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Review on IoT Assisted Hydroponic Farming as a Sustainable Model for Climate Resilient Urban Food Production

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ABSTRACT

Modern age of agriculture 4.0 is focused on data driven precision farming that mostly employs the Internet of Things (IoT), artificial intelligence (AI), machine learning, big data analytics, robotics and drones. But due to lack of space, soil based agriculture has become quite challenging. Now the focus has been shifted to food production in urban regions where less space can be utilized using a new type of farming technique. This is called hydroponic farming technique. It does not require soil base for the production but only requires nutrient based solution which can be prepared easily at home. Also, a controlled environment inside a house can be used as a climate resilient. In this paper different methods proposed by researchers have been discussed on the sustainable model of soilless food production in less spacious regions by the help of cutting edge technology like Internet of Things.

Keywords—Soilless farming, IoT, Climate Resilience, Hydroponics

1. INTRODUCTION

In the modern era of civilization, crop production for mankind is going to be more challenging by 2050. According to the news report published by the Department of Economic and Social Affair, United Nations, about 56% increase in food production is required to feed 9.8 billion people of the world [1-2]. This huge increment in crop production requires more resources for farming. But, with the gradual increase in population of the world, the scarcity of available resources for farming has increased. Therefore, management of available resources for farming has to be done without delay. While considering the important resources for crop production, location and size of the farm field, sufficient availability of fresh water and quantity of the available nutrients in the soil cannot be ignored. To increase crop production, the size of the farm field has to be larger. But a considerable amount of space is reduced to accommodate the increased population. According to the article produced by the Food and Agricultural organization of the United Nations [3], global per capita arable land has decreased by 18-20% within the year 2000-2020 due to increase in population. Journal published by Indian Journal of Agricultural Research [4], indicates an alarming 0.45% loss of arable land with 1% increase of population and urbanization. These data indicates an alarming situation for the availability of arable land in order to produce the required crop. Coming to the requirement of fresh water for farming, it has been observed that around 70% of water is globally used by traditional irrigation methods. There are several methods of traditional irrigation. But all of them are inefficient because the amount of water applied during irrigation mostly penetrates deeper into soil where the roots of plants cannot reach. This situation is called percolation. Also the irrigation water is lost because of evapotranspiration from the leaves and evaporation from the surface of the soil with time. Almost 40% to 70% of the fresh water gets wasted due to the reasons stated earlier [5]. Traditional farming utilizes large horizontal space and requires periodic fresh water irrigation of which most of the water is lost in various forms. Methods discussed so far reveal that soil-based farming has several limitations. Additionally, more than 70% tests carried out on soil samples produce excess acidity or alkalinity issues that impact the yield and plant health [6]. A study [7-8] published in India states that soil degradation in India is causing poor nutrition of plants and susceptibility to soil-based disease with decline in crop health. Although, multi-cropping in a farm field other than mono-cropping is found to be beneficial in soil-based farming, but, adding of excessive nutrients and insecticide could worsen the soil fertility.

The above discussion on soil-based farming indicates that increase in crop production requires large space which is reducing day by day. Hence, we need a better way to manage space. Water management is improved by avoiding traditional irrigation, but it cannot avoid the losses due to percolation, evapotranspiration and evaporation. Multiple cropping is beneficial but excessive nutrients and insecticides affect the soil health. It is clear that to grow more crops these limitations must be minimized. At present Soilless farming techniques have been considered as an alternative method to minimize these limitations. Though the foundation of this technique is from the ancient ages of the 17th century [9], its application for commercial purposes begins from the 21st Century. Currently the modernization of this technique has recovered various limitations that are to be discussed in the literature review section.

2. LITERATURE REVIEW

Soil-less farming got its commercial niche in the twentieth century when Dr. William F. Gericke in 1924 demonstrated impressive plant growth in soilless media. He coined the term "Hydroponics" which is a technique to grow the plants in a nutrient solution, in addition with gravels, vermiculite or rock wool to support the plant mechanically. [10]. In this section the basic parameters of hydroponic systems and their control using IoT have been discussed.

Hydroponic is a soilless farming technique where the plant cultivation is done in a mineral rich nutrient solution in water. It uses 90% less water in comparison to the traditional soil based system. Hydroponics is free from soil borne disease and pests. Though it requires significant nutrition related knowledge and technical expertise to monitor the system. The aeroponics system uses nutrient solution mist to the plant roots suspended in air. This technique provides good water efficiency with a high setup cost. Aquaponics integrates the hydroponics and aquaculture(fish farming) that uses fish excreta as nutrient to the plants. It helps to produce organic food with a high profit margin. But it also needs a high setup cost. Substrate culture provides bridge between hydroponics and conventional farming by providing nutrient solution to inert medium like sand, gravel, coco peat or perlite etc. It provides good mechanical support to the roots along with healthy nutrients from the applied solution [11-14]. As the cultivation of leafy plants is done on nutrient solutions, the parameters shown in **Table.1** require strict monitoring for the sustainable growth of plants under cultivation.

