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IoT-Based Plant Irrigation Information Management System

Diveadarsini A. Jagathison[1], Nureize Arbaiy[1]*

[1] *Fakulti Sains Komputer dan Teknologi Maklumat, Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, 86400, MALAYSIA*

*Corresponding Author: nureize@uthm.edu.my
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Abstract

Efficient irrigation is crucial for maintaining the health and growth of plants, particularly in regions experiencing unpredictable rainfall. Proper water management promotes optimal plant growth and addresses concerns about water usage and rising costs. Hence, this study proposes an IoT-Based Plant Irrigation Information Management System to monitor real-time soil moisture levels, weather conditions, and plant water requirements. The case study was conducted at Anna Nursery and utilized the newly built system. Integrating sensors and data analytics, the system provides automated irrigation solutions that optimize water usage while ensuring plants receive adequate moisture. The new system provides several essential modules such as user registration and login, sensor and data collection, control and automation, water usage tracking, and report analysis. The system was developed using Agile methodology, the PHP programming language, and the XAMPP database. The agile method facilitates iterative progress through small, incremental changes, which allow teams to respond quickly to changing requirements and user feedback. The use of PHP and XAMPP enables a robust back-end infrastructure that supports efficient data storage and processing; the implementation of this system in production nurseries aims to enhance crop health, increase production efficiency and reduce operational costs associated with water use. This approach promotes sustainable agricultural practices and enhances the profitability of nursery operations by ensuring that water is used appropriately.

1. Introduction

Applying artificial water to the soil to promote crops or plant growth and provide sufficient moisture for healthy development is known as plant irrigation. This is an essential agricultural technique because it helps maintain equilibrium between the water supply and the needs of the plants, particularly in regions with erratic rainfall [1]. Water stress can cause plants to grow less quickly, produce less, or even die if not adequately irrigated. Numerous elements, including soil composition, climate, and the unique water needs of diverse plants, contribute to the need for irrigation. Sustainably farmed land is promoted by using efficient irrigation systems that maximise water use while guaranteeing plants get the moisture they require without being overwatered.

In a production nursery, plants are bred and grown to the desired size. Most plants are concerned with gardening, forestry, or conservation biology [2]. Nurseries usually come in many different types and sizes. One of the critical factors for nursery management is the irrigation system. The issue of water use in production nurseries has long been discussed and is of concern to farm managers [3]. Water needs to be used in the correct quantity so that the cost of its use can be optimized with profit. An effective irrigation program will usually result in general gains in crop health, such as faster and healthier crop development, increased crop uniformity, higher production, and fewer stock losses and discards. Often, enterprises must incur additional costs for water use due to increased temperatures and risks to the water supply. With the price of water rising, management needs to keep a close eye on water usage issues. Beyond efficiency and profitability, water management is essential to company operations. Public scrutiny of water use in agriculture and horticultural production has intensified due to climate change and drought.

Anna Nursery, located in Kampung Parit Kadir, Batu, has been selected as the case study for this project. The nursery specialises in various plant species and relies on traditional manual irrigation practices to maintain plant health. The nursery is an essential resource for local gardeners and farmers, offering various plants suited for different climates and landscapes. The location in Batu Pahat provides a suitable environment for plant cultivation. However, the reliance on manual irrigation highlights the potential for more efficient, automated systems to be implemented, reducing labour efforts and optimizing plant care. Workers at Anna Nursery in Kampung Parit Kadir, Batu Pahat, have usually watered the rose plants twice daily, in the morning and the evening. There may be problems with overwatering or underwatering because this method, overseen by workers, is carried out without exact knowledge of the water requirements of the rose plants. Although consistent, this manual method ignores variables essential for the best possible health and growth of rose plants, such as specific plant requirements or varying soil moisture levels. Improving this process is crucial because it would lead to healthier plants and more sustainable nursery operations and increase water usage efficiency through more precise and responsive irrigation management.

Several obstacles affect the efficacy and efficiency of nursery operations at Anna Nursery, where the current manual irrigation method is used. Without accurate knowledge of the plants' actual water needs, labourers water twice a day, which can result in several problems. Overwatering can result in root rot and other water-related diseases, while underwatering can impede plant growth and cause wilting. Furthermore, this approach ignores variables that significantly impact determining the appropriate water requirement, such as temperature, humidity, and soil moisture. The ineffective use of water, a vital resource, particularly during dry spells, is another consequence of this lack of precision, which also impacts plant health. Furthermore, the manual method necessitates constant human intervention and is labour and time intensive. Because of this reliance on labour, there is a greater chance of operational errors like irregular watering schedules or missed watering sessions. These issues are made worse by the inability to track and modify real-time watering schedules, making it challenging to adapt to the unique requirements of various plants or shifting environmental circumstances. In general, the current approach cannot be sustained over the long run in terms of conserving resources or the nursery's capacity to provide top-notch plant care.

A Plant Irrigation Information Management System that automates and optimizes the irrigation process at Anna Nursery is suggested to address these problems. This project aims to design and develop an IoT-Based Plant Irrigation Information Management System. A network of sensors is integrated into this system to continuously monitor critical environmental parameters like temperature, air humidity, and soil moisture. The system can precisely meet each plant's unique needs by gathering this data and using it to make educated decisions about when and how much water to give each one. This focused strategy prevents the overuse of water resources while improving plant health by providing the right amount of water. The system has a data analysis and reporting module that monitors and evaluates irrigation techniques over time. This module's comprehensive reports can be used to spot patterns, maximize water use, and boost productivity. A more sustainable, economical, and dependable irrigation process will result from Anna Nursery switching from a manual to an automated system, improving resource management and producing healthier plants. The foundation for future agricultural practices that will be more sophisticated and scalable is laid by this solution, which also solves the current issues.

This paper is organized into several sections. The first section introduces the project background. It is then followed by the related work of this study. The project methodology is then explained in Section 3. Section 4 summarises the results and conclusions. Section 5 gives the conclusion.

2. Related Work

A production nursery is a facility dedicated to cultivating, propagating, and growing plants, trees, shrubs, and other greenery, typically for sale to the public or for commercial landscaping and agriculture [2]. These nurseries play a critical role in horticulture and agriculture, as they ensure the availability of healthy, well-developed plants for various purposes [4]. Production nurseries use controlled environments, including greenhouses or outdoor fields, to grow plants from seeds, cuttings, or grafts [5]. Efficient management in a nursery is critical to ensure high-quality output, with irrigation being a central component.

At Anna Nursery, the irrigation system is currently manual. This process involves physically watering the plants, typically using hoses or cans. However, this manual method can lead to inconsistent water distribution and higher labour costs and may only sometimes be efficient regarding water usage. The current system does not incorporate any automation or sensor-based monitoring to adjust irrigation based on real-time plant needs. Most plants grown at Anna Nursery are grown by hand, and manual irrigation techniques are now used. Regardless of the plant's demands, labourers water them twice daily according to set schedules. Plant development and health may be impacted by the uneven watering that this manual method frequently causes, either by overwatering or underwatering the plants. The nursery does not use any data-driven irrigation monitoring or management technologies. Only routine scheduling and visual evaluations of plant requirements determine when to water. No mechanism exists to monitor soil moisture levels or other environmental variables for more accurate watering.

