Republic of the Philippines
NEGROS ORIENTAL STATE UNIVERSITY
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College of Engineering and Architecture
Main Campus I and II

SENSOR-BASED PLANT WATERING AND MONITORING SYSTEM USING ARDUINO FEATURING UPS

A Mini Project
In Partial fulfillment of the Requirements for the course
ENS 341 Research Methods for Engineering
Negros Oriental State University Main Campus 1

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ADVISER'S CERTIFICATION

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APPROVAL SHEET

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ABSTRACT

This project aimed to design and evaluate a Sensor-Based Plant Watering and Monitoring System using Arduino technology to address the challenges of inefficient manual plant watering, especially in reforestation efforts. The system automates irrigation based on real-time soil moisture levels, using sensors that activate a water pump only when necessary. A developmental-experimental research design was used to prototype, test, and optimize the system in a real-world campus tree planting environment. Components including soil moisture sensors, an LCD, a relay module, and an uninterruptible power supply (UPS) were integrated to ensure continuous and efficient operation.

Results revealed a high precision in soil moisture detection, 93.83% for Plant 1, 94.30% for Plant 2, and 95.59% for Plant 3. The system maintained moisture levels at an average of 45.8% after watering, preventing overwatering and underwatering across five consecutive days. Additionally, it functioned reliably during power interruptions, confirming the effectiveness of the UPS. The system received a high level of acceptability due to its reliability, precision, and potential for scalability.

These findings suggest that the developed system offers a viable and sustainable solution for water-efficient irrigation, especially for tree planting programs. Future improvements may include broader soil calibration, rain sensor integration, user interface enhancements, and the provision of user training resources.

Keywords: automated irrigation, soil moisture sensor, Arduino, UPS, sustainable watering system, smart agriculture

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ABBRV.

LCD Light Crystal Display
UPS Uninterrupted Power Supply
SDA Serial Data
AWG American Wire Gauge
SCL Serial Clock
VCC Voltage Common Collector
GND Ground

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Internationally, water scarcity has evolved into one of the most pressing challenges of our time. Across continents, millions of people face daily struggles accessing clean, safe, and sufficient water. Droughts, climate change, and unsustainable consumption have pushed many nations to the brink of a full-blown water crisis. As global temperatures rise and populations swell, the pressure on freshwater sources becomes even more severe. The reality is clear: water, though abundant on Earth, is not always where or when we need it.

Nationally, the Philippines is not exempt from this dilemma. While surrounded by water, the country grapples with uneven water distribution, seasonal shortages, and the increasing demand brought on by urbanization and agricultural expansion. More than ever, the need for sustainable water management practices has become urgent, especially in a country vulnerable to both climate extremes and rapid development.

Zooming in on the local landscape, communities in Negros Oriental, like many others in the archipelago, face similar concerns. As cities grow and forests shrink, the delicate balance between nature and progress continues to tip. One of the casualties of this imbalance? Trees. Rampant modernization and land conversion have led to mass deforestation, weakening nature's ability to sustain the water cycle. Trees, often overlooked, play a pivotal role in water preservation, absorbing rain, replenishing groundwater, and even influencing local rainfall through the process of evapotranspiration. Without them, water becomes even more elusive.

In response to these environmental challenges, local initiatives have taken root. Among them is a meaningful project spearheaded by members of the Institute of Electronics and Communications Engineering of the Philippines – NORSU Student Chapter, under the guidance of Engr. Gwyn T. Balolong, PECE. One of their flagship projects, tree planting, aims not just to combat deforestation but also to help restore water sustainability. Yet, planting trees alone is not enough, they must be nurtured, watered, and monitored to survive and thrive. This is where innovation meets action.

The group introduces a Sensor-Based Plant Watering and Monitoring System powered by Arduino technology. This project offers a smart and sustainable solution: an automated watering system that detects soil moisture and supplies water only when needed. No more guesswork. No more wasted resources. The device is equipped with moisture sensors that prevent overwatering by detecting when the soil has reached optimal hydration. It draws water from a personal gallon reservoir, eliminating reliance on fixed irrigation infrastructure. And best of all, it operates on a scheduled basis, freeing up valuable time for users and ensuring consistent care for every plant.

Through this system, the researchers aim to build a device to promote a water-friendly garden, a living testament to how technology can complement nature. More than just a student project, this innovation embodies a deeper mission: to promote environmental responsibility, conserve water, and provide scalable solutions to pressing global and local issues.

1.2 Statement of The Problem

Tree planting programs have become common nowadays in battling various environmental issues. Watering the plants constantly and sufficiently has a direct impact on its survival and growth. Having to provide plants with water manually using a watering can or hose on a constant basis can be time consuming and is not always possible. Additionally, it is prone to human errors; over watering can make a plant rotten and lack of water can make it dry. A sensor-based plant watering and monitoring system can be a solution in which there is a timer set to water the plants on time and a system to monitor dryness to avoid lack of water and excessive watering. This study aims to develop a sensor-based plant watering and monitoring system that would benefit both the producer and the consumers.

This study aims to answer the following questions:

1. How precise is the system in sensing soil moisture?
2. How precise is the system in monitoring to prevent overwatering or underwatering?
3. What is the level of effectiveness of the Sensor-Based Plant Watering and Monitoring System in terms of convenience and detecting soil moisture level?
4. Is the system effective in terms of providing immediate water production for tree planting programs with the support of UPS?
5. What is the level of acceptability of the plant watering and monitoring system?

1.3 Objectives

This study aims to develop a sensor-based plant watering system using Arduino that can improve the efficiency and effectiveness of watering in tree planting programs. The following are the objectives of the study:

1. To design a sensor-based automatic plant watering system that monitor environmental conditions and control watering.
2. To know how the effectiveness of the system in providing an immediate water supply for newly planted trees.
3. To implement a timer-controlled features of irrigation intervals into better water management.
4. To organize a plant watering system using recycled materials.
5. To determine the reliability and performance of the system within the university's tree planting program environment.

1.4 Scope and Limitations

This study focuses on building a simple, automated plant watering and monitoring system using Arduino technology. The sensor transmits data to the Arduino while continuously assessing the state of the soil. The device automatically activates the pump to water the plant when the moisture content falls below a certain threshold. This type of automation makes sure that plants only receive water when they require it. The system also includes basic calibration for different types of soil. Since different soils hold water differently, the sensor values can be adjusted to fit the plant's needs more accurately. The logic that controls the system is programmed in the Arduino using simple conditions that determine when to water the plant. To keep things manageable, the project is tested in a controlled environment with small potted plants. For the early phases of development, this makes it possible for regular monitoring and simpler troubleshooting.

Despite its potential, the system has some significant drawbacks to be aware of. First, the technique isn't made for commercial or large-scale farming. It is intended for home gardens and tiny spaces. Expanding this setup to cover large plots would require significant upgrades in both hardware and system design. Second, there may be a limit to the soil moisture sensor's accuracy. These sensors may deteriorate or give erratic readings over time, particularly when used outdoors, as a result of things like corrosion, dirt accumulation, or inadequate soil contact. This may have an impact on the irrigation system's dependability. The system's failure to take into consideration additional environmental variables, such as air humidity or rainfall, is another significant drawback. The plants may be harmed by overwatering, for instance, if it rains soon after the system waters them. A rain sensor or a link to weather data may be included in a more sophisticated system, but that is outside the purview of this investigation. The system also depends on a steady power supply. It is not yet equipped with solar or battery power options, which would make it more appropriate for off-grid or outdoor use. The system just won't work if the power goes out. In terms of water supply, the system assumes there is always a source of water available at the right pressure. If the tank runs dry or the pressure is too low, the system won't be able to deliver water effectively but there's no alert or backup system included at this stage. Finally, there's no advance control interface. The user can't adjust settings remotely or monitor the system through a phone or computer. It works entirely on preset conditions and runs automatically. While this makes it simple, it also limits its flexibility and convenience

1.5 Significance of the Study

The results of this study will be significant and beneficial to the following sectors:

Faculty and Staff. As key drivers of institutional initiatives, faculty and staff play a crucial role in shaping the vision and objectives of tree planting programs. This study provides them with a practical, technology-driven solution that can enhance the sustainability and efficiency of such projects. It also supports informed decision-making when allocating resources and guiding environmental efforts.

Tree Planting Organizations. Manual monitoring and watering of saplings in small-scale planting activities are often labor-intensive and financially demanding. The proposed automated system significantly reduces operational costs by minimizing the need for constant human supervision, thereby allowing organizations to optimize their resources and expand their efforts more efficiently.

Students. With limited experience and time, students often struggle to maintain optimal plant care, leading to issues like overwatering or underwatering. This system not only ensures proper hydration for plants but also serves as a hands-on educational tool, introducing students to the principles of sustainable water management and environmental stewardship.

Future Researchers. The study lays a foundation for further exploration in the fields of automation, environmental sustainability, and smart agriculture. Future researchers can build on this work to develop even more effective and scalable technologies aimed at enhancing tree planting and conservation efforts.

CHAPTER II

LITERATURE REVIEW

This chapter presents a review of relevant literature and studies that support the foundation of this research. It explores key concepts, previous findings, and technological developments related to automated plant watering systems, sustainable water management, and tree planting initiatives. By examining existing works, this review aims to establish a clear context for the study and identify gaps that the current research seeks to address.

2.1 Related Literature

Plant. A plant is any living organism that belongs to the kingdom Plantae. What sets it apart is its ability to perform photosynthesis, which converts light energy typically from the sun into chemical energy to promote development. The ability of plants, which normally include roots, stems, and leaves, to produce oxygen, absorb carbon dioxide, and serve as the foundation of many food chains makes them essential for maintaining ecological balance (Elliot and Velasquez, 2024).

Plants come in a wide variety, including grasses, trees, shrubs, flowering plants, and aquatic plants. They provide essential resources including food, medicine, fiber, and shelter to humans and other living beings. Apart from their practical uses, plants improve people's mental and visual well-being and are commonly utilized in both indoor and outdoor environments. Because of their capacity to reduce stress and improve air quality, they are vital to both natural ecosystems and artificial environments (Douthat, 2021).

Sensor. A sensor is a device that detects and responds to changes in its surroundings. It converts physical phenomena like motion, temperature, humidity, and pressure into electrical impulses that can be measured and analyzed. From simple thermostats to complex robotics, sensors provide the real-time data needed for effective operation and control in a variety of systems and technologies (Lika, 2024).

Sensors are used in real-world sectors such as consumer electronics, healthcare, transportation, and agriculture to automate, monitor, and regulate processes. Sensors in agricultural contexts, for instance, may assess soil moisture levels, temperature, and light intensity, helping farmers make informed decisions to optimize crop yields. Because of their accuracy and efficiency, sensors are now crucial to the development of modern intelligent systems (Smith, 2025).

Plant Watering System. An electrical or mechanical device that may be used manually or automatically to supply plants with the proper amount of water is called a plant watering system. These systems range from basic drip irrigation configurations to complex automated systems that incorporate timers, moisture sensors, or even smartphone apps. Their primary function is to ensure plants are continuously watered, reducing the risk of either overwatering or underwatering (Carlsen, 2022).

Importance of Plant Watering System. To guarantee that plants continually receive the proper amount of water, a plant watering system is necessary. Particularly in garden and agricultural contexts, adequate hydration promotes robust plant development, increases plant resistance, and increases production. By distributing water effectively and only when needed, automated watering systems can save time and effort compared to human watering (Du, 2025).

Sensors and microcontrollers like Arduino are commonly used in automated plant watering systems to track soil moisture levels and modify water distribution accordingly. These systems are especially useful for those with busy schedules or in environments where maintaining a regular watering schedule may be challenging, such as large gardens or greenhouses. By using real-time data to decide when and how much to irrigate, these devices promote healthy plant development and help conserve water (Yogasubash, 2023).

High-tech plant watering systems that can be remotely operated and monitored via smartphones have been developed as a result of the increased interest in smart gardening. To further optimize watering cycles, these devices might also incorporate weather data and predictive algorithms. Plant watering systems are becoming more widely available and adaptable for both commercial crops and home gardeners as technology advances (Prodoehl, 2025).

Plant Monitoring System. A plant monitoring system is a configuration that tracks the health of plants using sensors and microcontrollers, with an emphasis on environmental variables including humidity, temperature, and soil moisture. Real-time soil moisture level monitoring is a key component of systems that identify when plants want water. A controller, like an Arduino, receives the data from the sensors that measure the soil's moisture content and determines whether it is below a certain threshold, which means the plant needs to be watered (Dhanavandan, 2022).

Importance of Plant Monitoring System. For plants to remain healthy overall, a plant monitoring system is essential. It enables users to make knowledgeable decisions regarding plant care by monitoring important environmental parameters including soil moisture, temperature, and light. Monitoring systems encourage more sustainable and accurate agricultural operations by preventing problems like overwatering or underwatering, which can result in poor plant health (Goncalves, 2019).

The decision-making process for plant watering is automated with the aid of this kind of monitoring system. The device can notify the user or even turn on an automated watering system only when required, eliminating the need for a set timetable or manual checks. This promotes healthier growth and more effective use of water resources by ensuring that plants are neither overwatered nor underwatered. These systems are particularly helpful in greenhouses, indoor gardening, and other locations where it might be challenging to keep a regular watering schedule (Frazier, 2022).

More sophisticated plant monitoring systems might also have wireless connection and data logging, which would enable users to monitor moisture levels over time via computer interfaces or smartphone apps. Users can better understand plant water requirements and modify system settings for optimum performance by examining these trends. With little manual labor, this clever incorporation of technology into gardening helps enhance plant care and decrease waste (Plant Ditech, 2024).

Arduino Sensors. Sensors that work with the Arduino microcontroller platform are referred to as Arduino sensors. Temperature, humidity, soil moisture, light, gas concentrations, mobility, and other physical changes in the environment are all detected and measured by these sensors. Their cost, adaptability, and simplicity of integration with Arduino boards make them popular for usage in educational projects, DIY electronics, and prototyping (Circuit Digest, 2024).

Importance of Arduino Sensors. An essential component of automating plant care systems are Arduino sensors. These sensors deliver messages to regulate devices like water pumps or alarms after detecting environmental factors like soil moisture levels. Because of their capacity to gather data in real time, automated decision-making is made possible, guaranteeing that plants receive the best possible care. Arduino is a well-liked option for creating intelligent agricultural solutions because of its adaptability, cost, and simplicity of integration (Soderby, 2025).

From basic weather stations to intricate home automation systems, a variety of projects can be constructed with Arduino-compatible sensors. An Arduino-connected soil moisture sensor, for example, may track the soil's water content and activate a watering system as necessary. Even novices can gather data, process it, and build automated reactions to changes in the environment thanks to the Arduino programming environment's simplicity (Svitla Team, 2023).

Arduino Sensors provide the information required to make well-informed decisions about plant care, making it an essential component of both monitoring and watering systems. For instance, soil moisture sensors that are linked to an Arduino board can continuously measure the soil's moisture content. The plant can be automatically watered by programming the Arduino to turn on a water pump or solenoid valve when the soil is too dry. In a similar vein, temperature, humidity, and light sensors can be used to keep an eye on the environment and modify watering schedules or notify users of undesirable circumstances. Because of its adaptability and programmability, Arduino is perfect for developing personalized, automated systems that assist guarantee plants get the proper amount of water at the correct time, improving plant health and efficiency (Winters, 2025).

Uninterrupted Power Supply (UPS). An electrical apparatus that, in the event that the primary power supply fails, supplies emergency power to a load. Through the use of batteries or other energy storage devices, it provides instantaneous, short-term power, guaranteeing that linked devices like computers, servers, or medical equipment continue to function even in the event of power outages, voltage drops, or surges. By enabling safe shutdown procedures or continuing operation until backup generators or power sources become available, a UPS helps prevent data loss, hardware damage, and system outages. It is extensively utilized in vital settings such as businesses, data centers, and hospitals (Gillis, 2024).

Importance of Uninterrupted Power Supply (UPS). For plant irrigation and monitoring systems to continue operating continuously, an Uninterrupted Power Supply (UPS) is essential. It shields the system against unplanned voltage swings and power interruptions that could interfere with data collecting or harm delicate components. A UPS protects the plants and the automation's dependability by supplying backup power, which keeps the system operating even in the event of disruptions (Elsley, 2024).

Effects of a Plant Watering and Monitoring System. Plant health and resource management benefit from the installation of a watering and monitoring system in a number of ways. Most importantly, it makes sure that plants get the proper amount of water at the appropriate time, which promotes better development, higher yield, and a lower chance of overwatering or dehydration. By supplying precise amounts based on real-time soil moisture monitoring, the technology improves water efficiency and reduces waste (Sankaran, 2024).

It also lessens the need for continual human supervision, which saves time and labor, particularly in remote or large-scale agricultural and gardening setups. Long-term improvements in plant care and prompt interventions are made possible by the monitoring feature, which also offers insightful information about environmental conditions. All things considered, this approach supports the growth of healthier and more fruitful plants while encouraging sustainable behaviors (Pereira, 2024).

Challenges of Using a Plant Watering and Monitoring System. Plant watering and monitoring systems have many benefits, but their installation and upkeep can present a number of difficulties. One major issue is the initial equipment and installation costs, which can be high, particularly for home gardeners, students, and small-scale farms. Furthermore, not all users may have the technical knowledge and abilities in electronics, coding, and sensor integration needed to set up and program these systems. The system's dependence on reliable power sources is another drawback; it might not operate reliably in places with frequent power outages or restricted access to electricity. Internet access becomes crucial for smart or IoT-enabled devices, and its unavailability can impede remote control and real-time monitoring (Agriculture Victoria, 2025).

Inaccurate readings and inappropriate watering may also result from sensor performance deteriorating over time as a result of exposure to moisture, dirt, or wear and tear. The responsiveness and dependability of the system may also be impacted by environmental variables like intense rain, intense heat, or uneven soil composition. The components may occasionally be disrupted by physical damage caused by animals, bugs, or human meddling. Because parts may require routine cleaning, recalibration, or replacement to keep the system functioning properly, maintenance becomes an essential activity. In order to deal with unforeseen faults, users must also receive training or familiarization with troubleshooting techniques (Sankaran, 2021).

