IntelliGROW

Smart Irrigation and Fertilization System

Capstone Project Report END SEMESTER EVALUATION

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ABSTRACT

India, primarily agrarian, sees around 70% of its population directly or indirectly dependent on agriculture for their livelihoods. Today, the agricultural sector in India is at a critical juncture as it grapples with the twin challenges of catering to a burgeoning population and addressing the impacts of climate change. To address these pressing issues, a transformative solution named "IntelliGROW" emerges as a beacon of hope, leveraging innovative technologies to revolutionize traditional agricultural methodologies and foster sustainability.

"IntelliGROW" integrates indigenous expertise with state-of-the-art technology, creating a solution that resonates with the unique agricultural landscape of India. The system's core components include advanced sensors strategically placed in the root zone of plants, including a soil moisture sensor, NPK sensor, and temperature-humidity sensor. These sensors facilitate real-time monitoring of critical parameters such as soil moisture, nutrient levels, weather conditions, and crop growth dynamics.

A pivotal element of "IntelliGROW" is its microcontroller-based gateway unit, which manages sensor data, activates actuators and transmits information to an isolated cloud server. Leveraging this data, "IntelliGROW" employs sophisticated algorithms developed with threshold values of soil moisture and nutrient levels to make informed decisions regarding irrigation scheduling and nutrient application, fostering a paradigm shift towards efficient resource management and optimized crop yield. The farmers can remotely access the "IntelliGROW" system through a user-friendly dashboard, receiving real-time insights on plant data and system performance.

Crucially, the system addresses sustainability concerns associated with chemical fertilizers, particularly the runoff of excess nutrients. By integrating the NPK (Nitrogen, Phosphorus, Potassium) sensor, "IntelliGROW" ensures that fertilization is precisely tailored to the needs of the crops, minimizing the risk of over-application and subsequent leaching. This approach not only enhances the economic viability of farming but also mitigates the environmental impacts of curbing the release of excess chemicals into water bodies.

Moreover, “IntelliGROW” addresses water usage concerns by incorporating an intelligent drainage system. The perforated drainage pipe efficiently prevents water-logging, safeguarding the roots from damage. Additionally, the system stores excess water for future use, promoting a sustainable water management paradigm.

In essence, “IntelliGROW” stands as a symbol of technological prowess and sustainability, offering a lifeline to Indian agriculture in the face of contemporary challenges.

DECLARATION

We hereby declare that the design principles and working prototype model of the project entitled IntelliGROW is an authentic record of our own work carried out in the Computer Science and Engineering Department, TIET, Patiala, under the guidance of Dr. Sharad Saxena and during 6th and 7th semester (2023).

Date: 19 December, 2023

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Lastly, we would also like to thank our families for their unyielding love and encouragement. They always wanted the best for us and we admire their determination and sacrifice.

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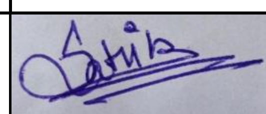
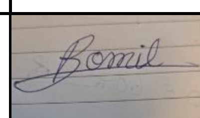
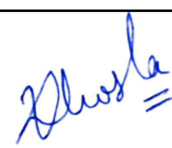
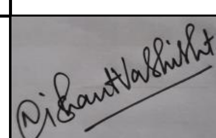
102003283	Satvik Maheshwari	
102003290	Romil Gupta	
102003295	Vardaan Khosla	
102003300	Nishant Sharma	
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

IDE	Integrated Development Environment
BI	Business Intelligence
NPK	Nitrogen Phosphorus Potassium

INTRODUCTION

1.1 Project Overview

Project Objectives:

The main objective of this endeavor is to enhance plant well-being by meticulously monitoring and maintaining essential factors such as water levels, nutrient equilibrium, and proper drainage. Specific goals encompass:

- Smart Irrigation: By employing water sensors, the system intelligently gauges soil moisture, administering water as required to prevent overhydration and underwatering.
- Nutrient Precision: Nutrient sensors evaluate soil fertilization levels, enabling accurate delivery of essential elements through irrigation to sustain optimal plant nourishment.
- Adaptive Irrigation Control: Through a sophisticated irrigation control mechanism, the system adapts watering and nutrient supply schedules based on real-time sensor data, specific plant types, and prevailing environmental conditions.
- Efficient Drainage: A specialized drainage management system prevents water accumulation and root rot by efficiently redirecting excess water away from the soil.

System Components:

The project amalgamates a variety of vital components:

- Sensors: Water sensors analyze soil moisture, while nutrient sensors scrutinize soil nutrient content, providing invaluable insights for informed decision-making.
- Microcontroller: Powered by an Arduino microcontroller, the system processes sensor inputs and orchestrates irrigation and drainage functions using

established algorithms.

- Actuators: Solenoid valves regulate water flow through the drip irrigation network, guaranteeing precise water distribution. Drainage pipes, equipped with perforations efficiently manage the elimination of surplus water.
- Fertilization Mechanism: A dedicated system dispenses fertilizers or nutrients into the irrigation stream, guaranteeing an optimal nutrient balance for thriving plant growth.

Benefits:

The "Automatic Irrigation and Fertilization System with Drainage Management" offers numerous advantages:

- Enhanced Efficiency: Water conservation is prioritized as water is supplied only as necessary, significantly curbing wastage.
- Improved Plant Health: Plants receive optimal water and nutrients, fostering vigorous growth and decreasing disease susceptibility.
- Reduced Labor Intensity: Manual intervention is minimized, affording farmers and gardeners more time for other tasks.
- Positive Environmental Impact: By curbing water usage and preventing nutrient runoff, the system contributes to overall environmental sustainability.

Conclusion:

Integrating sensor technology and intelligent control systems in the "Automatic Irrigation and Fertilization System with Drainage Management" constitutes a transformative approach to plant cultivation. The project aims to promote healthier, more productive, and ecologically sustainable agricultural and horticultural practices, revolutionizing the art of nurturing plants.

1.2 Need Analysis

Smart irrigation and fertilization systems are becoming increasingly important in modern agriculture. With a growing population and limited resources, the demand for food production is increasing daily. There needs to be more than the traditional methods of agriculture to meet the population's food demands. Thus, there is a need for more efficient and sustainable ways of agriculture.

In this context, the smart irrigation and fertilization system solves some of the challenges faced in traditional agriculture. The system monitors and controls the soil's condition, including nutrient content, moisture levels, and sunlight exposure. With this information, farmers can make data-driven decisions about when and how much to water their crops and which nutrients to apply.

The project has several benefits. Firstly, it can help to minimize crop wastage, as farmers can take early action to correct any issues with their crops or soil before they become severe. Secondly, the project can help to prevent waterlogging due to rain and minimize water wastage. By recycling the excess water flows, farmers can amplify the groundwater levels and ensure a more consistent water supply. This is particularly important in areas prone to droughts or with limited access to water resources.

The proposed irrigation system can be accessed through a mobile application to offer convenience to farmers. They can remotely monitor the irrigation system to save time and effort.

Moreover, the stagnant water can be a breeding ground for parasites such as mosquitoes and can make the roots prone to fungal attacks. Thus, the suction equipment can store excess water and help provide an advantage to prevent waterlogging and soil erosion.

The problem of a shortage of skilled labor is prevalent in many areas, making it difficult to manage large-scale agriculture operations. Thus, the smart crop monitoring and irrigation system helps mitigate the impact of labor shortages by automating the irrigation and fertilization processes. This allows farmers to focus on other essential tasks, such as crop management and harvesting.

In conclusion, the proposed project is essential in the current agricultural scenario. It addresses the need for more efficient and sustainable methods of agriculture and offers solutions to the challenges faced by traditional farming methods. It has the potential to enhance crop yield, minimize crop wastage, prevent water overlogging, amplify groundwater levels, and limit the amount of fertilizer runoff which ultimately contributes to the nation's food security.

1.3 Research Gaps

- Economic Viability and Adoption Challenges:
  The adoption of advanced agricultural technologies depends on their economic feasibility for farmers. Research is needed to assess the cost-benefit ratio of implementing the IntelliGROW system, considering factors such as initial setup costs, operational expenses, and potential increase in crop yield.
- Adaptive Water Storage and Management:
  The idea of a water storage solution is promising, but there is a research gap in designing an adaptive system that not only removes excess water from the soil but also intelligently manages the stored water based on predicted weather patterns, crop water requirements, and soil conditions.
- Scaling for Large and Diverse Agricultural Landscapes:
  Most research in smart agriculture focuses on small-scale trials. However, there's a gap in studying how the IntelliGROW system can be effectively scaled up and adapted for diverse agricultural landscapes, including different soil types, weather conditions, and crop varieties.
- Multi-Crop Adaptability:
  Most studies concentrate on a single crop type. Research could be conducted to evaluate the adaptability and effectiveness of the IntelliGROW system across a variety of crops, considering the unique growth patterns and nutrient requirements of each crop.
- User Training and Education:
  A research gap exists in designing effective training and educational materials for farmers to use and understand the IntelliGROW system. Exploring the most

efficient ways to transfer technical knowledge to farmers, especially in rural areas, is essential

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1.4 Problem Definition and Scope

Problem Definition:

Traditional plant care methods fall short in providing optimal growth conditions and efficient resource utilization in today's rapidly changing and toxic environment. Manual monitoring of plant health, soil nutrient levels, and moisture content leads to guesswork and inconsistent results. Furthermore, excessive waterlogging poses a threat to plant roots, resulting in stunted growth and wasted resources. There is a pressing need for an innovative solution that revolutionizes plant care by introducing real- time monitoring, intelligent feedback, and automated nutrient and water supply.

Scope:

The scope of this engineering capstone project, aptly named "IntelliGROW", encompasses the following captivating objectives:

- Real-time Monitoring: Implement sensors to continuously monitor plant growth, soil nutrient levels, and moisture content at regular intervals.
- Data Transmission and Engaging Dashboard: Pioneering a user-friendly dashboard, transmitting the gathered data instantly, empowering users with a captivating visual representation of their plant's journey, fostering a deeper connection between humans and nature.
- Intelligent Nutrient and Water Supply: Develop ingenious mechanisms that tap into the power of artificial intelligence, enabling the system to analyze the monitored data and autonomously supply plants with precise nutrients and water, ensuring their flourishing health.
- Excessive Moisture Detection: Incorporate sensors to detect excessive soil moisture levels and prevent root damage caused by waterlogging.

- Water Conservation: Design and integrate a reservoir system to collect and store excess water, thereby minimizing wastage and enabling future use during dry periods.

The IntelliGROW project transcends the ordinary, aiming to redefine plant care by harnessing the power of technology and intelligent automation. The focus lies in creating a working prototype that showcases the extraordinary potential of IntelliGROW. While commercial production is beyond the scope of this project, we lay the foundation for a future where plants flourish effortlessly and environmental stewardship thrives.

1.5 Assumptions and Constraints

Assumptions:

1. The system is designed for small rooted plants only, and may not be suitable for larger plants or crops.
2. The system assumes a consistent and reliable power supply to operate the sensors, microcontrollers, and other components.
3. The project assumes that the drip irrigation system, suction pump, and other on-ground components are installed and functioning properly.

Constraints:

1. The project may be limited by the budget available for purchasing the necessary components and tools.
2. The project may be constrained by the availability of skilled labour for installing and maintaining the on-ground components.
3. The system may be limited by the range and reliability of the wireless communication protocols used to transmit data between the sensors and the control system.

1.6 Standards

- IEEE 802.11 WLAN Standards
- IP65 (Ingress Protection)
- RoHS (Restriction of Hazardous Substances)
- Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC) standards
- Cloud Platform Security Standards

1.7 Approved Objectives

- Develop a smart irrigation system to monitor soil conditions, plant health, and environmental factors such as temperature and humidity
- Automate the system to predict the optimal timing for irrigation and fertilization using real-time data analysis.
- Creation of a user-friendly web application that allows farmers to monitor their crops remotely.
- Utilization of subsurface drainage system to drain out excess water by deploying perforated pipes.

1.8 Methodology

The methodology for building an automated irrigation and fertilization system by monitoring moisture and nutrient levels of small rooted plants using machine learning and IoT sensors involves several steps. These steps are-

1. **Requirement Gathering:** It involves defining the requirements for the system and selecting the required sensors. Sensors will gather data on various environmental factors like moisture, temperature, and humidity. The sensors involved are listed below-

Sensors Required	**Function**
Rain Drop Sensor	It can alert farmers about the risk of flooding in their fields, detect rainfall and automatically adjust irrigation schedules.
Temperature and Humidity Sensor	Monitors the agricultural planting environment's air temperature and humidity changes.
Flow Sensor Module	By measuring the flow rate of water, the flow sensor can detect leaks, ensure crops receive the optimal amount of water, track water usage, and perform preventive maintenance.
LDR Sensor	It will see the sunlight received throughout the day.
Water Level Sensor	It is helpful to determine the remaining water and fertilizers in the storage tanks so that the system never runs short of adequate amounts of these essential components.
Raspberry Pi/Arduino Uno	It is most widely used as the central controlling unit that can manage the operation of the various sensors and devices.
Soil NPK Sensor	The NPK sensor detects nitrogen, phosphorus, and potassium levels in the soil by measuring conductivity changes. This allows it to determine soil fertility based on the concentrations of these nutrients.
Mini Water Pump	A mini water pump is a small, portable device that pumps water from the reservoir to irrigate small gardens or potted plants.
Solenoid Valve	Solenoid valves are used in automatic irrigation systems to regulate water flow to different areas of a garden or farm. They can be programmed to open and close at specific times, ensuring plants get the proper water.

ESP8266 Wi-Fi Module	It can connect sensors that measure soil moisture, temperature, and other parameters to the internet. The module can transmit this data to a cloud-based server or web application using Wi-Fi.

Table 1: Sensors required and their functions

2. Hardware Development: This involves deploying the sensors on the field and testing them. Next, the architectural framework of pipes and irrigation systems is designed. It is adjusted according to the land size and placed with suction pumps so that the microcontrollers can activate it. On-ground testing ensures that the automated irrigation and fertilization system is functioning correctly, which includes checking the sensor readings, pump activation, and the effect of the design on the overall health and growth of plants. It will also involve designing a water and nutrient dispenser system that will supply water and nutrients as and when required.

3. Model Training: The dispenser system will be trained with sensor data and other sources to optimize crop irrigation schedules. It will be trained using scientifically established threshold data to predict when and how much water to apply to the crops, considering both weather patterns and soil conditions. Dispenser will use the real-time data to supply nutrients and water whenever there is a deficit in the soil. The irrigation and dispensing system will be programmed to turn on and off at times when specific conditions are not met.

4. Excess Water Storage: Suction facility will extract excess rainwater from the irrigation area and store it in a tank to minimize water wastage. This approach will not only help to conserve water but also prevent the irrigation area from becoming waterlogged.

5. Web Application: A web-based application will be developed for the system to provide ease to farmers. This would enable them to keep track of the irrigation schedules and provide them real time data updates.

6. Hardware & Software Integration: The finalized hardware architecture will be integrated with the developed web-application via a wireless Wi-Fi module and the real time data would be managed by a cloud facility such as Blynk IoT.

7. System Testing: The final step is to field-test the system under real-world growing conditions and optimize it based on the performance and feedback obtained during field testing.

