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Scalable Agri-Assistance System

Theme - Environment

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Scalable Agri-Assistance System

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EL Phase-III
Presentation Outline

- Introduction
- Problem Statement
- Objectives
- Literature Review
- Methodology
- Design and Implementation
- Components and Tools used
- Results/Simulation
- Challenges Faced
- Final Outcome
- Applications
- Future Scope
- Conclusion
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Introduction

- Our project focuses on developing a Scalable Agri-Assistance system that uses sensors and real-time (by leveraging sensors) data to optimize irrigation and **minimize water wastage**.
- This is crucial in addressing challenges like **water scarcity, soil degradation/erosion, and inefficiency in resource management**, especially for small-holder farmers.

Introduction

- Inefficient irrigation wastes 40% of water and pesticide overuse contaminates 30% of groundwater. This project offers a cost-effective solution to **optimize water use** and **prevent soil degradation**, crucial for sustainable farming.
- Over-irrigation and excessive pesticide use not only waste these valuable resources but also degrade soil health, leading to ***lower yields*** and ***higher long-term costs.***

Problem Statement

- In India, the overuse of water for irrigation is a persistent issue, primarily due to the lack of technological involvement in farming.
- Most farmers rely on traditional methods, such as **flooding entire fields**, which results in significant water wastage.
- These practices are often based on **“intuition”** rather than real-time data, leading to excessive irrigation even when crops may not require it.
- This not only depletes precious water resources but also contributes to **waterlogging**, **reduced soil fertility**, and **inefficient energy usage** for water pumps.

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Problem Statement

With groundwater levels depleting at an alarming rate in many regions, the need for technological intervention in irrigation practices has become critical to ensure sustainable water management and improve agricultural productivity.

- Many must **travel long distances** to check soil quality and irrigation status, a process that is not only **time-consuming** and **costly** but also ineffective in conserving resources.
- High-tech agricultural solutions that offer precision and efficiency exist, but they are too **sophisticated** and **expensive** for the average Indian farmer, putting critical data-driven approaches **out of reach**.

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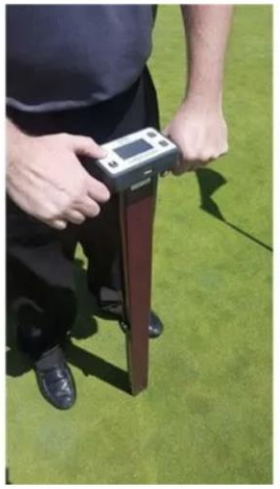
Problem Statement

Previous Attempts to Solve

- Western countries have addressed this issue using **expensive**, **high-tech** equipment, but these solutions are not **practical** or **affordable** for Indian farmers.
- Indian farmers need cost-effective, easy-to-use technologies that fit their unique challenges and **limited resources**.



Home/ Products/ Soil and Water/ FieldScout TDR 350 Soil Moisture Meter with Case

FieldScout TDR 350 Soil Moisture Meter with Case

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WatchDog 3250 ET Station Data Recorder

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Objectives

Main Objective: To Save water by using only the required amount of water.

Specific Objectives:

- **Cost-Effective Solutions**: Develop a smart irrigation system that utilizes affordable components and solar power, optimizing water usage while minimizing costs for scalable agricultural applications.
- **Enhance Water Efficiency**: Implement an irrigation system that optimizes water usage based on soil moisture levels, reducing waste and conserving resources.
- **Remote Monitoring and Control**: Create a user-friendly web interface that allows users to monitor soil moisture levels and control irrigation remotely via the ESP32.

Objectives

- **Predictive Irrigation**: Integrate **machine learning algorithms** to analyze weather data, enabling predictive irrigation decisions that adjust watering schedules based on **forecasted** conditions (in future)
- **Sustainability**: Promote sustainable farming practices by minimizing water consumption and reliance on external power sources, thereby supporting **eco-friendly** agriculture.

Literature Review

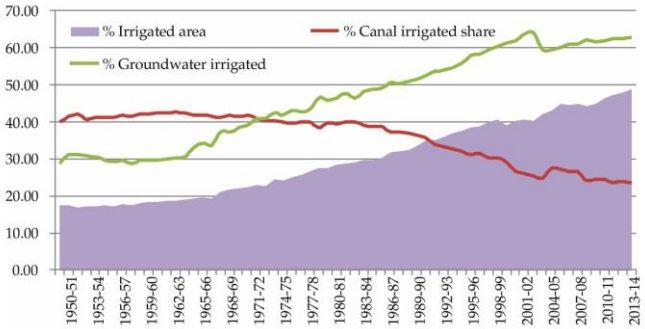
According to an estimate, there are more than 12 crore small and marginal farmers in India, with an average land holding size of less than 1.1 hectares. Most small and marginal

Decrease in Agricultural Holdings - pib.gov.in (03-March-2020)

As the average landholding of Indian farmers continues to decrease—now less than **1.08 hectares** for most smallholder farmers—inefficient farming methods are becoming increasingly unaffordable.

With smaller plots of land, every input such as water, fertilizer, and energy must be used carefully to maximize productivity and reduce costs. **Over-irrigation** and **excessive pesticide** use not only waste these valuable resources but also degrade **soil health**, leading to *lower yields* and *higher long-term costs*.

- **Wheat** is one of the most widely grown crops in India and it is often over-irrigated. It typically requires 4 to 6 irrigations during its growth cycle, but farmers apply water **more frequently than necessary**, assuming it will increase yields. (Water and Agriculture in India- Dr. Vibha Dhawan)

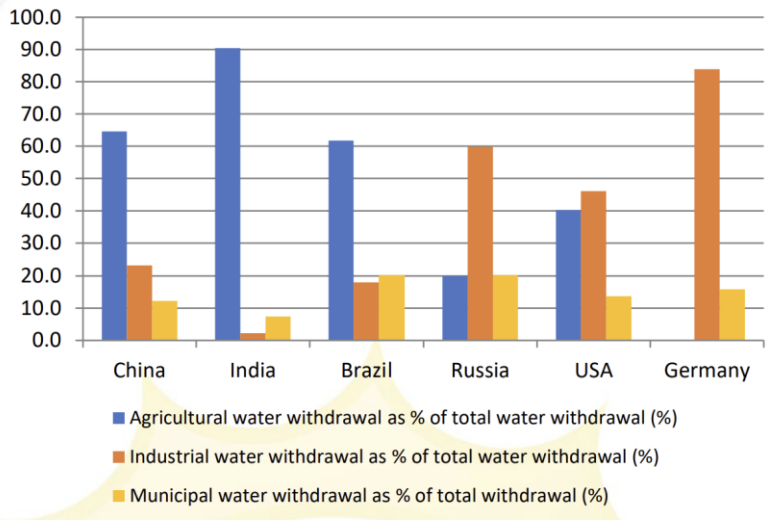


Irrigation in India-www.researchgate.net

The increasing trend in the usage of groundwater is expected to deplete at a faster rate

- Over-irrigation in wheat fields across Punjab and Haryana depletes groundwater by **over 1 meter per year**, threatening long-term water sustainability. These regions account for **over 80%** of India's wheat production, making this issue a critical concern.

(www.nipfp.org.in)



- Despite China being the **world's largest producer of many agricultural products**, including rice, wheat; which require a lot of irrigation, the **water withdrawal for agriculture in China is significantly lesser than India** which highlights the concern of over-irrigation in India.

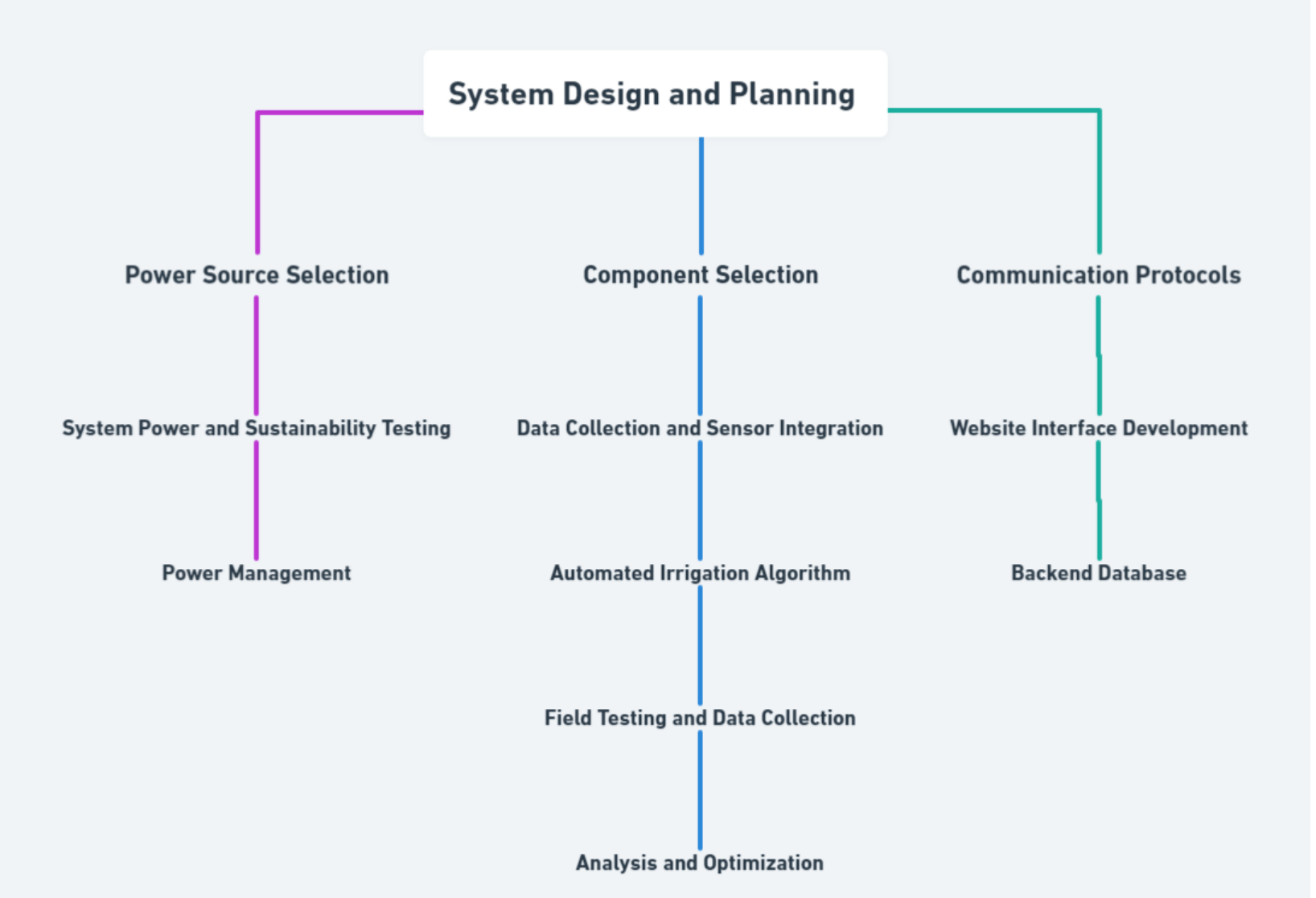
Parameter	China	India
Agricultural water withdrawal (10^9 m3/yr)	358	688
Agricultural water withdrawal as % of total water withdrawal (%)	64.61	90.41
Total water withdrawal per capita (m3/inhab/yr)	409.9	621.4
Water used per Agricultural Produce in 1000M3/US$	0.49	2.27

