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Use of IoT in Hydroponics

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Abstract: This study explores the Internet of Things (IoT) and hydroponics fusion, providing a thorough analysis of its benefits and possibilities for future agriculture. Since it uses fewer resources, increases crop yields, uses less water, and has less of an impact on the environment, the soilless farming technique known as hydroponics has become quite popular. Hydroponic systems with IoT integration can monitor vital environmental variables including temperature, humidity, pH levels, nutrient concentrations, and light intensity in real-time, allowing for data-driven decision-making and precise management of growing conditions. Additionally, IoT-based hydroponics encourages resource efficiency by reacting to shifting climatic patterns and supporting it through water recycling and precise fertilizer delivery. It also helps climate-smart farming methods. While early setup expenses and connectivity/reliability issues are significant drawbacks, the long-term gains of greater productivity outweigh these issues.

Keywords: Hydroponics, IOT and Sensors

I. INTRODUCTION

Since the start of human civilization, agriculture has been the foundation of human society, supplying food and a means of subsistence to people all over the world. Traditional farming has been the main way of growing crops for hundreds of years. It is heavily entrenched in historical customs and regional expertise. In this time-honored method, farmers nurture plants and generate plentiful harvests by utilizing the rich natural resources of the soil.

In areas used for agriculture, soil erosion is a significant issue during periods of excessive rainfall. The yield is influenced by the degrading of soil minerals. Similar to this, a disadvantage of conventional farming is a lack of workers. In India, agriculture is the primary industry, but workers are moving to other industries to make money for improved living conditions. Climatological changes are unpredictable as a result of global warming. Traditional farming is significantly impacted by climatic changes. The yield is lower where there is a lack of water. Water is a crucial component in plant growth.

Hydroponic crops are employed in daily life as a result of technological advancements that raise living standards. Crops grown hydroponically can be used in the house delightfully. Traditional farming has more challenges than modern farming, for example, it requires routine irrigation, and shortages of labor are the main issues. With the development of technology, crops can now be grown in soilless media. As more people went into the IT industry, they had less time to spend in the garden. However, with the help of the Internet of Things, even an average industry worker can take care of a hydroponic plant using an Android smartphone. Hydroponic plants can be automatically watered with the help of the Arduino microcontroller board, even if the owner is located far away. Nowadays, the use of sensors, microcontrollers, and internet connectivity makes human life easier.

With the help of the hydroponics approach along with the IoT, the previously mentioned problem can be completely solved. IoT now has a significant impact on every industry. The use of smart farming aids farmers in monitoring the state of their plants. Farmers can collect data and perform analyses based on the data by integrating with IoT. When a vacant space is available, hydroponics can be used in a house, terrace, or terrace. Even if the owner is far from the hydroponic garden, proper care can be given. One can check the farm's current status using an Android smartphone. Water and labor expenses are cheaper with hydroponics than with traditional gardening. Hydroponics needs constant observation, which is made possible by IoT, which can keep an eye on the plants even if the farm owner is a long way away.

There are plenty of additional methods to grow through hydroponics such as gravel, Rockwool, perlite, etc. The crop grows two times faster in a hydroponics system, there is no need for soil setup, there is less labor needed compared to traditional farming, crops can be grown all year round, less pesticide is used, water can be reused multiple times, which encourages water conservation, and harvesting crops in a hydroponics system is much easier.

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The Nutrient Film Technique (NFT) was identified by R. Vidhya et al. [1] in 2018 as one of the primary hydroponics techniques after analyzing several different ways. In NFT, fertilizer solution is continually applied over plant roots through slanted channels. This hydroponic method encourages effective nutrient uptake and quick plant growth by continuously supplying water, oxygen, and essential nutrients to the roots. NFT is recognized for its simplicity of use, excellent yields, and capacity to grow a wide variety of plants under regulated conditions.

The Deep Water Culture (DWC) technique is an important hydroponic technology in addition to the Nutrient Film Technique (NFT). In DWC, plant roots are immediately submerged in nutrient-rich water, where they receive constant oxygenation through air stones or diffusers. This process guarantees optimum nutrition and supports healthy plant growth. Both NFT and DWC are well known for their simplicity, effectiveness, and capacity to grow a wide variety of crops under regulated circumstances.