Real-time data on soil moisture and environmental conditions might be obtained by adopting an Internet of Things-based irrigation information system. This kind of system automatically starts irrigation when necessary. By supplying the appropriate amount of water at the proper time, this data-driven approach would maximize water usage and enhance the health of the rose plants. Most rose growers use substrate water with 30-50% LF to avoid reducing osmotic potential and accumulating necessary and unnecessary ions in the rhizosphere [6]. Water availability and quality affect the photosynthesis and productivity of soilless grown cut roses. The nursery uses data-driven irrigation technologies, resulting in efficient water consumption and good plant health management. Because there is no real-time monitoring, irrigation is not matched to the needs of the rose plants, which could lead to uneven watering and stress. To solve these problems, a new IoT-Based Plant Irrigation Information Management System is required.

The development of the new IoT-Based Plant Irrigation Information Management System relies on two crucial technologies: the Internet of Things (IoT) and Web-Based Systems. IoT technology plays a key role in automating irrigation by linking devices such as the NodeMCU ESP8266, soil moisture sensors, and DHT11 sensors to monitor environmental conditions. This real-time data allows for automated irrigation when the soil moisture level falls below a predetermined threshold, reducing the necessity for manual intervention and ensuring efficient water usage. The web-based system allows users to engage with the platform through a browser, enabling real-time monitoring, control, and reporting. This web interface allows users to access data and system functions remotely, providing a user-friendly method to oversee irrigation processes from any device, thereby improving accessibility and control. Combined, these technologies form a robust, automated, and readily available system for managing irrigation, ultimately enhancing efficiency and productivity.

Table 1 *IoT Application in Agriculture*

Author	Application	Findings
Mahmud et al.,2023[7]	Sensing and automation technologies for ornamental nursery crop production: status and prospects	Sensors used: Soil moisture sensor, Camera (RGB and thermal), humidity sensor and weather data. Results: Adopting technologies and areas for future research to further enhance crop production efficiency and sustainability.
Naik et al., 2021[8]	IoT-based nursery management system	Sensors used: Arduino Uno board, sensors, and Raspberry Pi model B. ThingSpeak. Results: Preserving several climatic factors, such as humidity, temperature, and certain gases, is crucial to producing high-quality plants.
Florea et al., 2024[9]	Digital Farming Based on a Smart and User-friendly IoT Irrigation System: A Conifer Nursery Case Study	Sensors used: Sensors, solenoid valves, Raspberry Pi microcontrollers, fuzzy logic systems, a web interface and a cloud service. Results: IoT technologies for improved water management and plant health.
Prathyusha et al., 2021[10]	Nursery automation and monitoring in IoT using ThingView Free	Sensors used: Arduino AT Mega 328, ESP 8266 Wi-Fi module, and sensors like humidity, temperature, and soil moisture. Results: Monitor the nursery to ensure all the plants are growing in good condition and in a suitable environment.

Table 1: (cont.)

Author	Application	Findings
Singh et al., 2020.[11]	Smart Nursery with Health Monitoring System Through Integration of IoT and Machine Learning	Sensors used: Pressure, humidity, temperature, light, moisture, conductivity, and air quality. Results: Utilizing IoT and machine learning in nurseries to monitor plant health and demonstrate enhanced sustainability, economic efficiency, and plant management.

The IoT-Based Plant Irrigation Information Management System aims to use IoT technology to automate and improve the irrigation process for rose plants. This system will use soil moisture sensors, air temperature and humidity sensors, and a web-based interface to monitor and control the system in real time. Using IoT will significantly improve water management and decrease the need for manual labour, which will help ensure the best possible growth for the plants. While the system will benefit from IoT's automation and data-driven decision-making, it will also address potential security concerns through integrated data analysis and control features. Table 1 tabulates the application of IOT in agriculture, especially in the plant nursery section.

The new system is created with IoT (Internet of Things) technology and an information system, which combines physical devices, sensors, and the Internet to create an innovative, automated plant irrigation system. The system's primary components are soil moisture sensors and DHT11 sensors, which measure environmental elements such as soil moisture, temperature, and humidity. These sensors interact with a web-based control platform in real-time, allowing customers to monitor and regulate irrigation remotely. The web-based information system is convenient for remote irrigation process management since it can be accessed from any device that has internet connectivity. Easy use is guaranteed by its user-friendly design, even for non-technical users. The system provides a comprehensive picture of the irrigation process and plant health by centralizing control and data management on a single platform. This eliminates manual checks and offers a contemporary, effective method of managing plant irrigation. Table 2 tabulates the application of web-based information systems in production nursery management.

Table 2 *WBIS in production nursery management*

Author Year	Application	Findings
Porto et al., 2011 [12]	Developing integrated computer-based information systems for certified plant traceability: A case study of Italian citrus-plant nursery chain	At the plant supply-chain level, integrated computer-based information systems (ICBISs) should be created to achieve traceability for each plant produced. These systems will gather data from various production centres and existing FISs, incorporating information on the plant production process and all sub-products.
Aviana and Hartanti, 2023 [13]	Data System Management in Mahogany Tree Seedlings (Swietenia mahagoni) Based on Website.	This web-based system was written to simplify the process of managing nursery data so that the plant process is transferred to make it more effective and efficient in supporting activities.
Teoh and Arbaiy, 2023 [14]	Succulent Plant Management Information System for Nursery Gardening Store	The system can enhance task performance in a succulent nursery by planning, monitoring progress, and generating reports.
Maman et al., 2017 [15]	Design of e-commerce information systems for houseplants: The case of Yasyifa Nursery plantation	The platform is beneficial for showcasing houseplant products like aglaonema, bromeliad, and anthurium on the internet store, enhancing sales results and reducing the possibility of management mistakes in sales transactions.
Ampatzidis et al., 2016 [16]	Cloud-based harvest management system for hand-harvested specialty crops	The PLMS data on labour activities was received and processed by software based on the cloud. It showed the gathered information, extracted the required data for management reports, and automated document completion.

Table 3 *System's Comparison*

System/ Features	Smart Rain	Irriot	Net afim	IoT-Based Plant Irrigation Information Management System
User Register and Log in	√	√	√	√
Control and Automation	√	√	√	√
Water Usage Tracking	√	√	√	√
Data Analysis and Reporting	√	√	√	√
Soil moisture sensors	X	√	√	√
Air humidity and temperature	X	X	√	√
Plant Information	X	√	X	√
System Database	X	√	√	√

3. Methodology

The agile software development methodology has quickly grown to become a widely utilized technique in software development. Instead of the lengthy release cycles of the waterfall methodology, the agile method recommends frequent short-sprint release cycles [17]. The Prototyping Model and Agile methods were selected for this project due to their shared focus on adaptability, continuous improvement, and user feedback. The Agile approach divides the project into small, controllable iterations, enabling quick development and adjustments based on changing needs. Within the IoT-Based Plant Irrigation Information Management System, utilizing both a prototyping strategy and Agile sprints allows for advancing and enhancing system features like automated irrigation controls, sensor data processing, and user interfaces through stakeholder feedback.

