# Implementation of Smart Hydroponic Farming Using AI Controller with Mobile Application System

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**Abstract**

Agriculture is the foundation of human civilization and enables the production of high-quality food for the world's population. Three parts to the intelligent hydroponic system can automated by the Internet of Things. A camera module, sunlight, turbidity, pH, temperature, and NPK soil sensors will be part of the initial stage of the hardware environment. By a web app, data collected by sensors can be analysed to define parameters for automation depending on the requirements of different plants for maintaining a healthy life cycle. To ensure optimal growth cycle all treatments can be done precisely and promptly using the acquired data, these models can also be further refined to categorize plant health and forecast possible illnesses. Linear Regression, XG Boost and Prediction-Based Deep Learning models like Deep Learning Convolutional Neural Networks (DLCNN) have been utilized to analyse the performance of Smart Hydroponic Farming. It has been observed that DLCNN outperforms in comparison with other techniques in terms of accuracy and F-measure.

**Keywords**: DLCNN, IoT, TDS, pH

## 1 Introduction

Rapid population increase, climate change, urbanization, and the need for food security have all contributed to a heightened worldwide need for sustainable farming techniques [1] in recent years. Water consumption, land availability, and environmental deterioration pose serious problems for traditional agricultural practices, especially in dry and semi-arid countries [2]. So, to solve these problems and make farming more efficient and productive, new agricultural solutions are being created. Among these developments, SMART Hydroponic Farming stands out as a state-of-the-art method that uses technology and sophisticated farming techniques to grow plants without soil, which might be a great answer to the problems that farmers face today [3]. SMART Hydroponic Farming integrates cutting-edge technology like sensors, automation, data analytics, and artificial intelligence with the principles of hydroponics, which is a way of cultivating plants in a solution of water rich in nutrients. There is a rising need for sustainable food production techniques that can be used in both urban and rural areas, and this demand is being answered by incorporating technology into agricultural processes [4]. For a long time, hydroponics has been known as a soil-less growing technique that maximizes water utilization and nutrient delivery [5]. This allows plants to develop efficiently, unlike in conventional soil-based agriculture. But now there's SMART Hydroponic Farming, which takes this approach to the next level by making data-driven farming systems that are very efficient using real-time monitoring, environmental control systems, and predictive analytics. Fundamentally, SMART Hydroponic Farming is a system that optimizes plant growth by using a number of technologies. Growing system sensors record vitals like pH, temperature, humidity, light intensity, and nutrition content, among others [6]. A centralized system receives and analyzes this data to make sure the plants are growing in the best possible circumstances. To cater to the demands of the crops, automated devices modify ambient parameters, such water temperature and light exposure. Farmers may achieve better crop yields and more effective use of resources with this degree of automation since it eliminates the need for regular human intervention in growing conditions. In comparison to more conventional farming techniques, SMART hydroponic farming uses significantly less water, which is one of its main benefits. Evaporation, runoff, and ineffective irrigation methods account for a large percentage of water loss in traditional farming. Hydroponics, on the other hand, allows water to be recirculated inside the system, thus cutting down on water use and waste [7]. In areas where water is scarce, this is of utmost importance since conventional agricultural methods tend to make things worse. SMART hydroponic systems go above and beyond water conservation by constantly monitoring water quality and only restocking when needed, thereby reducing water wastage. The ability to make the most efficient use of available space is another great advantage of SMART hydroponic farming. In heavily crowded metropolitan areas, vast plots of land are often unavailable, making traditional



