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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINNERING
OPTION OF ELECTRICAL TECHOLOGY

Final year project

DESIGN AND IMPLEMENTATION OF IOT BASED PLANT SECURITY WITH WATERING SYSTEM

submitted in partial fulfillment of the requirement for award of advanced diploma in Electrical Technology

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DECLARATION A

This research study is my original work and has not been presented for a Degree or any other academic award in any University or Institution of Learning". No part of this research should be reproduced without the authors' consent or that of ULK Polytechnic Institute.

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DECLARATION B

I confirm that the work reported in this research project was carried out by the candidate under my supervision and it has been submitted with my approval as the UPI supervisor.

Name: Eng. **KARIKURUBU Emmanuel**

Sign: ____________________________ Date: __________________

DEDICATION

I dedicate this work to the Almighty God that helped us right from the beginning to the completed advanced diploma (A1) in Electrical Technology, at ULK Polytechnic Institute. I also dedicate this hard work to my classmates, Lecturers, family, and friends, School administration especially to my supervisor KARIKURUBU Emmanuel and everyone who has contributed to the realization of this study. May God bless them all abundantly and their relentless efforts finally make the world around them a better place.

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And also, our sincerely gratitude is due to the entire administration of ULK Polytechnic Institute especially to Department of Electrical Technology from which we obliged all knowledge I have had, without their knowledge and assistance this work would not have been successful.

All thanks to my dear lovely elder family and friends who have helped and supported me during my study to the completion of this work and also I would like to give my special thanks to ULK Polytechnic Institute Lecturers and all staff for giving us enough knowledge and skills that made me innovation and successfully research and compile of this final year project God bless you for all.

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ABSTRACT

The Internet of Things (IoT) has advanced quickly, changing traditional agricultural practices through improved resource management, automation, and monitoring. This Project examines the planning and execution of an Internet of Things system created specially to meet the irrigation and security requirements of cannabis farming. The system tackles both legal compliance and operational efficiency, given Rwanda's highly regulated cannabis farming environment, where stringent government controls are placed on cultivation for medical and scientific purposes. The case study focuses on the legal framework for cannabis cultivation in Rwanda, which stipulates strict security measures, such as round-the-clock video surveillance, as stated in the final Cannabis Cultivation License that was acquired through Irembo.

To provide optimal irrigation based on soil moisture levels and real-time monitoring, the IoT system integrates security cameras with automated watering mechanisms. Two soil moisture sensors keep an eye on the environmental conditions surrounding the plant, and the ESP32 CAM is used for security surveillance. Plants only receive water when necessary and a relay that is connected to a NodeMCU and controls a 5V water pump. The system is sustainable and energy-efficient. To facilitate remote monitoring and control, all sensor data and camera footage are combined into a MySQL database and made available via a web-based interface.

This project is important because it has the potential to improve cannabis cultivation's security and productivity while guaranteeing compliance with Rwanda's strict regulations. Grid power's incorporation of renewable energy highlights the system's sustainability even more. In addition to helping Rwandan cannabis farmers, this project acts as a template for other high-value, regulated crops around the world where environmental control and security are crucial.

This book is divided into multiple chapters, beginning with an overview that describes the project's motivations and goals. Subsequently, a thorough analysis of the research methods, system architecture, and implementation procedure is covered. A review of the outcomes, difficulties encountered, and suggestions for future advancements round out the section. The study advances the rapidly expanding field of smart agriculture and shows how the Internet of Things has the power to completely transform the monitoring, cultivation, and cultivation of regulated crops, assuring sustainability, efficiency, and compliance.

Keywords: Automated irrigation, soil moisture sensor, Arduino NodeMCU, MySQL

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LIST OF ABBREVIATION AND TERMS

A: Ampere

API: Application Programming Interface

Blynk: IoT Platform for Mobile Applications

DC: direct current

GPIO: General-Purpose Input/output

I2C: Inter-Integrated Circuit

IDE: Integrated Drive Electronics

IoT: Internet of Things

IoT: Internet of Things

LCD: Liquid crystal Display

MCU: Microcontroller Unit

NC: Normally Close

NO: Normally Open

P: Power

PC: personal computer

PCB: Printed Circuit Board

VCC: Voltage Common Collector

Wi-Fi: Wireless Fidelity

CHAPTER 1: GENERAL INTRODUCTION

1.0 Introduction

The use of IoT in agriculture, sometimes known as "smart farming," has completely changed the way plants are grown by enhancing the automation, security, and monitoring of crucial farming procedures. The creation of an Internet of Things (IoT) system especially suited for cannabis cultivation a highly regulated crop in Rwanda is the main goal of this project. This system maximizes agricultural efficiency and ensures legal compliance by combining automated irrigation with advanced surveillance technology. The system complies with Rwanda's cannabis cultivation regulations, which place a strong emphasis on the requirement for strong security measures.

1.1 Background of the Study

The application of Internet of Things (IoT) technology to agriculture is transforming crop management and cultivation. With the help of IoT, farmers can improve farm security overall, automate irrigation systems, and keep an eye on the environment in real time. The production of high-value crops like cannabis, which need careful management and protection, has shown to benefit greatly from these technological advancements. An efficient and safe growing system is essential in nations like Rwanda, where the cultivation of cannabis is strictly regulated for both medical and scientific uses (Brown, L. , 2022, March 10).

The government's digital service platform, Irembo, provides access to Rwanda's cannabis cultivation regulatory framework, which includes strict security guidelines for licensed growers. The final Cannabis Cultivation License stipulates that in order to prevent illegal access and guarantee legal compliance, farms must install sophisticated security systems, including round-the-clock video surveillance. ((RDB), 2020). Growers of cannabis are required by law to put in place reliable monitoring systems to keep tabs on the development, storage, and transportation of their plants. License revocation, fines, and even legal action may follow noncompliance with these rules. Cannabis farms must thus quickly implement cutting-edge technology to both comply with legal requirements and maximize farming techniques. (Aman, 2021).

While security monitoring and irrigation have historically been handled by hand in traditional farming methods, these techniques can be labor-intensive, ineffective, and prone to human error. Under watering or overwatering crops due to manual irrigation can produce less than ideal growth conditions. Likewise, inconsistent manual security checks can expose farms to theft or unauthorized access. Farmers can automate these procedures and obtain real-time insights into plant health, soil conditions, and farm security by utilizing IoT-based solutions. This results in improved regulatory compliance, lower labor costs, and increased efficiency.

Maintaining the ideal level of soil moisture is essential for cannabis cultivation in order to support healthy plant growth, particularly in controlled environments where stringent regulations must be adhered to. Better yields are produced when plants receive the appropriate amount of water at the appropriate time thanks to Internet of Things systems that are outfitted with soil moisture sensors and automated irrigation. Furthermore, farms can be continuously watched by integrating a camera surveillance system like the ESP32 CAM. This allows for real-time video footage to be sent to authorities and farm managers, guaranteeing that security breaches are quickly found and fixed.

In order to bridge the gap between conventional farming methods and the current legal requirements for Cannabis cultivation, this study is creating an Internet of Things (IoT) system that combines automated irrigation with security surveillance. A variety of electronic components are used in the system, such as a water pump for automated irrigation, an ESP32 CAM for real-time video monitoring, soil moisture sensors for environmental control, and a NodeMCU for data management and control. Since solar energy powers the entire system, it is both economical to operate over time and environmentally benign (Nwankwo, 2020).