Nevertheless, with careful planning, appropriate user training, and routine maintenance, many of these problems can be resolved. These systems, which provide sustainable solutions for effective plant care and water conservation, are becoming more accessible and user-friendly as a result of technical improvements and increased awareness of smart agriculture (Mccray, 2023).

2.2 Related Studies

According to the study entitled "Design of a Low-Cost Sensor-Based IOT System for Smart Irrigation" by Kunal Singh and Raman Kumar (2020), the system consists of an intelligent control system that is configured to fulfill specific crop moisture requirements and a low-cost rope-and-pulley hardware arrangement for managing irrigation across crop fields. With the use of real-time data from moisture, temperature, and rain sensors, the system can modify irrigation in response to changing environmental circumstances. Sensor data is recorded on an embedded memory card for further analysis and is wirelessly accessible on desktop or mobile devices using open-source IoT platforms. The ultimate objective is to keep soil moisture levels constant by keeping an eye on environmental changes and adapting accordingly.

According to the study entitled "Automation of soil moisture sensor-based basin irrigation system" by Monalisha Pramanik, Manoj Khanna, Man Singh, D.K. Singh, Susama Sudhishri, Arti Bhatia, and Rajeev Ranjan (2022), discusses a study aimed at improving irrigation efficiency using an IoT-based automated system in surface irrigation, which is widely used due to its simplicity but often suffers from inefficiencies like deep percolation and uneven water distribution. The study was conducted in a closed-end level basin with loamy soil, using a wireless communication setup between capacitance-based soil moisture sensors and an automatic check gate controlled by the Croplytics® software. Sensors were strategically placed at various depths and distances (15 m, 30 m, and 45 m) along the field, and the gate was installed in a concrete water channel. The system was tested over nine irrigation events under bare soil conditions and evaluated under different soil moisture deficit scenarios (40%, 30%, and 20%). Results showed that sensor placement significantly impacted efficiency, with optimal performance achieved by placing sensors at 37.5 cm depth near the inlet for high moisture deficits and at 7.5 cm depth near the outlet for low deficits. The automated system improved irrigation application efficiency up to 86.6%.

According to the study of A Suhana Nafais; K Mir Maaz Hussain; S Dhanush Kumar; and J Tamil Mani (2024) entitled "IoT Based Plant Watering System", introduces an IoT-based Plant Watering System designed for rooftop plantations to address water scarcity and space limitations in urban areas, where 25–30% of water resources are often used for gardening. The system uses sensors, actuators, and a central control unit to monitor soil moisture and automate watering in real time, ensuring precise and efficient irrigation. Key hardware components include soil moisture sensors, microcontrollers, and water pumps, all coordinated through C++-based software. The system has shown promising results, achieving up to 30% water savings compared to traditional methods. Additionally, its implementation has the potential to increase urban green cover by 20–30%, with projections suggesting a 25% boost in overall greenery. This smart solution not only conserves water but also supports sustainable urban ecosystems by enhancing green spaces.

According to the study entitled "Multiple Sensor Data Fusion Based Top-Down Embedded System for Automatic Plant Pot Watering" by Saraswati, B. Alekya himabindu, Dr. M. V. Subramanyam (2022), since both overwatering and underwatering can be detrimental, this initiative focuses on providing the exact amount of water that plants require. It makes use of two sensors: a photoresistor to gauge the amount of sunlight and a soil moisture sensor to determine the amount of water in the soil. A linear proportional formula determines the precise amount of water needed based on the data from these sensors. To make sure the plant gets precisely the proper amount of moisture, a basic motor is then turned on to spray water for a certain amount of time. This method encourages precise and effective plant watering.

According to the study entitled "Design and implementation of an automatic plant watering system using Arduino uno" by Bachir Ousman Mahamat (2024), the expanding worldwide water shortage brought on by population growth and demand is highlighted in this paragraph, which has a substantial effect on plant health and emphasizes the necessity of effective water management. Due to stagnant water, traditional irrigation techniques like flooding and sprinklers are becoming more and more wasteful and inefficient, and they frequently aid in the spread of disease. The project suggests an automated plant watering system that determines when and how much water is required using soil moisture sensors in order to address this issue. The method minimizes waste and promotes sustainable irrigation by delivering only the bare minimum of water required based on an analysis of environmental conditions and moisture content.

According to the study entitled "Arduino based Smart Irrigation System for Home Gardening" by Kailasam Selvaraj; Iswarya M; Ramyasri S; Anu Keerthika M S (2021), the creation of an automatic irrigation system for home gardening that runs without human assistance is the main goal of this article. The system continuously checks the amount of moisture in the soil beneath trees and plants. When the moisture drops below a predetermined level, it not only notifies the user but also uses a connected water storage source to water the plants automatically. The device, which uses a soil moisture sensor to assess whether irrigation is necessary, is made to work well in all types of climates, but it is particularly effective in regions with little rainfall or dryness. This method guarantees healthy plant growth even when people are not around and helps conserve water.

According to the study entitled "An Economical Sensor-Based Automated Plant Watering System for Smart Irrigation" by Modupe Agagu (2024) stated that water scarcity significantly affects plant growth and agricultural productivity by reducing photosynthesis. Traditional irrigation methods often waste water and fail to meet plants' specific needs, especially in dry regions, and can also create health hazards due to stagnant water. To address these issues, the study developed an automated plant watering system using an Arduino-based setup with moisture sensors and other components. This intelligent system waters plants based on soil moisture levels, reducing water waste and ensuring efficient irrigation. The system was successfully tested and is suitable for both small gardens and large farms.

According to the study entitled "Project Report on Automated Watering the Plants Using Arduino" by Asifur Rahman (2025) stated that the project "Automated Watering the Plants Using Arduino" addresses the need for efficient water management in agriculture and gardening. It features a cost-effective, automated irrigation system using an Arduino Uno, a soil moisture sensor, and a relay-controlled water pump powered by a rechargeable battery. The system waters plants only when necessary, based on real-time soil moisture levels, reducing water waste and manual effort. Designed for scalability, it can be upgraded with features like mobile app control or weather-based automation, making it ideal for modern, sustainable irrigation.

According to the study of Earl Joseph S. Villaruz, Joelyn P. Ladroma, Jahnna Mae R. Eyana, Benjamin Mahinay, and Iris Mae C. Mendoza (2022) entitled "Automated Plant Irrigation System and Monitoring System" stated that the project focuses on automating plant irrigation by controlling time and water pressure to improve farming efficiency. Using an Arduino-based system, it was designed specifically for Ladroma's Farmland in Montevista, Davao De Oro. The system monitors temperature, humidity, water level, and soil moisture, and can operate manually or automatically. It delivers the precise amount of water needed based on real-time soil moisture data. A wireless sensor network triggers the water pump when the soil dries, reducing the burden on farmers and enhancing productivity through real-time monitoring.

According to the study entitled "Design and Performance Evaluation of a Low-Cost Autonomous Sensor Interface for a Smart IoT-Based Irrigation Monitoring and Control System" by Sani Abba, Jonah Wadumi Namkusong, Jeong-A Lee, and Maria Liz Crespo (2019) stated that this study presents a low-cost, IoT-based autonomous irrigation system designed to optimize water use and support remote farming. Using sensors and actuators, the system automates water delivery from a reservoir to crops based on soil needs. Developed with the System Development Lifecycle and waterfall model, it incorporates tools like Proteus 8.5, Arduino IDE, and embedded C. The prototype includes power supply, monitoring, control, and internet connectivity, enabling remote access. Results show the system's flexibility, efficiency, and potential to reduce manual supervision while supporting agricultural productivity and economic growth.

According to the study entitled "Design of a smart hydroponics monitoring system using an ESP32 microcontroller and the Internet of Things" by Anees Abu Sneineh and Arafat A.A. Shabaneh (2023) stated that this study presents the development of a hydroponics monitoring system using an ESP32 microcontroller integrated with sensors for temperature, water level, pH, and total dissolved solids (TDS). The system automatically collects and evaluates data to control pumps that adjust water, nutrients, or salt levels in the plant basin. Users can monitor and manually control the system via the Blynk smartphone app, while the ESP32 can also make adjustments automatically when parameters deviate from optimal levels. The system was successfully built, tested, and shown to support efficient, automated hydroponic farming through IoT integration.

Chapter III

METHODOLOGY

This chapter discusses the methodology used in this study. The sections of this chapter describe the research design, materials used (hardware/software), experimental procedures, data collection methods, and analytical techniques.

3.1 Research Design

The research employed a developmental-experimental research design to create and assess a sensor-based automated plant watering system using an Arduino equipped with an Uninterruptible Power Supply (UPS). The system was designed to water by time coded activation and suspend watering operations when the soil is dry. The system helps in minimizing water waste while ensuring efficiency and reliability, particularly within tree-planting programs.

Furthermore, the study is design-based research, which focuses on building and perfecting the watering system by continuous prototyping and testing. The system was then put to the test in a real outdoor setting to see how well it functioned in actual circumstances. This enabled the researchers to evaluate its precision, reliability, and capability to function well beyond a regulated environment.

The researchers conducted published literature and technical references to support this system design, focusing particularly on timers and Arduino-controlled soil moisture sensors. After fabrication, field testing began to check the ability of the system to do the following:

- Apply the watering time interval
- Perform efficiently in an outdoor and indoor environment

This design option also enabled researchers to discuss the practical use and efficiency of sustainable watering systems on campuses in reforestation programs.

3.2 Materials Used (Hardware/Software)

3.2.a Hardware

The following is a list of hardware that will be used in the study:

- Arduino Uno

  Arduino UNO is an open-source microcontroller board used to develop electronics projects. It is the brain of the plant watering and monitoring system, reading the inputs and executing instructions that have been applied. (Lab, 2020)
- Breadboard

  A breadboard is a board for prototyping. It is a simple and useful tool for connecting a circuit quickly and temporarily without soldering (SwellFox, 2024).

- Jumper Wires

  A jumper wire is a simple wire often used with breadboards and other prototyping tools to modify a circuit or diagnose problems in a circuit. (Seotechwriter, 2023)

- Liquid Crystal Display (LCD)

  A Liquid Crystal Display (LCD) is a flat panel display technology that carries out its role by carefully controlling light using liquid crystals in order to create images or text on the screen and are especially designed to display letters and numbers. (LME Editorial Staff, 2025; Orient Display, 2021).

- Uninterrupted Power Supply (UPS)

  A UPS is a device that provides immediate power during a power failure. Its systems use batteries or supercapacitors to store energy. It acts as a backup (Electrical4U, n.d.).

- DIY Container

  This part of the system does not need to be anything expensive and fancy; a simple 1L bottle of water will suffice (McGehee, 2024).

- Relay Module

  Relay is a kind of electro-mechanical component that functions as a switch that allows small currents to activate larger ones safely and is commonly used in an automatic control circuit. It enables the Arduino to control the water pump and provides electrical isolation to protect the Arduino from high voltages (Agarwal, 2021).

- Switch

  A switch is a controlling device. It interrupts the flow and changes the direction of a current in a circuit. It controls the ON and OFF operations of a device in the circuit (Technology, 2025).

- 5 volts Water Pump

  A water pump suitable for small automation. The pump functions as a transmitter for it delivers water to the plant by suction or pressure. A small water pump is capable of lifting water from a reservoir to the plants. Its miniature size makes it ideal for small-scale irrigation (Cirkit Design, n.d.).

- Soil Moisture Sensor

  A soil moisture sensor is a small device consisting of two main parts: the sensor probes and comparator module. It is used to measure the water level in soil. It utilizes capacitance to gauge the water content of the soil or its dielectric permittivity. The probes work by sticking them into the soil which measures the soil moisture and the comparator module provides both digital and analog outputs (Lucas-Fernando, n.d.; Last Minute Engineers, n.d.).

- 5/16" Tube

  A hollow tube that allows the water to flow from the source to its destination. It acts as a conduit to ensure efficient water delivery. Flexible, durable, and malleable tubing is preferred to prevent leaks (McGehee, 2024).

- AWG (American Wire Gauge) #22 – STRANDED

  This wire is flexible and easier to work with wire. It has a gauge of 22. Great durability and is less likely to break when bent or twisted (Pololu, n.d.).

- Cable Tie

  Cable ties are used to bundle, secure and organize wires to maintain order and safety (NEMA, n.d.).
- 9 volts Battery Power Supply

  A 9V battery is a Direct Current (DC) power source with a voltage of 9 volts. 9V batteries have high energy density and long service life. These batteries are usually in a rectangular shape having dimensions of approximately 26 mm × 44 mm × 17 mm (Jinftry Electronics, n.d.).

3.2.b Software

The following is the software used in the research:

- Arduino IDE

  Arduino IDE where IDE stands for Integrated Development Environment is an open-source software used to program the Arduino boards. The software allows users to write and upload code to any Arduino boards making the code as the backbone of the system for it defines how the components interact and function (Andandprof, 2024).

Table 1. *Materials and its Costs*

MATERIALS	QUANTITY (by piece)	COST (PHP)
Breadboard	1	85.00
Cable Ties	20	25.00
Jumper Wires	10	50.00
Tube	1	17.00
Soil Moisture Sensor	1	35.00
Arduino Uno	1	599.00
Relay Module	1	45.00
1 liter Container	1	Free (Recycled)
Liquid Crystal Display	1	30.00
Uninterrupted Power Supply	1	250.00
9 volts battery	1	31.50
5 volts Water Pump	1	62.00
Switch	1	10.00
AWG #22 – Stranded	2	8.00
TOTAL		**1247.50**

The project utilized various materials to build an automated plant watering system with a total cost of PHP 1,247.50. Key components included one Arduino Uno board priced at PHP 599.00, a breadboard at PHP 85.00, a 5V water pump for PHP 62.00, and a soil moisture sensor costing PHP 35.00. Additional components were a relay module (PHP 45.00), a liquid crystal display (PHP 30.00), a 9V battery (PHP 31.50), and an Uninterrupted Power Supply (PHP 250.00) to ensure continuous operation. The system also required jumper wires (PHP 50.00), AWG #22 stranded wires (2 pieces at PHP 8.00 each), a switch (PHP 10.00), a tube (PHP 17.00), and 20 cable ties (PHP 25.00). A 1-liter container, used as a water reservoir, was sourced for free as a recycled item. These components collectively supported the construction of a low-cost and functional automated irrigation prototype.

3.3 Experimental Procedures

The study solely relied on pure research and analysis to identify and recommend friendly and less costly-effective plant watering system in Negros Oriental State University. The study related with planting which included the deliberation of real time clock or the use of Arduino for the sensor in tree planting. The planning involved a systematic approach to how the project would be done its features, limitations and customize the water schedules and thresholds based on specific plant needs. The site would be used is at IECEP-NSC smart garden. After the site selection, the evaluation of the site parameters is the next step. The parameters were evaluated and used to obtain the design parameters became the next step. To obtain the design parameters of Breadboard, jumper wires, LCD, uninterrupted power supply (UPS), DIY container, relay module, switch, 5 Volts water pump, soil moisture sensor, tube, AWG #22-stranded, cable tie, power supply, monitor the sensor specifically the Arduino. Once the design was created and the project parameters were monitored the selection of materials and equipment followed.

The components were then assembled, including the configuration of the connection of the monitoring system, these are the Soil Moisture System Setup followed by:

- Connect the soil moisture sensor to the relay module. Power the jumper wires on the breadboard using a 9-volt battery.
- Connect the breadboard to the Arduino Uno using jumper wires.
- Connect the liquid crystal display (LCD) module to the Arduino Uno.
- Connect the water pump to the relay module using AWG #22-stranded.
- Install the 5-volt water pump in the hose to prepare for water release.

This setup employs a soil moisture sensor to continuously assess the water content of the soil. The sensor's readings are processed and displayed on an LCD screen as a percentage, giving users real-time insight into soil conditions. When moisture levels drop below a predefined threshold, indicating the need for irrigation, the system activates a relay module that powers a water pump. This ensures the soil remains adequately hydrated without requiring manual intervention, thereby improving water efficiency and supporting optimal plant health. (Bhatt, D., & Bhatt, S., 2020).

After they were all assembled, the next step was the installation and testing the system on the site. After testing the given compositions of the Plant Watering and Monitoring System, the results were documented, analyzed and integrated. Lastly, the study ended with the conclusion and recommendations for the proposed project.

3.4 Data Collection Methods

This project uses a hands-on, experimental approach to test how well an automated plant watering system works compared to traditional manual watering. The system was built using an Arduino microcontroller and various sensors to monitor environmental conditions and control watering based on soil moisture level (Shifa, 2018)

3.4.a How Data Was Collected

A. Sensor Data (Automatic Collection) The researchers used several sensors connected to the Arduino to collect data automatically. These included:

- A **Soil Moisture Sensor** to check how wet or dry the soil is.

The Arduino reads data from these sensors regularly. When the soil gets too dry, it triggers a relay module that turns on a small water pump, which waters the plant automatically. The pump then turns off once the soil is moist enough again (Hassan, et al, 2018)

This data-like moisture levels, temperature, humidity, and when the pump was on or off was recorded through the Arduino's serial monitor and could also be sent to a cloud platform if needed.

These observations will help the researchers understand how the automated system affected the plant's soil moisture level.