Table 4 *Functional Requirement*

No	Module	Description
1	Registration and Login Module	• Enables users to sign up and establish new accounts. • Permits current users to sign in using their login information. • Verifies that only individuals with permission can use the system and its features. • Steers users to their customized dashboard after logging in successfully.
2	Sensor and Data Collection Module	• Enables live tracking of soil moisture, temperature, and humidity. • Gathers sensor information and sends it to the database. • Allows constant monitoring of environmental conditions. • Enables users to access and analyse past sensor data.
3	Control and Automation Module	• Enables users to schedule automated irrigation based on sensor information. • The irrigation system is operated by hand if the user chooses a manual option. • Modifies watering based on user-set limits for soil moisture levels. • Guarantees water preservation by abstaining from unnecessary watering.
4	Water Usage Tracking Module	• Enables users to track sensor data in real time through a web interface. • Provides a dashboard that makes it easy to interact with the system. • Allows users to access and modify settings from a distance.
5	Data Analysis and Reporting Module	• Enables users to create reports detailing water usage during specific time frames. • Examines data to minimize water wastage and enhance system efficiency. • Allows users to monitor system efficiency and sensor precision. • Enables data visualization to display patterns in plant watering.

Table 4: (cont.)

No	Module	Description
6	System Maintenance Module	• Enables users to conduct system diagnostics. • Informs users about the availability of hardware or software updates. • Backs regular inspections to verify that the IoT sensors and components are operating effectively. • Offers help with fixing and maintaining systems from a distance. • Aids in recording errors to pinpoint and solve system malfunctions.

3.1 Requirement Phase

The main goal of the requirement phase is to collect requirements from stakeholders regarding the system's goals, limitations, and scope. Sub-activities include determining the objectives of the irrigation system, performing feasibility studies, and interviewing labourers and the nursery's owner to learn about their needs. Methods like stakeholder interviews, requirement-gathering sessions, and feasibility studies ensure that the suggested system satisfies user expectations and aligns with nursery operations.

Developing an IoT-Based Plant Irrigation Information Management System requires careful consideration of system requirements. The functional and non-functional needs of the system, which are acquired from stakeholders, are the main emphasis of this phase and are identified and documented. Clarity on what the system needs to accomplish to satisfy its users' needs—in this case, Anna Nursery—is the main objective of this examination.

The functional requirements cover the system's primary functions, including user login and registration, irrigation process control and automation, real-time temperature, humidity, soil moisture monitoring, and data analysis for report generation. These features guarantee that the system accomplishes the nursery's main objectives: increasing water efficiency for plant growth and automating watering.

Conversely, the non-functional criteria cover the system's performance, dependability, security, and usability. For example, the system must safeguard sensitive user data, including login credentials, and maintain high dependability to prevent irrigation failures. It also needs to deliver real-time data updates. Furthermore, the system interface needs to be simple and intuitive, especially for non-technical users like Madam Ruby and the workers at Anna Nursery.

Table 5 *Non-Functional Requirement*

No	Requirement	Description
1	Performance	The system needs to uphold immediate monitoring and control without any delays for optimal performance.
2	Operational	The mobile and web interfaces of the system need to load in 3 seconds for operational purposes.
3	Security	Security measures should include secure authentication and protect all user data.
4	Usability	The system needs to be user-friendly, easy to navigate, and intuitive.

3.2 Analysis Phase

The Use Case Diagram in Figure 1 illustrates the interactions within the IoT-Based Plant Irrigation Information Management System between two main actors: labourers/users and administrators.

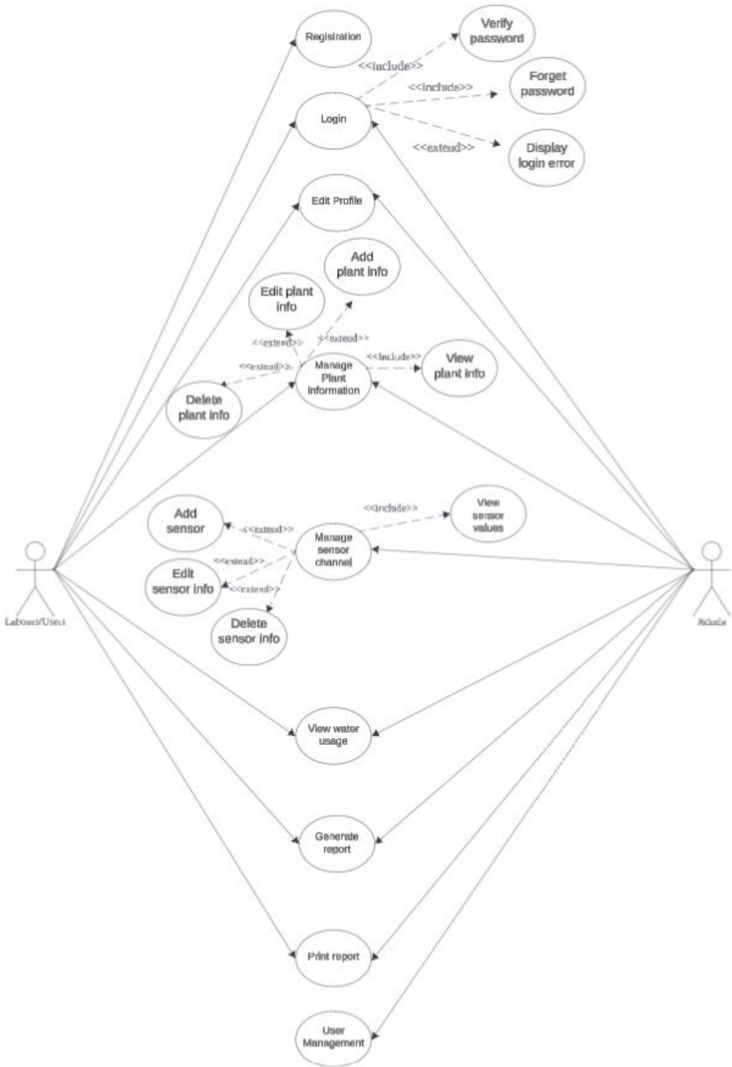


Fig. 1 *Use case diagram*

The class diagram in Figure 2 illustrates the structure of an IoT-driven plant irrigation system, outlining the classes, their attributes, functions, and connections.

