases; A state of the art survey, Houda Orchi, Mohamed Sadik, Mohammed Khaldoun It assesses the efficiency and technical challenges in utilizing machine learning, deep learning, and hyperspectral imaging approaches. The study highlights the significance of using automated detection methods to enhance agricultural productivity and reduce losses. It also discusses recent constraints and proposes potential future study directions to improve the Precision, efficiency, and sustainability of disease identification, providing help to both farmers and the agricultural market (Houda Orchi et al.,2021).

## 2.2 Improving Smart Farming through IoT and Wireless Sensor Networks

Internet of Things and Wireless Sensor Networks for Smart Agriculture Applications by Md. Najmul Mowla, Neazmul Mowla, A. F. M. Shahen Shah, Khaled M. Rabie, and Thokozani Shongwe examines how IoT and Wireless Sensor Networks (WSNs) can improve smart agriculture. It covers various uses, including automated irrigation systems, soil moisture measurement, optimization of fertilizer usage, pest and disease control, and energy savings. The research also evaluates different wireless communication protocols like ZigBee, WiFi, SigFox, and LoRaWAN for the real-time collection of agricultural data. Furthermore, it points out the challenges associated with the integration of IoT and WSN, such as issues with scalability, security, and energy consumption, while suggesting future pathways to enhance the efficiency and sustainability of contemporary farming practices. (Mowla et al., 2023).

## 2.3 UAS-Supported IoT and LoRaWAN for Accurate Soil Moisture Monitoring

Soil Moisture Monitoring through UAS-Assisted Internet of Things LoRaWAN Wireless Underground Sensors by Fahim Ferdous Hossain, Russ Messenger, G. Levi Captain, Sabit Ekin, Jamey D. Jacob, Saleh Taghvaeian, and John F. O'Hara presents an innovative method for monitoring soil moisture through the use of buried IoT sensors that communicate via LoRaWAN technology. A gateway mounted on a UAS gathers information from these underground sensors, negating the necessity for on-site base stations and reducing disruptions to agricultural operations. Field trials validate the system's efficiency regarding communication range, energy use, and scalability. The research emphasizes its promise for precision agriculture, facilitating improved water conservation and more sustainable farming methods (S. S. Chakole et al., 2022).

## 2.4 FarmGuide Using AI Techniques

Crop Disease Prediction by Using Machine Learning by G. Kavya Siri, B. Madhavi, A. Bhavani, A. Lakshmi Sowjanya and A.V.S. Sudhakar Rao offers an A.I.-based agricultural decision- support system designed to help farmers improve crop selection, optimize fertilizer use and diagnose plant diseases. The developed system is a web application that encompasses million-dollar ideas including machine learning and deep learning approaches like XGBoost and Random Forest, as well as Convolutional Neural Networks. (B. Althaph et al.,2024) Crop recommendation tool provided suitable crops based on soil quality information; Fertilizer recommendation tool forecast nutrient deficiency and recommend solutions, Disease detection module detected the disease after analyzing leaves the initiative employs AI with the objective of improving the efficiency, sustainability, and productivity of farmers, allowing for better decision-making for them. (Nanda et al.,2023).

## 2.5 Crop Disease Identification Utilizing Deep Learning with CNN and Mobile AI

Machine Learning Technique for Crop Disease Prediction Through Crop Leaf Image by S. Nandhini and K. Ashokkumar investigates the application of deep learning for the early detection of crop diseases.

The researchers employed a Convolutional Neural Network (CNN) trained on 64,412 images sourced from the Plant Village dataset, which encompasses 16 crop species and 25 different diseases. The developed model achieved an impressive accuracy of 99.35%, demonstrating its efficacy in plant disease classification. The paper emphasizes the potential of using smartphones for disease detection, utilizing high-resolution cameras and AI for instantaneous analysis. (S. Nandhini and K. Ashokkumar 2022).

