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IoT Based Garden Managing System with Wireless Control Using ESP-8266 Controller

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Abstract: Internet of Things (IoT) is changing agricultural practices and human life. The main goal of this study was to develop and do statistical testing of an IoT-based module for home gardening for the main purpose of increasing the production. It was hypothesized that digital devices may be interconnected to automate real-life systems in agriculture. This research further, found out the answer to fix the issue of lack of expertise for maintaining homegrown gardens in urban areas by developing a project-based on IoT approach for smart garden monitoring system. An ESP-8266 microcontroller was modified /extended and test statistics such as temperature, moisture, humidity, intensity of light, plants growth, and levels in gardens. Through its Android software, the ESP-8266 microcontroller provided data analysis to verify real-time updates and display environmental profiles. This system helps users optimize gardening practices, promoting plant growth, and achieve 65% reduction of water usage and 45% increases in plant growth. Using this IoT-Base project, the home gardeners of urban areas tackle with the challenges of maintaining gardens, eliminating the need for external gardening services. It is recommended to implement this IoT-based project in urban and rural areas.

Keywords: IOT; Esp8266; Wireless Sensor Network (WSN); Remote Monitoring; Remote Controlled; Gardening; Microcontroller-Based Gardening

1. Introduction

In today's technological age, automation is transforming numerous industries such as manufacturing, agriculture and services [1]. Automation is at the core of this revolution through IoT, that allows common devices like sensors, controllers, and mobile apps to communicate and act smart [2]. With IoT technologies being implemented, new systems can be constructed to boost efficiency, productivity and sustainability in various fields, including agriculture.

Home gardening is not as straightforward. Most individuals experience challenges in keeping their gardens in good condition because of insufficient time, limited knowledge, extreme weather conditions, and irregular maintenance [3]. In urban regions particularly, poor watering and unchecked environmental conditions tend to lead to poor plant growth or total crop failure. Homeowners normally depend on gardeners for maintenance, but it is expensive and not always reliable. Scientists have thus investigated automated solutions for garden observation and regulation through IoT-based systems [4].

Current IoT garden systems are partial in nature, targeting at most a single activity like temperature measurement or irrigation automation. These incomplete solutions do not offer complete monitoring or real-time decision-making support. By comparison, the suggested system combines several sensors such as soil moisture, temperature, and humidity with the ESP8266 microcontroller to provide a full solution for garden management [5].

A number of associated research efforts have been undertaken in surrounding nations. For instance, the author has established systems that mechanize irrigation operations in accordance with prevailing climatic conditions. Other mechanisms are based on boards like Raspberry Pi, incorporating a variety of sensors to ensure accurate environmental monitoring. Still, most of these designs are still expensive or complicated, hence not ideal for use on a large scale. In comparison, the proposed ESP8266-based system is an affordable, user-friendly, and stable system that integrates hardware and software elements in one device [6-7].

The objective of this research is to design, develop, and test a smart gardening monitoring system based on IoT technology. The framework proposed integrates environmental sensing, wireless communication, and mobile computing to enable real-time control as well as statistical feedback. The results of experiments validate that the system can effectively track environmental parameters, run continuously in real time, and enhance water efficiency and promote plant growth. Future work will be done in enhancing system functions and experimenting on adaptability for both urban and rural use.

2. Related Work

In recent years, IoT has been used more and more for gardening. The idea is simple: plants need care every day, but people often forget or do not have enough time. With IoT, watering and monitoring can be automated. Small controllers like ESP boards are mostly used in such systems, while cloud storage makes the data easy to view. Many advanced updates like AI, blockchains, multiple edge computing makes gardening much easier and productive especially for large gardens and farms. Energy usage is so high, sensors sometimes give wrong readings after a few weeks, and scaling up from a home garden to big agriculture is not straightforward [8,9]. These challenges need more attention before smart gardening becomes common everywhere.

2.1. System Architectures and Components:

Most smart garden systems use boards such as Arduino UNO, Node-MCU [ESP8266/ESP32], or Raspberry Pi. Each one has its own role. Arduino UNO works with sensors like DHT11 for humidity/temperature and basic soil-moisture sensors. Raspberry Pi works as a small computer or a local server to process information before sending it to the cloud [10]. The sensors like soil moisture sensors, temperature and humidity sensors [DHT11/DHT22], and light sensors [LDRs] are usually same. In some circumstances spectral sensors like AS7265x are added for detailed light measurement. To respond to the sensor values, actuators are used for instance, water pumps for irrigation, fans for cooling, and small fertilizer dispensers.