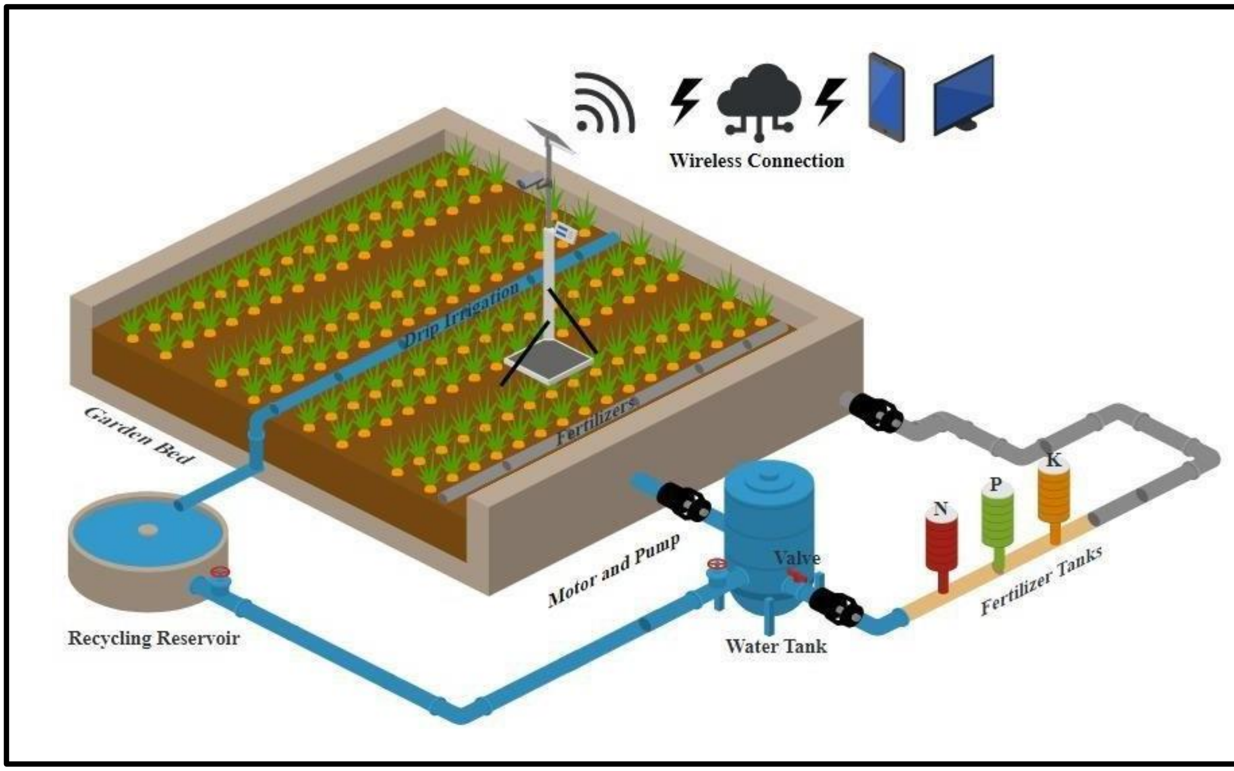


Fig 1: Smart Irrigation and Fertilization System

1.9 Project Outcomes and Deliverables

Project Outcomes:

1. **Optimization of plant growth and health:** The project's primary outcome is the optimization of plant growth and health through precise irrigation, nutrient management, and drainage control. This translates into increased crop yield, improved quality, and healthier plants.

2. **Resource Efficiency**: By employing advanced sensor technology and intelligent control systems, the project enhances resource efficiency. Water and nutrient utilization is optimized, reducing wastage and promoting sustainable agricultural practices.

3. **Labor Reduction**: The automation of essential plant care tasks reduces manual labor demands. Farmers and gardeners can allocate their time more effectively, leading to improved productivity and enhanced livelihoods.

4. **Environmental Sustainability:** "IntelliGROW" contributes to environmental sustainability by curbing water wastage and nutrient runoff. This has a positive impact on local ecosystems and water bodies.

Deliverables:

1. **Automated Irrigation and Fertilization System:** The project will deliver a fully functional automated system that integrates sensors, microcontrollers, and actuators to manage irrigation, fertilization, and drainage processes.
2. **User-Friendly Dashboard:** A user-friendly dashboard will be provided for remote monitoring and control. It will offer real-time data visualization, alerts, and insights for informed decision- making.
3. **System Documentation:** Comprehensive documentation outlining the system's design, components, operation, and maintenance procedures will be delivered.
4. **Educational Materials**: Workshops, training sessions, and educational materials will be developed to educate farmers about the benefits and usage of IntelliGROW.

1.10 Novelty of Work

One of the key differentiators of IntelliGROW is its intelligent plant health monitoring system. Unlike conventional methods that rely on periodic checks, IntelliGROW employs real-time monitoring of crucial plant growth parameters, such as soil nutrient levels and moisture content. By integrating advanced sensors and data analysis techniques, the system provides instant feedback, enabling precise and timely care for each plant's specific needs.

IntelliGROW takes plant care to the next level with its automated nutrient and water supply system. Powered by the combination of Machine Learning, IOT and AI, it autonomously regulates the delivery of nutrients and water based on the unique requirements of each plant. This tailored approach maximizes efficiency, minimizes resource waste, and ensures optimal nourishment for thriving plant growth.

What sets IntelliGROW apart is its unprecedented application in the field of plant care. While traditional methods prevail, IntelliGROW emerges as a pioneering solution that brings the power of technology and automation to the forefront. By seamlessly integrating state-of-the-art algorithms, intelligent monitoring, and automated care, IntelliGROW redefines the boundaries of plant care practices.

2.1 Literature Survey

2.1.1 Theory Associated with Problem Area

The problem that "IntelliGROW" solves lies at the intersection of agricultural resource optimization, crop yield enhancement, and environmental sustainability. The theoretical underpinnings of this problem encompass several key concepts:

- **Resource Scarcity Theory:** Agriculture often faces the challenge of resource scarcity, particularly water and nutrients. As the global population grows and water availability becomes more unpredictable due to climate change, there's an urgent need to optimize resource utilization.
- **Yield Gap Theory:** The yield gap refers to the difference between a crop's potential yield and its actual yield on a farm. This concept highlights inefficiencies in resource allocation and management.
- **Environmental Stewardship Theory:** Modern agriculture is under pressure to reduce its ecological footprint. Excessive use of water and fertilizers can lead to pollution of water bodies and soil degradation.
- **Automation and Smart Technology Theory:** This theory recognizes the potential of automation to streamline agricultural operations, improve outcomes, and enhance efficiency by reducing manual labor.

"IntelliGROW" tackles a multifaceted problem by addressing these theoretical aspects by providing a holistic solution that integrates technology, science, and sustainability. Its approach aligns with the evolving needs of modern agriculture, striving to enhance productivity while promoting responsible resource management and environmental conservation.

2.1.2 Existing Systems and Solutions

Fasal

Fasal is an Indian startup specializing in agriculture technology. Fasal uses farm-level data to predict growth conditions and resource requirements - including irrigation, sprays, fertigation, and other preventive measures and notifies farmers to make informed decisions. The Fasal system continuously checks water availability in the soil to ensure that the irrigation requirement of the crop is precisely met at all times, based on the crop, its stage, and soil characteristics. The Fasal disease prediction and assessment systems forewarn farmers and agri institutions about the possibility of crop disease, its severity, and the possibility of a pest outbreak. [1]

Unnati's AgTech Insight Solutions

A new-age fintech-powered digital farming company offering end-to-end support to farmers nationwide. Driven by soil data and image data of fields, Unnati's AgTech solutions provide access to real-time information, transaction history for the farm, and satellite data for actionable insights. The advanced data analytics tools Unnati uses enable farmers to make more informed decisions about their farm business.[4]

Arable Mark-3 and Arable Vision

Arable Crop Intelligence Solutions such as Arable Mark-3 and Arable Vision uniquely combine weather, plant, and soil/irrigation data with advanced modelling and machine learning for comprehensive, real-time crop insights.[5]

CropX Agronomic Farm Management System

CropX is an easy-to-use yet powerful agronomic farm management system that connects farm data, real-time conditions, and agronomic knowledge to guide successful and sustainable farming while aggregating all agronomic farm data in one place for easy tracking and sharing. The CropX system is a one-stop shop for insights and advice for performing irrigation, disease, nutrition, and effluent management activities to help users minimize the use of inputs while maximizing yields.[2]

AquaSpy IoT Ag Platform Solution

The AquaSpy IoT Ag Platform is an affordable, easy-to-use, wireless solution that significantly improves resource efficiency, predictability, and quality of crop yield for large and smallholder farms. By "listening" to each crop type, farmers can better manage inputs, including nutrients and water. Precise timing and amounts of irrigation saves resources and reduces pollutants and runoff. AquaSpy multi-sensor probes vertically monitor moisture, temperature, and EC data at 4-inch intervals and transmit it to the AgSpy cloud-based IOT platform. It is auto-analyzed and presented to the grower for insights and critical decision-making.[3]

2.1.2 Research Findings for Existing Literature

S.No.	Roll No.	Name	Paper Title	Findings	Citation
[1]	102003300	Nishant Sharma	Design and Development of Co st- effective Automatic Fertilization System for Small Scale Indian Farm	Design and development of a hardware unit that adjusts the number of fertilizers to be added to the water supply of drip irrigation. An accurate control system using an Arduino board is developed to control the number of fertilizers.	Savani, V., Mecwan, A., Patel, J.G., & Bhatasana, P.M. (2019).
[2]	102003300	Nishant Sharma	Smart Fertilizer Dispensary System for Automated Drip Irrigation	Design and development of wireless smart fertilizer dispensary systems using ZigBee and GSM technology. Use of GSM mobile to wirelessly control and operate solenoid valves.	Bhattacharje e, D., Prakash, O., & Islam, H. (2018).

[3]	102003300	Nishant Sharma	Automated Irrigation System Using a Wireless Sensor Network and GPRS Module	Basics of Evapotranspiration (ET). Implementation and demonstration of automatic irrigation using distributed wireless sensor network and communication links based on a cellular- Internet interface using general packet radio service (GPRS) protocol.	Gutiérrez, J., Villa-Medina, J.F., Nieto-Garibay, A., & Porta-Gándara, M.Á. (2014).
[4]	102003290	Romil Gupta	Automatic Drip Irrigation System Using Fuzzy Logic And Mobile Technology	Classification of irrigation controllers into Open-loop and Closed-loop. Basics of FAO Penman-Monteith Formula to calculate evapotranspiration. Design and implementation	Anand, K., Jayakumar, C., Muthu, M., & Amirneni, S. (2015).

				of Fuzzy Logic.	
[5]	102003283	Satvik Maheshwari	Design and Development of an IoT Based Smart Irrigation and Fertilization System for Chilli Farming	Case Study on Chilli Farming. Calculation of Evapotranspiration (ET) and parameters affecting it. Design and development of a system composed of Edge Nodes and IoT Gateway Nodes. Basics of Irrigation Planning for chilli plants depending on the nature of the soil where they are grown. Comparison between Dripping and Channels Irrigation, Influence of the Height of the Transmitter and Location in the Fields on the Attenuation of the signal.	Prabha, R., Sinitambirivoutin, E., Passelaigue, F., & Ramesh, M.V. (2018).

[6]	102183036	Sundaram Srivastava	Design and Optimization of loT Based Smart Irrigation System in Sri Lanka	Introduction to the Hidden Markov Model (HMM) basics to make weather predictions. Implementation of an irrigation system equipped with a water supply control unit, soil moisture sensing unit, Wi-Fi communication unit, and local processing unit. Investigation of various weather forecasting models along with temperature, humidity, and soil moisture prediction.	Laksiri, H.G., Dharma Gunawardhana, H.A., & Wijayakulasooriya, J.V. (2019).
[7]	102003295	Vardaan Khosla	Smart Irrigation: A Smart Drip Irrigation System Using Cloud, Android and Data Mining	Data Mining Basics for the prediction of future outcomes. Examination of large pre-existing data (here, plant data) to produce the new information. Cloud Computing concepts for communication	Ghosh, S., Sayyed, S.B., Wani, K., Mhatre, M.P., & Hingoli Wala, H.A. (2016).

				between Wi-Fi Module, Sensors, and PC.	
[8]	102003290	Romil Gupta	Smart Irrigation System using IoT based Control Valve	A new sophisticated approach by connecting one mother/feeder pipe to various child pipes, which in turn covers the entire area for watering. The water supplied to the crops is controlled by IoT using LoRa (Long Range) technology. Preference for OGT (Oval Gear Transmitter) flowmeter to be used in the system.	Mujoo, S., Sharma, A., Gaikwad, K., Madhe, S.P., Joshi line, A., Sista, S., & Khatape, M. (2021).
[9]	102003283	Satvik Maheshwari	Real Tim e Automation of Agriculture Environment for Indi an Agricultural	Efforts to automate the irrigation process and its monitoring through the Blynk application to define the irrigation flow rate and time. Use of NodeMCU ESP8266 to	D, E., Sb, K., N, G., & Kumar, D.S. (2022).

			System using IoT	transport data via Wi- Fi technology.	
[10]	102183036	Sundaram Srivastava	Design of Humidity Control with Automatic Drip Irrigation System Based on Fuzzy Logic Using Node-RED and MQ TT on Cact us Plants	Implementation of Node-RED-based MQTT (Message Queue Telemetry Transport) protocol. Use of Fuzzy Logic integrated with MQTT protocol, DHT22 temperature sensor, and soil moisture sensor.	Dianty, R., Mardiati, R., Mulyana, E., & Supriadi, D. (2021).
[11]	102003300	Nishant Sharma	AgriSens: IoT-Based Dynamic Irrigation Scheduling System for Water Management of Irrigated	Design of a real-time automated irrigation system for crop fields using IoT. Proposition of an algorithm for automatic dynamic irrigation treatments in the different phases of a crop's life cycle. Design of a low-cost water-	Roy, S.K., Misra, S., Raghuwanshi, N.S., & Das, S.K. (2020).

			Crops	level sensor that generates discrete values according to the water level present in a field. Provision of information to the farmers through visual display, cell phone, and Web portal using general packet radio service (GPRS)- enabled light-emitting diode (LED) array and liquid crystal display (LCD), global system for mobile communication (GSM) technology, and the Internet.	
[12]	102003300	Nishant Sharma	Towards Smart Agriculture Monitoring Using Fuzzy Systems	Proposition of a framework that enables advanced fuzzy logic to control a pump's switching time according to user-defined variables, whereby sensors are the main aspect of	Abdullah, N., Durani, N.A., Shari, M.F., Siong, K.S., Hau, V.K., Siong, W.N., & Ahmad, I.K. (2021).

				and contributor to the system.	
[13]	102003295	Vardaan Khosla	PFDCs Research Findings on Fertigation	Introduction and background of Fertilizers used in India, the significance of Fertigation, and its equipment. Standards of different fertilizers used for different types of crops.	Patel N. (2017).

Table 2: Literature Survey Findings

2.1.3 Problems Identified

- Systems like Fasal focus on predicting growth conditions and resource requirements but lack comprehensive solutions for precise irrigation and fertilization. On the other hand, Unnati aims at providing financial support and real-time information but does not extensively address irrigation and fertilization management for optimized crop growth based on real-time crop and soil conditions.
- Currently, the systems in practice consume very high power and lack economic feasibility. These solutions may not adequately consider the needs of poor and uneducated farmers and, while being technologically advanced, can inadvertently exclude a significant portion of the agricultural community.

- The cost of these systems is prohibitive for small-scale and economically disadvantaged farmers who lack the financial resources to make such investments. Beyond initial costs, some of the existing solutions involve ongoing maintenance, upgrades, and data connectivity expenses, which further makes it challenging to sustain such commitments.

- Another major problem identified is that of the complexity of some existing systems. Data interpretation and technical operation can overwhelm farmers with limited formal education. This complexity makes the solution less accessible and usable to farmers lacking technical knowledge.

- There is a notable absence of solutions designed specifically to cater to the intricacies of Indian farmlands. Most of the solutions in practice are developed for large commercial farms and might need to be more adaptable to small-scale farmers' diverse crops and farming practices in India.