3.5 Analytical Techniques

This system was developed to ensure efficient, reliable, and functional performance in automating plant irrigation. Several techniques and considerations were applied for data analysis, performance evaluation, and system diagnostics to achieve accurate and effective results. The core components of the system are described below:

1. Soil Moisture Sensing
   A soil moisture sensor provides analog output to indicate the level of moisture in the soil, which is displayed on an LCD screen. This allows continuous monitoring of the soil's hydration level, typically expressed in percentage. (MyTecTutor, 2021)
2. Arduino
   The Arduino serves as the system's central processor. It reads the analog data from the moisture sensor and, based on pre-programmed thresholds, determines whether to activate the water pump. (ArduinoGetStarted, 2024)
3. Relay Module
   The relay module functions as an electronic switch that enables the Arduino to control the power supply to the water pump safely and efficiently. (Sui, 2017)
4. Water Pump
   A small electric water pump is responsible for delivering water to the plants. When the soil moisture drops below the defined threshold, the pump is triggered by the system. The watering duration can be customized based on the specific needs and watering requirements of the plants. (Sui, 2017)

3.5.a Analytical Techniques in Action:

1. Sensor Calibration:

The soil moisture sensor may require calibration to ensure accurate readings. this involves establishing a baseline reading when the soil is dry and when it is wet, allowing the Arduino to compare subsequent readings against these reference values. (Bato and Alindogan, 2024).

2. Threshold Value:

A threshold value is set in the Arduino program, defining the moisture level at which the water pump should be activated. This value can be adjusted based on the specific plant's needs and soil type (Bato and Alindogan, 2024).

3. Data Logging and Analysis:

In some systems, the Arduino can log the sensor readings over time, providing insights into soil moisture patterns and plant water consumption. This data can be analyzed to optimize watering schedules and adjust the threshold value for more accurate watering (ArduinoGetStarted, 2024).

CHAPTER IV

DESIGN AND IMPLEMENTATION

This chapter presents the overall design and implementation process of the Sensor-Based Plant Watering and Monitoring System using Arduino. It outlines the systematic approach taken to develop the prototype, including the selection of components, circuit configuration, and programming logic. The chapter also discusses how each component functions within the system to ensure efficient water management. Through careful integration of hardware and software, the project aims to provide a cost-effective and reliable solution for automated plant irrigation.

4.1 Detailed Description of the System Design

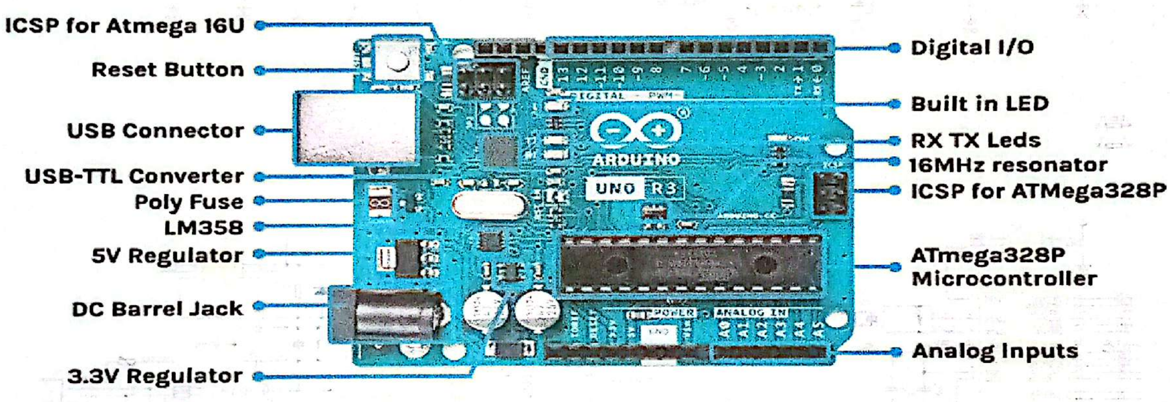

Figure 1: Arduino Uno

Arduino UNO is a low-cost, flexible, and easy-to-use programmable open-source microcontroller board that can be integrated into a variety of electronic projects. This board can be interfaced with other Arduino boards, Arduino shields, Raspberry Pi boards and can control relays, LEDs, servos, and motors as an output. (Ashely, 2021)

PARTS:

- ***USB Type-B*** **-** Used to connect the Arduino to a computer for programming and power supply.
- ***DC Power Jack*** **-** Allows external power supply (7–12V) when USB is not used.
- ***RESET Button*** **-** Restarts the program running on the Arduino. Useful for testing and debugging.
- ***Crystal Oscillator*** **-** Provides a clock signal to the microcontroller to keep operations timed accurately (usually 16 MHz).

- ***Pin 13 LED*** **-** Built-in LED connected to digital pin 13. Often used for basic testing (like the "blink" program).
- ***Digital Pins (PWM~)*** **-** Pins 0–13 can read/write digital signals. Pins with "~" support Pulse Width Modulation (PWM), useful for controlling things like LED brightness or motor speed.
- ***Analog Inputs (A0–A5)*** **-** Used to read analog signals (0–5V). Commonly used with sensors like temperature or light sensors.
- ***Microcontroller*** **-** The "brain" of the board (typically an ATmega328P). It executes code and controls all other components.

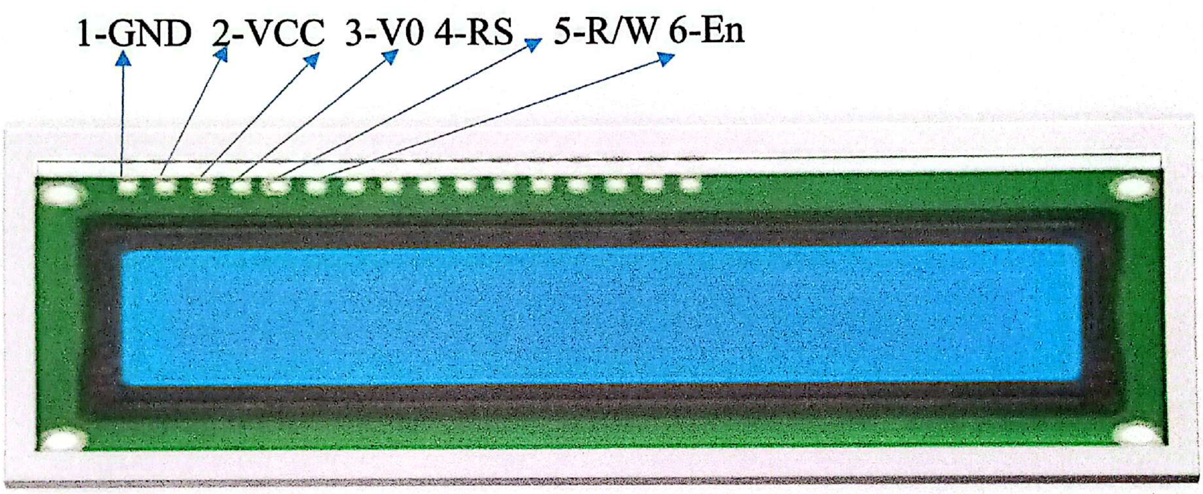

Figure 2: Liquid Crystal Display (LCD)

An Arduino LCD, short for Liquid Crystal Display, is a commonly used display module for Arduino projects that allows you to output information to the user, such as text and basic characters. It's a flat-panel display that utilizes liquid crystal technology to visually represent data. These displays are popular for projects where you need to show sensor data, program status, or other information in a simple visual format. (Dejan, 2022)

PARTS:

Pin	Name	Function
1	GND	Ground
2	VCC	+5V Power
3	VO	Contrast Control
4	RS	Register Select

Pin	Name	Function
5	RW	Read/Write
6	EN	Enable
7-14	D0–D7	Data Bus
15	A	Backlight Anode
16	K	Backlight Cathode

The LCD module used in the system has 16 pins, each serving a specific function essential for display operation. Pin 1 (GND) is connected to the ground, while Pin 2 (VCC) supplies the module with +5V power. Pin 3 (VO) controls the display contrast. Pin 4 (RS), or Register Select, determines whether the input data is a command or display data. Pin 5 (RW) is the Read/Write pin, used to set the module to either read from or write to the display, though it is commonly grounded to enable only writing. Pin 6 (EN), or Enable, is used to latch the data sent to the display. Pins 7 to 14 (D0–D7) make up the data bus, which transmits the data and commands to the display. Finally, Pins 15 (A) and 16 (K) are used for the LCD backlight, with A being the anode (positive) and K the cathode (negative), providing illumination for better visibility.

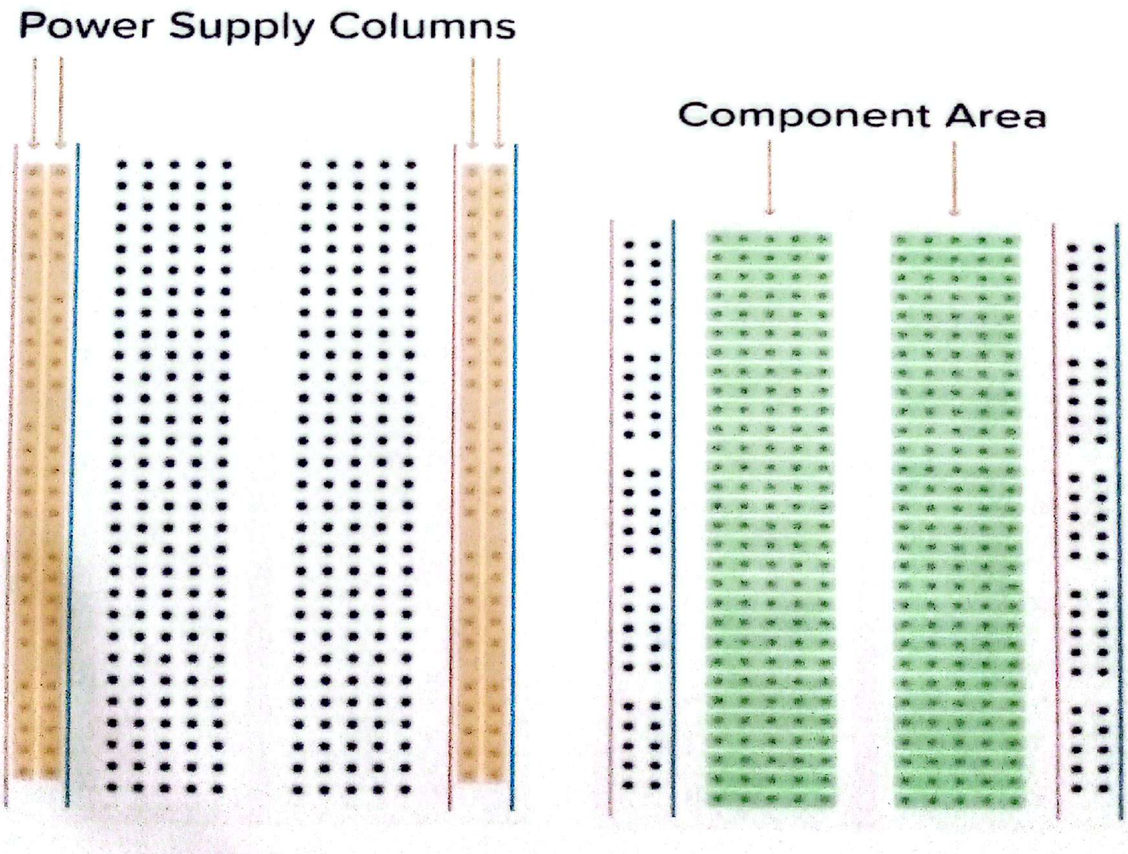

Figure 3: Breadboard

A breadboard is a rectangular plastic board with a bunch of tiny holes in it. These holes let you easily insert electronic components to prototype (meaning to build and test an early version of) an electronic circuit, like this one with a battery, switch, resistor, and an LED (light-emitting diode). (Science Buddies, 2020)

PARTS:

1. **Power Supply Column**

   Normally, you use the columns on the sides to connect your power supply. And you use the rows in the middle to connect your components.

   It's common to use the columns on the left and right for connecting the power supply. These columns are connected vertically. So, if you connect 5 volts to the top hole of one of the side columns, you will have 5 volts in all the holes of this column/

2. **Component Area**

   In the middle of the board, you'll find the component area. This is where you normally connect your components. Here, the holes are connected horizontally, in rows. And the left side is separated from the right side.

This means that the pins of your component must be on different rows, or on different sides of the board.

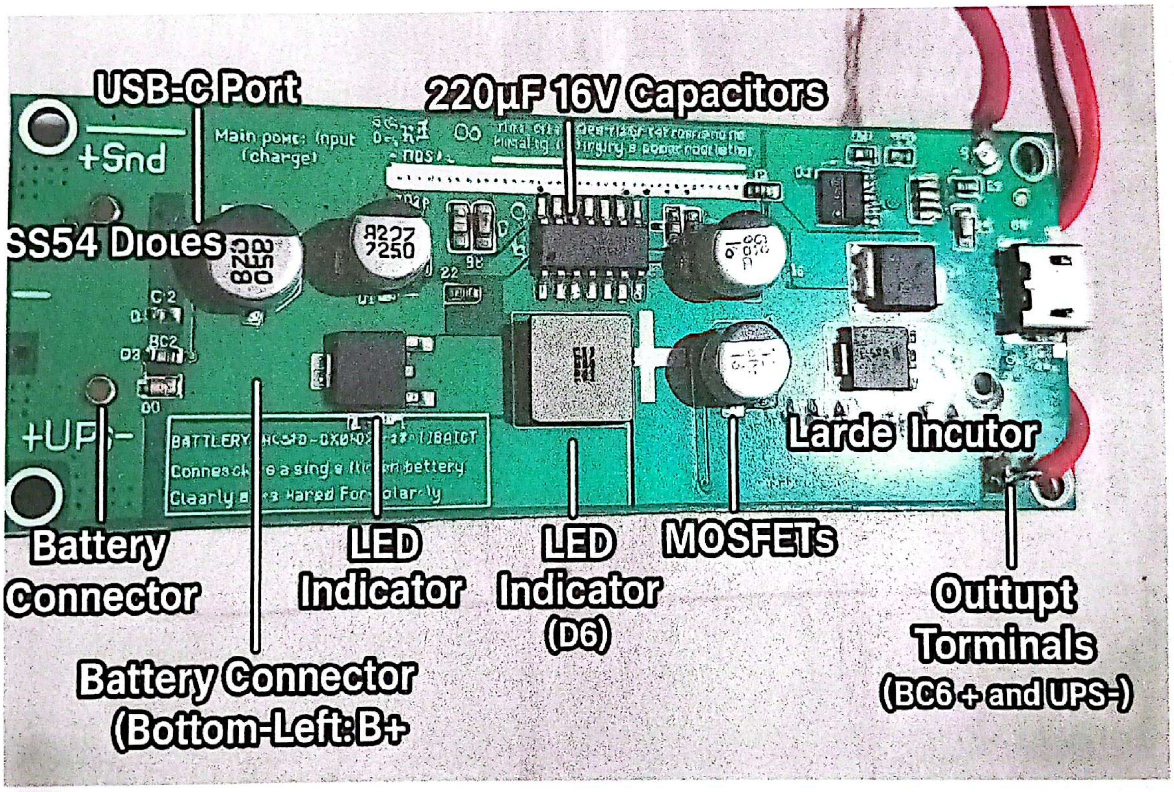

Figure 4: Uninterrupted Power Supply (UPS)

An uninterruptible power supply (UPS) is a device that allows a computer to keep running for at least a short time when incoming power is interrupted. Provided utility power is flowing, it also replenishes and maintains energy storage.

A UPS protects equipment from damage in the event of a power failure. It is used in any situation where electrical equipment is sensitive to power loss or issues with power quality, for example, if a system experiences unsafe changes in voltage output. UPSs are typically used in settings pertaining to computer systems, data servers or industrial devices, or in settings with mission-critical equipment, such as medical and laboratory systems. (Gillis and McFarlane, 2024)

PARTS:

- ***USB-C Port (Top-Center) Purpose*** **-** Main power input to charge the battery and power the output. Likely supports 5V input from a regular USB charger.
- ***SS54 Diodes (x3) Type Schottky Barrier Rectifier Purpose*** **-** Used for power rectification, preventing reverse current flow. Placed near the power input and output sections.
- ***220µF 16V Capacitors (x4) Purpose*** **-** Filtering and stabilizing voltage. Smoothing out voltage fluctuations during charging and discharging.
- ***Large Inductor (Labeled with 'R'/Ferrite Coil) Purpose*** **-** Part of a buck/boost converter to regulate voltage. Helps in maintaining steady output voltage during switching.
- ***IC Chips (Middle-Left and Lower-Center) Likely Functions*** **-** Charging controller for lithium battery. Voltage regulation controller for buck/boost conversion.
- ***MOSFETs/Transistors (Right Side near Inductor) Purpose*** **-** High-speed switching in voltage regulation circuitry.
- ***LED Indicator (Bottom-Center, D6) Red Light*** **-** *Power* status or charging status indicator.
- ***Battery Connector (Bottom-Left: B+ and Purpose*** **-** Connects to a single lithium battery (3.7V Li-ion or Li-Po). Clearly marked for polarity.
- ***Output Terminals (Bottom: UPS+ and UPS-) Purpose*** **-** This is the regulated output from the UPS that continues supplying power during outages.