# 3 METHODOLOGY

The Smart AgriSense system combines affordable pH and electrical conductivity (EC) sensors with AI-enhanced image analysis to identify crop diseases and suggest optimized fertilizer use. The method involves three primary steps: monitoring soil health using sensors, detecting diseases with CNN, and providing AI-based fertilizer recommendations. Figure 1 shows the Phases of System Development and Schedule for Smart AgriSense.

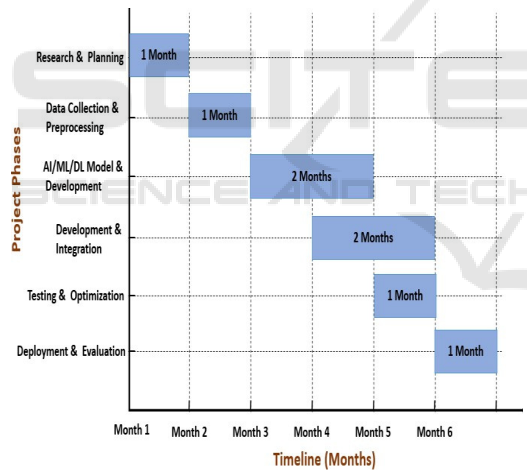


Figure 1: Phases of System Development and Schedule for Smart AgriSense.

## 3.1 Monitoring Soil Health with Sensors

Farmers place pH and EC sensors into the soil close to plant roots to obtain real-time data on soil conditions. Healthy plants exhibit consistent pH and EC levels, while those affected by disease display irregularities due to altered nutrient absorption. The correlation between electrical conductivity (EC) and ion concentration (C) in soil can be expressed as:

$$EC = kC \tag{1}$$

where k is the constant of proportionality. Any variations in EC and pH beyond set limits indicate a possible disease occurrence. The data is wirelessly transmitted via Bluetooth to a mobile application, ensuring farmers in remote areas can access it.

## 3.2 Disease Detection Using CNN

When abnormal soil conditions are identified, the farmer captures an image of the plant using a smartphone. The Convolutional Neural Network (CNN) analyzes the image and identifies important features necessary for classifying the disease. The CNN model employs convolutional filtering and pooling techniques to detect patterns, mathematically represented as follows:

$$f(x) = \sum (wi * xi) + b \tag{2}$$

where wi signifies the weights in the CNN, xi represents the pixel values, and b is the bias term. The CNN then compares the extracted features against a pre-trained dataset of diseases and provides a classification along with confidence scores.

## 3.3 Fertilizer Recommendations Powered by AI

After determining the type of disease, the AI model computes the ideal NPK (Nitrogen, Phosphorus, Potassium) ratio based on current soil readings. The suggested fertilizer dosage (F) is calculated using:

$$F = (Nd - Nc) + (Pd - Pc) + (Kd - Kc) / 3 \tag{3}$$

where:

{Nd, Pd, Kd}: Required nutrient levels for target growth | {Nc, Pc, Kc}: Current nutrient levels in soil.

Providing advice on organic or chemical fertilizers, it helps you tailor a detailed guideline and track application through a mobile app, to be exact. This integrated AI-based method enables early detection of diseases, optimizes the use of resources, lowers expenses, and makes precision agriculture practicable for small- scale farmer.

