Smart Agriculture: IoT-Enhanced Plant Irrigation Through Soil Moisture Analysis

Yedhu Gopan
M. Tech, Department of Mechanical Engineering NSS College of Engineering,
Palakkad Perinthalmanna, India

Abstract:- In modern agriculture, technology plays a crucial role in optimizing resource utilization and improving crop yield. This research introduces an innovative Automatic Plant Irriga- tion System that relies on soil moisture, integrating an extensive array of sensors for moisture, temperature, and humidity. These sensors are connected to an Arduino microcontroller, allowing continuous real-time monitoring of soil conditions. Utilizing Wi- Fi connectivity, the collected data is efficiently transmitted to a cloud-based platform, enabling seamless remote access and control. Farmers can easily access essential information on soil moisture levels and environmental parameters through a user- friendly mobile application or web interface. Furthermore, the system incorporates actuators to regulate water flow, ensuring precise irrigation schedules tailored to the specific needs of crops. The primary goal of this project is to revolutionize traditional farming practices by implementing technology-driven solutions that enhance water efficiency, minimize resource wastage, and optimize agricultural output.Through the integration of IoT technology, the Automatic Plant Irrigation System represents a forward-thinking approach to sustainable and precision agricul- ture. The incorporation of IoT technology is envisioned to provide a transformative impact, contributing to the advancement of agriculture through improved water management and enhanced precision in irrigation practices.

Keywords:- *IoT (Internet of Things), Smart Irrigation System, Agriculture Automation, Soil Moisture Sensors,Wireless Connectivity, Cloud-based Data Transmission, Arduino Microcon- Troller.*

I. INTRODUCTION

➢ *Research Motivation*

Modern agriculture is confronted with the formidable task of optimizing water usage while ensuring robust crop yields. This project introduces an innovative Smart Irrigation Sys- tem powered by IoT technology, aimed at revolutionizing conventional farming practices. By amalgamating the ESP32 micro controller with cutting-edge moisture sensors, this sys- tem promises unparalleled real-time monitoring and precise watering solutions tailored to the specific needs of differ- ent crops.Traditional irrigation methods have long suffered from inherent flaws leading to water wastage and ineffi- ciencies, adversely affecting both resource sustainability and crop health.Through the integration of IoT technology, this project endeavors to redefine these practices.The proposed smart irrigation system is engineered to adapt watering sched- ules dynamically,responding to real-time soil moisture levels, weather forecasts, and historical data analysis. Furthermore, eco-conscious approaches such as rainwater collection and water recycling mechanisms are being explored to bolster conservation endeavors. This comprehensive overview underscores a pioneering project poised at the vanguard of agricultural progress,aiming to address water usage challenges while championing sustainable, technology-driven irrigation methodology.

➢ *Problem Identification*

In modern agriculture, the optimization of water usage re- mains a significant challenge, requiring an innovative solution that balances the efficient utilization of resources with the imperative need for crop productivity. Conventional irrigation practices often exhibit inefficiencies, leading to water wastage and diminishing the overall sustainability of resources.This situationis exacerbated by manual control mechanisms that struggle to accurately gauge and respond tothe dynamic water requirements of crops, resulting in adverse impacts on both plant health andthe environment. Moreover, the dependency on traditional irrigation methods, compounded by the lack of real- time monitoring and adaptive control systems, poses a signifi- cant obstacle in ensuring precise and efficient watering tailored to the specific needs of crops.The absence of data-driven insights and technological integration in irrigation systems contributes to the challenge of achieving optimal water usage and crop health. Therefore, the identified problems encompass inefficient water utilization, manual control limitations, and the absence of real-time monitoring and data-driven systems. Addressing these issues requires a pioneering approach that integrates advanced technologies, such as IoT-driven smart irrigation systems, to optimize water usage, enhance crop health, and promote sustainable agricultural practices.

➢ *Goals and Objectives*

These objectives are designed to help modernize farming practices, ensuring environmental friendliness and improved crop productivity. By blending technology with traditional methods,this project aims to provide a holistic solution that tackles issues like water scarcity and ineffective irrigation practices. It strives to empower farmers with tools for better decision making, aiming to revolutionize farming practices towards more sustainable and precise methods.

Optimizing Water Usage and Water Conservation: The primary aim is to revolutionize the way water is utilized in agriculture by leveraging advanced technology.This objective strives to introduce innovative methods that optimize water consumption through precise, real-time monitoring of soil moisture and weather patterns. By doing so,it not only seeks to mitigate water wastage but also fosters the efficient utilization of this precious resource in irrigation, promoting sustainability in agriculture.

Enhancing Plant Health and Augmenting Growth: Another critical goal is to improve the overall health and vitality of crops. By deploying state-of-the-art IoT-based systems,the project intends to provide crops with precisely the right amount of water they need, thereby ensuring optimal growth conditions. This objective aims to enhance crop yields,boost plant health, and ultimately contribute to a more sustainable and productive agricultural landscape.

Developing Remote Automated Monitoring via IoT: The project aims to create a cutting-edge,remote automated moni- toring system using IoT technology. This system will allow farmers to monitor and manage irrigation processes from any location, enabling them to access real-time data on soil moisture levels, weather conditions, and plant requirements. By incorporating IoT,this objective seeks to empower farmers with the tools for efficient decision-making, ensuring a proac- tive approach to irrigation management and fostering greater agricultural productivity.

II. LITERATURE REVIEW

- *Revolutionizing Agriculture: An IoT- Driven Intelligent Irrigation System for Sustainable Crop Management*

Agriculture vital for food and water faces challenges due to environmental degradation and population growth impact- ing water resources. To address this, an intelligent irriga- tion approach leveraging automated and IoT technologies is proposed. This study focuses on an intelligent agricultural management system using GPS and Radial Function Network (RFN) for controlling irrigation, predicting temperature, regu- lating air pressure, and managing water humidity. Employing IoT sensors and the Internet of Everything (IOE), the system oversees intelligent solar irrigation. Its aim is to optimize agriculture via automation, encompassing tasks like weeding, irrigation, humidity sensing, and remote device control. The design targets reduced water use, lowered operational costs, and improved productivity. The proposed RFN demonstrated promising accuracy, sensitivity, hit rate, and caching rate for the system.

- *Intelligent Irrigation System using STM 32 and NB IoT Technology*

An intelligent irrigation system, leveraging STM32 and BC95, is developed to address prevailing issues in traditional irriga- tion methods, like time inefficiency, low reliability, and water wastage. This system acquires soil information through tem- perature and humidity sensors, transmitting data from the sampling node to the remote terminal serial port. Upon reception, the controller interprets this data, triggering intelligent irrigation actions at the output end. The application of STM 32 and NB-IoT technology for wireless data transmission successfully reduces time consumption and enhances system reliability. This approach fulfills the objectives of data transmission for both intelligent irrigation and water-saving techniques. The observed fluctuations in soil moisture data depict substantial changes, showcasing the system’s effectiveness.

