[Journal Publication of International Research for Engineering and Management](#) (JOIREM)
Volume: 04 Issue: 4 | April-2026
ISSN (O) 3107-6696

IOT-BASED MOBILE APPLICATION FOR MONITORING OF HYDROPONIC VERTICAL FARMING

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Abstract

Hydroponic vertical farming is widely seen as a very productive form of farming, at least to some extent. It is a technique of growing plants without soil, which also contributes to the change in how we use space and our resources more efficiently. However, these types of farm setups need a certain environment for the plants to grow and complete their production cycle. One way to achieve this is by continuously monitoring different environmental and nutrient parameters, which is very difficult to do manually. To address this issue, here is a project for an IoT-based mobile app system that monitors and controls hydroponic vertical farming through automation. The brain of the system is an Arduino Mega 2560 which is the primary controller. It collects live data from a range of sensors including a pH sensor for checking the nutrient solution, a DHT11 sensor for recording temperature and humidity, and a soil moisture sensor for determining moisture levels. Besides these, a color sensor and an IR sensor are used to analyze the health and behavior of the plants. The collected data can be displayed locally on an LCD and it is also transmitted remotely via a NodeMCU module.

Key Words: Hydroponic vertical farming, Internet of Things (IoT), smart agriculture, Arduino Mega 2560, real-time monitoring, mobile application, automation, pH sensor, environmental sensing, nutrient management.

1. INTRODUCTION

Agriculture is partly shifting to adapt the increasing population, limited land availability, and the necessity of resource sustainability. Methods such as traditional farming, which use the soil and depend on large land areas, usually face problems with the unpredictable nature of the climate, water shortage, and the inefficient use of resources. In this situation, hydroponic vertical farming is being recognized as a potential substitution because it enables the growth of plants without soil by the use of nutrient-filled water solutions and in the arrangements of vertically stacked plants. This method is the one to drastically lower the quantity of water needed, make the best use of space, and even allow growing in cities.Conditions, factors that influence plant growth and yield, include pH level temperature humidity, and nutrient concentration. Slight changes away from the most suitable conditions can cause a disturbance in the plant's nutrient supply, a decrease in the rate of growth, or even stress. While in conventional agriculture, the soil can be considered as a buffer of sorts, hydroponic systems need to be checked and managed very regularly because of their high sensitivity.Manual monitoring is still predominant in many small rural home setups. Users (for example, farmers) periodically check readings on the sensors, or visually inspect the condition of plants. But there are many drawbacks to this method. First of all, it is very time consuming, and since people are involved, it is also quite error-prone. At the same time, this way of monitoring is totally incapable of giving the information in real-time. The changes that happen in nature suddenly may be missed, and then the corrective measures are taken late, and there may be losses in the crops. Pumping and irrigation systems that are operated manually not only lead to lower efficiency but also require more human input.

Embedded systems combined with the Internet of Things (IoT) technology provide a smarter and more reliable way of dealing with these problems. IoT allows for data gathering as it happens, it enables the monitoring from a distance and also the intelligent management of agricultural systems. By linking together the sensors, the controllers, and the communication modules, it is even feasible to have a continuous observation of the environmental conditions, and at the same time, based on certain levels that have been set, the responses could be automatically sent out. This way accuracy is significantly improved, and at the same time, the human in the loop for these operations is greatly reduced finally this also contributes to the overall work-efficiency of the system.This project's proposal details an IoT-based mobile application for monitoring and controlling hydroponic vertical farming. Arduino Mega 2560 is a drastic change in system as the main controller with other interfaces of different sensors from which environmental and plant-related data are taken. A pH sensor is used for monitoring the nutrient solution quality, DHT11 sensor senses the temperature and humidity; soil moisture sensor is there for checking moisture level in the growth medium.

user-friendly, which means it can very well adapt to the current agricultural methods while at the same time effectively addressing the problems related to efficiency, accuracy, and resource optimization.