- Despite various smart agriculture solutions, there remains a significant gap in addressing the specific problem of water logging and precision drainage management. No system, as of now, addresses the crucial aspect of managing excess water through effective drainage systems.

2.1.4 Survey of Tools and Technologies Used

In the domain of smart irrigation and fertilization systems, a diverse array of tools and technologies has been employed to enhance agricultural efficiency. The integration of these tools optimizes irrigation and fertilization practices. Notable components and technologies encompass:

1. Sensors and Data Collection:

- NPK Sensors: These sensors assess soil nitrogen, phosphorus, and potassium levels, crucial for informed fertilization decisions.
- Temperature Sensors: Monitoring ambient temperature aids in assessing plant health.
- Moisture Sensors: These sensors gauge soil moisture levels to tailor irrigation

schedules.

- Water-level Sensors: Used to monitor soil and tank water levels, ensuring proper hydration.

2. Microcontrollers and Embedded Systems:

- Arduino: Employed to construct tailored sensor interfaces and facilitate data collection.

3. Communication Protocols:

- ESP8266 Wi-Fi Module: Facilitates internet connectivity, enabling remote data access and control.

4. Web Application Development and Visualization:

- Blynk: Aids in crafting web and app dashboards for real-time data monitoring and visualization.

5. Database Management:

- MySQL: Selected for storing sensor data and user-related information securely.

6. Control Mechanisms:

- Actuators: Solenoid valves for precise water flow control.

7. Irrigation Management:

- DC Motors: Utilized for water distribution from reservoir to plant.

2.2 Software Requirement Specification

2.2.1 Introduction

2.2.1.1 Purpose

The central purpose of the "IntelliGROW" initiative is to transform agricultural and horticultural methods through the creation of an Internet of Things (IoT)-driven automated system. This system is designed to optimize plant growth, vitality, and the efficient use of resources. The purpose is further outlined as follows:

Enhancing Efficiency: This project's core objective is to elevate plant care efficiency by integrating cutting-edge sensor technology and intelligent control systems. By automating irrigation, fertilization, and drainage procedures, the system ensures that plants receive precisely measured amounts of water, nutrients, and proper drainage. This process eradicates wastage and operational inefficiencies.

Optimal Resource Utilization: IntelliGROW addresses the intricate challenge of resource management in agriculture. By actively monitoring real-time soil moisture, nutrient levels, and drainage patterns, the system allocates water and nutrients intelligently based on the specific requirements of each plant. This approach reduces the overuse of resources while maximizing their effectiveness.

Promoting Healthier Plant Growth: A central aim of this project is to foster robust plant growth. By efficiently maintaining optimal moisture and nutrient levels, the system curtails undernourishment and water-related stress issues, enhancing overall plant health.

Reducing Labor Demands: The IntelliGROW initiative strives to curtail the traditionally associated with plant care manual labour.by automating essential processes like irrigation, fertilization, and drainage, gardeners can more judiciously allocate their time and energy, dedicating their efforts to other critical tasks that necessitate human intervention.

Advancing Environmental Sustainability: An inherent purpose of this project lies in its substantial contribution to environmental sustainability. By employing precise resource management practices and curtailing water and nutrient wastage, the system actively conserves vital resources and mitigates the ecological impact of excessive irrigation practices.

In summation, the central focus of the "IntelliGROW" undertaking is to engineer an innovative, IoT- driven automated system. This system not only elevates agricultural efficiency and productivity but also extends its influence toward ecological sustainability and the propagation of knowledge.

2.2.1.2 Intended Audience and Reading Suggestions

The "IntelliGROW" project is designed to cater to a diverse audience involved in agriculture, horticulture, and technological innovation. The following groups can benefit from the project's insights and outcomes:

1. **Small scale Farmers and Gardeners:** Those directly engaged in crop cultivation and horticulture will find valuable insights on optimizing plant care, reducing labor, and improving yield through advanced automation.

2. **Agricultural Researchers:** Researchers interested in technology-driven solutions for sustainable agriculture can explore the project's innovative approach to irrigation, nutrient management, and drainage.

3. **Educational Institutions**: Agriculture and horticulture students can benefit from the project's methodologies and outcomes as educational material.

For individuals and groups interested in delving deeper into the concepts and methodologies of the "IntelliGROW" project, you can read about Internet of Things (IOT), Agricultural research and Irrigation Management

2.2.1.3 Project Scope

The scope of this engineering capstone project, aptly named "IntelliGROW”, encompasses the following captivating objectives:

Real-time Monitoring: Implement sensors to continuously monitor plant growth, soil nutrient levels, and moisture content at regular intervals.

Data Transmission and Engaging Dashboard: Pioneering a user-friendly dashboard, transmitting the gathered data instantly, empowering users with a captivating visual representation of their plant's journey, fostering a deeper connection between humans and nature.
Intelligent Nutrient and Water Supply: Develop ingenious mechanisms that tap into the power of artificial intelligence, enabling the system to analyse the monitored

data and autonomously supply plants with precise nutrients and water, ensuring their flourishing health.

Excessive Moisture Detection: Incorporate sensors to detect excessive soil moisture levels and prevent root damage caused by waterlogging.

Water Conservation: Design and integrate a reservoir system to collect and store excess water, thereby minimizing wastage and enabling future use during dry periods.

The IntelliGROW project transcends the ordinary, aiming to redefine plant care by harnessing the power of technology and intelligent automation. The focus lies in creating a working prototype that showcases the extraordinary potential of IntelliGROW. While commercial production is beyond the scope of this project, we lay the foundation for a future where plants flourish effortlessly and environmental stewardship thrives.

2.2.2 Overall Description

2.2.2.1 Product Perspective

IntelliGROW is an innovative product designed to optimize water usage and enhance crop productivity in agricultural and horticultural settings. It combines advanced sensor technology, automation, and data analytics to create an intelligent and efficient irrigation and fertilization solution. Here are some key perspectives to consider from a product standpoint:

1. Water Conservation: One of the primary goals of the smart irrigation and fertigation system is to minimize water wastage. By utilizing real-time weather data and soil moisture sensors, the system can accurately determine the irrigation needs of the crops. It ensures that water is delivered precisely when and where it is needed.

2. Precision Fertigation: In addition to irrigation, the system incorporates fertigation capabilities. It enables precise and controlled application of fertilizers directly through the irrigation system. By analysing soil conditions and plant nutrient requirements, the system can deliver the right amount of fertilizers at the right time. This precision fertigation approach optimizes nutrient uptake by the crops, leading to improved growth and higher yields.

3. Automation and Remote Monitoring: The system operates autonomously, relieving farmers from manual intervention. Farmers can also monitor and control the system remotely through a web-based dashboard, providing convenience and flexibility.

4. Sensor Technology and Data Analytics: The system employs various sensors such as soil moisture sensors, and soil nutrient sensors to gather real-time data about environmental conditions and crop health. This data is analysed using advanced algorithms to generate insights and recommendations. By harnessing this information, farmers can make data-driven decisions regarding irrigation timing, fertilization requirements, and overall crop management.

By considering these perspectives, the system can offer significant benefits to farmers, including improved crop yields, reduced water and fertilizer consumption, streamlined operations, and increased sustainability in agriculture.

2.2.2.2 Product Features

Real-Time Monitoring: The product provides continuous real-time monitoring of various environmental factors such as soil moisture, temperature, humidity, and nutrient levels. This enables users to have up-to-date information about their plants' conditions.

Data Analysis and Insights: The system collects and analyses data from the sensors to provide valuable insights into the plant's growth and health. It identifies trends, patterns, and potential issues, helping users make informed decisions.

Customized Nutrient and Water Supply: IntelliGROW tailors nutrient and water supply based on each plant's specific requirements. This personalized approach optimizes resource utilization and ensures that plants receive the exact amount they need.

Automated Action: The system's intelligence allows it to take automated actions based on the data it collects. For instance, it can adjust watering schedules, nutrient levels, and other conditions to ensure optimal growth.

Prevention of Waterlogging: By draining excess water, the system prevents waterlogging, which can harm plant roots. This feature helps maintain the overall health of the plant.

2.2.3 External Interface Requirements

2.2.3.1 User Interfaces

The dashboard, a pivotal element of the project, and its primary user interface is currently in its development phase, aimed at providing users with an intuitive and interactive platform for managing plant care in real-time. While the design is a work in progress, its intended features offer a glimpse into its promising functionality.

Interactivity and Real-time Monitoring: The dashboard offers dynamic updates with real-time data, displaying nutrient levels (N, P, K), humidity, temperature and moisture level along with the valve status for quick insights into plant conditions.

Intuitive Layout: Designed for clarity, the dashboard features organized sections for each parameter, allowing users to easily grasp plant health status and needs.

Visual Representation: Graphs, charts, and icons provide visual aid, aiding users in understanding parameter trends and patterns.

Interactive Controls: Users can take proactive measures, by just giving a single click command to turn the valve on/off depending upon the requirement.

2.2.3.2 Hardware Interfaces

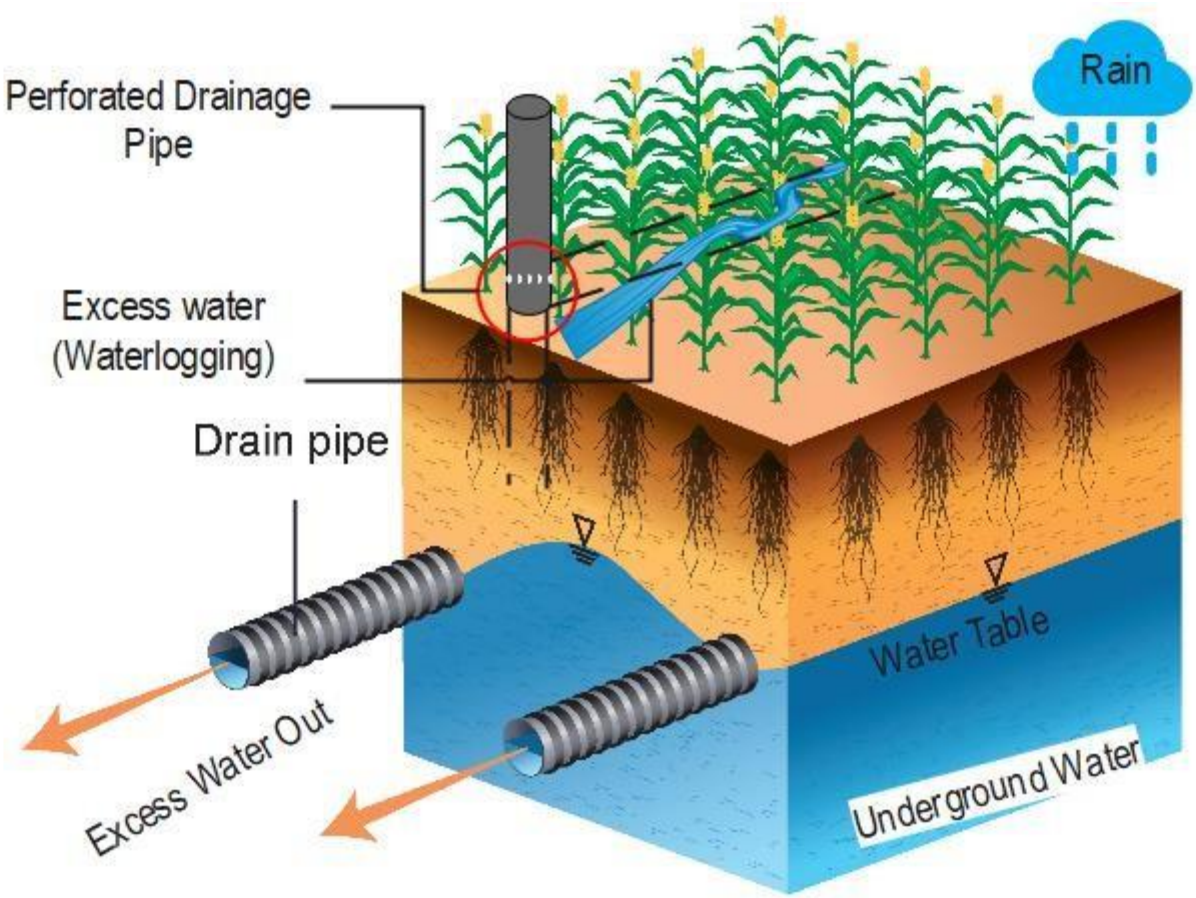


Fig 2: Subsurface Drainage System

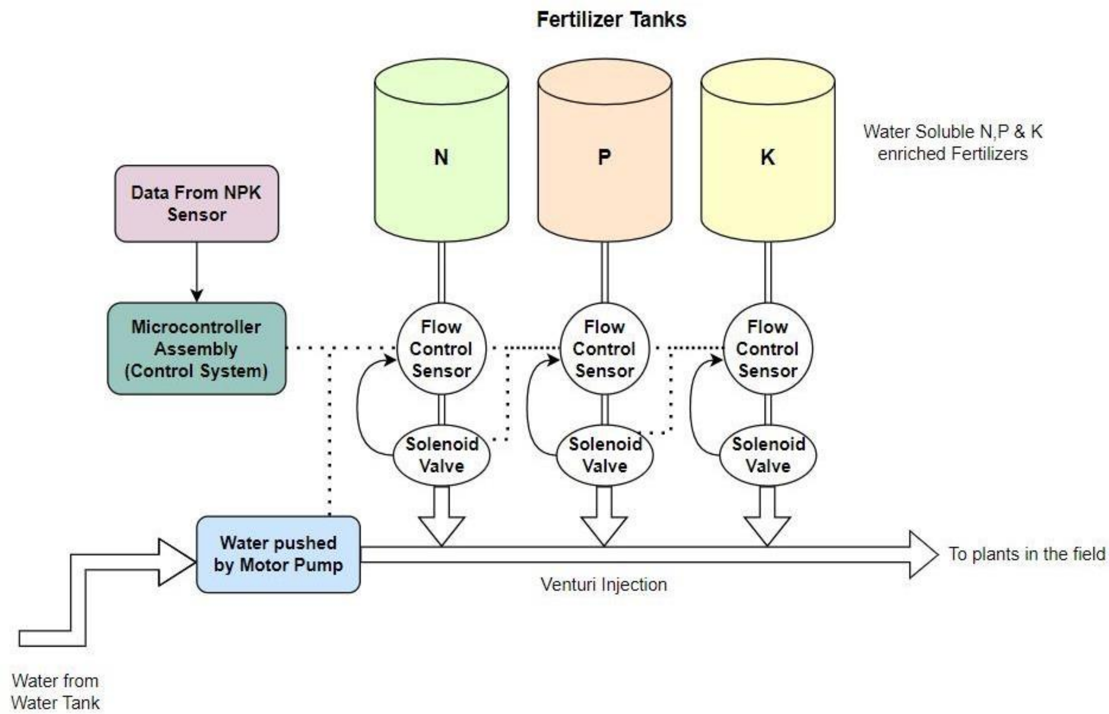


Fig 3: Smart Fertilization System Assembly

Hardware	**Technical Specifications**
Soil Moisture Sensor	Measures soil moisture, analog/digital, 3.3V - 5V
Temp & Humidity Sensor	Measures temp & humidity, digital, 3.3V - 5V
Soil NPK Sensor	Measures NPK levels, analog/digital, 5V
12V Low Noise DC Motor	For mechanisms, 12V
ESP8266 WiFi Module	Wireless connectivity, Wi-Fi, 3.3V - 5V
Breadboard & Wires	Prototyping, connecting components
Mini Water Pump	Small water pump, 3V - 5V

Table 3: Hardware Interfaces

2.2.3.3 Software Interfaces

Software Component	**Functionality and Description**	**Software Tools**
Web Dashboard	User-friendly interface for real-time monitoring and control	Tableau
Database	Stores historical sensor data and user settings	MySQL
Communication Protocols	Facilitates data exchange between hardware and software components	MQTT, CoAP
ThingSpeak API	Creates APIs for data integration and retrieval from ThingSpeak platform	ThingSpeak

Table 4: Software Interfaces

2.2.4 Other Non-functional Requirements

This section gives an overview of non-functional requirements.