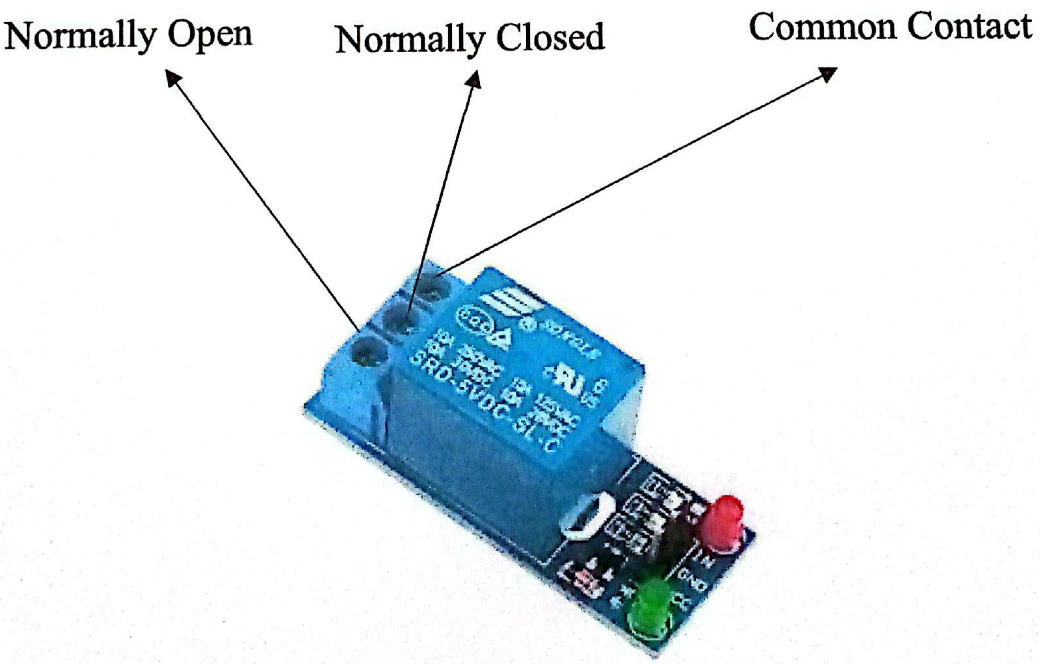

Figure 5: Relay Module

A relay module is an electrically operated switch used in electronic systems to control high-power devices using a low-power signal. It acts as an interface between a microcontroller (like an Arduino or Raspberry Pi) and high-voltage components such as motors, lights, or pumps. Instead of connecting the microcontroller directly to a high-power device, which could damage it, a relay safely separates the low-voltage control circuit from the high-voltage power circuit.

When the control circuit sends a small current to the relay, it activates an internal switch (electromagnetically), allowing a larger current to flow to the connected high-power device. This design helps prevent electrical coupling or failures, ensuring safer and more reliable operation by isolating the two circuits. Relay modules are essential in automation systems, smart home devices, and protective electrical designs where control and safety are priorities (Digital, 2025)

PARTS:

1. ***VCC (Voltage Common Collector)***
    - Function: Power supply pin for the relay module (typically 5V or 3.3V, depending on your module).
    - Connects to: The 5V or 3.3V output of your microcontroller (e.g., Arduino).
2. ***GND (Ground)***
    - Function: Common ground connection for the circuit.
    - Connects to: The GND pin of your microcontroller or power source. This completes the circuit.
3. ***IN (Input)***
    - Function: Signal pin used to trigger the relay.
    - Connects to: A digital output pin from a microcontroller (e.g., Arduino pin 7).
    - How it works:
        - When LOW or HIGH (depending on relay logic), it activates the relay to switch between normally closed and normally open.
4. ***COM (Common Contact)***
    - Function: The common terminal where current flows in or out.
    - Used with: Connect this to either power or load depending on what you are switching.
    - Switches between:
        - NC (Normally Closed) - when relay is inactive
        - NO (Normally Open) - when relay is activated

5. ***NC (Normally Closed)***

- Function: Connected to COM when the relay is OFF.
- Use this if you want the circuit to be normally ON and turn OFF when the relay activates.

6. ***NO (Normally Open)***

- Function: Connected to COM when the relay is ON.
- Use this if you want the circuit to be normally OFF and turn ON when the relay activates.

The relay module plays a vital role in enabling automated control within electronic systems, such as Arduino-based projects. By understanding the functions and proper connections of each pin, VCC for power supply, GND for grounding, IN for signal control, and COM, NC, and NO for switching, the module can be effectively integrated into various circuits. This configuration allows devices to switch between powered and unpowered states, depending on whether the relay is activated. Overall, the relay module is essential for controlling high-power components with low-power signals, offering flexibility, safety, and efficiency in modern automation and electronic control systems.

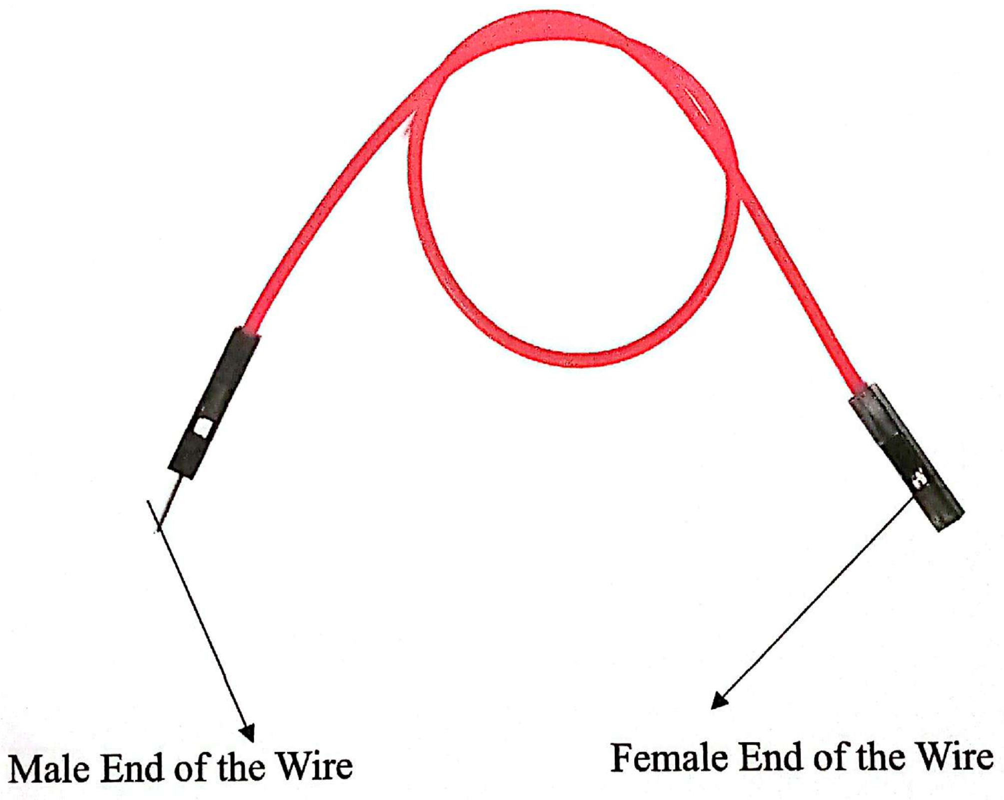

Figure 6: Jumper Wire

Jumper wires are simply wires that have connector pins at each end, allowing them to be used to connect two points to each other without soldering. Jumper wires are typically used with breadboards and other prototyping tools in order to make it easy to change a circuit as needed. Fairly simple. In fact, it doesn't get much more basic than jumper wires. (Hemmings, 2018)

TYPES:

Type	*Connector A*	*Connector B*	*Common Use*
Male to Male	Pin	Pin	Arduino to breadboard
Male to Female	Pin	Socket	Sensor/module pin to breadboard/Arduino
Female to Female	Socket	Socket	Module to Arduino (when both have male pins)

In electronics prototyping, jumper wires are categorized by the connector style at each end and chosen to match the headers on a board, sensor, or breadboard. Male-to-male wires have metal pins on both ends, making them ideal for linking the male header pins on an Arduino (or similar microcontroller) directly to the spring contacts in a breadboard. Male-to-female wires feature a pin on one side and a socket on the other; they are used when a sensor or module exposes a male pin that needs to plug into either a female header on the Arduino or into the breadboard. Finally, female-to-female wires have sockets at both ends and are useful when both boards or modules expose male pins, for example, when you need to connect a breakout board with male headers to the male header row on an Arduino. By selecting the correct jumper type, you ensure secure, reliable connections while keeping the wiring layout neat and easy to modify.

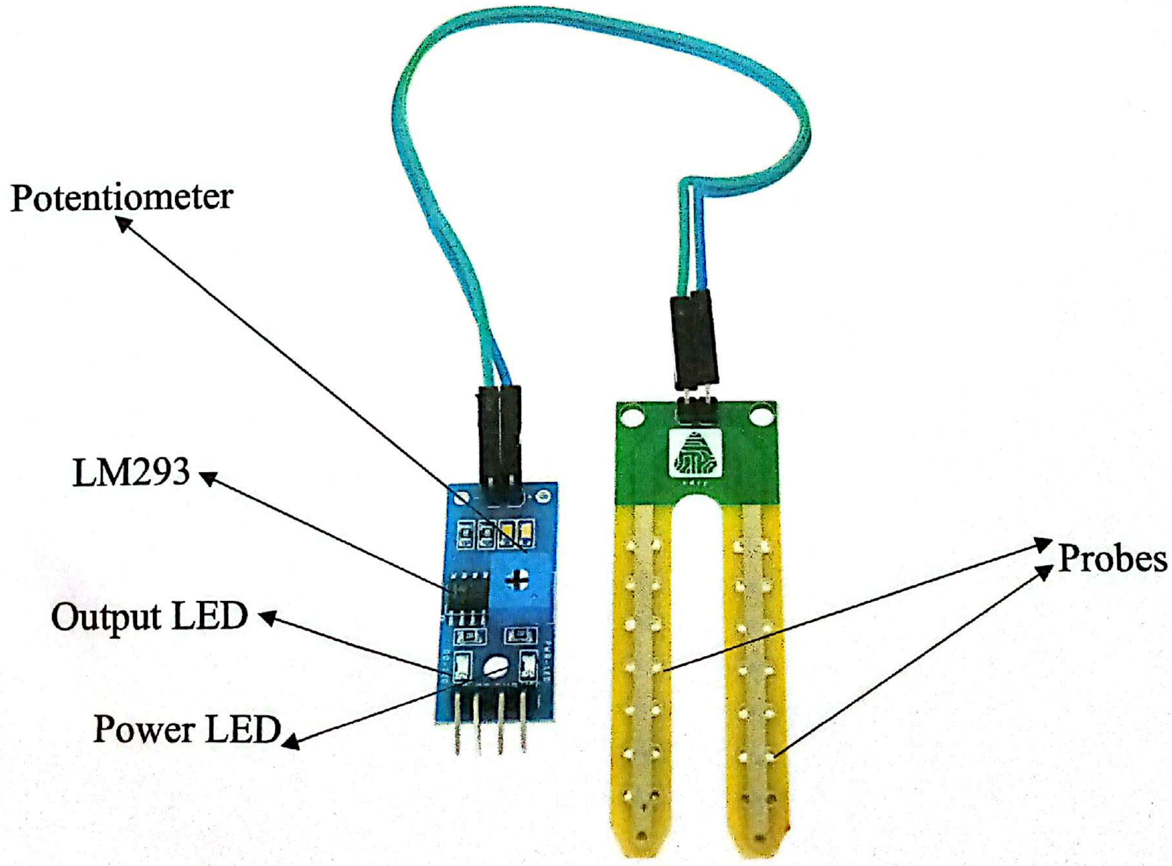

Figure 7: Soil Moisture Sensor

A moisture sensor for Arduino is an electronic device designed to detect how much water is present in the soil. It's especially popular in automated plant watering systems, smart gardens, and environmental monitoring. The sensor usually includes two probes (or metal pins) that are inserted into the soil. These probes act as conductors. When the soil is wet, water allows electricity to pass through more easily between the probes, resulting in lower electrical resistance. When the soil is dry, there's less water to carry the current, so the resistance becomes higher. The sensor measures this change in resistance and converts it into a voltage signal. This signal can then be read by an Arduino (a microcontroller board), which can interpret the moisture level. (Cherlinka, 2025)

PARTS:

1. ***Probes***
   - Function: These two metal prongs are inserted into the soil to detect moisture levels.
   - How it works: Moist soil conducts electricity better than dry soil. The probes sense the resistance or voltage drop across the soil to measure moisture.
2. ***Potentiometer***
   - Function: A small adjustable knob used to set the sensitivity of the sensor.
   - How it works: By turning the potentiometer, you adjust the threshold at which the output changes (e.g., when to trigger watering or signal the LED).
3. ***Power LED***
   - Function: Indicates that the sensor is powered on.
   - How it works: When the module receives voltage (usually 3.3V or 5V from Arduino), the LED lights up.
4. ***Output LED***
   - Function: Lights up when the soil moisture is below or above the set threshold.
   - How it works: It works with the comparator chip (LM293) and turns on depending on the soil's dryness and the potentiometer setting.
5. ***LM293 (Comparator Chip)***
   - Function: This chip compares the voltage from the soil probes to the reference voltage set by the potentiometer.
   - How it works:
     - If the soil is wet, the probe voltage is higher → Output may be LOW.
     - If the soil is dry, the voltage drops below threshold → Output goes HIGH (or vice versa, depending on wiring).

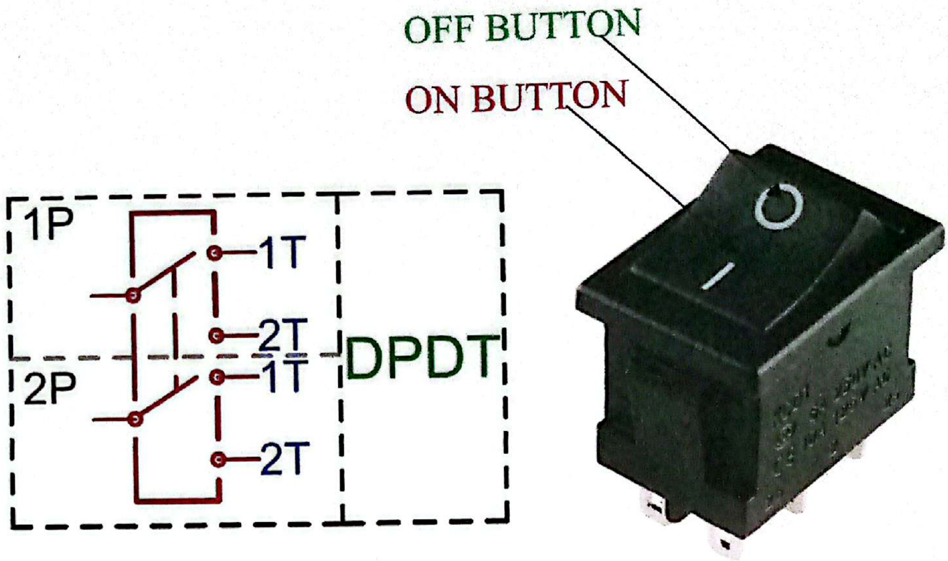

Figure 8: Switch Button

A switch is a basic yet essential component in an electrical circuit that allows you to control the flow of electricity. It works by either opening (breaking) the circuit to stop the current or closing (connecting) the circuit to allow the current to flow. This lets users turn devices on or off without having to disconnect wires manually. Switches come in many forms, like push buttons, toggle switches, or slide switches, but they all serve the same purpose: to give users control over when and how electricity flows in a system. They're especially important in circuits that require user input, like turning on a fan, starting a water pump, or activating lights in a smart watering system. (SparkFun Learn, n.d.)

PARTS:

DPDT Rocker Switch Overview DPDT stands for Double Pole Double Throw

It is a type of switch that controls two separate circuits (double pole) and each circuit can connect to one of two outputs (double throw). Often used for reversing polarity, such as motor direction control, or switching between two power sources.

Schematic Symbol Explanation From left to right in the symbol:

- ***1P and 2P (Pole Terminals)*** These are the input terminals (sometimes labeled as common or center terminals). Each "P" represents a pole, or independent circuit the switch can control.
- ***1T and 2T (Throw Terminals - Top)*** These are the first set of output terminals. When the switch is flipped to one position, the poles (1P and 2P) connect to 1T and 2T.
- ***1T and 2T (Throw Terminals - Bottom)*** These are the second set of output terminals. When the switch is flipped to the other position, the poles (1P and 2P) connect to this lower set of throws.

In the symbol, it's shown that the center contact can connect to either of the two throws depending on the switch position.

Pysical Switch Pins (Right Image) The actual DPDT switch shown in the image has 6 pins:

- [1T] [2T] [1P] [2P] [1T] [2T] (Physical layout may vary slightly, but functionally, there are two rows of three pins each.)

How It Works Switch in One Position: 1P → Top 1T, 2P → Top 2T Switch in Opposite Position:

- 1P → Bottom 1T, 2P → Bottom 2T This allows the switch to: Alternate between two power sources Reverse polarity to a motor Switch between devices or modes.

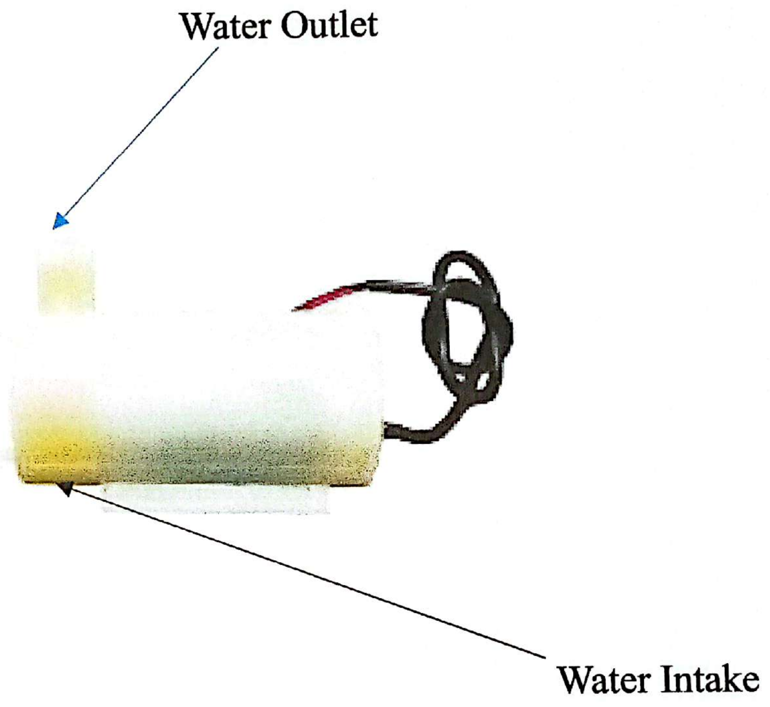

Figure 9: Mini water pump

A 5-volt water pump is a small, low-power device commonly used in electronics and DIY projects to move or circulate water. It operates on a 5V DC power source, making it compatible with microcontrollers like Arduino or Raspberry Pi, as well as USB power supplies. Inside the pump, a miniature motor spins an impeller that draws water in and pushes it out, enabling simple water flow. Due to its compact size and low voltage requirement, it's ideal for applications such as automated plant watering systems, small fountains, or educational experiments. Its ease of use, safety, and efficiency make it a popular choice for low-pressure water movement in hobby and electronics projects. (Woodard, 2019)

PARTS:

This mini water pump is designed for small-scale water transfer applications such as DIY projects, plant watering systems, or electronics cooling. It operates on a DC voltage of 3 to

5V, making it ideal for low-power setups and compatible with common microcontrollers like Arduino.

