A Major Project Report on

## “IOT Aeroponics”

*Submitted in partial fulfillment of the requirements for the award of the degree of*

# BACHELOR OF TECHNOLOGY

## in

### ELECTRONICS AND COMMUNICATION ENGINEERING

by

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Assistant professor



## Department of Electronics and Communication Engineering BVRIT HYDERABAD College of Engineering for Women (UGC - Autonomous)

**(Approved by AICTE, New Delhi and Affiliated to JNTU, Hyderabad)**

### Accredited by NBA and NAAC with A Grade Bachupally, Hyderabad – 500090

**2024-25**

**DECLARATION**

We here by declare that the work described in this report, entitled **“IOT Aeroponics”** which is being submitted by us in partial fulfilment for the award of the degree of **Bachelor of Technology** in the Department of **Electronics and Communication Engineering** at **BVRIT HYDERABAD College of Engineering for Women(UGC Autonomous),** affiliated to **Jawaharlal Nehru Technological University Hyderabad**, Kukatpally, Hyderabad – 500085 is the result of original work carried out by us under the guidance of **Mr.N.M.Sai Krishna, Assistant Professor**.

This work has not been submitted for any Degree/Diploma of this or any other institute/university to the best of our knowledge and belief.

**Place:** Hyderabad

**Date:** 16-06-2025

### Names and signatures of the students

Ms.B.Sathwika -

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**Certificate**

This is to certify that the major project report, entitled **“Aeroponics”** is a record of bonafide work carried out by Ms.B.Sathwika - 21WH1A0472, Ms.A.Sonika - 21WH1A0474, Ms.D.Bhashitha - 21WH1A04B0, Ms.M.Jayakeerthana - 21WH1A04C7 in partial fulfilment for the award of the degree of **Bachelor of Technology** in the department of **Electronics and Communication Engineering** at **BVRIT HYDERABAD College of Engineering for Women,** affiliated to **Jawaharlal Nehru Technological University Hyderabad**, Kukatpally, Hyderabad – 500085.

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# ACKNOWLEDGMENT

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Aeroponics farming has emerged as a revolutionary and sustainable alternative to traditional soil-based agriculture, offering a remarkable reduction in water usage up to 98% while requiring significantly less space. This innovative farming method suspends plants in an air or mist environment, eliminating the need for soil. Despite its potential, maintaining ideal environmental conditions and nutrient levels poses a considerable challenge. The objective is to design and implement a monitoring and control system for aeroponics farming, with the goal of predicting crop yield, and providing actionable insights to guide farming practices.

The proposed system employs IoT sensors to monitor critical environmental parameters such as pH and TDS. These sensors provide real-time data, enabling continuous monitoring of the farming environment. The collected data is processed to identify patterns, analyze trends, and predict optimal growth conditions for the plants. Additionally, the system forecasts crop yield based on observations from pH sensors and other monitoring tools. It features a user-friendly interface that displays real-time data, actionable suggestions.

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# INTRODUCTION

### Overview of Aeroponics

Aeroponics is a cutting-edge farming method that utilizes a soil-free setting for plant cultivation. This technique involves suspending the roots of plants in the air and nourishing them with a fine spray of nutrient-dense water. Unlike conventional methods, which rely on soil, aeroponics does away with the need for soil and instead focuses on creating ideal conditions for root growth through direct access to oxygen, nutrients, and water in a closely regulated setting.

This method of farming is particularly relevant in modern agriculture due to its numerous advantages, including:

#### Water Efficiency:

Aeroponics systems use up to 98% less water compared to traditional farming methods. This remarkable reduction in water consumption makes aeroponics particularly advantageous for regions with limited access to water resources.

#### Space Efficiency:

The vertical design of aeroponics systems allows for high-density crop production. This makes them ideal for urban farming and areas where space is constrained, maximizing productivity in limited areas.

#### Faster Growth and Higher Yields:

Plants grown in aeroponics systems benefit from optimal nutrient delivery and increased oxygen exposure, resulting in faster growth and higher yields compared to traditional soil or hydroponics-based methods.

#### Reduced Pesticide Use:

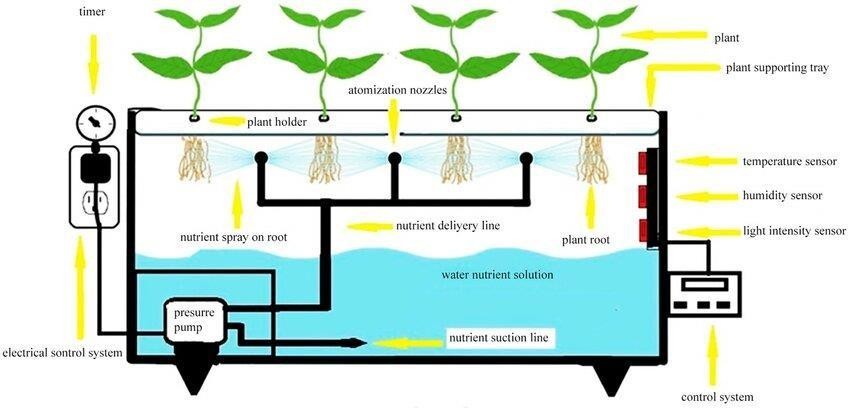
The controlled environment of aeroponics systems significantly reduces the need for pesticides. This leads to a cleaner and healthier growing process, ensuring safer produce.

#### Improved Nutrient Efficiency:

By delivering nutrients directly to plant roots in a controlled mist, aeroponics systems ensure precise nutrient absorption. This minimizes wastage, maximizes nutrient efficiency, and leads to healthier plants with increased yields

#### Year-Round Farming:

Aeroponics systems allow for year-round farming by creating controlled environments, which eliminates the dependence on external weather conditions. This results in a steady production of crops and helps improve food security, particularly in regions with severe climates.



**Fig.1 Aeroponics System**

* **Benefits of IoT Integration in Aeroponics Systems**

1. **Remote Monitoring**

IoT sensors placed throughout the system can track environmental conditions like TDS, pH levels, and nutrient concentrations in real-time, enabling farmers to monitor their crops from anywhere.

#### Automation

IoT technology automates critical farming tasks, ensuring plants always receive optimal care:

* + **Nutrient Delivery:** Controlled and precise nutrient supply based on plant needs.
  + **Lighting Adjustments:** Automated changes to lighting intensity and duration for optimal growth.
  + **Water Misting:** Scheduled or condition-based misting to maintain the required moisture levels.

#### Predictive Analytics

IoT systems utilize historical data and current environmental trends to:

* + Anticipate the future needs of plants.
  + Improve resource allocation, such as water and nutrients, for maximum efficiency.
  + Enhance crop yields by preemptively addressing potential issues or deficiencies.

**1.2**. **Comparison Between Aeroponics, Hydroponics, and Soil Farming**

Aeroponics is an advanced and highly efficient method of plant cultivation where the roots are suspended in the air and periodically misted with a nutrient-rich solution. This technique eliminates the need for any solid or liquid growing medium, offering an ideal environment for root development. In contrast, hydroponics involves growing plants with their roots submerged in a nutrient-infused water solution. While it does not use soil, it still relies on a medium like water or inert substances (e.g., perlite or clay pellets) to support the roots. Traditional soil farming, on the other hand, utilizes natural soil as both a support and nutrient source, requiring larger space and greater dependency on environmental conditions.

One of the most significant differences between the three systems lies in water efficiency. Aeroponics is the most water-conserving method, using up to 90% less water than conventional soil farming and even less than hydroponics. Since the mist delivers nutrients directly to the roots, there is minimal waste or runoff. Hydroponics also uses less water compared to soil farming, but it requires constant management of water levels and nutrient concentration. Soil farming consumes the most water, with a significant amount lost through evaporation, drainage, or inefficient absorption.

Another major distinction is the availability of oxygen to the roots. Aeroponics provides maximum root aeration because the roots are exposed directly to air, which significantly accelerates plant growth and root health. Hydroponics offers a moderate level of oxygen, typically aided by air pumps or stones to keep the solution oxygenated. In soil farming, oxygen availability can vary depending on the type and quality of the soil, often becoming a limiting factor in dense or waterlogged soils.

When it comes to growth rate and yield, aeroponics has been shown to outperform both hydroponics and soil farming. Due to the precise and efficient delivery of nutrients and oxygen, plants in aeroponic systems grow faster and can yield more produce in less time. Hydroponics also offers faster growth than traditional methods, but it is still slightly slower compared to aeroponics. In contrast, soil farming is heavily dependent on external factors like weather, pests, and soil quality, making it the least consistent in terms of yield and speed.

The space efficiency of aeroponics is another advantage, especially in urban or indoor farming scenarios. The vertical stacking of plants is easily achievable in aeroponic setups, making them ideal for compact environments like greenhouses, rooftops, and indoor farms. Hydroponics is also space-efficient and suitable for vertical farming but requires larger reservoirs and support systems. Soil farming typically requires large plots of arable land, limiting its feasibility in densely populated or land-scarce regions.