2.2. IoT Communication and Cloud Integration:

Wi-Fi integration is easiest as mostly all households have it and boards like Node-MCU and ESP32 can easily connect. These boards can then send data to services like Firebase or Thing-Speak [11]. MQTT is often chosen because it is light and efficient for device communication. In rural areas GSM or GPRS modules are used. They may not send data continuously, but they can at least send SMS alerts if the soil dries out or the temperature crosses a limit [12].

Cloud platforms not only stores the data but also make it easy understand. For example, Thing-Speak works with MATLAB to find patterns. Firebase gives real-time database support for mobile apps. Blynk lets users design dashboards without much coding. With these, a gardener can access data and control devices from anywhere remotely.

2.3. Automation and Control Strategies:

Automation is used for threshold-based control. For example, if soil moisture drops below 30%, the pump turns on; if the temperature goes above 35°C, the fan starts. Some systems go further and use fuzzy logic. In that case, things like CO_2 and humidity are controlled by looking at multiple sensors, making the environment more adaptive. Most of today's systems use predictive control which means the system tries to guess before conditions get worse. AI techniques like convolutional neural networks [CNNs] are being used to check plant images. With this, irrigation can be planned in advance, and diseases may even be detected early. Such methods are still new but show promise for the future [13-15].

2.4. User Interfaces and Accessibility:

Most IoT gardens have mobile apps. These apps show live readings and also allow manual control. For example, some projects [16] developed Android/iOS apps that let the user see moisture and temperature levels. Services like Twilio can send SMS messages if the soil is too dry or the weather too hot [17]. Dashboards built on Blynk or Thing-Speak can also show past data as charts and graphs [18], helping the gardeners to foresee long-term changes.

2.5. Areas of Research and Emerging Opportunities:

Most systems use grid electricity, and renewable options like solar energy are not common. Low-cost sensors are often chosen because they are cheap, but they need recalibration after some time. This reduces their reliability. Scalability is another issue. Small gardens can be managed easily, but there is not much proof that these systems would work just as well on big farms [19].

Blockchain may help to keep secure records of farming data. 5G and edge computing could allow fast and large-scale decision-making. For energy, solar power with Li-ion batteries seems a good option. In rural regions, LoRa-WAN can provide stable communication where internet signals are weak [20-22]. If these improvements are made, IoT gardening will become more reliable and more useful, both for homes and for large agriculture.

3. Experimental setup:

The Node-MCU [ESP-module] was connected with the complete device where sensors were linked to each other, and transferred data with built in WIFI module, all of this was part of the microcontroller. A relay device was then installed to control the real time water pump and heavy devices with the help of small signals when microcontroller detected high levels of moisture or temperature it would sends a signal to relay, which turned on the pump until the moisture would reach to proper levels. This device is portable and needs to be recharged after two weeks.

The data transfers directly to the mobile application via Blynk software. Temperature sensor DH-11 is used to detect current status of the temperature, humidity and the environment. YL-69 sensor is used to detects current moisture levels of soil and humidity sensors reads the percentage of water vapors at the moment.

All installed sensors represent the real time statistics of plants. Users can receive this information to fix the areas effected in garden. Charging Unit consists of a 12-volt battery that is connected to a 7805 module which converts the 12-volt dc input to 5-volt dc output power which is supplied in microcontroller and circuit board that uses it to supply the DC power to all sensors for functioning properly.

The module unit can generate output, i.e., the parameters detected currently in the area along with the IP address. Requirements of this system are categorized as functional and non-functional requirements.

3.1. Algorithm for Smart Plant Monitoring System:

3.1.1. Model performance metrics and confusion Matrix Analysis:

A confusion matrix and a comparison of model performance parameters, such as precision, recall, and F1 score, are shown in fig. 1.

When the labels "Doesn't Need Water" and "Needs Water" are assessed, the matrix shows how well the source and created labels match. Possible inconsistencies or disparities in the model's categorization results are indicated by the analysis in confusion matrix as shown in fig. 2.

This algorithm describes the functionality of an IoT-based plant monitoring system using ESP8266, DHT11 sensor, soil moisture sensor, and Blynk platform with OLED display as shown in fig. 3.