In this situation, increasing productivity through the use of IoT technologies in agriculture especially in the context of cannabis cultivation while also guaranteeing legal compliance is important. The high value of cannabis and the requirement for regulatory oversight make security, sustainability, and automation even more crucial in its cultivation. This project shows how smart agriculture can change Rwanda's cannabis industry by incorporating IoT into the cultivation process. This will help farmers meet legal and operational requirements while promoting sustainable farming practices (Ministry of Health, 2020).

This study will support Rwanda's efforts to modernize its agricultural sector and offer insightful information about how IoT can improve agricultural practices, especially in regulated industries like cannabis cultivation. The project demonstrates how technology can solve difficult legal and environmental problems, improving farming's long-term efficiency, security, and sustainability.

1.2 Statement of the Problem

Although growing cannabis is legal in Rwanda under certain conditions, it requires strict security measures and careful control of the environment. Traditional methods of watering and monitoring the plants take a lot of time, are not very efficient, and can easily lead to mistakes. Manual watering and security checks might not be fast or effective enough to meet Rwanda's regulations for cannabis farming. To improve both productivity and security, a system that automates watering and provides real-time surveillance of the farm is needed.

1.3 Purpose of the Study

1.3.1 Main objectives

The main objective of this project is to design and implement IoT based plant security with watering system.

1.3.2 Specific Objectives

i. To develop a technologically advanced system that will automatically water cannabis plants and keep security cameras trained on them.
ii. To ensure that the system complies with Rwanda's cannabis cultivation regulations, particularly the necessary security measures.
iii. To create a website that allows users to view and control data from cameras and sensors from a distance.

1.5 Research Questions

i. How can IoT improve security and watering in Cannabis cultivation?
ii. How can the system meet Rwanda's legal requirements for Cannabis farming?
iii. How can camera and sensor data be managed through a website?

1.6 Scope

1.6.1 Geographical Scope

The Project focuses on the controlled cultivation of cannabis for scientific and medical purposes in Rwanda, where the plant is permitted by law. The farm that is the subject of the particular case study obtained a cultivation license through Rwanda's Irembo platform.

1.6.2 Theoretical Scope

The theoretical framework addresses the relationship between smart agriculture and IoT technology, emphasizing automated irrigation and security monitoring. The study highlights the benefits of integrating sensors, cameras, and data management systems on a single platform by referencing previous research on Internet of Things applications in agriculture.

1.6.3 Content Scope

The design, installation, and testing of an Internet of Things (IoT) system that combines automated irrigation with security cameras for cannabis growing are all included in this project. The research looks at both software (MySQL database, camera integration) and hardware (ESP32 CAM, soil moisture sensors, NodeMCU, relay, etc.). It also takes into account the system's power management.

1.7 Significance of the Study

This work adds to the increasing corpus of research on intelligent farming, particularly as it relates to heavily regulated plants like cannabis. The creation of an integrated irrigation and security system could improve cannabis farming's productivity, sustainability, and adherence to the law. The study shows how farmers can meet Rwanda's strict cannabis cultivation regulations while managing their farms more efficiently by utilizing IoT technology. Moreover, the system's use of renewable energy supports international initiatives to improve the sustainability of agriculture.

1.8. Structure/Organization of the study

The Research Design and implementation of IoT based plant security with watering system is organized into five chapters as follows: Chapter I. General Introduction, this chapter is focusing on the Objectives of the project, Problem statement, Purpose /General Aim/General Objective of the Study Objectives of the Study Research Questions/Hypotheses and Scope of the study, Chapter II. Literature review, this chapter deals with different related research topics to the project., Chapter III. Research Methodology, this chapter focuses on the methodology used in this project and the data-gathering techniques., Chapter IV. Design and Implementation, this chapter focuses on and describes the design and Implementation project. And Chapter V. Conclusion and Recommendations, the last chapter is made up of the conclusion and recommendation for further improvements of the software.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

A thorough review of the body of research that is pertinent to the topic is given in this chapter. It will include important ideas, viewpoints, and concepts from a range of writers and specialists, giving readers a sense of how the topic has been approached in earlier studies. After a discussion of the theoretical stances that guide this research, a review of previous studies that have looked at related subjects will take place. The objective of this chapter is to pinpoint the gaps in the current literature that this study attempts to fill.

2.1 Concepts, Opinions, Ideas from Authors/Experts

This section examines the main ideas and scholarly viewpoints regarding the goals of the study. It looks at Internet of Things (IoT) applications in agriculture, security surveillance technologies, automated irrigation systems, and smart farming using renewable energy sources like solar power. The study's variables IoT-based security, automated watering, and regulatory compliance in cannabis cultivation will inform the organization of the literature. The review will focus on the methods used by earlier researchers to address these problems, the relationships found, and the gaps that remain. The way that the current research adds to the body of knowledge will be guided by these gaps.

2.1.1 Solar-Powered Irrigation Systems

Systems that run irrigation pumps and sensors on solar energy in order to supply water to crops. Typically, these systems are made up of irrigation hardware, batteries, controllers, and solar panels (Clark, M., 2021).

2.1.2 Soil Moisture Sensors

instruments that gauge the soil's moisture content. Real-time data from these sensors helps to optimize irrigation scheduling and avoid over- or under-watering (Roberts, L., 2020).

2.1.3 Automation in Agriculture

technology used to carry out agricultural tasks without the need for human intervention. Among them are automated irrigation systems that modify water delivery in response to sensor readings (Smith, B. , 2022).

2.1.4 Sustainable Agriculture

farming methods that provide food while preserving or enhancing ecosystems and the environment. One sustainable method that lessens dependency on non-renewable energy sources is solar-powered irrigation (Brown, L., 2021).

2.2 Theoretical Perspectives

The basis for comprehending the layout and operation of plant irrigation with security systems comes from theoretical viewpoints. The materials and technologies used to create and implement these systems are covered in this section. The following materials are used to implement irrigation systems powered by grid:

2.2.1 Controllers

Process data from soil moisture sensors to control the irrigation system's operation by modifying the water flow. Controllers are necessary in order to automate irrigation (Green, M. , 2019).

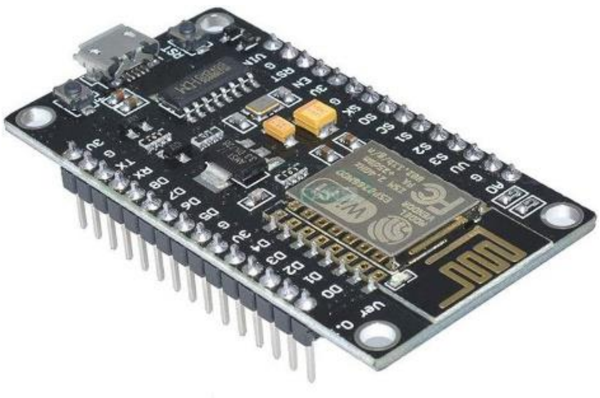

Figure 1: Node MCU

The NodeMCU functions as the IoT system's central control unit. In order to control the relay and pump motor, it receives data from the soil moisture sensors and processes it. It also serves as a communication link, transmitting sensor data to the MySQL database and projecting pertinent data onto the LCD screen. The NodeMCU manages all automated actions based on preset conditions, ensuring the security and watering systems run smoothly.

