CHAPTER II
LITERATURE REVIEW

Solving problems to achieve the expected research goals and results requires information and selecting the correct method. Therefore, Chapter 2 will explain some theories relevant to the purpose of this study. The literature review discussed in this chapter includes a discussion of IoT-based Vertical Farming. The main topics of this chapter discussed are types and implementation, current research, variables to be controlled, new challenges and perspectives, summary (table), and application of IoT-based Vertical Farming.

2.1 Introduction

At the current level of scattered agriculture, they still use large tracts of farmland to meet market demand. However, due to declining land availability due to urban development and other factors, the agricultural sector had to be sacrificed. While the agricultural sector, based on data from the Central Statistics Agency, is the second largest economic support sector for the Indonesian economy. Not only that, but agriculture is also very important for the human body; this is in line with the presentation of the journal Iqbal, who explained that vegetables are nutritious foods that provide adequate amounts of nutrients needed for normal body function, maintenance, and reproduction (Iqbal, 2006). Therefore, the agricultural sector must continue running to meet human Nutrition.

With technological advances, the application of embedded vertical farming with IoT systems is likely necessary. This aligns with the statement of Amir Masoud Rahmani, who explained that IoT is a phenomenon that currently covers all aspects of human life and has created a chain of interdependent creatures. It is so intertwined with human life that nowadays, it is very strange and difficult to imagine a lifestyle without smart applications, sensors, and tools (Rahmani et.al., 2021). IoT in agriculture can help farmers care for and maintain their crops without having to spend time and energy checking plants every day. Therefore the application of IoT in agriculture is very appropriate.

2.2 Types and implementations of vertical farming embedded with IoT system

The main principle of implementing vertical farming is to save land and water while increasing business efficiency through repeated use of nutrients, especially if aquaculture is added as a source of nutrient water for plants. This is one of the efforts of the cultivation system, which is considered environmentally friendly. According to the Prakati team on the website explains that three types of vertical farming systems are most popular in the world (Prakati, 2021), namely:

2.2.1 Hydroponics

It is a method of growing food in water using mineral nutrient solutions without soil. The basic advantage of this method is that it reduces soil-related cultivation problems like soil-borne insects, pests, and diseases, as shown in Figure 2.1.

Figure 2.1 Hydroponics (Prakati, 2021)

2.2.2 Aeroponics

In 1990, the National Aeronautical and Space Administration (NASA) in the United States encouraged the invention of aeroponics as an efficient way to grow plants in space. Aeroponics, as seen in Figure 2.2, does not use traditional planting media or containers. In Aeroponics, mist or nutrient solution is used instead of water. By supporting the plant and spraying the roots with a nutrient solution, this method requires much less space, water and soil.

Figure 2.2 Aeroponics (Prakati, 2021)

2.2.3 Aquaponics

The term "aquaponics" is created by combining the words "aquaculture," which refers to the farming of fish, and "hydroponics," the method of cultivating plants without soil. This technique establishes a symbiotic relationship between the plants and fish, as depicted in Figure 2.3. The symbiosis is achieved by utilizing nutrient-rich waste from fish tanks as a fertilizing agent for the hydroponic beds. These beds also serve as bio-filters, removing gases, acids, and chemicals like ammonia, nitrates, and phosphates from the water. Additionally, the gravel beds provide a habitat for nitrifying bacteria, enhancing nutrient cycling and water filtration. As a result, the purified water can be recirculated back into the fish tanks.

Figure 2.3 Aquaponics (Prakati, 2021)

2.3 Recent research on the design and fabrication of vertical farming embedded with IoT system

Several sources of journals and theses discuss IoT system-based Vertical Farming. But for the presentation of this project, we designed it differently. The following is the latest research that became a source of information in making this project.

2.3.1 Vertical farming monitoring system using the internet of things (IoT)

Chin, Y. S., & Audah, L. published a journal with the title Vertical farming monitoring system using the internet of things (IoT) (Chin and Audah, 2017). In this journal, they explain several stages; There are several stages involved in implementing this system. The first stage involves the installation of sensors on vertical farm structures to collect the required data based on the current conditions. These sensors are connected to the analog input (AIN) of the BeagleBone Black (BBB), enabling the direct transmission of all collected data to the BBB. The appropriate action will be automatically taken if the sensor input value falls outside the acceptable range, such as activating the irrigation system when the soil moisture level is very low.

