Chapter 1

Introduction

Efficient water management in agriculture is crucial for sustainable food production and resource conservation, especially in the face of growing global water scarcity and climate change challenges. Traditional irrigation practices often result in inefficient water usage, leading to environmental degradation and economic losses. To address these issues, the development of automated systems for soil moisture monitoring has become increasingly important. These systems leverage advanced technologies, such as Arduino microcontrollers, soil moisture sensors, temperature sensors, and LCD displays, to enable precise and timely monitoring of soil conditions. By continuously assessing moisture levels and environmental factors, farmers can optimize irrigation schedules, ensuring crops receive adequate water while minimizing waste. This approach not only enhances agricultural productivity and resilience but also promotes sustainable farming practices by conserving water resources and reducing environmental impact. In this context, Arduino-based automatic soil moisture monitoring systems represent a significant innovation, offering practical solutions to enhance water use efficiency and support the long-term sustainability of agricultural practices.

Effective water management in agriculture is essential for sustainable food production amid increasing global water scarcity and climate variability. Traditional irrigation methods often lead to inefficient water use, exacerbating environmental degradation and economic losses. Addressing these challenges requires innovative solutions like Arduino-based automatic soil moisture monitoring systems. These systems utilize Arduino microcontrollers alongside soil moisture and temperature sensors to continuously monitor soil conditions. By providing real-time data on moisture levels, these systems enable farmers to optimize irrigation practices, ensuring crops receive the right amount of water at the right time. This approach not only improves crop yields and farm profitability but also promotes resource conservation and environmental sustainability by reducing water wastage and minimizing the environmental footprint of agricultural activities. Thus, Arduino-based soil moisture monitoring systems play a pivotal role in enhancing water use efficiency and supporting sustainable agricultural practices in the face of evolving climate and environmental pressures.

Chapter 2

Literature survey

1. ” Automatic Plant Irrigation System using Arduino” by Devika CM (2017) provides a comprehensive review of Arduino-based smart irrigation systems, emphasizing the integration of sensors, actuators, and data analytics to enhance agricultural water management. The study underscores the importance of real-time data for optimizing irrigation schedules and improving water use efficiency, crucial for sustainable agriculture. They discuss various IoT platforms and protocols used for sensor integration and data transmission, aiming to minimize water wastage and maximize crop yield through precise irrigation scheduling based on soil moisture and weather conditions.

2. “Sensor Networks for Precision Agriculture” by Tagarakis (2011) discuss wireless sensor networks (WSNs) in smart agriculture, emphasizing soil moisture monitoring technologies and communication protocols. Their review focuses on the deployment of WSNs to gather accurate and timely data, essential for making informed irrigation decisions and maintaining crop health in varying environmental conditions. The paper highlights the role of sensor nodes in measuring soil moisture levels at different depths and locations within fields, enabling precise irrigation management tailored to crop requirements.

3. “Water usage approximation of automated irrigation system using IOT” by Kishor C (2018) detail the development of an IoT-based automated irrigation system that integrates soil moisture sensors and weather data. Their system aims to optimize irrigation scheduling by considering crop water requirements and environmental factors. This research highlights the practical implementation of IoT technologies to enhance agricultural productivity while conserving water resources effectively. Alam et al. emphasize the integration of cloud computing for real-time data processing and decision-making, enabling farmers to remotely monitor and control irrigation operations based on accurate sensor data. papers contribute significant insights into soil moisture monitoring and water management in agriculture. Ahmad et al. (2017) review IoT-based smart irrigation systems, highlighting sensor integration and data analytics to enhance irrigation efficiency.

Chapter 3
Objectives & Problem Statement

3.1 Objectives

The objective of this mini-project is to develop an Arduino-based automatic soil moisture monitoring system aimed at optimizing water usage in agricultural fields. The system will integrate soil moisture and temperature sensors with an Arduino microcontroller to continuously monitor soil conditions. The primary aim is to provide real-time data on moisture levels, enabling farmers to make informed decisions regarding irrigation schedules. By automating the monitoring process, the project seeks to enhance water use efficiency, reduce water wastage, and improve crop yields through timely and precise irrigation management.

3.2 Scope

We're focusing on an automatic irrigation system with soil moisture and temperature sensors, along with a DC motor pump controlled by a relay (without IoT), the scope remains significant for enhancing agricultural efficiency and sustainability. These systems can autonomously monitor soil moisture levels and temperature, ensuring precise irrigation management tailored to crop requirements. The DC motor pump, controlled by a relay, provides reliable and efficient water delivery based on sensor data, optimizing water usage and minimizing manual intervention. This technology is particularly beneficial in optimizing resource allocation, reducing labor costs, and improving crop yield by ensuring plants receive adequate water and optimal growing conditions.