2.2.2 Pumps

Distribute water from the source to the crops. Grid-powered pumps are used in these systems to deliver water efficiently, reducing the need for manual intervention (Brown, L., 2021).

Figure 2: Pump motor 5v

The primary part in charge of providing water to the plants is the 5V water pump. The pump draws water from a reservoir and directs it to the soil when the relay is activated, making sure the plants receive enough irrigation. Without requiring human intervention, this automated watering system guarantees consistent plant growth while saving time.

2.2.3 Irrigation Hardware

consists of parts that supply water to the crops, like sprinklers, valves, and pipes. Together with the 5v powered system, these elements guarantee appropriate water distribution. (Clark, M., 2021).

Figure 3: Pipes

2.2.4 LCD 16×2 Display

Display devices called liquid crystal displays are used in embedded systems to show different system parameters and statuses. An LCD 16x2 is a 16-pin device with two rows that each hold sixteen characters. You can use LCD 16x2 in either 4-bit or 8-bit mode. (Ghirardello et. al, 2018).

Figure 4: 16X2 LCD

Vital system data, including pump status, current soil moisture levels, and system alerts, are shown on the LCD screen. With its user-friendly interface, the user can quickly and easily monitor real-time data, including the security camera's status and the irrigation system's health. The prompt feedback guarantees that users can promptly detect any problems with the system.

2.2.5 Relay module

A relay is a switch that can be used to electrically or mechanically open and close circuits. Relays operate by opening and closing contacts in other circuits to control one electrical circuit. According to the relay diagram, when a relay contact is typically open

(NO (woodford, 2021)

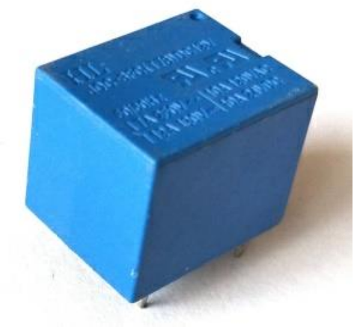

Figure 5: relay

This system's relay functions as an electronic switch to regulate the water pump's operation. It receives signals from the NodeMCU and determines whether to activate or deactivate the pump based on data from the soil moisture sensor. The efficient irrigation process is guaranteed by this automation, which only activates the water pump when the soil moisture levels fall below the ideal threshold.

2.2.6 Soil Moisture Sensor

This can be used to indicate to a plant when it needs watering through an automated plant watering system or as a signal of some other kind.

Figure 6: Soil moisture sensor

In order to make sure the plants get enough moisture, the soil moisture sensors are in charge of keeping an eye on the amount of water in the soil. The NodeMCU receives data from these sensors in real time and uses it to determine whether irrigation is necessary. These sensors assist in preserving the ideal growing conditions for the cannabis plants by continuously monitoring the moisture levels, thereby avoiding both overwatering and under watering.

2.2.7 The ESP32 CAM

The ESP32 CAM is a low-cost, powerful microcontroller with integrated Wi-Fi and Bluetooth, designed for IoT applications. It features an onboard camera module capable of capturing images and video, making it ideal for security and surveillance systems. The ESP32 CAM supports micro SD card storage for saving images locally and can stream video data over the network for remote monitoring. Its compact size and versatility make it a popular choice for smart agriculture and home automation projects.

Figure 7: ESP CAM 32

The central component of this project's security system is the ESP32 CAM. It records live video from the cannabis farm, allowing for round-the-clock monitoring. Its built-in Wi-Fi allows it to stream the video to a website running MySQL, which enables remote farm monitoring. Additionally, the ESP32 CAM has motion detection capabilities, which improve security on the farm by warning the system of any unauthorized activity or access.

2.3 Related Study

2.3.1 Study on Solar-Powered Irrigation Systems

(Davis, K., 2021) carried out a study assessing solar-powered irrigation systems in arid areas, emphasizing how well they work to improve water use efficiency and lessen reliance on traditional energy sources. The study showed that by offering a dependable and sustainable power source for water distribution, solar-powered systems could greatly enhance irrigation techniques.

2.3.2 Study on Soil Moisture Sensors

(Miller, A. , 2019) examined developments in soil moisture sensor technology, highlighting the importance of these sensors for precision farming. According to the study, precise measurements of soil moisture are essential for determining the best irrigation schedules, which improve crop yields and save water.

2.3.3 Study on Automation in Irrigation

(Smith, B. , 2022)investigated the impact of automation on irrigation efficiency, focusing on how automated systems can enhance water management and reduce labor costs. The study found that automation not only improves water use efficiency but also simplifies the irrigation process, making it more manageable for farmers.

2.3.4 Study on the Use of Solar Energy in Agriculture

(Turner, N. , 2020) examined the uses of solar energy in agriculture and discussed the advantages and difficulties of doing so. According to the study, solar energy can significantly contribute to sustainable farming methods by lowering the need for non-renewable energy sources and raising agricultural systems' overall efficiency.

2.3.5 Security Measures for Growing Cannabis

A study by (Nwankwo, 2020) concentrated on security measures for valuable crops like cannabis. Their study made clear how important it is to incorporate surveillance systems in order to keep an eye on farm activities and stop illegal access. According to the study, IoT and security cameras work well together to offer a dependable way to monitor farms in real time, especially when it comes to legally permitted crops like cannabis.

CHAPTER 3: DATA COLLECTION AND ANALYSIS PROCEDURES

3.0 Introduction

The research methods utilized to develop and execute IoT based plant security with watering system for the Farming cooperative are described in this chapter. It includes information on the population, sample size, sampling technique, instruments used in the study, procedures for collecting data, methods for analyzing and interpreting data, ethical considerations, and study limitations. Ensuring a methodical approach to data collection and analysis is the goal in order to produce accurate and trustworthy results.

3.1 Research Design

In order to explore and describe the integration of an IoT-based security and watering system in cannabis cultivation, the research uses a descriptive survey design. This design was selected in order to ensure a thorough understanding of the ways in which technology affects the security and efficiency of the cultivation process. It also allows for the collection of both qualitative and quantitative data. The method is perfect for this study because it incorporates aspects of both qualitative and quantitative approaches, such as sensor reading data and observation.

3.2 Research Population

Experts in cannabis cultivation, farm owners, and tech professionals working with Internet of Things-based agricultural systems make up the study's population. The intended audience is anyone with a license to cultivate cannabis in Rwanda; particular attention is paid to people or businesses who are putting in place irrigation and security systems through the Internet of Things. The study's goal is to extrapolate its conclusions to comparable farming practices throughout Rwanda.

3.3 Sample Size

Thirty respondents, comprising farm managers, IoT engineers, and agricultural professionals with familiarity with automated systems in cannabis cultivation, will make up the sample size. According to research standards, a moderate-sized sample can adequately represent the larger population in agricultural research, which is why this sample size was selected (Cochran, 1977). The results were trustworthy because the sample was yield enough information for both qualitative and quantitative analysis.

3.3.1 Sampling Procedure

The method of purposive sampling was utilized in order to choose the respondents. This method works well for focusing on particular people who have relevant expertise and experience with IoT technology and cannabis farming. Professionals involved in Rwanda's licensing and security regulation processes, as well as farm owners who have installed Internet of Things-based security and irrigation systems, was included in the sample.

3.4 Research Instrument

Checklists for observations, interviews, and surveys are the main tools used in research. These devices are made to gather information about the current irrigation methods and how the security system with Camera is being implemented, and the results that have been seen.

