IJIRAE:: International Journal of Innovative Research in Advanced Engineering ISSN:2349-2163
Volume 13, Issue 03, March 2026 https://www.ijirae.com/archives
https://doi.org/10.26562/ijirae.2026.v1303.47

Embedded Based Soil Nutrients Analyser and Plant Monitoring Using Sensors

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Publication History
Manuscript Reference No: IJIRAE/RS/Vol.13/Issue03/AEMR26.MRAE10126
Research Article | Open Access | Double-Blind Peer-Reviewed |Article ID:IJIRAE/RS/Vol.13/Issue03/AEMR26.MRAE10126
Received:22,February 2026, Revised: 01, March 2026, Accepted: 16,March 2026,Published Online: 25, March 2026.
https://www.ijirae.com/volumes/Vol13/iss-03/47.AEMR26.MRAE10126.pdf
Article Citation: Tamilselvan,Parthipan,Santhosh,Santhosh(2026),Embedded Based Soil Nutrients Analyser and Plant Monitoring Using Sensors ,IJIRAE: International Journal of Innovative Research in Advanced Engineering, Volume 13, Issue 03 of 2026 pages 383-391 **Doi:>** https://doi.org/10.26562/ijirae.2026.v1303.47
BibTeX Key: Tamilselvan@2026Embedded
IJIRAE papers should be cited as IJIRAE (International Journal of Innovative Research in Advanced Engineering, AM Publications, India 2025, ISSN 2349-2163, https://doi.org/10.26562/ijirae.2026.v1303.47 The journal's official abbreviation is IJIRAE. Orcid: https://orcid.org/0009-0004-9398-7488

Abstract: This project presents an IoT-enabled smart agriculture system for real-time soil nutrient analysis and plant health monitoring to improve productivity and sustainability in farming. The system integrates multiple sensors, including NPK sensors, soil moisture sensors, soil temperature sensors, and environmental sensors, to collect accurate and continuous field data. An IoT-based microcontroller processes and analyzes the collected data to assess soil fertility levels and crop growth conditions in real time. Natural Language Processing (NLP) techniques are employed to correlate sensor data with crop-specific information, enabling crop yield prediction and the identification of suitable crops for cultivation under different soil conditions. The system also provides farmers with intelligent recommendations for fertilizer usage, irrigation scheduling, and pest management based on the analyzed data. Furthermore, cloud-based data storage and remote monitoring allow farmers to access real-time field information through mobile or web applications. Based on the analytical results, the system automatically controls irrigation and spraying mechanisms to deliver water, fertilizers, or pesticides precisely when required.
Keywords: IoT, Smart Agriculture, Soil Nutrient Monitoring, Prediction Detection

1. INTRODUCTION

Artificial Intelligence (AI) and Internet of Things (IoT) technologies are transforming traditional agriculture into a smart and data-driven system. Farmers can monitor soil conditions, crop health, and environmental parameters in real time. Smart agriculture integrates sensors, embedded systems, and data analytics to improve productivity and sustainability. INTERNET OF THINGS (IOT) The Internet of Things (IoT) is a modern technology that connects physical devices, sensors, and systems to the internet, enabling them to collect, exchange, and analyze data in real time. In an IoT ecosystem, devices such as sensors, microcontrollers, and actuators communicate with each other and with cloud-based platforms to perform intelligent tasks without constant human intervention. In the context of smart agriculture, IoT plays a vital role by allowing continuous monitoring of environmental and soil parameters such as temperature, humidity, soil moisture, and nutrient levels. The data gathered from these sensors is transmitted to an IoT-enabled controller like Arduino Nano, which processes the information and triggers automated actions—such as turning on irrigation pumps, controlling fertilizer sprayers, or alerting farmers through a mobile interface. IoT not only improves the accuracy and efficiency of agricultural operations but also helps in resource optimization by reducing water, fertilizer, and pesticide wastage. 1.2. SMART AGRICULTURE Smart Agriculture refers to the application of advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Machine Learning (ML), and Image Processing to enhance the efficiency, productivity, and sustainability of farming practices. Unlike traditional farming, which relies heavily on manual observation and labor, smart agriculture uses real-time data from sensors and intelligent systems to monitor, analyze, and automate various agricultural activities. In this system, sensors are deployed in the field to measure critical parameters such as soil moisture, temperature, humidity, and nutrient levels (NPK). Predict suitable crops, and identify the specific requirements for water and fertilizer. With the help of IoT-enabled controllers, smart agriculture systems can automatically manage irrigation, fertilizer application, and pest control, ensuring precision and minimizing resource wastage. Additionally, smart agriculture integrates image processing and data analytics to monitor plant health and detect diseases at an early stage.