Literature Survey

Scientists are coming up with smart and automated hydroponic farming solutions to help conventional agriculture methods which are not able to keep pace with climate changes, water shortage, and the decreasing availability of arable land. Furthermore, combining Internet of Things (IoT), embedded systems, wireless communication, and mobile applications, especially when used in real-time, it is not only possible to keep an eye on and control various environmental parameters and nutrients, but also the crop production area is in focus of these technologies along with reduction of manual work and effective resource utilization. At present, most of the systems are focusing on independent monitoring and automation instead of providing a complete integrated solution with mobile application support. Current review article attempts to take into account key studies on IoT-based hydroponic monitoring systems.

[1] Gaganjot Kaur et al. – IoT-Based Mobile Application for Hydroponic Vertical Farming

Gaganjot Kaur, et al. have created an IoT-based hydroponic vertical farming system that is controlled and monitored through a mobile app. Sensors are utilized for the measurement of different parameters such as temperature humidity pH, Total Dissolved Solids (TDS), and water level. The gathered data is sent to the ThingSpeak cloud platform with the help of microcontrollers such as Arduino and Raspberry Pi, which allows plant growth to be monitored remotely via a mobile app.The system enables users to see the conditions of plant growth at the moment and exert remote control over environmental factors. It is also capable of automation, e. g. regulating light, water flow, and nutrient supply. The mobile app offers a simple interface with which even non-experts can easily operate the system.Besides sensing the environment, the system is capable of continuous logging of changes, thus assisting the analysis of growth trends and condition variations. It may be used for the determination of practices that lead to the optimization of production and higher yields. The cloud storage feature also facilitates data availability from any location.On the other hand, the setup entails more complexity and costly operations because of the use of multiple controllers and cloud integration. Moreover, its primary focus is on monitoring and control only, essentially ignoring the aspect of plant health analysis or smart decision-making. Besides, the lack of predictive analytics or AI-driven recommendations restricts its capability to come up with proactive solutions.

[2] Huu Cuong Nguyen et al. – Automatic Monitoring System for Hydroponic Farming (Extended)

Nguyen et al. proposed an IoT based automatic monitoring system that assists observing environmental and nutrient parameters of hydroponic farming. The system gathers the real-time data through sensors and wirelessly transmits it to the cloud server. The users can get the data through the web interface to monitor and control farming conditions.The experiment of plant growth shows that the system is reliable and stable performance. Besides, it is capable of storing data and carrying out the analysis, which provides an opportunity to users to understand more about the effect of environmental factors on crop development.Moreover, the system architecture is such that it can be scaled up to be used for bigger farming setups.The system is predominantly based on web monitoring, which in spite of its benefits, might restrict user accessibility as it does not have a separate mobile app. Apart from that, although there are automation features, the system is not highly integrated with intelligent control functionalities. Also, the absence of real-time alerts and notifications can potentially make the system less responsive during emergencies.

[3] Tharun et al. – Improving Hydroponic Systems Using ARUCO Markers (Extended)

Tharun et al. came up with a innovative hydroponic system that utilizes image processing through ARUCO markers for leaf detection and analysis. This system mainly aims at enhancing plant monitoring by locating leaves, measuring their size, and determining their orientation using computer vision techniques.The method not only improves plant health tracking by offering visual results that are superior to those obtained from measuring only sensors but it also assists in optimizing plant growth by studying the environment and plant response. It is a perfect example of how image processing and IoT can be merged to achieve smart farming.Moreover, taking into account the visual data, it is possible to identify plant stress, disease, or growth irregularities at an early stage, which might not be detected by the environmental sensors alone. This leads to an increase in the precision of plant monitoring and consequently decision-making is improved. One of the benefits

Journal Publication of International Research for Engineering and Management (JOIREM)
Volume: 04 Issue: 4 | April-2026
ISSN (O) 3107-6696

of the system is that it can be expanded through the integration of machine learning models for automatic classification of plant health. The downside however is that the system comes with increased computational complexity and cost, which is a disadvantage for low-cost or small-scale systems. Also, it is primarily geared towards plant analysis and less towards full automation and control of the hydroponic system. Since it requires cameras and processing units, the system becomes more complex and consumes more power.