The second stage involves the utilization of the Sierra Wireless Module coordinated with the BeagleBone Black to provide access to 4G LTE networks through a selected Telco service. The SIM card module connected to the wireless module contains a SIM card subscribed to an internet package from a specific Telco (Digi-Telco was used in this project). Global Positioning System (GPS) data is retrieved from a Global Navigation Satellite System (GNSS) receiver inside the wireless module to determine the location of the equipment being used.

Furthermore, the third stage involves the use of the BeagleBone Black microcontroller as the central processing unit (CPU) to manage the data accumulated from sensors through the analog input (AIN) pin. The data is then uploaded directly to the cloud with network access supported by the Sierra Wireless Module. The irrigation systems are also programmed to activate when the soil moisture level falls below a certain threshold.

The Thingspeak Internet of Things (IoT) platform is employed to store information and develop web-based applications. This application can analyze statistics in the cloud and visualize them as graphs, charts, or tables for better understanding. Although the system is programmed to automatically react when unacceptable inputs are detected, it must also be user-controllable. Hence, there is a connection between the web-based application and the BeagleBone Black.

The prototype system consists of a water tank, circuit board, and Thingspeak duct. Since most vertical farming structures are placed indoors and lack sunlight exposure, the prototype system is equipped with RGB LED lights to provide a light source for plants to carry out photosynthesis. The LDR Photoresistor and LM35 temperature sensor are installed in the system to monitor light intensity and ambient temperature, respectively. Unlike traditional horizontal farming, ambient temperature and light intensity significantly impact vertical farming. Therefore, this data needs to be monitored in real-time so that appropriate action can be taken when issues arise. The Figure of this journal can be seen in Figure 2.4.

Figure 2.4 Vertical Farming Monitoring System Using the Internet of Things (Chin and Audah, 2017)

2.3.2 Design and Implementation of Smart Hydroponics Farming Using IoT-Based AI Controller with Mobile Application System

Bhasker Dappuri published a journal titled Design and Implementation of Smart Hydroponics Farming Using IoT-Based AI Controller with Mobile Application System (Dappuri et.al, 2022). They discussed the Design and Implementation of Smart Hydroponics Farming Using an IoT-Based AI Controller with Mobile Application System. The abstract of this journal provides a concise overview of the topic. Hydroponics, a soil-less agriculture system, offers advantages such as reduced water consumption and resource usage compared to traditional soil-based farming. However, effectively monitoring hydroponics farming poses challenges, including the need to oversee multiple parameters, provide nutrition suggestions, and diagnose plant issues. Recent technological advancements have addressed these challenges by incorporating artificial intelligence (AI)-based control algorithms in agriculture. This article focuses on the implementation of an AI-based smart hydroponics expert system, referred to as AI-SHES, integrated with an Internet of Things (IoT) environment through a mobile application. The proposed AI-SHES with IoT encompasses three phases. In the first phase, a hardware environment is established, comprising real-time sensors such as NPK soil, sunlight, turbidity, pH, temperature, water level, and a camera module, which are controlled by the Raspberry Pi processor. The second phase incorporates a deep learning convolutional neural network (DLCNN) model for accurate nutrient level prediction and detection/classification of plant diseases. The third phase enables farmers to monitor sensor data and assess the status of plant leaf diseases using an Android-based mobile application connected to the IoT environment. This empowers farmers to continuously track their field's status through the mobile app. Furthermore, the proposed AI-SHES system also includes an automated mode, enabling the complete environment to be controlled automatically and taking necessary actions to enhance productivity in the hydroponics field. Simulation results of disease detection and classification using the AI-SHES system with IoT demonstrate exceptional performance, with accuracy and F-measure scores of 99.29% and 99.23%, respectively. The Figure of this journal can be seen in Figure 2.5.