However, aeroponics does come with higher initial setup costs and maintenance needs. It requires specialized equipment like misting nozzles, pumps, sensors, and microcontrollers (like ESP32), along with a reliable power source and constant monitoring. Hydroponic systems are comparatively simpler and more affordable to set up and maintain, although they still require pumps and regular water testing. Soil farming, being the oldest and most natural method, involves the least technological involvement and cost, but it is also the most labor-intensive and prone to inefficiencies due to pests, weeds, and inconsistent nutrient levels.

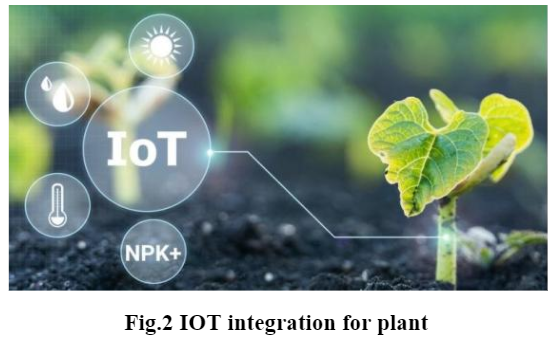
Finally, in terms of disease susceptibility, aeroponics provides a cleaner environment with lower chances of soil-borne diseases. Since the roots are suspended and not exposed to a shared water medium, contamination is less likely. Hydroponics, however, can quickly spread waterborne pathogens if the nutrient solution gets contaminated. Soil farming faces the most issues with pests, fungi, and diseases due to the complexity and variability of the soil ecosystem.

### 1.3. IoT-Based Monitoring Systems in Aeroponics

#### Key Parameters Monitored:

IoT-based monitoring systems in aeroponics track several key parameters to ensure that plants grow under the best possible conditions:

* **TDS:** TDS values for the plants are monitored and on reaching a particular criterion, nutrient solution is dispensed automatically using solenoid.
* **pH Levels:** The pH of the nutrient solution is carefully monitored to ensure optimal absorption by plants.
* **Nutrient Concentration:** IoT sensors measure nutrient concentrations and adjust mist levels accordingly.
* **Light Intensity:** Real-time monitoring of light intensity also allows for adjustment of grow lights to provide plants with the necessary amount of light for photosynthesis.



* **Data Collection and Automated Environmental Control**

Continuous data collection is integral to aeroponics systems using IoT technology. Sensors constantly collect environmental data, which is then transmitted to a central database. The system utilizes the data and makes necessary adjustments in real-time. For example:

* **Automatic Adjustments**: In the event that pH or TDS levels deviate from the ideal range, the system will promptly regulate the environment by adding nutrient solution.
* **Nutrient Delivery:** The nutrient levels are constantly monitored and automatically adjusted by the system, always ensuring the perfect mix of nutrients and water for the plants using solenoid.
* **Energy Efficiency:** The system has the ability to control energy usage by adjusting light brightness or harnessing solar energy during daytime.

### 1.4. Data Processing and Decision Support

#### Analysis of Environmental Data for Optimal Plant Growth

Efficient plant growth in aeroponics relies heavily on data analysis. The IoT technology enables the collection and processing of data from multiple sensors, including pH, and TDS. By doing so, it provides a thorough understanding of the optimal growing conditions. As a result, this analysis greatly contributes to maximizing growth potential.

* **Optimizing Growth Conditions:** By regularly comparing the current environment with predetermined optimal conditions, the system can make

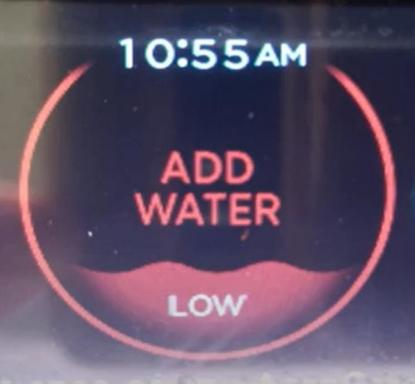
necessary adjustments to maintain the plants' optimal growth.

* **Tracking Trends**: Examining changes in data (such as temperature or nutrient levels over a period of time) enables more accurate predictions and preparation for the future requirements of plant growth.

#### Role of Anomaly Detection in Enhancing Efficiency :

Anomaly detection algorithms play a key role in enhancing system efficiency and preventing potential issues before they impact the crop:

* **Proactive Measures**: Flags may be raised for anomalies, such as unexpected temperature decreases or excessive humidity levels. In those instances, automated system reactions may occur.
* **Continuous Optimization**: IoT systems can analyze and adapt from previous anomalies. This results in improved responses for future occurrences, ultimately leading to increased efficiency in operations.

**=**

**Fig.3 Alert indicating water deficiency**

### 1.5. User-Friendly Interfaces for Aeroponics System

#### Importance of Intuitive Interfaces for Data Visualization

To fully utilize IoT-based aeroponics systems, it is crucial to offer an intuitive and user-friendly interface for data display. This enables farmers to easily comprehend complex information and make well-informed choices. A proficient interface should:

#### Real-Time Dashboards:

Present data in a user-friendly manner, utilizing elements like graphs and gauges, to convey the current state of all tracked variables.

#### Trend Analysis:

Offer visual representations of changes over time, such as nutrient levels, pH shifts, and TDS fluctuations facilitating sustainable decision-making.

#### Web Platforms for Remote Monitoring

Remote monitoring of aeroponics systems is crucial, and web-based platforms play a significant role in this process. They offer farmers the ability to track their crops and make necessary changes from any location, thereby enhancing flexibility and efficiency. Notable features of such platforms include:

**Cloud Integration**: Web platforms are designed to seamlessly connect with cloud- based systems, providing instant updates and allowing access to data on any device, regardless of location.

**Data Access and Control**: By having access to data and receiving alerts remotely, farmers can make necessary adjustments to the system to maintain optimal conditions for their plants.

### 1.6. Challenges and Limitations

#### Technical Challenges and Cost Considerations

Despite the numerous advantages offered by IoT-based aeroponics, they do come with their own set of challenges.

* + - * **High Initial Investment**: Incorporating sensors, automation technology, and communication systems can significantly increase the initial expenses of implementing IoT-enabled aeroponics systems.
      * **Technical Complexity:** The successful implementation and upkeep of an IoT-based aeroponics system necessitates specialized knowledge. Consistent maintenance of monitoring systems, sensors, and software may pose a challenge for small-scale farmers.
      * **System Integration**: Designing and testing are crucial in achieving seamless integration of components such as sensors, control systems, and user interfaces. This task can be challenging and requires attention to detail.

#### Sustainability and Energy Consumption

* **Energy Use**:

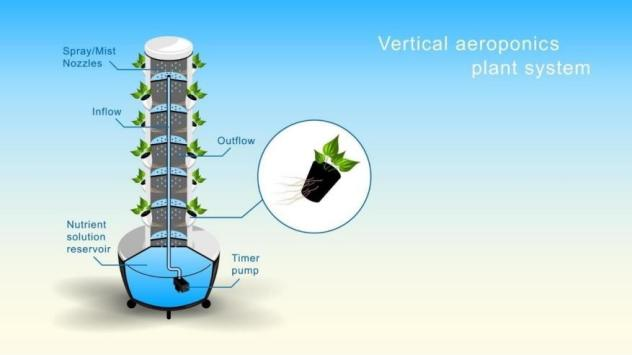
The use of non-renewable energy sources in IoT systems, such as artificial lighting and misting systems, can result in high energy consumption. This poses a challenge to the sustainability of aeroponics farming if not carefully monitored.

#### Waste Generation:

Inefficient system design may result in the production of electronic waste, as sensors, devices, and other components may require frequent replacement.

## Literature Survey

Aeroponics is a form of vertical farming where the plant grows in a suspended manner. As the roots are placed inside a protection chamber, a fine mist of nutrients is sprayed over the container. One potential solution to enhance farming systems is by utilizing resources and boosting production. The monitoring of stress and its contributing factors during cultivation.



**Fig.4 Vertical Aeroponics system**

### The Evolution of Aeroponics

Aeroponics, as a cultivation technique, has a history that dates back nearly a century. The concept of growing plants without soil, where roots are suspended in air and misted with nutrients, first began to take form in the **1920s**, primarily in laboratory research. Scientists were fascinated by the idea of eliminating soil as a growth medium in order to study plant physiology under more controlled and observable conditions. This idea laid the foundation for what would later become a revolutionary agricultural method. However, during this early stage, aeroponics was not yet practical for widespread agricultural use. The focus was primarily academic, aimed at understanding how plants absorb nutrients, grow roots, and respond to various external stimuli.