2.2.4.1 Performance Requirements

- Response Time: Data updates to the web app should occur within 5 seconds after sensor readings.
- Throughput: System should support at least 100 data updates per minute from sensors.

- Availability: The system should have a high uptime, ensuring access to data and controls without significant disruption.

2.2.4.2 Safety Requirements:

- Sensor Safety: Sensors should meet safety standards for outdoor use.
- Fail-Safe: System should halt irrigation in case of failure to prevent crop damage.

2.2.4.3 Security Requirements:

- Data Encryption: Data transmission should use strong encryption (e.g., HTTPS).
- User Authentication: Strong user authentication, including multi-factor, is required.
- Data Privacy: User data must be securely stored and anonymized.
- Regular Auditing: System should maintain activity logs for security monitoring.

2.3 Cost Analysis

Component	Price(in ₹)
Soil Moisture Sensor	100
Temp and Humidity Sensor	150
Flow Sensor Module	450
Water Level Sensor(for tank)	230
Soil NPK Sensor	5500
Mini Water Pump	400
ESP32 WiFi Module	450
ESP8266 WiFi Module	300
Connecting Wires	80
Breadboard	80
LM2596 Buck Converter	50
4 Channel Relay Module	200
RS485 TTL Converter	150
12 Volt Battery	250
Miscellaneous Expenses	1500
Total Cost	**9890**

Table 5: Cost Analysis

2.4: Risk Analysis

1. Sensor Malfunction

- **Impact:** Inaccurate sensor readings could lead to incorrect irrigation and fertilization decisions, affecting crop health and yield.
- **Predictable Factors:** Regular sensor maintenance and calibration protocols can help minimize the risk of malfunction.
- **Mitigation Plan:** Conduct routine sensor calibration and test for errors in the software to identify abnormal data.

2. Data Loss

- **Impact:** Data transmission failures between sensors, microcontrollers, and the cloud could lead to delays and loss of critical data.
- **Predictable Factors:** Monitoring network connectivity and data transfer logs can provide early indications of communication issues.
- **Mitigation Plan:** Implement data buffering and data backup protocols to avoid data loss, utilize cloud storage solutions.

3. Data Breach

- **Impact:** Unauthorized access to sensitive data could compromise farmer and crop information, eroding trust.
- **Predictable Factors:** Regular security audits and penetration testing can help identify vulnerabilities.
- **Mitigation Plan:** Implement strict access controls, encrypt sensitive data, regularly update security measures.

3.1 Investigative Techniques

S.No.	Investigative Projects Techniques	Investigative Techniques Description
1.	Descriptive	Comprehensive Literature Review: Conducted an exhaustive analysis of over 15 research papers spanning various domains, including existing technologies, advancements, and potential improvements in plant care automation and sensor technology. Technology Landscape: Mapping out the evolving landscape of plant care systems involves describing the prevailing methodologies, sensor integration techniques, and data transmission methods in the field.
2.	Comparative	Market Analysis: Explored current market trends, available products, and technological advancements in plant care systems to identify gaps and opportunities for innovation. Sensor Selection: Researched and evaluated various sensors, such as soil moisture sensors, temperature and humidity sensors, and NPK sensors, to determine the most suitable options for accurate data collection. Data Transmission Evaluation: Explored diverse data transmission approaches, encompassing cloud-based solutions, to assess their viability, dependability, and security in facilitating real-time data streaming.

3.	Experimental	Iterative Prototyping: Employed an iterative prototyping approach as an ongoing part of the project's development process, actively refining the system's design and functionality. Research Expedition: Undertook a visit to Punjab Agricultural University (PAU), Ludhiana, as a research initiative acquiring firsthand knowledge of plant care methodologies, soil management strategies, and emerging trends in agricultural technology. Additionally, valuable insights were gained into the prevailing technologies, systems, and products currently employed in the field. Home Garden Field Testing: Conducted comprehensive field testing at a home garden using a chilli plant as a model, validating the IntelliGROW system's efficacy in real-world conditions. Environmental Impact Study: Conducted an analysis of the system's environmental impact, particularly in terms of water savings and sustainable resource management.

Table 6: Investigative techniques

3.2 Proposed Solution

IntelliGROW represents a pioneering approach to plant care that leverages the latest advancements in technology to create a holistic, automated system that nurtures plants in a more efficient, precise, and sustainable manner. At the heart of this solution lies the integration of real-time monitoring, data analysis, and intelligent automation.

IntelliGROW’s core strength lies in its ability to continuously monitor and assess the environment in which plants thrive. Sensors, including those for soil moisture, temperature, humidity, and nutrient levels, work together to gather a comprehensive set of data points that provide a holistic view of the plant's surroundings. By collecting this real-time data, IntelliGROW gains insights into the changing conditions that affect the plant's growth, health, and overall well-being.

This data-driven approach is not limited to mere observation. When it comes to nutrient and water supply, the system precisely tailors its actions based on the specific needs of each plant. This customization ensures that resources are utilized optimally, minimizing wastage and avoiding over- fertilization or over-watering.

Furthermore, IntelliGROW’s intelligence extends to addressing a common concern in plant care: waterlogging. By actively monitoring soil moisture levels, the system can identify situations where excess water might threaten the plant's health. In such cases, IntelliGROW takes preventive measures to prevent root damage and efficiently manages water resources by storing excess water for future use.

In a broader context, the proposed solution is not just about technological innovation. IntelliGROW embodies a sustainable ethos by promoting responsible resource management. By optimizing nutrient and water delivery, it contributes to water conservation and efficient use of fertilizers. This aspect aligns with global efforts to address environmental challenges and underscores the importance of technology in achieving these goals.

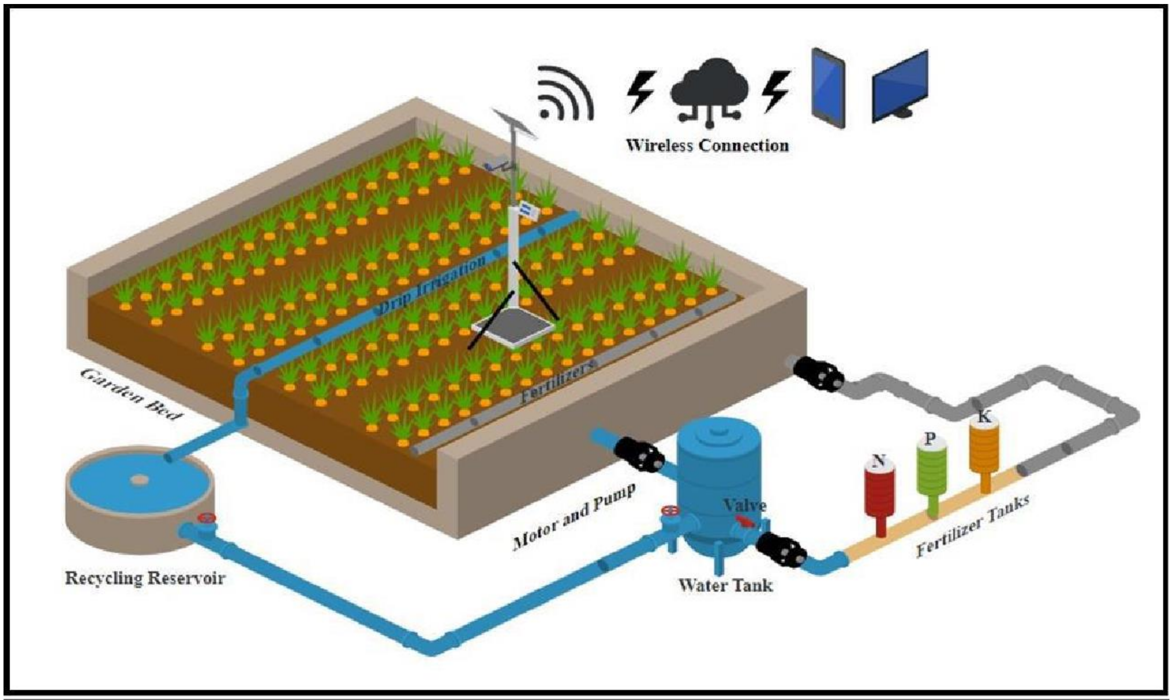


Fig 4: The Proposed Irrigation and Fertilization System

Ultimately, IntelliGROW is more than a project; it's a testament to the synergy between technology and nature. It envisions a future where plants are nurtured with the utmost precision, where automation and smart algorithms work in harmony with the environment. This proposed solution speaks to a new era in plant care, where innovation and sustainability go hand in hand, offering a glimpse into a future where technology is an ally in cultivating healthier, vibrant, and thriving plants.

3.3 Work Breakdown Structure

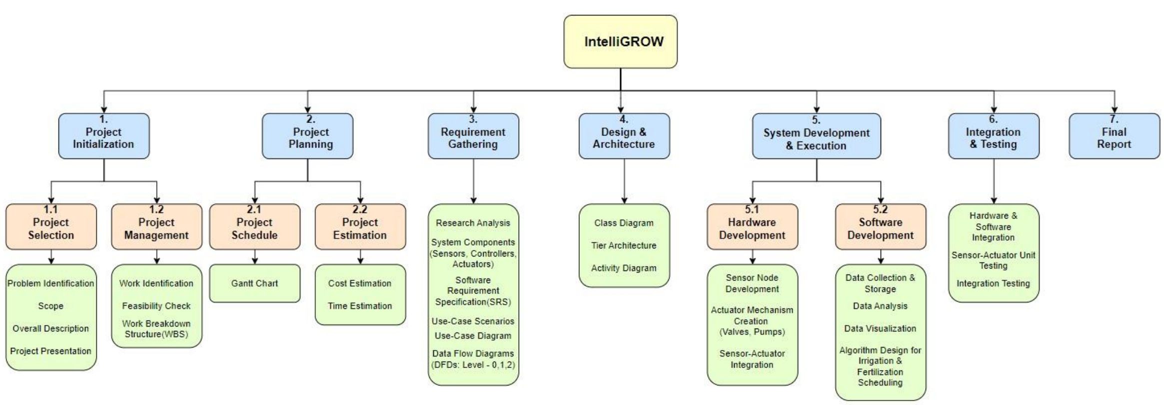


Fig 5: Work Breakdown Structure

3.4 Tools and Technology

- **Sensors and Data Collection:**
  - NPK Sensors: To measure nitrogen, phosphorus, and potassium levels in the soil.
  - Temperature Sensors: For monitoring ambient temperature.
  - Moisture Sensors: To gauge soil moisture content.
  - Water-level sensors: To level water level of soil and tank

- **Microcontrollers and Embedded Systems:**
  - Arduino: Building custom sensor interfaces and data collection.

- **Communication Protocols:**
  - ESP8266 Wi-Fi Module: For connecting sensors to the internet.

- **Control Mechanisms:**
  - Actuators: Relay module for controlling water flow, pumps for water storage and for opening and closing compartments in the fertilizer tank.
- **Irrigation management**
  - DC motors: small, portable device that pumps water from the reservoir to irrigate the plant.