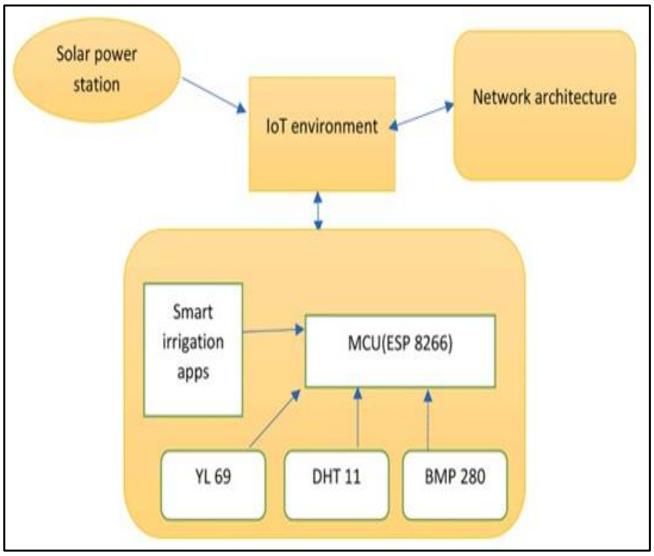


Fig 1 Block Diagram of Smart Irrigation System

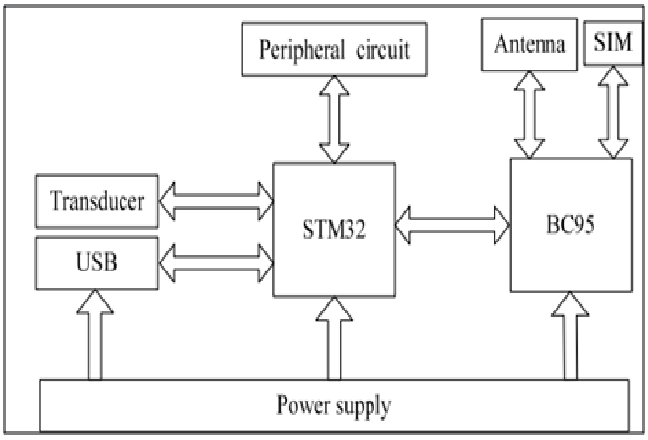


Fig 2 System Hardware

- *Empowering Agriculture: An IoT-Enabled Automatic Irrigation System for Sustainable*

FARMING This paper aims to create a cost-effective Auto- matic Irrigation System to assist under privileged farmers in saving both time and money. Agriculture, vital to countries like India,heavily relies on rainwater and depleting underground water sources due to poor management. Droughts and erratic electricity supply further compound these issues, causing dis- tress to farmers. Lever-aging modern technology, particularly IoT applications, this article proposes an innovative irrigation system designed to automate irrigation while granting farm- ers manual control via an Android app. Utilizing Arduino Uno, GSM Modules, and sensors like temperature and soil moisture sensors, this system ensures a user-friendly interface and cost effectiveness by employing affordable hardware and eliminating additional labor cost Keep your text and graphic files separate until after the text has been formatted and styled.

- ➢ *Enhancing Crop Irrigation: Leveraging IoT for Smart and Efficient Solutions*

Irrigation stands as a critical process, vital for fostering robust crop growth and aiding home based garden maintenance. While previous innovative irrigation techniques have targeted enhanced water efficiency to alleviate environmental pressures, the lack of accessible information for users remains a challenge. Traditional irrigation approaches for organic home gardens possess both advantages and drawbacks, stemming from manual intervention and a lack of feed- back mech- anisms, perpetuating water wastage. In the face of climate variability,the absence of structured decision-making exacer- bates water mismanagement, despite supporting crop growth significantly. Addressing these concerns, a proposed irrigation methodology leverages sensors(temperature, humidity, soil moisture, and air moisture) to furnish essential insights for user decision-making. This method not only bolsters crop growth but also facilitates remote monitoring via the Internet of Things(IoT). By harnessing IoT-driven smart irrigation, this approach not only improves crop yield and quality but also ensures efficient water management, surpassing the limitations of conventional irrigation methods.

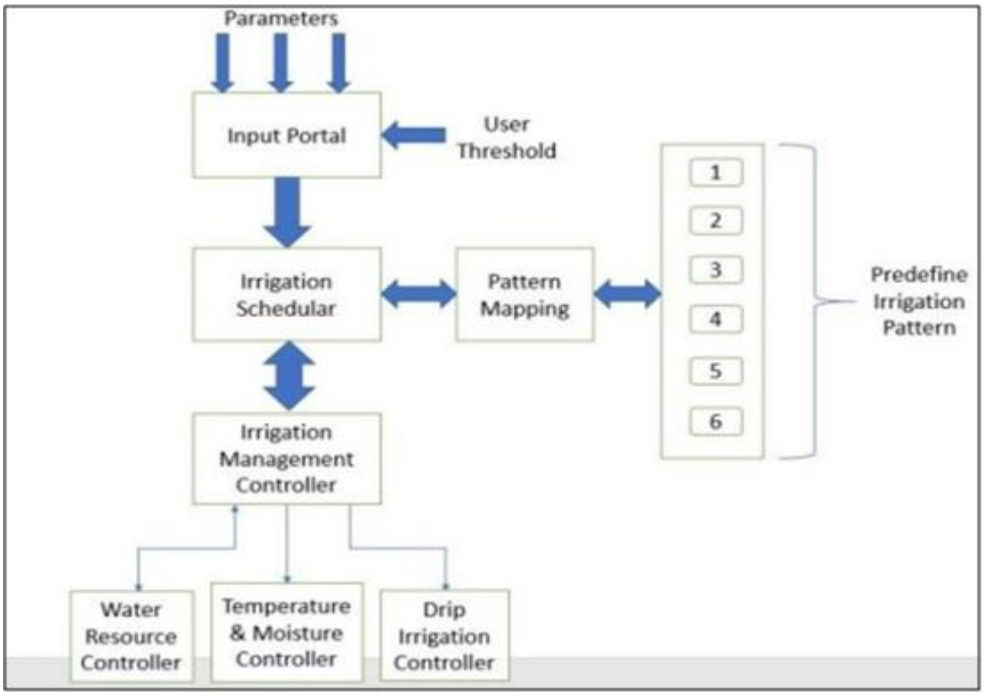


Fig 3 System Architecture

- ➢ *Smart Water Supply System: Integrating IoT for Agricultural Efficiency*

This study proposes an automated water supply system for agricultural land utilizing Raspberry Pi 3, Arduino micro controllers, Wi-Fi modules, GSM shields, relay boards, and various Sensors. The employed components ensure a robust, scalable, and dynamic implementation.The system operates based on soil moisture levels and daylight intensity, allowing it to identify optimal watering times for plants and prevent water accumulation around their roots. Analog data from sensors are converted to digital signals by the Arduino and transmitted via Wi-Fi Module to the Raspberry Pi 3. Furthermore, the system can alert the administrator about any water scarcity in the main supply and enables communication through SMS, where specific keywords trigger system actions. This versatile system finds application not only in farmland but also in smaller potted plants. Its implementation yields promising outcomes, ensuring the scientific sustenance and nurturing of plants in an efficient manner.

- ➢ *Smart Water Supply System: Integrating IoT for Agricultural Efficiency*

The Internet of Things (IoT) represents a network where interconnected objects communicate, primarily relying on in- ternet connectivity. In agriculture, IoT stands as a crucial player in supporting the estimated 9.5 billion population by 2050. The application of IoT in crop- field monitoring and automated irrigation, often termed as Smart Farming, aids in minimizing wastage by optimizing fertilizer and soil water usage, ultimately enhancing crop yield. This project involves implementing a system that employs sensors (Temperature, Humidity, Soil Moisture) to monitor crop fields and automate irrigation.Sensor data is wireless transmitted to the Thing speak API database, facilitating easy visualization of read- ings on a dedicated web page in JASON format. Notably, irrigation is automated based on predefined thresholds of soil moisture, ensuring optimal crop growth.Regular notifications are dispatched to both a web page dashboard and a mobile app tailored for farmers, granting them remote access to monitor field conditions at their convenience,irrespective of location.