[4] Chan Jia Jun – IoT-Integrated Mobile Application for Hydroponic Farming (Extended)

Chan Jia Jun created an IoT-connected mobile app for monitoring hydroponic farm systems. The work is about a system that integrates direct monitoring, remote control, and easy interaction through a mobile app for the farm management. As main interface of the application brings the monitoring of the environmental variables of the farm such as temperature, moisture, and nutrients levels without going to the farm. On the other hand, it also has functionalities like real-time notification, alert, and data visualization which is a user- switching way to keep getting updated at the farm condition. Its performance is heavily reliant on correct sensor data and well- executed link-ups with physical gadgets. Besides, the introduction of high-end features such as machine learning models might complicate the system.

1. Proposed Methodology

The system has been developed to track, manage, and automate hydroponic vertical farming through the interaction of embedded systems, sensors, and Internet of Things (IoT) technologies. Methodology is a sequential plan according to which several hardware components and software components are combined to create the right environment for the plants to grow. The proposed system will keep track of the farming environment continuously, make the best use of resources, and require very little human intervention while at the same time providing high accuracy and reliability.

1.1 System Architecture

The system architecture is a visual aid showing the whole structure of the hydroponic monitoring system that is being proposed, and it also depicts how various components interact to carry out the desired functions.

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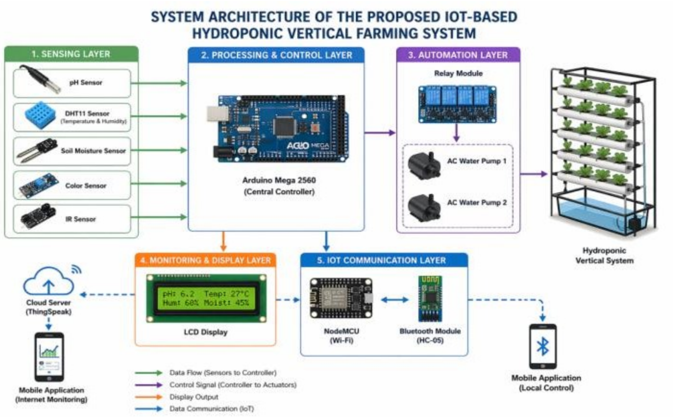


Fig. 3.1: System Architecture of the Proposed System

As illustrated in Fig. 3.1, the structure of the proposed system comprises several tiers such as the sensing tier, processing and control tier, automation tier, monitoring and display tier, and IoT communication tier. Such a multi-layered layout makes the system modular, flexible, and quite simple to be kept in good condition.

Sensing Layer

The sensing layer mainly collects very precise information about the environment, which is then used for decision making. Sensors are strategically installed in the hydroponic system to achieve adequate coverage and provide dependable results. A color sensor adds a smart element by recognizing changes in leaf color that may indicate nutrient deficiency, disease, or stress at the earliest stage. An IR sensor is an aid in detecting plant movement or position, which may be an indication of environmental reaction. Together, these sensors lead to a comprehensive understanding of the plant environment so that all the important factors are considered.

Processing and Control Layer

The processing and control layer serves as the brain of the system where the raw data collected by all sensors are analyzed and processed. For this project, an Arduino Mega 2560 was selected as the primary controller because of its capable nature of handling multiple sensor and output control tasks simultaneously with ease. It keeps on receiving live running data from sensors like pH sensor DHT11 soil moisture sensor, color sensor, and IR sensor. If any sensor helper value is out of their proper range, then the system marks that as an unhealthy working mode and gets ready for fixation.The brain status updates in this level are done by the programmed rules and if-else conditions. Take a case of that the soil moisture remains at a low level, or some circulation is needed for the nutrient solution. Here, the controller dispatches instructions to energize the relay modules. In the same way, change in temperature or pH may call for the system to do one or more of the suitable responses.This way the system is capable of acting fast and keeping the environment stable even without human intervention all the time.Communication between various system components like sending the processed data to LCD for local display as well as interacting with NodeMCU and

Bluetooth module for monitoring purposes both remote and local are some of the other roles control layer performs apart from control functions.