- Annual precipitation in India is estimated to be around **4000 BCM**, and the usable resource potential is **1870 BCM**
- India uses almost **700 BCM** of water for agriculture every year, whereas China uses about **361 BCM**.
- It is expected to rise to **1200 BCM** by the year **2050** if this continues
- This highlights the efficient water usage policies of China and the **inefficient water usage in India**

Water Footprint in M^3/MT[1]			
Crops	India		Global
Wheat	1654	>	1334
Rice	2850	>	2291
Sugarcane	159		175

Virtual Water Use for Crops in $M^3/Tonne$[2]				
Crops	India		U.S.	China
Rice	4254	>	1903	1972
Wheat	1654	>	849	690
Corn	1937	>	489	801
Soya beans	4124	>	1869	2617
Sugarcane	159	>	103	117
Cottonseed	8264	>	2535	1419
Roast coffee	14500	>	5790	7488

Methodology



Methodology

Timeline

Week (1 to 2) - Phase 1: Planning and Design

- Finalize project **concept** and **objectives**.
- Design system architecture, sensor selection, and microcontroller setup.
- Research on **communication protocols**, **power supply options**, and **battery life**.

Week (3 to 4) - Phase 1: Prototype Development

- Begin initial assembly of hardware components.
- Integrate **sensors** and **microcontrollers** for basic functionality.
- Set up initial communication protocol and basic data transmission.

Methodology

Week (5 to 6) - Phase 2: Prototype Testing and Demonstration

- Test **real-time data transmission** and control of irrigation **via relay**.
- Demonstrate the working of the prototype, focusing on **scalability** and **connectivity**.
- Troubleshoot and optimize the system for better **performance** and **reliability**.

Week (7 to 8) - Phase 2: Scalability and Portability Testing

- Finalize testing of the prototype for connectivity between modules and scalability.
- Demonstrate the ability to control water flow via remote nodes.

Methodology

Week (9 to 10) - Phase 3: Field Testing and Refinements

- Begin extensive field testing with soil moisture sensors and irrigation control.
- Implement solar panels to make the modules self-sustaining.
- Design custom 3D-printed casings for modules to protect components.

Week (11 to 12) - Phase 3: Final Testing and Adjustments

- Conduct final tests to evaluate system performance in various conditions.
- Fine-tune the user interface and system outputs for usability.
- Make final design improvements based on feedback from field testing.
- Prepare final documentation and presentation for project review.

Methodology

System Design and Planning

- **Objective:** To develop a low-cost, automated irrigation system using the ESP32 microcontroller, soil moisture sensors, and a website interface.
- **Power Source Selection:** Design a **solar-powered system with battery backup** to ensure continuous operation. Solar panel and battery specifications chosen based on power requirements for the ESP32, sensors, and potential expansion to additional nodes.
- **Component Selection:**
  - **ESP32 Microcontroller**: Selected for its low cost, Wi-Fi capability, and ease of integration with sensors.
  - **Soil Moisture Sensors**: Measure real-time soil moisture to control irrigation.
  - **Relay Module**: Interface with the irrigation pump to enable or disable water flow based on soil moisture data.

Communication Protocols: To determine protocols for ESP32 communication with the website to send real-time data and receive manual control inputs.

Methodology

Data Collection and Sensor Integration

- **Moisture Sensor Calibration**: Test and calibrate moisture sensors in various soil types and moisture levels to ensure accuracy.
- **ESP32 Programming**: Code the ESP32 to:
  - Continuously monitor moisture sensor data.
  - Transmit data to a remote database for real-time monitoring on the website.
  - Activate the relay to trigger irrigation when moisture levels fall below a set threshold.
- **Data Transmission**: Configure the ESP32 to transmit sensor readings to the cloud via Wi-Fi, ensuring reliable connectivity to the website.

Website Interface Development:

- **Real-Time Monitoring Dashboard**:
  - Display current moisture levels, system status, and irrigation history.
  - Use a simple, user-friendly interface optimized for desktop and mobile viewing.
  - Add controls for users to activate or deactivate the irrigation system manually, overriding automated responses if necessary.

Methodology

- **Backend Database**: Store real-time and historical sensor data for trend analysis and potential future expansion to predictive irrigation models.
- **Automated Irrigation Algorithm**
  - **Threshold-Based Control**: Set threshold moisture levels that, when crossed, automatically activate irrigation.
  - **Testing and Optimization**:
    1. Adjust thresholds based on field conditions, crop type, and soil properties to ensure optimal water usage.
    2. Fine-tune the timing and duration of irrigation to prevent waterlogging or excessive dryness.

Methodology

System Power and Sustainability Testing

- **Solar and Battery Optimization**: Size the solar panel and battery based on ESP32 and sensor energy consumption to ensure continuous operation, even during low-sunlight days.

Field Testing and Data Collection

- **Initial Testing** : Test the system in controlled conditions to validate moisture readings, irrigation accuracy, and website communication.

Real-World Deployment : Install the system in a field environment to test response accuracy under varying moisture levels, network stability, and battery performance.

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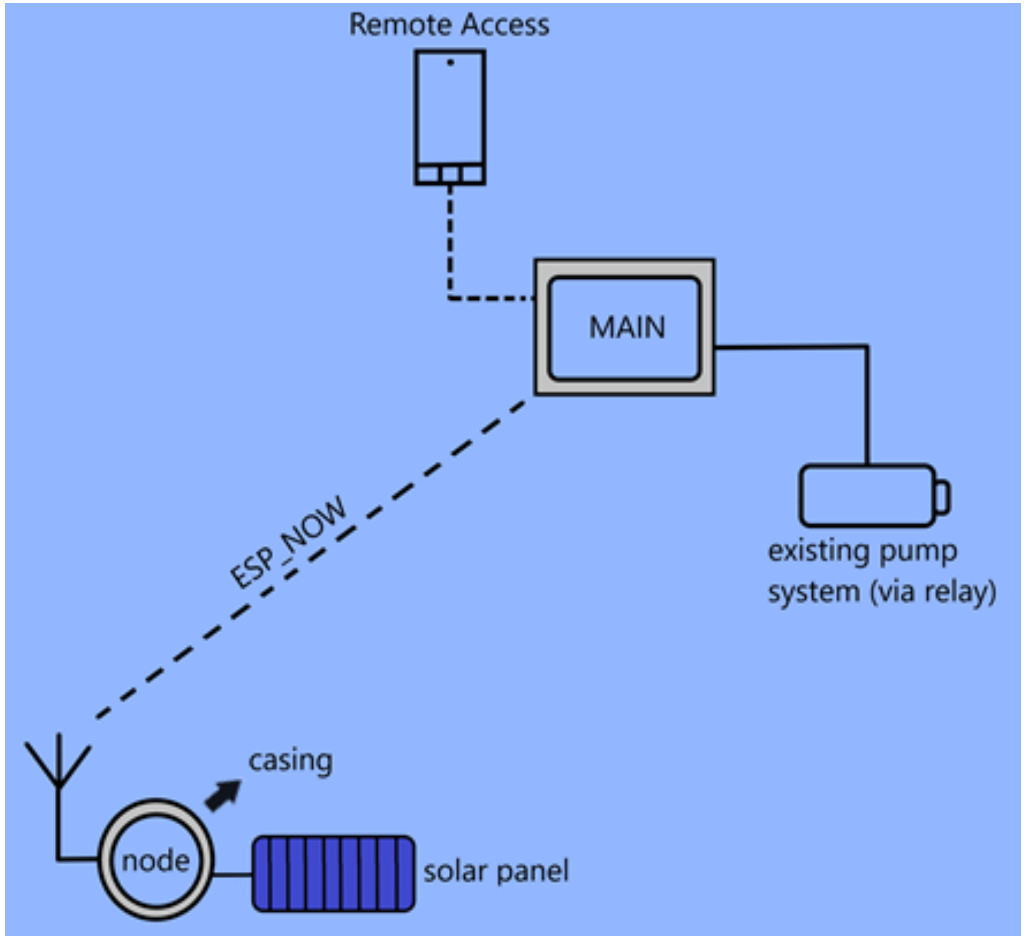
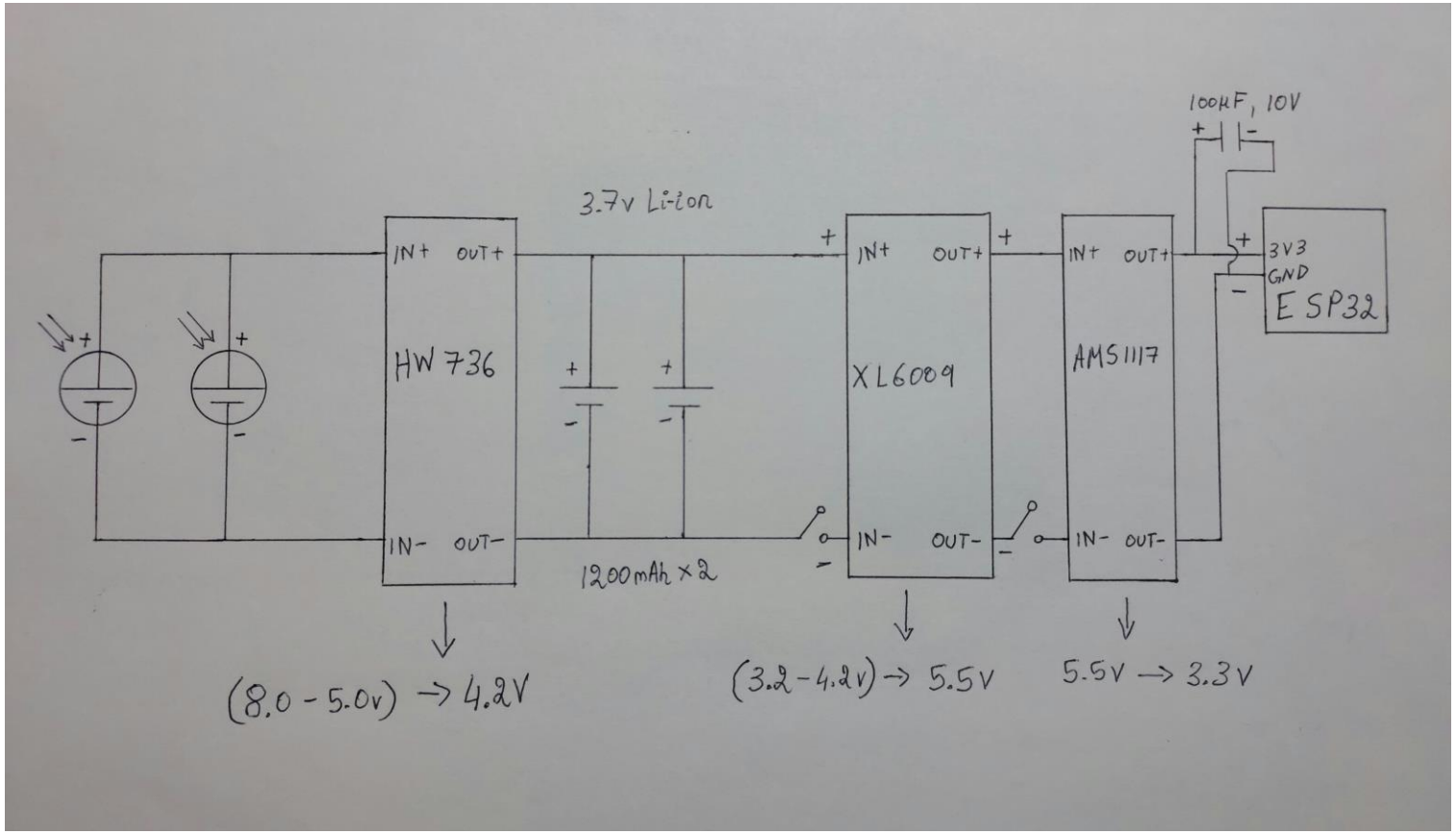
Design and Implementation