4.1 System Architecture

Block Diagram

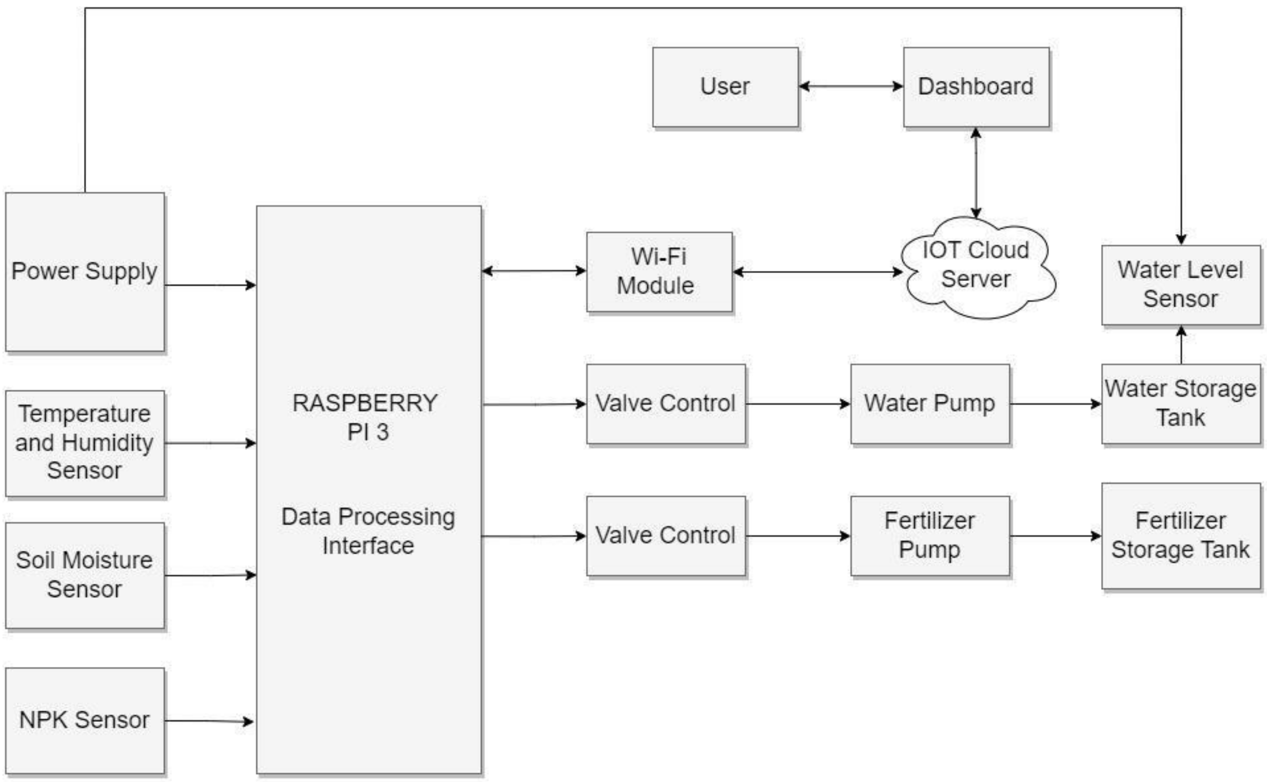


Fig 6: Block Diagram

Tier Architecture Diagram

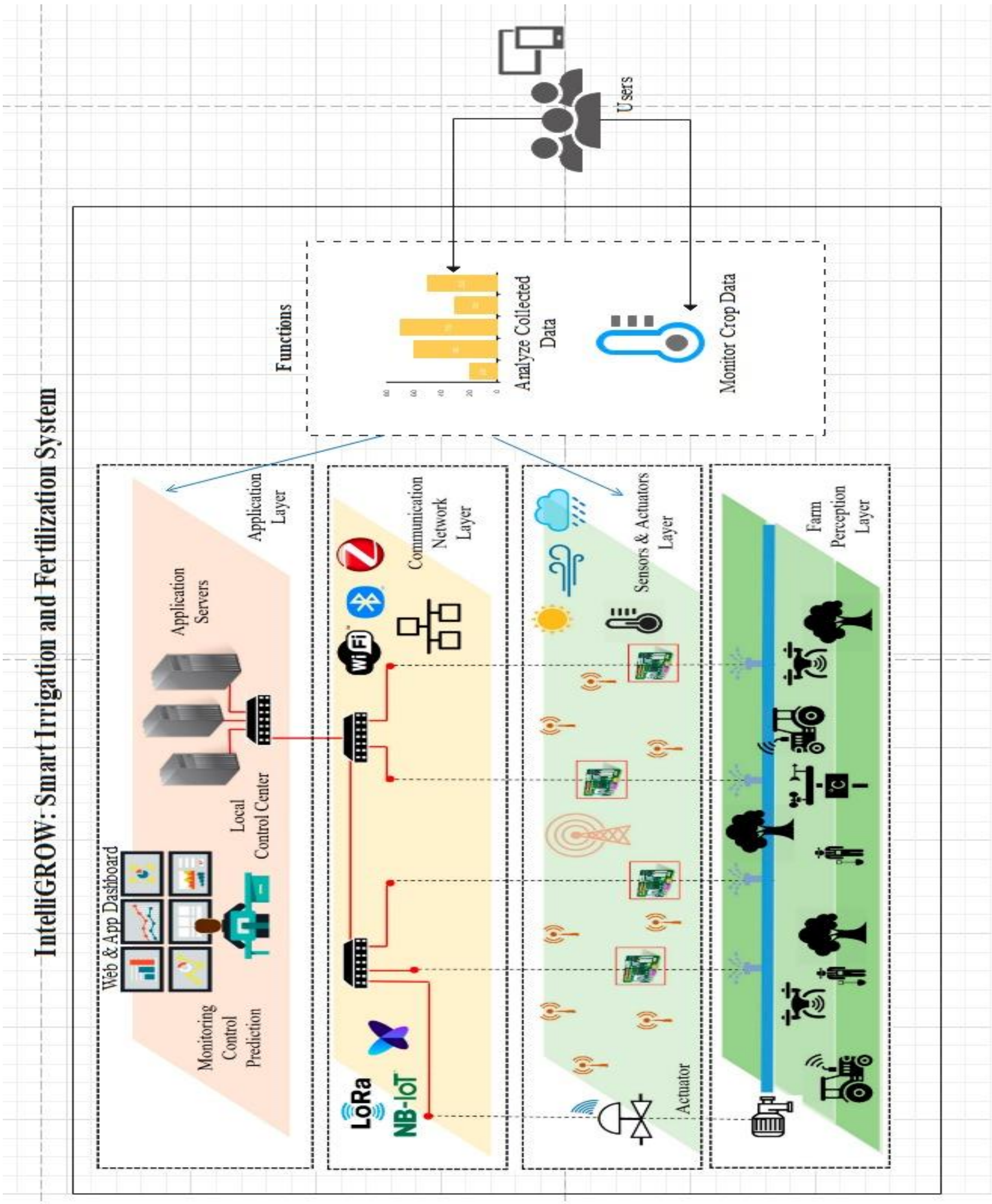


Fig 7: Tier- Architecture Diagram

4.2 Design Level Diagrams

Class Diagram

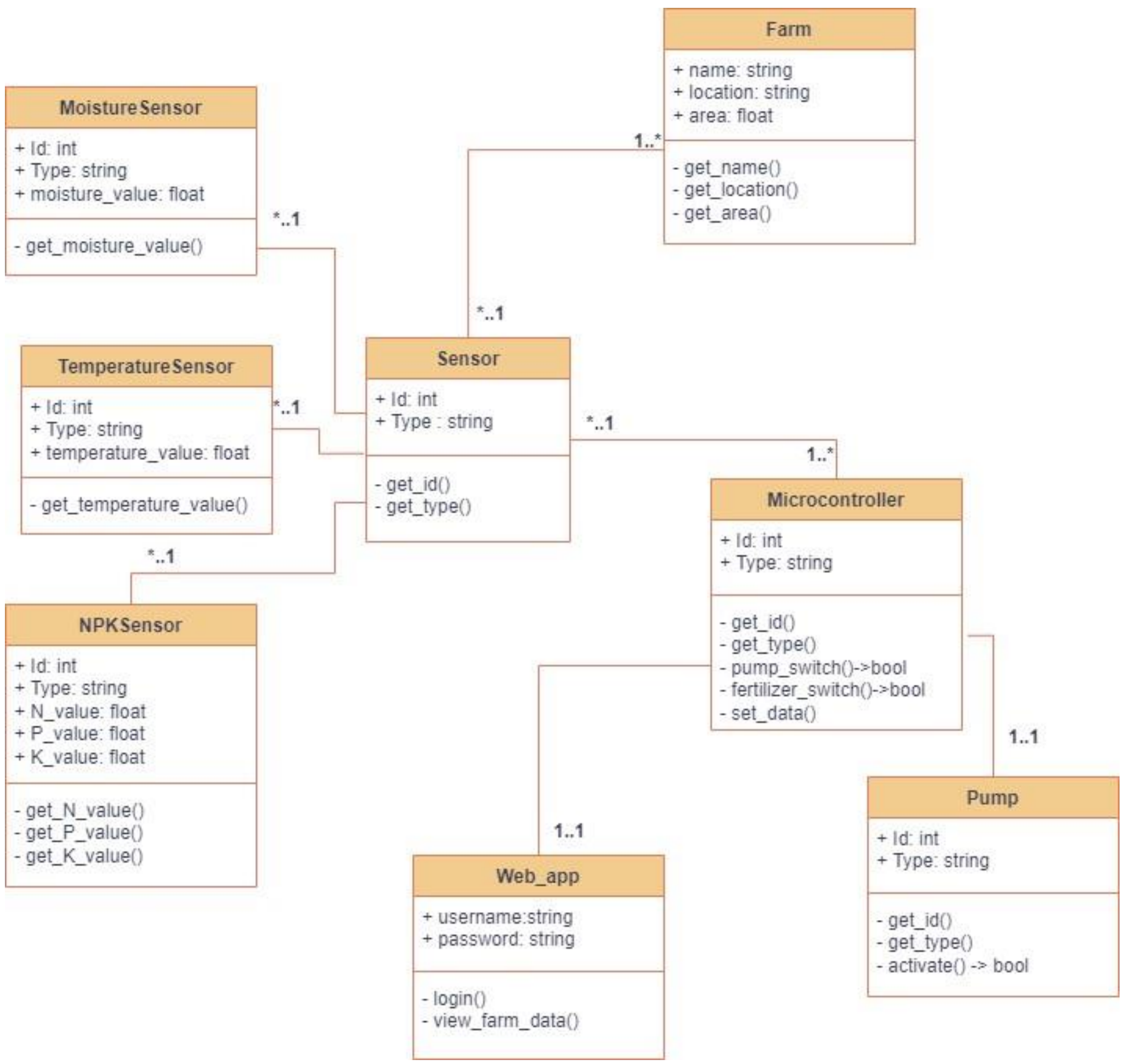


Fig 8: Class Diagram

Fig. 8 depicts the class diagram for IntelliGROW that provides an overview of the different classes in the system and how they are related.

Data Design - ER Diagram

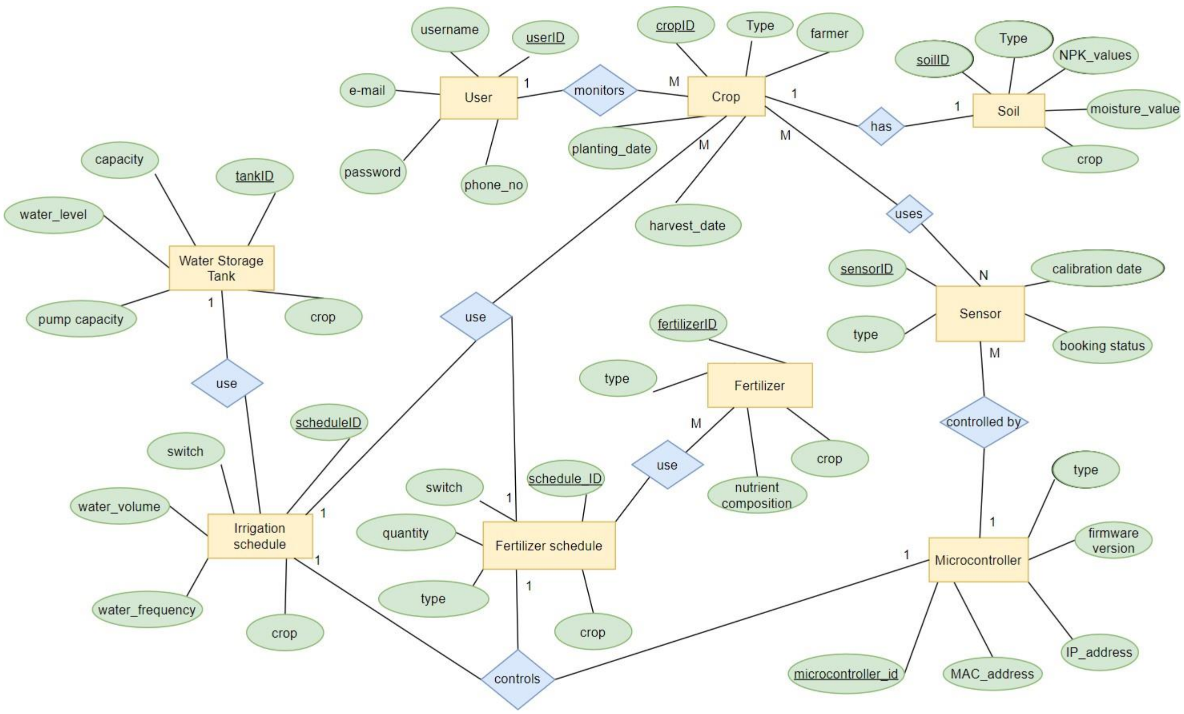


Fig 9: Entity Relationship (ER) Diagram

Data Flow Diagrams (DFD)

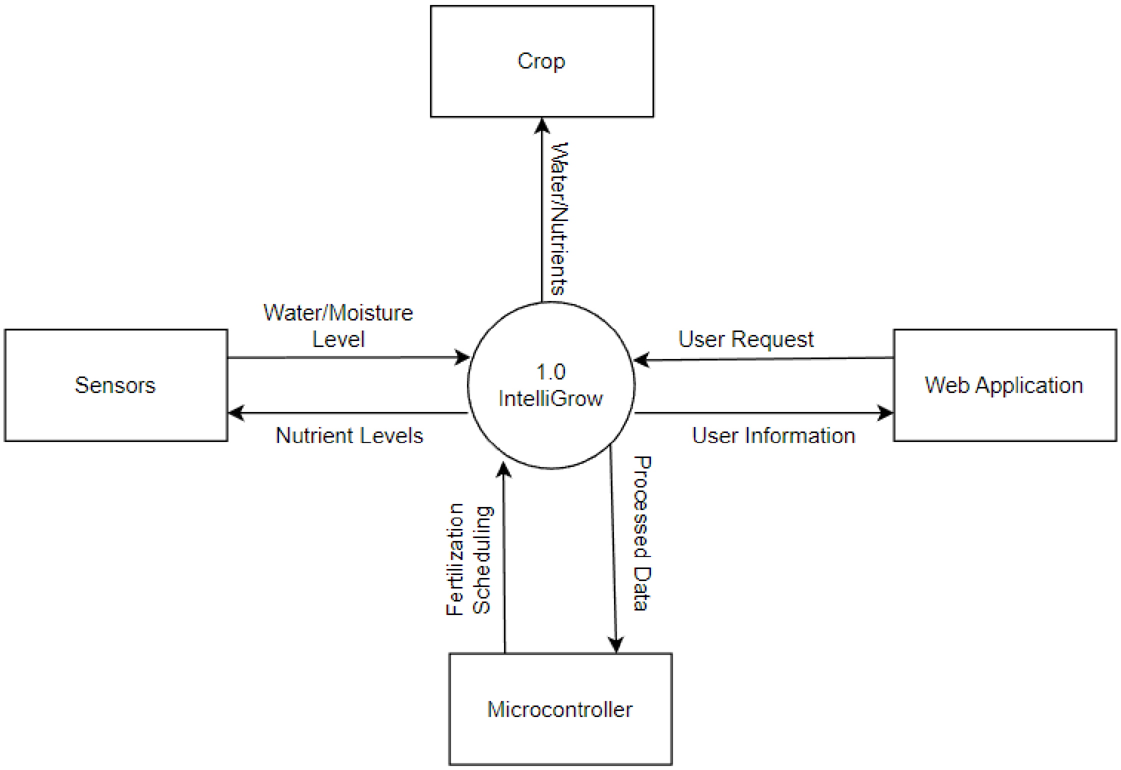


Fig 10: Level 0 DFD

Fig. 10 displays a Level 0 Data Flow Diagram (DFD), which presents a high-level view of the complete system, demonstrating key processes and data exchange between various components.