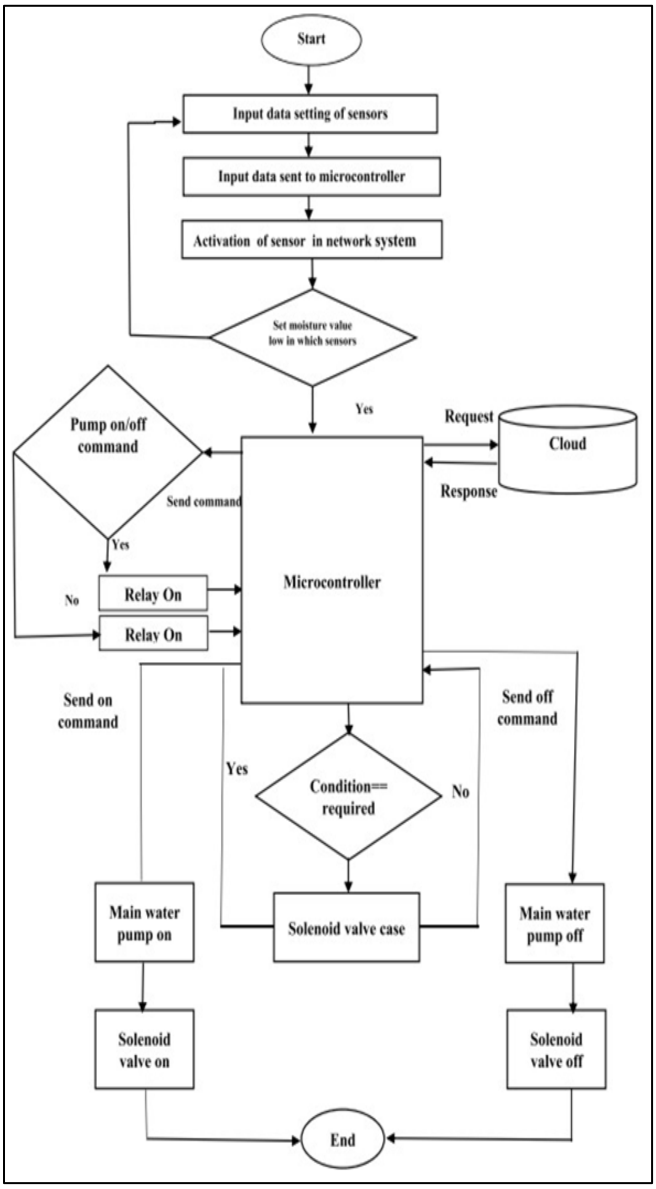
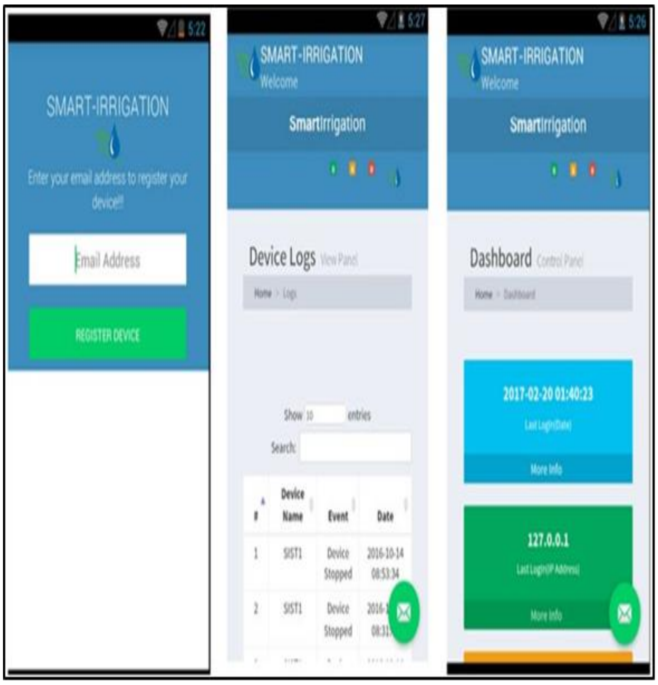


Fig 4 Process Flowchart for Controlling the IoT-System

➢ *IoT-Based Intelligent Irrigation System for Enhanced Crop Growth: A Case Study on Carrot Farming*

The agricultural sector, pivotal for economic growth, encounters challenges in meeting food quantity and quality demands. To address these, Informa- tion and Communication Technology(ICT) applications in agriculture are crucial. This research focuses on optimizing crop growth through intelligent irrigation systems using IoT technology. This system comprises a transmitter reading soil moisture wirelessly transmitted to a receiver, which controls a water pump based on received data and Mobile Application Interface. The study, conducted on a carrot farm, compared manually irrigated beds to machine-to-machine (M2M) irri- gated beds. The evaluation criteria encompassed pre-harvest parameters like plant height and leaf count and post-harvest indicators such as plant weight, length, and diameter. Results indicated that crops irrigated through M2M communication ex- hibited superior growth compared to manually watered crops. This suggests the efficacy of IoT-based intelligent irrigation in enhancing crop performance.



#	Device Name	Event	Date
1	SIST1	Device Stopped	2016-10-14 08:53:34
2	SIST1	Device Stopped	2016-1 08:31

Fig 5 Mobile Application Interface

➢ *Sensory-Based Irrigation Systems for Sustainable Crop Management*

Countries globally are actively pursuing agricultural sustain- ability through technology integration to improve operations. Improving irrigation systems is critical for enhancing water- use efficiency, aligning with Sustainable Development Goals (SDGs) like Goal 6 and Target 6.4 of the United Nations. This paper explores the role of IoT-enabled SMART irrigation systems and sensory technologies concerning SDGs. Employ- ing a qualitative approach and relying on secondary data, the study highlights the importance of automated irrigation in conserving water a crucial aspect in agriculture. Integration of IoT and automation in farming techniques enhances overall processes, fostering effectiveness and efficiency. Sensory sys- tems play a pivotal role in aiding farmers to better comprehend their crops, reducing environmental impacts, and conserving resources. These advanced systems facilitate thorough soil and weather monitoring and ensure efficient water management. Recognized as a positive contributor to optimized irrigation, these systems prompt continuous research and development to bolster sustainable operations and reduce costs. Additionally, the review delves into the challenges and benefits associated with the implementation of sensory-based irrigation systems. This comprehensive review aims to assist researchers and farmers in comprehending irrigation techniques and adopting approaches suitable for irrigation-related activities.