The **1940s** marked a significant turning point in the development of aeroponics. In **1942**, botanist **W. Carter** was among the first to successfully experiment with “air culture.” He described a technique in which plant roots were suspended in a chamber and exposed to a fine mist of nutrient-enriched water vapor. His goal was to create a method that allowed easier observation and access to the root systems of plants for scientific purposes. Around the same time, **Klotz**, a plant pathologist, also began utilizing mist to grow citrus plants. His motivation was to study diseases that affected citrus and avocado roots, and he found that mist-based nutrient delivery greatly facilitated root health and experimental observation. These early experiments established aeroponics as a legitimate scientific tool and sparked further interest among researchers.

By the **1950s**, advancements in misting technology enabled larger plants to be grown in air culture environments. In **1952**, **G.F. Trowel** managed to grow **apple trees** using a spray culture method. His work demonstrated that even woody perennials with more complex root systems could be supported by aeroponics. Although his system was still experimental and used mainly for academic purposes, it proved that aeroponics had the potential to move beyond small-scale or laboratory environments and be applied to the cultivation of food crops.

The true commercial viability of aeroponics began to materialize in the **1980s**. In **1983**, the first commercial aeroponic system, known as the **Genesis Rooting System** (or **Genesis Machine**), was introduced by a company called GTi (General Technologies Inc.). This system was groundbreaking for its time. Controlled by a microchip, it allowed users to automate nutrient misting and environmental monitoring. Its plug-and-play design made it user-friendly, requiring only a standard electrical outlet and a connection to a water source. This was the first time aeroponics became accessible to growers outside of research institutions—particularly hobbyists, indoor gardeners, and small-scale commercial operations. The Genesis Machine marked a critical evolution from theory to practice, enabling the technique to be tested under real-world agricultural conditions.

The **1990s and 2000s** saw a steady rise in interest in sustainable and soilless agriculture due to growing concerns over land degradation, water scarcity, and food security. During this period, aeroponics was further refined, particularly in controlled environment agriculture (CEA) settings such as greenhouses and vertical farms. These systems began incorporating programmable logic controllers (PLCs), timers, and environmental sensors to better regulate misting cycles, humidity, and light exposure. As awareness of climate change grew, aeroponics was increasingly recognized as a resource-efficient and climate-resilient method of crop production. This was especially relevant for urban environments and arid regions where traditional farming was impractical.

A major catalyst for aeroponic advancement came from **NASA**. In its quest for sustainable life-support systems in space, NASA began exploring soil-less cultivation methods that could function in microgravity environments. Traditional soil farming is infeasible in space, and even hydroponics, which uses a nutrient solution, poses challenges due to fluid behavior in zero gravity. Aeroponics, however, uses nutrient-rich mist, which can be more easily controlled in such conditions. NASA’s experiments conducted aboard space shuttles and in Earth-based simulators demonstrated that aeroponically grown plants could thrive in space-like conditions while conserving water and providing essential nutrients.

What was particularly fascinating in NASA’s findings was that aeroponically grown plants contained up to 80% more essential minerals compared to those cultivated through hydroponics. This revelation was monumental. It not only proved the efficiency of aeroponics in terms of nutrient uptake but also highlighted its potential to improve nutritional density in food—an essential factor in long-duration space missions. These results prompted further investment and development in aeroponic technologies for both space and terrestrial applications.

In the last two decades, aeroponics has undergone another wave of transformation—this time driven by digital technologies and the Internet of Things (IoT). The integration of IoT has enabled real-time monitoring, data logging, and automation in aeroponic systems. Using microcontrollers such as the ESP32, connected via protocols like MQTT (Message Queuing Telemetry Transport) and HTTP, environmental data such as temperature, humidity, TDS (Total Dissolved Solids), and pH levels are gathered and transmitted to cloud platforms like ThingSpeak or mobile apps like Blynk. This enables farmers and growers to receive instant alerts and adjust conditions remotely, ensuring optimal plant health.

Moreover, pH sensors, electrical conductivity (EC) sensors, and actuators like solenoid valves have allowed aeroponic systems to automate the precise delivery of nutrients. These systems compare real-time readings against predefined thresholds and make adjustments—such as adding water, nutrients, or even pH modifiers—without human intervention. This has drastically reduced errors, saved labor, and optimized crop yield. As a result, precision agriculture is no longer limited to large-scale farms; it is now feasible even in compact, indoor environments.

An equally important development in recent years has been the use of Life Cycle Assessment (LCA) tools to measure the environmental and economic sustainability of aeroponics. LCAs consider various factors including energy usage, carbon emissions, material lifecycle, and operational costs. Studies have shown that although the initial setup of an aeroponic system can be more expensive than hydroponics or traditional farming, the long-term benefits far outweigh the costs. Aeroponics significantly reduces water consumption, minimizes fertilizer runoff, and produces higher yields per square meter, making it a compelling solution in the face of global food challenges.

Today, aeroponics plays a crucial role in urban agriculture, vertical farming, and space-based food systems. Its journey from a laboratory curiosity to a commercially viable and globally impactful farming method reflects the synergy of scientific exploration, technological innovation, and sustainable thinking. As we look toward the future with increasing demand for food, shrinking arable land, and uncertain climate conditions aeroponics stands out as a promising path forward for agriculture in the 21st century and beyond.

### Work of Various Authors

González-Amarillo and Fernández-Ahumada utilize humidity and temperature data for activating irrigation, ventilation, and heating systems. In comparison, Mohamed and Poyen determine irrigation requirements through daily evapotranspiration measurements. Jamroen applies a fuzzy controller to regulate irrigation based on humidity and water stress index, while Lloret implements automated irrigation through crop measurements and weather conditions or remote access via a mobile application.

Lucero oversaw the greenhouse's temperature and humidity for aeroponic cultivation, setting irrigation schedules for day and night based on three stages corresponding to production days. In their suggestion, if the temperature surpasses 35

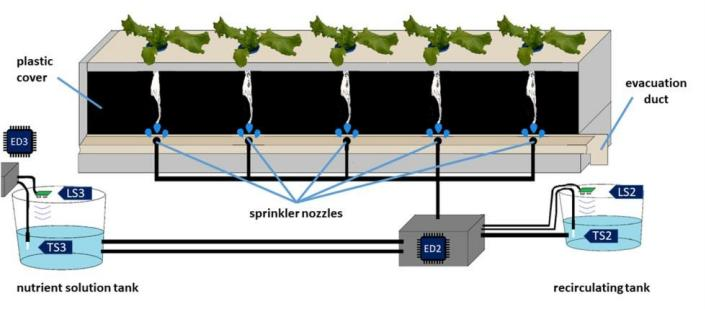
°C, the irrigation time is shortened. Gour recommended implementing a central processor with an interface connecting sensors, actuators, and machine learning tools for an automated cultivation process.

The convergence of Internet of Things (IoT) technology and precision agriculture has been the subject of extensive research in recent years. In particular, the application of IoT in aeroponics farming systems has shown significant potential for enhancing food production efficiency, reducing resource consumption, and enabling real-time monitoring and control. Several studies have highlighted the impact of IoT on traditional and modern agricultural systems. According to Zhang et al. (2017), IoT enables the collection of granular environmental data, which can be used for decision-making and automation in farming operations. Similarly, Wolfert et al. (2017) discussed how digital agriculture platforms improve productivity through data integration and predictive analytics.

Research by Stoner and Clawson emphasized that aeroponics systems use up to 95% less water than conventional soil-based farming and offer faster plant growth rates due to direct nutrient delivery. The absence of soil reduces disease spread and supports cleaner and controlled crop production. The role of environmental sensors in modern agriculture is critical. Studies by Kumar et al. (2019) and Mishra et al. (2020) demonstrated how sensors for temperature, humidity, pH, and nutrient levels can continuously monitor and regulate optimal plant growth conditions. These sensors, integrated with microcontrollers and communication modules, allow real-time data collection and remote monitoring. Machine learning and predictive models have been increasingly applied in agriculture to anticipate plant needs and forecast yields. Patel et al. (2021) used historical environmental data and growth patterns to predict optimal nutrient delivery schedules and yield outputs. Their work showed that AI-driven models enhance crop planning and reduce wastage. The effectiveness of IoT systems also depends on their usability. Work by Lee and Park (2018) emphasized the importance of intuitive dashboards and mobile interfaces that allow farmers to receive alerts, visualize trends, and take corrective action. Their study found that well-designed interfaces increased system adoption and decision-making efficiency. Despite the potential, challenges in IoT-based aeroponics systems include sensor calibration, data accuracy, system scalability, and cost. However, recent advancements in low-power communication protocols (e.g., LoRa, Zigbee) and edge computing offer promising solutions for scalable and efficient deployment.