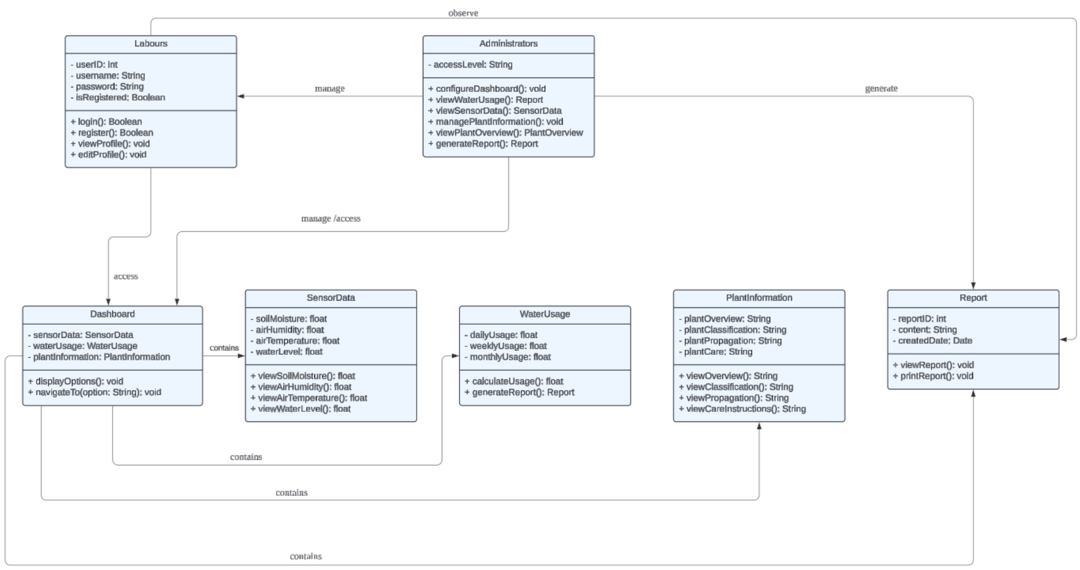


Fig. 2 *Class Diagram*

Figure 3 is an illustration that depicts the database architecture for a plant irrigation information management system based on IoT technology. The system's fundamental entities and connections are outlined to guarantee effective data handling and operational movement.

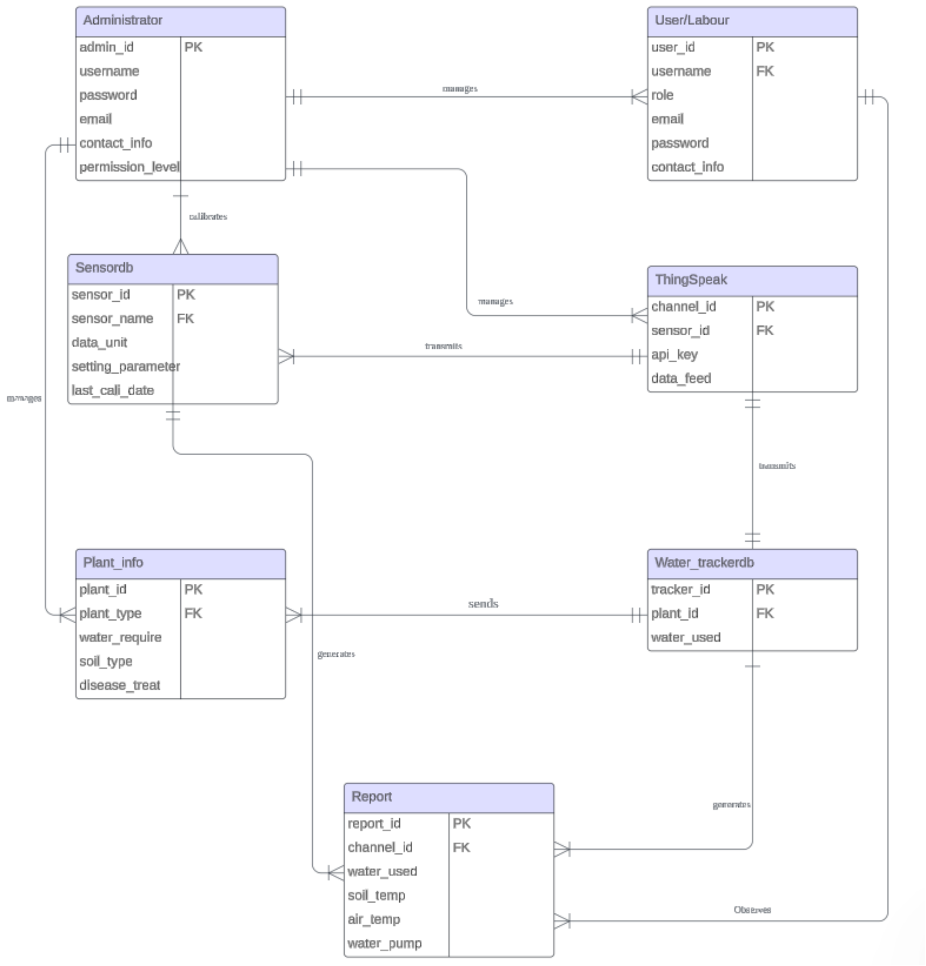


Fig. 3 *Entity-Relationship Diagram*

3.3 System Design

The database is intended to recognize the data type contained in the attribute. Throughout the development of this system, the MySQL server served as a database. This section will provide a compilation of databases along with their capabilities.

i. Tbl_admin (adminID,username,passord,email,contact,permission level)

ii. Tbl_user/labours (userID,username,role,email,password,contact)

iii. Tbl_sensor (sensorID,sensor_name,status,data_unit,last_configuration_data)

iv. Tbl_plant (PlantID,plant_type,water requirement,soil_type,plant_pic)

v. Tbl_water_tracker (TrackerID,PlantID,water_used)

vi. Tbl_report (reportID,channelID,API_key,water_usage,soil_moist,air_temp,air_humid,water_pump)

vii. Tbl_ThingSpeak (ChannelID,SensorID,API_key,data_feed)

The following figures from 4-8 show the interfaces designed based on each process. The wireframes were created using Canva.