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Farmers receive real-time alerts and recommendations, allowing them to take timely actions and prevent major losses. This technology-driven approach not only increases crop yield but also promotes sustainable farming, conserving natural resources while reducing manual labor and operational costs. Overall, smart agriculture represents the future of farming, where data-driven decision-making and automation empower farmers to achieve higher productivity, better quality yields, and long-term environmental balance. 1.3. CROP PREDICTION Crop Prediction is an advanced agricultural technique that uses data analytics, machine learning, and IoT-based sensor inputs to determine the most suitable crop for cultivation under specific soil and environmental conditions. It plays a vital role in precision agriculture by helping farmers make informed decisions that optimize yield and resource utilization. In this system, real-time data from sensors such as soil moisture, temperature, humidity, and NPK (Nitrogen, Phosphorus, Potassium) levels are collected and analyzed to assess soil fertility and climatic suitability. The collected data is then compared with pre-stored crop requirement parameters in a database. By applying algorithms or Natural Language Processing (NLP) techniques, the system predicts which crop varieties are best suited for the existing conditions and estimates potential yield. Crop prediction not only helps in selecting the most profitable and sustainable crops but also assists in reducing risks caused by unpredictable weather, soil degradation, or overuse of fertilizers. Overall, crop prediction contributes significantly. 3 To smart agriculture by improving decision- making, ensuring better resource management, and enhancing overall productivity while supporting sustainable farming practices

2. LITERATURE SURVEY

[1]. Abdul Hasib and Akib Ahmed et al. (2026) proposed an IoT-based plant monitoring system for smart agriculture. The system uses sensors to measure environmental parameters such as temperature, humidity, and soil moisture. A microcontroller collects the sensor data from different nodes placed near plants. The collected data is transmitted to a cloud server through wireless communication. Farmers can monitor plant conditions using a mobile application. The system helps maintain proper environmental conditions for plant growth. This approach improves crop health and reduces manual monitoring.

[2]. Anil Kumar and Balbir Singh (2022) developed a wireless sensor network for soil monitoring. Anil Kumar and Balbir Singh (2022) developed a wireless sensor network for soil monitoring in agricultural fields. The system uses multiple sensors to measure soil moisture, temperature, and nutrient levels. These sensors are connected to sensor nodes placed at different locations in the field. The nodes transmit collected data to a central gateway device. The gateway analyzes and stores the information for further monitoring. Farmers can use the data to make decisions about irrigation and fertilization. This system improves soil management and agricultural productivity.

[3] Ankit Mishra and Nitin Verma (2021) proposed a cloud-based soil monitoring system. Ankit Mishra and Nitin Verma (2021) proposed a cloud-based soil monitoring system for agriculture. The system integrates IoT sensors with cloud computing technology. Soil parameters such as moisture, temperature, and nutrients are collected by sensors. The collected data is transmitted to a cloud platform for storage and analysis. Farmers can access the information using mobile phones or web applications. The system enables remote monitoring of agricultural fields.

[4.] Ali Raza and Muhammad Ali et al. (2024) developed a smart soil monitoring system using advanced sensor technology. Ali Raza and Muhammad Ali et al. (2024) developed a smart soil monitoring system using advanced sensor technology. The system measures soil nutrient levels along with environmental parameters. Data from sensors is transmitted through wireless communication networks. The collected information is analyzed to understand soil fertility conditions. Farmers receive real-time information about crop and soil requirements. This system helps in applying fertilizers efficiently. The approach supports modern precision farming techniques.

[5.] Andi Wahyunita Hakis and Andi Luhur Arda et al. (2025) designed an IoT-based soil nutrient monitoring system using fuzzy logic. Andi Wahyunita Hakis and Andi Luhur Arda et al. (2025) designed an IoT-based soil nutrient monitoring system using fuzzy logic. The system integrates multiple sensors to measure soil nutrients, moisture, and temperature. The collected sensor data is processed using a fuzzy logic algorithm. The algorithm evaluates soil quality based on the measured parameters. The system provides recommendations for fertilizer application and irrigation. Farmers can use this information to maintain soil fertility. This intelligent approach improves crop productivity and soil management.