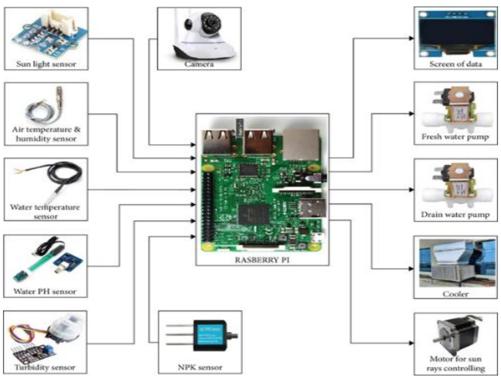

Figure 2.5 Automation of Aquaponic Choy Sum and Nile Tilapia Using Arduino Microcontroller (Dappuri et.al, 2022)

2.3.3 Implementation of smart monitoring system in vertical farming

Y D Chuah published a journal titled Implementation of smart monitoring system in vertical farming (Chuah et.al, 2019). The results of the study demonstrate that the implementation of a Cyber-Physical System (CPS) in vertical farming enables remote monitoring of plant growth. Utilizing current CPS technology, an Android-based system for remote monitoring and control of plantation systems was developed. The evaluation of this newly developed CPS system revealed a significant reduction in the workforce required to monitor and control crucial growth factors such as light, humidity, temperature, pH level, and CO2 levels. Moreover, the CPS system effectively mitigates the growth of algae, which can negatively impact plant growth. As a result, the application of CPS technology in vertical farming offers practical benefits in optimizing plant growth rates and enhancing overall plant quality. The Figure of this journal can be seen in this Figure 2.6

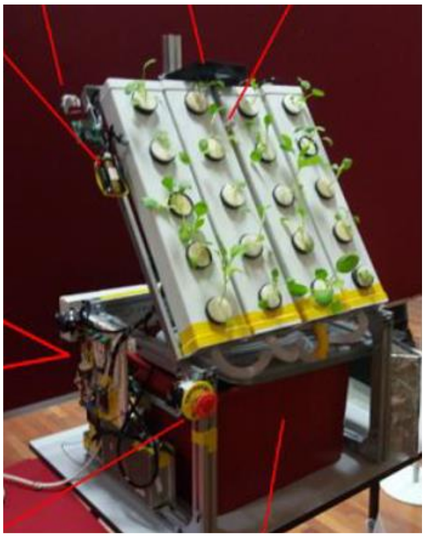

Figure 2.6 Implementation of smart monitoring system in vertical farming (Chuah et.al, 2019)

2.3.4 An Automated Hydroponics System Based on Mobile Application

Kunyanuth Kularbphettong published a journal titled An Automated Hydroponics System Based on Mobile Application (Kularbphettong et.al., 2019). In an effort to boost agricultural productivity, the Thai government has launched the

"Thailand 4.0" campaign, which aims to educate farmers, increase their incomes, and enhance their overall living standards. To align with this objective, there is a significant shift from traditional to modern agriculture with a focus on Smart Farming. Among the various modern farming methods, hydroponics has gained popularity for its soil-less approach, and numerous studies have shown that plants grown using hydroponics exhibit high quality while consuming fewer resources compared to traditional methods.The objective of this research is to design and develop an automated system for controlling and monitoring plant growth in hydroponics. The system effectively manages environmental factors such as temperature, humidity, and water, while also automatically adjusting the nutrient solution to maintain the desired parameters. Additionally, it collects data on the amount of solution used during planting, enabling cost estimation and profitability analysis for different vegetable crops.Through this study, the successful application of hydroponics for improving pH sensor stability is demonstrated. The system operates efficiently in automated mode, showcasing its potential for optimizing plant growth and resource utilization.. The Figure of this journal can be seen in this Figure 2.7.

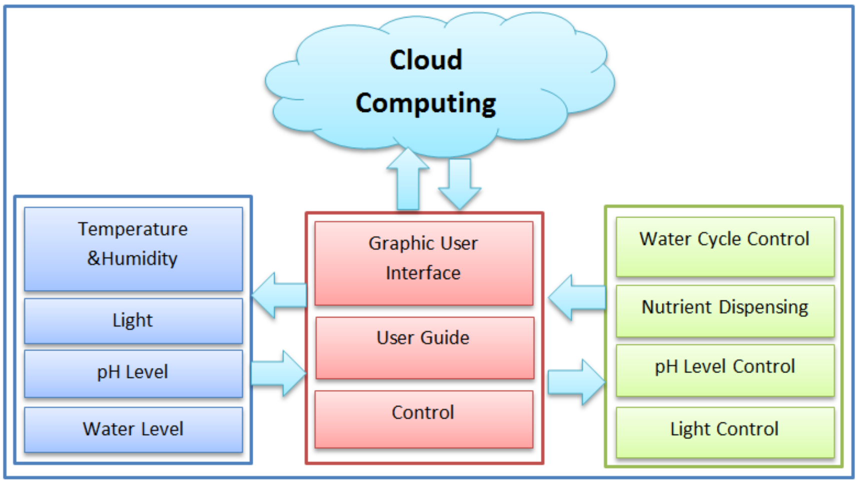

Figure 2.7 An Automated Hydroponics System Based on Mobile Application (Kularbphettong et.al., 2019)