➢ *Smart Precision Agriculture: Integrating IoT and Machine Learning for Efficient Irrigation*

For centuries, traditional agriculture has been fundamental for global development, yet rising population and increasing demands necessitate innovative solutions to address water scarcity in farming. The emergence of Agriculture 4.0 in- tegrates technologies like artificial intelligence and IoT to revolutionize decision-making in farming practices. This study introduces a smart and adaptable irrigation system, cost-effective and suitable for diverse contexts, leveraging machine learning algorithms for precision agriculture. The approach involves sensor integration (measuring soil humidity, temperature, and rainfall) in an environment conducive toprolonged plant growth. Collected data is structured via Node-RED platform and MongoDB. Multiple models—KNN, Logistic Regression, Neural Networks, SVM and Na¨ıve Bayes—were applied based on this data. Results highlight K-Nearest Neighbors as superior, achieving a 98.3percent recognition rate and a root mean square error (RMSE) of 0.12 compared to LR, NN, SVM, and NB. Additionally, a web application consolidates sensor data and model predictions,offering enhanced visualization and environment supervision.

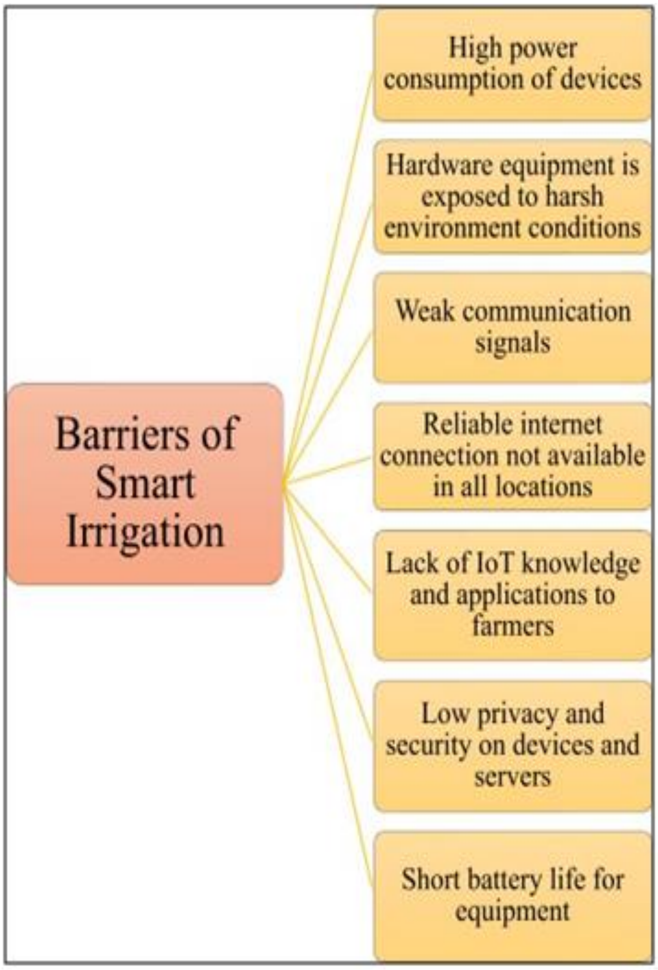


Fig 6 Barriers of Smart Irrigation Systems

- *Enhancing Agriculture with IoT-Based Smart Irrigation Systems for Improved Crop Yield and Water Management*

Irrigation plays a crucial role in enhancing crop growth and aiding home-based gardening. Innovative irrigation methods aim to improve water efficiency and reduce environmental impact. Existing conventional methods lack insights into crop growth, suffer from manual intervention, and lack feedback systems, leading to water wastage. Amid climate change,manual decision-making contributes to water waste. The proposed method addresses these issues by utilizing sensors for temperature, humidity, soil moisture, and air moisture to furnish essential data for informed decision-making. Additionally, it enables remote monitoring via the Internet of Things (IoT). This IoT-based smart irrigation promises improved crop growth, efficient water management and remote accessibility, surpassing the limitations of traditionalirrigation.

- *Optimizing Agriculture with Artificial Intelligence: Integrating Threshold Values for Efficient Farmingpractices*

Agriculture stands as a pivotal economic sector, experiencing a shift towards automation that addresses the burgeoning demands of a growing population. Traditional farming practices proved insufficient in meeting escalating food requirements and addressing employment needs.The introduction of automated techniques ushered in a new era, satisfying food demands and creating extensive job opportunities worldwide. Artificial Intelligence (AI) has catalyzed an agricultural revolution by safeguarding crop yields against climate fluctuations, population surges, employment challenges, and food security issues. This paper scrutinizes the multifaceted applications of AI in agriculture, notably in irrigation, weeding, and spraying, employing sensors integrated into robots and drones. These technologies curtail water and agro chemical overuse, preserving soil fertility, optimizing manpower, and enhancing productivity while elevating produce quality. Additionally, the review covers diverse soil water sensing methods and delves into two automated weeding techniques.

- *Precision Irrigation: Monitoring Crop Water Stress Via Acoustic Emission and Threshold Values*

Precision irrigation techniques play a crucial role in optimizing water utilization in agriculture, and accurate detection of crop water stress forms its cornerstone. This study pioneers a real-time crop water stress monitoring system employing acoustic emission (AE) measurements, integrating soil, crop, and weather factors. Utilizing a virtual instrument platform, this automated system not only manages water stress and atmospheric drought but also enables automatic control of greenhouse environments. Focused on potted tomato plants,strategically positioned AE sensors provide indirect insights into the plant's water status. The system, facilitated by a Peripheral Component Interconnect - Data acquisition (PCI-DAQ) based virtual instrument, effectively monitors environmental parameters. Under water stress conditions, weakened cohesion between water molecules triggers cavitation within plant conduits, generating AE energy. The correlation observed between AE counts and crop hydraulic structure underscores plant adaptation to varying environmental factors, with AE fluctuations mirroring changes in temperature, humidity, carbon dioxide levels, and transpiration. This study establishes a mathematical model linking AE to crop water stress, promising advancements in precision irrigation strategies.

III. METHODOLOGY

A. *Components and Specifications*

- *12V DC Pump:*

This pump operates by converting elec- trical energy from a 12-volt direct current (DC) power supply into mechanical energy. When connected to a power source,it propels water through its mechanism, making it suitable for various applications, including irrigation systems or water circulation in hydroponics.

Fig 7 12V DC Pump

- *ESP32 Development Kit:*

The ESP32 is a powerful micro controller with built-in Wi-Fi and Bluetooth capabilities. This development kit allows for the creation of IoT applications.Its main functions include collecting sensor data, processing information, and facilitating wireless communication, enabling the device to connect to the internet for data transmission and reception.

Fig 8 ESP32

- *Capacitive Moisture Sensor:*

This sensor measures soil moisture levels by analyzing changes in capacitance. When placed in the soil, it detects the dielectric constant variation caused by soil moisture, providing analog or digital output proportional to the moisture content.This data helps determine when and how much to irrigate, optimizing water usage.

- *0.96-inch OLED Display:*

An OLED (Organic Light- Emitting Diode) display module that utilizes organic com- pounds to emit light when an electric current is applied. It showcases information like sensor readings, system statuses, or alerts in a clear and energy-efficient manner.