- ***Water Intake***: The pump features a 5 mm diameter inlet to draw water from the source efficiently.
- ***Water Outlet***: The outlet has an outer diameter of 7.5 mm and an inner diameter of 4.5 mm, suitable for connecting to small tubing for smooth water flow.

Figure 10: AWG #22 STRANDED

22 AWG stranded wire is a thin, flexible wire commonly used in electronics for low-voltage applications such as internal device wiring, prototyping, and small DIY projects. Its stranded construction—made up of multiple fine copper strands—makes it much more flexible than solid-core wire, which is especially useful in tight spaces or projects that require frequent movement, like effects pedals, Arduino builds, and robotics. This wire is ideal for carrying small signals in control panels, computers, and office equipment. Due to its compact size and ease of routing, it's preferred for connecting sensors, switches, and components on breadboards or circuit boards. However, it's not suitable for high-current applications, as its thin gauge has higher resistance compared to thicker wires.

PART:

1. ***Conductor (Core Wire)***

- Material: Usually copper (sometimes tinned copper for corrosion resistance)
- Function: Carries the electrical current
- Gauge Size: 22 AWG (0.64 mm or 0.0253 inch in diameter)

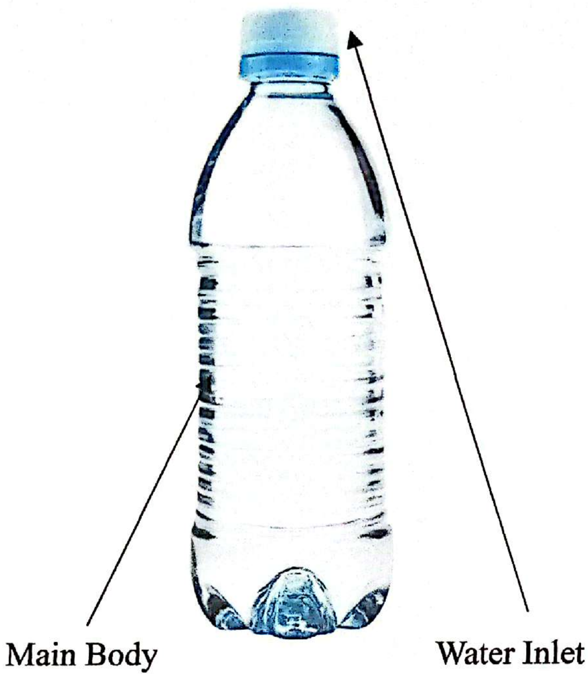

Figure 11: Plastic Container

A plastic container in a sensor-based plant watering and monitoring system serves as the main water reservoir, storing the water that will be supplied to plants when needed. When the soil moisture sensor detects dryness, it signals the microcontroller (such as an Arduino) to activate a water pump, which then draws water from the plastic container and delivers it to the soil. This setup ensures efficient and automated irrigation. Plastic containers are ideal for this role because they are lightweight, waterproof, durable, and cost-effective, making them a practical choice for storing water in automated watering systems (Wmsadmn, 2023)

PARTS:

1. **Main Body (Container Itself)**
    - The actual vessel that holds water.
    - Usually made of plastic (like a bottle or small bucket).
2. **Water Inlet (Opening or Lid)**
    - Used to fill the container with water.
    - May be a removable cap or open top.
3. **Pump Access Hole** *(optional, if pump is inside)*

- A small hole or opening to let pump wires or tubing pass through.

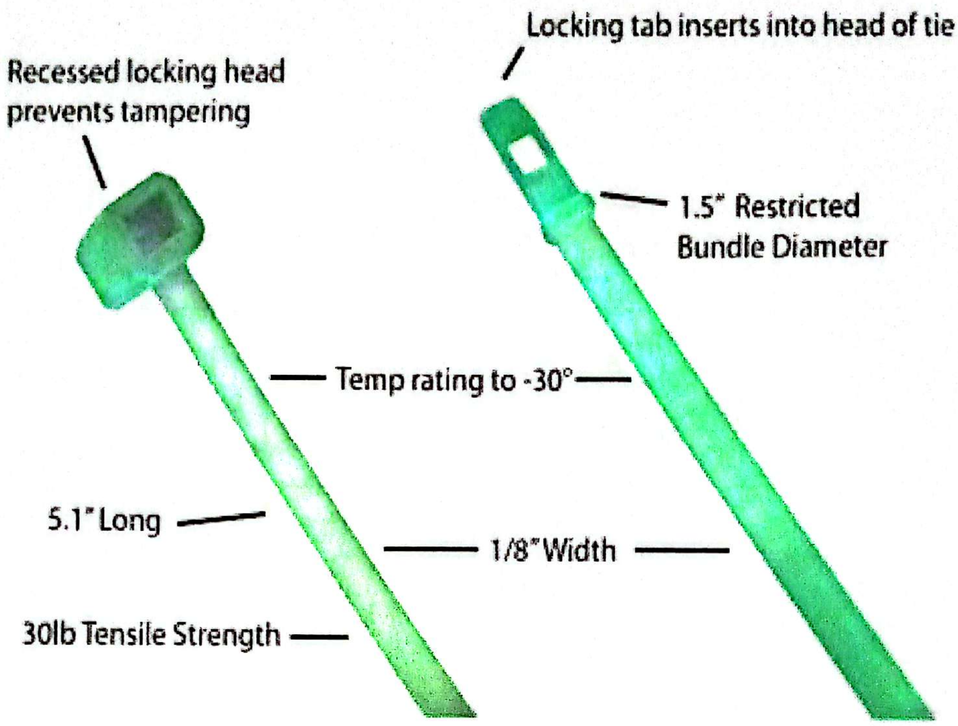

Figure 12: Cable Tie

In electronics, cable ties are essential for keeping wires, cables, and components neat and well-organized. They are used to bundle multiple wires together, securing them in place to prevent tangling and clutter within electronic setups. By holding cables firmly, cable ties help maintain a clean and efficient workspace, making troubleshooting or maintenance easier. They also contribute to safety, as organized wiring reduces the risk of accidental disconnections, electrical shorts, or tripping hazards. Whether in small DIY projects or complex control panels, cable ties help improve both the functionality and reliability of electronic systems. (Sayed, 2023)

PARTS:

1. **Recessed Locking Head Description -** This is the square or rectangular part at the end of the tie.
    - Function: Houses the locking mechanism.
    - Recessed Design: Prevents tampering or accidental unlocking, enhancing security.
2. **Locking Tab Description -** A small plastic tooth or tab on the tie strip.
    - Function: Engages with ridges inside the head to lock the tie in place once it's inserted.
    - Action: One-way mechanism tightens easily but can't be loosened without cutting.

3. **1.5" Restricted Bundle Diameter Description** - The maximum diameter of the object bundle that this zip tie can hold when fully tightened.

- Use: Helps estimate how many cables or how large an object it can secure.

4. **5.1" Long Description:** The total length of the zip tie.

- Use: Determines how much material you can wrap around. Longer ties handle larger bundles.

5. **5. 30 lb Tensile Description** - The maximum pulling force the tie can withstand before breaking.

- Use: Important for selecting the right tie for heavier loads or applications.

6. **1/8" Width Description** - The width of the tie strap.

- Function: Affects both strength and flexibility. Narrower ties are more flexible but hold less weight.

7. **Temp Rating to -30° Description:** The lowest temperature at which the tie remains effective.

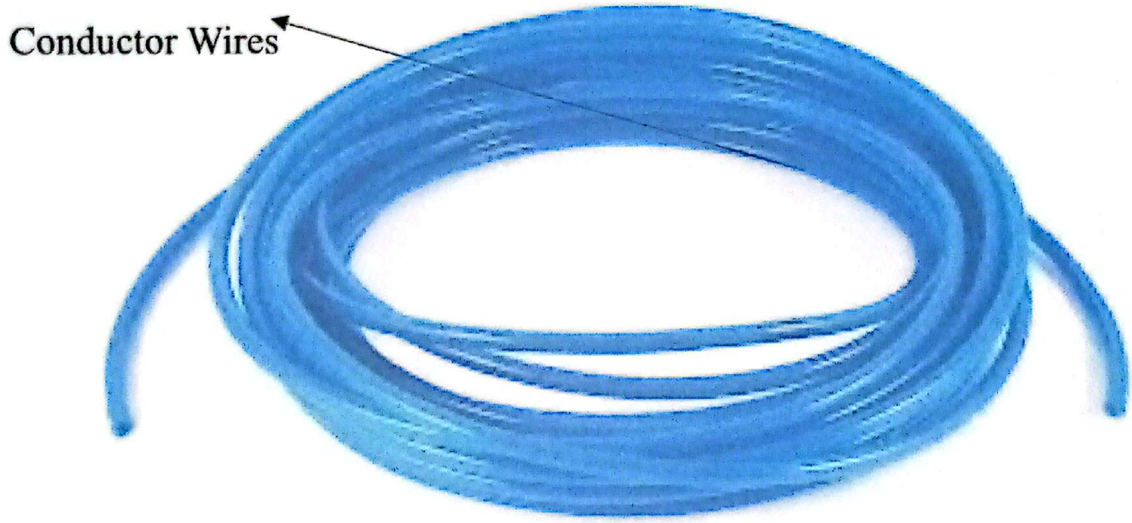

Figure 13: Water hose/ Tube

In a plant watering and monitoring system, the water hose acts as the conduit that delivers water from the source, typically a water pump connected to a container, directly to the base of the plants. Once the sensor detects low soil moisture and triggers the pump, the hose channels the water efficiently and accurately to where it's needed. Its flexible structure makes it easy to position around pots or garden beds, ensuring that water is distributed precisely and with minimal waste. Overall, the water hose is an essential link in the system, enabling smooth and controlled water flow from storage to soil. (Kolstad, 2025).

1. **PARTS:** ***Hose Tube (Main Body)***

   - The flexible tube that carries water.
   - Usually made of rubber, plastic, or silicone.
   - Comes in various diameters depending on the pump and flow rate

4.2 Circuit Schematics

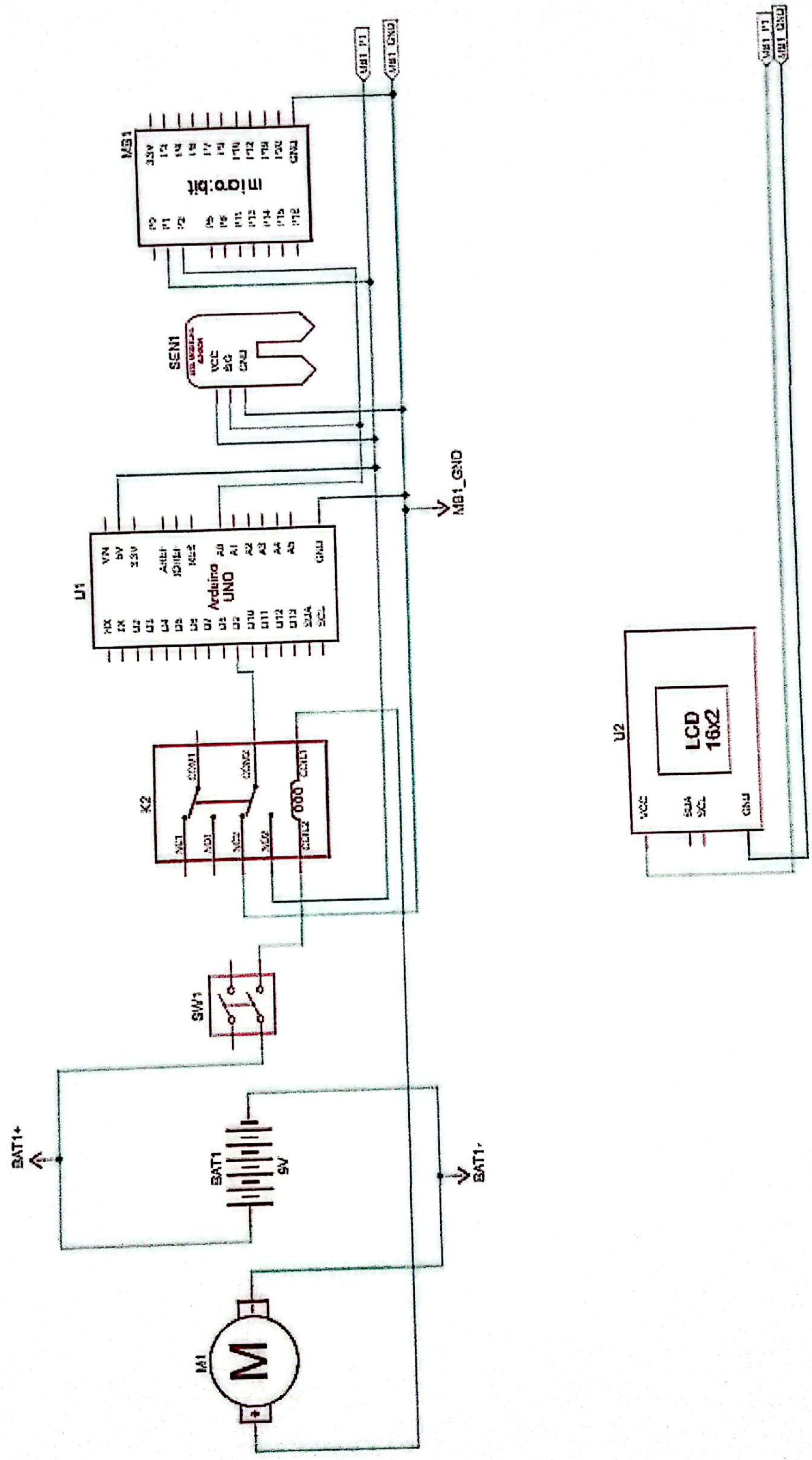

Figure 14. Schematic Diagram

4.3 Simulations

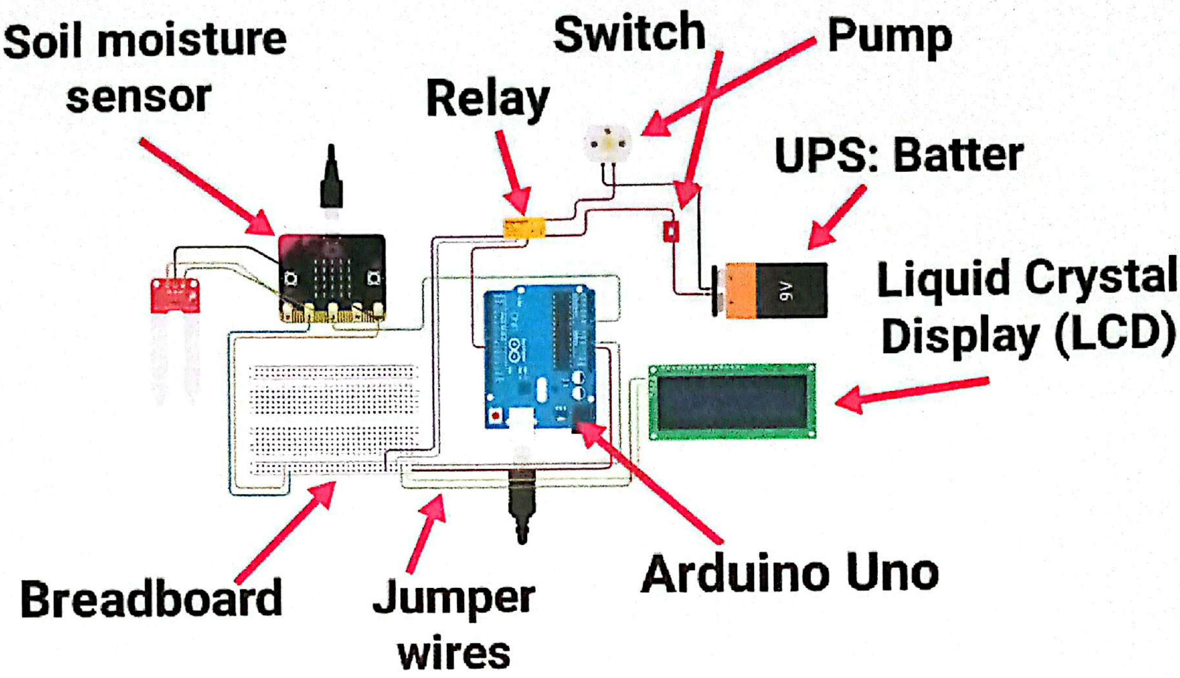

Figure 15. 3D Simulation

System Components:

1. ***Arduino Uno***
   The heart of the system, processing sensor data and controlling the water pump. And where all the program/ coding was taken into account (Arduino Official Website, 2025).
2. ***Soil Moisture Sensor***
   Soil moisture sensor which is connected to the Arduino, measures the volumetric water content in soil or measures the amount of moisture in the soil. This sensor uses the two probes to distribute current across the soil and then examines the resistance to determine the moisture level. (SparkFun Electronics, 2018).
3. ***Relay Module***
   Used to switch the water pump on and off activation based on signals from the Arduino (Storr, 2025)
4. ***Water Pump***
   Supplies water to the plant when the moisture level is below to the desired water level percentage (Instructables Community, 2023).
5. ***Power Supply***
   Provides power to the entire system (Arduino, 2025).
6. ***LCD Display***
   Displays soil moisture readings in percentage and system status. (Arduino, 2025).
7. ***Uninterrupted Power Supply***
   When the main power source fails, the UPS instantly switches to battery power, allowing the system to continue running until the main power is restored (Seidle, 2018)

8. ***Jumper Wires***

A jump cable is used to connect the test plate, the prototype, or the internal circuit with other non-joined instrument (Electronics Tutorials, 2018)

4.4 Implementation Steps

1. Prepare all the needed hardware and software tools and step by step the components should be properly connected.
2. Hardware:
   - In Figure 14 and 15, we can see the connection made between the Arduino Uno, Relay Module, Soil Moisture Sensor, LCD, Switch, Water Pump and the UPS.
   - Here we used two types of power supplies a 9V battery for powering Arduino and a UPS for the water pump.
   - Using jumper wires connect the analog pin wires of the capacitive soil moisture sensor to the A0 pin of the Arduino and VCC and GND of the sensor to VCC and GND of the power supply column of the breadboard, respectively.
   - Connect the trigger pin (IN) of the relay module to the digital pin (9) of the Arduino and connect the VCC to VCC of the power supply column of the Breadboard and GND to GND of the power supply column of the breadboard.
   - Connect the relay module to the water pump and the switch using a #22 AWG stranded wire.
   - Attach a tube to the water pump and install a water container and put the water pump inside.
   - Using #22 AWG Stranded Wire connect the Uninterruptible Power Supply (UPS) to the switch and water pump.
   - Set up an LCD and connect it to the power supply column of the breadboard using jumper wires; VCC to VCC and GND to GND. The SDA of LCD to Analog IN pin A4 of Arduino and SCL of LCD to Analog IN pin A5 of the Arduino.
   - Connect the Arduino to the power supply column of the breadboard using jumping wires; GND to GND and 5V to VCC.
3. Software:
   - Download and install Arduino IDE Software from its official website. After installing, download and unzip libraries in order to use the sensor with the Arduino board.
   - Connect the Arduino Uno board to the laptop using the Arduino connector cable.
   - Enter the code that contains the instructions and commands which the develop model is expected to perform to the Arduino IDE Software.
   - Upload the code and start the trials.