Another commonly employed hydroponic technique is ebb and flow, also referred to as flood and drain. A fertilizer solution is periodically splashed onto plants in Ebb and Flow systems before being allowed to drain back into a reservoir. In order to promote healthy growth and avoid waterlogging, this cyclical process makes sure that the plant roots receive both nutrients and oxygen. The simplicity and adaptability of ebb and flow systems make them popular since they are appropriate for a range of plants and varieties of crops.

II. LITERATURE SURVEY

There is a rising understanding of the need for more sustainable and effective farming approaches in light of the drawbacks associated with conventional soil-based agriculture. A promising alternative has arisen in the form of soilless hydroponics. Integration with the Internet of Things (IoT) has become necessary for it to achieve its full potential. Hydroponic systems may be intelligently monitored, managed, and optimized by utilizing IoT technologies, overcoming major issues in conventional farming like water constraints, labor shortages, soil degradation, and environmental effects from excessive chemical use.

This review of research focuses on the IoT and hydroponics fusion, covering all the benefits it brings and the revolutionary potential it has for modern agriculture. We provide clarity on how IoT-based hydroponics represents an approach toward sustainable food production and robust farming ecosystems by conducting a systematic examination of the results of existing research.

The introduction of IoT brings a new level of automation and intelligence to farming in the context of IoT-based hydroponics. IoT is a system of interconnected objects with built-in sensors that automatically gather and transmit data over the internet. With the help of this idea, hydroponic systems can develop into self-monitoring, networked ecosystems that enable the collection of real-time data from a variety of internal sensors. Farmers can receive useful insights regarding important environmental elements, including temperature, humidity, nutrient levels, and light intensity, by utilizing IoT capabilities. These data-driven insights enable farmers to take well-informed decisions and optimize crop growing conditions, resulting in higher output and more effective use of resources.

Additionally, the IoT's promise goes beyond individual hydroponic systems. The internet's capacity to connect devices and share data creates opportunities for farmers to collaborate and exchange best practices across national borders and across the world. The advancement of farming methods, the stimulation of innovation, and the advancement of robust and environmentally friendly agricultural practices can all be facilitated by this common knowledge.

III. HOW IOT HELPS HYDROPONICS?

The application of IoT to hydroponics has produced encouraging results in terms of improving crop yield and resource efficiency [2].

A. Keep the Right Nutrient Solution Up

Incorporating IoT technology into hydroponic systems offers a sophisticated solution to maintain the proper nutrient solution temperature. By deploying IoT-enabled sensors within the reservoir, continuous monitoring of the temperature becomes possible. Real-time data transmission to a central IoT platform facilitates automated adjustments when deviations occur. If the temperature exceeds the optimal range, cooling mechanisms like fans or water chillers can be activated to rectify the issue. Conversely, if the temperature drops too low, heaters or heat pumps can be engaged.

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This seamless integration of IoT ensures that nutrient solution temperature remains within the ideal range, fostering optimal plant growth and preventing root rot. With remote accessibility and data-driven insights, hydroponic farmers can efficiently manage temperature conditions and cultivate thriving crops.

B. Top off Your Hydroponic Reservoir

IoT technology provides a useful method for topping off hydroponic reservoirs in circulation systems. IoT-enabled systems are able to continuously monitor water levels by integrating water level sensors into the reservoir. The sensors provide real-time data to a central IoT platform when the water level falls below a predetermined threshold as a result of evaporation or plant absorption. With the help of this platform, the reservoir can be automatically filled with the right amount of water, maintaining the smooth operation of the hydroponic system. In order to help farmers act rapidly alerts or notifications can be sent to mobile devices when the water level exceeds critical levels. This seamless connectivity to the Internet of Things makes reservoir management easier and guarantees consistent, ideal water quality.

C. Continuous pH and EC Monitoring

IoT devices, such as pH and EC sensors, are essential for assuring the ideal nutrient solution conditions in hydroponics. The sensors, which are placed inside the nutrient solution and linked to a microcontroller or IoT gateway, continuously monitor pH (acidity or alkalinity) and EC (Electrical Conductivity) levels to reflect nutritional amounts.