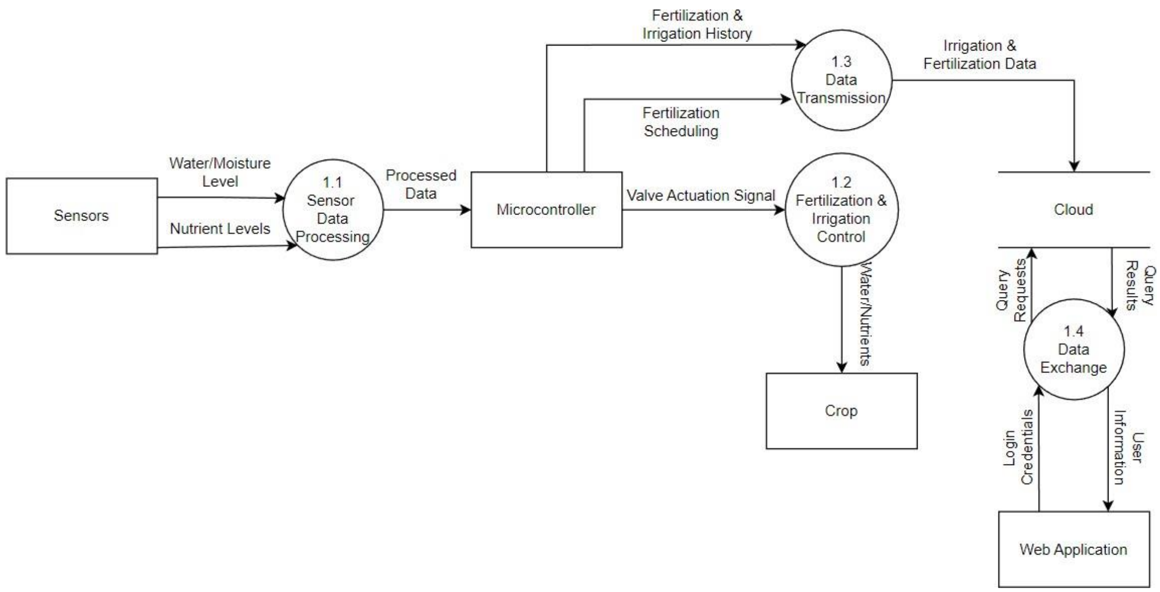


Fig 11: Level 1 DFD

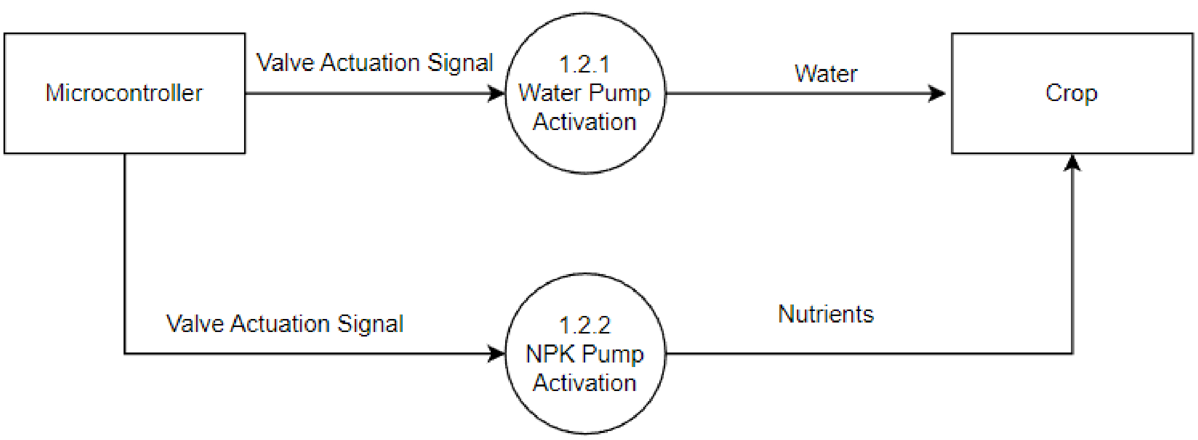


Fig 12: Level 2 DFD

4.3 User Interface Diagrams

Use Case Diagram

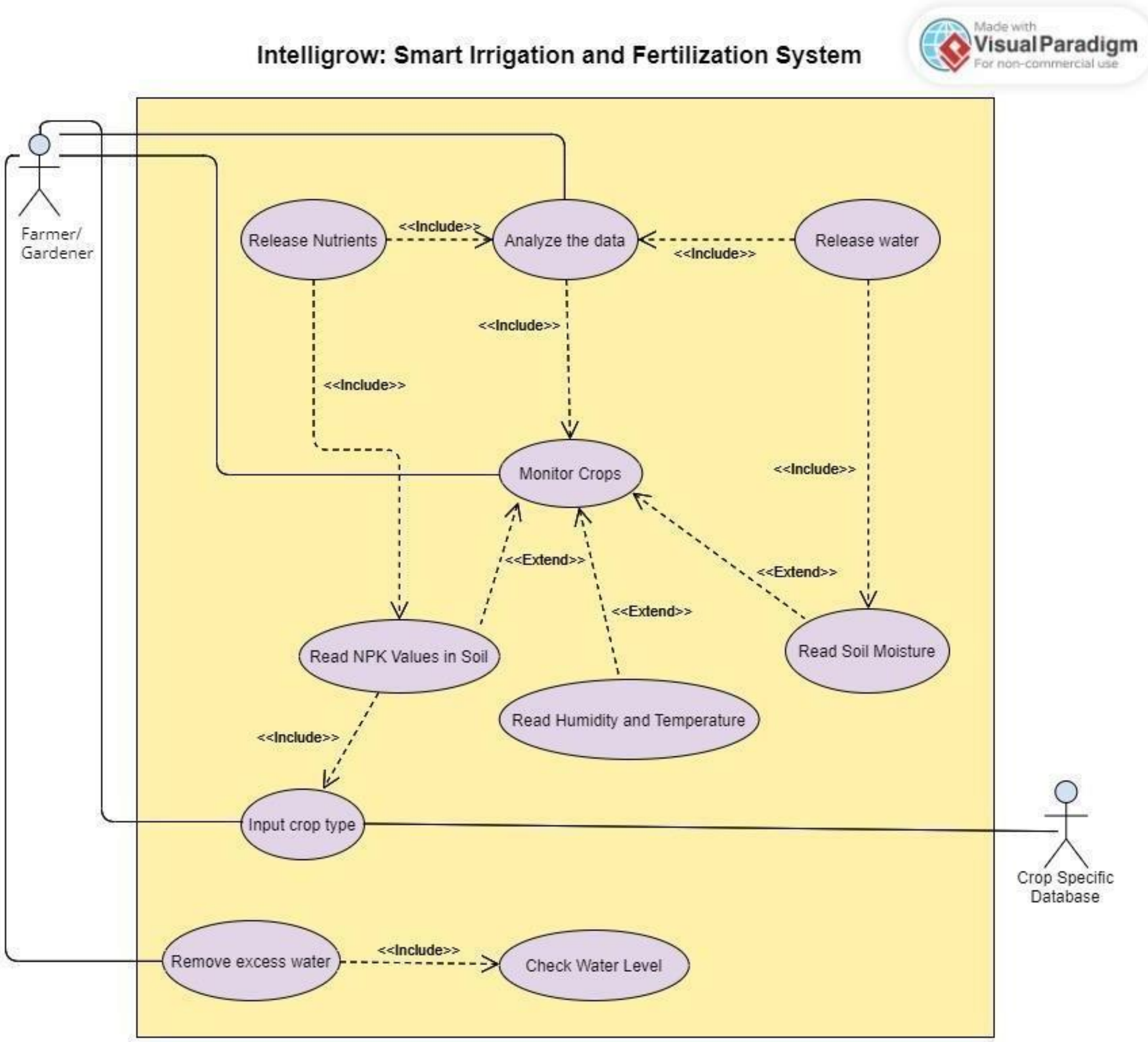


Fig 13: Use Case Diagram

4.4 Snapshots of Working Prototype

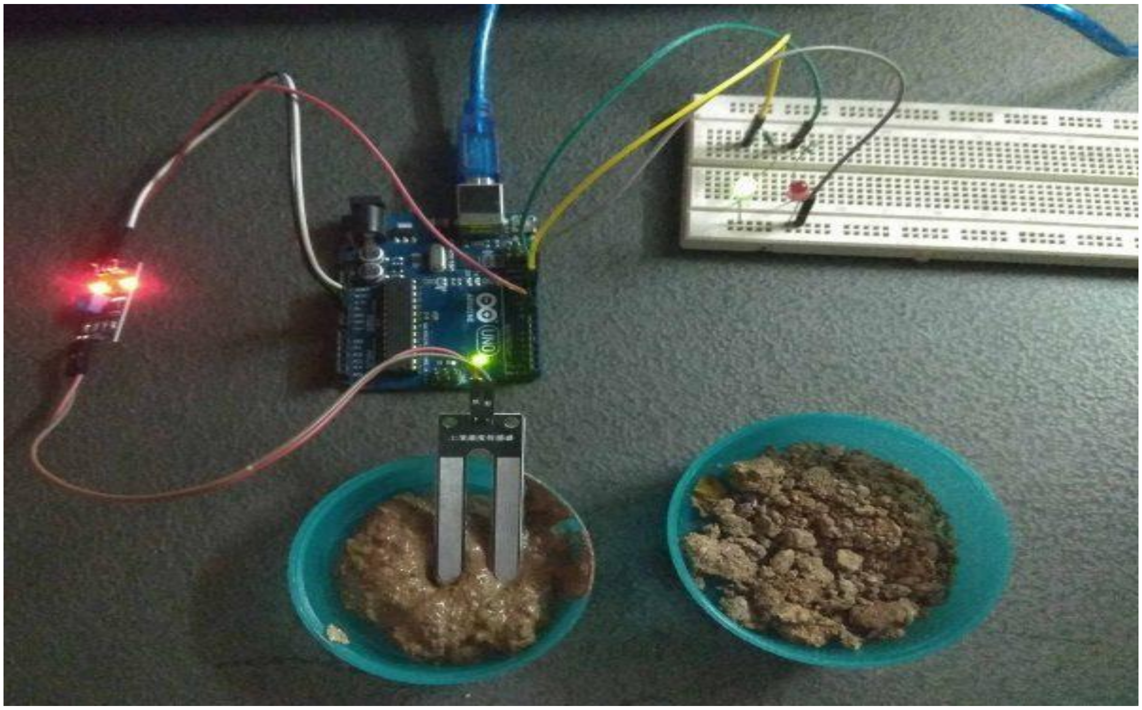


Fig 14: Soil Moisture Sensor Testing

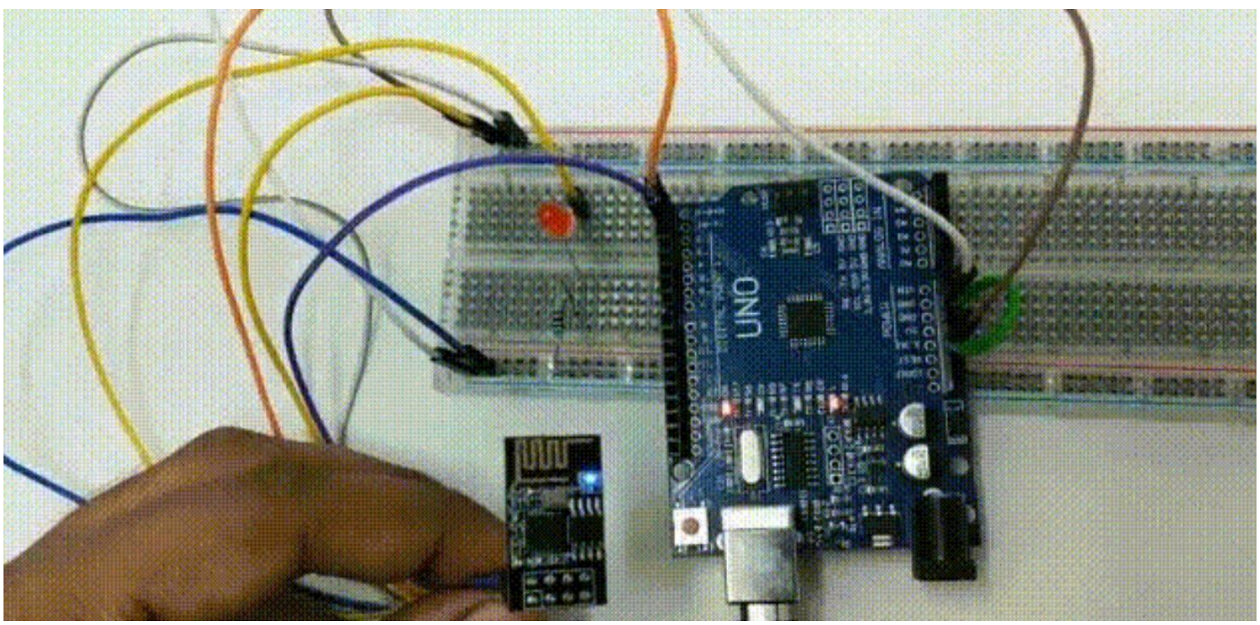


Fig 15: ESP8266 Wi-Fi Module

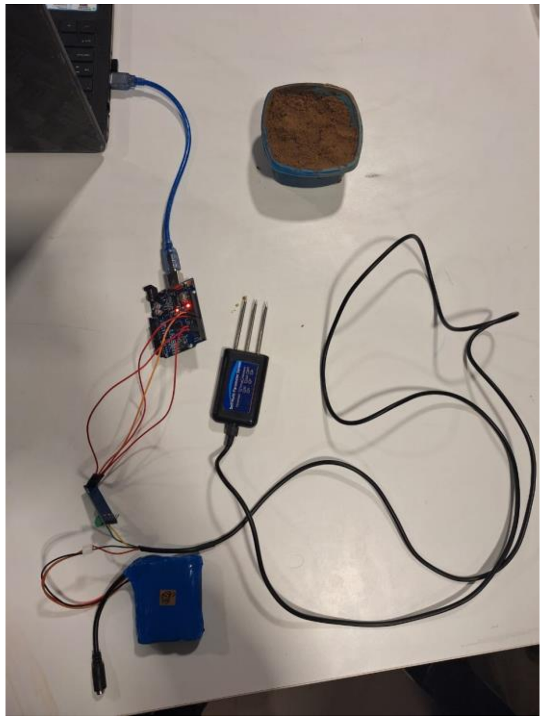


Fig 16: NPK Sensor

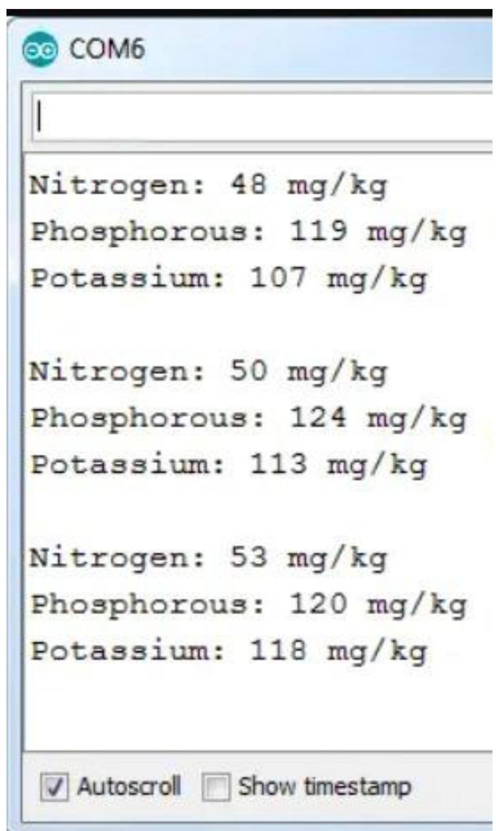


Fig 17: NPK Sensor Output

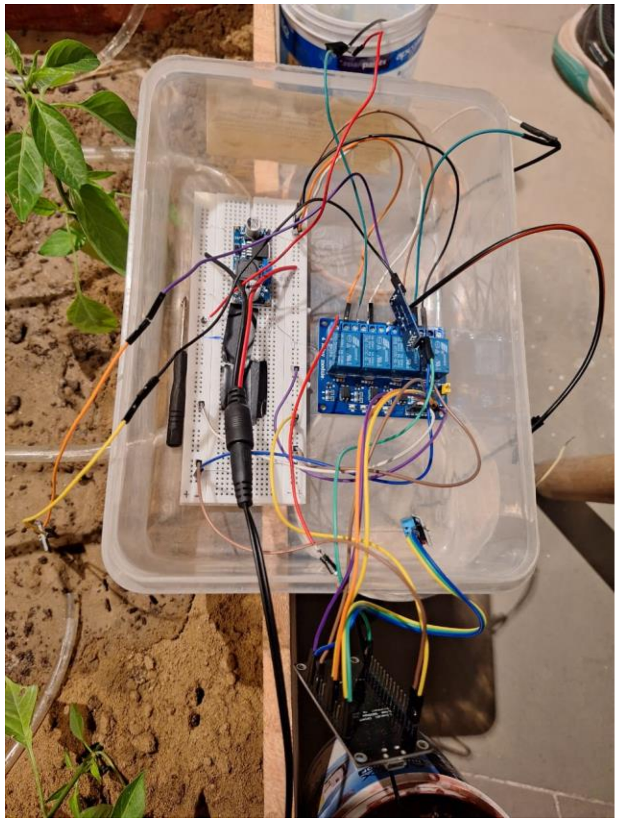


Fig 18: Final Circuit

IMPLEMENTATION AND EXPERIMENTAL RESULTS

5.1 Experimental Setup

5.1.1 Hardware Configuration

ESP8266 WiFi Module: The central controller interfacing with various sensors and pumps for remote monitoring and control.

Sensors Placement: NPK sensor, soil moisture sensor, and temperature/humidity sensor strategically placed within the agricultural setup.

Relays and Pumps: Configured with an external 12V power supply to control the dispensing of liquid fertilizers and irrigation water.

Blynk App Interface: Configured to enable seamless communication with the ESP8266 module for real-time monitoring and manual intervention.

5.1.2 Sensor Calibration

NPK Sensor: Calibrated to ensure precise measurements of nitrogen, phosphorus, and potassium levels.

Soil Moisture Sensor: Calibrated to establish accurate thresholds for triggering automated irrigation.

Temperature and Humidity Sensor: Calibrated for precise environmental readings under various conditions.

5.1.3 Pump and Relay Configuration

Fertilizer Pump Configuration: Integrated with NPK containers, controlled based on sensor readings and manual input through the Blynk app.

Irrigation Pump Configuration: Connected to the soil moisture sensor, with manual control via the Blynk app for automated irrigation.

5.1.4 Rainwater Management

Filter Pipes: Strategically placed to redirect excess rainwater, preventing waterlogging.

Storage Tank: Utilized for storing redirected rainwater, ensuring efficient water resource management.