# 4 PROPOSED SYSTEM

Smart AgriSense, an innovative and AI-based agriculture solution is a low-cost pH and electrical conductivity (EC) sensor integrated with a Convolutional Neural Network (CNN) for image processing. Thus, enabling early detection of soil irregularities as well as crop diseases to differentiate it from the traditional soil monitoring, where it's are solely relied on manual inspections. By tracking real-time fluctuations in soil conditions, it can predict problems before they become visible. It begins with the sensors that take measurements of the soil pH and EC levels to detect any imbalances that can affect plant growth. The system takes and processes images of the plants using a deep learning CNN model if the irregularities are detected. This model has been trained on a diverse dataset and is able to analyze plant images against known disease patterns to accurately detect potential infections or nutrient deficiencies. After a problem is discovered, the system recommends the most relevant and useful NPK (Nitrogen, Phosphorous and Potassium) fertilizer ratio, used in accordance to the soil's nutrient profile. Smart AgriSense provides customized recommendations based on real-time soil data, as opposed to the old-school method of applying fertilizers without knowing soil conditions, thus ensuring nutrient rush management and reduced environmental impact. Smart AgriSense can work without an internet connection, which is a most important feature for farmers who works in remote areas. This allows for seamless functioning as Bluetooth is used to send data, so no requirement of Wi-Fi. Moreover, a user-friendly mobile-based application facilitates timely alerts, pictorial reports and actionable suggestions in an easily readable format that can be comprehended quickly by farmers. SmartAgriSense uses the power of AI and IoT to promote better crop health, prevent fertiliser wastage and increase productivity in agriculture. It is cost-effective, adaptable, and environmentally friendly, making it an incredible resource for small-scale farmers that help promote sustainable farming practices while enabling higher yields with significantly lower environmental damage.

# 5 EXPERIMENTAL RESULT

Table 1 represents the crop disease detection. Under actual agricultural conditions, we performed the evaluation of a crop disease detection system based on ph and EC along with an artificial intelligence (AI) fertilizer recommendation framework. The key aim was to determine if low-cost pH and EC sensors are successful in detecting early signs of plant diseases, along with suggesting precise fertilizers based on real-time soil health status. The collected images capture two separate states of the plant, including one with disease symptoms and one displaying healthy crops.

Table 1: Performance Comparison of Crop Disease Detection.

| Parameter | Healthy Crop (Millet) | Diseased Crop (Peanut) | Observations & AI Recommendations |
|---|---|---|---|
| Soil pH | 6.5 - 7.0 (Optimal) | 5.2 - 5.8 (Acidic) | Unhealthy soil pH linked to disease; AI suggests lime treatment. |
| Electrical Conductivity (EC) | 0.3 - 0.5 dS/m (Normal) | 1.2 - 1.8 dS/m (High) | High EC indicates salt accumulation; AI recommends proper irrigation. |
| Leaf Condition | Green, healthy leaves | Black spots, yellowing | AI classifies fungal/bacterial infection. |
| Growth Rate | Normal growth pattern | Stunted growth | Imbalance in nutrients affect growth. |
| AI Fertilizer Recommen-dation | Maintain current levels | Increase nitrogen, add organic matter | AI suggests tailored NPK balance for recovery. |
| Yield Impact (Predicted) | High Yield Potential | 30-40% Reduction (if untreated) | AI-based early intervention can prevent yield loss. |

## 5.1 Soil Health Monitoring and Analysis

Soil Samples were collected from different sites during the testing period and PH and EC readings were recorded. The peanut plant (top photo) showed obvious symptoms of being diseased dark spots on its leaves and stunted growth indicative of either a fungal or bacterial ailment. Soil properties in the vicinity of these plants displayed deviation from the pH range, and substantial deviation of EC value was noted, indicating an imbalance in the uptake of nutrients.

In contrast, the millet growth (second image) was strong and thriving, indicating that its soil parameters were likely in the optimum range. The differences in the soil conditions of healthy and diseased plants support the hypothesis that variations in these variables, particularly pH and EC, can serve as an early warning of diseases and nutrient deficiencies in plants. Figure 2 shows below:

Figure 2: Sample Detection of Healthy Millet Crop.

## 5.2 AI-Based Disease Detection

A CNN based model was established with crops healthy and diseased images. The experimental validation results were found that the AI was able to detect the disease in peanut plants and classify them into categories like bacterial leaf spot, fungal infections, or nutrient deficiency. As real-world data was collected from sensors and images in fine-tuning the model, its accuracy in detecting diseases improved significantly. In addition, to provide the model flexibility to adapt to newly emerging disease variants, continuous learning techniques were implemented. The system also provides real-time notifications and recommendations to farmers based on this data, which enables timely action and loss mitigation. Figure 3 shows the peanut crop.