3.4.1 Choice of the Research Instrument

An observation checklist and structured questionnaires were the main research tools utilized in this study. Farm operators will be surveyed to obtain information on the efficacy of IoT-based systems, and the observation checklist will enable the researcher to evaluate the system's dependability and functionality in an actual farming setting. The selection of these tools is predicated upon their capacity to gather pertinent and organized data.

3.4.2 Validity and Reliability of the Instrument

To ensure the validity of the research instruments, the observation checklist was reviewed in the field of agricultural technology and Cannabis regulation. Reliability and was assessed through a pilot test with 5 participants who are not part of the main sample, allowing for adjustments based on feedback. The internal consistency of the questionnaire will be measured using Cronbach's alpha.

3.5 Data Gathering Procedures

There are multiple steps involved in gathering data: The research instruments first were fine-tuned through a pilot test. Second, the target respondents were given questionnaires, and observations of IoT systems in use of documented. Lastly, in order to get more detailed information and clarify responses, follow-up interviews might be done.

3.6 Data Analysis and Interpretation

Statistical techniques, such as descriptive statistics like mean, mode, and standard deviation, will be applied to the analysis of quantitative data. We will use inferential statistics, like Pearson's correlation, to evaluate the connection between security measures and system efficiency. Thematic analysis of the qualitative data will be used to pinpoint important trends and themes in the replies concerning the difficulties and performance of the system.

3.7 Ethical Considerations

All participants will give their informed consent in accordance with ethical guidelines. Respondents will be guaranteed the privacy of their answers, and their identities will be kept anonymous. The appropriate authorities will grant ethical clearance, and participants will be free to leave the study at any time without incurring any fees.

3.8 Limitations of the Study

The study admits a number of shortcomings.

Sample Size and Generalizability: The results may not be as applicable to other areas or crops due to the sample size.

Restrictions on Data Collection: The extent and depth of data collection may be impacted by time and resource limitations.

Technological Limitations: The results of the study may be impacted by the accessibility and dependability of the technology utilized in the irrigation system.

CHAPTER 4: SYSTEM DESIGN, ANALYSIS AND IMPLEMENTATION

4.0 Introduction

This chapter presents the results obtained from the Design and Implementation of IoT Based Plant Security with Watering System, including irrigation control based on soil moisture levels and camera for security of crops. The results are supported by tables, graphs, and diagrams to provide a clear understanding of the system's performance. The accuracy and significance of the data collected are also discussed, along with potential sources of error and comparison with theoretical expectations. Additionally, cost estimation for the project is provided to give a comprehensive understanding of the financial requirements.

4.1 Calculations

In this section, all necessary calculations carried out during the project design are presented. These include power requirements for the various components such as the pump motor, soil moisture sensor, and the overall power consumption of the system using NodeMCU. The formulas used for calculating power, voltage, and current in the system, along with the soil moisture sensor calibration, are outlined to show how the system operates within optimal parameters.

The necessary calculations for the power requirements and system design are provided, taking into account the use of 220V AC power converted to 5V DC for the NodeMCU, sensors, and other components. The following key aspects were calculated:

4.2.1. Power Conversion

The system uses a 220V AC supply, which is converted to 5V DC using a step-down converter. The formula for power is given by:

$P = V \times I$

Where:

- P is power in watts
- V is voltage in volts
- I is current in amperes

The NodeMCU operates at 5V DC, and the typical current consumption is around 0.2A. Thus, the power consumed by the NodeMCU is:

$P=5V\times0.2A=1W$

4.2.2 Pump Motor Control

The irrigation system is powered by a 5V DC pump motor. The system is designed to turn on the pump when the soil moisture content falls below 30% and turn it off when the moisture level exceeds 60-80%. The power consumption of the pump motor is given by:

$Ppump=5V\times Ipump$

Assuming the pump draws 1A, the power consumption is:

$Ppump=5V\times1A=5W$

The system will continuously monitor soil moisture using the sensor and adjust irrigation accordingly.

4.2.3 Soil Moisture Control

The soil moisture sensor triggers the pump motor when the soil moisture level is below 30% and turns it off when it exceeds 60-80%. This hysteresis ensures that the system avoids frequent switching of the pump motor. The system checks soil moisture values regularly to maintain optimal irrigation.

4.2.4 Uploading Sensor Values to database

The NodeMCU uploads both soil moisture readings to the database platform at regular intervals. To calculate the time taken to upload sensor data to MySQL server, consider the internet connection speed and data packet size. The typical upload interval is set to 10 seconds, which ensures timely updates without overwhelming the system.

Assuming the data payload for each upload is approximately 100 bytes and the network speed is 1 Mbps (1,000,000 bits per second):

Upload time=Data Size (in bits) / Network Speed

Converting bytes to bits (1 byte = 8 bits), we get:

Upload time=100×8/1,000,000=0.0008 seconds

Thus, the upload time is negligible (0.8 milliseconds), allowing sensor values to be uploaded efficiently within the 10-second interval.