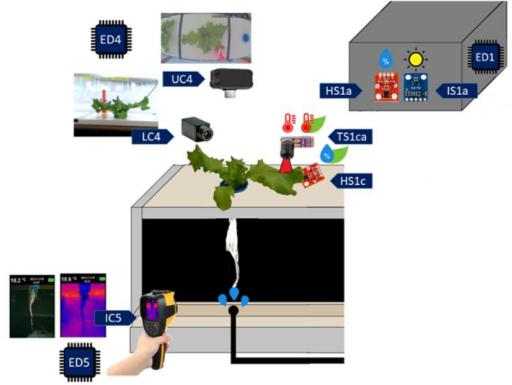
#### Key Work done by the Authors:

1. **Aeroponic System Setup**:
   1. Created a growing chamber of specific dimensions for lettuce plants.
   2. Included a nutrient delivery system with two tanks for irrigation and recirculation, monitored by HC-SR04 and DS18B20 sensors for water level and temperature.
   3. Utilized R385 diaphragm pumps for nutrient distribution and collection, as well as a submersible pump for solution mixing.



#### Fig.5 Aeroponics growing system by authors

1. **Sensor Integration**:
   1. Incorporated various cameras (such as a webcam, IP camera, and thermographic camera) for plant surveillance.
   2. The development of plants, their root size, and the measurement of colors.
   3. Utilized cutting-edge imaging techniques to evaluate both crop well-being and other factors.



#### Fig.6 Location of sensors and visual inspection system

1. **IoT Architecture Design:**
   1. Introduced a four-layer structure for IoT:
      1. **Device Layer:** Consisting of five end devices (ED1 to ED5) responsible for collecting sensor data, controlling pumps, and operating cameras.
      2. **Fog Layer:** Utilized microservices for tasks such as irrigation scheduling, reservoir management, image processing, and system control.
      3. **Cloud Layer:** Provided storage for data and remote accessibility.
      4. **Application Layer:** Equipped with a user-friendly interface for managing settings and monitoring system status.

#### Microservices Implementation:

* 1. The microservices implementation involved developing functions such as irrigation control, image processing, alert generation, and data exchange between sensors and cloud servers. To ensure efficient storage of sensor readings and images, a local database was also created.

#### Environmental and Growth Monitoring:

* 1. Conducted real-time surveillance of environmental conditions such as temperature, humidity, and light levels.
  2. Employed cameras for monitoring of plant growth indicators including height, leaf area, and root development.
  3. Utilized thermographic imaging to analyze root temperatures.

#### Data Analysis and Visualization:

* 1. Developed a system for continuous data transmission to the fog layer, where it is analyzed and generates valuable information for users.
  2. Incorporated alert mechanisms to detect anomalies, such as inadequate nutrient levels or unusual plant growth patterns.

**3. SOFTWARE AND HARDWARE** **REQUIREMENTS**

**3.1. Hardware Requirements :**

**3.1.1. pH Sensor**

The pH sensor measures the acidity or alkalinity level of the nutrient solution used in the aeroponic system. pH is a crucial factor because it influences nutrient availability; certain nutrients become less soluble or unavailable to plants if the pH is

too high or too low. The pH sensor typically consists of a glass electrode that produces a voltage proportional to the hydrogen ion concentration in the solution. This voltage is read by the ESP32’s analog input and converted into a pH value. By continuously monitoring the pH, the system can alert the farmer or automatically adjust the solution by adding acid or base to keep the pH within the ideal range for the crops.



**Fig 7. pH Sensor**

A circuit board with wires connected to it

AI-generated content may be incorrect.

**Fig 8. Ph sensor Interface**

**3.1.2 TDS Sensor :**

The Total Dissolved Solids (TDS) sensor used here is to measure the concentration of dissolved substances such as salts, minerals, and nutrients in the water or nutrient solution. This measurement is essential for maintaining the nutrient balance within the aeroponic system. The TDS sensor works by passing an electrical current through the solution and measuring its conductivity; higher conductivity indicates a higher concentration of dissolved solids.

A close-up of a circuit board

AI-generated content may be incorrect.

**Fig 9. TDS Sensor**

A circuit board connected to a device

AI-generated content may be incorrect. **Fig 10. TDS Sensor interface**

The sensor outputs an analog voltage that the ESP32 converts to parts per million (ppm), representing the nutrient concentration. If the TDS level rises above a certain threshold, the system can activate solenoid valves to dispense water or nutrient solution, automatically correcting the concentration and ensuring optimal plant growth.

**3.1.3. Relay:**

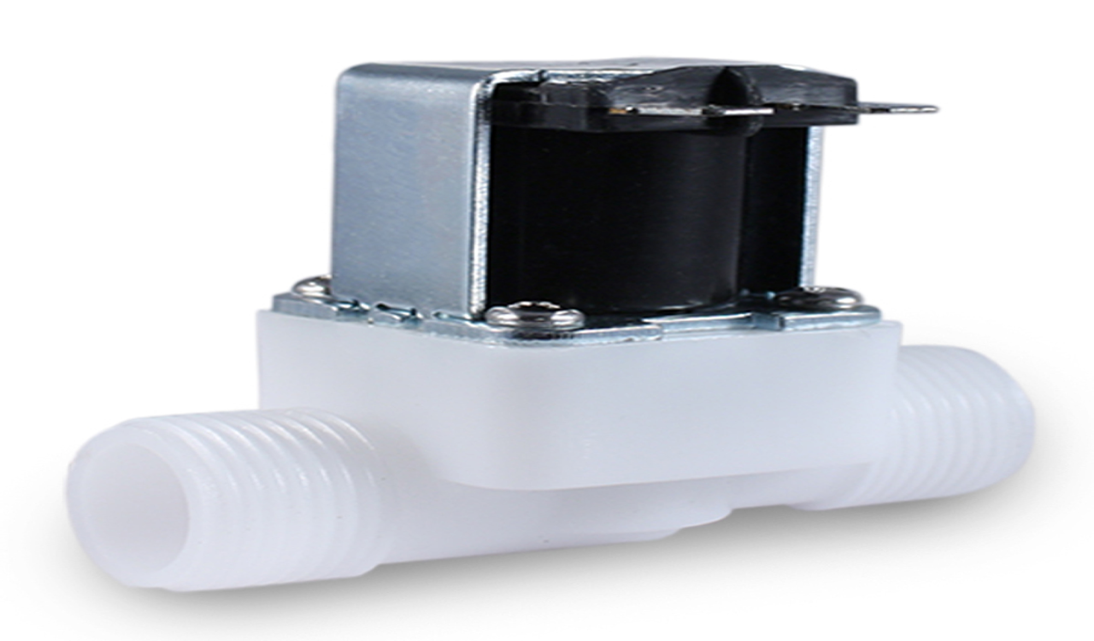
A relay acts as an electrically operated switch that enables the microcontroller (ESP32) to control high-power devices such as solenoid valves that operate on external voltage levels (typically 9V–12V), which the ESP32 itself cannot directly supply. The relay provides isolation between the control circuit (low voltage) and the actuator circuit (high voltage), ensuring safety and stability of the system. The ESP32 controls the relay by sending a digital HIGH or LOW signal to its input pin. When the input signal is HIGH, the relay coil energizes and closes the switch on the high-voltage side, allowing current to flow to the solenoid valve. Conversely, when the input signal is LOW, the switch opens, cutting off power to the valve. This allows precise on/off control of the nutrient flow mechanism based on real-time sensor inputs. The relay module used is typically a 1-channel or 2-channel 5V relay, which is powered using the ESP32’s 5V output and controlled via one of its GPIO pins. An onboard transistor, diode, and LED indicator assist in switching operations and protecting against voltage spikes generated during switching.



**Fig 11. Relay**

**3.1.4. Solenoid:**

A solenoid valve is an electromechanical device that controls the flow of liquids or gases. In this system, it is used to control the release of either pure water or diluted nutrient solution into the main tank when the TDS level rises above acceptable limits. The valve operates using the principle of electromagnetic induction when an electric current flows through the solenoid coil, it generates a magnetic field that moves a plunger, opening or closing the valve. In our setup, a normally closed (NC)solenoid valve is preferred. This means that under normal (unpowered) conditions, the valve remains closed, ensuring no leakage or unintentional flow. When activated via the relay, the solenoid opens, allowing fluid to flow for a specified duration determined by the microcontroller logic. The solenoid valve is chosen based on parameters such as voltage rating (typically 12V DC), current requirements, material compatibility with nutrient solution, and flow rate. It is connected to a separate reservoir or water tank that supplies the diluting solution, and the outlet is connected to the main nutrient mixing tank.