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farming a challenge [8]. Crops may be cultivated in very small areas using hydroponic systems, which can be arranged vertically or in regulated indoor settings. Particularly effective is vertical farming, which increases output per square meter of land by growing various crops in successive levels within the same footprint. The capacity to cultivate crops inside city limits provides the opportunity for regional food production, which lessens the need for food imports and the environmental impact of transportation. Improved accuracy and reliability in harvests are further benefits of SMART Hydroponic Farming's use of data analytics and automation [9]. In order to make better choices about fertilizer distribution, irrigation schedules, and environmental controls, farmers may gather and analyze data on different environmental aspects. This will help them understand how these elements impact plant development. To make sure the plants get all the nutrients they need for maximum development, the system may do things like automatically change the quantities of minerals if it finds that the nutrition solution is lacking in one. Herbs, lettuce, and microgreens are high-value crops, and this level of accuracy makes them healthier and provide better output [10]. It is impossible to exaggerate the importance of AI in SMART Hydroponic Farming. Systems driven by AI may learn from past data, forecast future outcomes, and adjust to new circumstances in real-time. As an example, AI systems can determine the best time to harvest crops by analyzing growth trends and environmental factors. Farmers are able to better allocate labor and resources because to these predictive capabilities, which also increases harvest quality and quantity. Furthermore, by evaluating data on plant health and seeing early warning signals before they spread, AI may aid in disease diagnosis and pest control. This preventative method of plant health management may lessen the need on chemical pesticides, leading to a greener and more sustainable agricultural system overall [13]. The scalability and adaptability of SMART Hydroponic Farming is a major selling point. The SMART Hydroponic system is versatile enough to be used in a variety of settings, from little rooftop gardens in cities to massive commercial greenhouse operations. In densely populated cities, when space for arable land is at a premium, local food production may be achieved by the integration of hydroponic farming systems into existing infrastructure, such as disused roofs or abandoned warehouses [14]. The role of architects in integrating hydroponic systems into urban environments in India, aiming to enhance food security and sustainability has been described through innovative design solutions [15].The integration of IoT technologies in soilless agriculture systems like hydroponics, provides potential to enhance resource efficiency and ensure stable, high-yield crop production [16]. The hydroponic techniques utilized for lettuce cultivation, evaluating their productivity, resource efficiency, and scalability, incorporates the integration of advanced technologies like AI in hydroponic systems [17]. Utilizing SMART Hydroponics, commercial farms may boost output, save labor expenses, and make their operations more environmentally friendly on a bigger scale. While there are many benefits to SMART hydroponic farming, there are also several obstacles that must be overcome before it can be widely used. Incorporating artificial intelligence (AI), sensors, and automation into an advanced hydroponic system can significantly increase the initial setup expenses. Costs associated with SMART Hydroponic systems are currently high, but they are anticipated to fall as technology advances and becomes more widely used, allowing more farmers to afford them. Some people may also find it difficult to administer and run these systems because they lack the necessary knowledge and experience. But as time passes more and more farmers will be able to operate SMART Hydroponic systems effectively, thanks to the proliferation of educational materials and training programs.