2.3.5 CPS/IoT ecosystem: indoor vertical farming system

Isakovic Haris published a journal titled CPS/IoT Ecosystem: indoor vertical farming system (Haris et.al., 2019). To develop large-scale IoT applications, extensive infrastructural support is required, encompassing hardware, software, and communication channels that facilitate the interconnection of diverse components. The CPS/IoT Ecosystems project aims to explore the infrastructure needed for such applications, focusing on real-world scenarios such as smart parking, smart agriculture, and intelligent buildings.In this paper, a modular indoor vertical farming system is proposed, utilizing the infrastructure provided by the CPS/IoT Ecosystem and Arrowhead IoT framework. Vertical farming is a sustainable technology with numerous benefits, including reduced use of harmful chemicals and water, as well as the ability to provide healthy and fresh food regardless of climate or environmental conditions. By leveraging IoT, these systems can be integrated into a Production-as-a-service (PaaS) ecosystem to optimize food production, minimize waste, and reduce energy consumption. The software and hardware infrastructure for IoT play crucial roles in achieving these objectives. The Figure of this journal can be seen in this Figure 2.8

Figure 2.8 CPS/IoT Ecosystem: Indoor Vertical Farming System (Haris et.al., 2019)

2.3.6 Automated smart hydroponics system using the internet of things

Ravi Lakshmanan published a journal titled Automated smart hydroponics system using the internet of things (Lakshmanan et.al., 2020). This paper introduces the design and implementation of an intelligent hydroponics system that utilizes the Internet of Things (IoT). The main objectives of this system are to address the increasing global food demand and explore sustainable farming methods through the integration of IoT technologies. The design incorporates components such as NodeMcu, Node-Red, MQTT, and carefully selected sensors based on specific parameters. Data collected by the sensors is transmitted to the cloud for monitoring and processing.To inform the design, a comprehensive review of previous works in the field of IoT and hydroponic systems was conducted. The prototype was then constructed, programmed, and thoroughly tested. Sensor data from different environments was collected and monitored through a cloud-based web page, accessible via a mobile application. Additionally, a bot was introduced to enhance supply chain control and provide notifications. The system's performance has been significantly improved, leading to the successful implementation of the overall objectives. Future work could focus on overcoming certain limitations, such as incorporating data science techniques using artificial intelligence to further enhance crop production and achieve better outcomes. Furthermore, an end-user platform could be designed to facilitate user interaction, offering an attractive interface without requiring extensive technical configurations.. The Figure of this journal can be seen in this Figure 2.9.

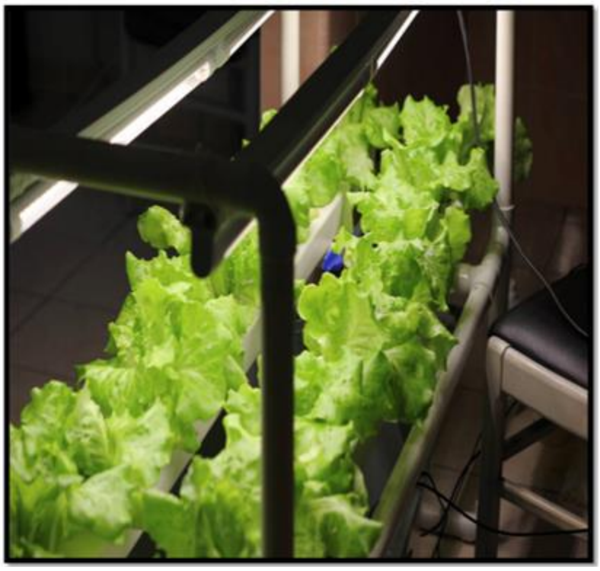

Figure 2.9 Automated smart hydroponics system using the internet of things (Lakshmanan et.al., 2020)