Fig 9 Capacitive Moisture Sensor

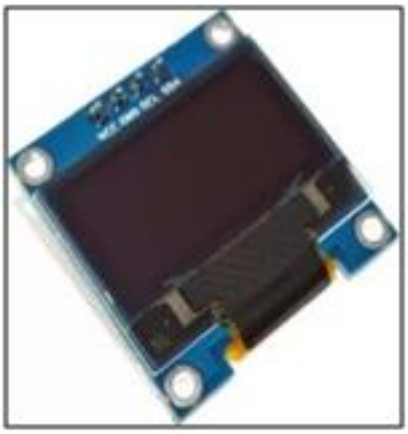


Fig 10 0.96 inch OLED Display

- *Capacitors (100F, 300nF, and 330nF):*

These capacitors play roles in stabilizing voltage,filtering noise, and timing con- trol within circuits. The 100F capacitor helps in maintaining stable power supplies, while the 300nF and 330nF capacitors assist in noise reduction and voltage regulation in different parts of the circuit.

Fig 11 Capacitors

- *LM7805:*

This component is a voltage regulator that maintains a constant 5-volt output from higher input voltages. It ensures a stable power supply for other components in the system,preventing voltage fluctuations.

- *DHT 11 Sensor:*

This sensor measures temperature and humidity levels. It utilizes a digital signal to provide accurate readings, crucial for monitoring environmental conditions like temperature and humidity in an IoT setup.

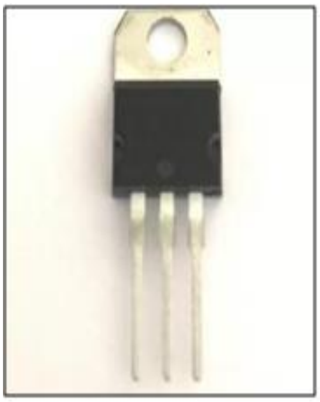


Fig 12 LM7805

Fig 13 DHT 11

- *Buzzer:*

A sound-producing component that generates audible alerts or signals in response to specific conditions or events programmed into the system, providing an audibleindication of certain actions or states.

Fig 14 Buzzer

- *LEDs:*

Light-emitting diodes that function as visual indicators. They emit light when a current flows through them, offering visual cues for system status, alerts, or mode changes in an IoT device.

- *TIP122:*

A power transistor used for switching high- power devices or components. It amplifies current to control devices such as motors or solenoids in the system.

Fig 15 LED

Fig 16 TIP122

- *Resistor (100 Ohms):*

This resistor limits current flow, protects components from excessive currents, and modifies signal levels within the circuit.

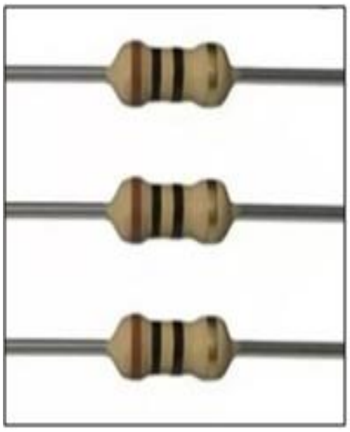


Fig 17 Resistor (100 Ohms)

- *Diodes:*

These semiconductor devices permit current flow in one direction. They are used for rectification, voltage regulation,and protection against reverse polarity or voltage spikes within the circuit. These components work together within an IoT system to collect environmental data, process information, control devices, and display relevant information, enabling a smart and automated system for monitoring and controlling various aspects of the environment or devices.

Fig 18 Diode

B. *Project Circuit Diagram*

This schematic outline discloses a fastidiously planned plant water system regulator, controlled by a balanced out 12V DC supply and organized by the savvy ESP32 micro controller.This focal handling unit assembles crucial natural information through incorporated sensors, including the DHT- 11 for temperature and mugginess, and a devoted dampness sensor for soil examination. Directed by continuous informa- tion and pre-modified calculations, the ESP32 unequivocally controls the watering plan. Advanced yield pins like D23 and D22 actuate the TIP122 semiconductor, guaranteeing proficient and designated conveyance of nurturing dampness. Visual markers, including LEDs and a ringer, give clear func- tional input, affirming siphon initiation and potential blunder cautions. This minimal and proficient framework focuses on asset preservation by disposing of pointless watering rehearses. Through an information driven water system, the regulator advances ideal plant well being by fitting water conveyance to explicit requirements, adding to a flourishing and reasonable climate.

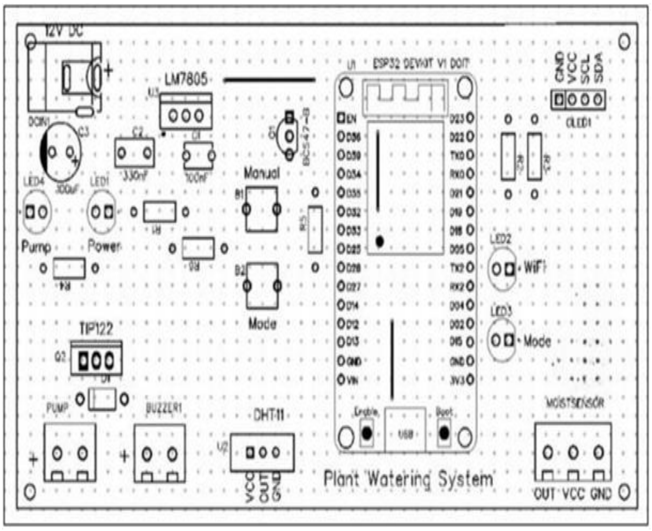


Fig 19 Arrangement of Components

IV. COMPREHENSIVE ANALYSIS OF EMBEDDED SYSTEM CODE STRUCTURE

A. *Initialization and Configuration*

The initial segment focuses on setting up crucial parameters essential for system operation. It begins by defining Wi-Fi credentials (ssid and pass) and Blynk-specific information. This section also initializes pins for various components such as sensors, relays, LEDs, and buttons. It includes library imports for necessary functionalities like OLED display, Wi- Fi, Blink, DHT sensors, and Ace Button. Object instantiation for these components is initialized, establishing connections and setting up the groundwork for the entire system.