4.2 Drawings

4.2.1 Flowchart

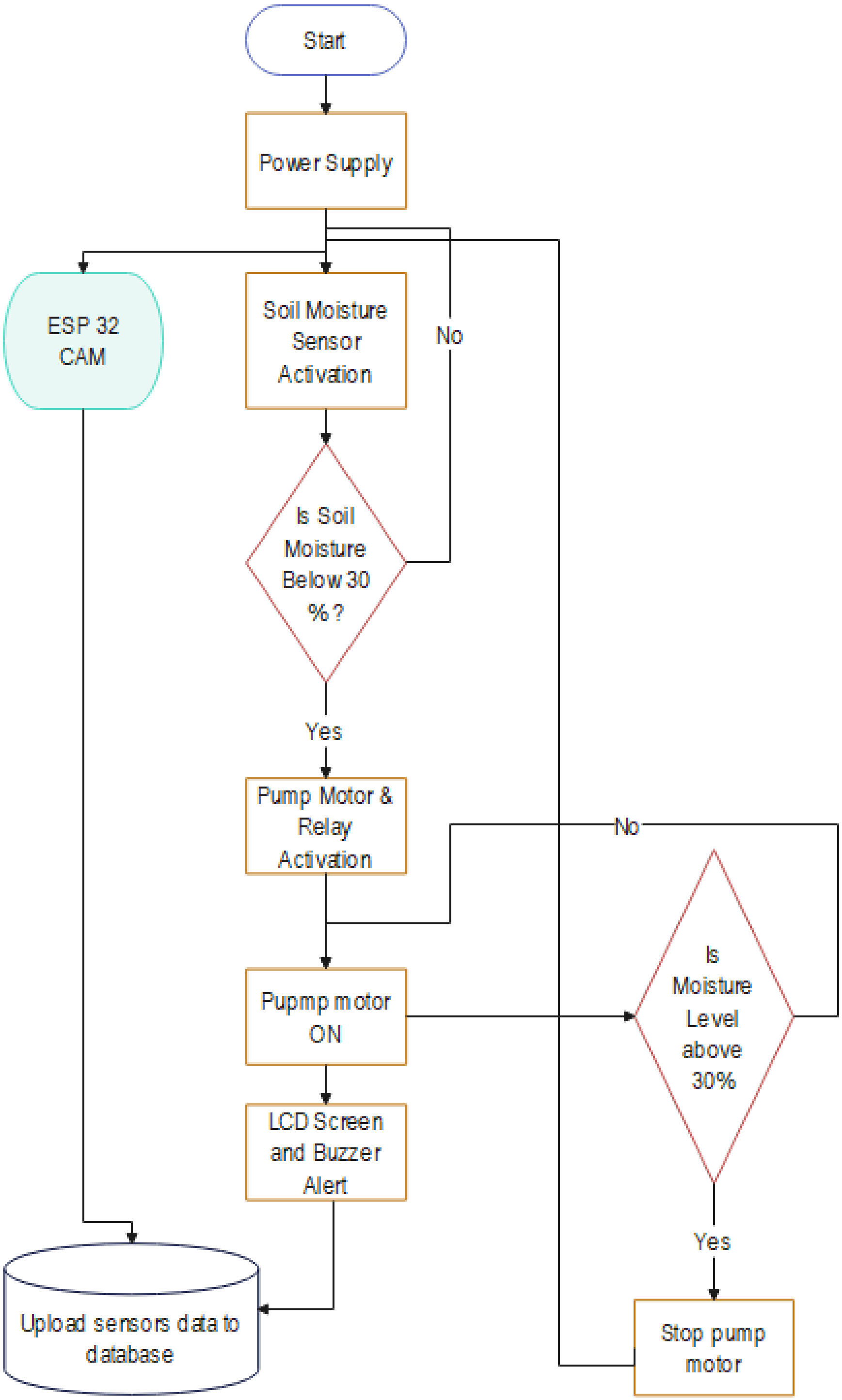

Figure 8: Flow chart

Utilizing sensors and Internet of Things technology, the Design and Implementation of an IoT Based Plant Security with Watering System automates irrigation and keeps an eye on plant security. A soil moisture sensor is activated to determine the water content of the soil after the system is powered up by grid energy. The system activates the pump motor and relay to water the crops if the moisture content falls below a predetermined threshold. During irrigation, a buzzer sounds an alert, and an LCD screen shows the current status. In order to ensure efficient water management and plant security, the system also incorporates a camera to monitor crops. All sensor data is uploaded to the Database platform for remote control and monitoring.

4.2.2 System Block Diagram

The system block diagram provides a visual representation of the interconnections between various components within the crop irrigation with security system. It illustrates how the NodeMCU communicates with the Camera sensor, soil moisture sensor, relay module, and pump motor, show casing the flow of data and control signals. The block diagram also highlights the connection to the database platform for remote monitoring.

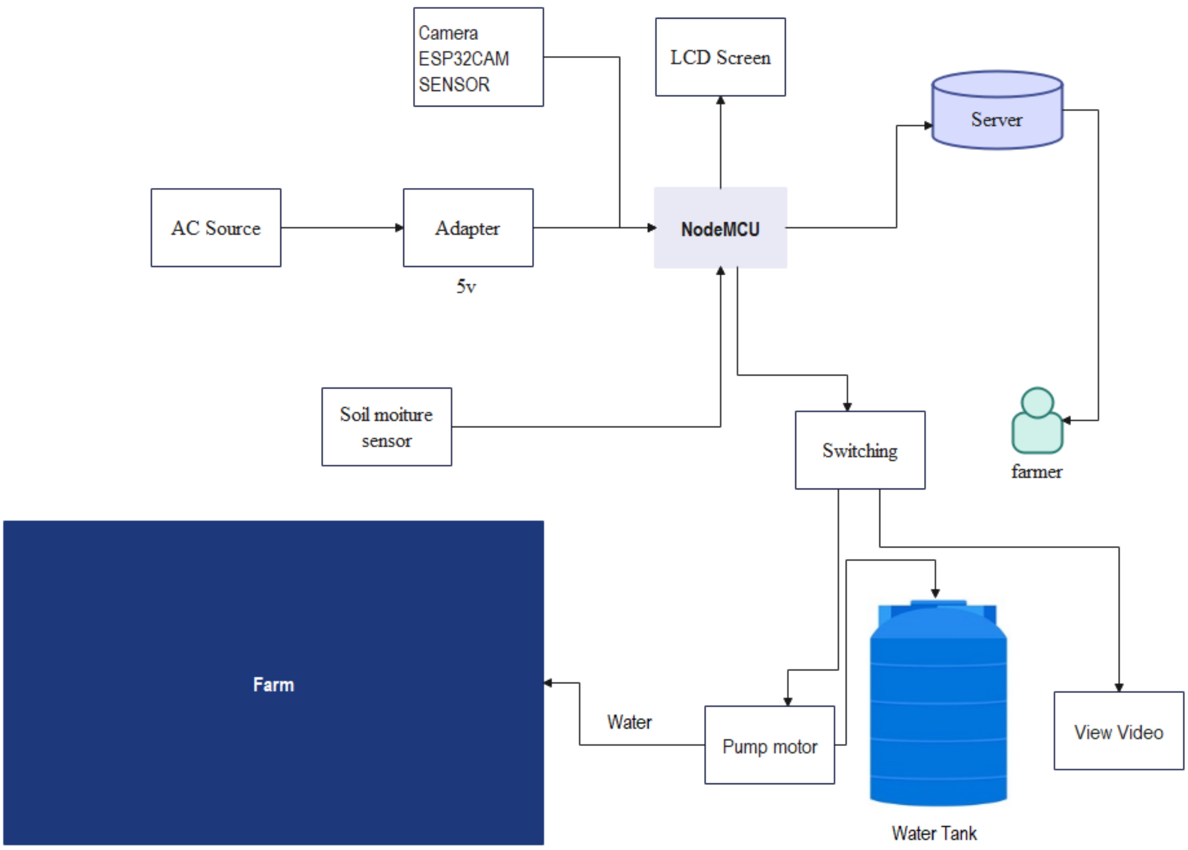

Figure 9:block diagram

The system architecture for the irrigation project is depicted in the provided diagram. The NodeMCU, a microcontroller that processes data from multiple sensors and regulates actuators, is the central component of the system. The Camera Sensor provides vital information for preserving ideal growing conditions by keeping an eye on the crops security. Farmers can easily monitor the farm environment by looking at the real-time information about these parameters displayed on the LCD screen.AC provides the system with power enabling continuous operation. When irrigation is required, the pump motor is activated by the soil moisture sensor, which determines the soil's moisture content. The switching mechanism allows for the control of the pump, Farmers can effectively manage their farm by using a web platform to enable remote monitoring and control of their crops.

4.2.3 Circuit Diagram

The circuit diagram depicts the electrical connections between the components of the smart irrigation system. It illustrates how the NodeMCU interfaces with the Camera sensor and soil moisture sensor, as well as how the relay module controls the pump motor and camera view. This diagram is essential for understanding the wiring and ensuring proper functionality during implementation.