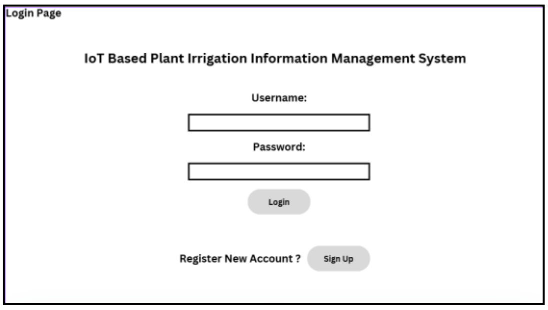


Fig. 4 *User Login Interface Design*

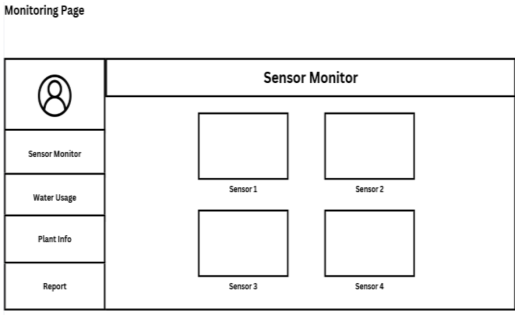


Fig. 5 *Monitoring page Interface Design*

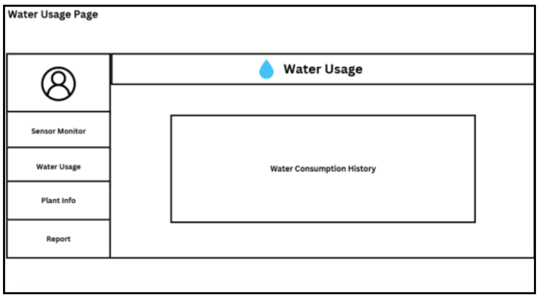


Fig. 6 *Water Usage Page Interface Design*

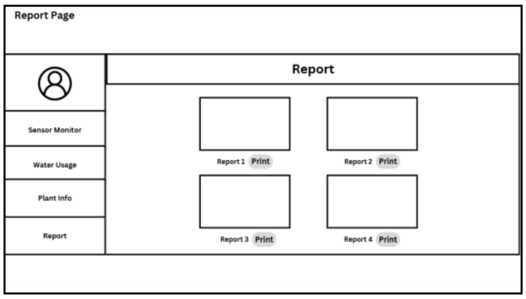


Fig. 7 *Report page Interface Design*

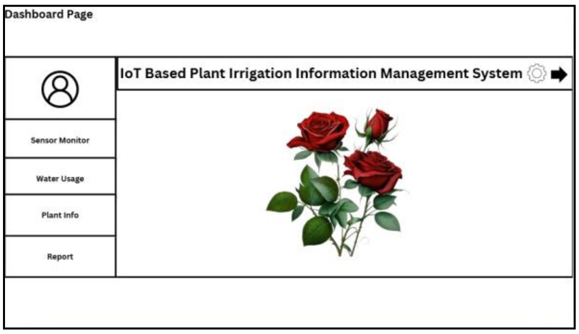


Fig. 8 *Dashboard Interface Design*

4. Implementation and Testing

This section discusses the Implementation Phase and the Testing Phase of the IoT-Based Plant Irrigation Information Management System. The implementation involved developing both the administrative and monitoring interfaces, integrating IoT hardware for real-time data collection, and building automated control features based on sensor feedback. The system was developed using PHP, HTML, CSS, JavaScript, and MySQL for the web-based admin panel, while ESP8266 microcontrollers were used to collect environmental data (temperature, humidity, soil moisture, and water usage) and transmit it to the server via ThingSpeak API.

```
<form method="POST" action="register_action.php">
    <h2>Register New Account</h2>
    <label for="username">Username:</label>
    <input type="text" id="username" name="username" required>

    <label for="password">Password:</label>
    <input type="password" id="password" name="password" required>

    <label for="firstname">First Name:</label>
    <input type="text" id="firstname" name="firstname" required>

    <label for="lastname">Last Name:</label>
    <input type="text" id="lastname" name="lastname" required>

    <label for="role">Role:</label>
    <select name="role" required>
        <option value="Admin">Admin</option>
        <option value="Labor">Labor</option>
    </select>

    <label for="email">E-mail Address:</label>
    <input type="email" id="email" name="email" required>
```

Fig. 9 *Account Registration Source Code*

Fig. 10 *Homepage*

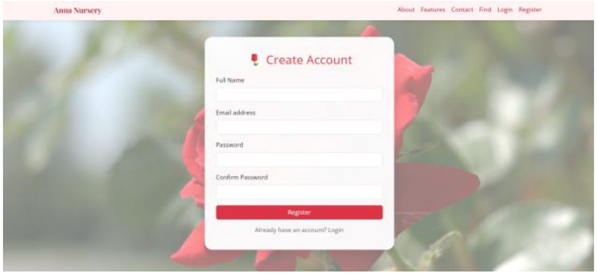


Fig. 11 *Account Registration User Interface*

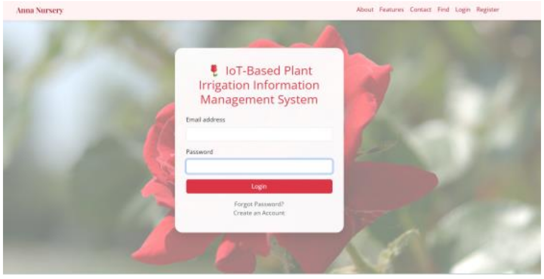


Fig. 12 *Account Login User Interface*

The Account Registration and User Login Module is designed to allow labor users to register for an account, while administrators can log in directly using pre-created credentials. As shown in the figures, the registration form collects details such as full name, email, and password, and sends the data to the server for processing. The homepage provides buttons for both login and registration. Labor users must register before logging in, whereas admins do not require registration and can access the system directly. This module ensures secure access control for both user types.

a. Admin and Labor Dashboard Source Code and Interface

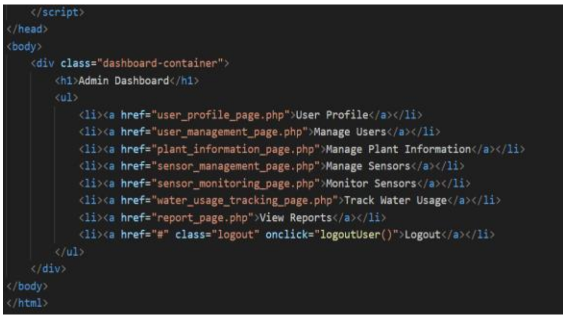


Fig. 13 *Admin Dashboard User Interface*

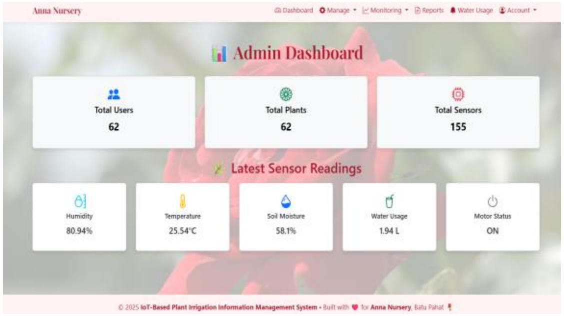


Fig. 14 *Admin Dashboard User Interface*

Fig. 15 *Labor Dashboard User Interface*

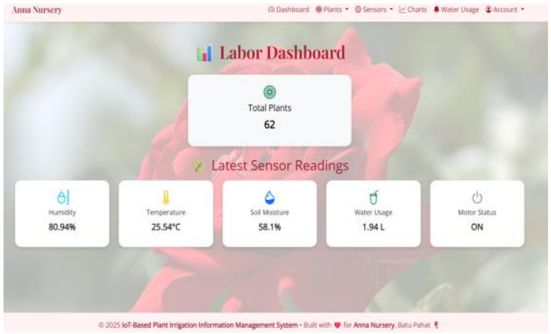


Fig. 16 *Labor Dashboard User Interface*

Figures 13 to 16 show the Admin and Labor Dashboards of the system. Figure 13 displays the code for the Admin Dashboard menu, which includes links to manage users, plants, sensors, and reports. Figure 14 shows the Admin Dashboard interface with totals for users, plants, and sensors, as well as real-time sensor readings. Figure 15 shows the code used to display the Labour Dashboard, which is simpler and only shows relevant data for labour users. Figure 16 displays the Labour Dashboard interface, where labour users can view the total number of plants and the latest sensor readings like humidity, temperature, soil moisture, and water usage.