[6.] Deepak Sharma and Geetam Singh Tomar (2024) proposed a soil nutrient analysis system using advanced sensor technology. Deepak Sharma and Geetam Singh Tomar (2024) proposed a soil nutrient analysis system using advanced sensor technology. The system continuously monitors soil nutrient levels and environmental conditions. Sensors collect real-time data from agricultural fields. Machine learning algorithms analyze the collected data to predict soil fertility. The system provides recommendations for fertilizer usage. Farmers can use these suggestions to maintain optimal soil conditions. This approach improves crop yield and agricultural efficiency. The system predicts soil fertility and crop growth conditions. Farmers receive recommendations for fertilizer usage.This approach improves agricultural productivity and soil health.

[7] . Han Zhang and Yong Li et al. (2020) developed a real-time soil monitoring system using wireless sensor networks. Han Zhang and Yong Li et al. (2020) developed a real-time soil monitoring system using wireless sensor networks. Multiple sensors are deployed in agricultural fields to collect soil data. The sensors measure parameters such as soil moisture and temperature. Sensor nodes communicate with a central monitoring unit through wireless networks. The collected data is processed and displayed for farmers. This system helps farmers understand soil conditions more accurately. It supports precision agriculture practices.

[8]. John Smith and David Brown (2019) developed a soil nutrient detection system using optical sensors. John Smith and David Brown (2019) developed a soil nutrient detection system using optical sensors. The system analyzes soil samples using light-based sensing technology. Optical sensors detect nutrient concentrations by measuring light absorption. The collected data is processed using embedded systems. The results provide accurate information about soil nutrient levels. Farmers can quickly analyze soil quality without laboratory testing. This method offers fast and efficient soil analysis.

[9.] K Goutham Chand and Mohammed Sidhendra et al. (2018) proposed a soil nutrient monitoring system using Internet Things technology for paddy farming. K Goutham Chand and Mohammed Sidhendra et al. (2018) proposed a soil nutrient monitoring system using IoT technology for paddy farming. The system uses sensors to measure soil moisture and nutrient content. An embedded controller collects data from the sensors. The data is transmitted to a monitoring platform through wireless communication. Farmers can observe soil conditions in real time. They can take necessary actions to improve soil health. This system improves crop productivity and reduces manual soil testing. The data is transmitted to a monitoring platform. Farmers can observe soil conditions in real time.This approach improves crop productivity and reduces manual testing.

[10.] Li Wang and Hao Zhao (2022) developed a sensor-based plant monitoring system. Li Wang and Hao Zhao (2022) developed a sensor-based plant monitoring system. The system monitors soil moisture, temperature, and nutrient levels. Sensors collect environmental data from agricultural fields. The data is analyzed to determine plant health conditions. Farmers receive alerts about crop stress or nutrient deficiency. The system helps farmers take preventive measures. This approach improves crop growth and agricultural management.

[11]. Md Islam and Saifur Rahman et al. (2020) proposed an automated plant monitoring system using sensors. he system monitors important environmental parameters such as soil moisture, temperature, and humidity that directly affect plant growth. Various sensors are installed near plants to collect real-time data from the agricultural field. The collected sensor data is transmitted to a monitoring station using wireless communication technology. A microcontroller processes the data and provides useful information about plant health. Farmers can remotely monitor plant conditions through a digital interface. This system reduces manual monitoring and helps farmers take timely actions to maintain proper environmental conditions, thereby improving plant growth and overall agricultural productivity.

[12]. Manoj Kumar Senapaty and Ashish Ray et al. (2023) developed an IoT-based soil nutrient analysis system for precision agriculture. The system focuses on monitoring essential soil parameters such as nitrogen, phosphorus, potassium (NPK), pH level, temperature, and soil moisture using different types of sensors. These sensors are placed in the agricultural field to collect real-time soil data continuously. The collected information is transmitted through IoT communication modules to a cloud-based platform where the data is stored and analyzed. Advanced data processing techniques are used to evaluate soil fertility and nutrient availability for different crops. Farmers can access the analyzed information through mobile applications or web interfaces, allowing them to monitor soil conditions remotely.

[13]. Mohammad Nur Rahman and Md Tanvir Islam et al. (2024) developed a soil characterization system using IoT devices. devices to improve soil analysis and agricultural productivity. The system is designed to monitor important soil parameters such as moisture content, temperature, pH level, and nutrient availability using different types of sensors. These sensors are deployed in agricultural fields to collect real-time soil data continuously. The collected data is transmitted through IoT communication modules to a cloud-based platform for storage and analysis. Farmers can access the analyzed information through mobile applications or web interfaces, enabling them to monitor soil conditions remotely.