CHAPTER V

RESULTS AND DISCUSSION

Throughout the study, a range of methodologies, including pure research, analysis, and experimental design, were employed to investigate the effectiveness and efficacy of the sensor-based plant watering and monitoring system using Arduino featuring UPS. Hence, this chapter of the study deals with the presentation, analysis and interpretation of data gathered in connection with the problem raised in the investigation.

This inquiry aimed to determine the effectiveness and efficacy of the sensor-based plant watering and monitoring system using Arduino featuring UPS in the soil moisture level.

5.1 Results

Basis for Table 2

PRECISION (%)	REMARK
85 - 100%	Precise
70 – 84.99%	Moderate
Below 70%	Inaccurate

Table 2. *Sensor Precision in Measuring Soil Moisture of Plant 1*

TRIAL NO.	ACTUAL MOISTURE LEVEL (%)	SENSOR READING (%)	PRECISION (%)	REMARKS
1	18	20	90	PRECISE
2	20	22	90.90	PRECISE
3	20	23	86.96	PRECISE
4	23	24	95.83	PRECISE
5	23	24	95.83	PRECISE
6	23	24	95.83	PRECISE
7	25	26	96.15	PRECISE
8	25	26	96.15	PRECISE
9	25	26	96.15	PRECISE
10	26	28	92.86	PRECISE
AVERAGE	**22.8**	**24.3**	**93.83**	**PRECISE**

LEGEND:

COLUMNS	DESCRIPTION
Actual Moisture Level (%)	The true or reference moisture content of the soil measured by a standard method.
Sensor Reading (%)	The value output by the Arduino soil moisture sensor.
Precision (%)	Indicates how close the sensor reading is to the actual value
Remarks	An evaluation of sensor performance based on its precision value

Table 2 shows the precision of a sensor used to measure the soil moisture of Plant 1 across ten trials. The precision percentage was calculated in each trial by comparing the sensor reading with the real moisture level. With precision values ranging from 86.96% to 96.15%, the results demonstrate that the sensor often generated readings that were in close proximity to the real moisture levels. Trials 4 through 9 showed the highest precision, with sensor readings falling within a very small range of the real levels. Overall, the average precision was 93.83%, with the average sensor reading being 24.3% and the average real moisture level throughout all trials being 22.8%. Every reading was marked as "PRECISE," signifying that the sensor operated with enough precision and dependability during the testing period.

Basis for Table 3

PRECISION (%)	REMARK
85 - 100%	Precise
70 – 84.99%	Moderate
Below 70%	Inaccurate

Table 3. *Sensor Precision in Measuring Soil Moisture of Plant 2*

TRIAL NO.	ACTUAL MOISTURE LEVEL (%)	SENSOR READING (%)	PRECISION (%)	REMARKS
1	31	32	96.875	PRECISE
2	26	27	96.30	PRECISE
3	25	27	92.59	PRECISE
4	25	27	92.59	PRECISE
5	24	25	96	PRECISE
6	24	25	96	PRECISE
7	24	26	92.31	PRECISE
8	23	26	88.46	PRECISE
9	23	24	95.83	PRECISE
10	23	24	95.83	PRECISE
AVERAGE	**24.8**	**26.3**	**94.30**	**PRECISE**

LEGEND:

COLUMNS	DESCRIPTION
Actual Moisture Level (%)	The true or reference moisture content of the soil measured by a standard method.
Sensor Reading (%)	The value output by the Arduino soil moisture sensor.
Precision (%)	Indicates how close the sensor reading is to the actual value
Remarks	An evaluation of sensor performance based on its precision value

The precision of the sensor in determining Plant 2's soil moisture over ten trials is displayed in Table 3. The precision percentages were computed by comparing the sensor readings with the actual moisture levels. The precision results showed a high degree of accuracy in every experiment, ranging from 88.46% to 96.875%. With the maximum precision recorded in Trial 1 and consistently high results in Trials 2, 5, and 6, the sensor reliably reported readings that were near to the real moisture levels. The average sensor reading was

26.3%, but the average real moisture level was 24.8%. As a result, the average precision was 94.30%. Since every trial was designated as "PRECISE," it was evident that the sensor continued to operate dependably and consistently throughout the measurements for Plant 2.

Basis for Table 4

PRECISION (%)	REMARK
85 - 100%	Precise
70 – 84.99%	Moderate
Below 70%	Inaccurate

Table 4. *Sensor Precision in Measuring Soil Moisture of Plant 3*

TRIAL NO.	ACTUAL MOISTURE LEVEL (%)	SENSOR READING (%)	PRECISION (%)	REMARKS
1	32	33	96.97	PRECISE
2	32	33	96.97	PRECISE
3	32	33	96.97	PRECISE
4	32	34	94.12	PRECISE
5	32	33	96.97	PRECISE
6	33	34	97.06	PRECISE
7	33	35	94.29	PRECISE
8	33	35	94.29	PRECISE
9	33	35	94.29	PRECISE
10	33	35	94.29	PRECISE
AVERAGE	**32.5**	**34**	**95.59**	**PRECISE**

LEGEND:

COLUMNS	DESCRIPTION
Actual Moisture Level (%)	The true or reference moisture content of the soil measured by a standard method.
Sensor Reading (%)	The value output by the Arduino soil moisture sensor.
Precision (%)	Indicates how close the sensor reading is to the actual value
Remarks	An evaluation of sensor performance based on its precision value

Table 4 shows the sensor's precision in measuring the soil moisture of Plant 3 across ten trials. The actual moisture levels and corresponding sensor readings were compared to determine the precision of each measurement. The precision percentages ranged from 94.12% to 97.06%, showing consistently high accuracy. Most readings were within one to two percentage points of the actual values, indicating the sensor's strong reliability. The highest precision, at 97.06%, occurred in Trial 6, while multiple trials (1, 2, 3, and 5) also demonstrated precision close to 97%. The average actual moisture level recorded was 32.5%, while the average sensor reading was 34%, resulting in an overall average precision of 95.59%. All readings were marked as "PRECISE," reinforcing the sensor's consistent and dependable performance when measuring soil moisture for Plant 3.

Basis for Evaluation (Table 5)

Trigger Threshold

- The system is programmed to trigger watering when soil moisture is below 10%.
- In this test, all "before" readings were 1%, which qualifies for watering.

Watering Outcome

- If soil moisture after watering increased to ≥ 40%, the watering is considered effective and necessary.
- Therefore, the sensor system was accurate and responsive if it triggered watering correctly and raised soil moisture sufficiently.

Basis for Remarks (Table 5)

CRITERIA	REMARK
Moisture before is below 10%, watering is triggered, and after-watering reading is ≥ 40%	PRECISE
Moisture before is below 10%, watering is triggered, but after-watering is < 40%	MODERATE
No watering despite low moisture OR excessive watering	INACCURATE

Table 5. *Watering Precision and Timing (Overwatering/Underwatering)*

DAY	SOIL MOISTURE BEFORE (%)	WATERING TRIGGERED?	SOIL MOISTURE AFTER (%)	WAS WATERING NECESSARY?	REMARKS
1	1	YES	56	YES	PRECISE
2	1	YES	50	YES	PRECISE
3	1	YES	41	YES	PRECISE
4	1	YES	41	YES	PRECISE
5	1	YES	41	YES	PRECISE
AVE.	**1**	**YES**	**45.8**	**YES**	**PRECISE**

LEGEND:

COLUMNS	DESCRIPTION
Day	The specific test day of observation.
Soil Moisture Before (%)	Initial moisture level before automatic watering, measured by the sensor.
Watering Triggered?	Indicates whether the system automatically triggered watering based on low moisture reading.
Soil Moisture After (%)	Moisture level after watering, measured by the sensor.
Was Watering Necessary	Manual assessment (based on threshold) whether watering was needed at that time.
Remarks	Indicates system performance based on whether the response was appropriate.

Table 5 shows the precision and timing of the watering system in relation to soil moisture levels over five consecutive days. On each day, the soil moisture level before watering was recorded at 1%, which triggered the system to initiate watering. After watering, the moisture levels increased significantly, ranging from 41% to 56%. In every case, watering was deemed necessary due to the very low initial moisture levels, and the system responded appropriately. The average moisture level before watering across the five days remained at 1%, while the average moisture level after watering was 45.8%. All instances were marked as "PRECISE," indicating that the system consistently made accurate decisions regarding when to water, effectively preventing both overwatering and underwatering.

Basis for Evaluation (Table 6)

CONDITION	***CONSIDERED SYSTEM SUCCESS?***
Power is lost AND UPS activates AND watering continues	YES
Power is available AND watering still occurs as normal	YES
Power is lost AND UPS fails OR watering does not occur	NO

Table 6. *Water Availability with UPS Support*

EVENT 1	POWER STATUS	UPS ACTIVATED?	WATERING OCCURRED ?	DELAY (SECONDS)	SYSTEM SUCCESS
1	Power Lost	YES	YES	5	YES
2	Normal	NO	YES	5	YES
3	Power Lost	YES	YES	5	YES
4	Normal	NO	YES	5	YES
5	Power Lost	YES	YES	5	YES
SUCCESS RATE					**5/5 = 100%**

LEGEND:

COLUMNS	**DESCRIPTION**
Power Status	Indicates the availability of power during the watering event (e.g., *Power Lost* or *Normal*)
UPS Activated?	Shows whether the Uninterruptible Power Supply (UPS) activated when power was lost.
Watering Occurred?	Indicates whether the watering system still functioned regardless of the power condition.
Delay (Seconds)	Time between power loss and system reactivation or watering continuation.
System Success?	States if the system successfully continued operation without interruption, even during power outages.

Table 6 shows the system's ability to maintain water availability during power fluctuations with the support of an Uninterruptible Power Supply (UPS). During five events, the system was tested under both normal and power loss conditions. In the instances where power was lost (Events 1, 3, and 5), the UPS was activated, and watering proceeded with only a 5-second delay. During normal power conditions (Events 2 and 4), the UPS was not needed, yet watering still occurred with the same delay. In all five cases, the system successfully completed the watering process, regardless of power status, resulting in a 100% success rate. This confirms that the UPS effectively ensured continuous operation and water delivery during power interruptions.

5.2 Discussions of Findings

1. *How precise is the system in sensing soil moisture?*

   The system shows promise in the precision of sensing soil moisture level with an overall precision of 93.83% for Plant 1, 94.30% of Plant 2, and 95.59% for Plant 3. All the readings of Table 1, 2 and 3 show a "Precise" remark. Moreover, the sensor continued to have readings that are similar with the actual moisture level of the soil of the three plants, hence the sensor displays a precise performance in sensing soil moisture level.

2. *How precise is the system in monitoring to prevent overwatering or underwatering?*

   The table shows the precision and timing of the watering system in relation to soil moisture levels. The experiment was conducted in 5 consecutive days after the assemble of the prototype. It is shown that from Day 1 to 5 the system sensed a 1% moisture level before the watering process of the prototype. After watering, the prototype sensed a soil moisture level with an average of 45.8%. Overall, the system displays precision in monitoring soil moisture level to prevent overwatering/underwatering.

3. *What is the level of effectiveness of the Sensor-Based Plant Watering and Monitoring System in terms of convenience and detecting soil moisture level?*

   The level of effectiveness of the sensor in terms of convenience and detecting soil moisture level is remarked as "Precise" as shown on the findings of Table 1, Table 2, and Table 3 for Plant 1, Plant 2 and Plant 3, respectively.

4. *Is the system effective in terms of providing immediate water production for tree planting programs with the support of UPS?*

   Table 5 demonstrates the system's ability to maintain water availability during power interruptions and power lost, as supported by an Uninterrupted Power Supply (UPS). It is shown that from 2 different events which were the power lost and usage of normal power, the watering still proceeds with the same precision and timing. This means that the system shows a continuous performance to ensure watering and monitoring.

5. *What is the level of acceptability of the plant watering and monitoring system?*

   The plant watering and monitoring system demonstrates a high level of acceptability. It consistently provides accurate soil moisture readings, makes precise watering decisions, and functions reliably even during power interruptions. With high sensor precision, effective watering performance, and 100% system reliability, the system proves to be dependable and well-suited for automated plant care.

CHAPTER VI

CONCLUSION AND RECOMMENDATIONS

This section presents the conclusions and making informed recommendations, offering valuable results and experimentation on the effectiveness and efficacy of the sensor-based plant watering and monitoring system using Arduino featuring UPS.

6.1 Conclusions

The conclusions drawn from this study highlight the significant findings and outcomes obtained through the research process. These conclusions are based on the analysis and interpretation of data, as well as the fulfillment of research objectives. The key conclusions of the study are as follows:

1. Precision in Sensing Soil Moisture

   The system proved to be highly precise in sensing soil moisture, with overall precision rates of 93.83% for Plant 1, 94.30% for Plant 2, and 95.59% for Plant 3. All data presented in Tables 1, 2, and 3 were remarked as "Precise," confirming that the sensor consistently delivered readings closely aligned with actual soil moisture levels.
2. Precision in Monitoring to Prevent Overwatering or Underwatering

   The system effectively monitored soil moisture to ensure proper irrigation. From Day 1 to Day 5, the moisture level before watering was consistently at 1%, and the average moisture level after watering was 45.8%, indicating that the system was able to determine the correct timing and amount of water needed, thereby avoiding overwatering or underwatering.
3. Effectiveness in Terms of Convenience and Moisture Detection

   The sensor system demonstrated high effectiveness in terms of convenience and detecting soil moisture. The data from all three plants (Tables 1, 2, and 3) confirmed consistent and precise moisture detection, contributing to a user-friendly and efficient plant monitoring solution.
4. Effectiveness in Providing Immediate Water Supply During Power Interruptions

   As presented in Table 5, the system maintained full functionality during power loss events through the support of an Uninterrupted Power Supply (UPS). Watering continued with the same accuracy and timing whether on normal power or backup, proving the system's reliability in ensuring uninterrupted operation.
5. Level of Acceptability of the Plant Watering and Monitoring System

   The overall performance of the system reflects a high level of acceptability. It achieved precise soil moisture sensing, timely and appropriate watering actions, and uninterrupted performance even during power interruptions. With a 100% system success rate, the system is deemed dependable and suitable for real-world applications in smart and automated plant irrigation.

6.2 Recommendations

Based on the findings and conclusions of the study, the following recommendations are proposed:

1. Improve sensor calibration across different soil types to maintain or enhance the current high precision levels (93.83% to 95.59%) in sensing soil moisture. Testing on a broader range of soil conditions can ensure consistent accuracy across various environments.

   Basis: The system demonstrated high precision in sensing soil moisture (93.83%–95.59%) across three plants. However, this was tested under specific soil conditions. Broadening calibration to different soil types will ensure that the system maintains accuracy in diverse environments.

2. Incorporate environmental sensors such as rain detectors to complement the soil moisture readings and prevent unnecessary watering. This would further refine the system's ability to avoid overwatering or underwatering, especially during unexpected weather changes.

   Basis: While the system showed precision in moisture detection and watering control, it relies solely on soil moisture readings. Unexpected rainfall could lead to overwatering if not detected. Including environmental sensors enhances accuracy by considering external conditions.

3. Enhance user interface and adjustability by integrating a simple control panel or mobile app to allow real-time monitoring and customization of watering schedules. This would improve the system's convenience and user experience, especially in settings with varying plant needs.

   Basis: The system was shown to be effective and precise, but convenience and customization can be improved. Real-time adjustments through a control panel or mobile app would enhance usability, especially for users managing multiple plants with different watering needs.

4. Strengthen the UPS integration with backup alerts to ensure that users are notified of power interruptions or UPS failures. This would guarantee uninterrupted operation during tree planting programs and ensure water delivery remains consistent.

   Basis: Table 5 confirmed the system's reliability during power interruptions with a 100% success rate. However, adding alerts or notifications will further improve resilience by informing users of UPS status and avoiding unnoticed failures during critical operations like tree planting.

5. Expand acceptability through training and support materials such as user manuals or video tutorials to guide users in setup, maintenance, and troubleshooting. This will help sustain the system's high acceptability and reliability in both home and community garden settings.