Automation Layer

Automation layer converts decisions made by processing and control layer into physical actions in real-time. In fact, its role is very much essential in limiting manual intervention and making sure that the hydroponics system functions effortlessly and effectively. The pump in the system is active only as per the schedule and duration, so the system indirectly controls the amount and time of water and nutrient supply to plants and even helps in avoiding issues such as over-irrigation or nutrient deficiency.In short, with the addition of an automation layer, the entirety of the system becomes more productive, dependable, and stable. Whereas, manual labor is significantly minimized simultaneously the exact controlling of the agrarian conditions is allowed. This increase not only the growth of the plant and the quantity of the harvest but also it is more effective in using water and nutrients. The element of automation, by generating a stable and regulated environment, significantly enhances the overall accomplishment of a hydroponic farming system.

Monitoring Layer

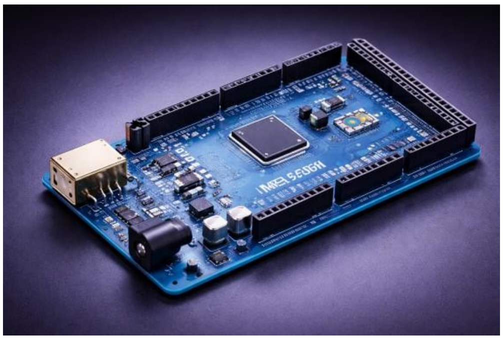
The monitor and display layer mainly involves telling the user what is currently going on within the system. In other words, it is the user's window into the system. In this example, an LCD module was used to show the output values of the sensors giving pH level temperature humidity, and system status of the whole system.What is shown on the LCD can be said as a 'live' view as the display is refreshed with newly taken sensor values all the time. Users can safely assume that the data seen there is a faithful representation of conditions in the hydroponic environment at that very moment. By checking these figures on the spot, a user is in a better position to judge if the system is running smoothly or if any one of the parameters is off.This is the stage at which the system would be of maximum value, for example, when initiating the system, carrying out periodic service, or fixing any faults Generally, the monitoring and display level increases the openness of the system and the communication with the users. It offers an easy and reliable method for checking system results, making sure that users are always aware of the conditions of the plant growth. This leads to an increase in the trust of the users and the effectiveness in control of the hydroponic system.

IoT Layer

IoT communication layer is a crucial component of an IoT system, which significantly impact its performance. The communication layer serves as the system's "nervous system" and connects different components. More specifically, the communication layer carries the signals, including control signals, between the different system elements. IoT systems can be designed to work within a limited area as well as globally through the internet. This is the main difference between web-based and non-web-based systems. The communication layer in a web-based or internet-based system should provide a way for the system to be connected to the internet and allow sharing of real-time data to the users while at the same time the users are able to control the system remotely. In this project, a NodeMCU module is made use of for this purpose. This data that has been saved can be very helpful in recognizing trends, monitoring the performance of a system, and basing any decisions in a way that would lead to better growth of plants. Generally, the communication layer of the IoT helps communication among system components, and it is a very important part of a well-operating system. It also has a big impact on system configuration and realism, which in turn affect the success and inefficiency of the entire system, especially interactive systems.

Hardware Components

Hardware components make up the physical base of the proposed hydroponic monitoring system and provide real-time sensing processing control, and communication capabilities. Every part has been dedicated a function and they all collaborate with each other to guarantee seamless system operation. The system's features are environmental monitoring sensors, data processing controllers, communication modules for IoT connectivity, automation actuators, and power supply units. Altogether, these parts enable the system to engage with the hydroponic environment, gather data, and carry out control actions effectively.