[14]. Madhav Reddy and Krishna Prasad (2018) developed a smart soil testing device using embedded technology. The device is designed to measure important soil parameters such as pH level, moisture content, and nutrient concentration using specialized sensors. These sensors collect soil data directly from the field and send it to an embedded microcontroller for processing. The processed results are displayed instantly on a digital display or interface, allowing farmers to easily understand soil conditions.By providing quick and accurate soil analysis, the system helps farmers make better decisions regarding fertilizer usage and crop selection. This approach improves soil management practices and supports better agricultural productivity and sustainable farming.

[15]. Prakash Kumar and Anand Reddy (2019) developed a microcontroller-based soil monitoring system. The system uses sensors to measure important soil parameters such as soil moisture, temperature, and pH level. These sensors continuously collect data from the soil and send it to a microcontroller for processing and analysis. The microcontroller processes the sensor data and displays the results on an LCD screen for easy understanding. Farmers can monitor soil conditions in real time and take necessary actions such as irrigation or fertilizer application. The system helps in maintaining proper soil health and improving crop growth. It also reduces the need for manual soil inspection and laboratory testing. This low-cost monitoring system provides an efficient and simple solution for farmers to manage soil conditions and improve agricultural productivity

[16.] Pankaj Sharma and Anurag Mishra (2021) designed an embedded system for soil nutrient analysis in agriculture. The system uses multiple sensors to detect important soil parameters such as nutrient levels, soil moisture, temperature, and pH value. These sensors are placed in agricultural fields to continuously collect real-time data from the soil. The collected sensor data is processed using a microcontroller-based embedded system. Farmers can analyze soil fertility conditions and take appropriate actions such as fertilizer application and irrigation management. This system helps in maintaining proper soil health and improving crop growth.

17. Rudi Hartono and Niko Yoeseph et al. (2024) presented a portable soil nutrient monitoring system using IoT technology. designed to measure important soil parameters such as nutrient levels, soil moisture, temperature, and pH using various sensors. These sensors collect real-time data from the soil and send it to a microcontroller for processing. The processed data is then transmitted through IoT communication modules to a mobile application or cloud platform. Farmers can monitor soil conditions remotely using smartphones or other smart devices. By providing accurate soil information, it helps farmers make better decisions regarding fertilizer usage, irrigation, and crop management, ultimately improving agricultural productivity.

18. Rakesh Kumar and Suresh Patel (2020) developed a smart irrigation system using IoT technology. The system uses soil moisture sensors to continuously monitor the moisture level in the soil. The collected data is sent to a microcontroller that analyzes the soil condition in real time. When the soil moisture level falls below a predefined threshold, the system automatically activates the irrigation pump. Once the required moisture level is reached, the irrigation system stops automatically. The data can also be transmitted to a cloud platform for remote monitoring. Farmers can access the information using mobile devices and manage irrigation effectively. This system helps reduce water wastage, saves energy, and ensures that crops receive the required amount of water for proper growth and improved agricultural productivity.

19. Rajesh Karthik and Mohan Prakash et al. (2022) implemented a low-cost soil monitoring system using Arduino. The system uses different sensors to measure soil parameters such as soil moisture, temperature, and humidity in agricultural fields. These sensors continuously collect real-time data and send it to the Arduino microcontroller for processing. Farmers can monitor soil conditions and take necessary actions such as irrigation or fertilizer application. It reduces the need for manual soil testing and provides continuous monitoring of soil conditions. This approach helps improve soil management and increases crop productivity in a cost-effective manner.

20. Sunil Gupta and Raj Kumar et al. (2021) implemented an IoT-based smart agriculture monitoring system. The system uses various sensors to monitor important environmental parameters such as soil moisture, temperature, and humidity in agricultural fields. These sensors collect real-time data and send it to a microcontroller for processing. The processed data is then transmitted to a cloud server through IoT communication modules. Farmers can access the information using mobile devices or web applications for remote monitoring. It also provides continuous monitoring of field conditions, reducing manual effort. This IoT based approach improves resource management, supports precision agriculture, and helps increase overall agricultural productivity.