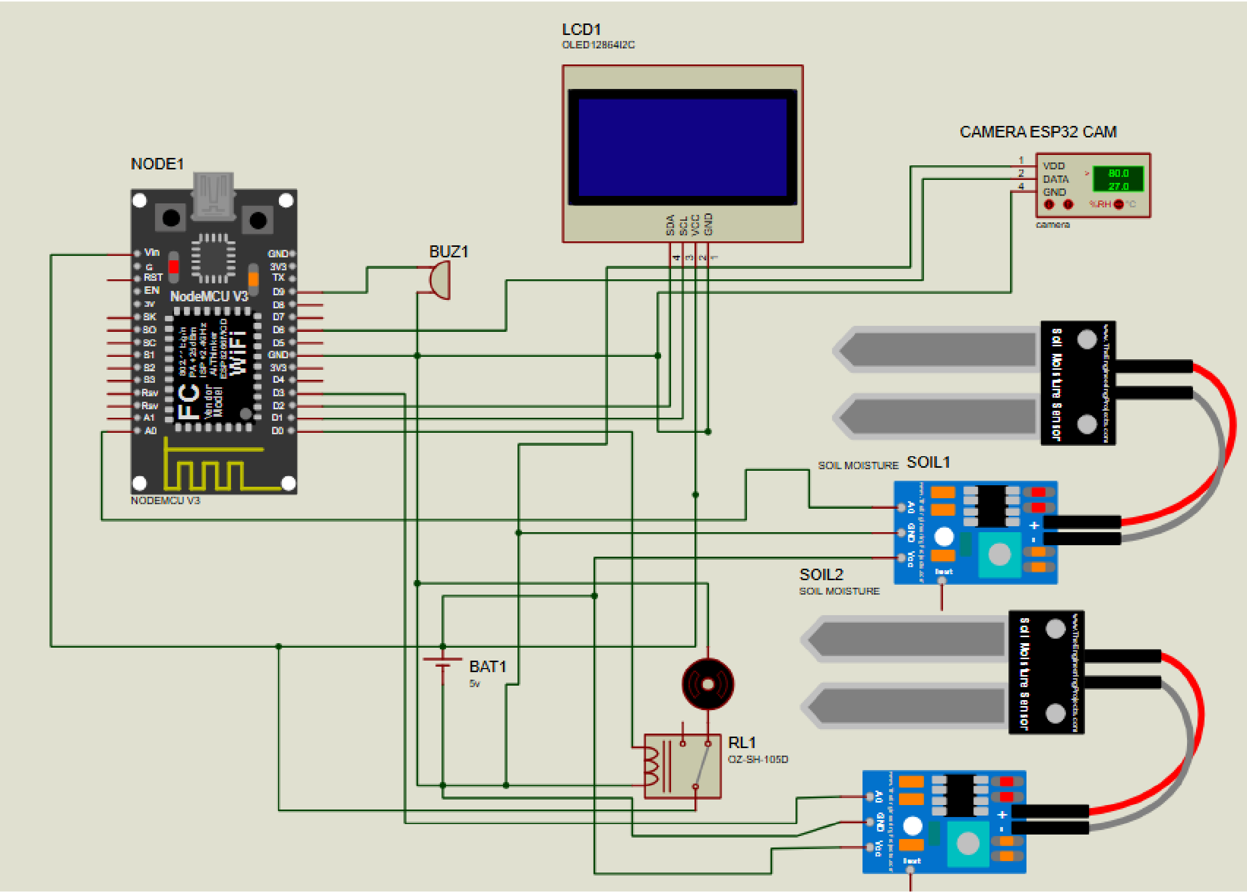

Figure 3. 1: Circuit diagram

The circuit diagram shows a smart irrigation automation system that is run on a 5V battery (BAT1) and managed by a NodeMCU (ESP8266). Important sensors include a soil moisture sensor to track soil conditions After processing the data from these sensors, the NodeMCU turns on two relays: Relay 1 (RL1) activates a pump motor for irrigation in low-soil conditions, in addition, the system has LCD display for real-time data display and a buzzer (BUZ1) for alarms. The pump motor which also powers the relays.

4.3 Specifications

Table 1: specification

S/N	Component	Specification
1.	**NodeMCU (ESP8266)**	Microcontroller: ESP8266 Operating Voltage: 3.3V Digital I/O Pins: 11 Analog Input Pins: 1 (10-bit ADC) Clock Speed: 80MHz/160MHz Flash Memory: 4MB Connectivity: Wi-Fi (802.11 b/g/n) Power Consumption: 170mA (max during Wi-Fi transmission) Dimensions: 48mm x 26mm
2.	**LCD Screen**	Type: 16x2 Character LCD (I2C) Operating Voltage: 5V Backlight: LED Communication Interface: I2C Power Consumption: ~30mA Dimensions: 80mm x 36mm
3.	**Pump Motor**	Type: Submersible Water Pump Operating Voltage: 5V Current Draw: 350mA (maximum) Flow Rate: 120-200L/h Head Height: 0.4-1.1m Dimensions: 45mm x 30mm x 25mm Power Consumption: 1.75W
	Relay Module	Type: 1-Channel Relay Module Operating Voltage: 5

4.		Trigger Voltage: 3.3V (compatible with NodeMCU) Max Load: 10A @ 250V AC or 10A @ 30V DC Isolation: Opt coupler isolation between input and output Dimensions: 50mm x 26mm x 18.5mm
5.	**ESP 32 CAM**	RAM: 520 KB SRAM Flash Memory: 4 MB SPI Flash Camera: OV2640 2MP camera (can be upgraded with OV7670, OV5640) Connectivity: Wi-Fi 802.11 b/g/n and Bluetooth 4.2 Operating Voltage: 3.3V GPIO Pins: 10 usable GPIO pins Power Consumption: 160 mA to 300 mA during normal operation MicroSD Slot: Supports up to 4GB microSD card Interface:UART, SPI, I2C, PWM, ADC, and DAC
6.	**Soil moisture sensor**	Operating Voltage: 3.3V to 5V Current Consumption: Less than 20 mA Output Voltage: Analog signal (varies with soil moisture level) Output Range: 0V (dry) to 4.2V (wet), depending on soil moisture level Interface: Analog output, typically connected to an ADC pin on a microcontroller like the ESP32 Working Principle: Capacitive sensing technology that measures the dielectric permittivity of the soil, which changes with moisture content Length: 3.84 inches (9.8 cm)

4.4 Cost estimation

Table 2: Cost Estimation

S/N	Item	Quantity	Unit Price (Rwf)	Total (Rwf)
1.	NodeMCU	1	10000	10000
2.	Soil Moisture Sensor	2	5000	10000
3.	Two-channel Relay Module	1	5000	5000
4.	Pump Motor	1	5000	5000
5.	ESP32 CAM	1	30000	30000
6.	Jumper Wires	1 Set	2000	2000
7.	LCD Screen	1	8000	8000
8.	Pipes	2 meters	1000	2000
9.	Power Supply (5V)	1	7000	7000
10.	cover	Small tank, MDF Wood, Supergun, Nail, Etc….	15000	10000
11.	**Total Cost**			**89000**

The total cost of implementing the smart irrigation system is approximately **89000 Rwf**, which is a reasonable investment for small to medium-scale farmers seeking to automate operations.

4.5 Implementation

In this section, the physical construction and realization of the smart irrigation system are discussed. The project integrates various components, including sensors, the NodeMCU microcontroller, relays, and a pump motor. Each component plays a crucial role in ensuring the system functions as intended to automate temperature control and irrigation.

Figure 10: NodeMCU in implementation

The NodeMCU acts as the brain of the system, processing data from the soil moisture sensor and camera sensor (for security). It sends commands to activate or deactivate the relay connected to the pump motor based on sensor readings. Additionally, it connects to the MySQL database web platform, uploading real-time data for remote monitoring and control by the farmer.