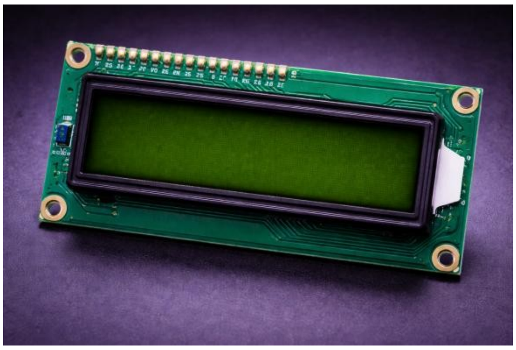


Microcontroller – Arduino Mega 2560

The Arduino Mega 2560 has a central role in the entire setup as the master "brain". It manages the collection of sensor data, the data processing and issuing of control commands if certain pre-set conditions are met. Also, it is equipped with a very large number of input/output pins which allows it to work with many sensors and modules simultaneously. The pH temperature humidity soil color and IR sensors continuously sending their information to Arduino. On processing the information, Arduino measures the values with the normal ones to make sure the plant's environment is the most suitable one.

[Journal Publication of International Research for Engineering and Management](#) (JOIREM)
Volume: 04 Issue: 4 | April-2026
ISSN (O) 3107-6696

Once Arduino understands the data thoroughly, it will communicate the rest of the system by only turning on/off the water pumps through relays. Besides, it is connected with NodeMCU and Bluetooth module to share data and offer the user a more interactive experience



LCD Display for Real-Time Monitoring

The LCD module displays sensor readings and system status in real-time. It shows users at a glance some of the major parameters such as pH level temperature humidity, and parts of the system that are running.By enabling direct system monitoring without the need for other devices, this element raises the convenience level of the system significantly. Setting up and inspecting the system become easy since the display helps in understanding the system's working and locating errors swiftly.

pH Sensor for Nutrient Monitoring

One of the most significant components of a hydroponic system is the pH sensor as a pH sensor measures the acidity/alkalinity of the nutrient solution. The pH level must be maintained at the proper level for plants to absorb nutrients efficiently. The sensor monitors the pH level continuously and communicates with the Arduino device for data transfer. When the level rises or drops beyond the set limits, the system can make a correction through the automation layer. Hence, the nutrient environment that supports healthy plant growth is maintained.

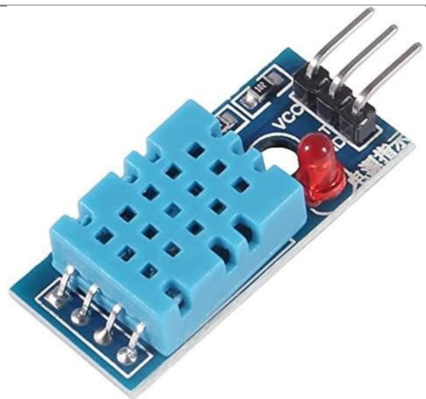


Fig. 3.2.4 DHT11 Sensor

The DHT11 sensor is used to measure ambient temperature and humidity, which are essential environmental parameters for plant growth in a hydroponic system. Proper temperature and humidity levels help in maintaining a stable growing environment, ensuring that plants can absorb nutrients efficiently and grow at an optimal rate. The sensor continuously monitors these conditions and provides real-time data to the controller for analysis. The data collected by the DHT11 sensor is used by the system to detect any variations from the desired environmental range. If abnormal conditions such as high temperature or low humidity are observed, the system can take necessary actions to restore balance. This early detection helps prevent plant stress, improves overall plant health, and ensures consistent growth. By maintaining stable environmental conditions, the sensor contributes significantly to the efficiency and reliability of the hydroponic farming system.

2. Objectives

As indoor farming requires continuous monitoring, attention, and accuracy for optimum plant growth. However, it is not possible for a human being to continuously monitor the parameters required for plant growth, thus it may result in human error. Therefore, in order to reduce human intervention, IoT-based automation is an effective method for monitoring and control of plant growth by providing a user interface through mobile phones and web-based application The objective of this research is to design an IoT-based automated Vertical farming system for Romaine Lettuce plant. This IoT-based system can access and control all the plant growth parameters such as temperature, humidity, pH, TDS, and water flow through mobile applications. The specific aims of the study are

- To design and develop an automated Vertical farming setup
- Enabling the technologies that can be integrated

with vertical farming setup. So that the system could maintain the required growth parameters, automatically turn LED's ON/OFF, automatically balance pH and TDS and automatically maintain water level when required and

Finally integrating the above system with the IoT platform and providing the user interface using the mobile application.