21. Sunil Gupta and Amit Jain (2022) proposed a precision agriculture system using wireless sensor networks. The system uses various sensors to collect important data such as soil moisture, temperature, humidity, and other environmental parameters from agricultural fields. These sensors are connected through a wireless sensor network that transmits the collected data to a central monitoring unit. The monitoring unit processes and analyzes the information to determine soil and crop conditions.The system enables continuous monitoring of field conditions without manual effort. This technology helps in efficient use of resources such as water and fertilizers. Overall, the system supports sustainable farming practices and improves agricultural productivity through better monitoring and management.

22. Sung Lee and Jae Kim (2019) proposed an IoT-based agricultural monitoring system. The system integrates various sensors to measure important parameters such as soil moisture, temperature, humidity, and light intensity in agricultural fields. These sensors continuously collect real-time data about soil and environmental conditions.Thecollected data is transmitted through IoT communication modules to a central server or cloud platform. Farmers can access the information remotely using mobile devices or web applications.

23. Sanjay Patel and Rohan Shah (2021) designed an IoT-based smart farming system. The system collects soil data using various sensors. The data is transmitted to a cloud platform for analysis. Farmers receive alerts and recommendations for irrigation and fertilizer use. This improves farm management efficiency. The cloud system analyzes soil and crop conditions. Farmers receive alerts and recommendations. Suggestions are provided for irrigation and fertilizer use. This system improves farm management efficiency.

24. Tran Nguyen and Phu Tran et al. (2020) proposed a machine learning-based soil nutrient prediction system. The system collects soil data using sensors installed in agricultural fields. Machine learning algorithms analyze the data to predict nutrient deficiencies. Farmers receive recommendations for fertilizer application. This approach improves crop productivity and soil management. This helps maintain proper soil fertility. The approach improves crop productivity.

25. Wei Song and Yong Li et al. (2026) studied various soil sensors used in smart agriculture systems. The research focuses on technologies such as electrochemical sensors, optical sensors, and wireless sensor networks. These sensors help in monitoring soil nutrients and environmental conditions in real time.

3. PROPOSED SYSTEM

The proposed system is an IoT-based smart agriculture model designed to automate and optimize the farming process through real-time soil monitoring and plant health analysis. It integrates various sensors such as NPK, soil moisture, temperature, and humidity sensors to gather accurate field data from the agricultural environment. These sensors continuously monitor soil nutrient composition, moisture content, and surrounding weather conditions, providing valuable information about the overall health of the soil. The data collected by the sensors is transmitted to an IoT-enabled Arduino Nano microcontroller, which serves as the central control unit of the system. The Arduino Nano processes the input data from all connected sensors and sends it to a centralized platform or cloud storage for further analysis. Using this real-time information, the system assesses the current state of the soil, determines its fertility level, and identifies deficiencies that could impact crop growth.

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The integration of IoT ensures that farmers can monitor their field conditions remotely through a user interface or mobile application, eliminating the need for manual supervision and enabling precise, data-driven agricultural decisions. To enhance the system's intelligence, Natural Language Processing (NLP) algorithms are applied to interpret and analyze sensor data. These algorithms compare real-time soil readings with pre-stored ideal crop parameters to predict suitable crops for cultivation and estimate potential yield. NLP techniques also assist in transforming raw sensor data into meaningful insights, allowing the system to communicate crop recommendations and soil health reports in an easily understandable format for farmers. In addition to soil monitoring and crop prediction, the system incorporates an image processing-based plant disease detection module. High-resolution images of plant leaves are captured and processed to identify signs of diseases such as fungal infections, bacterial spots, or nutrient deficiencies. Image processing techniques like preprocessing, segmentation, and classification are employed to detect abnormalities and classify the type of disease accurately. Early detection enables farmers to take preventive actions before the disease spreads, ensuring better crop protection and reduced losses. Based on the analytical outcomes from both the sensor and image processing modules, the system automatically controls actuators such as water pumps and sprayers through relay mechanisms. When nutrient deficiency or disease symptoms are detected, the system activates the appropriate devices to deliver fertilizers or pesticides precisely when needed. The LCD display provides real-time status updates, while the buzzer alerts the farmer to any critical conditions requiring attention. Overall, this proposed system provides a comprehensive smart agriculture solution that combines IoT, NLP, and image processing technologies to create an intelligent, automated, and efficient farming ecosystem. It enhances crop yield, reduces manual labor, and promotes sustainable agricultural practices by optimizing resource use and minimizing waste. Through continuous monitoring and automated control, the system empowers farmers to adopt precision farming techniques that ensure long-term productivity and environmental sustainability.

