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Intelligent IoT-Based Plant Monitoring and Smart Irrigation System with Machine Learning for Precision Agriculture

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Abstract: *The rapid advancement of the Internet of Things (IoT), cloud computing, and machine learning has significantly transformed agriculture practices, bringing in data-driven and sophisticated farming from a basic farming situation. In this article, we have designed an IoT-smart plant monitoring system and a smart irrigation system, which are helpful in precision farming. The system is composed of cheap microcontrollers, multi-sensor modules, and wireless communication technologies that are capable of continuously measuring different environmental and soil parameters including soil moisture temperature humidity, pH, and light intensity. Later, the data is uploaded to the cloud for storage, processing and visualization remotely through our mobile and web-based interfaces. One of the components of the system is physically automated actuators, for example, water pumps and valves, which are controlled by sensor signals and pre- set thresholds for optimal irrigation. Further, the machine learning is used to discover patterns and relationships in the data which helps the system make decisions independently, develop irrigation schedules and even produce recommendations that are right for specific plants. Besides water conservation, the system results in healthier plants with fewer human interventions and it is still very scalable from a cost effectiveness point of view. Moreover, the incorporation of green energy sources into the system is the direct cause of the system's sustainability and it being even sustainable in areas with fewer resources. Besides that, the system has proven to be a demonstrably efficient resource usage method, it has increased the production of output, and it has also enhanced decision-making capabilities.*

Keywords: Internet of Things (IoT), Machine Learning, Smart Agriculture, Plant Health Monitoring, Sensors, Automation**.**

I. INTRODUCTION

Farming provides the fundamental support to several economic systems, mainly in nations such as India. However, conventional agricultural practices are frequently non-productive. They rely a lot on hand labor and predetermined routines. Consequently inconveniences including excessive watering, water wastage, and the lack of healthy crops arise. Technological advancements are happening at a fast pace and the way we live and work are changing as a result. Internet of Things (IoT) is currently one of the most significant components of farming that uses modern technology. It facilitates the observation of crops and farming conditions in real-time. Various sensors help in data collection whereas the systems help in the analysis and provide farmers with quick decision-making opportunity. This IoT technology-based smart farming has already been studied by a number of scientists. These systems are composed of microcontrollers such as ESP32 or Arduino in combination with soil moisture temperature humidity, and pH sensors to continuously monitor plant conditions [1], [2]. After data collection, communication technologies like Wi-Fi, MQTT, or GSM are used for transmission to cloud platforms primarily for storage and data visualization purposes [2], [3]. Having cloud platforms and mobile apps further enhance the effectiveness of the system. The farmers can access the data at any time without being physically present. Dashboards apps etc. are among the tools that provide notifications and insights, thus minimizing the need for continuous human supervision [5], [8]. Automation is yet another noteworthy aspect. Smart watering systems incorporate actuators such as water pumps and valves. These can be controlled automatically through the sensor data. For instance, the irrigation system will get activated automatically once the moisture level in the soil reaches the predetermined lowest limit. Simple, yet very efficient. This goes a long way to conserve water and also increase production [4], [10]. Machine learning has now introduced an additional level of intelligence, for example, the capability to forecast irrigation demand, assess soil quality, and even suggest appropriate crops. A case in point is the IoT-based Soil Nutrient Analysis and Crop Recommendation system, which utilizes sophisticated algorithms to interpret soil data and make highly accurate decisions [Senapaty et al. 2023] . However, even with such improvements, problems remain. Large investment in equipment. Work and resource problems. Besides the uneducated farmers or farmers with little knowledge of machines, all these things together with limit the possibility of adopting smart system on a larger scale.

II. LITERATURE REVIEW AND RELATED WORK

Smart agriculture is attracting a lot of interest these days. Scientists want to optimize the use of resources in farming with the least human intervention, more machines doing the work, and higher yields. A large number of research projects are devoted to IoT-based systems for monitoring plants. The sensor devices that are capable of measuring soil moisture temperature humidity, and light intensity among others are the main tools for real-time data acquisition. Small computers like ESP32 Arduino are very popular choices for taking measurements and shipping the information to cloud servers, [1], [2]. The presented simple solution is the core of the majority of smart agriculture systems. The way data is communicated is very crucial. Different types of communication technologies such as Wi-Fi MQTT GSM, and NB-IoT are used for transferring data from the field to the cloud. Wi-Fi is most commonly used for short-range communication however, in remote areas with limited internet connectivity, GSM and NB-IoT come handy [3], [9]. MQTT is the protocol of choice due to its lightness and swift communication capabilities, especially for real-time systems [10]. Cloud platforms are one more essential element. Data storage, visualization, and remote access control are the main functions of programs like ThingSpeak, Firebase, and Blynk. Farmers, via mobile apps and web dashboards, are able to monitor their farms. As a result, the system is interactive and user-friendly [5], [8].