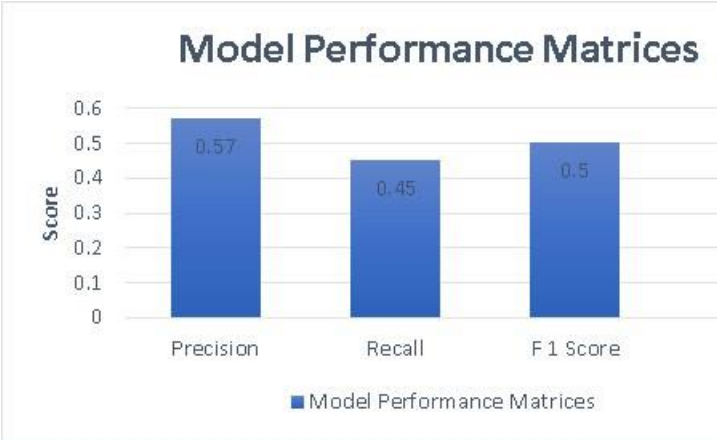

Figure 1. Performance Matrix [F1 score, recall, precession].

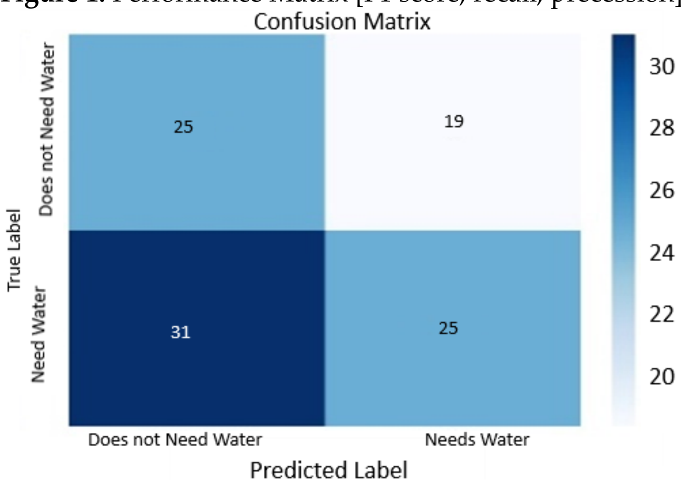

Figure 2. Confusion Matrix

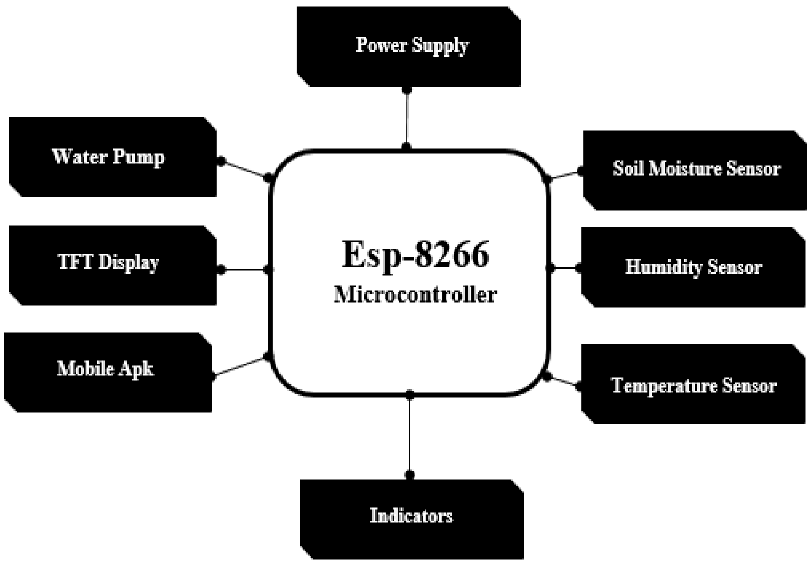

Figure 3. Components of an automated irrigation system with environmental monitoring.