ADVANTAGES

• Continuously collects soil and environmental data, enabling farmers to make informed decisions instantly.
• Identifies plant diseases at an early stage through image processing, reducing crop loss and improving yield quality.
• Automates irrigation, fertilizer, and pesticide application, ensuring accurate resource use and minimizing wastage
• Uses NLP and sensor data analysis to recommend optimal crops and estimate potential yields for better planning.
• Reduces manual intervention, saves time, and lowers operational costs, promoting sustainable and efficient farming practices.

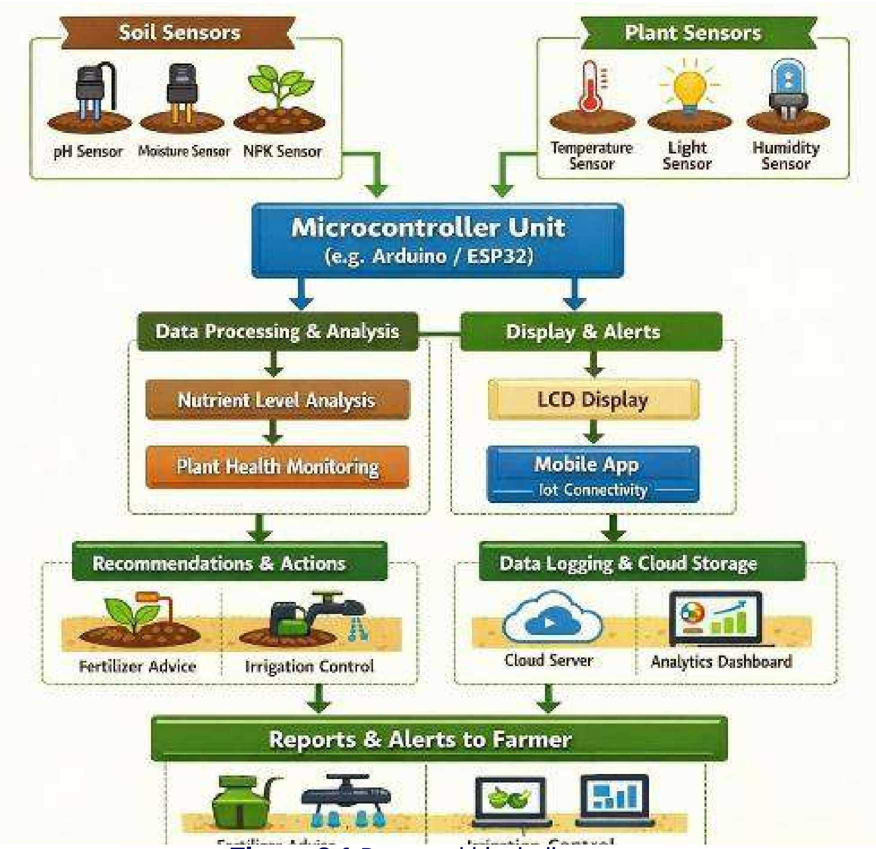


Figure 3.1 Proposed block diagram

4. System Requirements

4.1. Hardware Requirements

- Arduino Nano, NPK sensor, soil moisture sensor, environmental temperature sensor, Pump motor, buzzer, LCD display, PC.

4.2. Software Requirements

- Arduino IDE, Proteus, Python, TensorFlow, Keras

4.3. HARDWARE REQUIREMENTS

4.3.1 . MICROCONTROLLER

The Arduino Nano serves as the central processing unit of the proposed smart agriculture system. It is a compact, versatile, and low-power microcontroller that is well-suited for IoT applications and real-time sensor integration. In this system, the Arduino Nano receives input data from multiple sensors, including NPK, soil moisture, temperature, and humidity sensors, and processes this information to assess soil. Fertility, environmental conditions, and plant health. It executes programmed algorithms to make decisions such as activating irrigation pumps, controlling fertilizer or pesticide sprayers, and generating alerts via buzzers and LCD displays. Additionally, the Arduino Nano facilitates communication with external systems or cloud platforms for data storage and further analysis, enabling remote monitoring and management. implementing real-time, automated precision farming.