5.2 Experimental Analysis

5.2.1 Data

NPK Sensor Data: Collected data on nitrogen, phosphorus, and potassium levels from the NPK sensor.

Soil Moisture Data: Gathered readings indicating soil moisture levels from the soil moisture sensor.

Temperature/Humidity Data: Recorded environmental conditions using the temperature and humidity sensor.

5.2.2 Performance Parameters

NPK Sensor Accuracy: Evaluated the accuracy of the NPK sensor in measuring nitrogen, phosphorus, and potassium levels in the soil.

Soil Moisture Sensor Accuracy: Assessed the precision of the soil moisture sensor in determining soil moisture content.

Temperature/Humidity Sensor Accuracy: Examined the reliability of temperature and humidity sensor readings under various environmental conditions.

5.3 Working of the project

5.3.1 Procedural Workflow

Sensor Data Acquisition: The ESP8266 module collects data from the NPK sensor, soil moisture sensor, and temperature/humidity sensor.

Decision-Making Logic: Based on sensor readings, the system decides whether to initiate fertilization, irrigation, or both.

User Interaction: Users can manually control fertilization and irrigation through the Blynk app, providing flexibility and control.

Rainwater Management: In the event of rain, excess water is redirected through filter pipes to prevent waterlogging, and the rainwater is stored in a tank.

5.3.2 Algorithmic Approaches used

Automated Fertilization Algorithm: Utilizes NPK sensor readings to determine the appropriate amount of nitrogen, phosphorus, and potassium required for optimal soil fertility.

Automated Irrigation Algorithm: Relies on soil moisture sensor data to trigger automated drip irrigation, maintaining ideal soil moisture levels for plant growth.

5.3.3 Project Deployment

Hardware Integration: The system components, including sensors, relays, pumps, and the ESP8266 module, are integrated into the agricultural setup.

Connectivity: The ESP8266 module establishes a connection to the Blynk app for remote monitoring and control.

Power Supply: Ensures a stable power supply for the ESP8266 module, relays, and pumps, with an external 12V power source.

5.3.4 System Screenshots

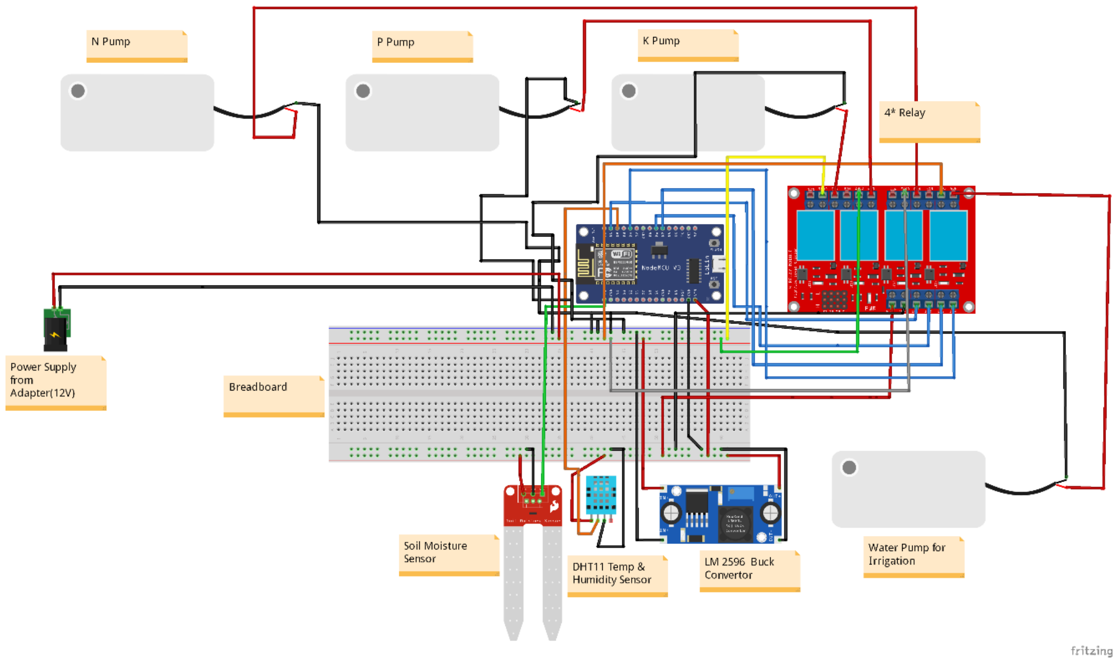


Fig 19: Schematic Diagram

Fig 20 Final Setup

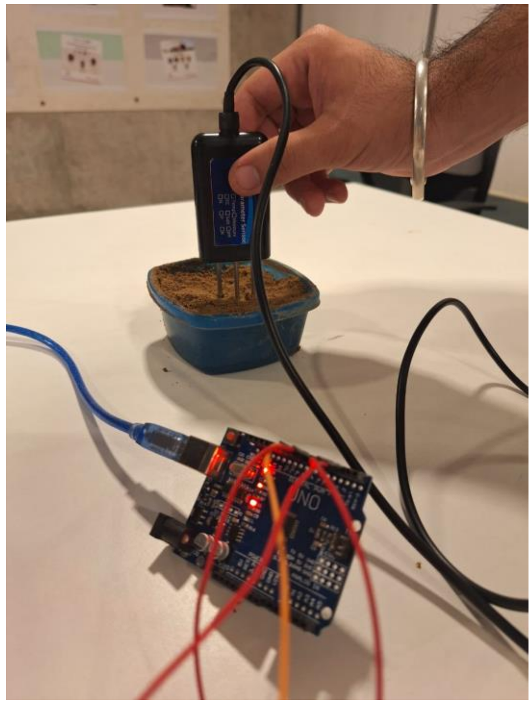


Fig 21: Testing of NPK Sensor

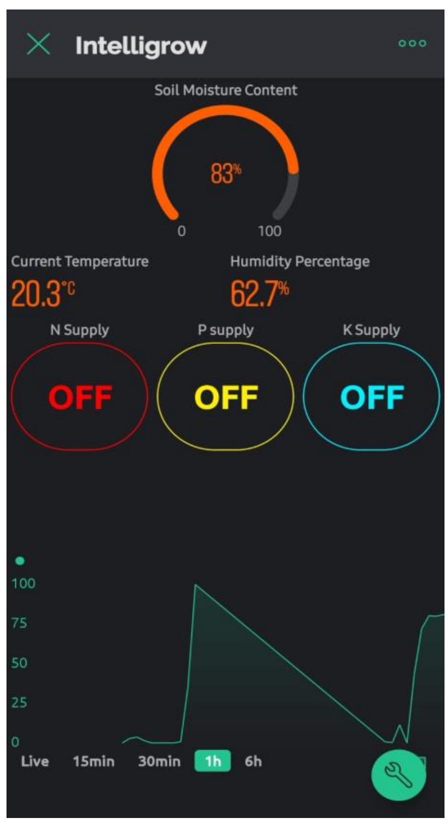


Fig 22: App Dashboard

5.4 Testing Process

5.4.1 Test Plan

The testing process was initiated with a carefully crafted test plan, outlining the systematic approach and methodologies to be employed. The plan incorporated considerations for functional testing, with a focus on validating the core objectives of the smart agriculture system. It delineated the testing phases, resource allocation, and the overall timeline to ensure a comprehensive evaluation.

5.4.2 Features to be tested

Some of the important features to be taken care of includes:

- Automated irrigation and fertilization.
- Nutrient Precision Mechanisms
- Adaptive Controls on a dashboard
- Efficient drainage management

5.4.3 Test Strategy

We have separately tested the individual features of our project and finally tested the integrated system.

5.4.4 Test Techniques

Functional testing involved unit testing, integration testing, and system testing to verify individual components and their collaborative functionality.

5.4.5 Test Cases

Scenario	Test Step	Expected Outcome	Actual Outcome	Type of Testing
Pump Control: Manual Activation	Press the "Activate Pump" button on Blynk	The pump starts operating, and water is supplied to the field	Pump activates as expected, and water is supplied	Functional

Pump Control: Manual Deactivation	Press the "Deactivate Pump" button on Blynk	The pump stops operating, and water supply ceases	Pump deactivates as expected, and water supply stops	Functional
Sensor Data Upload: Regular Intervals	Observe the Blynk dashboard over time	Sensor data (moisture, temperature, etc.) is regularly updated	Sensor data updates at regular intervals on the dashboard	Performance
Sensor Data Accuracy: Normal Conditions	Compare sensor readings with actual values	Sensor readings on Blynk align with expected environmental conditions	Sensor readings are accurate under normal environmental conditions	Functional
Sensor Data Accuracy: Abnormal Conditions	Introduce extreme temperature or humidity	Sensor readings on Blynk should reflect the abnormal conditions	Blynk dashboard displays accurate sensor readings under abnormal conditions	Robustness

Drainage System Testing	Observe the system's response to simulated water logging by introducing excess water in a localized area	The drainage system, utilizing inclination or other mechanisms, removes excess water, preventing waterlogging	The drainage system successfully removes excess water, preventing waterlogging	Functional
NPK Sensor Failure Testing	Intentionally expose the NPK sensor to extreme conditions or faults	The NPK sensor should accurately measure NPK levels and display them on the Blynk dashboard	The NPK sensor fails to provide accurate readings.	Robustness

Table 7: Test Cases

5.4.6 Test Results

Test Scenario	Result
Pump Control: Manual Activation	Pass
Pump Control: Manual Deactivation	Pass
Sensor Data Upload: Regular Intervals	Pass
Sensor Data Accuracy: Normal Conditions	Pass
Sensor Data Accuracy: Abnormal Conditions	Pass
Drainage System Testing	Pass
NPK Sensor Failure Testing	Fail

Table 8: Test Results

5.5 Results and Discussions

5.5.1 Sensor Performance

5.5.1.1 NPK Sensor

Accuracy: The NPK sensor exhibited high accuracy, providing readings closely aligned with known soil nutrient levels.

Impact on Fertilization: Accurate NPK readings significantly improved the precision of fertilization decisions, ensuring optimal nutrient application for enhanced crop growth.

5.5.1.2 Soil Moisture Sensor

Effectiveness of Irrigation: The soil moisture sensor demonstrated reliability, effectively triggering automated drip irrigation in response to variations in soil moisture levels.

Water Resource Management: The system's responsiveness, guided by the soil moisture sensor, contributed to efficient water resource management, minimizing water usage while maintaining ideal soil moisture conditions.

5.5.1.3 Temperature/Humidity Sensor

Environmental Monitoring: The temperature and humidity sensor consistently provided reliable readings across various environmental conditions.

Impact on Crop Health: Accurate environmental data from the sensor played a crucial role in ensuring favorable conditions for crop health and growth.

5.5.2 Overall System Performance

Integration Success: The seamless integration of sensor data, algorithmic decision-making, and user interaction through the Blynk app showcased the overall efficiency of the system.

User Interaction: Users reported a positive experience with the Blynk app interface, emphasizing the convenience of manual control options.

5.6 Inferences Drawn

In examining the outcomes of the smart agriculture system, several key inferences can be drawn. The precise measurements provided by the NPK sensor allowed for tailored fertilization strategies, promoting optimal crop health. The soil moisture sensor, guiding automated irrigation, played a pivotal role in resource-efficient water management. The seamless integration of sensors, algorithmic decision-making, and user interaction through the Blynk app showcased a well-coordinated system. Comparative analysis revealed tangible improvements in crop health and resource utilization. Despite challenges in calibration, iterative refinement underscored the importance of continuous learning in sensor-based systems. Looking forward, identified opportunities for refinement and future enhancements provide a promising trajectory for advancing the system's effectiveness in precision farming. The inferences collectively affirm the positive impact of the smart agriculture system on crop management practices.

5.7 Validation of Objectives

5.7.1 Smart Irrigation

The objective of implementing smart irrigation was effectively validated through the utilization of water sensors. The system demonstrated intelligent monitoring of soil moisture levels, ensuring precise irrigation to prevent both overhydration and underwatering. This adaptive approach enhances water conservation and promotes optimal soil conditions for plant growth.

5.7.2 Nutrient Precision

The goal of achieving nutrient precision through nutrient sensors was successfully validated. The system accurately evaluated soil fertilization levels, allowing for the precise delivery of essential elements through irrigation. This targeted nutrient management ensures sustained and optimal plant nourishment, contributing to improved crop health and yield.

5.7.3 Adaptive Irrigation Control

The objective of adaptive irrigation control was validated through a sophisticated mechanism that adjusts watering and nutrient supply schedules in real-time. This adaptability, informed by sensor data, specific plant types, and environmental conditions, ensures a customized approach to irrigation. The system's ability to dynamically respond to changing variables underscores its effectiveness in optimizing resource usage and promoting plant well-being.

5.7.4 Efficient Drainage

The specialized drainage management system successfully validated the objective of efficient drainage. By strategically redirecting excess water away from the soil, the system prevents water accumulation and the risk of root rot. This proactive drainage approach contributes to a healthier soil environment and mitigates potential waterlogging issues.

CONCLUSION AND FUTURE DIRECTIONS

6.1 Conclusions

Integrating sensor technology and intelligent control systems in the "Automatic Irrigation and Fertilization System with Drainage Management" constitutes a transformative approach to plant cultivation. The project aims to promote healthier, more productive, and ecologically sustainable agricultural and horticultural practices, revolutionizing the art of nurturing plants.

6.2 Environment. Social and Economic benefits

Environmental Benefits:

Water Conservation: "IntelliGROW" minimizes water wastage by delivering water precisely when needed. This conserves water resources and mitigates the strain on local water supplies.

Reduced Nutrient Runoff: Through intelligent nutrient management, the project reduces nutrient runoff, which can harm water bodies. This preserves water quality and aquatic ecosystems.

Biodiversity Preservation: The efficient use of resources minimizes the disruption of local ecosystems, promoting biodiversity conservation and healthier soil and plant ecosystems.

Economic Benefits:

Increased Crop Yield: "IntelliGROW" optimizes the allocation of water and nutrients, resulting in higher crop yields. This translates into increased revenue for farmers and a strengthened agricultural economy.

Cost Savings- On a large scale, precise resource management leads to reduced water and fertilizer consumption, which lowers operational costs for farmers. Additionally, automated systems minimize the need for manual labour, further reducing expenses.

Technology Adoption: The project promotes the adoption of modern technology in agriculture, leading to greater innovation. This technological advancement can have a ripple effect across various industries, fostering economic growth.

Social Benefits:

Enhanced Food Security: By optimizing plant growth and yield, "IntelliGROW" contributes to increased agricultural productivity, ensuring a more consistent and reliable food supply. This directly benefits communities and reduces food scarcity concerns.

Reduced Labor Intensity: The automation of irrigation, fertilization, and drainage processes decreases the labour burden on farmers and gardeners. This enables them to focus on other essential tasks, leading to improved livelihoods and reduced physical strain.

Rural Development: Adoption of such advanced systems can revitalize rural economies. As farmers gain access to technology-driven solutions, it enhances their income potential and quality of life, discouraging migration to urban areas.

6.3 Reflections

While reflecting on the implementation and outcomes of the smart agriculture system, several key observations and reflections come to light. The successful integration of sensor technologies, irrigation control mechanisms, and user interfaces has demonstrated the system's potential to revolutionize traditional farming practices. The precision in nutrient delivery and irrigation, guided by real-time sensor data, has underscored the importance of technology in achieving resource-efficient and sustainable agriculture.

Reflections also extend to the challenges faced during the calibration processes and the iterative refinement required for optimal sensor performance. These challenges, while inherent in the development of sensor-based systems, have provided valuable insights into the intricacies of precision farming. The system's adaptability to varying environmental conditions and plant types highlights the importance of flexibility in agricultural technologies to cater to diverse farming scenarios.