The objective of this mini-project is to design and implement an Arduino-based automatic soil moisture monitoring system for agricultural applications. The system aims to provide real-time monitoring of soil moisture levels using sensors integrated with an Arduino microcontroller. By leveraging this technology, the project seeks to optimize irrigation practices by ensuring crops receive adequate water while minimizing wastage. The scope includes developing a robust hardware setup and intuitive user interface, possibly utilizing an LCD display, to display critical moisture data. This project aspires to contribute to sustainable agriculture by enhancing water use efficiency and supporting informed decision-making among farmers regarding irrigation management.

3.3 Problem Statement

1. Identifying the Need: Begin by recognizing the overarching need for efficient water management in agriculture. Highlight the significance of water scarcity and environmental sustainability as driving factors behind the project's focus on soil moisture monitoring.

2. Current Challenges: Outline the existing challenges faced by farmers, such as reliance on manual irrigation methods, inconsistent soil moisture assessments, and the lack of real-time data for informed decision-making. Discuss how these challenges contribute to water wastage, reduced crop yields, and economic inefficiencies.

3. Technical and Practical Limitations: Address the technical limitations associated with traditional soil moisture monitoring techniques, including labor-intensive manual measurements, limited accuracy of visual assessment methods, and the inability to adapt irrigation practices dynamically to changing soil conditions and environmental factors.

4. Project Objectives: Clearly state the objectives of the project, which include developing an Arduino-based automatic soil moisture monitoring system. Emphasize the goal of providing farmers with a reliable, automated solution that offers real-time soil moisture data and facilitates optimized irrigation scheduling to maximize water use efficiency and crop productivity.

5. Impact and Sustainability: Discuss the broader impact of implementing such a system, highlighting its potential to conserve water resources, mitigate environmental impacts of agriculture, and promote sustainable farming practices. Consider how the project aligns with global sustainability goals and contributes to enhancing agricultural resilience in the face of climate change.

By defining the problem statement in this structured manner, the project aims to address critical gaps in current agricultural practices related to water management, offering a technological solution that meets the practical needs of farmers while promoting sustainable development in agriculture.

Chapter 4

Methodology & Block Diagram

4.1 Methodology

Firstly, the project will begin with a comprehensive review of existing literature and technologies related to soil moisture monitoring and automated irrigation systems. This review will provide insights into state-of-the-art sensors, Arduino microcontroller capabilities, and integration techniques for achieving real-time monitoring and data acquisition. By understanding the strengths and limitations of current methodologies, the project can identify suitable components and methodologies to achieve the desired objectives.

Secondly, the hardware development phase will focus on assembling and configuring the necessary components. This includes selecting and calibrating soil moisture sensors and temperature sensors compatible with the Arduino platform. Additionally, integrating an LCD display for user interface and feedback will be essential for visualizing real-time data. The Arduino microcontroller will serve as the central processing unit, facilitating sensor data acquisition, interpretation, and control of irrigation equipment through a relay module.

Thirdly, the software development phase will involve programming the Arduino microcontroller to read sensor inputs, process data, and execute control actions based on predefined algorithms. This will include developing algorithms to determine soil moisture thresholds for irrigation activation and deactivation. Integration with the LCD display will ensure that farmers can easily monitor soil conditions and system status in real time. Testing and iterative refinement will be conducted to validate system functionality, optimize sensor calibration, and ensure reliability in varying environmental conditions.

Overall, the methodology encompasses a systematic approach from literature review to hardware integration and software development, aiming to deliver a robust and effective Arduino-based automatic soil moisture monitoring system that meets agricultural needs for water management and enhances sustainable farming practices.

4.2 Block diagram

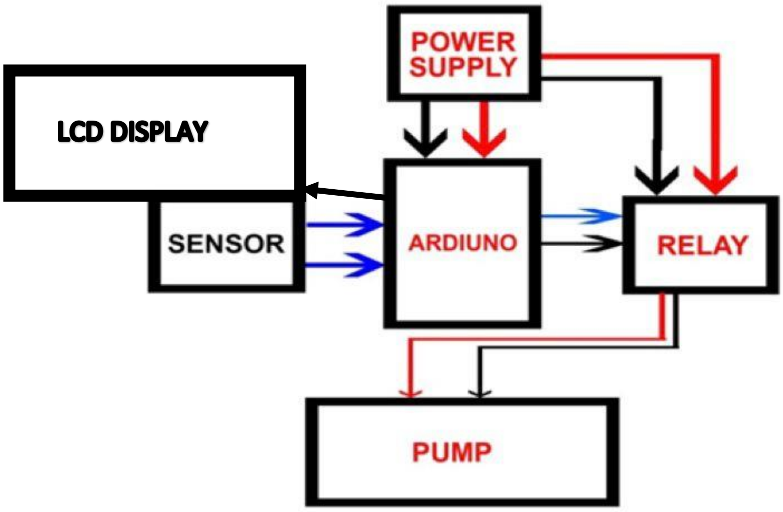

Fig. 4.1 : Block-diagram of the proposed methodology

Power Supply: This block provides the electrical power to run the entire system. It can be a battery or a plug-in adapter.