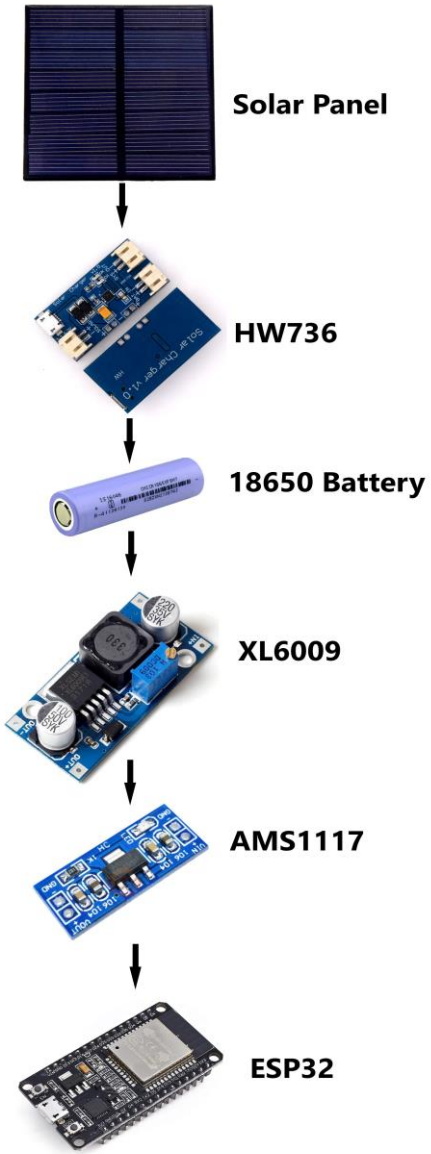
- **Node Design**: Included a soil moisture sensor, ESP32, and a solar panel in a protective casing.
- **Communication Setup**: Designed the ESP-NOW communication link between the node and the main module.
- **Main Module Integration**: Connected the main module to the existing pump system via a relay for motor control.
- **Remote Access Design**: Incorporated a remote access module for mobile-based control and monitoring.



Design and Implementation

Circuit Design of Nodal Module





Design and Implementation

1. **Solar Input**:
   - Two solar panels are connected in parallel, providing input voltage in the range of **8.0V to 5.0V**.
   - These serve as the primary energy source for charging the battery.
2. **Charging Circuit (HW-736 Module)**:
   - The solar panel output is fed into the **HW-736 module**, which regulates the voltage to charge the batteries at **4.2V**.
   - This module ensures safe charging of the Li-ion batteries.
3. **Battery Bank**:
   - **Two 3.7V, 1200mAh Li-ion batteries** are connected in parallel for increased capacity.
   - The battery pack serves as the energy storage for powering the system.

Design and Implementation

4. Step-Up Conversion (XL6009 Booster Module):

- The output of the battery pack **(3.2V–4.2V)** is fed into the XL6009 step-up converter, which boosts the voltage to **5.5V**.
- This boosted voltage is required as an intermediate stage for further regulation.

5. Voltage Regulation (AMS1117 3.3V Regulator):

- The **AMS1117** voltage regulator takes the boosted **5.5V** from the **XL6009** and steps it down to a stable **3.3V** output.
- This ensures the ESP32 operates within its required voltage range.

6. Capacitor for Stability:

- A **100µF**, **10V** capacitor is added at the ESP32 input for noise suppression and voltage stabilization.

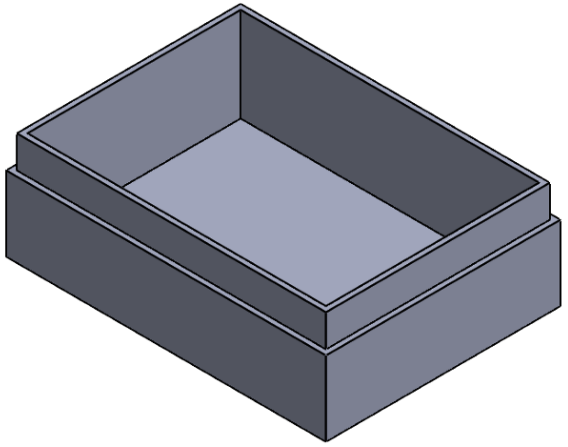
7. Output to ESP32:

- The final output of **3.3V** is directly supplied to the ESP32 module, powering its operation.

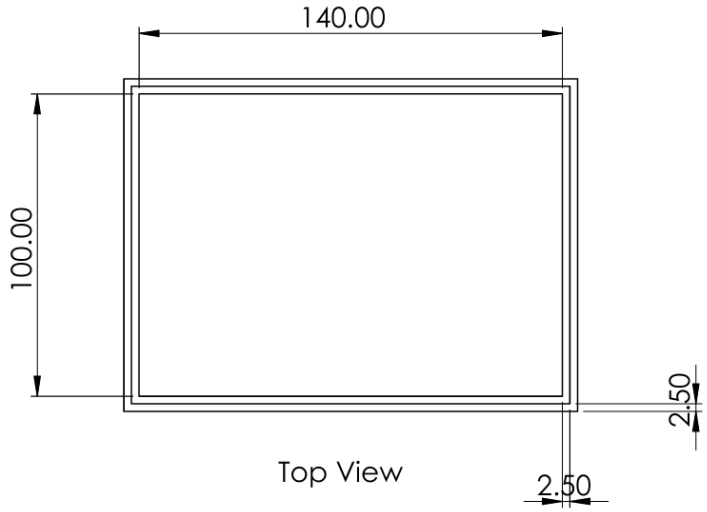
Design and Implementation

SolidWorks Drawing for Case (BOX)

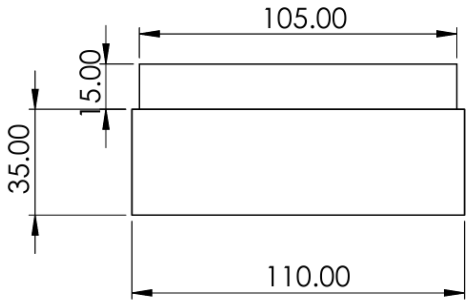
Box



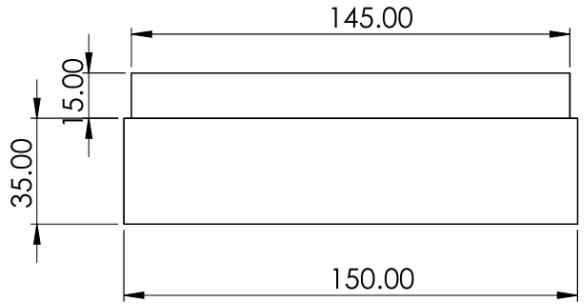
Isometric View



Top View



Left View

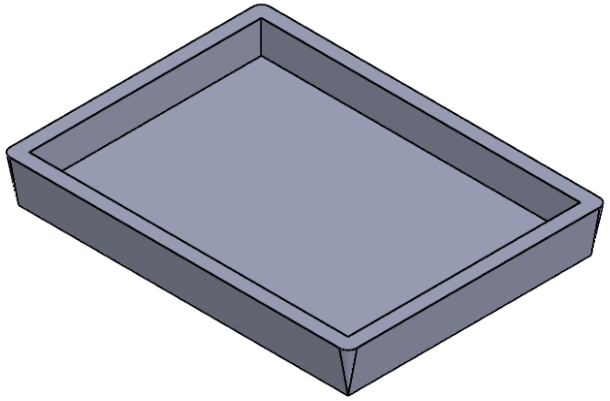


Front View

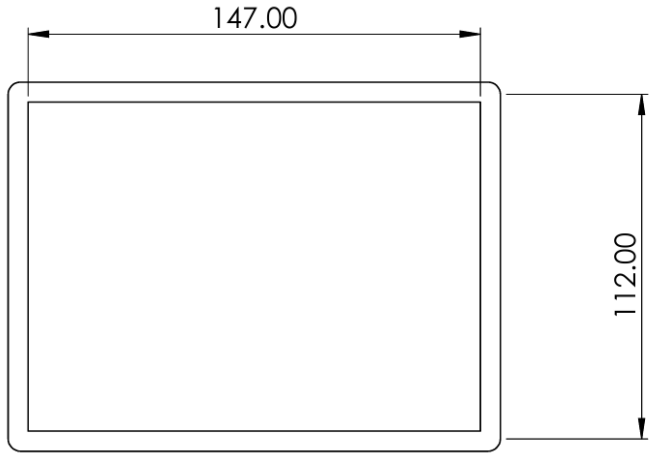
Design and Implementation

SolidWorks Drawing for Case (LID)