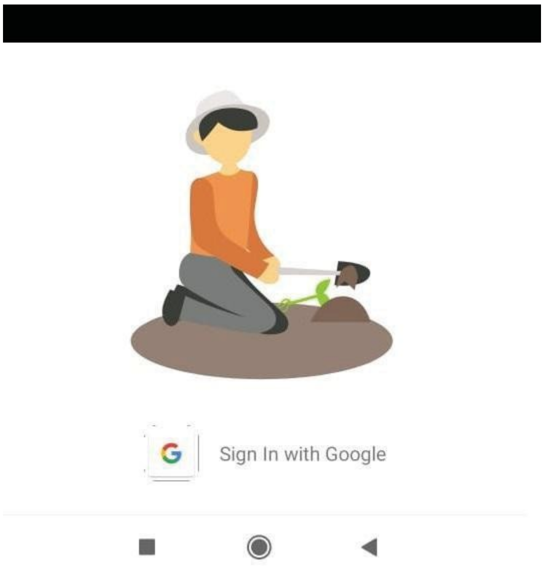
Fig. 1. Vertical Farming Hydroponic Setup

A. ***Proposed Vertical Farming Setup***

B. In this project, the hydroponic vertical farming structure of Pindfresh Tashi Home is used. It is a 3-tier stack setup that includes three pipes on each tier. Each pipe consists of nine plantation holes and as a result, has a capacity of growing 81 plants in the 3-tier setup as shown in Fig.1. The setup also consists of the tank for a nutrient solution and pump to circulate nutrient solution to all the tiers. This setup is based on DFT (Deep Flow Technique) hydroponic techniques in which plantation is done in shallow beds and nutrient solution is constantly flowing over the roots.

3. Verti farm control Application

The user interface designed for **VertiFarmControl** application consists of Splash Screen and Login Screen. The splash screen is initially used for loading the app. It is used as an entry point of this application and has a hold-on time of five seconds which is achieved by a Handler. The handler freezes the main thread for five sec and then redirects to the login activity/screen.



Further, *Login Screen* Fig.2 is used to authenticate the users by making them login into the application using the authentication facilitated by Firebase and Google Cloud. Each user is assigned a random and unique string as a user ID (UID). The initial details of each user such as name, email, profile picture, and UID are stored in Firebase's real-time database. The login screen determines whether the user is authenticated.

Journal Publication of International Research for Engineering and Management (JOIREM)
Volume: 04 Issue: 4 | April-2026
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After the validation of the user account, the user is diverted to the Main Screen of the ***VertiFarmControl.*** The main screen consists of a three fragment *Climate Fragment*, *Nutrient Fragment* and *Image Fragment* as shown in Fig.3

Climate Fragment: This holds and displays data related to the climatic factors associated with the vertical farming which are temperature, humidity, light and toxicity level