2.3.7 Vertical farming using internet of things

Karishma sahoo published a journal titled Vertical farming using the internet of things (Sahoo et.al., 2022). ertical farming is an innovative approach to maximize land usage by cultivating plants in vertically stacked layers, making it suitable for indoor implementation. The key concept of vertical farming revolves around the utilization of controlled-environment agriculture (CEA) technology, which enables precise control over all environmental factors. To achieve this, an automatic Internet of Things (IoT) system is implemented in this project, aiming to create a controlled environment for vertical farming. The primary objective of this project is to develop a system that monitors soil moisture and controls water content through various devices, including laptops, mobile phones, and compact handheld devices, via a web browser interface. A soil moisture sensor is employed to detect the moisture level in the soil of the vertical farm, allowing continuous monitoring and ensuring sufficient water supply for the plants. Whenever a low moisture level is detected, signals are transmitted to the Arduino platform. The collected data is stored in the Arduino IDE software and simultaneously transmitted to the web browser via an Ethernet connection to an internet router. Users can conveniently monitor their plants' status through the web browser, accessing real-time soil moisture readings and controlling the water valve to provide additional water whenever necessary. This development has proven to be highly beneficial, as it enables regular monitoring of vertical farming without requiring constant operator presence at the site.. The Figure of this journal can be seen in this Figure 2.10.

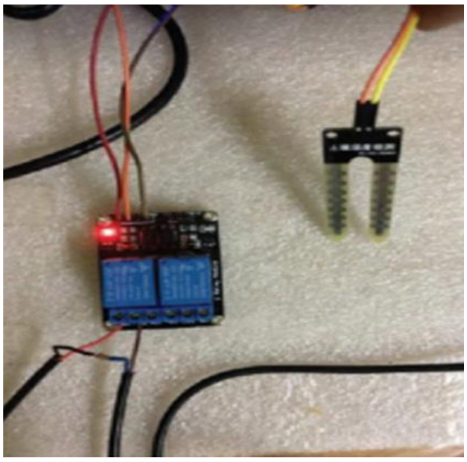

Figure 2.10 Vertical Farming Using the Internet of Things (Sahoo et.al., 2022)

2.3.8 Automation in Hydroponic System Using PLC

Piyush Patil published a journal titled Automation in Hydroponic Systems Using PLC (Patil et.al., 2016). The objective of this project is to implement automation in hydroponic systems, which involve the cultivation of plants in water without soil. Hydroponics is an innovative agricultural production method where plants are grown in soil-less mediums, utilizing either artificial soil or water as the growing medium. Nutrients and fertilizers are supplied to the plants through the water. To ensure optimal plant growth, prevent diseases, and accelerate growth rates, hydroponic systems require a controlled environment. This project focuses on automating the monitoring and control of environmental parameters such as temperature, humidity, and light intensity.The system incorporates various sensors to measure temperature, humidity, and light intensity. If these values exceed or fall below their predetermined set points, the system initiates appropriate control actions to bring the parameters back to their desired average values. By implementing automation in hydroponics, this project aims to streamline the growing process and ensure optimal conditions for plant growth.. The Figure of this journal can be seen in this Figure 2.11.

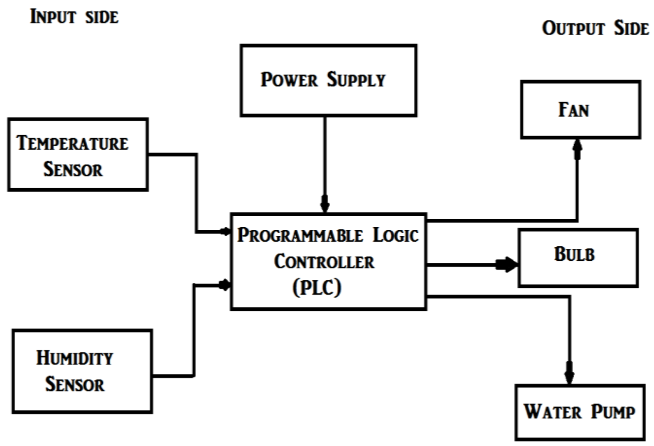

Figure 2.11 Automation in Hydroponic System Using PLC (Patil et.al., 2016)