   Basis: The system received a high level of acceptability due to its performance and reliability. Providing user-friendly materials such as manuals or video guides will help sustain this acceptance, especially among non-technical users in home and community garden setups

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APPENDICES

APPENDIX A
CODES FOR SENSOR AND LCD DISPLAY

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

// LCD address and size
LiquidCrystal_I2C lcd(0x27, 16, 2);  // Change 0x27 to 0x3F if needed

const int pumpRelayPin = 9;          // Pump relay connected to digital pin 9
const int soilSensorPin = A0;        // Soil moisture sensor connected to
analog pin A0
const int soilThreshold = 500;       // Threshold for dryness (adjust as
needed)

const unsigned long pumpOnTime = 5000;    // Pump ON duration
const unsigned long pumpOffTime = 5000;   // Pump OFF duration
const unsigned long wetPauseTime = 10000; // Delay if soil is wet

void setup() {
  pinMode(pumpRelayPin, OUTPUT);
  digitalWrite(pumpRelayPin, LOW); // Ensure pump is off at start

  pinMode(soilSensorPin, INPUT);

  lcd.begin(16, 2);       // Initialize the LCD
  lcd.backlight();        // Turn on backlight
  lcd.setCursor(0, 0);
  lcd.print("System Starting...");
  delay(2000);
  lcd.clear();
}

void loop() {
  int soilValue = analogRead(soilSensorPin);

  // Convert to moisture percentage (0 = dry, 100 = wet)
  int moisturePercent = map(soilValue, 1023, 0, 0, 100);
  moisturePercent = constrain(moisturePercent, 0, 100); // Clamp values

  // Display on LCD
  lcd.setCursor(0, 0);
  lcd.print("Moisture: ");
  lcd.print(moisturePercent);
```

```
  lcd.print("%   "); // Extra spaces to clear leftover characters

  if (soilValue < soilThreshold) {
    lcd.setCursor(0, 1);
    lcd.print("Soil Wet. Wait... ");
    digitalWrite(pumpRelayPin, LOW);
    delay(wetPauseTime);
  } else {
    lcd.setCursor(0, 1);
    lcd.print("Watering...       ");
    digitalWrite(pumpRelayPin, HIGH);
    delay(pumpOnTime);