Sensor: This block represents the soil moisture sensor and the temperature sensor. The soil moisture sensor detects the moisture level in the soil. The temperature sensor measures the ambient temperature. These sensors send their readings to the Arduino.

Arduino: The Arduino is the brain of the system. It receives signals from the sensors, processes them according to the program uploaded, and controls the relay which in turn controls the water pump.

Relay: A relay is an electrically operated switch. The Arduino controls the relay, turning it on or off. When the relay is on, it allows current to flow to the water pump.

Pump: The water pump delivers water to the plants. When the soil moisture sensor detects that the soil is dry and the temperature is within the desired range, the Arduino turns on the relay, which activates the pump and delivers water to the plants.

This is a basic system, and there are many variations possible. For example, you could add a timer to control how often the pump is activated, or you could use a more sophisticated sensor that measures both moisture and nutrient levels in the soil.

4.3 Working Principle

1 **Initialization:** Start the system.

2 **Sensor Reading:** Read soil moisture and temperature values from sensors.

3 **Decision Making:**

- **Moisture Level Check:**
  - Compare soil moisture level with predefined thresholds.
  - Determine if irrigation is needed based on moisture status.
- **Temperature Check:**
  - Check temperature readings to adjust irrigation frequency if necessary.

4 **Control Signal Generation:**

- **Irrigation Decision:** If moisture level is below threshold and temperature conditions are suitable, generate an irrigation signal.
- **Pump Control:** Activate DC motor pump through relay control for water delivery to the plants.

5 **Irrigation Process:**

- **Watering Duration:** Determine the duration based on moisture deficit and crop water requirements.

6 **Monitoring:** Continuously monitor moisture levels during irrigation to avoid overwatering.

7 **End Cycle:** Complete irrigation cycle based on predetermined parameters.

8 **Standby Mode:**

- Return to standby mode after irrigation cycle completion.
- Continue monitoring soil conditions for the next cycle.