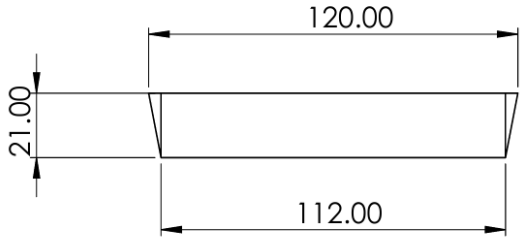
Lid



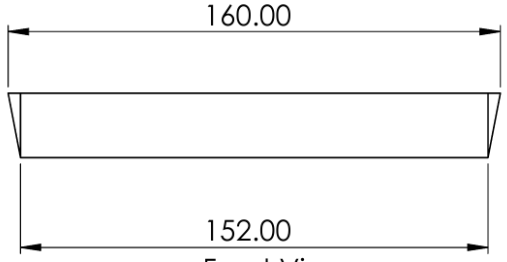
Isometric View



Top View



Left View

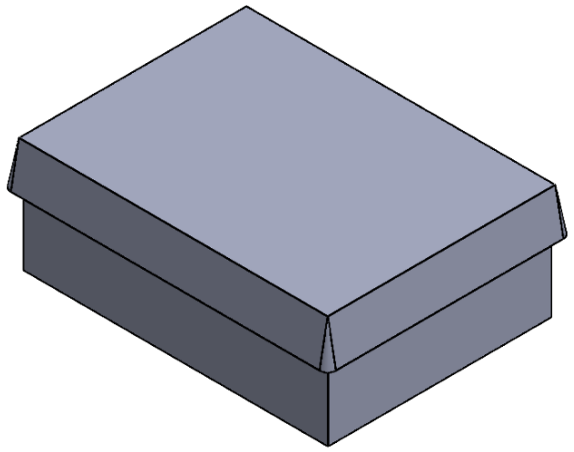


Front View

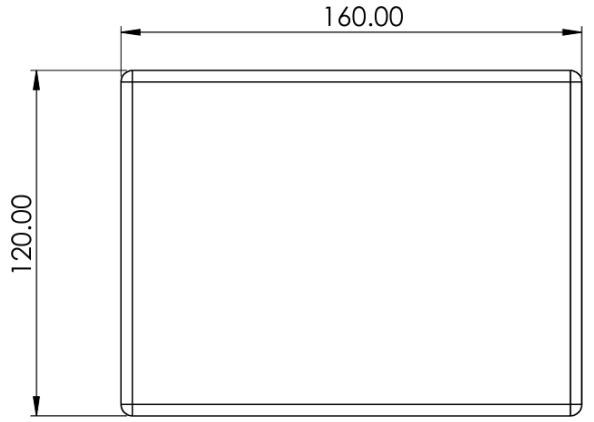
Design and Implementation

SolidWorks Drawing for Case (ASSEMBLY)

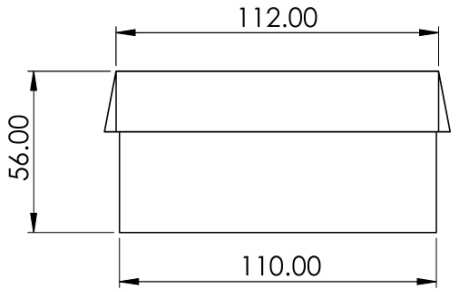
Box-Lid Assembly



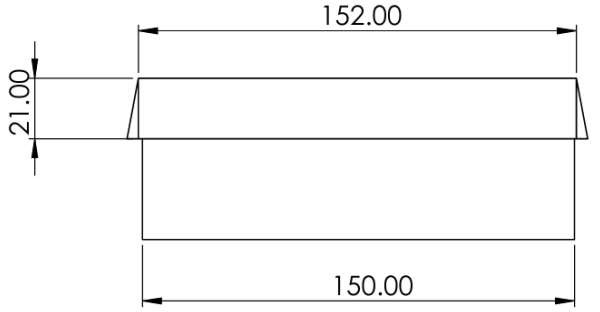
Isometric View



Top View



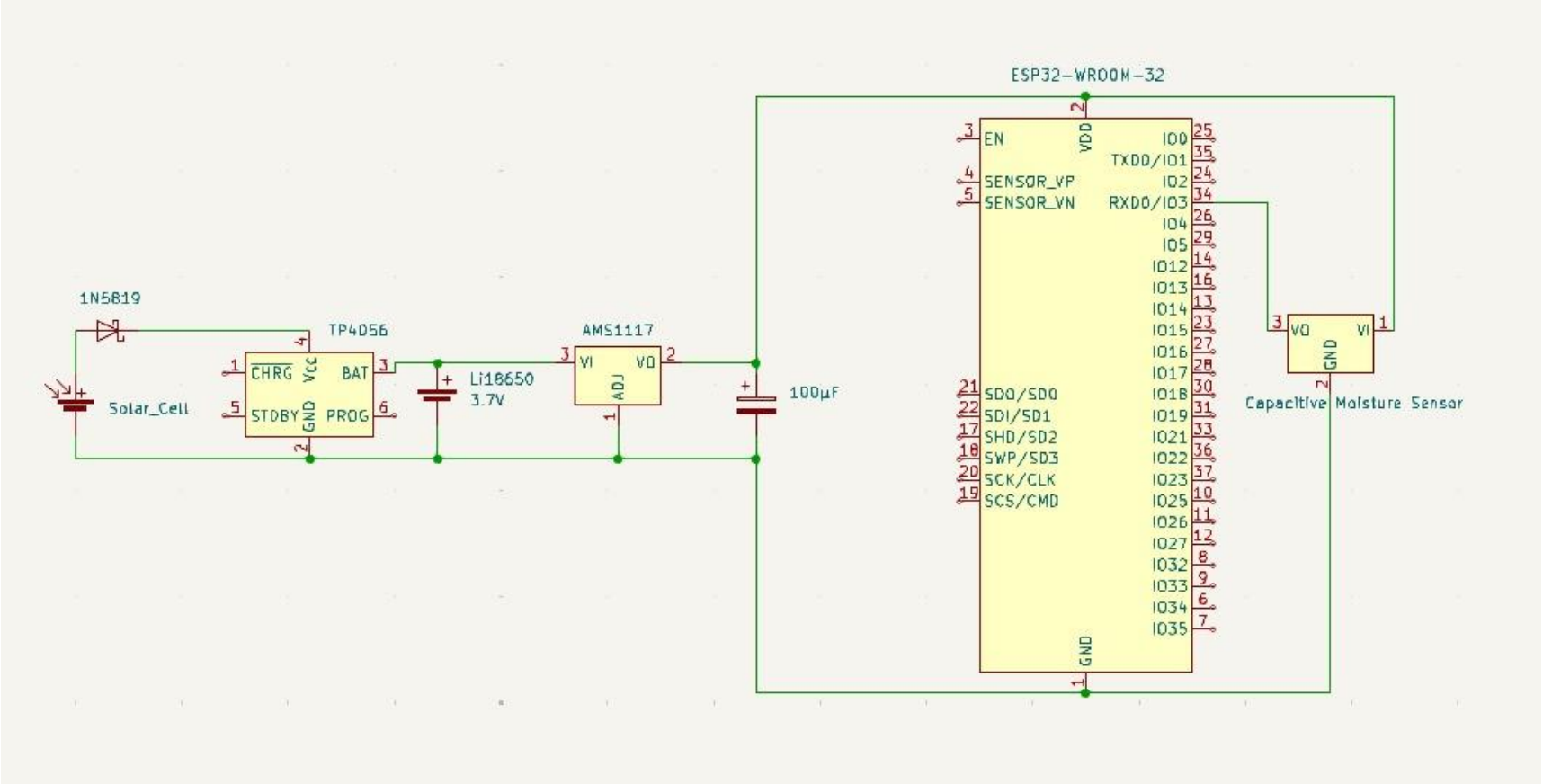
Left View



Front View

Design and Implementation

Circuit Layout Designed in KiCAD



Components and Tools Used

6. Tools and Techniques Used

Hardware

- **18650** Battery (3.7v) [power source]
- **HW736** [solar charger for Li-Ion batteries]
- **Esp32** [microcontroller]
- **AMS1117** (3.3v) [Voltage regulator]
- Capacitive moisture sensor (with 662k voltage regulator and **TLC555C** OR **TLC555I** chip)
- **XL6009** [Buck booster upto 30v]

Components and Tools Used

- **Veroboard** [Soldering Board]
- **Soldering Iron**
- **Soldering flux** [to remove oxidation layer]
- 2000-count **digital multimeter** [voltmeter, ammeter]
- Solid core wires [forming connections on veroboard]
- 6V **polycrystalline** solar panel [charging power source for battery]
- *Bread board,Motor driver (replicating 240v relay in existing system), Water pump and Plastic pipe*-*for demonstration only*

Components and Tools Used

- **Software**
- **Arduino IDE**
- ESP32 Windows Driver [**CP210x**]
- ESP32 Extension [**Espressif**]
- **VSC**
- **Canva** [for diagram]
- **SolidWorks2020** [3d encasing design]
- **UltiMaker Cura** [3D printing]
- **KiCAD** [circuit design]

Components and Tools Used

Esp32 compared to **Arduino**

ESP32	ARDUINO and other microcontrollers around same price
Built-In Connectivity - Comes with built-in Wi-Fi and Bluetooth, allowing seamless wireless communication without the need for additional modules	Most other microcontrollers (e.g., Arduino Uno, STM32, ATmega series) do not have built-in wireless capabilities, requiring external Wi-Fi or Bluetooth modules.
Power Efficiency and Advanced Sleep Modes - Equipped with various low-power/deep sleep modes, that significantly reduce power consumption, making it ideal for **battery** and **solar-powered applications**	While some microcontrollers support low-power modes, the ESP32's deep sleep functionality is more advanced and allows greater flexibility.
Cost-Effectiveness for Projects - ESP32 is very **affordable**, making it suitable for large scale deployments and cost-sensitive applications.	Some microcontrollers, especially those requiring additional connectivity modules, can become more **expensive** and **less practical** for low-cost IoT solutions.