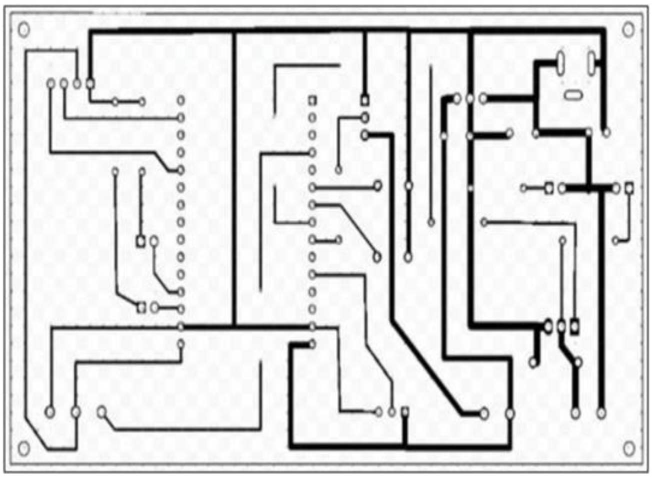


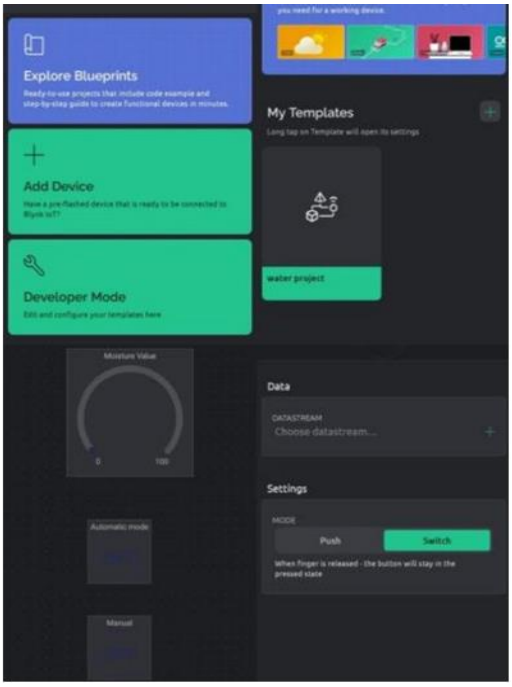
Fig 20 Circuit Connection

B. *Blynk Configuration and Interaction*

This segment acts as the vital bridge between the system and the Blynk application, enabling smooth interaction and control. Its core role involves interpreting signals received from the Blynk app, ensuring the system accurately executes user commands. Upon establishing successful connection, it synchronizes the system's virtual representation with its real state, guaranteeing precise data exchange. By swiftly decoding and executing commands from the app—like managing relays or altering operational modes—it empowers real-time adapta- tion to user inputs. Continuously monitoring the Blynk server connection, it upholds a stable link between the system and the external platform. Functioning as a pivotal segment bridges communication and control between the Blynk application and the embedded system. Its primary function revolves around interpreting user commands relayed from the app, enabling prompt and accurate responses. Upon successful connection, it aligns the virtual and physical states of the system, ensuring seamless information exchange. Swiftly executing commands, such as relay control or mode adjustments, it facilitates real- time adaptation to user inputs. Vigilantly monitoring the Blynk server connection, it maintains a robust link between the system and the external platform.

C. *Sensor Data Collection and Display*

This section is dedicated to gathering sensor data and presenting it to the user. It includes functions to collect data from moisture sensors (get Moisture()) and DHT sensors (get Weather()), ensuring accurate readings. The OLED display is configured (display Data()) to present this information clearly. The system continuously sendssensor data to the Blynk app via send Sensor()updating virtual pins. Additionally, it oversees the moisture control process, regulating the relay based on predefined moisture thresholds and operating modes.



Ready-to-use projects that include code example and step-by-step guide to create functional devices in minutes.

Have a pre-flashed device that is ready to be connected to Blynk IoT?

Edit and configure your templates here

Long tap on Template will open its settings

When finger is released - the button will stay in the pressed state

Fig 21 Blynk App Interactions

Fig 22 Data Collection and Display

D. *Setup and Loop*

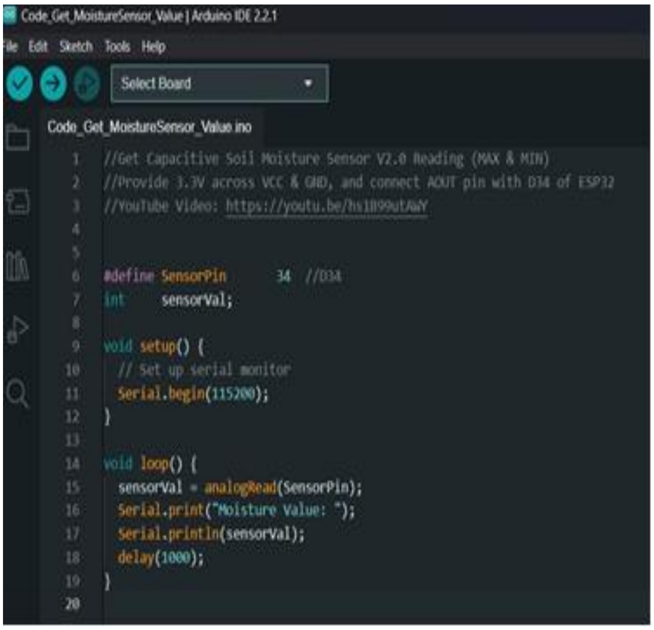
The setup function initializes the entire system. It configures the serial monitor, sets pin modes, initializes objects, and sets up the OLED display. The system establishes Wi-Fi and Blynk connections, sets timers for regular checks of Blynk server status and sensor data transmission, and initializes the buzzer. The loop function perpetually runs Blynk and timer functions, checks button states, and executes moisture control logic based on the current mode. Furthermore, it encompasses event handlers for buttons, reacting to specific button actions and updating system states accordingly.

E. *Moisture Sensor Data Reading And Display*

- Define Sensor Pin 34 //D34: Defines a constant Sensor Pin and assigns it the value 34, representing the pin number where the moisture sensor is connected.
- Int sensor Val;: Declares an integer variable sensor Val to store the analog value read from the moisture sensor.
- Void setup(): This function runs once at the beginning of the program. Serial.
- Begin (115200);: Initializes serial communication with a baud rate of 115200, enabling communication between the micro controller and a connected device like a computer. It sets up the serial monitor for data output. void loop(): The main function that runs repeatedly after the setup() function.
- Sensor Val = analog Read (Sensor Pin);: Reads the analog value from the pin defined by Sensor Pin using the analog Read() function. This function reads the analog voltage (0- 1023) and stores it in the sensor Val variable.
- Serial. Print (”Moisture Value: ”);: Outputs the text ”Moisture Value: ” to the serial monitor.
- Serial. Print (sensor Val);: Outputs the value of sensor Val (the analog reading from the sensor) to the serial monitor followed by a newline.
- Delay (1000);: Pauses the program for 1000 milliseconds (1 second) before the next iteration of the loop.

- *Overall Function:*

The code continuously reads analog data from the moisture sensor connected to pin D34 and displays the moisture values on the serial monitor every second. This can help in monitoring and observing changes in moisture levels detected by the sensor over time.



```
//Get Capacitive Soil Moisture Sensor V2.0 Reading (MAX & MIN)
//Provide 3.3V across VCC & GND, and connect AOUT pin with D34 of ESP32
//YouTube Video: https://youtu.be/hs1B99utAWY


#define SensorPin      34  //D34
int      sensorVal;

void setup() {
  // Set up serial monitor
  Serial.begin(115200);
}

void loop() {
  sensorVal = analogRead(SensorPin);
  Serial.print("Moisture Value: ");
  Serial.println(sensorVal);
  delay(1000);
}
```

Fig 23 Code for Moisture Sensor

F. Significance of Soil Moisture Management in Optimal Vegetable Growth

Soil moisture has a profound effect on root crops, especially in the root zone -the main areafor water and nutrient uptake. This zone acts as a lifeline for plants, facilitating important processes such as nutrient absorption and water absorption that are crucial for their development. The optimum humidity, usually between 41 and 80 percent, is degrees ideal for growing vegetables. This choice creates a balance and ensures adequate humidity for the viability of the plantwithout causing water stress or preventing oxygen flow to the roots. Insufficient moisture can cause wilting and reduced yield, while exces- sive moisture can cause root diseases. Proper soil moisture management is important, including consistent monitoring, appropriate watering practices, and careful monitoring of plant responses to moisture fluctuations. Keeping soil moisture- within this recommended range is key to healthy vegetable growth. Techniques such as regularmonitoring of soil moisture, use of appropriate irrigation methods and observation of plant responses to moisture levels are important. These practices allow growers to achieve an optimal balance that provides adequate moisture for vigorous growth and prevents problems associatedwith excess or insufficient moisture.