Looking ahead, future directions for the smart agriculture system involve continued refinement of sensor calibration algorithms, exploration of additional environmental sensors, and the incorporation of machine learning techniques for enhanced decision-making. The user-friendly interface of the Blynk app opens avenues for potential expansions, including data analytics features and predictive modeling.

In conclusion, the reflections on the smart agriculture system's journey unveil both achievements and opportunities for growth. The system stands as a testament to the potential of technology-driven precision farming, and the reflections gathered pave the way for continuous advancements and innovations in the field of smart agriculture.

6.4 Future Work

Product Refinement:

Refine and optimize the automated irrigation and fertilization system for enhanced accuracy and reliability. Thoroughly test and validate the system's performance across various plant types and environmental conditions.

Dashboard Enhancement:

Develop a user-friendly dashboard for remote system monitoring and control. Incorporate real-time data visualization, alerts, and insights to empower users with actionable information.

Cost Reduction:

Conduct continuous cost analyses to identify opportunities for minimizing expenses without compromising system quality. Source cost-effective, reliable components to ensure accessibility for small-scale and resource-limited farmers.

Funding Acquisition:

Secure additional funding through strategic initiatives such as grants, partnerships, and investor collaborations. Utilize funds to integrate cutting-edge technology, enhance system features, and expand user reach.

Community Engagement:

Engage with the farming and horticultural community through workshops, training sessions, and awareness programs. Educate farmers about the benefits of adopting "IntelliGROW" and create an active social media community to encourage knowledge sharing and user-driven improvements.

7.1 Challenges Faced

NPK Sensor Reliability: The NPK sensor's sensitivity to voltage changes posed a significant issue, leading to its malfunction during testing. Additionally, its calibration complexity added to the challenge, requiring extensive research for accurate readings.

Moisture Sensor Calibration: Difficulties in calibrating the moisture sensor rendered it unsuitable for automatic field irrigation. Manual intervention was necessary, impacting the system's intended automation.

Research-Intensive Nature: The project's research-intensive aspects posed challenges in adhering to deadlines. Extensive research, especially concerning sensor calibration, consumed more time than anticipated.

Sensor Sourcing: Locating required sensors proved to be challenging, as some sensors were not readily available locally. This sourcing issue may have led to delays in acquiring necessary components.

Prototype Cost-Efficiency: Finding cost-effective alternatives for the prototype, such as using paint boxes for tanks, became a necessity due to budget constraints or the unavailability of specific materials.

Power Distribution and Regulation: Implementing voltage regulators to accommodate diverse power needs for various components can lead to complexities in managing power distribution efficiently. Ensuring stable, regulated voltages across different parts of the system while considering power consumption of each component was challenging.

Space-Constrained Circuit Optimization: Streamlining the circuit layout on a limited-space breadboard while minimizing the use of wires posed a significant challenge. Balancing component placement, reducing wiring complexity, and ensuring signal integrity within the confined space demanded meticulous planning and precision to optimize the circuit effectively.

7.2 Relevant Subjects

Electrical Engineering: Understanding circuits, components, sensors, and interfacing, especially when dealing with ADCs, voltage regulators, and various sensors.

Mechanical Engineering: Designing and implementing the physical infrastructure like irrigation systems, tanks, and mechanisms for fertilization.

Agricultural Engineering: Knowledge about soil types, plant nutrient requirements, irrigation techniques, and crop-specific needs.

Computer Science/Embedded Systems: Programming microcontrollers (like Arduino or Raspberry Pi) for data processing, automation, and interfacing with sensors and user interfaces.

Data Science/Analytics: Analyzing sensor data for optimizing irrigation and fertilization schedules, as well as predictive analysis for plant growth based on environmental factors.

Environmental Science: Understanding the impact of environmental factors like temperature, humidity, and soil moisture on plant growth.

Geometry: Understanding shapes, angles, and spatial relationships is vital in designing the layout of the prototype system. Subjects like geometry and trigonometry contribute to determining optimal pipe lengths, tank placements, and the spatial arrangement of plants for an efficient and realistic representation of an agricultural field.

7.3 Interdisciplinary Knowledge Sharing

1.Agricultural Experts & System Designers collectively ensured the irrigation and fertilization system's adaptability for diverse plant types and growth environments.

2. IoT Specialists developed an intuitive interface for remote system management, prioritizing user experience.
3. Incorporated ethical and environmental considerations throughout the system's lifecycle.

4.Data Analysis was used to analyze plant behavior data to optimize nutrient delivery and irrigation.

5.Electronics and agriculture was integrated for a versatile system applicable to various farming methods.

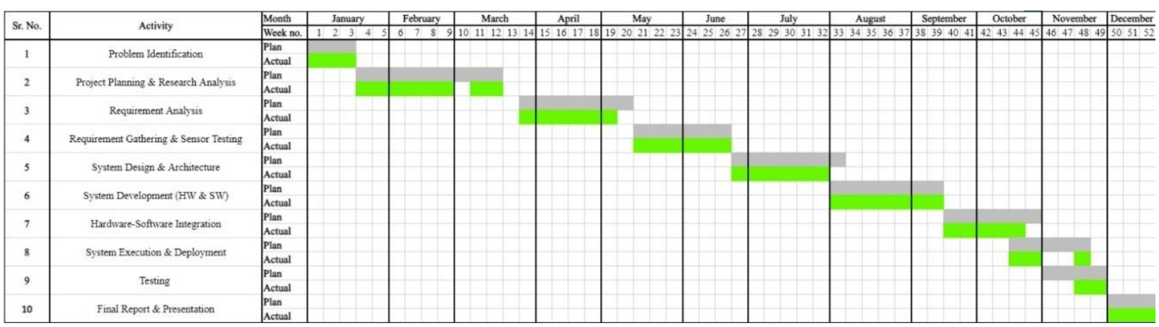
6.Interdisciplinary Team collaborated to ensure ethical design and operation aligned with societal values.

7.4 Peer Assessment Matrix

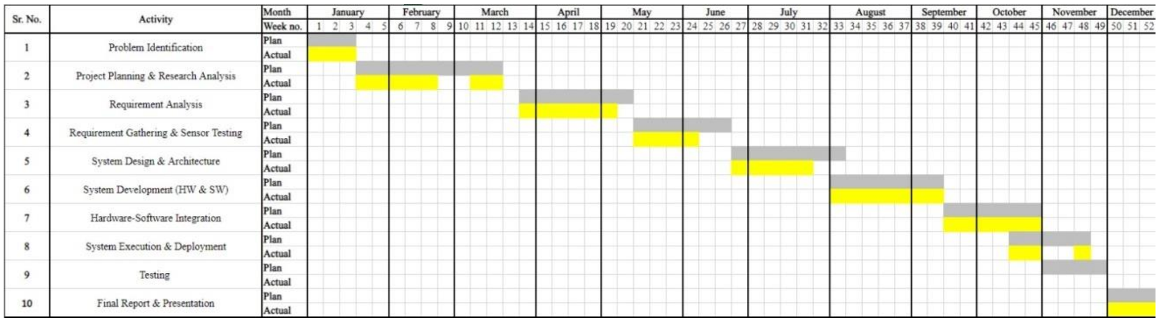
		Evaluation of				
	Team Members	Vardaan Khosla	Satvik Maheshwari	Sundaram Srivastava	Romil Gupta	Nishant Sharma
Evaluated by	Vardaan Khosla	____	4.5	4	5	4.5
	Satvik Maheshwari	4.5	____	5	4.5	4
	Sundaram Srivastava	4.5	5	____	4	4.5
	Romil Gupta	4.5	4.5	4.5	____	5
	Nishant Sharma	5	4	4.5	4.5	____

7.5 Role Playing and Work Schedule

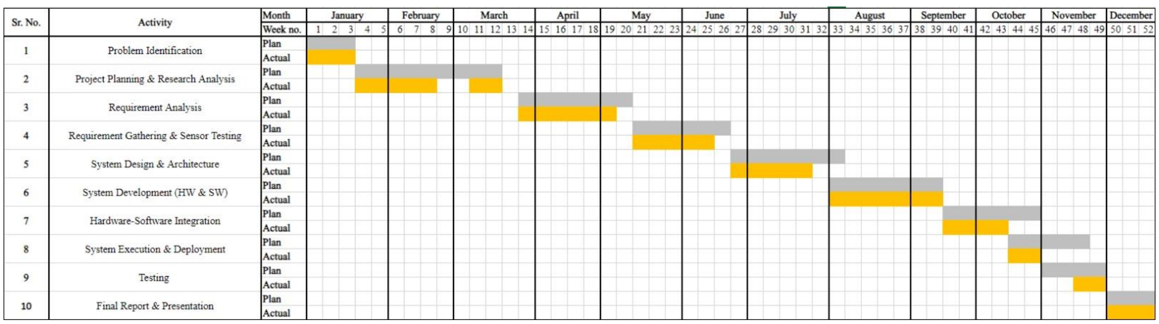
1.Nishant Sharma



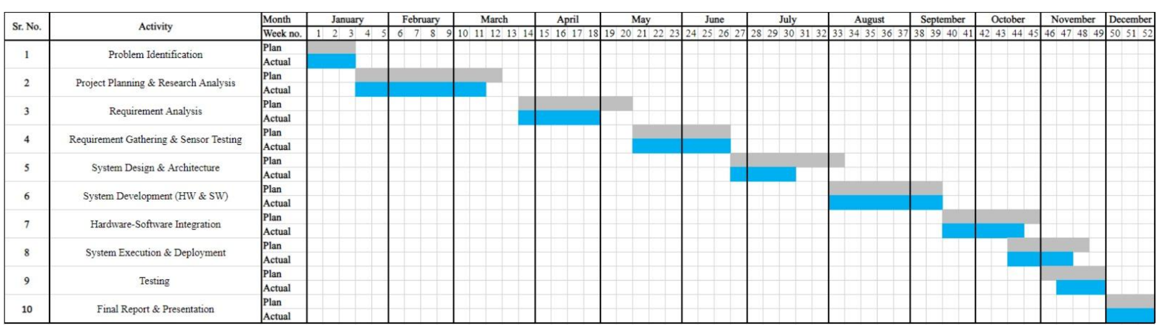
2. Satvik Maheshwari



3. Sundaram Srivastava



4. Vardaan Khosla



5. Romil Gupta

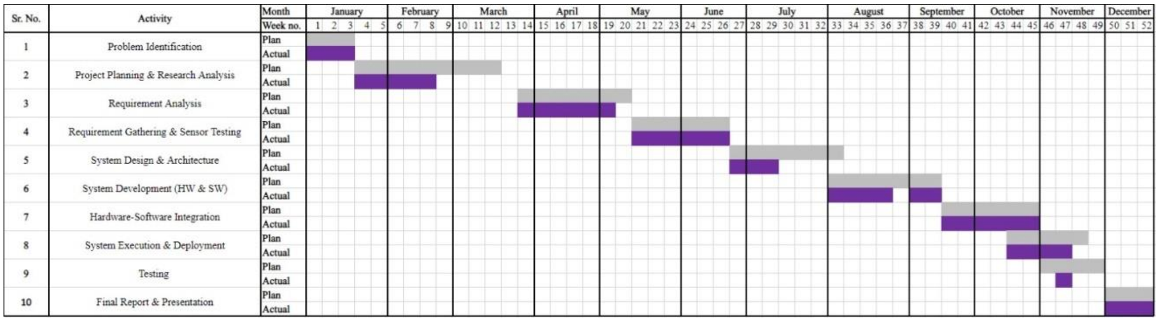


Fig 23: Role Playing and Work Schedule

7.6 Student Outcomes Description and Performance Indicators (A-K Mapping)

Description	Outcome	Performance Indicator
Applying Knowledge of Science and Engineering Principles	Ability to optimize agricultural processes using scientific and engineering concepts	(a) Applying plant biology and soil science in system optimization; (b) Integrating electronic principles for hardware development
Experimental Design and Data Analysis	Proficiency in conducting experiments for system enhancement and data interpretation	(c) Designing experiments for optimizing nutrient delivery; (d) Analysing sensor data to improve system effectiveness
Designing Solutions for Real-world Constraints	Ability to create practical systems considering agricultural limitations	(e) Designing a smart irrigation system within agricultural constraints; (f) Integrating software and hardware components
Collaborative Teamwork	Capacity to work effectively in multidisciplinary teams	(g) Collaborating with diverse team members to achieve project objectives
Problem Identification and Solution Formulation	Capability to identify and solve engineering challenges	(h) Identifying agricultural optimization challenges; (i)

Description	Outcome	Performance Indicator
		Formulating solutions integrating IoT, electronics, and agriculture
Ethical and Professional Responsibility	Understanding and application of ethical considerations	(j) Ensuring ethical development and operation of the system
Effective Communication	Ability to convey project findings and progress effectively	(k) Communicating project outcomes through comprehensive reports and presentations

Table 9: Student Outcomes Description

7.7 Brief Analytical Assessment

Q1. What sources of information did your team explore to arrive at the list of possible Project Problems?

Our preliminary phase, our team conducted a comprehensive analysis focusing on the 151 million individuals engaged in agriculture and orchard farming in India. Recognizing the need to optimize these sectors, we thoroughly examined the existing challenges and evaluated available technologies in the market. Our objective was to innovate a more cost-effective and advanced solution. To gather insights, we extensively researched relevant research papers and journals through online resources. Additionally, we sought valuable guidance from our mentor, collaborating to compile a comprehensive catalog of potential project challenges.

Q2. What analytical, computational and/or experimental methods did your project team use to obtain solutions to the problems in the project?

At the project's outset, our team extensively reviewed a plethora of research papers pertinent to the addressed issue. These readings provided valuable insights into a spectrum of IoT and Electronics designs, showcasing solutions and projects targeting similar challenges. Our implementation strategy centered on leveraging software tools like Blynk, a cloud platform, alongside our custom code developed within the Arduino IDE. On the hardware front, we integrated ESP8266 and employed voltage regulators to manage circuit voltages effectively. Additionally, the project incorporated various sensors—NPK sensor, DHT sensor, and soil moisture sensor—to acquire essential sensor data, enabling actionable insights.

Q3. Did the project demand demonstration of knowledge of fundamentals, scientific and/or engineering principles? If yes, how did you apply?

Yes, the project extensively relied on fundamental scientific and engineering principles. We applied these principles throughout the project lifecycle to ensure its successful execution. To address the complexities of agricultural optimization, we drew upon fundamental agricultural science principles encompassing plant biology, soil science, and nutrient requirements. Additionally, engineering principles were paramount in the design and implementation phases. We employed principles of electronics, circuit design, and sensor integration to build a robust hardware system. Understanding fundamentals such as voltage regulation, data interpretation from sensors, and programming languages like Arduino IDE were instrumental in achieving our project objectives. Overall, the project demanded the application of core scientific and engineering principles to develop an effective and innovative solution.

Q4. How did your team shares responsibility and communicate the information of schedule with others in team to coordinate design and manufacturing dependencies?

Our team embraced collective responsibility, ensuring an equitable distribution of tasks among members. Communication channels like Google Meet and Zoom Calls were instrumental in maintaining consistent and transparent information flow. Regular in-person meetings provided an avenue for comprehensive discussions, enabling progress updates and collaborative problem-solving. Coordination efforts were evident as we synchronized schedules for collective work sessions to address dependencies. Leveraging individual expertise, we engaged in collaborative learning sessions, fostering knowledge exchange and facilitating project milestones

APPENDIX A: REFERENCES

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APPENDIX B: PLAGIARISM REPORT

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Report: IntelliGROW Report for plag check

IntelliGROW Report for plag check

by Sharad Saxena

General metrics

81,832	11,028	944	44 min 6 sec	1 hr 24 min
characters	words	sentences	reading time	speaking time

Score

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Writing Issues

362	109	253
Issues left	Critical	Advanced

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Page 1 of 94