## 2 Literature Review

Various characteristics of hydroponic systems, including temperature, water limit, pH level, and fertilizer levels, has be collected using built monitoring system [1]. The performance of the conventional agricultural methods has been compared that rely on soil, hydroponics uses far less water and other resources. However, keeping an eye on hydroponics farming is no easy feat, what with having to oversee a plethora of factors, dietary recommendations, and plant diagnostic systems all at once. However, new innovation that uses AI-based control algorithms in the agricultural industry is a great way to address these issues. Thus, the deployment of an AI-SHES (smart hydroponics expert system) with an Internet of Things (IoT) environment is described [2]. Several sensors, including those for temperature, water level, total dissolved solids (TDS), and pH, can be integrated with an ESP32 microprocessor to create the monitoring system. The ESP32 microcontroller takes readings from the sensors, analyzes them, and then starts the water or salt pump to transfer the nutrients to the hydroponic system's reservoir [3]. After that, the user may check the hydroponic settings using their smartphone and a Web app. Alternatively, the ESP32 microcontroller may activate the pumps for water, nutrients, or salt automatically if the parameter values are not in the correct range, or the user can utilize the smartphone app interface to do it manually. Building and implementing the monitoring hydroponics system and the Internet of Things interface was a success. The system is based on Mobile applications. There are three stages to the proposed AI-SHES with IoT. In the first stage, a Raspberry Pi CPU controls a hardware environment that has real-time sensors for things like NPK soil, sunshine, turbidity, pH, temperature, water level, and a camera module. Phase two involves using a deep learning convolutional neural network (DLCNN) model to identify and classify plant diseases and make predictions about optimal nutrient levels. Using an Android-based mobile app that is linked via an IoT environment, farmers may track sensor data and the state of plant leaf diseases in the third phase. This way, the farmer may use the app on his mobile device to monitor the progress of his field in real-time. Also, the suggested AI-SHES builds an automated mode that controls everything in the environment and does what has to be done in the hydroponics field to boost production. [4]. One concern the system addresses is the increase in pests and illnesses brought about by a harsher environment as a result of climate change. There is much less farmable land now than there was before industrial zones expanded. In order to tackle these challenges, farmers must revamp their agricultural techniques and incorporate the latest scientific and technical developments into their work. This article details the process of creating an IoT-based automated monitoring system for hydroponic gardening. The technology enables the collection of sensor data in real-time. To upload and save this collected data to the cloud, an Internet of things (IoT) gateway and a virtual server were created. The user may manage the farming equipment and see sensor data from the environment and hydroponic solution using the online interface. Growing lettuce in an NFT hydroponic system allowed for testing and evaluation of the technology. Experiments validate the suggested system's stable operation and great dependability. The data recorded on the server from the sensors may be utilized to study how different environmental factors affect plant development in a controlled setting [6]. The development and launch of iPONICS, a smart, inexpensive, Internet of Things (IoT)-based greenhouse management and monitoring system for hydroponics. On this system, three distinct kinds of sensor nodes are built. Controlling the pump, monitoring the greenhouse water quality, and collecting and transferring data from the slave nodes are all responsibilities of the main (master) node. Slave nodes with environmental sensors record data about the greenhouse's atmosphere and relay it to the master node. Movement in the vicinity is monitored by security nodes [7]. To make sure crops are grown in the best possible circumstances according to hydroponics rules, the system keeps an eye on the temperature and humidity in the greenhouse as well as the water quality. By keeping an eye on these characteristics via a website, greenhouse keepers are able to do remote monitoring [8]. The length of plant irrigation is determined using a state-of-the-art fuzzy inference engine. To make it easier to run off the grid, the system is designed to use as little electricity as possible. The planning and execution of an IoT-based smart hydroponics system [9] has been described. The worldwide need for food is on the rise, and this system must find a way to meet that demand while also meeting the market desire for innovative, sustainable agricultural methods that make [10] use of the Internet of Things. During component selection, the necessary criteria were considered while selecting [11] Esp Board, Robodo Water level sensor, motor, and sensors. After reviewed existing literature, looked at the history of the Internet of Things, and investigated hydroponic systems. It all started with building, programming, and testing the prototype. Then, data can be collected from sensors and kept track of on a web-based website using a mobile. In addition a bot can be implemented to manage the supply chain and send out notifications. With its enhanced performance, the system was able to accomplish its complete goal. Future work may address these constraints by using data science and artificial intelligence to enhance crops and achieve better results. The last step is to create an end user platform that makes it easy for users to engage with the product via aesthetically pleasing design and minimal technical setup.

## 3 Proposed Methodology

This hydroponic farming system shows in Fig. 1 employs an advanced Internet of Things (IoT)-based approach, using the ESP8266 microcontroller as its core element, combined with a water level sensor and a water pump. This design provides efficient, adaptable, and user-friendly farm management with the options of both automated and manual modes for the different preferences and needs of farmers [9]. The ESP8266 microcontroller has an in-built web server which is accessible from an IP address. Farmers can monitor and control the system without any hassle. They get real-time data regarding water levels. They can manage the pump from a distance with the web platform. It works in automation mode by sensing the water level in the reservoir with the aid of the water level sensor continuously. If the water level falls below a predefined threshold as shown in Figure 2, the ESP8266 triggers the pump to replenish the reservoir. Once the desired water level is reached, the pump shuts off automatically, conserving resources while maintaining smooth operations without requiring manual intervention. To make the system more reliable and versatile, it has included a manual override switch that provides farmers with full control of the pump when needed. This means that users can bypass automation and operate the system manually, which makes it suitable for various scenarios and farming needs. This system, therefore, is integrated with IoT technology to offer farmers a streamlined and efficient way of managing hydroponic farming operations. The ability to monitor the real-time data and to remotely control the water supply ensures the timely replenishment of nutrients to create optimal conditions for plant growth. This innovative approach combines the simplicity of efficient techniques technology to offer farmers a streamlined and efficient way of managing hydroponic farming operations. Hence, the system enhances significantly the productivity, efficiency, and the ease of hydroponic farming. It empowers farmers to optimize resource use, reduce waste, and reduce labor, which makes it a transformative step forward in modern