A central IoT platform or cloud server receives the data and sends it for immediate analysis. Farmers monitor pH and EC levels through mobile or web-based programs, receiving notifications if abnormalities occur. IoT-enhanced hydroponics promote plant health, and growth, and save farmers significant time by automatically recording and modifications.

D. Ensuring Adequate Oxygenation

It's essential to maintain a well-oxygenated nutrient solution to support crucial plant functions and encourage healthy root growth. A healthy oxygen environment encourages the development of advantageous microorganisms that strengthen the root system. Additional air stones should be added to the hydroponic system to improve oxygenation because they aid in preserving a high quantity of dissolved oxygen there. This practice promotes maximum fertilizer absorption and great plant health, thereby helping the hydroponic system as a whole.

IV. ADVANTAGES OF USING IOT IN HYDROPONICS

A fundamental change in modern farming has recently been brought about by the fusion of the Internet of Things (IoT) with hydroponic systems, which provides a number of previously unheard-of benefits over conventional soil-based agricultural techniques. This ground-breaking strategy makes use of the IoT's potential to build intelligent, networked ecosystems that allow for real-time monitoring, data-driven decision-making, and fine-grained control over important environmental variables. The transformative potential of IoT-based hydroponics is examined in this study, emphasizing its many advantages that open the door to sustainable food production and resilient farming techniques.

For crops to grow healthy in hydroponics, the pH level of the nutrient solution must be maintained. In this regard, using an Arduino UNO microcontroller offers a substantial advantage. The microcontroller continuously checks the nutrient solution's pH value and automatically starts supplying the necessary nutrients depending on the unique pH requirements of each crop variety. This automatic pH control system makes sure that crops are grown in the ideal pH range, which promotes better plant health, quicker growth, and greater harvests. Hydroponic farmers may effectively and accurately manage the pH levels by utilizing the capabilities of the Arduino UNO, increasing the overall effectiveness and productivity of their hydroponic systems.[3]

Farmers can now monitor crucial environmental variables like temperature, humidity, pH levels, nutrient concentrations, and light intensity in real-time thanks to the integration of IoT in hydroponics. IoT sensors carefully placed throughout the hydroponic system gather data continually and send it to a centralized platform. Farmers can make informed judgments and adjust the growing conditions as necessary thanks to this data-driven strategy. For instance, the IoT system can engage cooling or heating processes to maintain ideal conditions if the temperature deviates from the desired range. To ensure plants receive the proper mix of nutrients, pH and nutrient levels can also be automatically changed. Utilizing IoT technology increases the efficiency of hydroponic farming, resulting in increased yields, better crop quality, and sustainable resource management [1].

Through accurate data monitoring and administration, IoT technology integration in hydroponic systems improves resource efficiency. Critical elements including water levels, nutrient concentrations, and ambient conditions are continuously monitored by IoT-enabled sensors, which continuously gather and communicate real-time data. This data-

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driven strategy optimizes resource use by providing precise control over the distribution of water and nutrients to the plants. In order to minimize waste and save water usage, the system can automatically change the fertilizer supply based on plant needs. Furthermore, thanks to the remote control and monitoring made possible by IoT, farmers can make necessary modifications and guarantee effective resource use even when they are miles away. IoT-based hydroponics not only boosts productivity but also encourages sustainable farming methods with a smaller environmental impact by lowering water use and fertilizer waste in the provided environment [4].

Through the use of vertical farming and small-scale installations, hydroponics combined with IoT technology provides a farming solution that is space-efficient. Urban farmers may maximize the use of constrained space and raise crops in controlled conditions by utilizing IoT sensors and data-driven insights. Plants can be stacked on numerous levels during vertical farming, maximizing vertical area and reducing horizontal footprint. The Internet of Things (IoT)-enabled technology continuously analyzes and modifies crucial elements like temperature, humidity, and nutrient levels to guarantee the best circumstances for plant growth. By enabling local and sustainable food production, minimizing the need for long-distance travel, and boosting resource-efficient agriculture in populated places, hydroponics-integrated IoT become a practical choice for urban settings.