2.3.9 Smart vertical farming using IoT

Rajermani Thinakaran published a journal titled Smart vertical farming using IoT (Thinakaran et.al., 2020). The vegetable industry in Malaysia is crucial for food supply, rural employment, and economic development. However, labor shortages pose challenges in meeting the increasing demand. To address this, the study proposes a Smart Vertical Farming System (SVFS) using IoT technology. The SVFS integrates Information and Communication Technologies into agriculture, presenting a green revolution. Developed using a qualitative approach and the waterfall model, the SVFS enables continuous monitoring of environmental factors like soil humidity, grow light, and temperature. A comparison with traditional farming methods was conducted by growing two types of vegetables. Results showed accelerated growth and increased leaf production in vegetables grown under the SVFS. This indicates the system's potential to enhance both the quantity and quality of vegetable yields, ensuring a sufficient market supply at reasonable prices. An IoT-based prototype and an Android application were designed and implemented, allowing users to control components and monitor temperature, humidity, and soil moisture in real time. The auto-control mode enables automation based on predetermined conditions, reducing the workload for vegetable cultivation and improving efficiency. The Figure of this journal can be seen in this Figure 2.12.

Figure 2.12 Smart vertical farming using IoT (Thinakaran et.al., 2020)

2.3.10 IOT-BASED Aquaponic Control And Monitoring System Design In Kutajaya Village

Nina Rahayu published a journal titled Vertical farming using the internet of things (Rahayu et.al., 2018). Aquaponics is an innovative technique integrating plant and fish cultivation, ideal for urban com munities with limited green spaces. It can be implemented in small house yards. Unlike traditional methods, aquaponics uses water as the growth medium, making it advantageous in water-abundant areas. This research employed data collection, analysis, literature review, prototype development, and testing. The study focused on designing and implementing an aquaponics control system using ultrasonic and dht22 sensors. These sensors monitored water level, temperature, and humidity. Data was transmitted to an Arduino UNO microcontroller, which controlled the water pump, lamp, and fan based on predefined conditions. The system could be conveniently monitored through an Android smartphone, providing users with an accessible interface for management and oversight.. The Figure of this journal can be seen in this Figure 2.13.

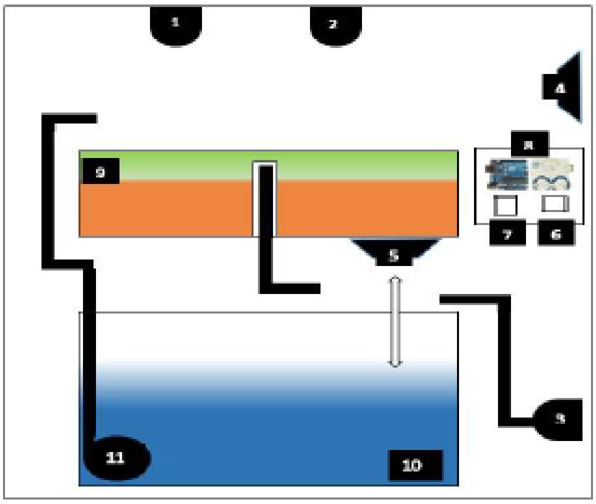

Figure 2.13 IOT-BASED Aquaponic Control And Monitoring System Design In Kutajaya Village (Rahayu et.al., 2018)

2.4 Variables to be controlled

Several variables will be controlled in the design and fabrication of vertical farming embedded with an IoT system, which is as follows :

2.4.1 Sunlight

The light referred to here is the light received by the plant because if the light received by the plant is less than expected, the plant will not grow well. Some causes of plants not receiving maximum light are when it rains, when it is overcast, or at night. Badgery-Parker, J. explains that light requires 200-400 footcandles (2152.78 - 4305.56 lux) (Badgery, 1999). Therefore, researchers set the light intake in plants around 4000 lux using the BH1750FVI sensor to measure the light.

2.4.2 Temperature

Temperature significantly affects the growth and development of plants. Plant growth will be optimal at the ideal temperature for growth. An increase or decrease in ambient temperature will affect its growth and development. Therefore, if the water temperature is considered too high, it can be changed to lower the water temperature. The reading of the water temperature will use the DS18B20 sensor as a water temperature measuring instrument. Therefore, plants have an optimum temperature between 10 to 38 degrees Celsius and while plants will not survive at temperatures below zero degrees Celsius and above 40 degrees Celsius (Setiawan, 2020).