b. Plant and Sensor Management Source Code and Interface

Fig. 17 *Plant Management Source Code*

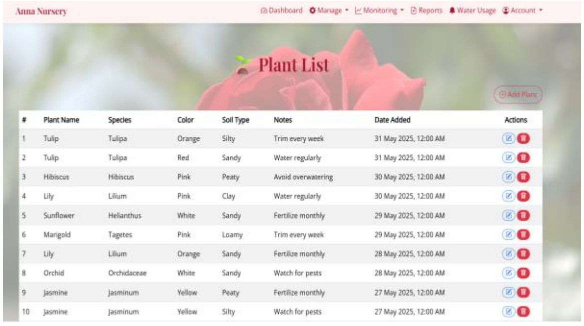


Fig. 18 *Plant Management Interface*

Fig. 19 *Sensor Management Source Code*

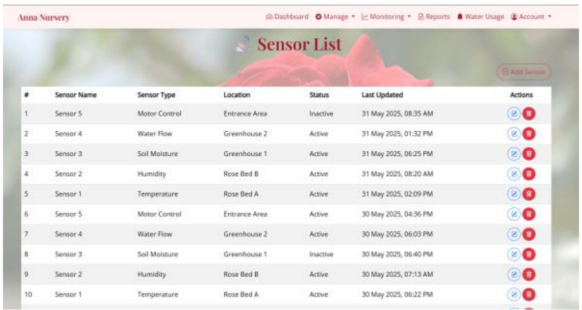


Fig. 20 *Sensor Management Interface*

Figures 17 to 20 present the Plant and Sensor Management components of the system. Figure 17 shows the source code for the Plant Management module, which allows administrators and nursery staff to add, edit, or delete plant records in the database. Figure 18 displays the Plant Management Interface, where a list of registered plants is presented in a table along with details such as species, color, soil type, and date added, with options to edit or delete each entry. Figure 19 illustrates the Sensor Management module source code, which fetches sensor data from the database and displays it in a structured table format. Figure 20 shows the corresponding Sensor Management Interface, where all registered sensors are listed along with details such as sensor type, location, and status. Action buttons are provided for editing or deleting each sensor entry, enabling efficient and centralized management of all IoT sensors deployed within the system.

c. Live Sensor Readings and Charts Source Code and Interface

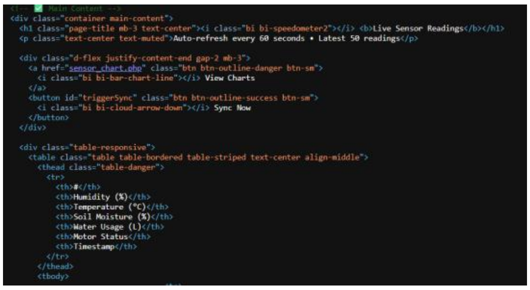


Fig. 21 *Live Sensor and Charts Readings Source Code*

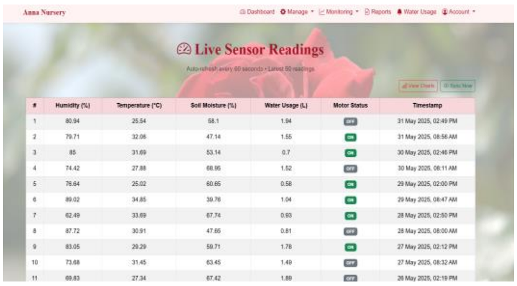
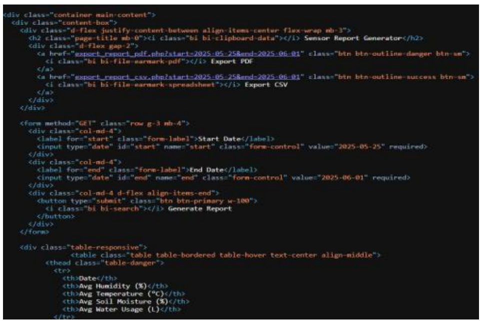


Fig. 22 *Live Sensor Readings interface*

Fig. 23 *Sensor Chart interface*

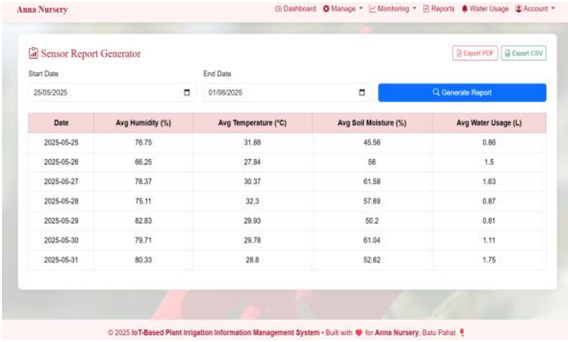
Figures 21 to 23 show the Live Sensor Readings and Chart module in the system. Figure 21 displays the source code that creates a live table showing humidity, temperature, soil moisture, water usage, motor status, and timestamps. Figure 22 shows the actual interface where users can view the latest 50 sensor readings, which are automatically refreshed every 60 seconds. There are also buttons to view charts and manually sync the data. Figure 23 shows the chart interface that visualizes sensor trends over the past 7 days, helping users understand environmental changes over time through line graphs.

d. Generate Report Source Code and Interface



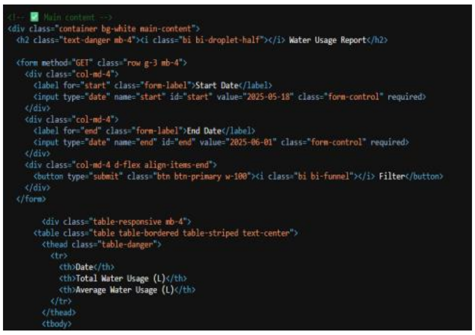
```
<div class="container main-content">
  <div class="content-box">
    <div class="d-flex justify-content-between align-items-center flex-wrap mb-3">
      <h2 class="page-title mb-0"><i class="bi bi-clipboard-data"></i> Sensor Report Generator</h2>
      <div class="d-flex gap-2">
        <a href="export_report_pdf.php?start=2025-05-25&end=2025-06-01" class="btn btn-outline-danger btn-sm">
          <i class="bi bi-file-earmark-pdf"></i> Export PDF
        </a>
        <a href="export_report_csv.php?start=2025-05-25&end=2025-06-01" class="btn btn-outline-success btn-sm">
          <i class="bi bi-file-earmark-spreadsheet"></i> Export CSV
        </a>
      </div>
    </div>

    <form method="GET" class="row g-3 mb-4">
      <div class="col-md-4">
        <label for="start" class="form-label">Start Date</label>
        <input type="date" id="start" name="start" class="form-control" value="2025-05-25" required>
      </div>
      <div class="col-md-4">
        <label for="end" class="form-label">End Date</label>
        <input type="date" id="end" name="end" class="form-control" value="2025-06-01" required>
      </div>
      <div class="col-md-4 d-flex align-items-end">
        <button type="submit" class="btn btn-primary w-100">
          <i class="bi bi-search"></i> Generate Report
        </button>
      </div>
    </form>

    <div class="table-responsive">
          <table class="table table-bordered table-hover text-center align-middle">
        <thead class="table-danger">
          <tr>
            <th>Date</th>
            <th>Avg Humidity (%)</th>
            <th>Avg Temperature (°C)</th>
            <th>Avg Soil Moisture (%)</th>
            <th>Avg Water Usage (L)</th>
          </tr>
```

