Chapter 17
IoT-Driven Automation Systems for Hydroponic Agriculture

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ABSTRACT

The paper develops an analysis in terms of the transformational impacts of IoT-driven automation systems in hydroponic agriculture. Sensors, actuators, and data analytics through IoT enable the creation of smart responsive environments for hydroponic systems. IoT automation enables real-time monitoring and control of variables relating to nutrient levels, pH, temperature, and humidity for optimally maximized growth and resource utilization. The architectural framework of IoT systems in hydroponics is explained with regard to sensor deployment for real-time data, as well as utilization of machine learning algorithms for predictive analytics, in addition to case studies illustrating improved yields, reduction in water and nutrient utilization, and lower operational cost. And finally, the chapter will conclude with insights into future trends, which include further advancements in AI and robotics, leading to further innovations in automated hydroponic farming systems.

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INTRODUCTION

In recent times, old norms are being changed by Internet of Things technology in many domains, and hydroponic agriculture is not excluded from this. Hydroponics, whereby plants are grown in a nutrient-rich water solution rather than soil, provides a controlled environment and could potentially lead to more effective resource use and perhaps higher yields. The management of hydroponic systems is, however, complex as several environmental factors require control to allow optimal growth in the plants, and it is here that automation systems driven by IoT step in, thereby offering a sophisticated approach to the management and optimization of hydroponic agriculture (Lakshmanan et al., 2020).

IoT technology comprises networks of connected devices that collect, share, and act on data in their environment. In hydroponic agriculture, IoT systems use a variety of sensors and actuators to track critical parameters such as nutrient concentration, pH levels, water temperature, humidity, and light intensity. This will help provide real-time data for making decisions, automating steps, and predicting probable cases before they affect plant health or productivity. The application of IoT in hydroponic agriculture starts with sensors that are installed and continuously collect data on the growing environment. Such a sensor can be used to gauge as wide a range of variables as the concentration of essential nutrients, the pH, and the electrical conductivity of the nutrient solution, ambient temperature, humidity, and light levels (Prasetia et al., 2021). IoT systems put together all such collected data to give a detailed overview of the hydroponic environment; thus, it allows for precise adjustments and optimizations.

One of the primary advantages that IoT-driven automation brings to the table is the ability to automate routine tasks and processes. This nutrient delivery system, in this case, would automatically adjust concentration based on real-time data, ensuring the plants receive the best possible nutrient balance throughout the growth cycle. Alternatively, an automated pH adjustment system will keep the nutrient solution within its preferred pH level, minimize direct intervention from human hands, and mitigate the possibilities of pH-related problems (Hariono & Putra, 2021). Besides automation, IoT systems can also support advanced data analytics and predictive modeling. Utilizing machine learning algorithms for extraction of trends from unfamiliar data at the time of the analysis, the predictive capability serves in preemptive action taken to maximize the growth environment to avoid any unbalance in nutrients or environmentally drastic conditions. All this gives growers an opportunity to make more informed decisions regarding their approach toward healthier plants, increased yields, and efficient resource usage (Maldonado et al., 2019).

The case studies of these IoT-based hydroponic systems show the extent of these technologies for agricultural usage. These automated hydroponic farms have saved more water and nutrients than the previous yields of plants while still exceeding the crop yield. Optimization of resource usage and waste minimization make these systems more sustainable and reduce the farm running costs. Another benefit of these hydroponics is that one can control and monitor these systems of hydroponic cultivation using remote control through IoT interfaces. This gives more flexibility and ease to the growers as they can have control over their farms from anywhere in the world (Susanto et al., 2021).

Integration of IoT with hydroponic agriculture is not without its challenges. The reliability of the IoT system and security are paramount here as even minor disruptions or security breaches can put the system performance and data to risk. With IoT technology and infrastructure, the initial investment may be expensive; this deters some growers from using this technology. However, long-term benefits such as efficiency, reduction of resource usage, and increased yields will possibly offset the initial investment costs. A very bright future awaits IoT-driven automation of hydroponic agriculture (Dudwadkar et al.,