    lcd.setCursor(0, 1);
    lcd.print("Pump OFF. Waiting ");
    digitalWrite(pumpRelayPin, LOW);
    delay(pumpOffTime);
  }
}
```

APPENDIX B
COMPUTATIONS OF DATA

FOR TABLE 2, 3 and 4

$$PRECISION\ (\%) = \frac{Actual\ Moisture\ Level}{Sensor\ Reading}\ x\ 100$$

Table 2

Trial 1

$PRECISION\ (\%) = \frac{18}{20}\ x\ 100 =$ **90%**

Trial 2

$PRECISION\ (\%) = \frac{20}{22}\ x\ 100 =$ **90.90%**

Trial 3

$PRECISION\ (\%) = \frac{20}{23}\ x\ 100 =$ **86.96%**

Trial 4

$PRECISION\ (\%) = \frac{23}{24}\ x\ 100 =$ **95.83%**

Trial 5

$PRECISION\ (\%) = \frac{23}{24}\ x\ 100 =$ **95.83%**

Trial 6

$PRECISION\ (\%) = \frac{23}{24}\ x\ 100 =$ **95.83%**

Trial 7

$PRECISION\ (\%) = \frac{23}{24}\ x\ 100 =$ **95.83%**

Trial 8

$PRECISION\ (\%) = \frac{25}{26}\ x\ 100 =$ **96.15%**

Trial 9

$PRECISION\ (\%) = \frac{25}{26}\ x\ 100 =$ **96.15%**

Trial 10

$PRECISION\ (\%) = \frac{26}{28}\ x\ 100 =$ **92.86%**

AVERAGE: $PRECISION\ (\%) = \frac{22.8}{24.3}\ x\ 100 =$ **93.83%**

Table 3

Trial 1

$PRECISION\ (\%) = \frac{31}{32}\ x\ 100 = \mathbf{96.875\%}$

Trial 2

$PRECISION\ (\%) = \frac{26}{27}\ x\ 100 = \mathbf{96.30\%}$

Trial 3

$PRECISION\ (\%) = \frac{25}{27}\ x\ 100 = \mathbf{92.59\%}$

Trial 4

$PRECISION\ (\%) = \frac{25}{27}\ x\ 100 = \mathbf{92.59\%}$

Trial 5

$PRECISION\ (\%) = \frac{24}{25}\ x\ 100 = \mathbf{96\%}$

Trial 6

$PRECISION\ (\%) = \frac{24}{25}\ x\ 100 = \mathbf{96\%}$

Trial 7

$PRECISION\ (\%) = \frac{24}{26}\ x\ 100 = \mathbf{92.31\%}$

Trial 8

$PRECISION\ (\%) = \frac{23}{26}\ x\ 100 = \mathbf{88.46\%}$

Trial 9

$PRECISION\ (\%) = \frac{23}{24}\ x\ 100 = \mathbf{95.83\%}$

Trial 10

$PRECISION\ (\%) = \frac{23}{24}\ x\ 100 = \mathbf{95.83\%}$

AVERAGE: $PRECISION\ (\%) = \frac{24.8}{26.3}\ x\ 100 = \mathbf{94.30\%}$

Table 4

Trial 1

$PRECISION\ (\%) = \frac{32}{33}\ x\ 100 = \mathbf{96.97\%}$

Trial 2

$PRECISION\ (\%) = \frac{32}{33}\ x\ 100 = \mathbf{96.97\%}$

Trial 3

$PRECISION\ (\%) = \frac{32}{33}\ x\ 100 = \mathbf{96.97\%}$

Trial 4

$PRECISION\ (\%) = \frac{32}{34}\ x\ 100 = \mathbf{94.12\%}$

Trial 5

$PRECISION\ (\%) = \frac{32}{33}\ x\ 100 = \mathbf{96.97\%}$

Trial 6

$PRECISION\ (\%) = \frac{33}{34}\ x\ 100 = \mathbf{97.06\%}$

Trial 7

$PRECISION\ (\%) = \frac{33}{35}\ x\ 100 = \mathbf{94.29\%}$

Trial 8

$PRECISION\ (\%) = \frac{33}{35}\ x\ 100 = \mathbf{94.29\%}$

Trial 9

$PRECISION\ (\%) = \frac{33}{35}\ x\ 100 = \mathbf{94.29\%}$

Trial 10

$PRECISION\ (\%) = \frac{33}{35}\ x\ 100 = \mathbf{94.29\%}$

AVERAGE: $PRECISION\ (\%) = \frac{32.5}{34}\ x\ 100 = \mathbf{95.59\%}$

Table 5

AVERAGE = 56 + 50 + 41 + 41 + 41 / 5 = **45.8**

Table 6

$$Success\ Rate = \frac{Number\ of\ Successful\ Events}{Total\ Events}\ x\ \frac{5}{5} = \mathbf{100\%}$$

APPENDIX C
PROJECT DOCUMENTATION

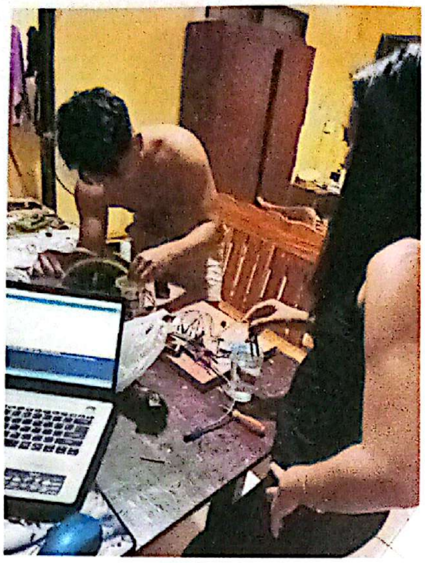

Figure 16. Initial Circuit Planning and Component Assembling

The system's early construction and preparation stages are shown in this picture. On the table are electronic components like a laptop, jumper wires, a relay module, an Arduino board, a breadboard, and a soil moisture sensor. In order to prepare for testing, components were arranged at this step, and basic wiring was started.

Figure 17. Working on Circuit Assembly

In this step, the Arduino's basic circuit was set up by connecting the LCD, power supply, and soil moisture sensor through a breadboard. Before complete integration, code was uploaded using the Arduino IDE to evaluate each component's function separately.

Figure 18. Finalizing the Interior Setup

All of the modules' wiring, including the relay module and water pump connections, was completed. Every part was examined to make sure it was positioned appropriately and was firmly attached. In order to prevent circuit errors during testing, this step was essential.

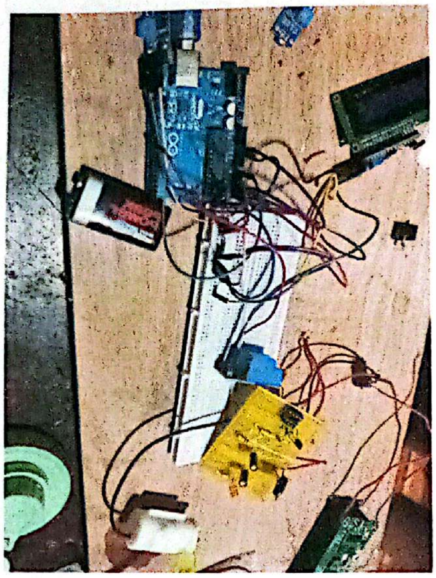

Figure 19. Illustration of a Breadboard Circuit

A close-up of the finished circuit on a breadboard is shown in this figure. The relay, LCD, power supply, and soil moisture sensor are all centrally connected to the Arduino. Quick troubleshooting and simple signal path identification were made possible by this clear setup.

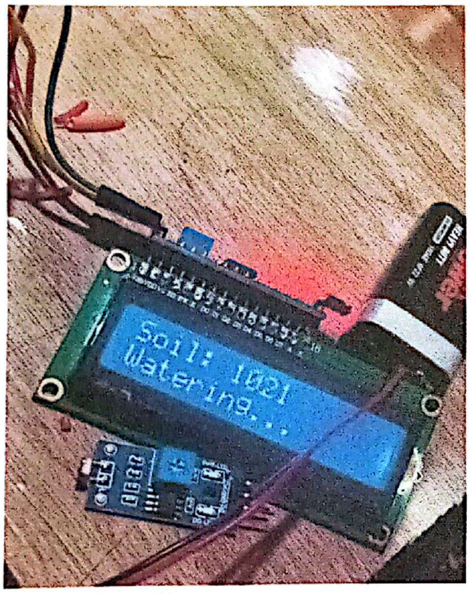

Figure 20. Testing the Quality of the LCD

This step focused on testing the LCD display, which was used to show live system updates like soil moisture levels and pump status. Testing the LCD display, which was utilized to show real-time system updates such soil moisture levels and pump status, was the main goal of this step. The Arduino was linked to the LCD, and text and numbers were shown using a straightforward test code. Before include it into the entire system, this verified that the screen was operational, readable, and properly wired.

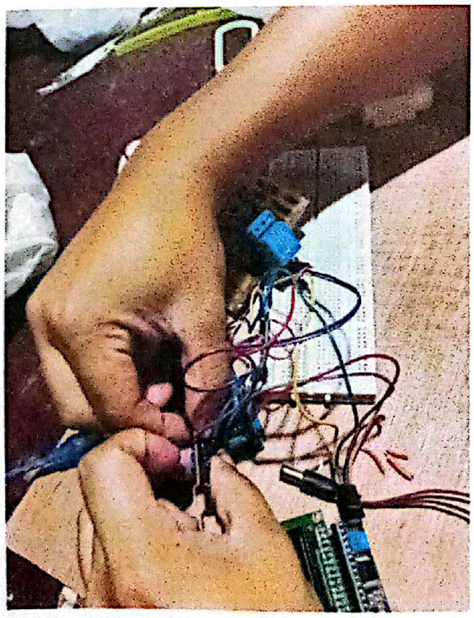

Figure 21. Creating Code for Arduino

During this step, the Arduino IDE was used to write and upload the main control program, which involved receiving data from the moisture sensors, using a relay to activate the pump when the soil was dry or wet, and using the LCD to show the status of the system.

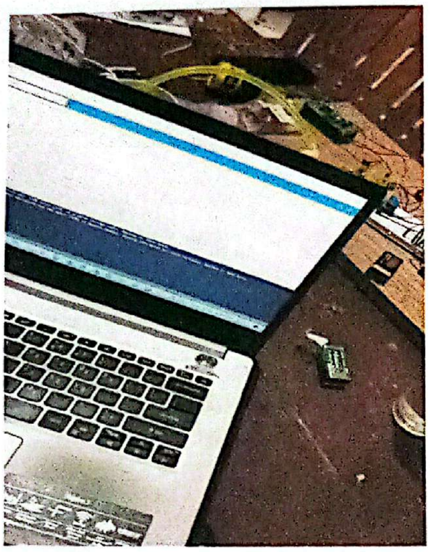

Figure 22.. Connecting the Sensor and Relay Module

The next step involved connecting the relay and soil moisture sensor wires to the breadboard. The proper positioning of the ground, power, and signal wires was carefully considered. This guaranteed reliable data transfer and pump control signal delivery.

Figure 23. First Trial of the Mini Water Pump

In this first test, a direct 9V battery supply was used to power the mini water pump, which was attached to the breadboard circuit. In this trial use rain sensor as a temporary substitute for a soil moisture sensor, which was not available at the time. The sensor was connected to the Arduino to simulate soil dryness detection. The trial's aim was to determine whether the pump could effectively pull water from a container and force it through a tube. To guarantee steady water flow and pressure, a few changes were performed.

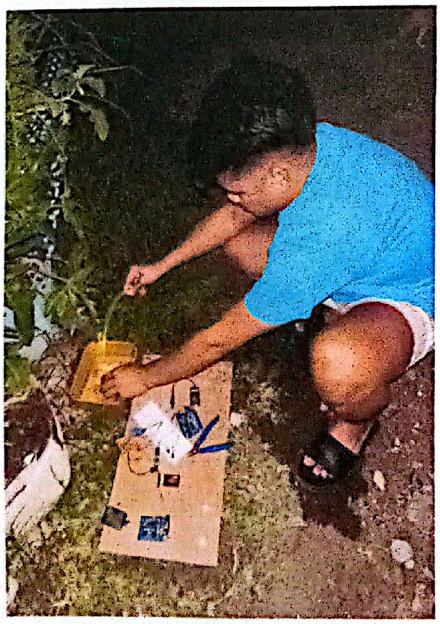

Figure 24. Second Trial of the Mini Water Pump

Following a few minor wiring and positioning changes, the second testing happened. The relay module was now used to activate the pump, enabling it to react to Arduino inputs automatically. This test confirmed that the relay could trigger the pump as intended and that the control logic was operating correctly.

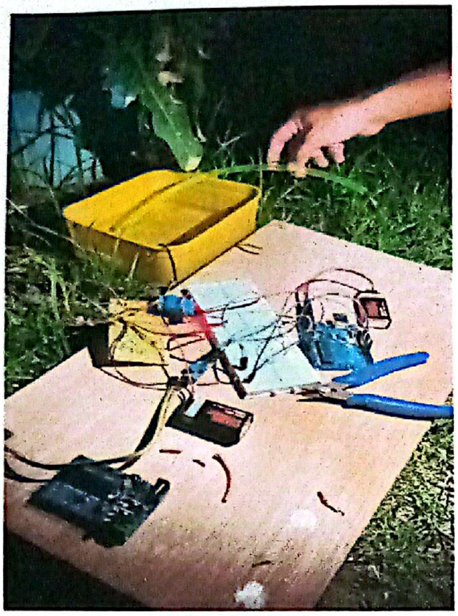

Figure 25. The Mini Water Pump's Final Trial

Based on the code time interval in the Arduino, the final trial tested the pump's consistency over a longer period of time. The pump was tested in conditions that were closer to the final system placement, and the wiring and water flow were optimized. The pump's stability, water flow rate, and suitability for formation into the entire automated watering system were all validated by this test.

Figure 26. Plotting the Components on the Plywood

Before assembly, the positions of each component were marked on a sturdy plywood board. An orderly arrangement with enough space for the Arduino, sensors, LCD, relay module, pump, and wire was ensured by this arranging process. The right distance was taken to allow for cable routing, access, and cooling.

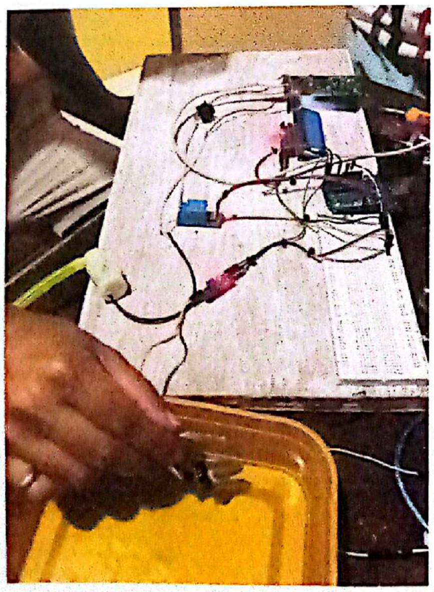

Figure 27. Testing the Soil Moisture Sensor

To confirm its data, the soil moisture sensor conducted separate tests. To ensure precise moisture level measurement, the sensor was placed into both dry and wet water samples, and the Arduino serial monitor was used to view the sensor's analog output.

Figure 28. Final Plotting of Component Positions

With testing completed, the exact placement of all components was finalized on the plywood board. This included alignment of the sensor inputs, control modules, and water pathways, optimizing both functionality and appearance.

Figure 29. Final Plotting of Component Positions

Once the layout was confirmed, the components were securely fixed to the plywood base using stick glue. This step ensured that no parts would shift during operation or transport, giving the prototype physical stability.

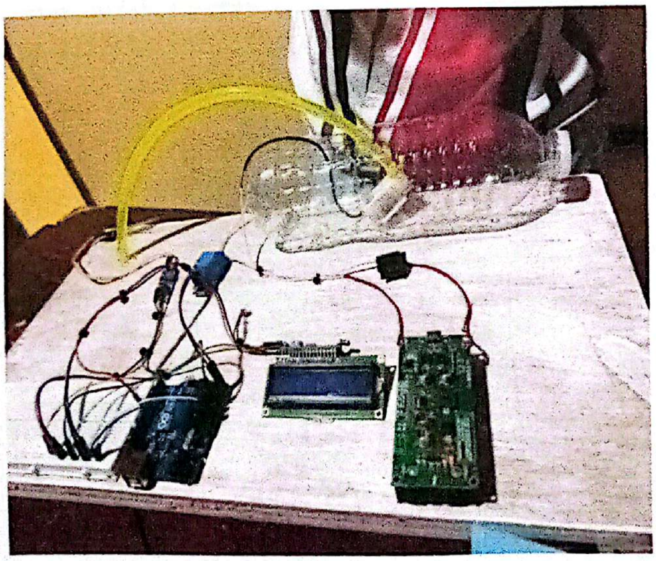

Figure 30. Final Layout of the Prototype

This figure shows the fully arranged prototype on the plywood, before powering it on. All components were now fixed in place with properly routed wiring. The layout was clean and accessible, ready for indoor and outdoor testing.

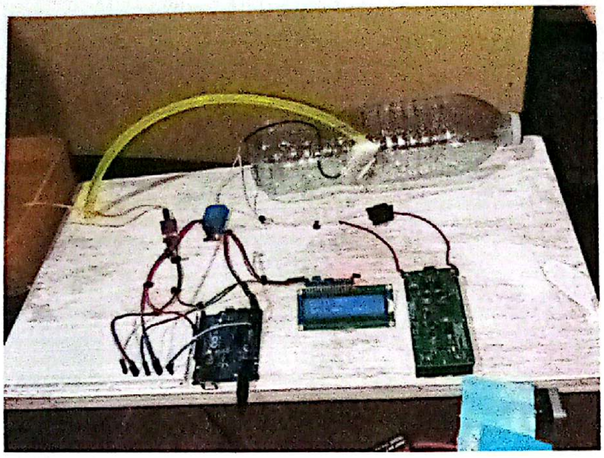

Figure 31. Final Indoor Prototype Assembly on Plywood Base (Powered ON)

The complete prototype was powered on for a live test. The LCD displayed real-time moisture levels, and the system was ready to respond to sensor readings. The pump, relay, and Arduino were fully functional and arranged for stable performance.

Figure 32. Walking to Deployment Site

The completed prototype was transported to an outdoor location for field testing. The plywood-mounted setup was portable and stable enough to be carried safely without disrupting the wiring or component layout.

Figure 33. Arrival at the Field Test Location

The test site was selected based on soil exposure and access to potted plants. The plywood prototype was positioned near plants for live environmental monitoring and system validation under natural conditions.

Figure 34. Preparing for On-Site Testing

Before activation, the pump and sensor were positioned appropriately. The system was powered and checked for stability in its new environment. This step ensured the hardware could operate under outdoor conditions such as sunlight, dust, or vibration.

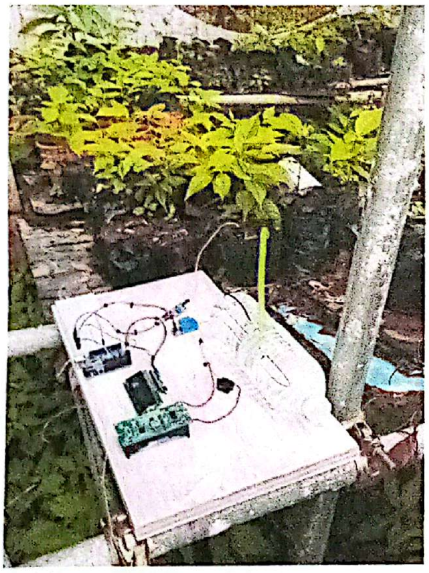

Figure 35. Outdoor System Placement Among Plants

The system was placed on the ground, among real potted plants, with the rain sensor inserted into the soil as a temporary input device. The LCD and wiring were visible and functional, and the water source was positioned for efficient delivery.

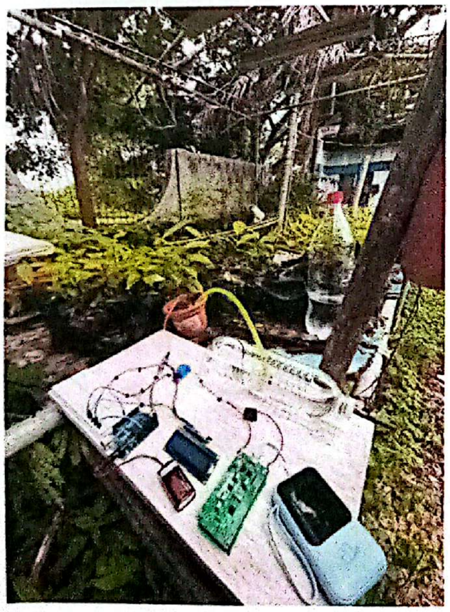

Figure 36. Real-Time Monitoring in Outdoor Conditions

The LCD displayed live values as the prototype monitored the soil conditions outdoors. When triggered by dry readings, the pump activated, watering the plant successfully. This test confirmed full system functionality under real-world conditions.

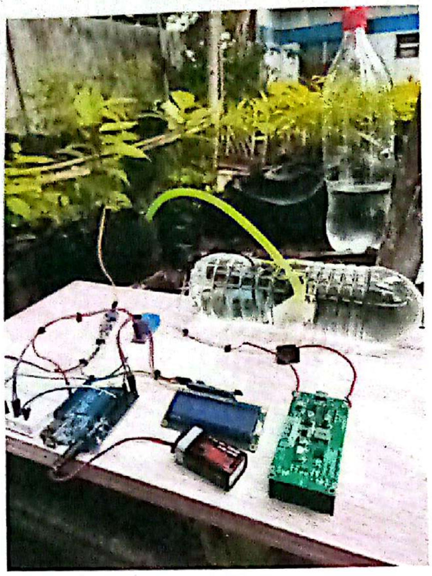

Figure 37. Final Outdoor Validation of the Prototype

In this final outdoor test, the fully assembled prototype was left running autonomously under natural environmental conditions. The soil moisture sensor was inserted into the plant's soil, and the system operated in real time, automatically activating the pump when dry conditions were detected. The stable mounting on the plywood base ensured secure placement, and the LCD displayed system status continuously. This figure marks the successful validation of the system's performance in a real-world setting.

Figure 38. Setup Check

The control circuit is reviewed and reconnected in the outdoor environment. Wiring and component stability are verified to ensure functionality before proceeding with continuous monitoring.

Figure 39. Examining and Collecting Data in Plant 1

Soil moisture readings are recorded from Plant 1. The sensor is observed for accuracy and response under current soil conditions.

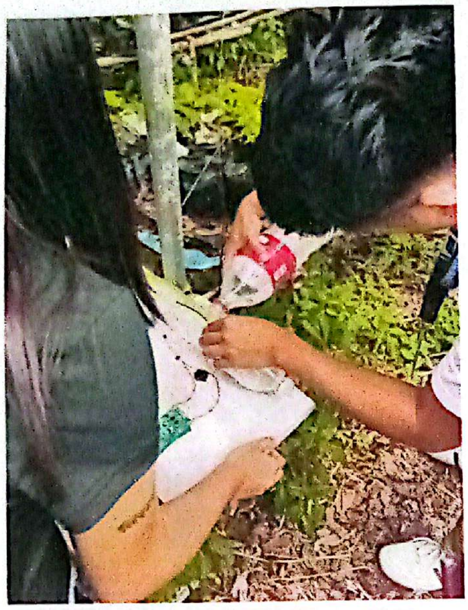

Figure 40. Refilling Water Supply for Continuous Testing

A recycled plastic bottle is used to store the water connected to the pump system. Refilling ensures sustained operation during real-time testing.

Figure 41. Examining and Collecting Data in Plant 2

The sensor is inserted near Plant 2 for continued monitoring. Data is gathered to compare moisture levels across multiple locations.

Figure 42. Final Adjustments Before Live Monitoring

Before initiating the automated watering logic, students verify all modules and sensor placements. This step involves reviewing both physical setup and microcontroller status to prevent faults.

Figure 43. Examining and Collecting Data in Plant 3

At Plant 3, moisture levels are checked and logged. Real-time feedback is reviewed to ensure the system remains consistent and responsive.

Figure 44. Sensor Calibration and Code Verification on Site

The control logic is checked using live data from the sensor. Code execution and sensor feedback are monitored via the LCD to ensure correct system behavior.

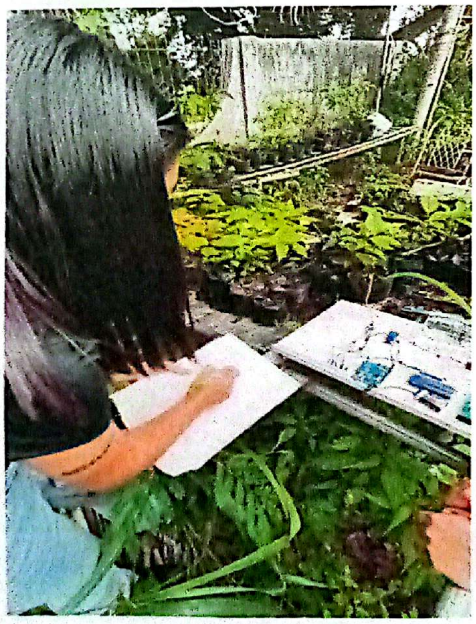

Figure 45. Inspecting Moisture Readings and Signal Response

The LCD module displays current soil moisture percentage and pump status. Signal flow from the sensor is checked to ensure correct threshold-based activation.

Figure 46. Field Group Discussion for Observational Logging

Group members engage in a brief discussion on sensor performance, water delivery consistency, and any observable plant response. Observational logs were used to support sensor data and assess reliability.

Figure 47. Assembly Check and System Reboot

In this step, check all system components before powering the device on again. Wiring, sensor placement, and code behavior are double-checked for reliability before further data is collected in the field environment.

Figure 48. Reviewing Setup and Observational Procedure

System functions and expected outputs are reviewed. A checklist is used to ensure that observations such as moisture levels, pump activation, and LCD display data will be recorded accurately during testing.

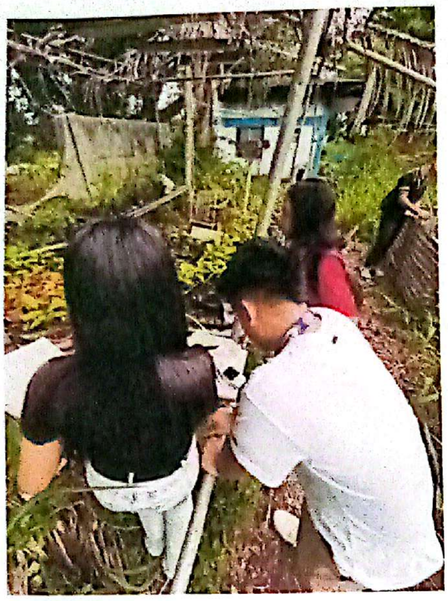

Figure 49. Testing the Moisture Sensor in Varied Soil Conditions

The moisture sensor is placed in different parts of the soil with varying moisture content. This confirms that the sensor can detect a range of soil conditions and respond appropriately based on the threshold values.

Figure 50. Fine-Tuning the Pump Activation Threshold

As the soil begins to dry, the system's logic is observed to ensure that the pump activates at the right moisture level. Adjustments are made in the code if needed to optimize responsiveness and water usage.

Figure 51. Securing Sensor Placement in the Soil

The soil moisture sensor is carefully embedded to ensure accurate readings. Proper placement prevents loose contact with the soil and guarantees that the sensor captures reliable data throughout the test period.

Figure 52. Collecting Real-Time Data During Operation

Moisture readings, LCD output, and watering behavior are monitored and recorded. Environmental conditions such as sunlight and soil texture are also noted to support system evaluation under realistic settings.

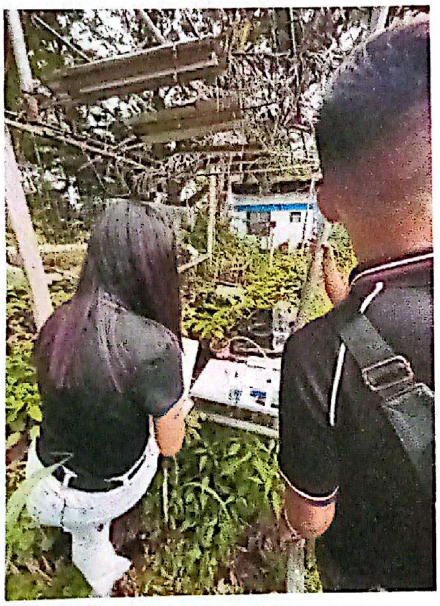

Figure 53. Observing the Soil and Plant Condition After Irrigation

Post-watering conditions are examined to evaluate how effectively the water reaches the plant roots. Changes in soil texture and moisture level are documented to verify irrigation

Figure 54. Verifying LCD Output and Final Results

The LCD is checked to ensure it displays accurate moisture levels and pump status. The values shown are compared with the actual conditions observed in the soil, confirming the reliability of the system's real-time feedback.

Figure 55. Wrapping Up and Leaving the Field Site After Testing

This figure shows the conclusion of the on-site testing session, with the individuals leaving the field area after successfully completing the data gathering and system evaluation. All components of the automated watering system have been tested under actual environmental conditions. With the prototype verified and observations completed, the fieldwork phase is formally concluded, marking the transition to results analysis and documentation.

Figure 56. Water Pump Consistency Trial 2

In the second trial, the pump is activated again under similar soil conditions. The results are compared with Trial 1 to determine if the water output remains steady and if the system responds with the same reliability and timing as before.

Figure 57. Water Pump Consistency Trial 3

The third and final trial further assesses whether the pump maintains consistent performance. Observations confirm whether the amount of water delivered and activation behavior are uniform across all three tests, verifying the system's reliability in repeated operations.

Figure 58. Successful Operation of the Water Pump in Final Trial

This figure shows the final observation in the water pump testing sequence. The system performed as expected, with the pump activating at the correct moisture threshold and delivering a consistent water flow. The successful result confirms the pump's reliability and stability after multiple trials, supporting its effectiveness for automated watering in real conditions.

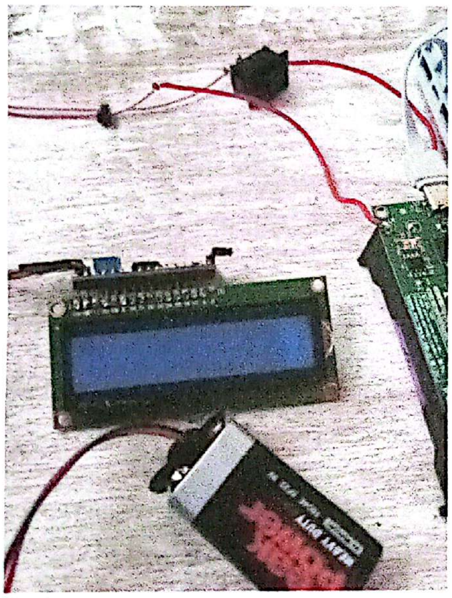

Figure 59. CD Display Showing Real-Time Sensor Readings During Testing

This figure displays the LCD output as it shows real-time data from the soil moisture sensor during testing. The screen provides important feedback such as current moisture levels and system status. This confirms that the sensor is actively communicating with the Arduino and that the LCD is functioning correctly for monitoring purposes.

Figure 60. Preparing for Component Labeling of the Final Prototype

This figure shows the preparation phase for labeling the individual components of the system. Materials such as printed labels, markers, and reference diagrams are used to identify each part of the prototype, including the Arduino, sensors, LCD, pump, and wiring. Clear labeling ensures ease of understanding, demonstration, and future maintenance.

Figure 61. Labeling of System Components for Identification and Clarity

This figure shows the completed prototype with all major components clearly labeled, including the Arduino board, soil moisture sensor, LCD display, relay module, water pump, power connections, and UPS. Labels assist in identifying each part of the system, making the setup easier to understand for presentation, troubleshooting, or instructional purposes.

Figure 62. Completion of the Fully Functional Prototype

This figure marks the successful completion of the prototype development and testing process. All system components have been assembled, tested, and verified to function as intended. The automated watering system is now fully operational, demonstrating accurate sensor readings, responsive pump activation, and real-time monitoring through the LCD. The final prototype is ready for further application, demonstration, or deployment.

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  Bookkeeping NC II-TESDA and NC III-TESDA
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  Setting Up Computer Networks- TESDA
  Maintaining Computer System and Networks-TESDA
  Installing and Configuring Computer Systems- TESDA

- **Experiences**

  English CSR in Amazon Retail
  English CSR in Wonders
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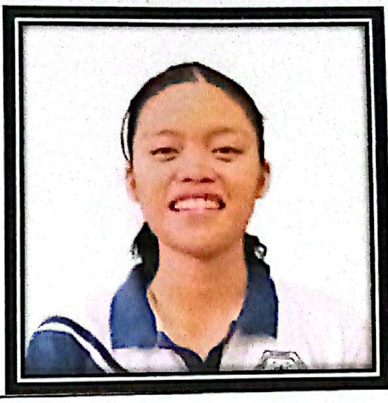
  Radio Installer at Richworld Infra Solutions
  Fiber Optic installer - 88th Avenue

- **Skills**

  Proficiency in House wiring installation

CURRICULUM VITAE



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  SY: 2008 – 2014

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  Photography and Photoshop Workshop CSPR – 2018
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- **Experiences**

  Work Immersion in Municipal Engineering Office of Valencia (February - March 2020)
  Interpreted and analyzed architectural plans and blueprints.
  Gained hands-on experience in house design and layout planning.
  Assisted in creating drafts using digital tools (AutoCAD)

- **Skills**

  Good knowledge of AutoCAD and drafting
  Adaptability