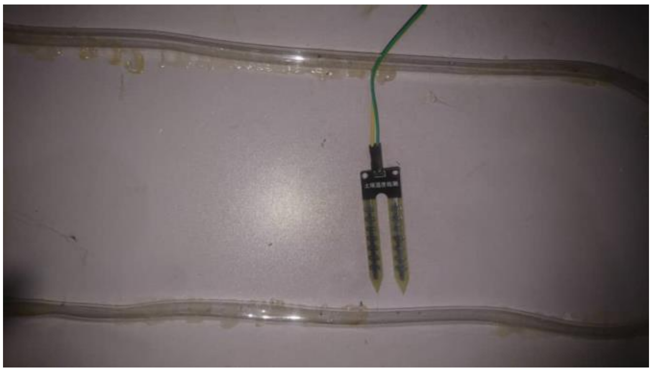

Figure 11: Soil Moisture Sensor

This sensor measures the moisture content in the soil. It continuously sends data to the NodeMCU, which uses the readings to determine when to start or stop irrigation. When the moisture falls below 30%, the pump motor is activated to water the plants. If the moisture exceeds 60-80%, the pump motor is turned off. This sensor ensures that the plants are watered optimally and reduces water wastage.

Figure 12: The LCD display

The LCD display is connected to the NodeMCU and shows real-time sensor readings for soil moisture. This allows the farmer to monitor the conditions of the irrigation locally without needing to access the web platform.

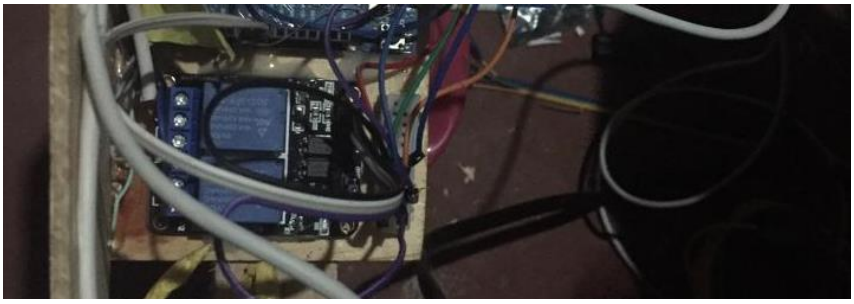

Figure 13: Relay in circuit

Two relays are used in the system: controls the 5V DC pump motor. The relays act as switches that are activated based on commands from the NodeMCU. They ensure that high-voltage and low-voltage devices can be safely controlled by the microcontroller.

Figure 14: Pump in small tank

The 5V DC pump motor is responsible for irrigation. When the soil moisture sensor detects that the moisture content is below the threshold (30%), the NodeMCU activates the relay to start the pump, delivering water from the tank to the farm. The motor is turned off when the soil moisture reaches the upper limit (60-80%).

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

This chapter summarizes the key findings of the project and how they meet the objectives set at the beginning. It also discusses the overall conclusions drawn from the results and suggests areas for future improvements and research.

5.1 Conclusions

The goal of this project was to Design and Implementation of IoT Based Plant Security with Watering System that could automatically control irrigation using a NodeMCU, soil moisture sensor. The system successfully monitored soil moisture levels, turning on the water pump when the soil was too dry and switching it off once the desired moisture level was reached. This ensured that water was used efficiently. Additionally, the camera shows and capture security of crop in farm.

By integrating the web platform, the project allowed for real-time monitoring, so farmers could check the crop conditions remotely. This feature reduces the need for constant human intervention, making the system easier to manage. Furthermore, the use of grid power made the system more sustainable, especially in areas where electricity supply might be unreliable.

The results show that the system successfully met the project's objectives. It provided an efficient way to control both irrigation and security, which are key to improving crop production. However, there is room for future improvement, especially in making the system work on a larger scale and adding more advanced features to further optimize crop conditions.

5.2 Recommendations

Although the project met its main goals, there are areas that could be improved in future versions. The current system is designed for small-scale farm It would be beneficial to explore how the system can be scaled for larger farms with the help of MINAGRI. Also, while the system allows for real-time monitoring, adding features like data analysis or predictions based on past data could help farmers such as different CO-Operatives make even better decisions about watering and temperature control. Additionally, improving the power system by extending the battery life or using both solar and grid power with the help of REG to distribute electricity to different farms by helping system to run with grid supply to ensure the system runs reliably in all conditions. Adding more sensors, like humidity or soil nutrient sensors, would give a more complete picture of the farm environment and help further improve plant health.

5.3 Suggestions for Further Study

The long-term effects of irrigation systems on crop yield and soil health require more investigation. It would be beneficial to look into the financial advantages and viability of expanding the system for larger farming operations. Further advancements in system efficiency and adaptability may be possible by researching the integration of cutting-edge technologies, such as IoT-enabled monitoring systems or automated weather-based irrigation adjustments. It might be advantageous to investigate the possibilities for hybrid solar and grid-powered systems in locations with sporadic electricity in order to improve irrigation techniques in various environments.