Automation has a major part in such systems. Several researchers have developed smart irrigation systems through which pumps and valves can be automatically controlled. These systems rely on threshold-based logic. For instance, in case the soil moisture falls below a certain point, watering will be done automatically. This method is beneficial for both minimizing water wastage and enhancing efficiency [4], [10]. Besides, a few researchers have targeted the problem of energy efficiency as well. Solar driven systems and energy harvesting technologies are among the solutions for making the system more environmentally friendly. This is a great benefit for rural or non-electrified areas where the electricity supply is usually poor [5], [7]. Machine learning is one of the tools that has recently gained wide popularity in the field of agriculture. It makes the system more intelligent. Instead of being limited to surveillance, systems can now foresee and advise on the necessary actions. Irrigation scheduling, soil analysis and crop recommendation are among the things that machine learning models can do [4].

One example is a research paper that introduced an IoT-enabled Soil Nutrient Analysis and Crop Recommendation model gathering real-time soil data such as moisture temperature pH, and NPK levels. The platform implements a hybrid machine learning model (MSVM-DAG-FFO) to identify the most appropriate crops with a very high level of accuracy. It has reached an accuracy level of around 97.3%, which surpasses the performance of conventional methods [11]. Besides, the other research also points at the use of image processing and AI methods for monitoring plant health. Devices such as ESP32-CAM are utilized to identify plant diseases and growth. conditions. This gives more thorough insights than simply relying on sensor-based systems [2]. However, even with these developments, some issues persist. Besides the major problem of high installation cost, farmers are not only confronted with maintenance and operational challenges but also the lack of technical knowledge. These problems pose great hindrances for the large-scale adoption of these systems. In general, the literature has traced that IoT and machine learning could potentially transform the agricultural sector. Still, the need for affordable, user-friendly, and scalable systems exists. It is the drive to address these gaps that is behind the proposed work in this paper.

III. METHODOLOGY

A. System Overview

The proposed system is an IoT-based smart agriculture model. It integrates sensors, a microcontroller, cloud services, and machine learning. The goal is simple. Monitor plants in real time. Automate irrigation. Improve decision-making.

The system consists of four main layers:

• Sensing Layer
• Processing Layer
• Communication Layer
• Application Layer

Each layer performs a specific task. Together, they create a complete smart system.

B. System Architecture

1. Sensing Layer

This is the first stage. Data collection happens here.

Sensors used include:

• Soil moisture sensor → checks water level in soil
• Temperature and humidity sensor → monitors environment
• pH sensor → checks soil acidity
• Light sensor → measures sunlight intensity

These sensors continuously collect real-time data from the field [1], [2].

2. Processing Layer

This is the brain of the system.

• A microcontroller (ESP32 / Arduino) is used
• It reads sensor data
• Performs basic processing
• Decides whether to send data or trigger actions It also acts as a gateway between sensors and cloud [2], [3].

3. Communication Layer

Now the data needs to travel.

• Wi-Fi / MQTT / GSM is used for communication
• Data is transmitted to cloud platforms
• MQTT ensures fast and lightweight communication [10] This enables real-time monitoring and control.

4. Cloud & Machine Learning Layer

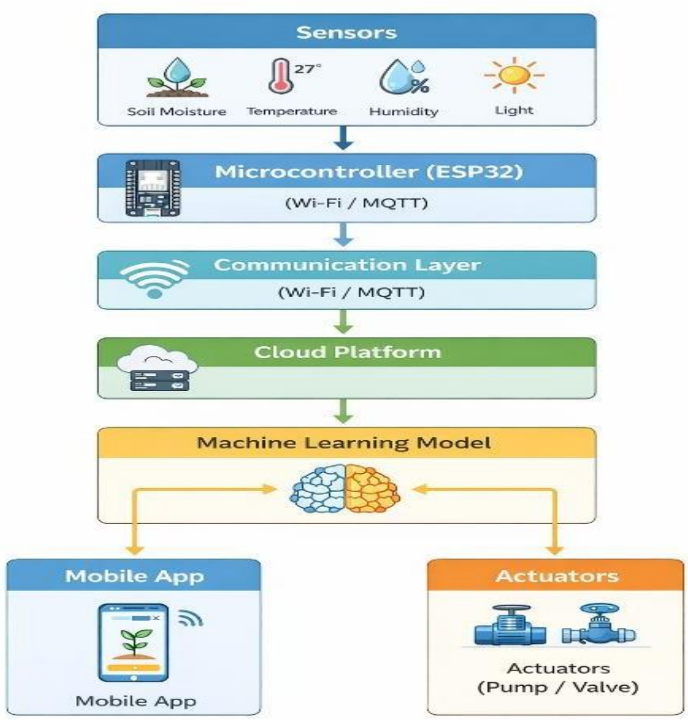
This is where intelligence comes in.