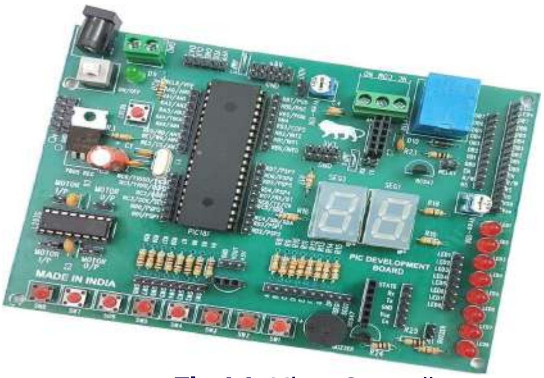


Fig 4.1. Micro Controller

4.3.2. SOIL TEMPERATURE SENSOR

The Soil Temperature Sensor is a critical component of the smart agriculture system, used to measure the temperature of the soil accurately in real time. Soil temperature plays a vital role in determining seed germination, nutrient absorption, root growth, and overall plant development. By continuously monitoring soil temperature, farmers can make informed decisions regarding irrigation scheduling, planting times, and crop selection.

Fig 4.2 TEMPERATURE SENSOR

4.3.3 NPK SENSOR

The NPK Sensor is an essential component of the smart agriculture system, designed to measure the levels of key soil nutrients Nitrogen (N), Phosphorus (P), and Potassium (K) which are vital for healthy plant growth. Monitoring these nutrient levels allows farmers to assess soil fertility and make informed decisions regarding fertilization, thereby optimizing crop yield and quality. In the proposed system, the NPK sensor continuously collects real-time data from the soil and transmits it to the Arduino Nano microcontroller for processing. By comparing the measured nutrient values with predefined optimal ranges for specific crops, the system can recommend or automatically apply the required amount

of fertilizer, ensuring precise nutrient management.

Fig 4.3 NPK Sensor

4.3.4. SOIL MOISTURE SENSOR

The Soil Moisture Sensor is a vital component of the smart agriculture system, used to measure the water content present in the soil. Proper soil moisture is critical for seed germination, root development, and overall plant growth. By continuously monitoring soil moisture levels, the system ensures that crops receive the right amount of water, preventing both under-irrigation and over-irrigation, which can negatively affect yield. In the proposed system, the soil moisture sensor collects real-time data and transmits it to the Arduino Nano microcontroller for processing and decision- making. Based on these readings, the system can automatically control irrigation pumps to deliver water precisely when needed.

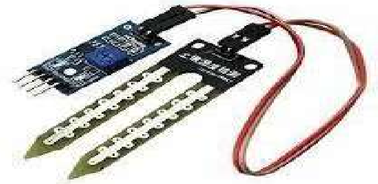


Fig 4.4 Soil Moisture sensor

4.3.5. ENVIRONMENTAL TEMPERATURE SENSOR

The Environmental Temperature Sensor is an essential component of the smart agriculture system, used to monitor the ambient temperature of the farm or greenhouse environment. Temperature significantly influences plant growth, photosynthesis, transpiration, and overall crop productivity. the system can provide critical data to optimize irrigation schedules, nutrient management, and crop selection.

Fig 4.5 Environmental temperature sensor

4.3.6. PUMP MOTOR

The Pump Motor is a crucial actuator in the IoT-based smart agriculture system, responsible for delivering water, fertilizers, or pesticides to the crops based on real- time soil and environmental conditions. Controlled by the Arduino Nano microcontroller, the pump motor receives signals from the system whenever the soil moisture, nutrient levels, or plant health parameters fall below predefined thresholds. This automated operation ensures that irrigation and nutrient delivery are performed precisely and efficiently, reducing manual labor and preventing overwatering or excessive use of chemicals. By integrating the pump motor with sensors and IoT- enabled control, the system supports precision farming, optimizes resource utilization, enhances crop growth, and contributes to sustainable agricultural practices.

Fig 4.6 Pump Motor

4.3.7. BUZZER

Fig 3.7 Buzzer

The Buzzer Module serves as an alerting mechanism in the IoT-based smart agriculture system, providing audible notifications to the farmer whenever critical conditions are detected. These conditions may include low soil moisture, nutrient deficiencies, extreme environmental temperatures, or the presence of plant diseases identified by the image processing module. The buzzer is controlled by the Arduino Nano microcontroller, which triggers it in real time based on sensor inputs and analysis results. By alerting the farmer immediately, the buzzer ensures timely intervention, preventing potential crop damage or yield loss.