Components and Tools Used

Esp32 compared to **Arduino**

ESP32	ARDUINO and other microcontrollers around same price
High I/O Count and Versatile Sensor Compatibility - Has a high number of GPIO pins and supports multiple communication protocols (e.g., I2C, SPI, ADC, PWM), making it easy to connect a wide range of sensors and peripherals.	Alternatives may have fewer I/O pins and **limited support for certain interfaces**, restricting the variety of sensors and devices that can be used in the system.
Scalability and **Compatibility with IoT Protocols** - Supports a range of IoT protocols, including MQTT and HTTP, allowing easy integration with cloud platforms and mobile applications.	Limited protocol support may restrict the ability to easily integrate with cloud-based or IoT systems, hindering scalability and real-time data sharing.
Ideal for **User-Friendly UI and App Integration** - With its connectivity, processing power, and memory, ESP32 is well-suited for applications that require user-friendly interfaces, such as mobile apps for real-time monitoring.	Limited by **lower memory** and **connectivity**, other microcontrollers may struggle with app integration or require additional hardware, reducing usability for end users.

Components and Tools Used

Capacitive Moisture Sensor (best choice)

- **Durability**: Capacitive sensors resist corrosion and withstand varying soil conditions, ensuring reliable long-term use in agriculture.
- **Accuracy**: They provide stable and precise soil moisture readings, enabling efficient irrigation and resource management.
- **Cost-Effectiveness**: While initially pricier than resistive sensors, their durability and accuracy reduce replacement costs, offering better long-term value.
- **Reliability**: maintain consistent performance with minimal maintenance, ideal for long-term applications.

Components and Tools Used

- **Resistive Sensors**: Prone to corrosion, requiring frequent calibration and maintenance, making them unsuitable for long-term agricultural use despite low cost.
- **Gypsum Blocks**: Degrade over time, have slow response rates, and are sensitive to soil salinity, limiting their reliability and practicality in diverse agricultural conditions.
- **HH2 Moisture Meter**: Highly accurate but expensive, bulky, and complex, making it impractical for small-holder farmers seeking cost-effective, user-friendly solutions.

Results/Simulation

Sustainability Testing (1)

- **The system was tested for sustainability by connecting a multimeter in Ammeter mode in series with the circuit.**
- A **3.7v Li-ion** Battery when fully charge has a terminal potential of **4.2V**
- So a **1200mAh** battery of 3.7v has **(1200 x 4.2)/1000 = 5.04 WattHours** of energy
- Here, **two 1200mAh** batteries are used in parallel combination to double the energy storage capacity, making the total energy stored at full charge approximately **~10 WattHours**

Results/Simulation

- Hence, the System will run on max power draw mode (**278.24mW**) for **(10/278.24mW) = ~ 36 Hours**
- The System can last for **1.5 Days** without any power source for charging which ***replicates a situation where sunlight is not bright/intense enough to fully charge the battery as planned.***

Test Case	Power draw (V x I)
Only XL6009 (buck booster)	243.46mW
XL6009+AMS1117 (3.3v regulator	251.6mW
XL6009+AMS1117+ESP32 (WIFI ON)	278.24mW

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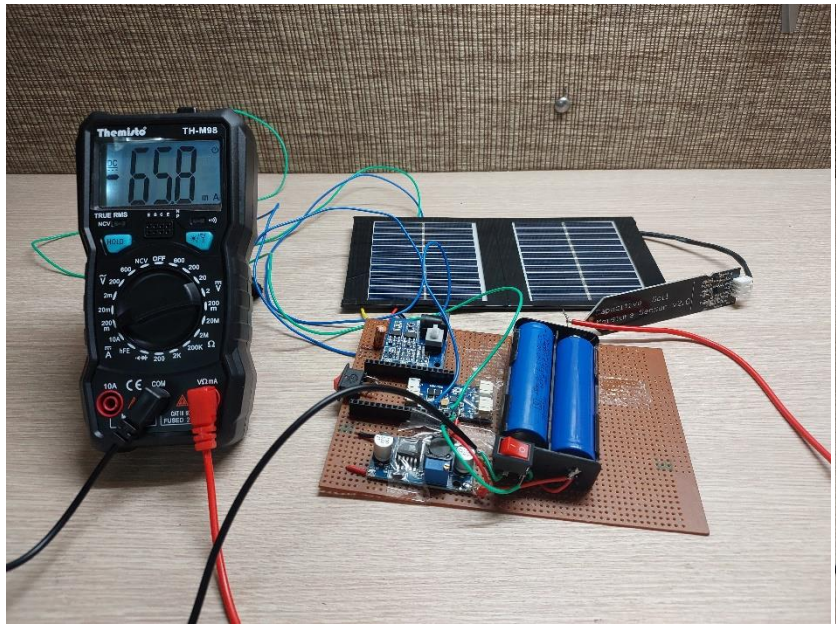
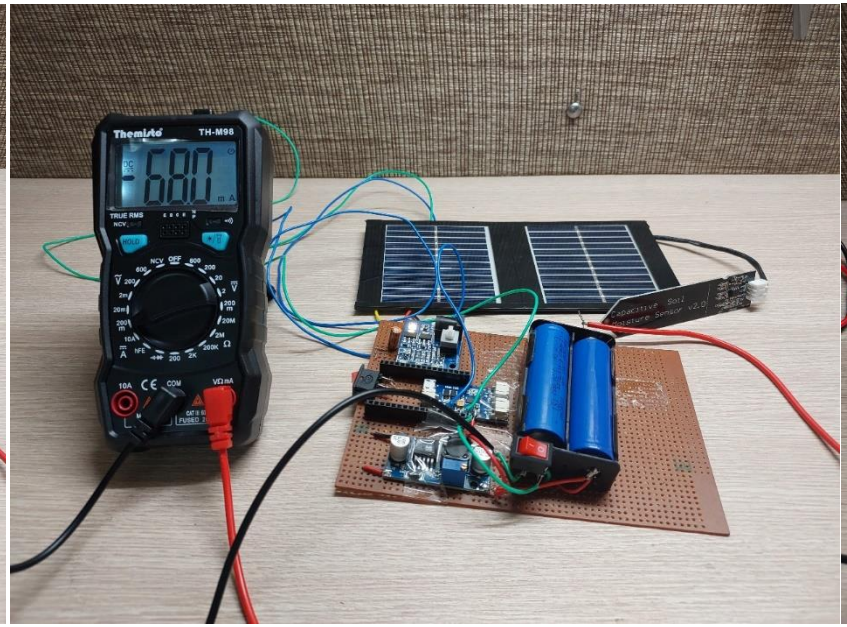
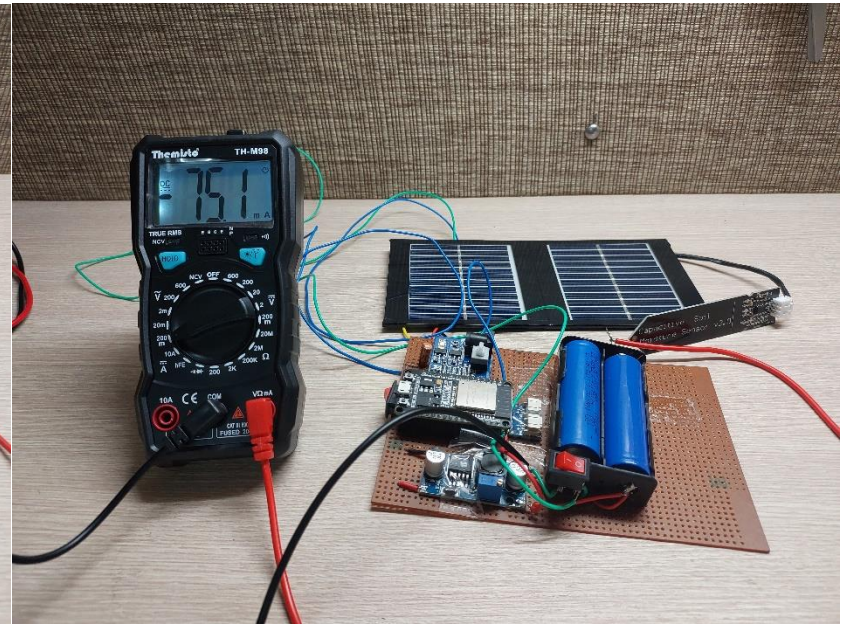
Results/Simulation







Results/Simulation

Sustainability Testing (2)

- **The system was tested for sustainability by connecting a multimeter in Voltmeter mode in Parallel config with the circuit.**
- The System's ability of **self sustainability** was tested by replicating real world conditions for solar charging of Battery.
- It was found that the *medium level bright sunlight* (sunlight through clouds) was more than enough to charge the battery which was observed as an increase in the voltage of the battery when the **system was in max power draw mode**.

Results/Simulation

- It was also found that the intensity of sunlight from **7am to 5pm** was enough to charge the batteries.
- The charging was tested with an initial battery voltage of **4.05V** which close to the max voltage of the battery and charging it when the capacity is closer to the full capacity is harder and requires more power**, simulating the "worst case scenario".**

Time	Voltage (V)
12:25PM	4.05
12:30PM	4.06
12:34PM	4.07
12:38PM	4.08
12:42PM	4.09
12:46PM	4.10
12:55PM	4.12
1:00PM	4.13
1:10PM	4.18