These parameters are necessary to be monitored continuously for the sustainable growth of cultivated plants. As any discrepancy in growth parameters may be dangerous for the health of plants, therefore, to make the entire system a weather proof sustainable technique, researchers have proposed and implemented various techniques some of which have been discussed here. Rajaseger, G et. al [18]. proposed real time environment monitoring system using IoT to track parameters like temperature, humidity, light intensity, nutrient concentration, pH etc,to rapidly respond to climate change and variation of necessary factors. Badgujar, J. T [19] proposed real time adjustment of nutrient delivery and other parameters to maintain optimal growth despite external fluctuations. Bouarroudj, K. [20] collected the data of the hydroponic system and analysed the data to predict the climate variability and enhance the climatic resilience for increasing crop productivity. Rajaseger,G.,et.al [21] mentioned optimization techniques of water and nutrient consumption using IoT. They have determined the schedule for providing nutrient and water doses to plant under erratic climate conditions. Bhavesh A. Dodiya [22] et.al developed a system to facilitate remote monitoring of the hydroponic system with timely alerts of changing environmental parameters via mobile or web interfaces.

3. DISCUSSION

Although various researchers have proposed methods to make a climate resilient hydroponic system. But still several issues need to be managed to make the system more robust against the climatic variations. Firstly, current systems should not rely on predefined threshold values. It must be adaptive and real time data need to be used to predict the climate stress for the plant growth. The systems must be energy efficient, i.e. must use low power IoT architecture to reduce space and financial expenses on bulky solar panels. Most of the time, the system robustness under diversified conditions is compromised. So, research for the improvement of robustness and sensor self calibration under different climatic conditions must be done. In spite of the availability of various predictive models, they must be improved to integrate the climatic variability data during seasonal anomalies. IoT-driven models requires uninterrupted internet connection. But in rural areas and also during climatic disturbances, the internet connection disruption may occur. Hence it is necessary to prepare a combination of edge computing as well as cloud computing models in the rural areas to support data synchronization. Hence this kind of hybrid model can be a good approach for minimizing data loss in climate resilient IoT architecture.

TABLE 1 THE ESSENTIAL PARAMETERS FOR HYDROPONICS

Sl No.	*Parameter*	*Role in Hydroponics*
1	pH	Nutrient solubility and uptake [15]
2	EC & TDS	Nutrient concentration and balance [15-16]
3	Temperature	Root oxygen solubility and metabolic activity [15,17]
4	Humidity	Transpiration, disease prevention[17]
5	Light Intensity	Photosynthesis control[16]
6	Water Level	Ensure continuous root immersion[16]
7	Dissolved Oxygen	Root respiration support [17]

4. FUTURE SCOPE

From the above discussion it is found that seasonal turbulence is one of the primary challenges in the hydroponic system that hinders food production by affecting the physical parameters in the same manner that it does in traditional methods. It is therefore necessary to control the parameters within an enclosed environment. It eventually increases the setup cost, but it needs to be managed through multilayer crop production in a vertical tower like soilless production facility that not only gives a controlled environment but also provides vertical space utility. AIML and IOT driven facilities will be also beneficial to implement in this setup for remote management and autonomous crop production system.

5. CONCLUSION

The above discussion reveals that soil-less farming is the future of cultivation in urban areas. It provides a good source of economic growth for people. Despite a little high investment, hydroponic systems are better for minimizing water consumption, soil based pest control and produce higher yield. In this paper, research methods of continuous monitoring of nutrient parameters and methodologies in hydroponics system have been discussed. But the challenge of proposing a robust system under diversified condition requires strong predictive models that can implement seasonal anomalies. Research proposal will be made by the authors in due course of time to minimize the anomalies to produce a robust climate resilient hydroponic system.

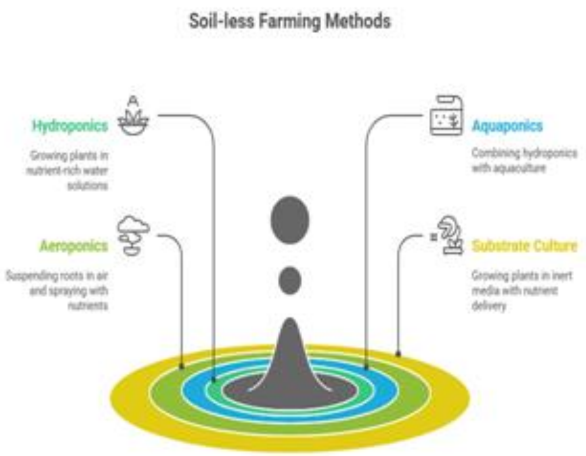

FIG. 1 DIFFERENT TYPES OF SOILLESS FARMING TECHNIQUES

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