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agricultural practices.. In order to provide plants, the exact attention they need, they categorize, forecast, and change nutrient levels in real time. These algorithms power a smartphone app that gives farmers useful insights from sensor data. This innovative method represents a giant leap forward in agricultural technology as it improves the efficacy, yield, and longevity of hydroponic farming.

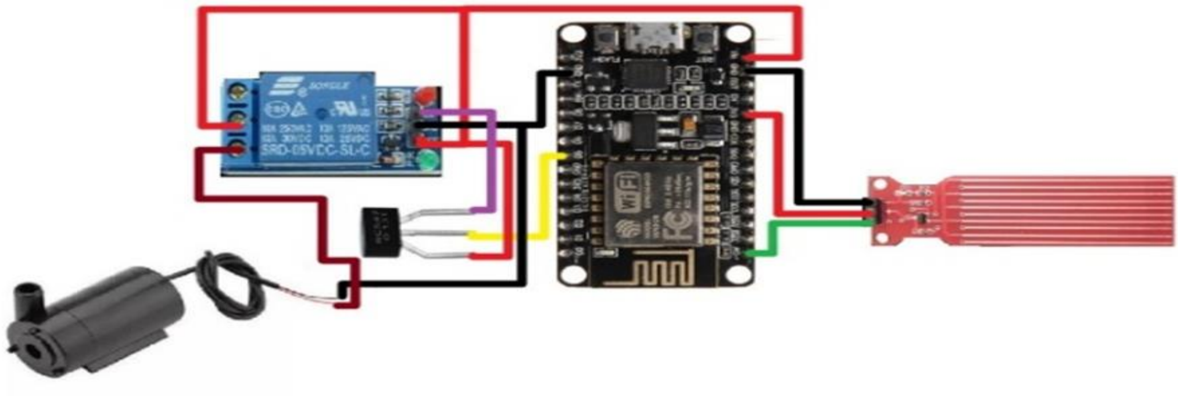


**Fig. 1.** Circuit Diagram

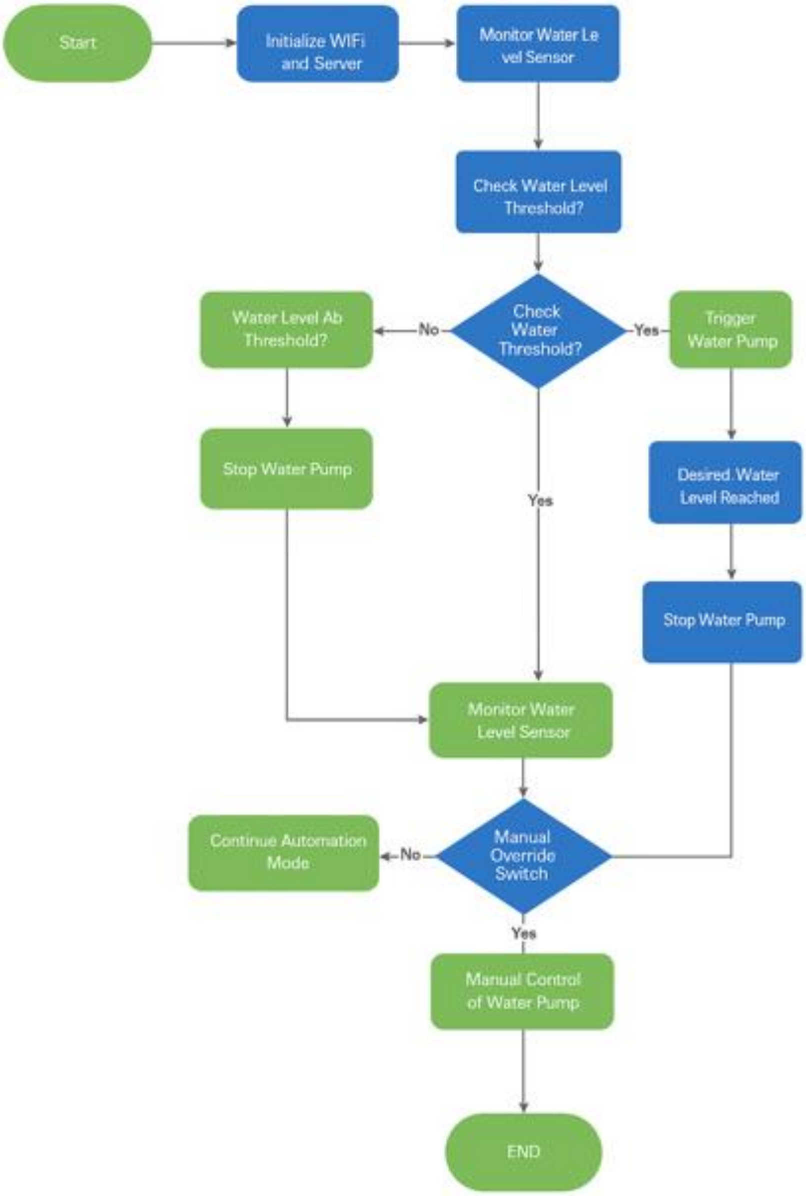


**Fig.2.** Flow Chart

## 4 Results and Discussions

Within the context of the Internet of Things (IoT), system's potential consequences has been examined. Results from using this system and the suggested model worked is shown in figure 3. Using industry-standard datasets for plant nutrition and leaf traits, the model can be pit against traditional approaches and exhaustive assessment of the proposed model's performance can be taken by performance analysis as seen in the figure above. Based on data collected from the Robodo Water level sensor and some more crucial data sensors like those for temperature, water level, total dissolved solids (TDS), and pH, etc. Samples can be taken in both the summer and winter and construction of deep learning algorithms can be done to make the process even more efficient. Through the analysis of sensor data in conjunction with the physiological reactions of the plants, the result is described in Table 1 (a) & (b) these sensors can be used to precisely forecast the nutritional requirements of the plants. A key component of the approach's efficacy can be the merging of ambient sensing with organism physiology. When building a Smart Hydroponics system some parameters and limitations to be considered are initial setup costs and limitations of the system. The result of the proposed system with the conventional system is shown in Fig. 5 (a) & (b) . As seen in the hardware setup shown in fig. 4 used a practical approach to build the setup required which while being minimalistic also provide the idea of the things that can be expected if the setup can be utilized in both small scale and large scale for commercial purposes.