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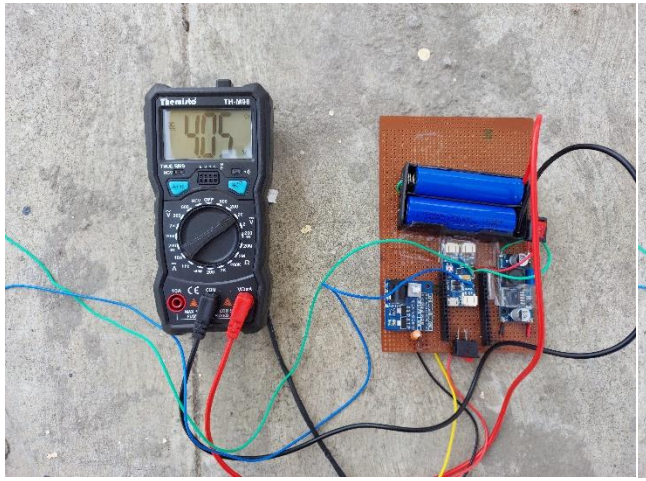
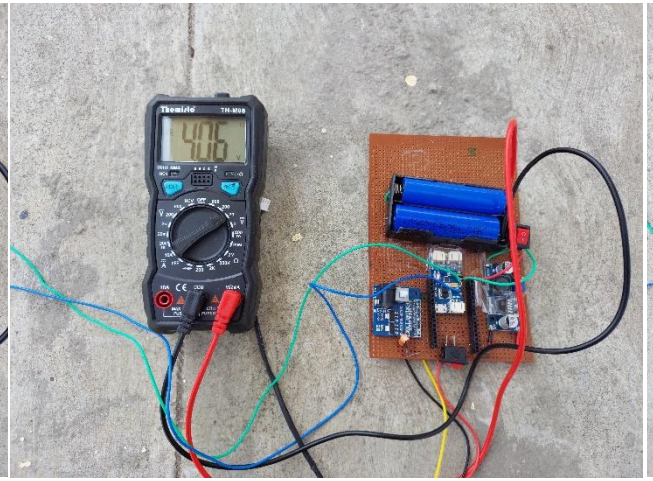
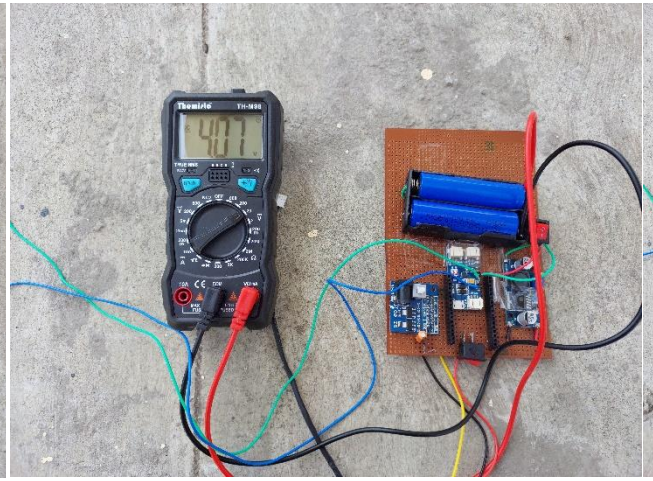
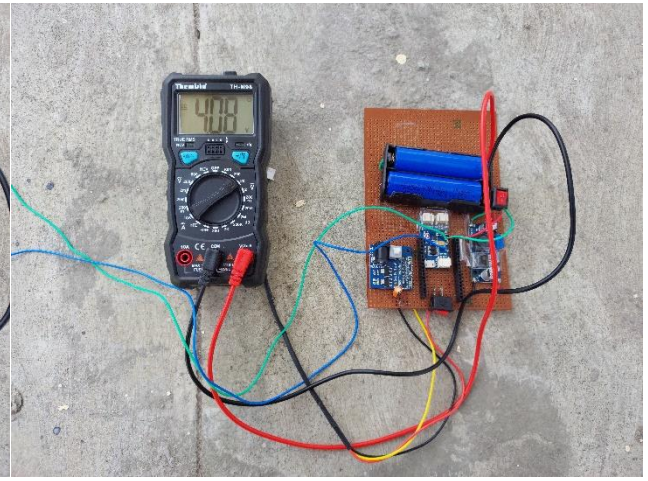
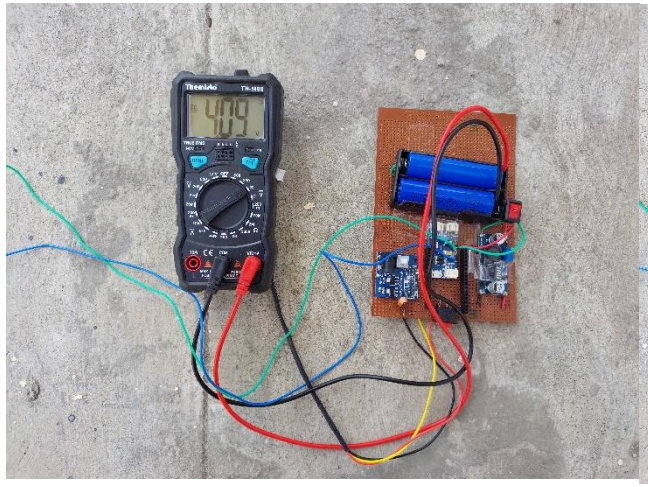
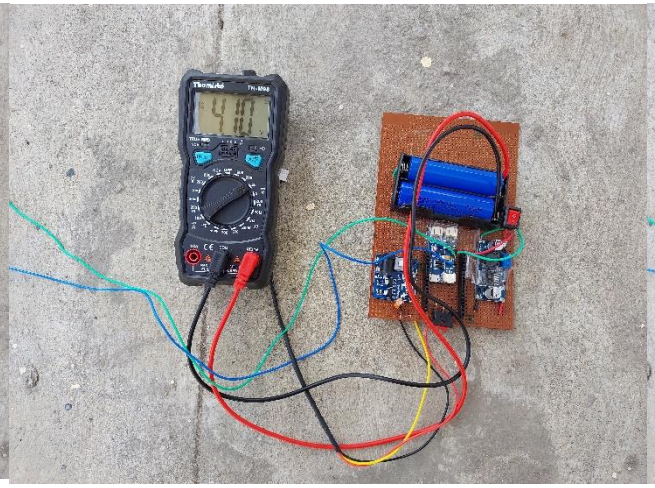
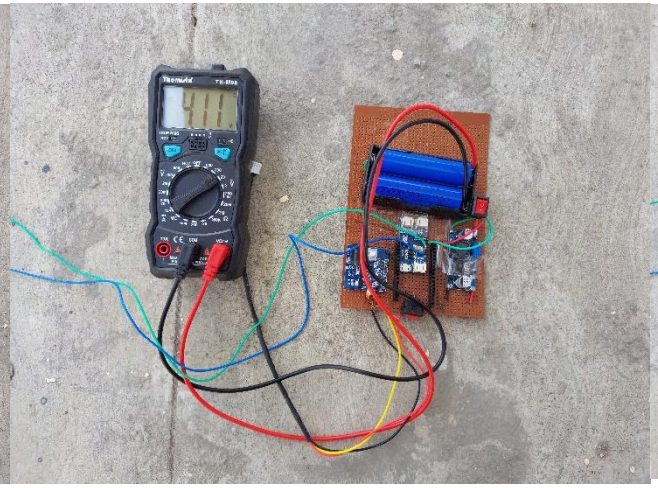
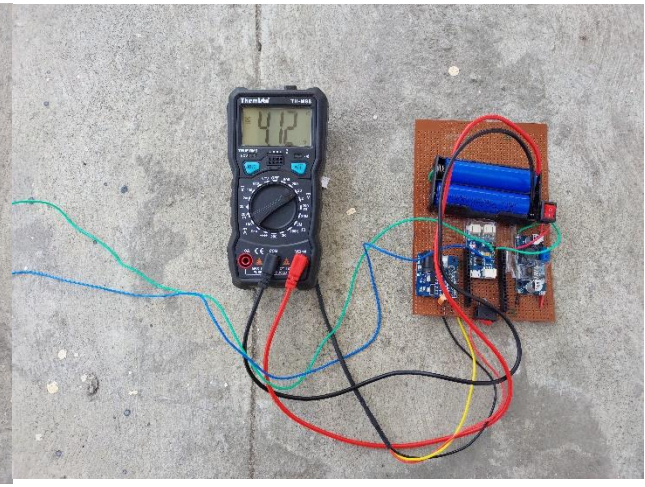
Results/Simulation