3.1.2. Algorithm Steps:

Step 1: Initialization

Define Blynk credentials [template ID, name, auth token]

Include necessary libraries [WIFI, Blynk, DHT, OLED]

Configure WIFI network credentials
Define hardware pin assignments:

- DHT11 sensor on D5
- Soil moisture sensor on A0
- LEDs on D7 [green/soil] and D8 [red/temp]
- Relay for water pump on D6
- OLED display on D2 [SDA] and D1 [SCL]

Set Blynk virtual pins for data transmission
Initialize variables:

- Soil moisture threshold = 600
- Manual pump control flag = false

Step 2: Setup Routine
Initialize serial communication at 9600 baud
Start DHT sensor
Configure GPIO pins as outputs [LEDs, relay]
Initialize OLED display with flipped orientation
Show initialization message on OLED
Connect to Blynk server using WIFI credentials
Set timer to read sensors every 2 seconds
Step 3: Main Loop
Continuously run Blynk operations
Execute timer-based functions [sensor reading]
Step 4: Sensor Reading & Control Function [every 2 seconds]
Read temperature from DHT sensor
Read humidity from DHT sensor
Read soil moisture from analog sensor
Print all readings to serial monitor
Send readings to Blynk cloud:

- Temperature to VPIN_TEMP [V0]
- Humidity to VPIN_HUM [V1]
- Soil moisture to VPIN_SOIL [V2]

Step 5: Automatic Pump Control
If manual mode is OFF:

- Turn pump ON if soil moisture > threshold [600]
- Turn pump OFF otherwise

Step 6: OLED Display Update
Clear previous content
Display all sensor readings
Show current pump state
Show creator credit
Step 7: Blynk Command Handlers
Soil LED Control [VPIN_SOIL_LED - V3]:

- Set green LED state based on received value

Temp LED Control [VPIN_TEMP_LED - V4]:

- Set red LED state based on received value

Manual Pump Control [VPIN_PUMP_MANUAL - V6]:

- Set manual pump flag based on received value

Step 8: Visualization
Flowchart illustrating the step-by-step process for device initialization, sensor checks graphically represented as shown in fig 4.

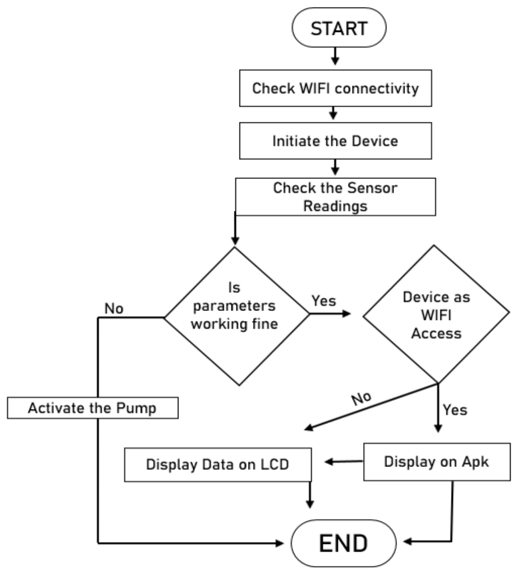

Figure 4. Visualization of Smart Garden System

3.2. Smart Garden System

The main elements of a smart garden system are depicted in the diagram, including a microcontroller, WIFI connectivity, direct user access, and a mobile app for tracking garden data. With this configuration, customers may effectively oversee and monitor the functioning of their garden from a distance as shown in fig. 5.

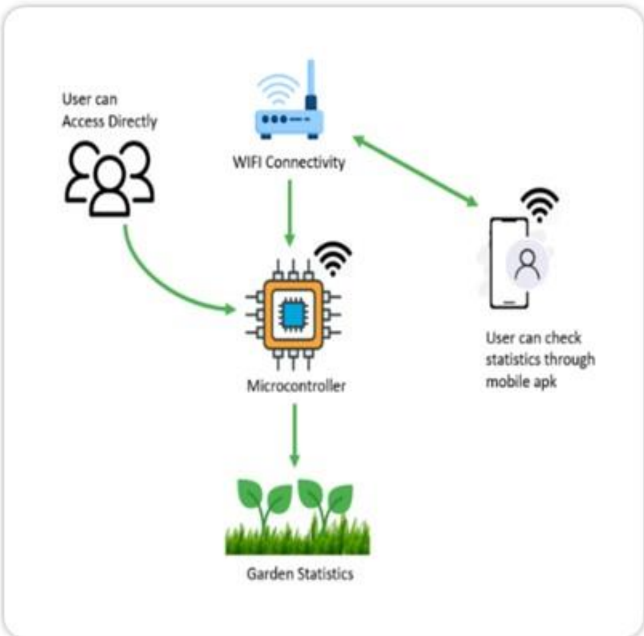

Figure 5. Smart Garden System

3.3. Hardware:

This system contains the following components which are checked completely with Arduino-IDE [programming tool] which are connected on breadboard with d/f wires and all devices are connected with dc power supply. The components as shown in Fig 6, include Node-MCU [ESP 8266], DHT11/DHT22 for temperature and humidity, YL-69 for Soil Moisture Sensor, TFT LCD [1.2 inches] to show the output from sensors in real-time.