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Appendix

Camera Code

```
#include "esp_camera.h"
#include <WiFi.h>
#include "esp_timer.h"
#include "img_converters.h"
#include "Arduino.h"
#include "fb_gfx.h"
#include "soc/soc.h"           // Disable brownout problems
#include "soc/rtc_cntl_reg.h"  // Disable brownout problems
#include "esp_http_server.h"

// Replace with your network credentials
const char* ssid = "Xperia";
const char* password = "123456789";

#define CAMERA_MODEL_AI_THINKER

// Pin definitions for AI-Thinker
#if defined(CAMERA_MODEL_AI_THINKER)
#define PWDN_GPIO_NUM     32
#define RESET_GPIO_NUM    -1
#define XCLK_GPIO_NUM      0
#define SIOD_GPIO_NUM     26
#define SIOC_GPIO_NUM     27

#define Y9_GPIO_NUM       35
#define Y8_GPIO_NUM       34
#define Y7_GPIO_NUM       39
#define Y6_GPIO_NUM       36
#define Y5_GPIO_NUM       21
#define Y4_GPIO_NUM       19
#define Y3_GPIO_NUM       18
```

```
#define Y2_GPIO_NUM       5
#define VSYNC_GPIO_NUM    25
#define HREF_GPIO_NUM     23
#define PCLK_GPIO_NUM     22
#define LED_GPIO_NUM      4    // Change to 33 if using normal LED
#endif

#define PART_BOUNDARY "123456789000000000000987654321"
static const char* _STREAM_CONTENT_TYPE = "multipart/x-mixed-replace;boundary="
PART_BOUNDARY;
static const char* _STREAM_BOUNDARY = "\r\n--" PART_BOUNDARY "\r\n";
static const char* _STREAM_PART = "Content-Type: image/jpeg\r\nContent-Length:
%u\r\n\r\n";

httpd_handle_t stream_httpd = NULL;

static esp_err_t stream_handler(httpd_req_t *req) {
   camera_fb_t * fb = NULL;
   esp_err_t res = ESP_OK;
   size_t _jpg_buf_len = 0;
   uint8_t * _jpg_buf = NULL;
   char * part_buf[64];

   res = httpd_resp_set_type(req, _STREAM_CONTENT_TYPE);
   if (res != ESP_OK) {
      return res;
   }

   while (true) {
      fb = esp_camera_fb_get();
      if (!fb) {
         Serial.println("Camera capture failed");
         res = ESP_FAIL;
      } else {
```

```
    if (fb->width > 400) {
      if (fb->format != PIXFORMAT_JPEG) {
        bool jpeg_converted = frame2jpg(fb, 80, &_jpg_buf, &_jpg_buf_len);
        esp_camera_fb_return(fb);
        fb = NULL;
        if (!jpeg_converted) {
          Serial.println("JPEG compression failed");
          res = ESP_FAIL;
        }
      } else {
        _jpg_buf_len = fb->len;
        _jpg_buf = fb->buf;
      }
    }
  }
  if (res == ESP_OK) {
    size_t hlen = snprintf((char *)part_buf, 64, _STREAM_PART, _jpg_buf_len);
    res = httpd_resp_send_chunk(req, (const char *)part_buf, hlen);
  }
  if (res == ESP_OK) {
    res = httpd_resp_send_chunk(req, (const char *)_jpg_buf, _jpg_buf_len);
  }
  if (res == ESP_OK) {
    res = httpd_resp_send_chunk(req, _STREAM_BOUNDARY,
strlen(_STREAM_BOUNDARY));
  }
  if (fb) {
    esp_camera_fb_return(fb);
    fb = NULL;
    _jpg_buf = NULL;
  } else if (_jpg_buf) {
    free(_jpg_buf);
    _jpg_buf = NULL;
  }
```

```
        if (res != ESP_OK) {
            break;
        }
    }
    return res;
}

void startCameraServer() {
    httpd_config_t config = HTTPD_DEFAULT_CONFIG();
    config.server_port = 80;

    httpd_uri_t index_uri = {
        .uri       = "/",
        .method    = HTTP_GET,
        .handler   = stream_handler,
        .user_ctx  = NULL
    };

    if (httpd_start(&stream_httpd, &config) == ESP_OK) {
        httpd_register_uri_handler(stream_httpd, &index_uri);
    }
}

void setup() {
    WRITE_PERI_REG(RTC_CNTL_BROWN_OUT_REG, 0);  // Disable brownout detector
    Serial.begin(115200);
    Serial.setDebugOutput(false);

    camera_config_t config;
    config.ledc_channel = LEDC_CHANNEL_0;
    config.ledc_timer = LEDC_TIMER_0;
    config.pin_d0 = Y2_GPIO_NUM;
    config.pin_d1 = Y3_GPIO_NUM;
    config.pin_d2 = Y4_GPIO_NUM;
```

```
config.pin_d3 = Y5_GPIO_NUM;
config.pin_d4 = Y6_GPIO_NUM;
config.pin_d5 = Y7_GPIO_NUM;
config.pin_d6 = Y8_GPIO_NUM;
config.pin_d7 = Y9_GPIO_NUM;
config.pin_xclk = XCLK_GPIO_NUM;
config.pin_pclk = PCLK_GPIO_NUM;
config.pin_vsync = VSYNC_GPIO_NUM;
config.pin_href = HREF_GPIO_NUM;
config.pin_sscb_sda = SIOD_GPIO_NUM;
config.pin_sscb_scl = SIOC_GPIO_NUM;
config.pin_pwdn = PWDN_GPIO_NUM;
config.pin_reset = RESET_GPIO_NUM;
config.xclk_freq_hz = 20000000;
config.pixel_format = PIXFORMAT_JPEG;

if (psramFound()) {
  config.frame_size = FRAMESIZE_UXGA;  // Full resolution (UXGA)
  config.jpeg_quality = 10;
  config.fb_count = 2;
} else {
  config.frame_size = FRAMESIZE_SVGA;  // Lower resolution for stability
  config.jpeg_quality = 12;
  config.fb_count = 1;
}

// Initialize camera
esp_err_t err = esp_camera_init(&config);
if (err != ESP_OK) {
  Serial.printf("Camera init failed with error 0x%x", err);
  return;
}

// Connect to WiFi
```

```
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("");
  Serial.println("WiFi connected");

  startCameraServer();
  Serial.printf("Camera Ready! Use 'http://%s' to connect\n", WiFi.localIP().toString().c_str());
}

void loop() {
  // Nothing is needed here, the server handles everything
}
```

NodeMCU code

```
#include <ESP8266WiFi.h>
#include <ESP8266HTTPClient.h>
#include <ESP32CAM.h> // For ESP32CAM

#define SOIL_SENSOR_PIN1 A0  // First Soil Moisture Sensor Pin
#define SOIL_SENSOR_PIN2 A1  // Second Soil Moisture Sensor Pin
#define RELAY_PIN D1         // Relay controlling the pump
#define WATER_THRESHOLD 600  // Soil moisture threshold to start irrigation

const char* ssid = "Xperia";           // WiFi SSID
const char* password = "12456789";   // WiFi Password
const char* serverName = "http://192.168.43.60/upload.php";  // Your PHP server

void setup() {
  Serial.begin(115200);

  // Initialize the Relay Pin
```

```
  pinMode(RELAY_PIN, OUTPUT);
  digitalWrite(RELAY_PIN, HIGH);  // Initially off

  // Initialize WiFi
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting to WiFi...");
  }
  Serial.println("Connected to WiFi.");

  // Initialize ESP32 CAM (if needed)
  esp32cam.begin();

}

void loop() {
  int soilMoisture1 = analogRead(SOIL_SENSOR_PIN1);
  int soilMoisture2 = analogRead(SOIL_SENSOR_PIN2);

  Serial.print("Soil 1: ");
  Serial.println(soilMoisture1);
  Serial.print("Soil 2: ");
  Serial.println(soilMoisture2);

  // If either sensor detects dry soil, activate pump
  if (soilMoisture1 > WATER_THRESHOLD || soilMoisture2 > WATER_THRESHOLD) {
    Serial.println("Soil is dry, activating pump...");
    digitalWrite(RELAY_PIN, LOW);  // Turn on the relay (active low)
  } else {
    Serial.println("Soil is wet, turning pump off...");
    digitalWrite(RELAY_PIN, HIGH); // Turn off the relay
  }
```

```
  // Send data to the server
  if (WiFi.status() == WL_CONNECTED) {
    HTTPClient http;
    String postData = "sensor1=" + String(soilMoisture1) + "&sensor2=" + String(soilMoisture2);
    http.begin(serverName);
    http.addHeader("Content-Type", "application/x-www-form-urlencoded");
    int httpResponseCode = http.POST(postData);
    if (httpResponseCode > 0) {
      String response = http.getString();
      Serial.println(httpResponseCode);
      Serial.println(response);
    } else {
      Serial.println("Error in sending data.");
    }
    http.end();
  }

  // Delay before next sensor read
  delay(5000);
}
```

php code

```
<?php
$servername = "localhost";
$username = "root";
$password = "";
$dbname = "irrigation";

// Create connection
$conn = new mysqli($servername, $username, $password, $dbname);

// Check connection
if ($conn->connect_error) {
  die("Connection failed: " . $conn->connect_error);
```

```
}

// Retrieve sensor data from the GET request
$sensor1 = $_POST['sensor1'];
$sensor2 = $_POST['sensor2'];

// Insert data into the table
$sql = "INSERT INTO soil_data (sensor1, sensor2, timestamp) VALUES ('$sensor1',
'$sensor2', NOW())";

if ($conn->query($sql) === TRUE) {
  echo "New record created successfully";
} else {
  echo "Error: " . $sql . "<br>" . $conn->error;
}

$conn->close();
?>
```