2.4.3 Nutrition

This nutrient is a complete fertilizer that contains all the macro and micro nutrients needed by plants. Fertilizers are specially formulated according to the type and phase of plant growth. Water nutrient measurements can be calculated using TDS (Total Dissolved Solids) sensors in ppm (parts per million). These nutrients will be taken from fish pond water, which will come from fish feed residues and waste. In order for nutrients for plants to be met, it is recommended that levels be maintained at 5 ppm or higher (Sallenave, 2016). Water nutrient measurements can be calculated using TDS (Total Dissolved Solids) sensors in ppm (parts per million). These nutrients will be taken from fish pond water, which will come from fish feed residues and waste. However, if the PPM water value has been overvalued, then it is necessary to replace the water.

2.4.4 Water pH

One of the most important factors in plants is the pH of the water. Many failures or imperfections in plant growth are caused not by nutrients but by the pH of the water. The plant absorbs nutrients necessary for growth through its roots in a water-soluble form. Water to plants is like air (O2) to humans. No matter how good the food or nutrients we take, we won't be healthy if the air we breathe is unhealthy. Therefore, in order for vegetables to remain healthy, the pH of pond water must remain in the range of 5 – 7 ppm (Riawan, 2016). In order for farmers to anticipate if the pH of the water is too high, farmers can change the water or add pH up liquid or pH down liquid.

2.5 New challenges and perspectives

The IoT system in Vertical farming is very good and appropriate because it can help users, especially petaani in caring for their plants. Because of this, farmers can get high quality vegetable crops and minimal crop failure. however, IoT systems in Vertical Farming are less impressive if there is an error or error, this can be caused by several things that may come from the wiring system, microcontroller, or others. Here are some of the challenges that users will face with IoT systems in Vertical Farming.

2.5.1 Device can't connect to network

Connectivity to the network is one of the most common problems facing users of IoT devices. One of the key challenges in IoT connectivity is ensuring all devices can communicate with each other. This requires a robust and reliable network infrastructure that can handle a large number of devices and data flows (Kumar, 2023). Considerations about the reliability of IoT devices are very important so that Vertical Farming monitoring can function properly and correctly. Therefore, users must be able to ensure that the network to be used will not interfere with the IoT system.

2.5.2 Improper sensor readings

There's nothing worse than an IoT device sending faulty sensor readings, which would cause plants to fail to grow or fish to survive. therefore it is necessary to call it period calibration, Usually calibration occurs periodically, so as to perform preventive calibration (Martins et.al., 2017). Therefore, calibration on the sensor periodically is very important so that the readings from the data that appear are the actual data.

2.5.3 Devices are difficult to control

Users often express reluctance to use IoT applications when they are near the vertical farming prototype. While remote monitoring and control of vertical farming is convenient from a distance, the inconvenience arises when individuals are in close proximity to the prototype without immediate access to a mobile phone. This can lead to frustration as they need to locate their device for interaction with the system.. The device and implementation system must be user-friendly, which can manage the operation process and operation calmly everywhere will not burden and frustrate consumers, leading to system disconnection (Muhammad et.al., 2017).

2.6 Summary (table)

Table 2.4 Summary of previous research

No	Title	Author	Advantage	Disadvantage	Remark
1	Vertical Farming Monitoring System Using the Internet of Things (IoT)	(Chin and Audah, 2017)	• Can measure the intensity of light • Can measure ambient temperature • Can measure soil moisture • There is a pump that is connected to a soil moisture sensor	• Cannot measure the Nutrition of water • Cannot measure water pH • Unable to measure water temperature • Light relies only on sunlight • Unable to monitor vertical farming online • No surveillance cameras	Based on this research several things can be developed through this research, such as the measurement of water nutrition, water pH, water temperature, and the addition of a UV lamp.
2	Design and Implementation of Smart Hydroponics Farming Using IoT-Based AI Controller with Mobile Application System	(Dappuri et.al, 2022)	• Can calculate water temperature and air humidity • Can calculate soil quality • It has automatic air conditioning • can control the light obtained by plants • There is a drain and inlet water pump	• The light source comes only from the sun	The equipment is almost complete, but the light source only comes from the sun.
3	Implementation of smart monitoring system in vertical farming	(Chuah et.al, 2019)	• There is a room temperature sensor connected to the fan • There is a pH sensor that is connected to the pH solution up and down • There is a room humidity sensor that is connected to the Humidity control • There is a Carbon Dioxide sensor connected to a Solenoid to release CO2	• There is no TDS sensor to measure water nutrients • No surveillance cameras • There is no water temperature sensor	No water temperature sensor will affect the quality of plant growth, and also, the plants cannot be checked at any time because there are no surveillance cameras.