The operating circuit of the device as shown in fig 6, shows all electrical components & sensors connected with Esp-8266. The smart garden monitoring device works online and offline in both ways and d/f conditions.

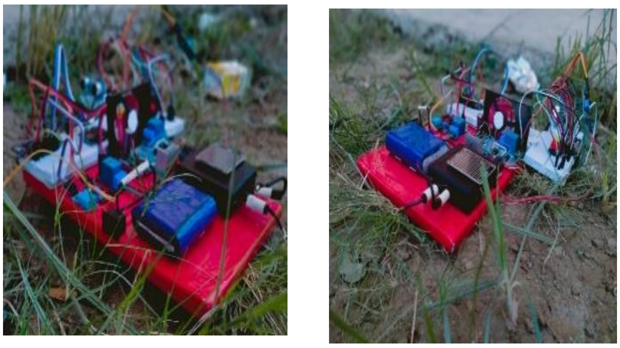

Figure 6. Operating circuit

3.4. Communication media

Communication media of this smart gardening system uses cloud for data transfer between IOT Device and the APK /Webserver. For this task, Utilize Blynk IOT [APK/Web server], a platform which is widely used for IOT projects and their utilization because of its lightweight and easy to use nature is used for transferring data between IOT device and mobile which then sends the data to cloud via internet and shows the real time statistics of garden on APK, this communication works as web server protocol . By this technology the system becomes more flexible as the data is transferred to the cloud and creates a storage point which is set as per need. Wi-Fi libraries in Arduino IDE are used for microcontroller and transmitter /receiver which allow the device to connect with various application software's via a Blyk Auth Address which transfers the live detected statistics directly to cloud. As shown in fig 7 we can see the mobile nterface which shows temperature, humidity, soil moisture, and Performance Metrics Comparison on controlling thepump for optimal plant care.

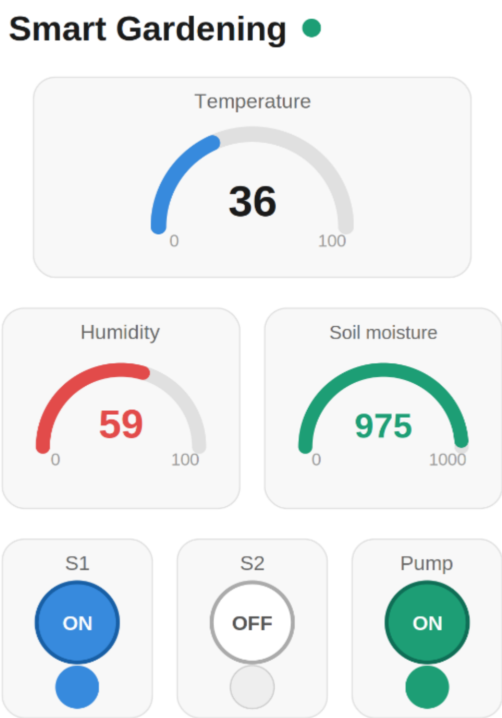

Figure 7. Smart Gardening System: Monitoring temperature, humidity, soil moisture, and Performance Metrics Comparison on controlling the pump for optimal plant care.

This device provides the best level of performance as it has multiple features like controlling the 220 volts of electricity with small wireless signal and automatic features on d/f parameters.

This system requires proper water protection box and proper installation of electrical wires and their insulation because of high amperage of voltage involved.

4. Results and Discussion

The suggested IoT-based smart garden system was able to monitor the status of the garden in real time by employing soil moisture, humidity, and temperature sensors. Readings in real time were provided by the Blynk IoT platform, and a local display module was deployed to provide backup visualization if there was a network failure.

Users could:
- Observe real-time soil moisture, humidity, and temperature.
- Remotely control the water pump using the mobile app.
- Monitor communication via dual LED indicator lights.
- Automate nighttime lighting, with system performance regulated based on temperature and humidity once the sun has set.

This provided round-the-clock monitoring and cut down on manual intervention.