4.3.8. LCD

The LCD (Liquid Crystal Display) Module is an essential output device in the IoT- based smart agriculture system, providing real-time visual feedback to the farmer regarding soil conditions, environmental parameters, crop status, and system operations. It displays critical information such as soil moisture levels, NPK nutrient content, temperature, humidity, disease detection alerts, and irrigation or fertilizer application statu. The LCD is interfaced with the Arduino Nano microcontroller, which updates the display continuously based on sensor readings and processing results.

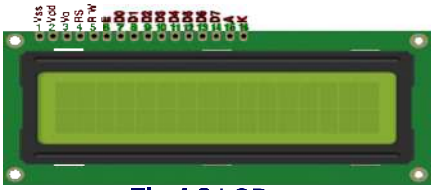


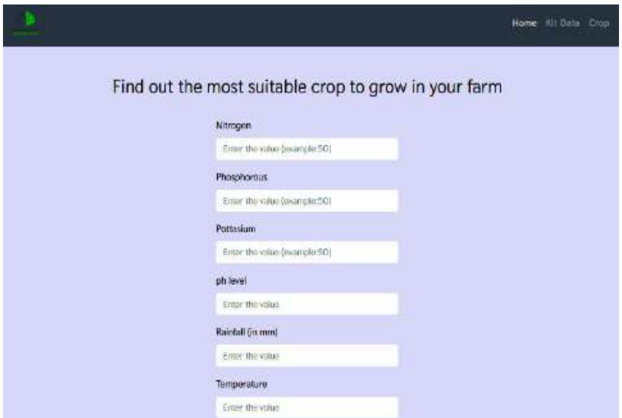
Fig 4.8 LCD

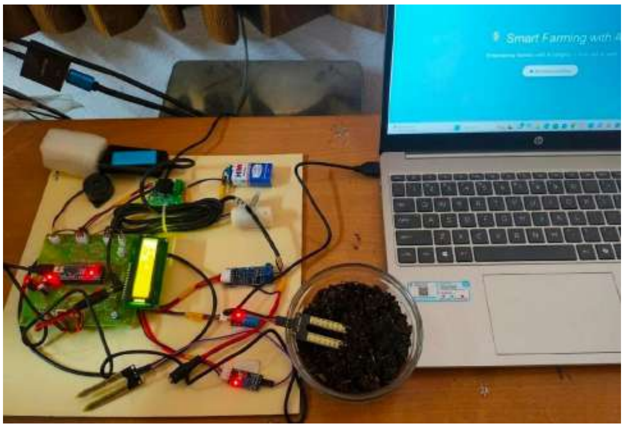
5. RESULTS AND DISCUSSION

The implemented system successfully monitored soil parameters and environmental conditions in real time. The crop prediction model recommended suitable crops based on soil nutrients and weather conditions. Disease detection using image processing helped identify infected plants at an early stage. The system successfully processed this data to assess soil fertility, environmental conditions, and overall plant health. The NLP-based crop prediction module analyzed soil and environmental parameters against predefined crop requirements and provided reliable recommendations for optimal crops along with estimated yield, helping farmers make informed decisions. The image processing- based disease detection module efficiently identified diseased regions on plant leaves, accurately classifying common infections through preprocessing, segmentation, and feature extraction techniques. Based on the sensor readings and disease analysis, the automated output control module triggered pumps and sprayers for precise irrigation and fertilizer/pesticide application, while the LCD displayed real-time system status and the buzzer alerted critical conditions. Overall, the simulation results indicate that the system can effectively integrate IoT, NLP, and image processing technologies to enable real-time monitoring, early disease detection, and automated precision farming. This approach significantly reduces manual intervention, optimizes resource utilization, improves crop yield, and supports sustainable and data-driven agricultural practices.

6. CONCLUSION

The proposed IoT-based soil nutrient analyzer and plant monitoring system provides an efficient and cost-effective solution for smart agriculture. Continuous monitoring of soil and environmental parameters such as soil moisture, temperature, humidity, and nutrient levels enables data-driven decision-making for irrigation and fertilization, thereby improving crop yield and supporting sustainable farming. The integration of sensors with an IoT-enabled microcontroller allows real-time data collection and automated control of irrigation and spraying systems based on the current field conditions. This reduces manual labor and ensures the optimal use of water, fertilizers, and other agricultural resources. In addition, the system can provide farmers with timely alerts and recommendations through connected devices, helping them respond quickly to changes in soil conditions or crop health. The collected data can also be stored and analyzed over time to identify patterns, improve crop planning, and support accurate crop prediction





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