Fig. 24 *Generate Sensor Report Source Code*



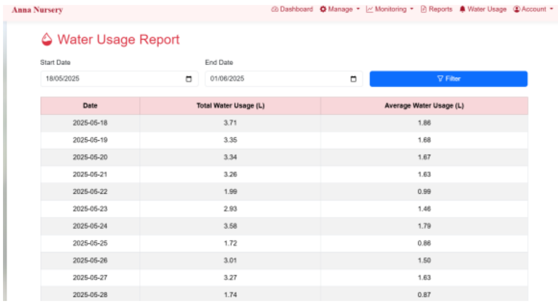
Date	Avg Humidity (%)	Avg Temperature (°C)	Avg Soil Moisture (%)	Avg Water Usage (L)
2025-05-25	76.75	31.88	45.56	0.86
2025-05-26	66.25	27.84	56	1.5
2025-05-27	78.37	30.37	61.58	1.63
2025-05-28	75.11	32.3	57.69	0.87
2025-05-29	82.83	29.93	50.2	0.81
2025-05-30	79.71	29.78	61.04	1.11
2025-05-31	80.33	28.8	52.62	1.75

Fig. 25 *Generate Sensor Report Interface*



```
<!-- ✅ Main content -->
<div class="container bg-white main-content">
  <h2 class="text-danger mb-4"><i class="bi bi-droplet-half"></i> Water Usage Report</h2>

  <form method="GET" class="row g-3 mb-4">
    <div class="col-md-4">
      <label for="start" class="form-label">Start Date</label>
      <input type="date" name="start" id="start" value="2025-05-18" class="form-control" required>
    </div>
    <div class="col-md-4">
      <label for="end" class="form-label">End Date</label>
      <input type="date" name="end" id="end" value="2025-06-01" class="form-control" required>
    </div>
    <div class="col-md-4 d-flex align-items-end">
      <button type="submit" class="btn btn-primary w-100"><i class="bi bi-funnel"></i> Filter</button>
    </div>
  </form>

      <div class="table-responsive mb-4">
    <table class="table table-bordered table-striped text-center">
      <thead class="table-danger">
        <tr>
          <th>Date</th>
          <th>Total Water Usage (L)</th>
          <th>Average Water Usage (L)</th>
        </tr>
      </thead>
      <tbody>
```

Fig. 26 *Generate Water Usage Report Source Code*



Date	Total Water Usage (L)	Average Water Usage (L)
2025-05-18	3.71	1.86
2025-05-19	3.35	1.68
2025-05-20	3.34	1.67
2025-05-21	3.26	1.63
2025-05-22	1.99	0.99
2025-05-23	2.93	1.46
2025-05-24	3.58	1.79
2025-05-25	1.72	0.86
2025-05-26	3.01	1.50
2025-05-27	3.27	1.63
2025-05-28	1.74	0.87

Fig. 27 *Generate Water Usage Report Interface*

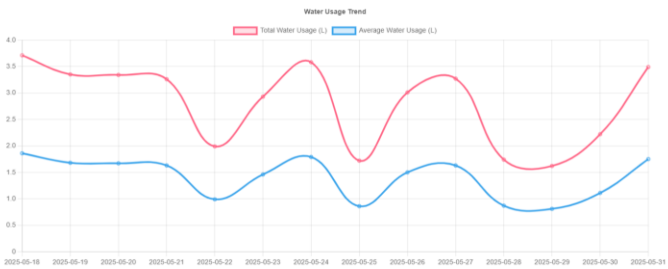


Fig. 28 *Water Usage Chart Interface*

Figures 24 to 28 show the full implementation of the system's reporting features for sensor data and water usage. Figure 24 presents the source code for the Sensor Report Generator, where users can select a date range and generate a table showing average humidity, temperature, soil moisture, and water usage. Figure 25 displays the interface of that report, including options to export it as a PDF or CSV. Figure 26 shows the code for the Water Usage Report, which filters total and average water usage by date. Figure 27 displays the report interface, where filtered data is clearly shown in table format. Finally, Figure 28 presents the Water Usage Chart Interface, which visualizes trends in total and average water usage over time using a line chart. This helps users easily interpret water consumption patterns and make informed irrigation decisions.

4.1 Testing

a. Account Registration and Login Module

This module was tested to ensure that both labor and admin users can register and log in. The test also checked whether the system blocks access when incorrect login details are entered. All tests confirmed that the system handles registration and login properly.

b. Sensor and Data Collection Module

This part of the system was tested to make sure sensor data such as temperature, humidity, soil moisture, and water usage is collected from IoT devices, saved correctly in the database, and displayed in real-time. The system successfully handled missing data and displayed appropriate messages when sensors failed.

c. Control and Automation Module

This module manages the automatic turning on and off of the motor based on soil moisture readings. It was also tested for manual control by the admin. All tests showed that the motor activates or deactivates correctly and reflects the current status on the dashboard in real-time.

d. Water Usage Tracking Module

This module tracks how much water is used during irrigation. Tests were done to confirm that the system correctly logs water usage, calculates daily totals and averages, and allows users to view reports based on specific date ranges. The module worked as intended.

e. Data Analysis and Reporting Module

This module was tested for generating reports based on selected dates and for showing daily average values. It also includes chart visualizations of sensor data trends. The system successfully generated accurate reports and displayed clear charts to help users understand the data.

5. Conclusion

The IoT-Based Plant Irrigation Information Management System marks a major advancement in agricultural techniques, especially for growing roses at Anna Nursery. By combining technologies such as IoT sensors, automation and real-time data analytics, the system improves water efficiency, minimizes manual efforts and ensures reliable plant maintenance. Features such as an intuitive interface, water usage tracking and comprehensive reporting empower workers and managers to make informed decisions. The system not only improves operational efficiency but also promotes sustainable irrigation methods, reducing resource waste. The initiative provides a practical approach to modernizing conventional irrigation techniques, paving the way for smarter and more sustainable farming practices. Looking ahead, several improvements can be made to further improve the IoT-Based Plant Irrigation Information Management System. Future developments may include the integration of advanced machine learning algorithms to predict water requirements based on environmental factors, enabling greater efficiency. Additionally, expanding the system to support a wider range of plant types and irrigation techniques could broaden its applicability across different agricultural settings. Implementing mobile access and notifications will allow users to monitor and manage irrigation remotely, increasing convenience and responsiveness. Furthermore, ongoing collaboration with agricultural experts can lead to continuous updates and improvements, ensuring that the system remains at the forefront of smart farming technology. This future work will not only enhance the system's functionality but also contribute to the advancement of sustainable agricultural practices on a larger scale.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

This journal requires that all authors take public responsibility for the content of the work submitted for review. The contributions of all authors must be described in the following manner:

The author confirms sole responsibility for the following: **study conception and design**: Diveadarsini, Nureize; **data collection**: Diveadarsini, Nureize; **analysis and interpretation of results**: Diveadarsini, Nureize; **draft manuscript preparation**: Nureize. All authors reviewed the results and approved the final version of the manuscript.