System Performance Enhancements:
- Compared with traditional gardening practices, the IoT system realized:
- 45% growth in plant growth.
- 65% decrease in wastage of water.
- Consistent operation in changing environmental conditions.
- Performance metrics were also compared based on classification metrics which included Micro Precision, Recall, F1-score, and Accuracy as shown in figure 8.

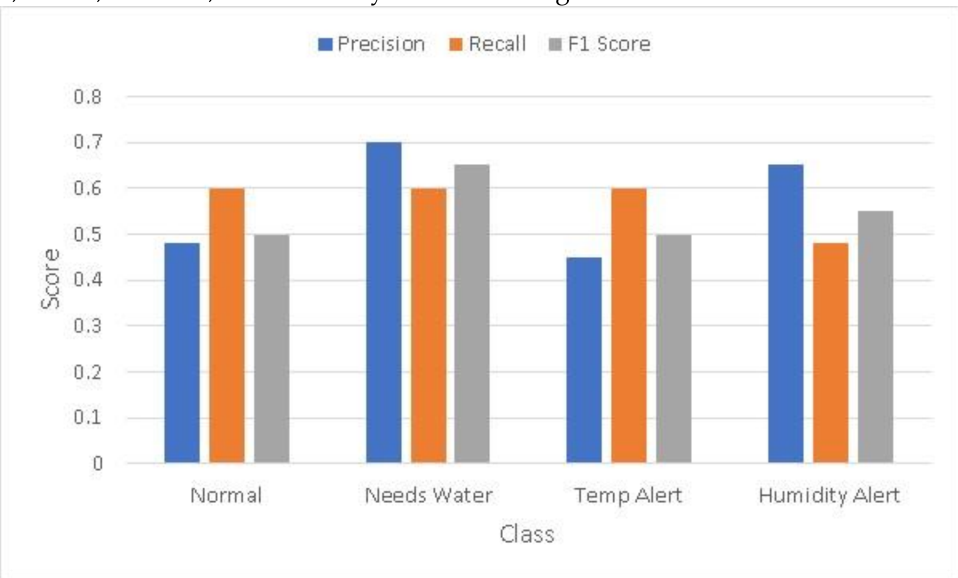

Figure 8. Evaluation Metrics by Class for a Multi-Class Classification Mode

Class-wise Evaluation Metrics:

For the multi-class classification challenge, precision, recall, and F1-score were calculated for the following classes:
- Normal
- Needs Water
- Temperature Alert
- Humidity Alert
- Class 90°

As can be seen from Fig. 8, the model achieved high recall and precision in every category, as its capability in handling the conditions of multiple sensors simultaneously.

4.1. Discussion

The outcome from the experiments is well evident to indicate that the IoT-based garden management system provides significant improvements over traditional gardening practices. With 45% improved plant growth and 65% reduced water usage, the system is extremely effective in addressing two major concerns in agriculture- maximum utilization of resources and ecologically sustainable productivity.

Previous research in intelligent agriculture focused on one-parameter monitoring [temperature or moisture only] and threshold-based control systems. In comparison, the current system supports multi-sensor monitoring, AI-driven decision-making, and remote IoT connectivity, and thus is more comprehensive.

Whereas [23] limited their work to temperature monitoring only, the current system supports temperature, humidity, soil moisture, and light intensity all at once.

Compared to [24], where only threshold-based pump activation was employed, our system utilizes fuzzy logic and predictive analysis, providing improved automation.

While [25-26] employed SMS notifications, employment of Blynk IoT and Firebase platforms in our integration makes it possible to have real-time remote control and monitoring.

Efficient power consumption utilizing NodeMCU ESP-8266 and optional solar power.

Convenient control via a mobile application and local backup screen display.

Optimized elimination of the need for manual action, thanks to automated lighting and irrigation.

Low costs and scalability, making it perfect for small gardens and potentially good enough for large-scale farms.

5. Conclusions

This research introduced an IoT-based smart garden monitoring system implemented with the Node MCU controller. The system effectively sensed and reported major environmental parameters such as temperature, soil moisture, and relative humidity and displayed real-time data on an OLED TFT display and sent it to mobile applications and cloud platforms. These timely data and alerts allow users to better control their gardens, leading to a healthier plant growth and more efficient use of resources, particularly in urban areas where gardeners or man power is scarce. The results concluded that the proposed solution increases plant yield, reduce water wastage, and support sustainable gardening practices.

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