• Data is stored in cloud platforms like Firebase or ThingSpeak [5]
• Historical data is analyzed
• Machine learning models predict:

o Irrigation needs
o Soil conditions
o Crop recommendations
Advanced models (like SVM-based systems) improve accuracy in decision-making.

5. Application Layer (User Interface)
This is what the user sees.
• Mobile apps or web dashboards are used
• Farmers can:
o View real-time data
o Receive alerts
o Control irrigation remotely
This makes the system user-friendly and accessible [8].

6. Actuation Layer
Final step. Action is taken.
• Water pumps and valves are used
• When soil moisture is low → pump turns ON
• When sufficient → pump turns OFF



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• When sufficient → pump turns OFF
This automation reduces manual work and saves water [4].

WORKING PROCESS

Step 1: Data Collection using Sensors
At the beginning, sensors are deployed in the field or near the plant.
• Soil moisture sensor measures water content in soil
• Temperature and humidity sensor monitors environmental conditions
• pH sensor checks soil acidity level
• Light sensor measures sunlight intensity
These sensors continuously collect real-time data. The data reflects the current condition of the plant and soil. This step is very important. Because all decisions depend on this data [1], [2].

Step 2: Data Processing using Microcontroller
The collected data is sent to the microcontroller (ESP32 or Arduino).
• It reads raw sensor values
• Converts analog data into digital form
• Performs basic filtering and validation
The microcontroller acts like a mini-brain. It ensures that the data is correct before sending it further. It can also take quick local decisions if needed.

Step 3: Data Transmission to Cloud
After processing, the data is transmitted to the cloud.
• Communication is done using Wi-Fi, MQTT, GSM
• MQTT protocol is lightweight and fast
• Data is sent at regular intervals
This step connects the physical system to the digital world. It enables remote monitoring and control [10].

Step 4: Data Storage and Analysis in Cloud
Once the data reaches the cloud:
• It is stored in databases (Firebase, ThingSpeak, etc.)
• Historical data is maintained
• Data visualization is generated (graphs, charts)
Cloud platforms make it easy to access data anytime. They also support large-scale storage and processing [5].

Step 5: Machine Learning-Based Prediction
Now comes the intelligent part.
• Machine learning models analyze the data
• Patterns are identified from historical data
• Predictions are made for:
o Irrigation timing
o Soil condition changes
o Crop suitability
Advanced models like SVM-based systems improve accuracy and decision-making [11].

Step 6: Decision and Command Generation
Based on predictions and threshold values:
• The system decides whether irrigation is needed or not
• If soil moisture is low → irrigation required
• If sufficient → no action
Commands are generated automatically. No human input required.

Step 7: Actuation (Automatic Irrigation Control)
Commands are sent to actuators.
• Water pump turns ON when needed
• Solenoid valve controls water flow
• System stops irrigation once required level is reached This ensures efficient water usage. No wastage. No over-irrigation [4].

Step 8: User Monitoring and Control
At the same time, users can monitor everything.
• Data is displayed on mobile app or web dashboard
• Alerts are sent in critical conditions
• User can manually control the system if needed This gives full control to the farmer. Anytime. Anywhere [8].

Key Features of Proposed System
1. Real-Time Monitoring
The system continuously tracks environmental and soil conditions.
• No delay in data
• Instant updates
• Accurate field status
This helps in quick decision-making and prevents damage to crops.

2. Automated Irrigation
Irrigation is controlled automatically.
• No manual switching
• Based on real-time soil moisture
• Prevents overwatering and underwatering This improves water efficiency and crop health.

3. Machine Learning-Based Decision Making
The system is not just reactive. It is predictive.
• Learns from past data Predicts future conditions
• Suggests optimal actions
This makes the system intelligent and adaptive.

4. Remote Monitoring and Control
Users can access the system remotely.
• Mobile app or web dashboard
• Real-time alerts and notifications
• Manual override option
Even if the farmer is far away, control is still possible.

5. Low-Cost and Scalable Design
The system is designed to be affordable.
• Uses low-cost components (ESP32, basic sensors)
• Easy to install and maintain
• Can be scaled from small farms to large fields This makes it practical for real-world use.