**Fig 12. Solenoid valve**

**3.1.5. External Battery:**

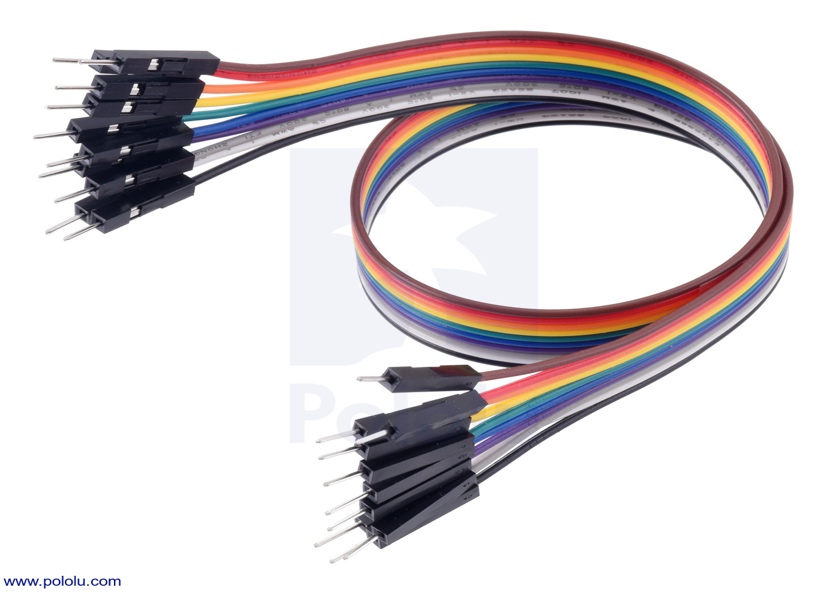
Since the solenoid valve requires more current than the ESP32 or a USB connection can provide, a dedicated external battery or DC power source is used. This ensures stable operation of the actuator components without putting stress on the microcontroller’s onboard power regulator. A 12V lithium-ion battery pack or DCadapter is commonly used for powering both the relay and solenoid. In our project, the power line is split using a common ground and power rail. The positive terminal is connected to the normally open terminal of the relay, while the output of the relay is connected to the solenoid valve. The negative terminal (GND) is shared across the battery, relay, ESP32, and solenoid to establish a common reference voltage. This external power arrangement allows continuous, uninterrupted operation of the automatic dispenser system, even during periods of high nutrient usage or power fluctuations. The battery is rechargeable and portable, making the system suitable for both indoor grow chambers and remote vertical garden setups.



**Fig 13. External battery**

**3.1.6. Jumper Wires:**

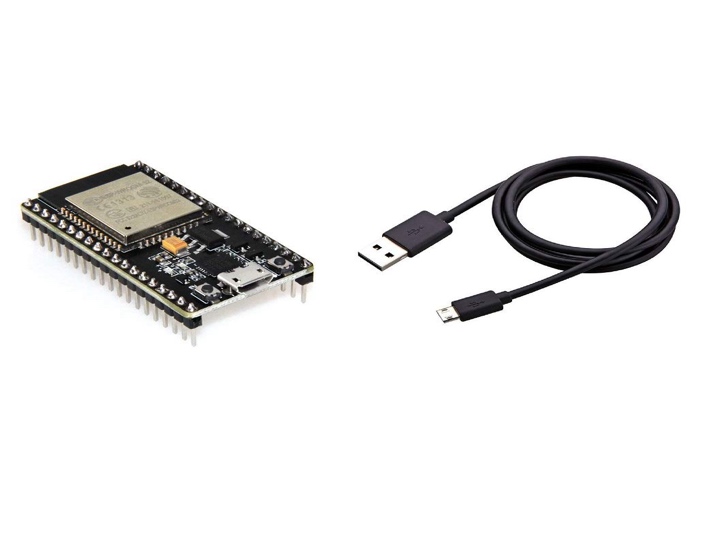
Jumper wires are insulated wires used to connect electronic components without soldering. They are commonly used to link microcontrollers, sensors, and USB modules on a breadboard. In USB connections, jumper wires transmit power (VCC and GND) and data (TX and RX) between devices. They come in male-to-male, male-to-female, and female-to-female types. These wires make prototyping and testing circuits easy and reusable. They're essential for connecting USB-to-serial converters to microcontrollers like Arduino or ESP32.



**Fig 14 . Jumper Wires**

**3.1.7. ESP32 Cable:**

An ESP32 cable is typically a USB to Micro USB cable used to connect the ESP32 development board to a computer. It allows for both power supply and data transfer, enabling code uploads and serial communication. This connection is essential for programming the ESP32 using the Arduino IDE or other platforms. The cable makes it easy to power the board and monitor outputs via the serial monitor. It is a plug-and-play solution commonly used in development and testing of IoT projects.

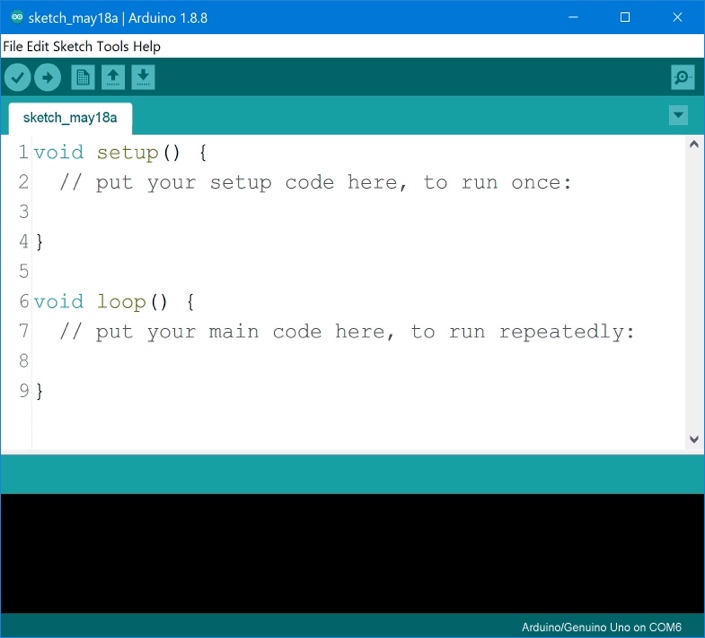


**Fig 15. ESP32 Cable**

**3.2. Software Requirements:**

**3.2.1. Arduino IDE:**

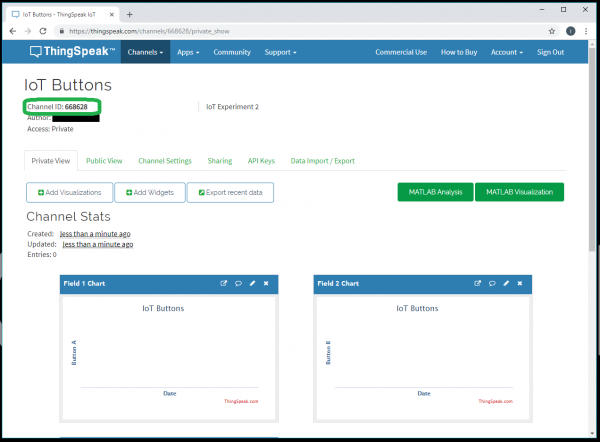
The Arduino IDE (Integrated Development Environment) is a software platform used to write, compile, and upload code to Arduino and compatible boards like the ESP32. It supports C/C++ programming and provides built-in functions for easy hardware control. The IDE includes a code editor, a compiler, and a serial monitor for debugging. It is simple and beginner-friendly, making it popular for electronics and IoT projects. The ESP32 board can be added to the Arduino IDE using the board manager.



**Fig 16. Arduino IDE**

**3.2.2. ThingSpeak Platform:**

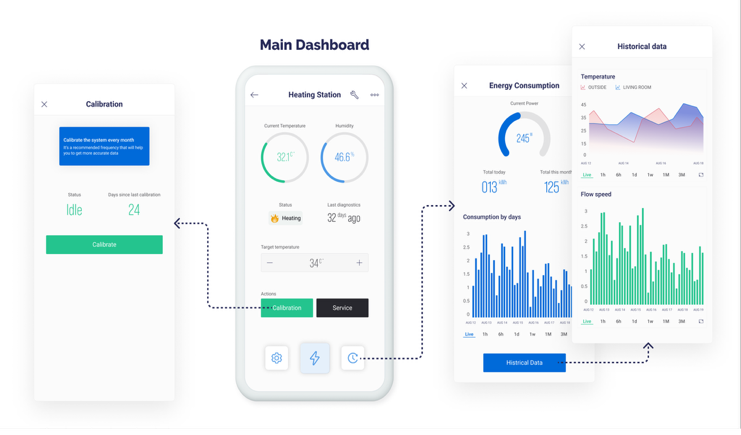
ThingSpeak is an open-source IoT analytics platform used to collect, store, analyze, and visualize sensor data in real-time. It allows devices like the ESP32 to send data over Wi-Fi and log it to the cloud. Users can create channels to store data, use MATLAB for analysis, and set up triggers or alerts. ThingSpeak is widely used in IoT projects for remote monitoring, such as weather stations, smart farming, and home automation. It is free for non-commercial use and easy to integrate with Arduino IDE and ESP32.