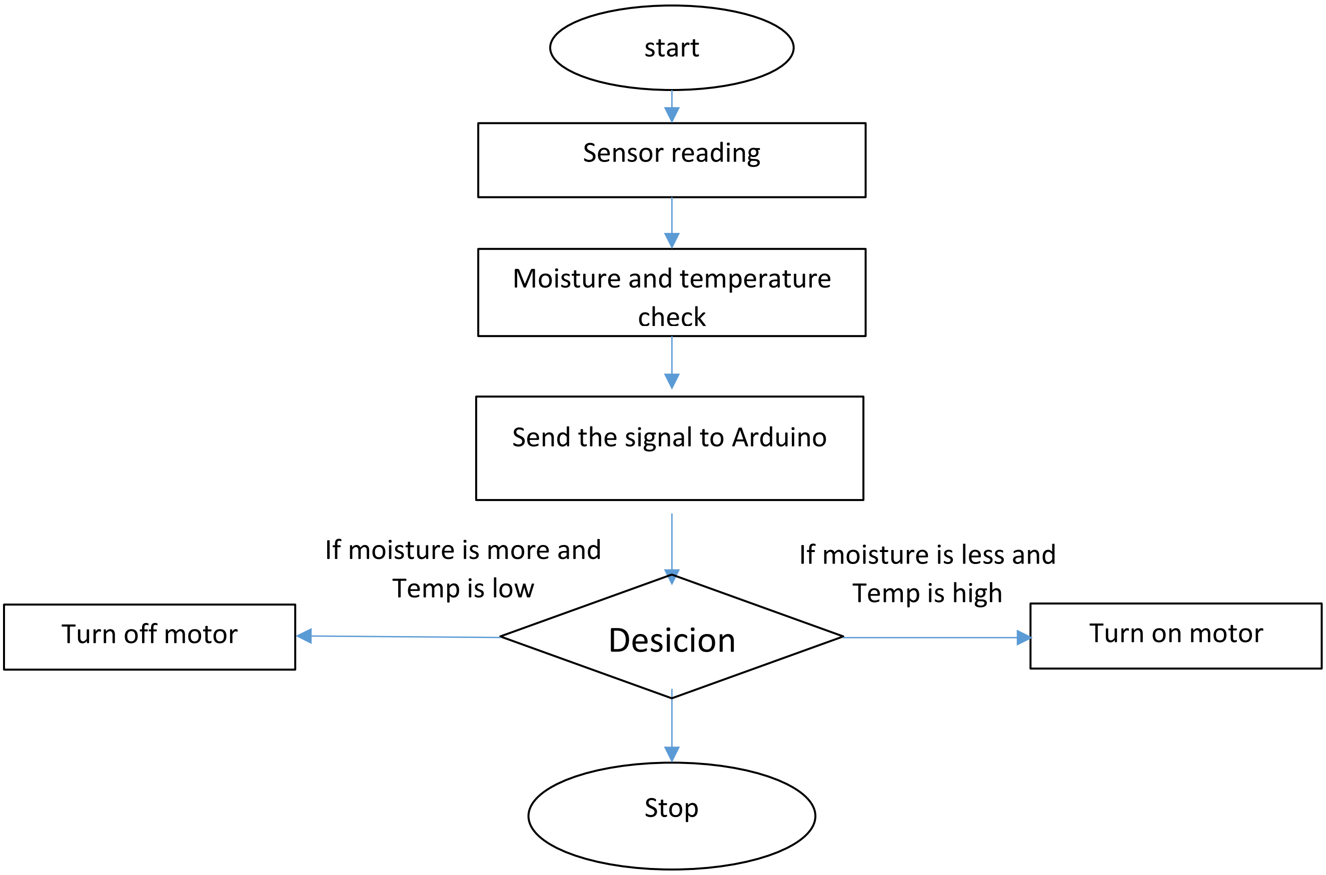

Fig 4.2: Flow-chart of the methodology used

Chapter-5

Hardware / Software tools Used

5.1 Hardware Components:

1. **Soil Moisture Sensor:**
    - Used to measure soil moisture levels.
2. **Temperature Sensor:**
    - Measures ambient temperature to adjust irrigation based on weather conditions.
3. **Microcontroller (e.g., Arduino):**
    - Controls the overall operation of the system based on sensor inputs and programmed logic.
4. **DC Motor Pump:**
    - Delivers water to the plants as per the control signals from the microcontroller.
5. **Relay Module:**
    - Controls the on/off operation of the DC motor pump based on signals from the microcontroller.
6. **Power Supply:**
    - Provides electrical power to the sensors, microcontroller, relay module, and DC motor pump.

5.2 Software Components:

1. **Arduino IDE:**
    - Used to write, compile, and upload the code (sketch) to the Arduino microcontroller.
2. **Programming Language:**
    - Used to write the code that controls the operation of the automatic irrigation system.