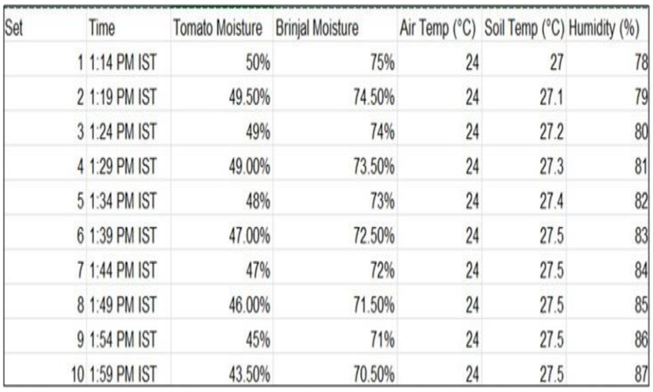
G. Threshold-Based Soil Moisture Management for Optimal Vegetable Growth

In the context of soil moisture measurement, a threshold value represents a predetermined limit for soil moisture levels. This value is a reference point that indicates when the moisture content reaches a critical level, either due to the need for irri- gation or the potential. accumulation of water. In this project, the determination of threshold values is crucial for effective moisture management. For example, the optimum humidity for vegetables is 41 to 80 percent. Setting a certain threshold in this area allows proactive action: Irrigation triggers: A lower threshold, perhaps around 50 percent moisture, can act as an indicator to start watering. When the soil moisture drops below this point, it activates the irrigation system, ensuring that the plants receive enough water before the critical stress level is reached. Avoidance of water resources: On the other hand, an upper threshold (eg 75-80 percent) can serve as a warning level. If the soil moisture exceeds this limit, it warns of possible water risks. This requires adjustments to avoid over watering, which can cause root suffocation and disease. Applying thresholds to your project allows automatic or manual operation based on predefined humidity limits. This proactive approach helps maintain soil moisture in the optimal range, optimizing plant growth while reducing the risks asso- ciated with under- and over-watering. Regular monitoring of moisture levels against these thresholds ensures timely action and promotes healthier and more productive vegetable crops.

H. Project Implementation and Component in- Tegration: A Comprehensive Overview

Project integrates an ESP32 Development Kit, capacitive moisture sensor, OLED display, various capacitors (100mf, 300nf, 330nf), sensors such as DHT11 for temperature and humidity, LEDs, and other components, operating at a standard voltage of 12 volts DC. The capacitive moisture sensor, nestled within the soil, accurately measures soil moisture levels, relay- ing this data to the ESP32 microcontroller. Simultaneously, the DHT11 sensor monitors environmental conditions, capturing temperature and humidity crucial for optimal plant health. The ESP32, functioning as the system's central processing unit, assimilates these sensor inputs and performs computations using predefined thresholds and settings. Upon analysis, the ESP32 triggers responsive actions, effectively controlling the irrigation system. For instance, when soil moisture levels drop below predetermined thresholds, the system activates the water pump to autonomously irrigate the plants. The OLED display serves as an interface for real time monitoring, showcasing essential data such as soil moisture, temperature, and humid- ity. Integrated LEDs offer visual indicators, while a buzzer provides audible alerts, ensuring users can easily comprehend the system's status and any critical conditions. The seamless integration of the system with the Blynk application empowers users to remotely monitor and regulate the irrigation process through smartphones or tablets, offering enhanced convenience and accessibility. Overall, this intelligent irrigation system amalgamates data-driven automation, user-friendly interfaces, and remote accessibility, fostering efficient water management and optimizing plant growth.

V. RESULT



Set	Time	Tomato Moisture	Brinjal Moisture	Air Temp (°C)	Soil Temp (°C)	Humidity (%)
1	1:14 PM IST	50%	75%	24	27	78
2	1:19 PM IST	49.50%	74.50%	24	27.1	79
3	1:24 PM IST	49%	74%	24	27.2	80
4	1:29 PM IST	49.00%	73.50%	24	27.3	81
5	1:34 PM IST	48%	73%	24	27.4	82
6	1:39 PM IST	47.00%	72.50%	24	27.5	83
7	1:44 PM IST	47%	72%	24	27.5	84
8	1:49 PM IST	46.00%	71.50%	24	27.5	85
9	1:54 PM IST	45%	71%	24	27.5	86
10	1:59 PM IST	43.50%	70.50%	24	27.5	87

Fig 24 Real Time Monitoring Data of Moisture

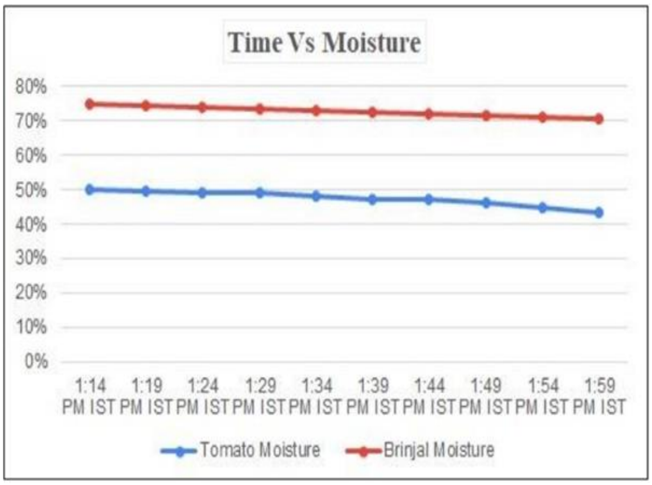


Fig 25 Time vs Moisture Graph with Respect to Temperature

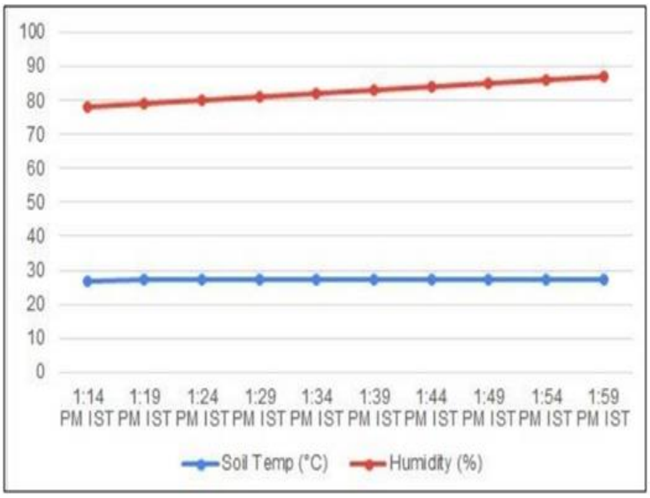


Fig 26 Soil Temperature and Humidity Graph with Respect to Time

This table meticulously documents the moisture fluctuations in both tomatoes and brinjals, accompanied by consistent environmental parameters, during the observed intervals from 1:14 PM to 1:59 PM IST. Notably, the gradual decline in plant moisture levels—starting at 50 percent for tomatoes and 75 percent for brinjals—signals a systematic trend, reducing by approximately 0.5 percent per interval. Concurrently, environmental factors exhibit stability, including a constant air temperature of 24°C, a progressive rise in soil temperature from 27°C to 27.5°C, and a steady climb in humidity from 78 percent to 87 percent. Critical to this monitoring system is its predefined threshold values for moisture levels. Upon reaching these thresholds, an automated mechanism triggers the operation of a motor, facilitating plant watering to maintain optimal moisture levels. This responsive approach reflects a meticulous control system implemented in a controlled environment, ensuring precise and timely interventions aligned with the plants' moisture needs. The consistent environmental conditions, especially the stable air temperature, underscore the methodical nature of this controlled setting conducive to monitored plant growth.