**Fig 16. ThingSpeak Platform**

**3.2.3. Blynk IOT:**

Blynk IoT is a platform that allows you to build and control IoT applications using smartphones or web dashboards. It supports microcontrollers like ESP32, enabling real-time data monitoring, control of devices, and automation over the internet. Blynk uses a mobile app and web interface, where you can drag and drop widgets to create custom dashboards. It connects to devices using the Blynk library and authentication token. Blynk is user-friendly, making it ideal for smart home, automation, and sensor-based projects.



**Fig 17. Blynk IOT**

**4. Methodology**

The proposed method integrates Internet of Things (IoT) technology with intelligent automation to optimize crop cultivation in an aeroponics setup. This system is structured into five main components: Data Acquisition, Data Processing & Analysis, Control and Automation, Decision Support & Forecasting, and Anomaly Alert Mechanism. The goal is to achieve precision agriculture by continuously monitoring environmental parameters and dynamically adjusting system operations based on real-time insights. The system continuously monitors water quality parameters (TDS and pH) using sensors connected to an ESP32 microcontroller. It sends real-time data to cloud platforms (ThingSpeak) for live monitoring and analysis. When nutrient levels exceed a preset threshold, the system automatically activates a solenoid valve to dispense nutrient solution, maintaining optimal conditions for plant growth.

The ESP32 is an open-source development board powered by a dual-core microcontroller, widely used for hardware automation projects. It features built-in Wi-Fi and Bluetooth capabilities, making it highly versatile for IoT applications and interfacing with various sensors, modules, and external circuits. The board includes multiple digital and analog I/O pins, allowing for flexible integration in numerous projects. Programming is done through the Arduino Integrated Development Environment (IDE) or MicroPython, and communication with a computer is established using a USB interface. Additionally, the ESP32 supports the use of expansion boards and libraries that extend its functionality for tasks such as wireless communication, motor control, and real time data processing.

A diagram of a circuit board

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**Fig 18. Circuit Diagram**

**4.1. Initialization and Wi-Fi Connection :**

When the system is powered on, the ESP32 microcontroller begins by initializing all core modules, including serial communication, GPIO configurations, analog-to-digital channels, and internal timers. Serial communication is established through the USB interface, enabling real-time debugging and development support via the serial monitor. Developers can view boot messages, Wi-Fi status, and sensor output instantly, ensuring transparent system behavior.

Following this, the microcontroller attempts to connect to a specified Wi-Fi network using stored SSID and password credentials. The ESP32 includes built-in support for 2.4 GHz networks, making it compatible with most home and commercial routers. If the network connection fails, retry mechanisms such as exponential backoff or timed delays are applied until a stable link is formed.

Once connected, the ESP32 authenticates with the Blynk IoT platform using a unique token. This secure token-based authentication ensures the device links to the correct user dashboard for real-time control and monitoring. In addition, this connection enables two-way communication, allowing sensor data uploads and remote user commands from mobile or web interfaces. A stable Wi-Fi link is critical to support cloud updates and app control functionality.

**4.2. Sensor Data Collection**

The system continuously collects environmental parameters using two key sensors:

**TDS Sensor**: Measures the Total Dissolved Solids in the nutrient solution, indicating the overall concentration of nutrients.

**pH Sensor**: Detects the acidity or alkalinity of the water, critical for nutrient uptake and root health.

The TDS sensor functions by measuring electrical conductivity in the solution, which is proportional to the dissolved mineral concentration. The pH sensor, on the other hand, uses a voltage differential between reference and measurement electrodes to quantify the acidity or alkalinity of the nutrient water.

Both sensors are connected to the analog input pins of the ESP32, which features 12-bit resolution analog-to-digital converters (ADCs). These ADCs convert analog voltage values into digital data ranging from 0 to 4095, representing fine variations in sensor output.

Sensor readings are captured at fixed intervals (e.g., every 5–10 seconds) to ensure continuous monitoring. In practice, a buffer-based smoothing algorithm (like moving average filtering) may be applied to mitigate minor fluctuations caused by electrical noise or fluid turbulence. Sensor placement is vital probes must be fully immersed in the nutrient reservoir and isolated from sources of electromagnetic interference.

**4.3. Data Conversion and Calibration**

Once the ESP32 receives raw analog readings from the sensors, the values are processed to obtain meaningful, real-world measurements.

For the TDS sensor, the ADC output is first converted to voltage using a reference formula involving the ESP32’s supply voltage and ADC resolution. This voltage is then mapped to TDS concentration in parts per million (ppm) using a calibration constant derived from standard solutions. Temperature compensation is often factored into this equation, as conductivity varies with water temperature.

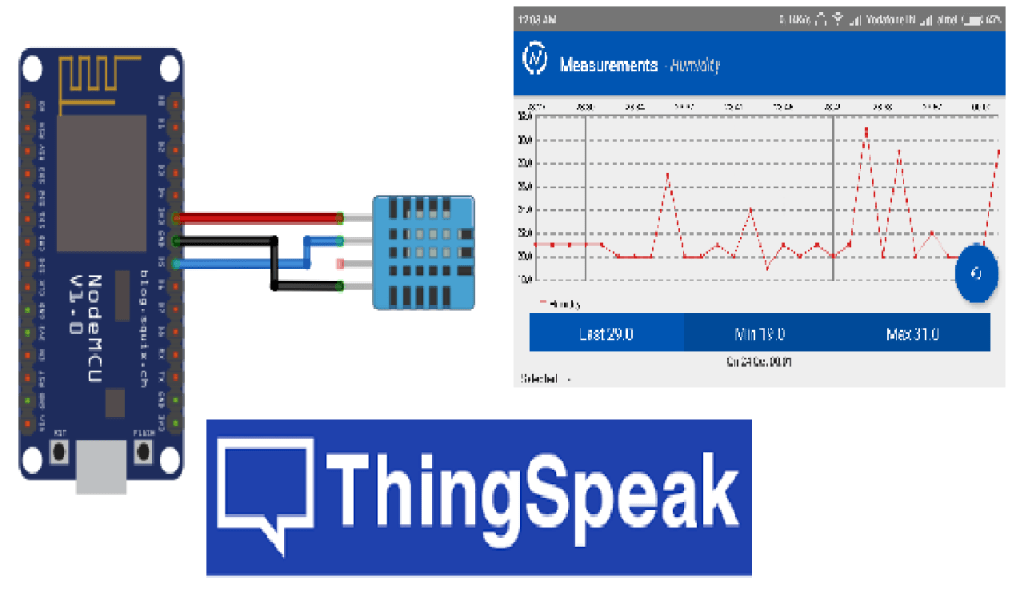
For the pH sensor, calibration involves plotting the output voltage against known buffer solutions, usually at pH 4.0 and 7.0. Based on this, a linear equation is derived to convert live voltage readings into pH values on a 0–14 scale. The slope and offset values are stored in code to adjust future readings automatically.

Calibration is essential to ensure accuracy. Users may be prompted periodically (via the app interface) to recalibrate sensors, especially if results appear unstable. Proper calibration not only improves measurement precision but also extends the sensor’s operational life.

**4.4. Data Transmission to Cloud and Mobile App**

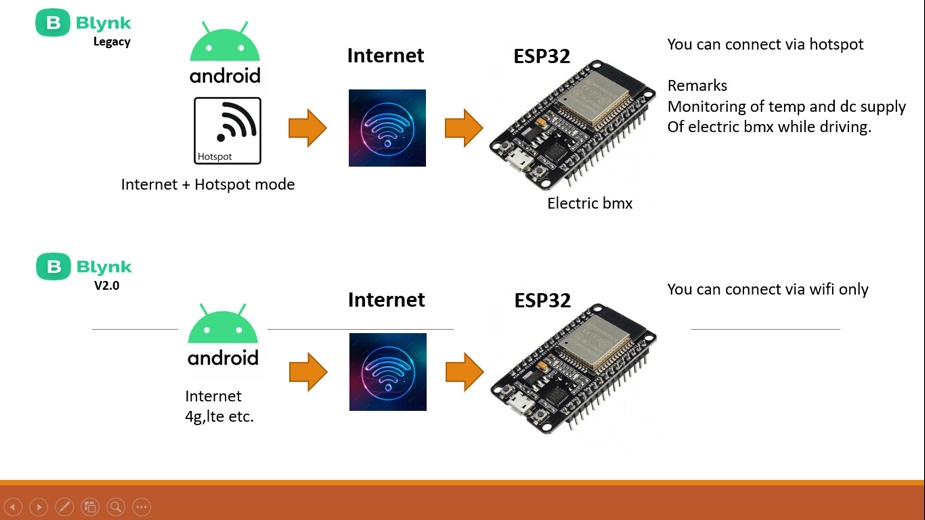
The ESP32 transmits processed TDS and pH values to cloud platforms to enable live monitoring, remote access, and data analysis.