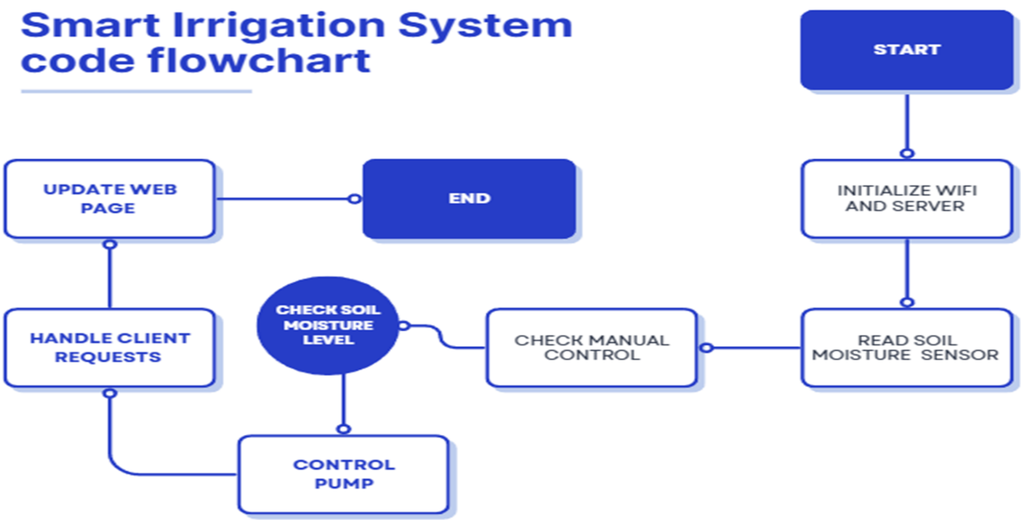


Fig. 3. Smart Irrigation System code flowchart

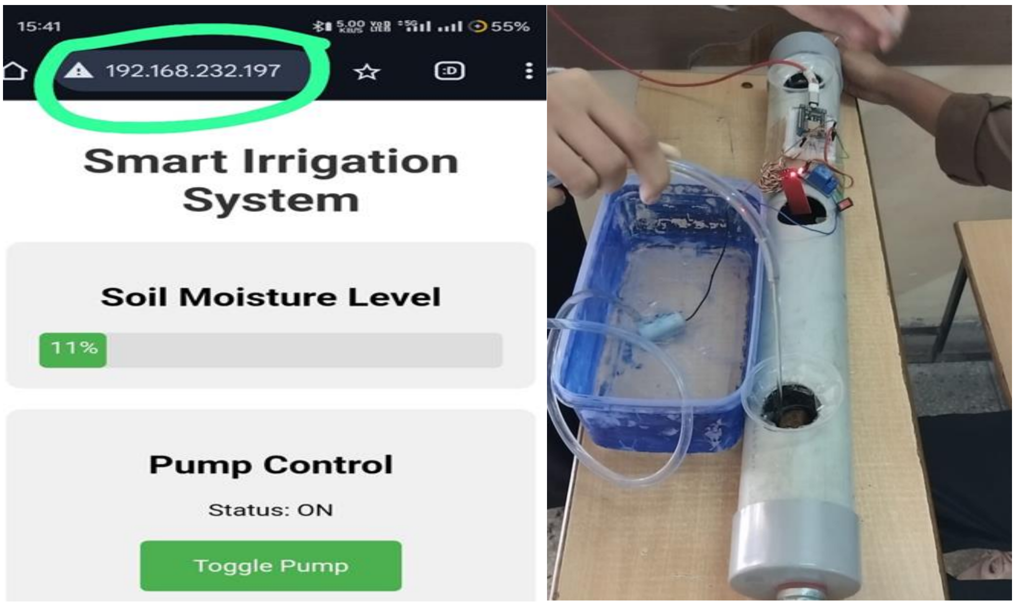


Fig. 4. Hardware setup

The graph illustrates in Fig. 5 (a) and 5 (b) show that SMART hydroponics performs noticeably better than basic and conventional hydroponics in a number of agricultural parameters. The incorporation of sophisticated algorithms and data-driven decision-making systems into SMART hydroponic farming is primarily responsible for this efficiency increase. Sensor Data Analysis and use Machine Learning Algorithms have been utilized, employing Intelligent hydroponic setups that incorporate numerous sensors that monitor pH levels, nutrients,

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humidity, temperature, and more. Techniques in supervised learning, including decision trees, support vector machines, or neural networks, are capable of forecasting optimal growth conditions and autonomously modifying settings. By employing regression techniques or time-series analysis, these systems have the capability to foresee agricultural output, identify initial indicators of illness, and enhance the utilization of resources, minimizing waste and increasing efficiency. SMART systems frequently utilize genetic algorithms or linear programming techniques to enhance the arrangement of plants, timing of lighting, and cycles of irrigation in order to boost output and reduce energy consumption.