Chapter-6

Photographs of the model/Simulation Results

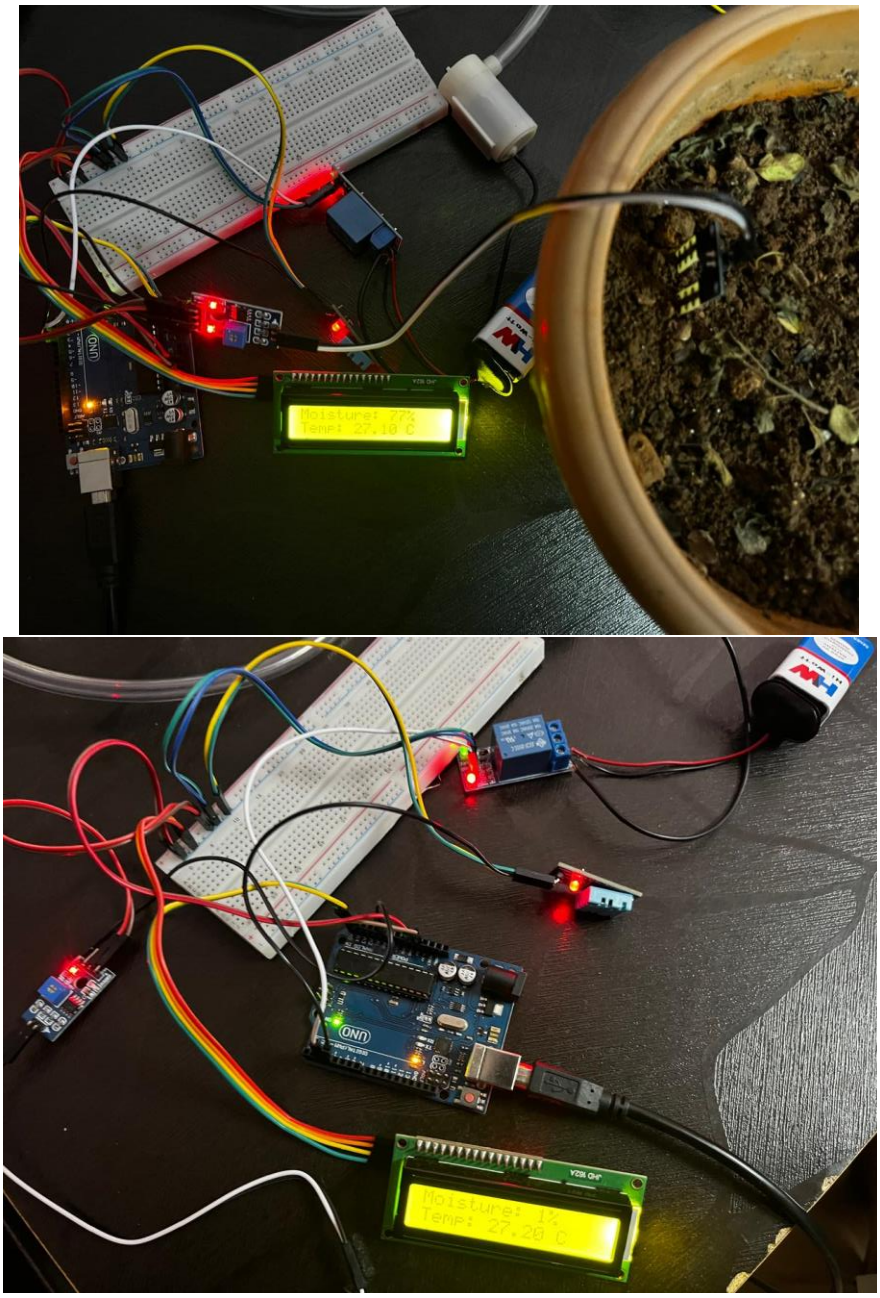

Fig6.1: Model developed

Chapter-7

Results and Discussions

7.1 Results

Results of implementing the automatic irrigation system with soil moisture and temperature sensors, alongside a DC motor pump controlled by a relay, have demonstrated significant improvements in agricultural productivity and water conservation. Firstly, the system consistently maintained optimal soil moisture levels tailored to crop requirements, resulting in enhanced crop yield and quality. By continuously monitoring soil moisture and adjusting irrigation schedules accordingly, the system effectively mitigated water stress and minimized the risk of under- or over-watering, crucial factors in promoting plant health and maximizing harvest yields.

Secondly, the integration of temperature sensors allowed for dynamic adjustments in irrigation timing based on weather conditions. This adaptive approach ensured that irrigation occurred during favorable temperature ranges, optimizing water absorption by plants and reducing evaporation losses. As a result, the system contributed to water conservation efforts by efficiently utilizing available resources while maintaining agricultural productivity. Farmers benefited from reduced water usage and operational costs, translating into improved economic sustainability and profitability over time.

Furthermore, the automated nature of the system streamlined irrigation management, reducing labor demands and enabling farmers to focus on other essential aspects of farm operations. Real-time monitoring and control capabilities provided by the system allowed for remote management, offering convenience and flexibility in irrigation scheduling. Overall, the successful implementation of this integrated hardware and software solution underscores its potential to enhance agricultural efficiency, conserve water resources, and support sustainable farming practices in various environmental conditions.

7.2 Discussion

The discussion of the automatic irrigation system with soil moisture and temperature sensors, coupled with a DC motor pump controlled by a relay, highlights several key insights and considerations for agricultural applications. Firstly, the precise control over soil moisture levels facilitated by the system has shown promising results in optimizing crop growth and yield. By maintaining soil moisture within ideal ranges specific to different crops, the system helps mitigate the risks associated with both drought stress and waterlogging, thereby improving overall plant health and productivity. This capability is particularly beneficial in regions prone to erratic rainfall patterns or limited water availability, where efficient water management is crucial for sustainable agriculture.

Secondly, the integration of temperature sensors into the irrigation system allowed for adaptive irrigation scheduling based on ambient weather conditions. Adjusting irrigation timing according to temperature variations optimizes water uptake efficiency by plants, minimizing unnecessary water losses due to evaporation during hotter periods. This adaptive approach not only conserves water resources but also enhances the system's resilience to climate variability, ensuring consistent crop performance even under changing environmental conditions. Furthermore, the ability to remotely monitor and control the system via the microcontroller and software tools offers operational flexibility and responsiveness, empowering farmers to make timely decisions to optimize irrigation practices.

Lastly, the economic and practical benefits of adopting such automated irrigation technologies are noteworthy. The reduction in manual labor associated with traditional irrigation methods translates into cost savings and labor efficiency for farmers. Moreover, by improving water use efficiency and crop yield, the system contributes to enhanced farm profitability and sustainability over the long term. However, challenges such as initial setup costs, technical expertise required for installation and maintenance, and the need for reliable power supply in remote agricultural areas should be carefully addressed to ensure widespread adoption and effective implementation of these technologies.

Chapter-8

Applications, Advantages, Outcome and Limitations

8.1 Applications

1. Agricultural Productivity:

-Optimized Water Management: The system ensures precise irrigation tailored to crop needs, improving water use efficiency and minimizing water wastage.

-Enhanced Crop Yield: By maintaining optimal soil moisture levels and adjusting irrigation schedules based on temperature, the system promotes healthy plant growth and higher yields.

2. Resource Conservation:

-Water Conservation: Adaptive irrigation scheduling based on real-time sensor data reduces water consumption by delivering water only when necessary and minimizing losses.

-Energy Efficiency: Efficient use of the DC motor pump and relay control reduces energy consumption, cntributing to sustainable resource management practices.

3. Climate Resilience:

-Adaptive Irrigation: The system adjusts irrigation timing and duration based on temperature readings, ensuring crops receive adequate water during varying weather conditions.

-Mitigation of Climate Risks: Helps mitigate the impact of climate variability by maintaining optimal growing conditions, thereby enhancing crop resilience to weather extremes.