* ThingSpeak: This IoT platform receives sensor readings through HTTP GET requests and stores them in defined channels. It offers time-series visualization through customizable line graphs, enabling users to observe trends in nutrient quality over time. ThingSpeak also supports integration with MATLAB, which allows advanced analytics, such as data smoothing, anomaly detection, and forecasting models.



**Fig 19. Data transmission to ThingSpeak**

* Blynk: A user-friendly IoT mobile platform, Blynk provides a real-time dashboard accessible via smartphones or tablets. Developers can create widgets like gauge meters, digital displays, graphs, and notifications. Each widget corresponds to a sensor variable, allowing users to visualize live data and control system actions (e.g., manually open the solenoid valve).



**Fig 20. Data transmission to Blynk IOT**

Both platforms support bidirectional communication. While sensor values are uploaded, commands from the user (such as system reset, calibration, or manual overrides) can be received by the ESP32 and executed in real-time. This dual capability makes the system interactive and responsive.

**4.5. Automated Nutrient Dispensing Control**

To maintain the nutrient concentration within ideal ranges, an automatic control system is embedded into the ESP32 firmware. The main logic compares real-time TDS readings against a preset upper threshold (e.g., 300 ppm).

If the measured value crosses this limit, the ESP32 triggers a solenoid valve using a relay or transistor switch. This valve controls the flow of either clean water or diluted nutrient solution from a storage tank into the main reservoir, thereby reducing the concentration and restoring balance.

A delay mechanism ensures the valve remains open just long enough to dilute the solution, after which it shuts automatically. The system then takes another sensor reading after a short stabilization period to confirm that the concentration has returned to acceptable limits.

In more advanced setups, a closed-loop PID controller could be implemented to optimize this adjustment process. Such controllers continuously analyze the error between current and target values and adjust the valve timing accordingly providing smoother and more precise nutrient control.

Although the current system only monitors pH and provides actions if it deviates from the range, future upgrades could involve automated pH correction using dosing pumps. These pumps would dispense acidic or alkaline solutions as needed to bring the pH back into the ideal 5.5–6.5 range for most plants.

**4.6. Decision Support and Forecasting (Future Enhancement)**

One of the long-term goals of this project is to evolve from reactive automation to intelligent decision support using AI and data analytics. As more data is accumulated, patterns can be discovered and used to optimize system behavior without human intervention.

By analyzing trends in water quality, nutrient usage, and environmental conditions, the system can:

* Recommend custom nutrient schedules tailored to the current crop and growth stage.
* Forecast nutrient depletion or pH drift and take corrective actions proactively.
* Identify slow changes that could indicate clogging, algae growth, or pump wear.
* Optimize water usage based on usage history and seasonal weather forecasts.

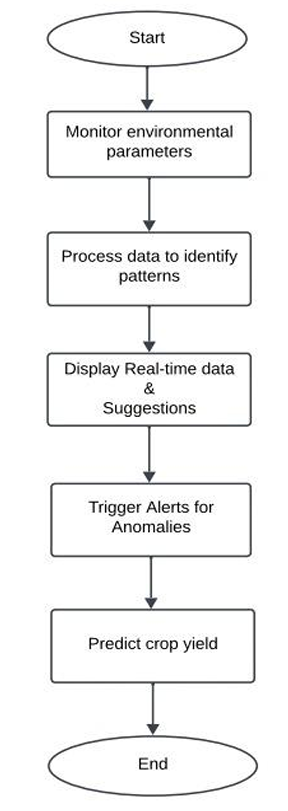
Machine learning models can be trained to recognize normal operating behavior and predict anomalies before they impact plant health. These models may run locally (on the ESP32 with TinyML libraries) or in the cloud using platforms like Azure or Google Cloud IoT.

This predictive intelligence turns a basic automation system into a smart farming assistant, capable of making data-driven decisions and improving both yield and sustainability.

The proposed system combines Internet of Things (IoT) technology and intelligent automation to optimize plant growth in an aeroponics setup. It uses an ESP32 microcontroller to collect real-time environmental data from Total Dissolved Solids (TDS) and pH sensors. This data is processed, calibrated, and transmitted to cloud platforms like ThingSpeak for storage and analysis, and to the Blynk app for live monitoring and remote access.

Once initialized, the ESP32 connects to Wi-Fi and continuously monitors nutrient solution quality. When TDS values exceed predefined thresholds, the system automatically activates a solenoid valve to dispense water or nutrients, ensuring optimal concentration. pH values are monitored similarly, and alerts are sent to users if they fall outside the ideal range. The system supports automation, remote control, and data-driven decision-making. Future enhancements may include predictive analytics and full automation of pH balancing, enabling smart, sustainable, and efficient precision farming.

**5. Implementation**



**Fig 21. Flowchart of the project**

The following flowchart represents the step-by-step operation of an intelligent agricultural system that utilizes Internet of Things (IoT) devices and data analytics to automate and optimize the crop growth process. This system is particularly suitable for aeroponics.

**1. Start**

The system begins with the initialization of all necessary modules. This includes booting up the microcontroller (e.g., ESP32), establishing Wi-Fi connectivity, and ensuring all sensors and cloud services are active and ready for data acquisition and processing.

**2. Monitor Environmental Parameters**

In this stage, various environmental parameters essential to plant health and growth are monitored using IoT-based sensors. These parameters may include:

* **pH:** To monitor the quality of nutrient solutions.
* **Light Intensity:** To ensure plants receive adequate artificial or natural light.
* **TDS:** to indicate the strength of the nutrient solution available to plant roots.

The sensors continuously collect real-time data, which is transmitted to a microcontroller and subsequently sent to cloud platforms like ThingSpeak or Blynk for storage and further analysis.

**3. Process Data to Identify Patterns**

The collected data is then processed using algorithms or basic machine learning models. The purpose of this step is to:

* Filter out noise and validate data accuracy.
* Analyze trends in environmental parameters over time.
* Detect recurring patterns that indicate optimal or suboptimal growth conditions.
* Make predictive inferences based on historical data.

**4. Display Real-Time Data & Suggestions**

The processed data is visualized on user interfaces such as mobile apps (e.g., Blynk) or cloud dashboards (e.g., ThingSpeak). These interfaces:

* Display real-time sensor values.
* Highlight warnings or optimal conditions.
* Provide actionable suggestions to the user, such as adjusting nutrient concentrations, increasing misting intervals, or modifying lighting.

These insights assist farmers or researchers in making informed decisions, improving both ease of use and productivity.

**5. Predict Crop Yield**

With sufficient data collected over time, the system can estimate future crop yield using:

* Regression-based models.
* Rule-based logic derived from ideal growth conditions.
* AI models trained on previous harvest data.

This prediction enables better planning, resource allocation, and market readiness. It also provides insights into how changes in environmental control affect the result.

**6. End**

This step signifies the completion of one cycle of data collection, analysis, and feedback. The system may either pause or continue running in a loop depending on the deployment context.

**5. Future Scope**

Aeroponics, an advanced method of growing plants without the use of soil or an aggregate medium, is rapidly gaining traction as a sustainable and efficient form of agriculture. With increasing concerns about climate change, soil degradation, urban space limitations, and food security, aeroponics represents a promising solution for the future of global agriculture. The technology involves suspending plant roots in air and misting them with a nutrient-rich solution, allowing precise control over environmental conditions. The scope for future development and adoption of aeroponics is vast, and its potential spans several key areas:

**5.1. Urban and Vertical Farming**

As urban populations continue to rise, the demand for locally grown, fresh produce will increase. Aeroponics can be easily integrated into urban vertical farming systems, enabling the growth of food within cities, on rooftops, or inside buildings using controlled environments. This reduces transportation costs, carbon footprint, and food wastage. In the future, smart aeroponic farms can be integrated into residential complexes, supermarkets, and corporate buildings, offering on-site production of vegetables and herbs.

**5.2. Sustainable and Resource-Efficient Agriculture**

Aeroponics uses up to 90-95% less water compared to traditional farming and even less than hydroponics. In an era where freshwater scarcity is becoming critical, aeroponics offers a sustainable alternative. Future research will likely focus on improving water and nutrient recycling systems, making aeroponic systems even more eco-efficient. Additionally, since aeroponics requires no soil, it eliminates issues such as soil erosion, pests, and the need for harmful chemical fertilizers and pesticides.

**5.3. Integration with IoT and Automation**

The incorporation of Internet of Things (IoT) and automation technologies will drive the future of aeroponics. IoT sensors can monitor temperature, humidity, pH, EC (electrical conductivity), and nutrient levels in real-time. This data can be used to automate misting systems and lighting schedules, ensuring optimal growth conditions. Future aeroponic systems may feature AI-driven control systems for predictive analysis and autonomous farming, reducing labor dependency and human error.