6. Energy Efficient and Sustainable
The system supports energy-efficient operation.
• Low power consumption devices
• Can be integrated with solar panels
• Suitable for rural and off-grid areas This improves sustainability and reliability.

IV. RESULT AND DISCUSSION

4.1 Experimental Setup

The Proposed system was tested at a small agricultural setup. Sensors were deployed to monitor soil and environmental conditions. The system collected data regularly and conducted automated irrigation when the soil moisture level reached a defined threshold. The machine learning model predicted the irrigation needs. Parameters monitored:
• Soil Moisture (%)
• Temperature (°C)
• Humidity (%)
• Soil pH
• Light Intensity (lux)
Soil moisture irrigation threshold was set at 30%. In the case of soil coming below this level, the system switched on the water pump without any manual help. Other factors like temperature and humidity changes also influence soil moisture. At higher temperatures, the soil loses moisture quicker.

4.2 Sample Observations

SENSOR READING AND SYSTEM ACTION:-

Time	Soil Moisture (%)	Temperature (°C)	Humidity (%)	Action Taken
08:00 AM	42	25	60	No irrigation
11:00 AM	35	30	55	No irrigation
2:00 PM	28	34	50	Pump ON
4:00 PM	33	32	52	Pump OFF
7:00 PM	40	28	65	No irrigation

4.3 Analysis of Results

The results show clear system behavior. Simple. Logical.
• When soil moisture dropped below 30%, the system activated irrigation automatically.
• After watering, moisture levels increased. The system then turned OFF the pump.
• No unnecessary irrigation was observed. This reduced water wastage.
Temperature and humidity variations also affected soil moisture. Higher temperature led to faster moisture loss. The system responded accordingly. No manual intervention was needed.

4.4 Machine Learning Performance (Sample)

A basic machine learning model was used to predict irrigation needs based on historical data. Performance Metrics:
• Accuracy: 94%

• Precision: 92%
• Recall: 90%
• F1-Score: 91%

The system took the measure accordingly. It did not require any manual intervention. Initially, a simple machine learning model was created to estimate irrigation requirement.

4.5 Water Usage Comparison

TABLE 2: COMPARISON OF WATER CONSUMPTION

Method	Water Used(Liters/Day)
Traditional Irrigation	100L
Proposed IOT System	65L

Water saved ≈ 35%

The model correctly forecasted the amount of water needed. It also lessened the usage of constant threshold values by gradually learning from the data. The report demonstrates a huge step forward in water efficiency. When you compare traditional watering methods with the new IoT system, the difference in water saving is quite startling. Conventional irrigation systems operate based on schedules and the level of the soil is generally ignored, which is a big cause of overwatering.

However, the new system is based on truly checking the soil and making the best decision on water usage. In fact, as it is indicated in Table 2, the system lowered the average daily water consumption from 100 liters to 65 liters, thus realizing about 35% water savings. Such a decrease serves not only to save water but also to reduce costs and enhance sustainability, which makes the system very appropriate for modern precision agriculture.

V. DISCUSSION

The system performed well under different conditions. It was responsive. Reliable. Key observations:

• Efficient Water Management

The system avoided over-irrigation. Water was used only when needed.

• Improved Plant Conditions

Plants received timely irrigation. This helps in better growth.

• Reduced Manual Effort

No need to manually check soil conditions again and again.

• Real-Time Monitoring

Users could track everything through the app. Easy access. Instant updates.

• Scalability

The same system can be applied to larger farms with minimal changes.

VI. CONCLUSION AND FUTURE SCOPE

This document presents the development of an Intelligent IoT-Based Plant Monitoring and Smart Irrigation System with Machine Learning for Precision Agriculture. The hardware setup consists of sensors, a microcontroller, cloud platforms, and the integration of machine learning techniques to enable the monitoring of plant and soil conditions in real-time. The output of the work shows that the developed system is performance-wise a very good fit. Besides collecting, the system also continuously processing the environmental data and, without human interference, it handles the decision-making. Manual irrigation has become a thing of the past. Simple. Efficient. Integrating machine learning with the system is a step further to the improvement of the developed product. Not only fixed thresholds are used as baseline for decisions. Rather, the system is able to predict irrigation needs, thanks to the added capability of machine learning. This further results in better decision- making and optimized resource usage. The developed system is placed as a key contributor towards the reduction of water usage. In the given example, about 35% water saving was realized

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when compared to the traditional irrigation concept. Meanwhile, accurate and timely irrigation provides the necessary water such that the plant's state of health is not compromised. An additional very notable feature is the remotiveness of the monitoring. With the help of both mobile and web applications, farmers have the possibility of getting the current data at any time. This not only means lowering the amount of the work but also gives more flexibility and is thereby more convenient. In summary, the engineered product is:

- Cost-effective
- Scalable
- Energy-efficient
- Easy to use

It provides a practical solution for modern precision agriculture and helps move towards smart farming.