As a method of farming that is climate-smart, hydroponics has a significant advantage when combined with IoT technology. Farmers may lessen the effects of climate change and maximize resource use by combining environmentally friendly practices with adaptable methods. Because hydroponics lacks soil, it is possible to create controlled settings, and the Internet of Things (IoT) real-time monitoring improves the accuracy of controlling crucial elements like temperature, humidity, nutrient levels, and light intensity. Farmers are able to adjust to shifting climatic trends and assure the adaptability and durability of their crops as a result. In addition, hydroponics with IoT encourages resource efficiency by encouraging water recycling and exact nutrient supply, which supports overall sustainability. This comprehensive approach helps farmers to lessen environmental impact and increase agricultural productivity in the face of a changing climate by embracing climate-smart methods [5].

V. DISADVANTAGES OF USING IOT IN HYDROPONICS

The high initial setup costs for IoT-based hydroponic systems are one of the barriers to adoption. Specialized sensors, microcontrollers, networking hardware, and software platforms must be purchased in order to integrate IoT technologies. The price of premium nutrition solutions, growing medium, and other required equipment can further increase overall costs. It is important to recognize that, despite substantial initial investment, IoT-enabled hydroponics offers long-term benefits, including enhanced resource economy, real-time monitoring, and automated control, which can eventually result in greater yields and cost savings. In addition, lower prices brought on by improvements in technology and rising market demand should make IoT-based hydroponics accessible to more people in the future [4].

Hydroponics can considerably minimize its demand for highly skilled staff by integrating IoT technology. Hydroponic systems with IoT capabilities offer remote monitoring and automation of numerous processes, including nutrient delivery, environmental management, and data analysis. Real-time data is collected via sensors and smart devices and sent to a central platform for analysis. This data-driven strategy reduces the need for manual intervention by enabling educated decision-making and precise control over the hydroponic system. As a result, less specialist labor is needed, which opens up hydroponics to a wider spectrum of people who are interested in sustainable and effective farming techniques.

Using IoT technology in hydroponics presents significant reliability and connection challenges. Any interruption or instability in the internet connection might have a negative impact on the system's performance because IoT devices rely on internet access to communicate and share data. Data loss, transmission delays, and command failures can happen, leading to erroneous monitoring and potential crop losses. Redundancy solutions, including backup communication channels or local data storage, can be added to address these problems and ensure went on data flow and reliable operation even in the case of connectivity outages. Additionally, improving network infrastructure and employing reliable IoT devices with improved connectivity capabilities can increase the system's overall equilibrium while minimizing any dangers brought on by connectivity issues.

In order to successfully deploy IoT-based hydroponics, it is essential to take into account the dependence on a reliable and consistent power source. For real-time monitoring and control, Internet of Things (IoT) devices are significantly reliant on uninterrupted power sources. Power interruptions or outages may temporarily impair the system's capacity to gather data, transmit information, and carry out automated activities, thus having an influence on crucial crop management functions. By integrating backup power sources, such as batteries or generators, the risk of power-related problems can be reduced. This will ensure that the IoT system will continue to operate even if there are power outages.

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Additionally, by maximizing the power consumption of IoT devices through energy-efficient design and programming techniques, farmers will be able to increase the hydroponic system's overall reliability and increase the operating duration of IoT devices.

Due to the sensitive nature of the data acquired, such as environmental conditions and crop health information, data security and privacy considerations in IoT-based hydroponic systems are essential. To avoid potential breaches and guarantee the integrity of farming operations, it is critical to protect private information from unauthorized access and online threats. The system's security can be improved by using robust encryption during data transfer and storage, tight access controls, and frequent software updates. Additionally, observing data privacy laws and securing user consent for data collection and usage promote compliance and confidence. By proactively addressing these issues, hydroponic farmers can confidently use IoT technology to optimize crop management while safeguarding the confidentiality of their priceless data.

VI. CONCLUSIONS

Modern agriculture has been transformed by the merger of IoT technology and hydroponics, which offers a productive and sustainable method of food production. IoT-based hydroponics optimizes resource use by providing real-time monitoring and data-driven decision-making, leading to higher agricultural yields and fewer negative environmental effects. Because of IoT's automation and remote monitoring capabilities, there is a lot less demand for highly skilled workers, which opens up hydroponics to a larger market. To achieve a smooth implementation, however, obstacles including high upfront expenditures, reliability concerns, and power supply requirements must be resolved. IoT-based hydroponics offers a possible route towards a resilient and climate-smart farming future due to ongoing technological improvements and growing demand for sustainable farming methods.

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