4. Operational Efficiency:

-Labor Savings: Automation reduces manual labor required for irrigation management, allowing farmers to focus on other farm tasks.

-Remote Monitoring and Control: Enables farmers to monitor and control irrigation operations remotely via connected devices, providing flexibility and convenience.

8.2 Advantages

1. Precision Irrigation:

-Optimal Water Management: Ensures that crops receive the right amount of water at the right time, based on real-time soil moisture and temperature data. This precision minimizes water wastage and enhances water use efficiency, contributing to sustainable agriculture practices.

2. Improved Crop Yield and Quality:

-Enhanced Growth Conditions: Maintains optimal soil moisture levels and adjusts irrigation schedules according to crop requirements and environmental conditions. This promotes healthier plant growth, leading to increased yield and improved crop quality.

3. Resource Efficiency:

-Water Conservation: Reduces water consumption by only irrigating when necessary, thereby conserving water resources and reducing operational costs associated with excessive water use.

-Energy Efficiency: Efficient operation of the DC motor pump, controlled by the relay, minimizes energy consumption, contributing to lower operational costs and environmental sustainability.

4. Automation and Labor Savings:

-Reduced Manual Intervention: Automates irrigation scheduling and operation, reducing the need for constant monitoring and manual adjustment of irrigation systems. This frees up labor resources for other farm tasks, improving overall operational efficiency.

5. Adaptability to Environmental Conditions:

-Climate Resilience: Adjusts irrigation schedules based on real-time temperature readings, ensuring crops receive adequate water during varying weather conditions. This enhances crop resilience to climate variability and extremes, safeguarding against drought and heat stress.

6. Data-Driven Decision Making:

-Real-Time Monitoring and Control: Provides farmers with real-time data on soil moisture, temperature, and irrigation status, enabling informed decision-making and timely adjustments to irrigation strategies. This improves crop management practices and overall farm productivity.

8.3 Outcome

1. Increased Crop Yield:

-By maintaining optimal soil moisture levels and adjusting irrigation schedules based on real-time sensor data, the system supports healthier plant growth. This leads to increased crop yields as plants receive the right amount of water at critical growth stages, enhancing overall productivity.

2. Improved Crop Quality:

-Consistent and precise irrigation helps improve the quality of harvested crops. Proper water management ensures that crops develop uniformly, reducing the incidence of diseases and disorders associated with fluctuating soil moisture levels.

3. Water Conservation:

-The system reduces water wastage by efficiently delivering water only when and where it is needed. This conservation of water resources is crucial in regions facing water scarcity or drought conditions, contributing to sustainable agriculture practices.

4. Operational Efficiency:

-Automation of irrigation processes reduces manual labor and operational costs associated with traditional irrigation methods. Farmers can optimize their time and resources, focusing on other farm management tasks to improve overall operational efficiency.

5. Environmental Sustainability:

-By minimizing water usage and energy consumption through efficient irrigation practices, the system promotes environmental sustainability. Reduced runoff and leaching of nutrients also contribute to maintaining soil health and ecosystem balance.

6. Resilience to Climate Variability:

-Adaptive irrigation scheduling based on temperature readings helps mitigate the impacts of climate variability such as droughts or heatwaves. This resilience ensures continuous crop production and minimizes crop losses due to adverse weather conditions.

7. Financial Benefits:

-Improved crop yields, reduced input costs (such as water and energy), and enhanced operational efficiency lead to financial benefits for farmers. Higher yields and improved crop quality can increase profitability and economic resilience over the long term.

8.4 Limitations

1. Initial Setup Costs: Implementing such a system requires upfront investment in sensors, microcontrollers, pumps, relays, and installation. These initial costs can be prohibitive for small-scale farmers or those with limited financial resources.

2. Technical Complexity: Designing and configuring the system, including sensor calibration, programming the microcontroller, and ensuring reliable communication between components, requires technical expertise. Farmers may require training or support to effectively deploy and maintain the system.

3. Reliability on Power Supply: The system relies on a continuous and reliable power supply to operate sensors, microcontrollers, and the DC motor pump. In areas with unreliable electricity access or frequent power outages, maintaining system functionality can be challenging.

4. Sensor Accuracy and Maintenance: Soil moisture and temperature sensors must be accurate and calibrated regularly to provide reliable data for irrigation decision-making. Sensor drift, degradation over time, or improper placement can affect the system's performance and efficiency.

5. Limited Compatibility with Existing Infrastructure: Retrofitting existing irrigation systems with automated components may not always be straightforward. Compatibility issues between new and old infrastructure components can arise, requiring additional modifications or upgrades.

6. Vulnerability to Environmental Factors: Extreme weather events, such as heavy rainfall or high winds, can potentially damage components of the system, affecting its operation and reliability. Adequate protection and maintenance are necessary to mitigate these risks.