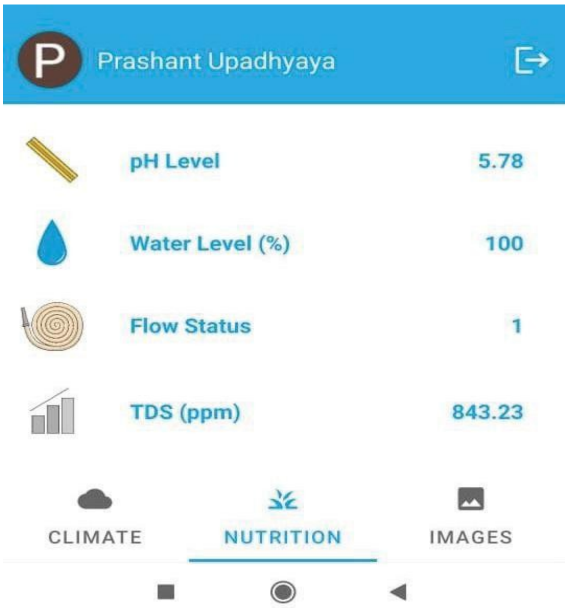
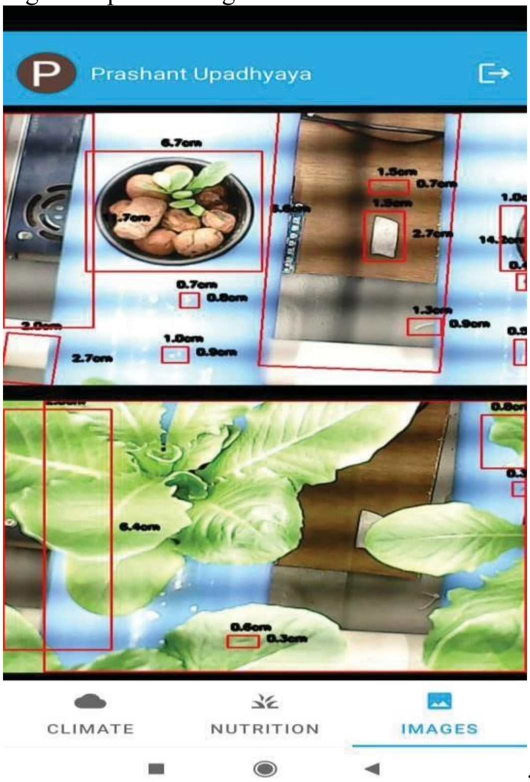


Fig. 3. The sample screen shot of the proposed VertiFarm Control for (a) Climate and (b) Nutrition monitoring system

The data in fragments is fetched by an API, the response of which is in JSON format. It is then parsed using the HTTP Volley library, which is a networking library made by Google. The parsed data is then displayed on the screen with enhanced visuals to increase the user experience.The data recorded from the sensors is also available at the ThinkSpeak IoT platform

Fig. 4. Captured image of the vertical farm.



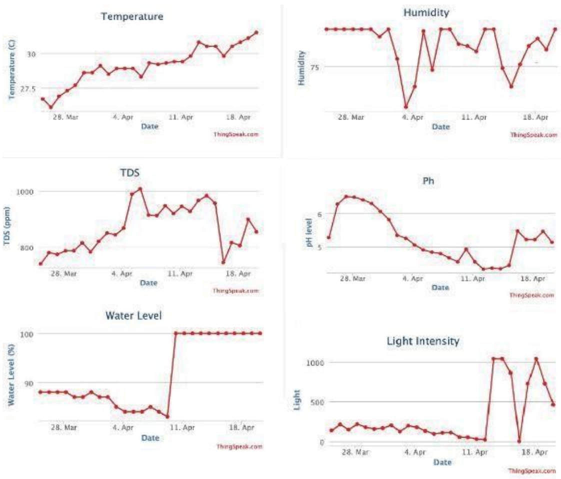


Fig. 5. Captured data using thinkspeak

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Volume: 04 Issue: 4 | April-2026
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Conclusions and Recommendations

With increasing population, decline in arable land and climate changes, agricultural production needs to be increased. Vertical farming and soil-less farming are new age popular techniques to deal with global scarcity. Aiming at SDG goal 2 which aims to end hunger, achieve food security and improved nutrition by 2030, an IoT based automated Vertical farming system is designed which is integrated with various sensors to monitor and control various plant growth parameters. Collected data is sent to ThingSpeak IoT platform and could also be acccessed from VertiFarmControl android application. The mobile application is capable of showing live data from various sensors and alert the user when sensor value falls out of range. This automated system along with VertiFarmControl application is able to sustain healthy plant life with minimum user intervention. In future,

we would also like to integrate the farming assistance in the developed application which can guide the farmer about the best technique used for the latest agriculture plant growth.

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