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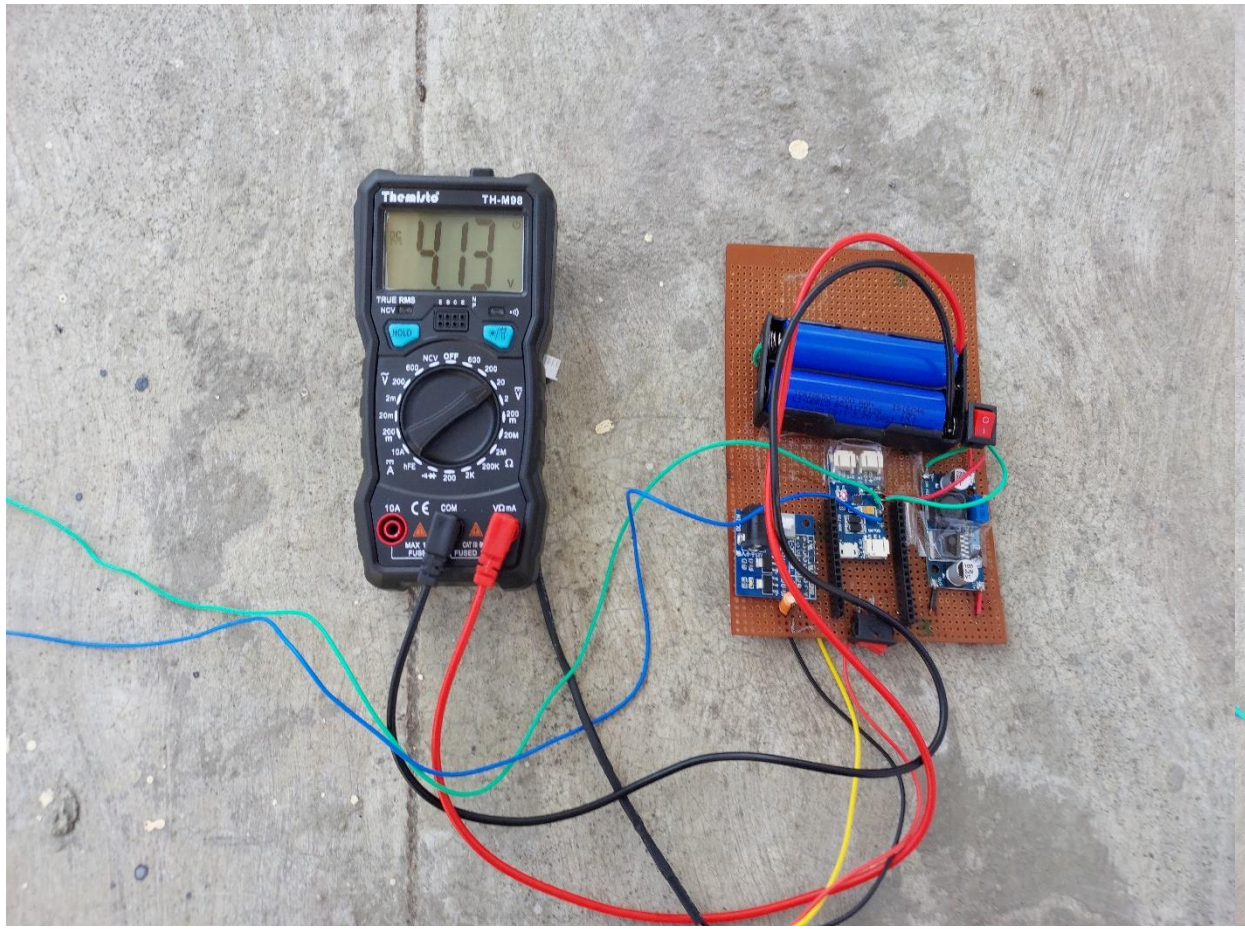
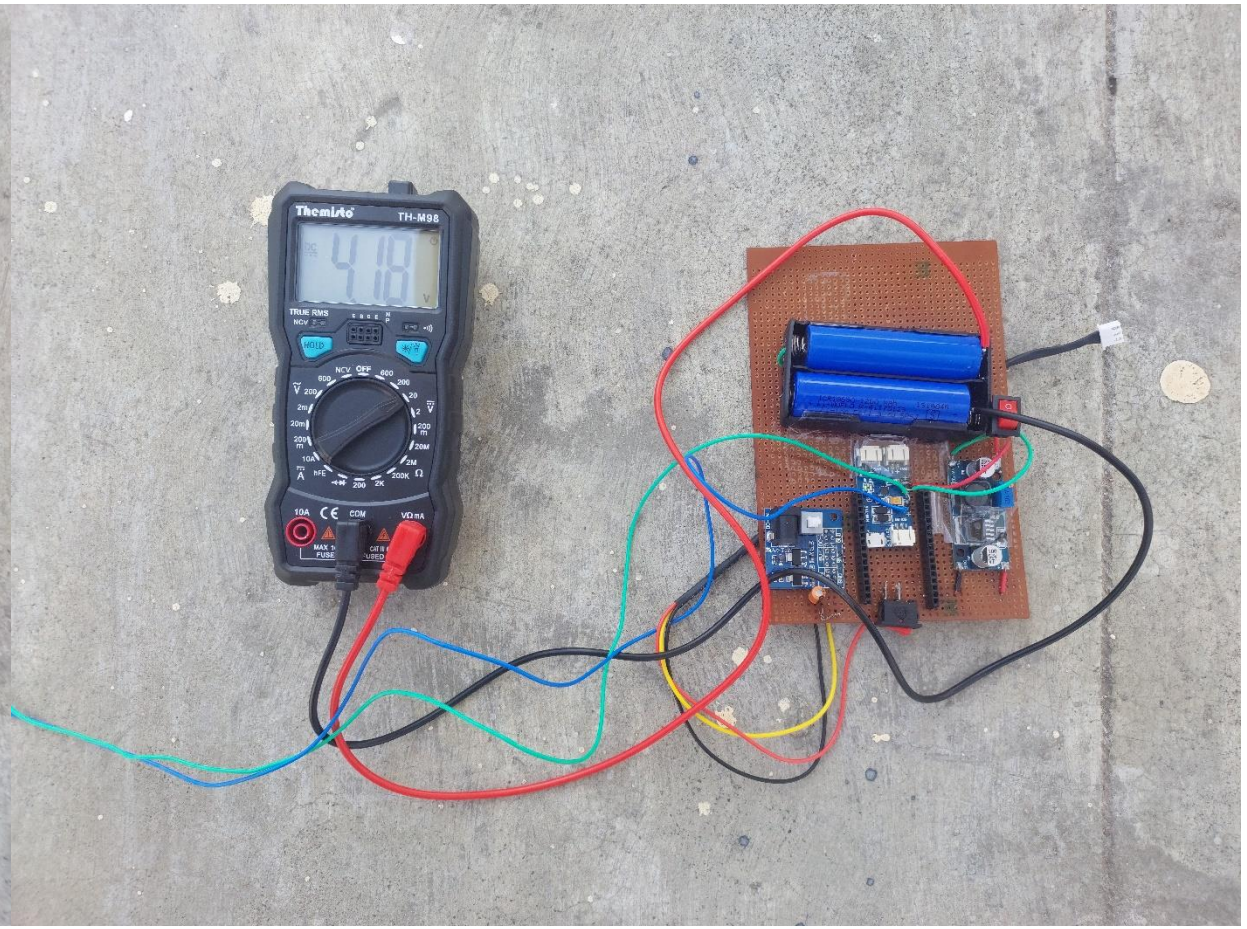
Results/Simulation





Results/Simulation

Field Testing

- The moisture sensor gives an output of range **(1000,4000)** where **1000 is completely wet** (dipped in water) and **4000 is completely dry** (in contact with nothing).
- Optimal soil wetness was tested for different types of soils and their respective moisture sensor readings were noted down.

Results/Simulation

- Higher value for Black soil is due to its excellent water retention properties.
- Lower value for laterite soil is due to its bad water retention properties.

Soil type	Optimal wetness reading
Alluvial	1500
Black	1800
Laterite	1300

Challenges Faced

1. **Variable Solar Voltage :**The solar panel output voltage varied significantly depending on sunlight intensity, causing inconsistent charging performance and system reliability.
   - **Solution :** Implemented an **HW-736** module for battery charging and management, as it efficiently handles variable solar input and regulates it to charge the Li-ion batteries.
2. **Noise from Voltage Regulator :** The voltage regulator introduced electrical noise that interfered with the ESP32's operation, causing unreliable data readings and potential communication issues
   - **Solution :** Added **10v 100µF** electrolytic capacitors were added in parallel combination with the output of **AMS1117** to filter the noise.

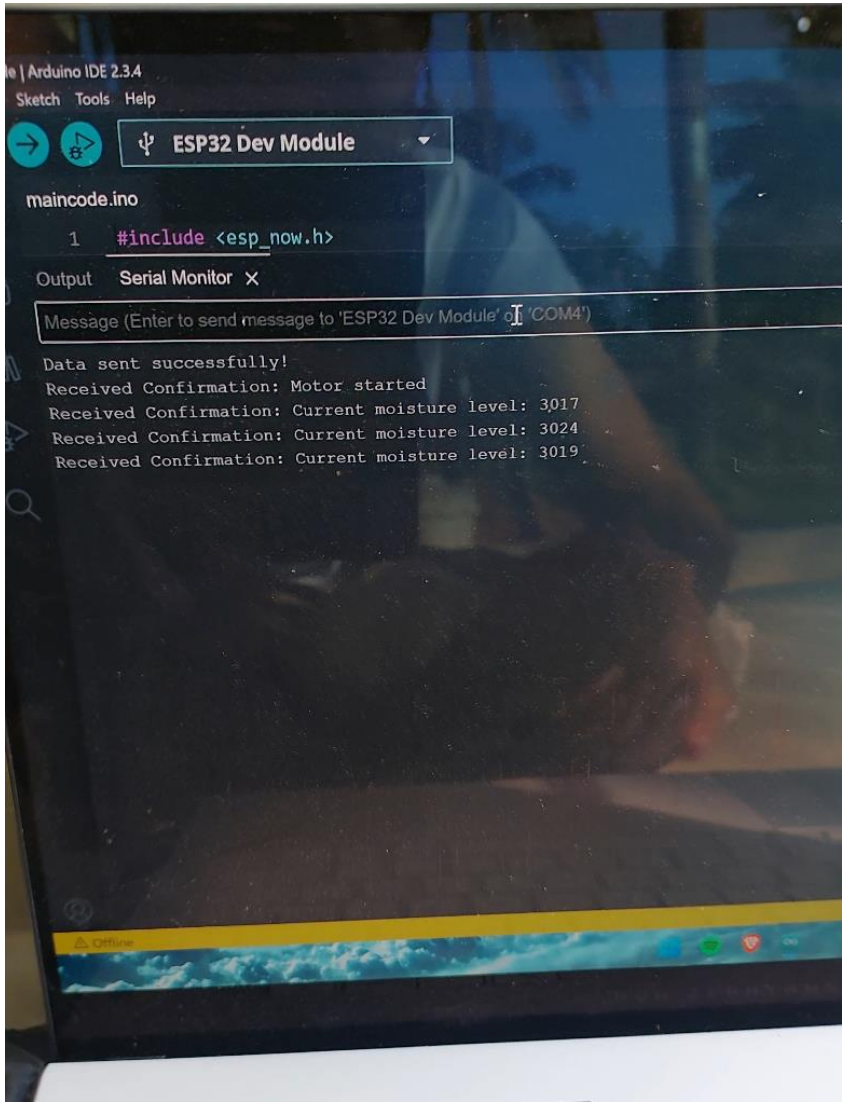
Challenges Faced

3. Making the 3.3V Regulator Work with Low Working Voltage : The AMS1117 regulator required an input voltage higher than the battery's terminal voltage to function reliably.

- **Solution :** Added **the XL6009 booster** to step up the battery voltage to a level suitable for the **AMS1117** regulator

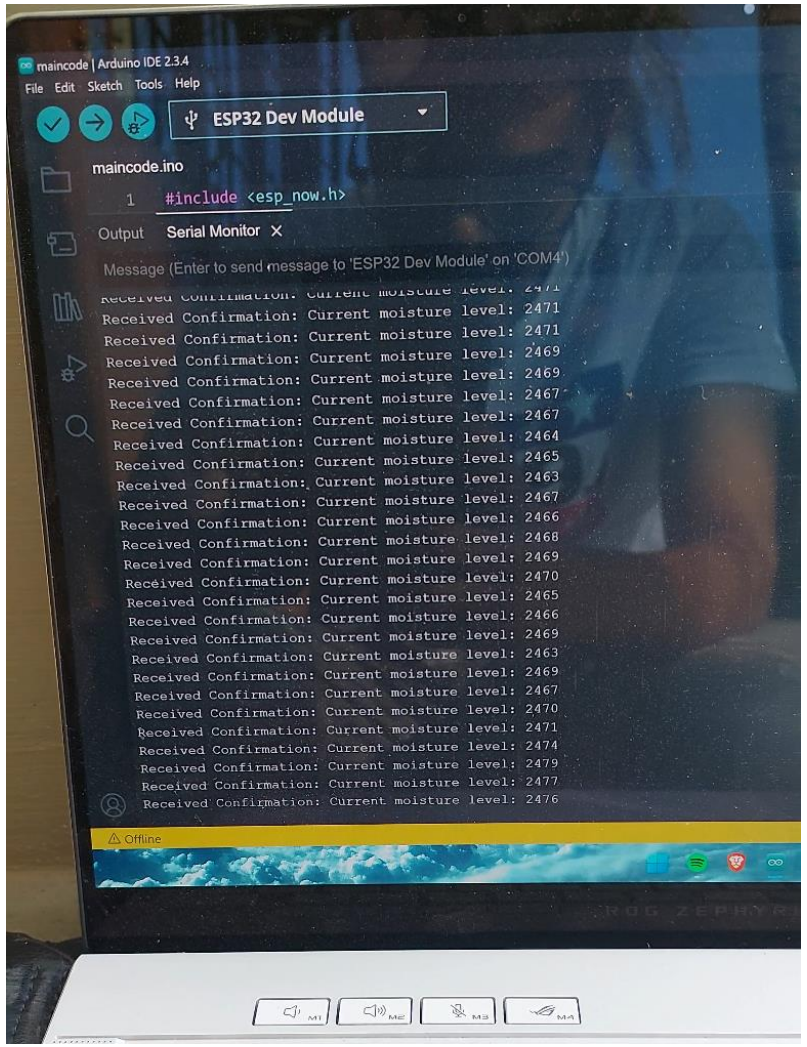
Final Outcome

- System was turned on at **2:00PM** and the main module initiated the turning on of the motor pump for drip irrigation.
- The Nodal module was placed at the **corner of the field** and the motor pump system was at the **center of the field.**
- The field was of **2 Acres** and the distance between the main and nodal module was calculated using pythagoras theorem : **root((90)^2+(90)^2) = ~125m**
- At this distance, **ESP_NOW** works perfectly and the data was transmitted via WiFi to main module.