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Appendix A : System Testing Form (Stakeholder)

UTHM
Universiti Tun Hussein Onn Malaysia

Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor

System Testing Form

Student's Name : Diveadarsini A/P A.Jagathison

Matric No : CI220107

Project Title : IoT-Based Plant Irrigation Information Management System

**Note: This System Testing Form is provided to obtain feedback from system users to find out the extent of the capabilities of the developed system. This form has 2 parts, namely Part A and Part B. Please answer all questions.

Please tick (/) the appropriate evaluation box.

Part A

1	Not Satisfactory
2	Satisfying
3	Moderately Good
4	Good
5	Very Good

Num.	Questions	1	2	3	4	5
1.	User-friendly system					/
2.	System uses appropriate colors					/
3.	System uses attractive displays					/
4.	Text displays make it easy for users to read and understand to use the system					/
5.	Position the login display in the appropriate place					/

Part B

Please tick (/) the answer Yes or No.

Num.	Questions	Answer Yes	Answer No
System's Content			
1.	The content presentation in the system is informative and relevant to irrigation monitoring	/	
2.	All buttons and interactive features function correctly	/	
3.	The system provides sufficient information about irrigation system management	/	
4.	The system helps administrators and laborers access irrigation-related data more easily	/	
User Friendly			
1.	The system is easy to use for daily irrigation-related tasks	/	
2.	Users can understand and interact with system features easily	/	
3.	The system supports users in efficiently managing irrigation processes	/	
Text			
1.	The writing used is clear and easy to read	/	
2.	The terminology used (e.g., motor status, soil moisture) is appropriate	/	
3.	Instructions and system messages are easy to understand	/	
4.	The text size used in the system is appropriate and readable	/	
Graphics			
1.	The background and visual layout are appropriate for data presentation	/	
2.	The color scheme used supports readability and conveys irrigation status effectively	/	
3.	The overall interface design is attractive and user-focused	/	
Overall System Assessment			
1.	This system is a helpful digital tool for managing plant irrigation activities	/	
2.	The system is easy to operate and navigate	/	
3.	The system functions without major errors or crashes	/	
4.	The sensor data and database values are displayed accurately in the interface	/	

Comments / Suggestions :

Signature and Stamp (if any) :

Date : 9.6.2025

Appendix B : System User Manual

- **Introduction**

This user manual provides guidance for the IoT-Based Plant Irrigation Information Management System. It is divided into two parts: server setup and environment, and system operation guide.

- **Server and Environment Setup**

This section outlines the guidelines for setting up the environment required for the system.

Minimum Hardware and Software Requirements

Aspect	Requirement
Operating System	Windows 10 or newer (64-bit recommended)
CPU	2.0 GHz dual-core processor or better (Intel Core i3 equivalent or higher recommended)
Memory	8 GB of RAM (16 GB or more recommended for demanding)
Storage	128 GB SSD or more (256 GB or 512 GB SSD recommended for better performance and storage)
Internet Connection	25 Mbps download / 3 Mbps upload or higher recommended
Browser	Latest stable version of a modern web browser (Google Chrome, Mozilla Firefox, Microsoft Edge, Safari)
Display	1280 x 720 resolution or higher (1920 x 1080 Full HD recommended)
Graphics	Integrated graphics capable of supporting the display resolution (Dedicated GPU recommended for graphics-intensive applications)
Peripherals	Keyboard and Mouse/Trackpad

- **Database Setup**

To activate the server, follow these procedures:

1. Install XAMPP (https://www.apachefriends.org).
2. Extract the IoT-Based Plant Irrigation Information Management System file to C:\xampp\htdocs.
3. Open XAMPP Control Panel, start "Apache" and "MySQL" modules.
4. Select "Admin" from Apache to view the Localhost Dashboard.
5. Select "phpMyAdmin".
6. Select "Import".
7. Click "Choose File" and select the database file (u381499631_iot_irrigation.sql).

- **Web-Based System: System Operation Guides**

This section provides comprehensive guidance on utilizing the web-based features, ensuring efficient monitoring and management of plant irrigation.

A. Landing Page

The initial entry point providing system overview, "Login" and "Register" buttons, and navigation links (About, Features, Contact, Find). Domain: annasmartirrigation.site

B. Register Page

Allows new Labor users to create an account by entering Full Name, Email address, Password, and Confirm Password, then clicking "Register". Existing users can click "Already have an account? Login".

C. Login Page

For all registered users (Admin/Labor) to securely access accounts. Users enter Email address and Password, then click "Login". Options include "Forgot Password?" and "Create an Account".

D. Forgot Password Page

For users who forgot their password. Enter email address and click "Send Reset Link". Instructions are sent via email. Option to return to Login page.

E. Dashboard Page

The main operational hub displaying real-time sensor readings and summaries.

i. Admin Dashboard
Provides a comprehensive overview with Total Users , Total Plants , Total Sensors , and Latest Sensor Readings (Humidity, Temperature, Soil Moisture, Water Usage, Motor Status). Navigation includes Manage (Users, Plants, Sensors), Monitoring (Sensor Readings, Alerts), Reports, Water Usage, and Account settings.

ii. Labor Dashboard
Tailored for daily tasks, focusing on Total Plants and Latest Sensor Readings (Humidity , Temperature , Soil Moisture, Water Usage , Motor Status). Navigation includes Plants, Sensors, Charts, Water Usage, and Account settings.

F. Plant List Page
Accessible to both Admin and Labor users for viewing, adding, editing, and deleting plant records. Displays Plant Name , Species , Color, Soil Type , Notes , and Date Added. Actions include "Add Plant" , "Edit" , and "Delete" (with confirmation).

G. Sensor List Page
Provides inventory of IoT sensors. Admin has full management; Labor can only view. Displays Sensor Name , Sensor Type , Location , Status , and Last Updated. Admin actions: "Add Sensor" , "Edit" , "Delete" (with confirmation). Labor users cannot access Add/Edit/Delete functions.

H. Live Sensor Readings Page
Accessible to both Admin and Labor users. Displays real-time data that auto-refreshes every 60 seconds , showing the latest 50 readings. Data points include Humidity , Temperature , Soil Moisture, Water Usage , Motor Status, and Timestamp. Users can "View Charts" for trends or "Sync Now" for immediate refresh.

I. Water Usage Report Page
Accessible to both Admin and Labor users. Allows filtering by Start Date and End Date ,then clicking "Filter". Report table includes Date , Total Water Usage (L) , and Average Water Usage (L).

J. My Profile Page
Accessible to both Admin and Labor users for managing their own profiles. Users can update Full Name , Email Address , Phone Number , House Address, and Favorite Plant. Password change is optional: leave fields blank to keep current password. Click "Update Profile" to save changes.

K. User Management Page
Admin-only page for managing user accounts. Displays Full Name ,Email, and Role. Admins can "Edit" user roles or "Delete" users (with confirmation).

L. Sensor Report Generator Page
Admin-only feature for generating historical sensor data reports. Users select Start Date and End Date , then click "Generate Report". The report table provides average daily data for Humidity , Temperature , Soil Moisture , and Water Usage. Reports can be exported as "PDF" or "CSV".