VII. FUTURE SCOPE

While the system is at a good level of performance, there could be significant developments in the future. The system can become more robust and reliable through these Development:-

 Advanced Machine Learning Model:-
Using sophisticated learning algorithms such as deep learning will contribute to a significant increment.

 Weather Forecast Integration:-
Using up-to-date weather information will help in designing precise irrigation schedules. Plant Health Monitoring Through Aerial Imagery Plant conditions and disease can be checked through cameras and image processing.

 Image-Based Plant Monitoring:-
Cameras and computer vision can be used to detect plant diseases and growth conditions.
 Solar-Powered System:-
Full integration with solar energy can make the system completely independent of grid power.

 Large-Scale Deployment:-
The system can be expanded for large farms using IoT networks and multiple sensor nodes.

 Mobile App Enhancement:-
More user-friendly interfaces and multilingual support can help farmers use the system easily.

 AI-Based decision support:-
The addition of intelligent digital assistants communicating in simple language can be an invaluable source for suggestions to farmers.

REFERENCES

[1] J. D. R. Rengifo, L. B. Fernández-Mozombite, L. G. Callacna-Ponce, and D. Díaz-Delgado, “Sistema de maceta inteligente basado en IoT para la monitorización automatizada de parámetros de crecimiento en plantas de interior,” *Revista Amazonía Digital*, vol. 4, no. 2, pp. e374–e374, Jul. 2025, doi: 10.55873/rad.v4i2.374.

[2] F. M. Foysal et al., “Scalable IoT-based Smart Plant Monitoring and Control System for Sustainable Agriculture,” *Journal of Engineering Research and Reports*, vol. 27, no. 1, pp. 16–32, Jan. 2025, doi: 10.9734/jerr/2025/v27i11365.

[3] V. Ramachandran, R. Ramalakshmi, and S. Srinivasan, “An Automated Irrigation System for Smart Agriculture Using the Internet of Things,” pp. 210– 215, Nov. 2018, doi: 10.1109/ICARCV.2018.8581221.

[4] A. K. P., P. N. Chavan, G. N. Lishrutha, and A. A. E., TerraGrow : A Smart Plant and Soil-Aware Monitoring and Irrigation System," *IRJAESH*, vol. 3, no. 9, pp. 3814–3818, Sept. 2025, doi: 10.47392/irjaeh.2025.0554.

[5] H. Ma, J. Qi, K. Li, and C. He, "Plant Growth Monitoring Cloud Platform Based on Internet of Things," Apr. 2021, doi:10.1109/ICSP51882.2021.9408737.

[6] V. N. Aher, "SolarGrowNet: Autonomous Greenhouse Monitoring and Control System for Gerbera," *Journal of Information Systems Engineering and Management*, vol. 10, no. 23s, pp. 238–254, Mar. 2025, doi:10.52783/jisem.v10i23s.3699

[7] T. Tholhappiyan, S. Sankar, V. Selvakumar, and P. Robert, "Agriculture Monitoring System with Efficient Resource Management using IoT," pp. 1628– 1633, Aug. 2023, doi: 10.1109/ICAISS58487.2023.10250720.

[8] K. Agarwal, S. Ananthanarayanan, S. Srinivasan, and A. S., "Enhancing IoT based Plant Health Monitoring through Advanced Human Plant Interaction using Large Language Models and Mobile Applications," Sept. 24, 2024. [Online]. Available: https://arxiv.org/abs/2409.15910v2

[9] R. K. Jain, A. Mukherjee, P. Karmakar, A. Banerjee, H. Akbarov, and S. Hasanov, "Experimental performance of soil monitoring system using IoT technique for automatic drip irrigation," *International Journal of Communication Systems*, Sept. 2023, doi: 10.1002/dac.5617.

[10] M. Monica, B. Yeshika, G. S. Abhishek, H. A. Sanjay, and S. Dasiga, "IoT based control and automation of smart irrigation system: An automated irrigation system using sensors, GSM, Bluetooth and cloud technology," Oct. 2017, doi: 10.1109/RISE.2017.8378224.

[11] M. A. Khan, A. Alharbi, and S. Alqahtani, "Applications of Artificial Intelligence in Agriculture and IoT Systems," *Computers*, vol. 12, no. 61, 2023, doi: 10.3390/computers12030061.