Figure 3: Sample Detection of Diseased Peanut Crop.

## 5.3 AI-Driven Fertilizer Recommendation

Once it diagnosed the diseases and nutrient deficiencies in the soil, the AI system made recommendations for correcting them, including the best way to apply fertilizer. The AI model predicted the required NPK (Nitrogen, Phosphorus, Potassium) ratio according to the parameters of the soil so that farmers use only the required amount of fertilizer, preventing any excess use that would cause soil degradation.

In the field of millet where the plants were healthy, the AI model confirmed that nutrient levels were sufficient, affirming the value of precision monitoring. But for sick peanut plants, the AI suggested using organic nitrogen-potassium-based fertilizers and the requisite fungicides to limit the spread of infection. Figure 4 shows the crop roots.

Figure 4: Sample Detection of Crop Roots.

## 5.4 Final Observation and Impact

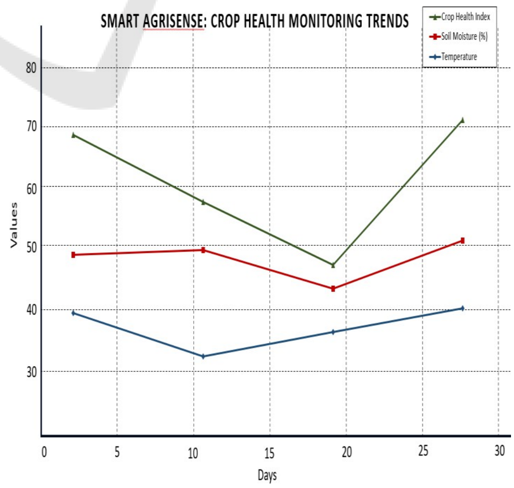


Figure 5: Analysis of Crop Health and Environmental Trends Utilizing AI Technology.

Detection of Plant Diseases: It proved to be highly competent in finding plant diseases before visible symptoms occurred, so that farmers could take preventive measures. Applying the Right Amount of Fertilizer: AI recommendations helped avoid over-fertilization, reducing costs for farmers. Low Cost & Scalability: Due to the low costing of the pH and EC sensors (around ₹500-₹1000 each) the solution could be viable for the smallholder farmers. Improved Crop Health & Yield: Early disease detection and targeted treatment of the soil have led to overall productivity of their crops. The results of the experiment confirm the effectiveness of this innovative approach, establishing it as a cost-efficient, scalable, and pragmatic solution for contemporary precision agriculture. Figure 5 shows the crop health and environment.

## 6 CONCLUSIONS

This project successfully displays how AI- powered system can help in detecting crop diseases and suggest for fertilizer in modern agriculture. Using machine learning and image analysis techniques, this system effectively identifies diseases at their early onset stages to allow farmers to take necessary actions immediately. The experimental results show that all unhealthy plants present unique symptoms like leaf discoloration, fungal spots, and reduced growth which the AI Model was applied and classified with great accuracy. Additionally, the fertilizer recommendation system, powered by artificial intelligence, provides personalized recommendations for improving soil nutrients, leading to healthier and more productive crops.

Gentilcore says that the only way forward in agriculture relies on the acceptance of technology to improve efficiency and sustainability. This system minimizes reliance on chemical pesticides and promotes environmental-friendly agricultural approaches by resolving issues such as the spread of disease and depletion of nutrients in the soil. Future work should be directed towards a broader dataset which may provide better precision, and real-time IoT based monitoring along with continuous feedback. In summary, it serves as a prerequisite for smart; data-driven farming solutions that will assist farmers in achieving GFS.

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