7. Data Security and Privacy Concerns: Systems that rely on IoT technologies for data transmission and storage may raise concerns about data security and privacy. Safeguarding sensitive agricultural data from unauthorized access or cyber threats is crucial for farmers adopting such technologies.

Chapter-9

Conclusions and Future Work

In this chapter, a brief conclusion of the proposed undergraduate mini-project work that is being done / undertaken has to be presented here in this conclusion chapter.

In concluding this project on automated irrigation, significant innovations have been achieved in precision agriculture and urban gardening practices. By integrating real-time soil moisture and temperature monitoring with automated control mechanisms using Arduino technology, the system enhances water efficiency and promotes sustainable plant growth. Key achievements include the accurate monitoring of soil conditions, dynamic irrigation control based on predefined moisture thresholds, and the development of a user-friendly interface for real-time data visualization. Standout features include precise irrigation scheduling tailored to local soil conditions, integration of temperature sensing for adaptive plant care, and a robust hardware setup ensuring reliability in diverse environments. While the project successfully meets goals in water conservation and plant health enhancement through smart irrigation practices, challenges remain in sensor accuracy under varying conditions and system robustness against electronic failures. Future improvements should focus on refining sensor calibration, exploring advanced monitoring technologies, and integrating predictive analytics for optimized irrigation management. Overall, this project lays a solid foundation for sustainable agriculture practices with potential for further innovation and application in broader agricultural and environmental contexts.

Looking ahead, future work on the automated irrigation system can significantly enhance its capabilities and applicability in agricultural and urban settings. One key area for development involves integrating advanced sensors beyond soil moisture and temperature, such as pH sensors and nutrient sensors, to provide comprehensive soil health monitoring. This enhancement would enable more precise irrigation and fertilization strategies tailored to specific crop needs. Additionally, implementing predictive analytics and machine learning algorithms using historical data and weather forecasts can optimize irrigation schedules, predicting plant water requirements more accurately and efficiently. Remote monitoring and control capabilities using IoT technologies offer another avenue for improvement, allowing users to manage the system remotely and receive real-time updates on soil conditions and irrigation status. Exploring energy-efficient solutions like solar power integration and optimizing system design for scalability and adaptability to different agricultural contexts will further enhance sustainability and operational flexibility. Enhancing the user interface with intuitive features for data visualization and decision support can empower users with actionable insights for improved crop management practices. Finally, fostering collaboration with stakeholders in agriculture and environmental sectors can validate system performance, gather user feedback, and refine algorithms to ensure practical and effective deployment of the automated irrigation system in real-world applications. These future directions aim to advance agricultural efficiency, resource conservation, and sustainable food production practices.

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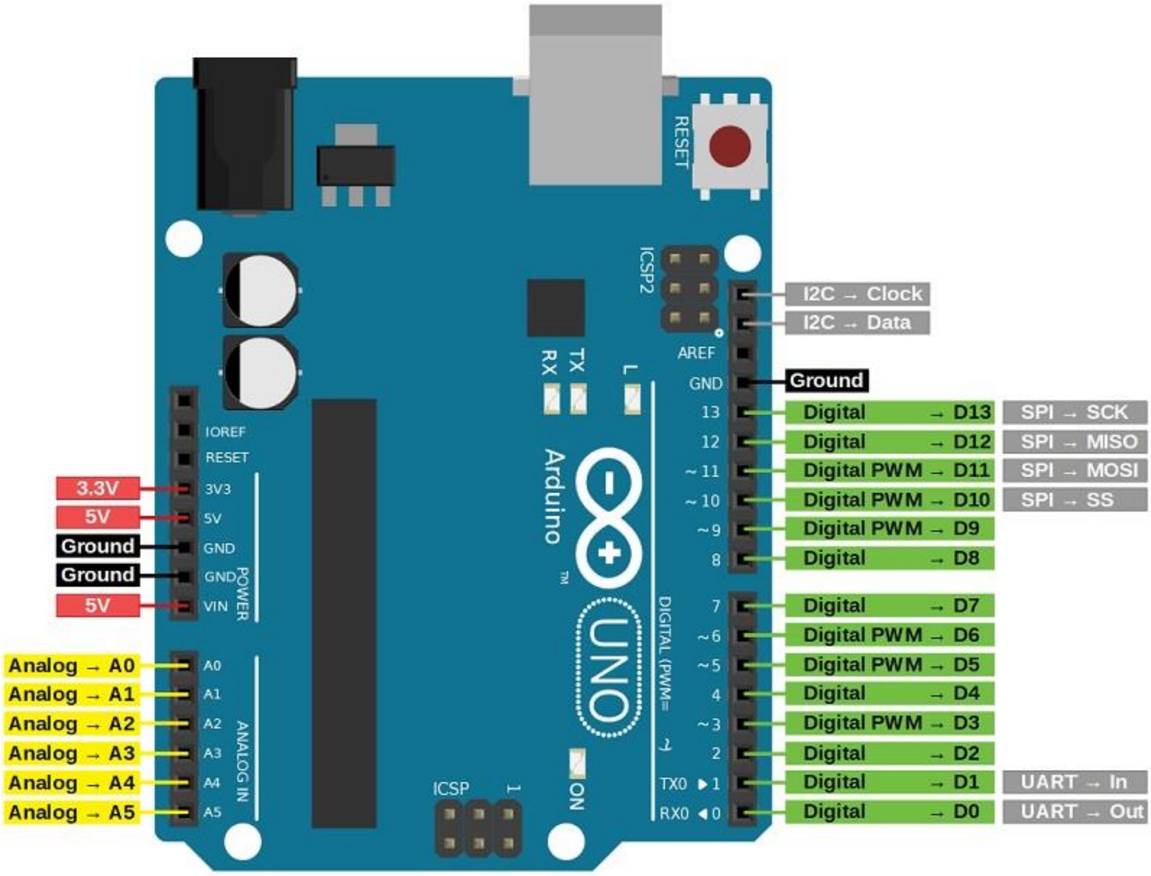
Appendix