			• There is a light sensor connected to the UV lamp		
4	An Automated Hydroponics System Based on Mobile Application	(Kularbphettong et.al., 2019)	• Can calculate water level • Can adjust pH level • Can control the distribution of nutrients	• No surveillance cameras • No application used for monitoring	Usage is still not optimized because users cannot check plants from faraway places.
5	CPS/IoT Ecosystem: Indoor Vertical Farming System	(Haris et.al., 2019)	• There is a TDS sensor • There is a temperature humidity sensor • There is a light sensor • There is a CO2 sensor	• There are no surveillance cameras • There is no pH sensor • There is no temperature sensor	Need a lot of development in this research
6	Automated smart hydroponics system using the internet of things	(Lakshmanan et.al., 2020)	• Can calculate room temperature and humidity • There are levels of fertilizers	• There are no surveillance cameras • There is no TDS sensor	Users should still be able to check plants manually
7	Vertical Farming Using the Internet of Things	(Sahoo et.al., 2022)	• There is a soil moisture sensor connected to the plant water pump • There are environmental temperature and humidity sensors	• There are no surveillance cameras • There is no TDS sensor • There is no pH sensor • There is no water temperature sensor • There is no light sensor; this research only relies on the sun as a light source. • Cannot be monitored online	A lot needs to be developed in this research, which relies only on soil moisture and environmental temperature and humidity sensors.

8	Automation in Hydroponic Systems Using PLC	(Patil et.al., 2016)	• There is a room temperature sensor • There is a room humidity sensor	• the water pump will run for 24 hours • Cannot be monitored online • There are no surveillance cameras • does not have a water pH sensor • Does not have a TDS sensor	We still need some extras because there are no sensors that plants need
9	Smart Vertical Farming Using IoT	(Thinakaran et.al., 2020)	• There is a DHT11 sensor • There is a soil moisture sensor	• Cannot be monitored through the app • There is no TDS sensor • There is no pH sensor • There is no water temperature sensor • There is no light sensor where the light source is only sunlight • There are no surveillance cameras	In this research, there are so many shortcomings
10	IoT-BASED Aquaponic Control And Monitoring System Design In Kutajaya Village	(Rahayu et.al., 2018)	• There is an ambient temperature sensor connected to a light bulb and fan • There is an ultrasonic sensor to measure the pool water level	• Cannot be monitored through the app • There is no TDS sensor • There is no pH sensor • There is no water temperature sensor • There is no light sensor where the light source is only sunlight • There are no surveillance cameras	In this research, there are so many shortcomings

2.7 Applications

IoT-based Vertical Farming is usually applied at two levels: household applications and the agricultural industry.

2.7.1 Household

Urban farming is one strategy that can shape family food security in urban areas. The Vertical Farming system is one of the urban farming activities. Small-scale Vertical Farming can be used on a household scale. Maximum care is needed in Vertical Farming cultivation to improve the growth and yield of vegetables and fish. Vertical farming can be solution that doesn't manage daily food expenses by getting a crop of fish and vegetables harvested each day. The Figure of this can be seen in this Figure 2.14.

Figure 2.14 Household Vertical Farming (Ariesalfajri, 2015)

2.7.2 Industry

"Industrial scale" means if the products from plants and fish have been traded. Agriculture and fisheries are generally separated or unrelated; additionally, agriculture and fisheries that use ancient methods require much land. Therefore, applying Vertical Farming is very profitable because the agricultural industry does not need a lot of lands to get two sources of finance: agriculture and fisheries. The Figure of this can be seen in this Figure 2.15.

Figure 2.15 Industrial Vertical Farming (George, 2015)