This systematic approach, integrating real-time moisture monitoring and automated watering responses when thresholds are reached, showcases a sophisticated and proactive methodology for maintaining optimal plant conditions within predefined moisture thresholds. Optimal soil moisture levels, typically ranging between 40 percent and 80 percent, are crucial for the flourishing growth of most vegetables, particularly within the root zone. This area serves as the primary space where plant roots seek water and nutrients essential for their development. When moisture levels fall within this specified range,it fosters an environment conducive to robust root growth and effective nutrient absorption. In-sufficient moisture, below the lower threshold of 41 percent, can lead to water stress, causing wilting, stunted growth, and reduced nutrient uptake. Conversely, excess moisture beyond 80 percent can trigger water logging, limiting oxygen availability to the roots and potentially causing root suffocation, hindering nutrient uptake, and fostering conditions ripe for fungal growth and root diseases. Maintaining soil moisture within the recommended range is vital for optimal vegetable growth. It not only ensures proper hydration for the plants but also facilitates efficient nutrient absorption and metabolic processes crucial for their vitality. This balanced moisture level supports healthy root development and overall plant vigor, allowing them to withstand environmental stressors and diseases more effectively. Moreover, it contributes to improved yields and better-quality produce. Regular monitoring and management of soil moisture within this range are essential practices for cultivating healthy and productive vegetable crops.

VI. CONCLUSION AND FUTURE SCOPE

In summary, the creation and deployment of the smart irrigation system, empowered by IoT, signifies a notable progression in contemporary agricultural methodologies. This system, integrating diverse technologies like IoT, sensors, and remote monitoring through the Blynk app, exhibits significant potential in reshaping conventional irrigation approaches. Through continuous monitoring of soil moisture, humidity, and temperature in real-time, this system offers a precise and effective strategy for managing water resources. The incorporation of IoT not only enhances water efficiency but also permits remote control, facilitating timely adjustments based on environmental conditions without physical intervention. Furthermore, the project showcases the fusion of ingenuity and sustainability. By minimizing water wastage and preserving crucial resources, it aligns with global sustainability objec- tives and advocates for environmentally conscious farming practices. Additionally, the adaptability and scalability of this system across diverse agricultural settings emphasize its ca pacity to transform farming practices at different levels. In essence, this project stands as evidence of technology's impact on addressing pivotal challenges in modern agriculture. The successful implementation and proven efficacy underscore the system's potential to improve crop productivity, optimize resource utilization, and contribute to a more sustainable future in agriculture

Integrating pH and nutrition-based sensors would further en- hance the system's capabilities by providing more comprehen- sive insights into soil health and plant nutrition. By incorporat- ing these sensors, the system can precisely analyze soil compo- sition and offer tailored recommendations for supplementing nutrients, optimizing plant growth, and mitigating deficiencies. Moreover, the inclusion of a wastewater recycling mechanism, particularly from kitchen sources, can significantly contribute to sustainable irrigation practices. By treating and repurposing kitchen wastewater based on plant requirements, the system can conserve freshwater resources while ensuring optimal hydration for the plants. Implementing these enhancements would transform the system into a comprehensive agricultural solution, promoting both environmental sustainability and improved crop yields through precise nutrient management and efficient water utilization. Additionally, integrating such advancements could pave the way for broader applications across various agricultural settings, underscoring the system's adaptability and scalability.

REFERENCES

[1]. Sangeetha, B. P., Kumar, N., Ambalgi, A. P., Haleem, S. L. A., Thilagam, K., Vijayakumar, P. (2022). IoT-based smart irrigation management system for environmental sustainability in India.*Sustainable Energy Technologies and Assessments, 52*(Part A), 101973. ISSN 2213-1388. https://doi.org/10.1016/j.seta.2022.101973.

[2]. Hu, X., Sun, X., Li, Q., He, Q., Li, Y. (2021). Design and implemen- tationof an intelligent irrigation system. E3S Web Conf., 260, Article Number 03010. https://doi.org/10.1051/e3sconf/202126003010.

[3]. Guntur, J., Raju, S. S., Jayadeepthi, K., Sravani, C. H. (2022). An automatic irrigation system using IoT devices. Materials Today: Proceedings, 68(Part 6), 2233-2238. ISSN 2214-7853. https://doi.org/10.1016/j.matpr.2022.08.438.

[4]. Karunakanth, M. Ramachandran, Venkatesan Kathrine, G. Jaspher. (2018). Iot based smart irrigation system for home based organic garden. International Journal of Pure and Applied Mathematics. 119. 16193- 16199.

[5]. Imteaj, Ahmed Rahman, Tanveer Hossain, Md Zaman, Saika. (2016). IoT based autonomous percipient irrigation system using raspberry Pi. 563-568. 10.1109/ICCITECHN.2016.7860260.

[6]. Ogunti, E. (2019, March). IoT Based Crop Field Monitoring and Irri- gation Automation System. IJISET - International Journal of Innovative Science, Engineering Technology, 6(3), 124. ISSN (Online) 2348 – 7968. Department of Computer Engineering, Federal University of Technology, Akure, Nigeria.

[7]. Kponyo, J. J., Opare, K. A. B., Abdul-Rahman, A., Agyemang, O. (2019).An Intelligent Irrigation System for Rural Agriculture. International Journal of Applied Agricultural Sciences, 5(3), 75-81. DOI: 10.11648/j.ijaas.20190503.13. ISSN: 2469- 7877 (Print); ISSN: 2469-7885 (Online). Retrieved from http://www.science publishing group.com/j/ijaas.

[8]. Obaideen, K., Yousef, B. A. A., AlMallahi, M. N., Tan, Y. C., Mah- moud, M., Jaber, H., Ramadan, M. (2022). An overview of smart irrigation systems using IoT. Energy Nexus,7, 100124. ISSN 2772-4271. https://doi.org/10.1016/j.nexus.2022.100124.

[9]. Tace, Y., Tabaa, M., Elfilali, S., Leghris, C., Bensag, H., Renault, E. (2022). Smart irrigation system based on IoT and machine learn- ing. Energy Reports, 8(Supplement 9), 1025-1036. ISSN 2352-4847. https://doi.org/10.1016/j.egyr.2022.07.088

[10]. Daudi S. Simbeye, Mbazingwa E. Mkiramweni, Bilal Karaman, Sezai Taskin, Plant water stress monitoring and control system, Smart Agri- cultural Technology,https://doi.org/10.1016/j.atech.2022.100066.

[11]. Tanha Talaviya, Dhara Shah, Nivedita Patel, Hiteshri Yagnik, Manan Shah, (Implementation of artificial intelligence in agriculture for optimization of irrigation and application of pesticides and herbicides, Arti- ficial Intelligence in Agriculture,https://doi.org/10.1016/j.aiia.2020.04.002.

[12]. Simbeye, D. S., Mkiramweni, M. E., Karaman, B., Taskin, S. (2023). Plant wa- ter stress monitoring and control system. Smart Agricultural Technology, 3, 100066. https://doi.org/10.1016/j.atech.2022.100066