IC Pin Configurations



Arduino uno pin Configurations

Developed Codes

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

// Replace '0x27' with the I2C address you found from the scanner
LiquidCrystal_I2C lcd(0x27, 16, 2); // Adjust the address as needed

// Define DHT11 pin and type
#define DHTPIN 3
```

```
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);

// Define pin numbers
const int soilMoistureSensorPin = A0; // Soil moisture sensor connected to analog pin A0
const int relayPin = 2; // Relay module connected to digital pin D2

// Define thresholds
const int soilMoistureLowThreshold = 30;  // Threshold to turn the pump on
const int soilMoistureHighThreshold = 70; // Threshold to turn the pump off

// Variable to keep track of the pump state
bool pumpOn = false;

void setup() {
  // Initialize serial communication for debugging
  Serial.begin(9600);

  // Initialize the LCD
  lcd.init(); // Initialize the LCD
  lcd.backlight();
  lcd.print("Initializing...");

  // Initialize DHT11 sensor
  dht.begin();

  // Set the relay pin as output
  pinMode(relayPin, OUTPUT);
  digitalWrite(relayPin, LOW); // Ensure relay is off initially

  delay(2000); // Delay to show initialization message
  lcd.clear(); // Clear the display
}
```

```
void loop() {
  // Read sensor values
  int soilMoistureRaw = analogRead(soilMoistureSensorPin);
  float temperature = dht.readTemperature();

  // Map soil moisture to percentage (100-0%)
  int soilMoisturePercent = map(soilMoistureRaw, 0, 1023, 100, 0);

  // Print sensor values to the serial monitor
  Serial.print("Soil Moisture: ");
  Serial.print(soilMoistureRaw);
  Serial.print(" (");
  Serial.print(soilMoisturePercent);
  Serial.println("%)");
  Serial.print("Temperature: ");
  Serial.print(temperature);
  Serial.println("C");

  // Display sensor values on the LCD
  lcd.setCursor(0, 0);
  lcd.print("Moisture: ");
  lcd.print(soilMoisturePercent);
  lcd.print("%   ");
  lcd.setCursor(0, 1);
  lcd.print("Temp: ");
  lcd.print(temperature);
  lcd.print(" C   ");

  // Check if soil moisture is low
  if (soilMoisturePercent < soilMoistureLowThreshold && !pumpOn) {
    // Turn on the pump/valve
    digitalWrite(relayPin, LOW);
```

```
    pumpOn = true;
    Serial.println("Relay ON: Pump activated");
  } else if (soilMoisturePercent > soilMoistureHighThreshold && pumpOn) {
    // Turn off the pump/valve
    digitalWrite(relayPin, HIGH);
    pumpOn = false;
    Serial.println("Relay OFF: Pump deactivated");
  }

  // Wait for a while before taking the next reading
  delay(2000);
}
```

Pin Connections

- **Arduino UNO Board**
  - **Analog Pins:**
    - A0: Soil Moisture Sensor (analog input)
  - **Digital Pins:**
    - D2: Relay Module (control pin)
    - D3: DHT11 Sensor (data pin)
  - **I2C Pins:**
    - A4 (SDA) and A5 (SCL): I2C Communication for LCD Display
- **Components**
  - **Soil Moisture Sensor:**
    - VCC to Arduino 5V
    - GND to Arduino GND
    - A0 to Arduino A0 (analog input)
  - **DHT11 Sensor:**
    - VCC to Arduino 5V
    - GND to Arduino GND
    - Data pin (DHTPIN) to Arduino D3
  - **Relay Module:**
    - VCC to Arduino 5V
    - GND to Arduino GND

- Control pin (relayPin, D2) to Arduino D2

- I2C LCD Display (16x2):

- VCC to Arduino 5V
- GND to Arduino GND
- SDA to Arduino A4 (for data)
- SCL to Arduino A5 (for clock)