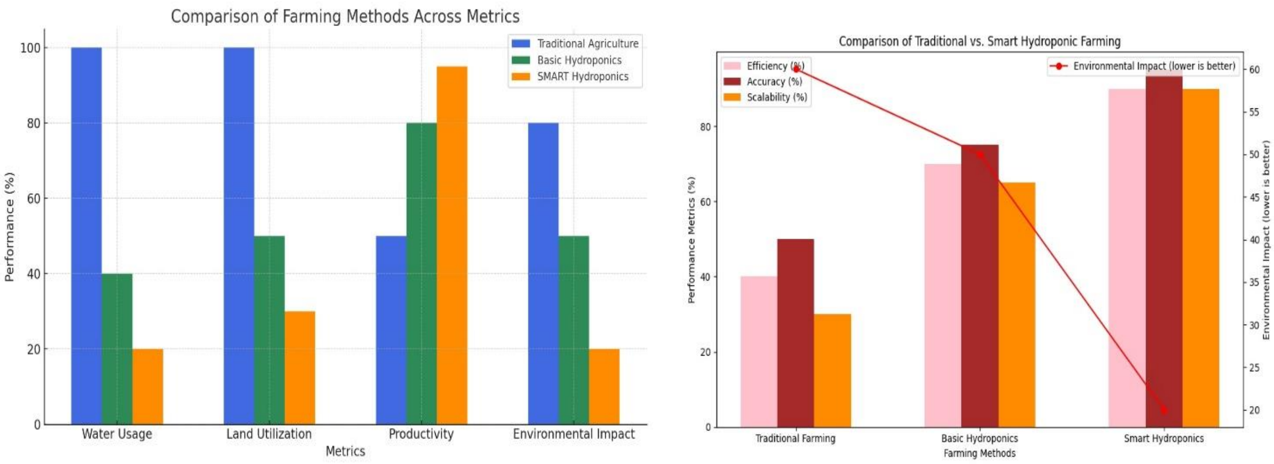
To further give an idea of how the system can be optimized an example will be useage of Deep Learning based Convolutional Neural Networks for disease prediction and plant health forecasting, Long Short Term Memory based models for prediction of future nutrients and environmental needs based on pre built databases or data collected by Sensors, usage of Fuzzy Inference systems and feedback from users to optimize the system based on user feedback and experience, Or as demonstrated and performed, using sensors like ESP8266, IoT environment and web app to automate and improve the system based on User Input.

**Table 1 a.** Comparison of traditional agriculture and SMART hydroponics

| Metrics | Traditional Agriculture | Basic Hydroponics | SMART Hydroponics |
|---|---|---|---|
| Water Usage | 100 | 40 | 20 |
| Land Utilization | 100 | 50 | 30 |
| Productivity | 50 | 80 | 95 |
| Environmental Impact | 80 | 50 | 20 |

**Table 1 b.** Comparison of traditional agriculture and SMART hydroponics

| Parameter | Tomatoes | Strawberries |
|---|---|---|
| Water Requirement | Moderate | Low |
| Relative Humidity | 60% - 70% | 50% -75% |
| Nutrient Solution | High in potassium and nitrogen | Balanced potassium and phosphorus |




(a) (b)

Fig. 5 (a) and (b) Performance Metrics

## 5 Conclusion

The proposed hydroponic farming system makes use of the IoT and automation concepts. This system enables smart, flexible, and effective farm management through the utilization of a web app, ESP WIFI Module, and Automation algorithms. Whether you choose manual or automatic operation, it can handle the fluctuating needs of hydroponic farming with ease. The proposed method outperforms traditional methods in terms of efficiency and accuracy. The use of the internet of things (IoT) and automation in hydroponic farming improves operational efficiency while simultaneously making modern agriculture more scalable and environmentally friendly. This method is a giant leap ahead as it sets a new benchmark for smart farming systems. Future system design advancements have a lot of possibilities, including the incorporation of cutting-edge sensors for real-time data analytics, the development of machine learning algorithms for predictive farming, usage of

AI based Neural Networks such as Deep Learning Convolutional Neural Network based model to vastly improve resources utilization and the expansion of the usage of renewable energy sources to lessen environmental effect. As these technologies advance, they will make it possible to control resources even more precisely, which might completely transform agriculture worldwide. The suggested approach establishes a new standard for agriculture's future and represents a significant turning point in the evolution of smart farming.

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