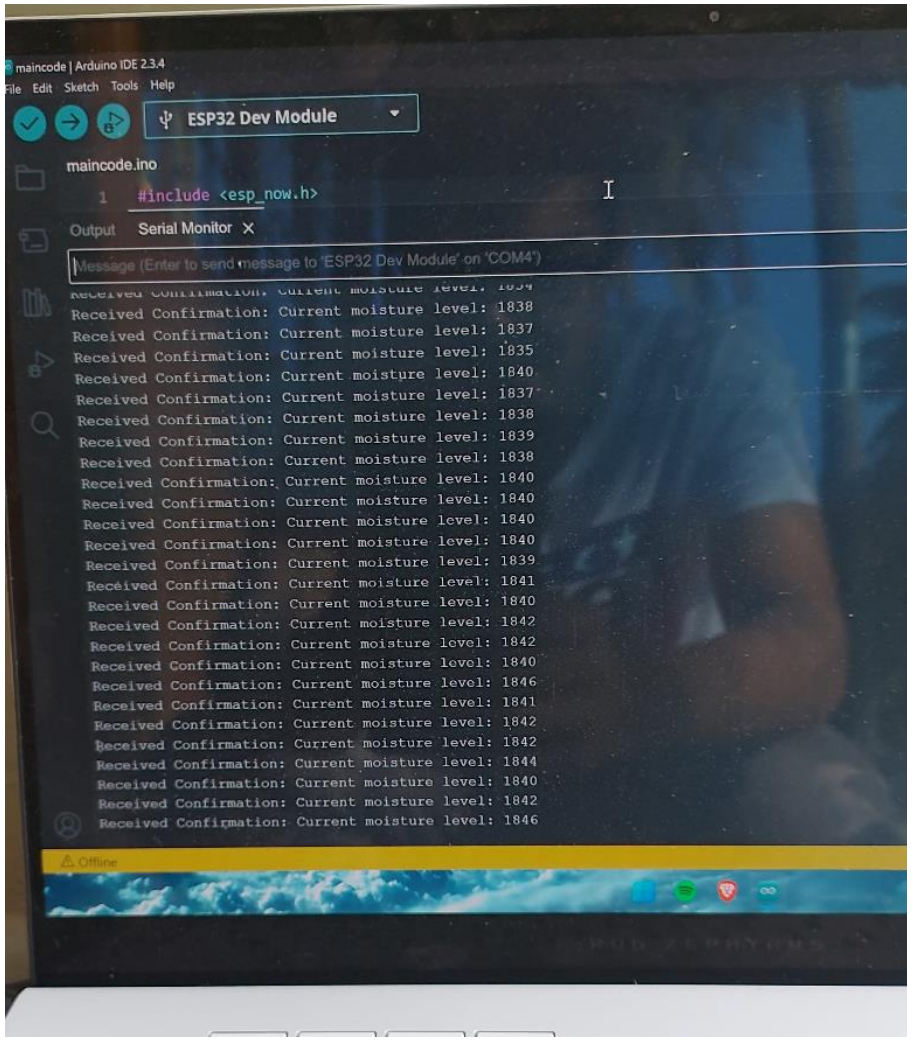


Final Outcome

2:45PM

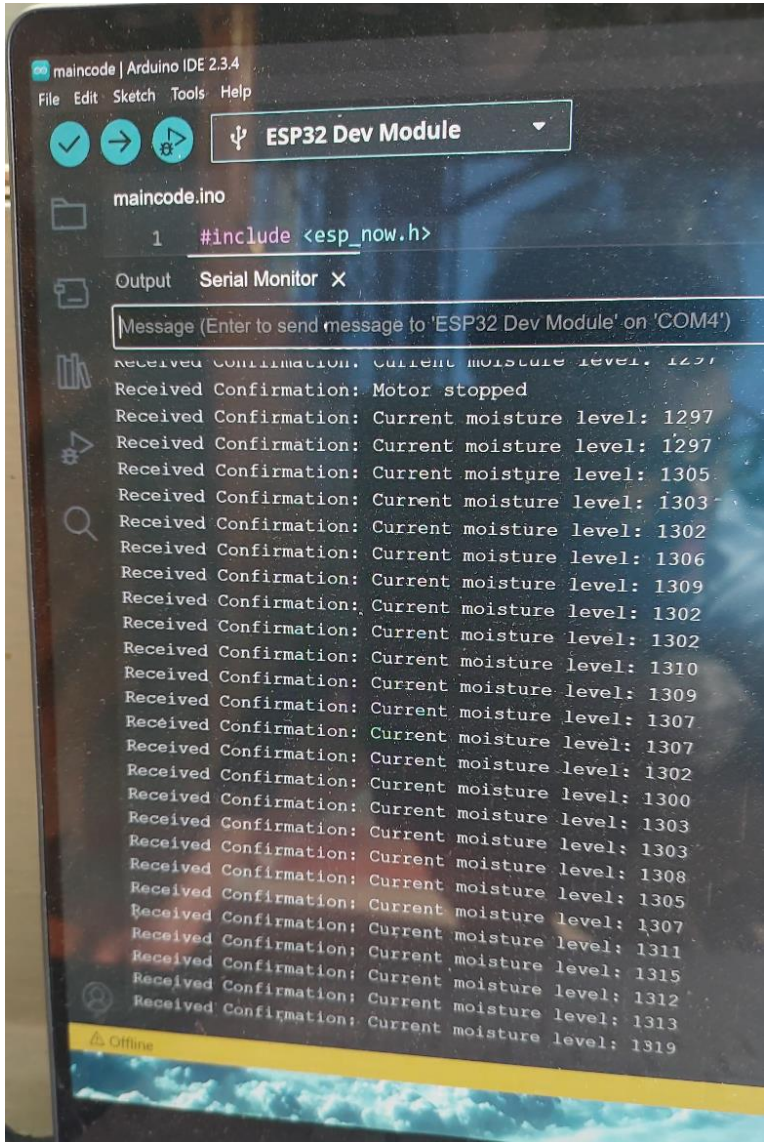


3:30PM



Final Outcome

- System was automatically turned off at **4:00PM** and the main module initiated the turning on of the motor pump for drip irrigation.
- When farmers around the same field were surveyed it was found that they usually turn the irrigation on for for 4-5 hours at a time, no water the soil wetness status.
- In contrast to the traditional system, Automated system was only ON for 2 hours based on the situation of the field status when tested



Final Outcome

- Based on this test result, the pump was ON for about **half** the time as the conventional system, implying the potential to save about **half as much as water** used traditionally.
- This value may vary more or less based on the soil wetness status on a daily basis.
- For example : The field used for testing consists of **70** coconut trees in a **2 Acre** land, where each tree requires about **100L** of water per day.
- This usage can be reduced to **50-60L** by using an automated system leading to savings of around **30L(reduced number due to hot summer days) per tree** per day.
- So per year, **upto (30x70x365) = 766,000** Litres of water can be saved

Real World Impact

1. **Empowering Smallholder Farmers**
   - Offers an affordable solution, improving productivity and profitability.
2. **Water Conservation**
   - Saves 20%–50% of water compared to traditional irrigation methods.
3. **Cost Savings**
   - Reduces labor and operational costs through automation and efficient resource use.
4. **Increased Crop Yields**
   - Ensures healthier plants and improved yields through optimized water management.
5. **Sustainability**
   - Supports environmentally sustainable and long-term farming practices.

Future Scope

1. **Power Detection for Irrigation Activation**
   - Implement a system to detect when power is on or off, triggering the irrigation system to activate only when necessary. This ensures energy efficiency and reduces wastage.
2. **Weather Data Integration**
   - Import weather data to predict rainfall and avoid unnecessary irrigation. This will help in optimizing water usage and preventing over-irrigation during rainy periods.
3. **Integration of Additional Sensors**
   - Add sensors for temperature, humidity, NPK (Nitrogen, Phosphorus, Potassium) levels, and rain detection to provide a more comprehensive understanding of field conditions and further optimize irrigation and crop management.
4. **Full-Scale Mobile Application**
   - Develop a comprehensive mobile application that provides farmers with guidance on using the system. The app could include crop-specific and soil-specific irrigation programs, personalized recommendations, and alerts to streamline farm management.

Conclusion

Efficient Water Management

- I learned how integrating smart irrigation with real-time soil moisture data can optimize water use, reducing waste and improving crop yields.

Solar Power Integration

- I gained hands-on experience in incorporating solar energy into the system, ensuring sustainability and enabling off-grid operation for remote farms.

Power Management Optimization

- The project taught me how to address challenges related to variable solar voltage, power consumption, and voltage regulation to ensure smooth system operation.

Data-Driven Decision Making

- I understood the importance of data collection and analytics in driving informed decisions for better resource management and operational efficiency.

User-Centered Design

- I learned the significance of creating simple, intuitive interfaces that make advanced technology accessible to farmers, ensuring widespread adoption and effective use.

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Acknowledgments

I would like to sincerely thank my mentor, Dr Bhuvaneswara Babu for their constant support, encouragement, and valuable insights throughout this project. Their expertise has been instrumental in shaping the outcomes of this work.

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Thank You!