**5.4. Space and Planetary Exploration**

NASA has already experimented with aeroponics aboard the International Space Station (ISS) as a method of growing food in space. With long-duration space missions and potential colonization of the Moon or Mars on the horizon, aeroponics offers a viable method for growing food in zero-gravity or hostile environments. Research in this area will continue to explore plant varieties suitable for space growth and systems that can be miniaturized and automated for extraterrestrial use.

**5.5. Medicinal and High-Value Crop Production**

Aeroponics offers precise control over nutrients and environmental factors, making it ideal for growing medicinal plants and high-value crops such as herbs, cannabis (where legal), and specialty greens. The pharmaceutical industry may benefit from using aeroponic systems to cultivate plants with consistent chemical profiles, which is often difficult with traditional methods. In the future, customized nutrient solutions and gene expression controls may be used to enhance the yield and quality of therapeutic compounds.

**5.6. Research and Genetic Studies**

Aeroponic systems are ideal for root studies and genetic research, as the exposed roots can be easily observed and manipulated. This is particularly useful for scientists studying plant physiology, root development, and nutrient uptake. Future research may involve genetic modification or breeding of plants specifically for aeroponic systems, optimizing traits such as faster growth, higher yield, or resistance to diseases in controlled environments.

**5.7. Economic and Commercial Expansion**

With decreasing costs of sensors, automation, and microcontrollers, aeroponic systems are becoming more accessible to small-scale farmers, educational institutions, and hobbyists. Governments and private sectors are likely to invest more in aeroponics as a part of sustainable agriculture policies. In the near future, aeroponics could form the backbone of community-supported agriculture (CSA) models, farm-to-table restaurants, and local cooperative farming systems.

**6. Results**

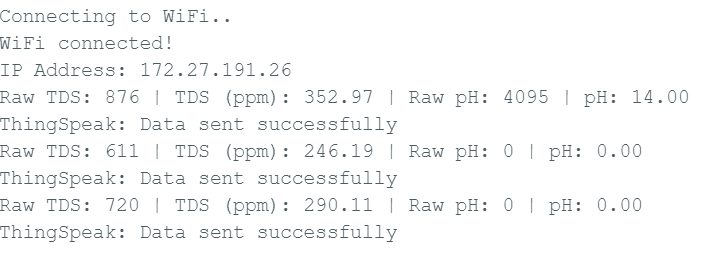
The proposed methodology measures the parameters of the soil health like Nitrogen, Phosphorus, and Potassium (macro-nutrients), pH, moisture content, and electrical conductivity and these parameters are mapped to that specific location where the soil sample is collected.

A table with numbers and letters

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**Table 1. TDS, PH readings**

The serial monitor displayed real-time readings of TDS and pH values collected by the sensors. The output format followed a pattern such as: “TDS: 148.28 | pH: 14.00” followed by “Data sent to ThingSpeak,” indicating successful data transmission to the cloud. Several readings were captured with TDS values ranging from around 148 to 457 ppm, while the pH consistently showed 14.00. These results confirm that the TDS sensor is functioning correctly, detecting changes in the nutrient solution. This type of monitoring is essential for aeroponics**,** where maintaining optimal nutrient levels and pH is critical for healthy plant growth. The successful data transfer to ThingSpeak further supports remote monitoring and automation in such system. The serial monitor displayed real-time readings of TDS and pH values collected by the sensors. The output format followed a pattern such as: “TDS: 148.28 | pH: 14.00” followed by “Data sent to ThingSpeak,” indicating successful data transmission to the cloud. Several readings were captured with TDS values ranging from around 148 to 457 ppm, while the pH consistently showed 14.00. These results confirm that the TDS sensor is functioning correctly, detecting changes in the nutrient solution. This type of monitoring is essential for aeroponics**,** where maintaining optimal nutrient levels and pH is critical for healthy plant growth. The successful data transfer to ThingSpeak further supports remote monitoring and automation in such system.



**Fig 22. Sensor values**

A screenshot of a computer

AI-generated content may be incorrect.

**Fig 23. Thingspeak Display**

A screenshot of a device

AI-generated content may be incorrect.

**Fig 24. Blynk display**

The data collected from the sensors was successfully uploaded and visualized on the ThingSpeak platform. The TDS values, shown in the Field 1 chart, varied between approximately 150 ppm and 450 ppm, indicating that the TDS sensor was actively detecting changes in the water's dissolved solids. This fluctuation is important in systems like aeroponics, where nutrient concentration must be monitored closely. In contrast, the pH values displayed in the Field 2 chart remained constant at 14.00 throughout the test. Overall, the system demonstrated the ability to read sensor data and transmit it to the cloud in real time, which is a key requirement for remote monitoring in precision agriculture applications.

**7.Conclusion**

In conclusion, the implementation of an IoT-based monitoring and control system in aeroponic farming marks a significant advancement toward precision agriculture. This system leverages the integration of multiple sensors measuring critical parameters such as temperature, humidity, pH levels, and nutrient concentration combined with real-time data processing and cloud connectivity to provide continuous and accurate monitoring of the crop environment. By automating the nutrient solution dispensing based on sensor feedback, particularly using TDS thresholds to regulate solenoid valves, the system ensures that plants receive the optimal balance of nutrients without human intervention, reducing the risk of over- or under-fertilization. The integration with cloud platforms like ThingSpeak and Blynk facilitates live data visualization, historical data logging, and remote monitoring, empowering farmers to make informed decisions backed by actionable insights. Furthermore, the real-time alert mechanisms enhance system reliability and crop safety by enabling immediate responses to any deviations from optimal conditions. This holistic approach not only maximizes crop yield and quality but also optimizes resource usage, minimizes labor, and reduces environmental impact, making aeroponic farming more sustainable and scalable. Overall, the system demonstrates how IoT and automation technologies can transform traditional farming into a smart, efficient, and highly productive practice that addresses the challenges of modern agriculture

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**9. Appendix**

#define BLYNK\_TEMPLATE\_ID "TMPL3beRuw9Kv"

#define BLYNK\_TEMPLATE\_NAME "Esp32"

#define BLYNK\_AUTH\_TOKEN "CTXo3nGByXvcS562gvrzZ3huBT5fbIYE"

#include <WiFi.h>

#include <WiFiClient.h>

#include <HTTPClient.h>

#include <BlynkSimpleEsp32.h>

#define PH\_SENSOR\_PIN 35 // GPIO35 for pH

#define TDS\_SENSOR\_PIN 34 // GPIO34 for TDS

const char\* ssid = "Ak's S24 Ultra";

const char\* password = "Aka050504";

const char\* server = "<http://api.thingspeak.com/update>";

const char\* apiKey = "0TX8BUNWOOHXQ8TI";

#define VIRTUAL\_PIN\_TDS V0

#define VIRTUAL\_PIN\_PH V1

void setup() {

Serial.begin(115200);

delay(1000);

Serial.println("Booting...");

WiFi.begin(ssid, password);

Serial.print("Connecting to WiFi");

while (WiFi.status() != WL\_CONNECTED) {

delay(500);

Serial.print(".");

}

Serial.println("\nWiFi connected!");

Serial.print("IP Address: ");

Serial.println(WiFi.localIP());

Blynk.config(BLYNK\_AUTH\_TOKEN);

Blynk.connect();

}

void loop() {

Blynk.run();

int tdsRaw = analogRead(TDS\_SENSOR\_PIN);

float tdsVoltage = tdsRaw \* (3.3 / 4095.0);

float tdsValue = tdsVoltage \* 500.0; // Adjust this based on calibration

int phRaw = analogRead(PH\_SENSOR\_PIN);

float phVoltage = phRaw \* (3.3 / 4095.0);

float pH = phVoltage \* (14.0 / 3.3); // Adjust this based on calibration

Serial.print("Raw TDS: "); Serial.print(tdsRaw);

Serial.print(" | TDS (ppm): "); Serial.print(tdsValue);

Serial.print(" | Raw pH: "); Serial.print(phRaw);

Serial.print(" | pH: "); Serial.println(pH);

if (WiFi.status() == WL\_CONNECTED) {

HTTPClient http;

String url = String(server) + "?api\_key=" + apiKey + "&field1=" + String(tdsValue) + "&field2=" + String(pH);

http.begin(url);

int httpResponseCode = http.GET();

if (httpResponseCode > 0) {

Serial.println("ThingSpeak: Data sent successfully");

} else {

Serial.print("ThingSpeak: Error code ");

Serial.println(httpResponseCode);

}

http.end();

} else {

Serial.println("WiFi disconnected. Cannot send to ThingSpeak.");

}

Blynk.virtualWrite(VIRTUAL\_PIN\_TDS, tdsValue);

Blynk.virtualWrite(VIRTUAL\_PIN\_PH, pH);

delay(20000);

}