CHAPTER I

INTRODUCTION

Global population growth is accelerating, with projections indicating that by 2030, there will be 8.5 billion people on the planet (UN, 2019). Consequently, more food should be produced in order to feed such a big population. The farming sector's continued growth is difficult due to the limited land and water supplies. Overuse and careless use of pesticides and fertilizers are also responsible for decreasing soil productivity, which in turn lowers the rate of agricultural growth. In addition to decreasing soil productivity, runoff from excessively treated fields degrades the water's quality by raising its phosphate and nitrogen levels. Water and soil availability are decreasing due to population growth, urbanization, and poor resource management. Soil erosion, water pollution and land fragmentation in rural and urban areas are worsening conditions for agriculture, resulting in reduced farm income. While aquaculture is the fastest-growing food sector, it faces challenges like high water use and nutrient release, causing eutrophication and creating dead zones in water bodies.

Agricultural water use varies widely, accounting for about 40% of water use in diverse economies but exceeding 95% in agriculture-dominated nations. Global population growth, projected to reach 8.9 billion by 2050, and water use increasing at twice the rate of population growth, have led to rising water scarcity, with 1.8 billion people facing extreme shortages by 2025 (UN, 2007). Asia allocates 86% of its water to irrigation, while domestic and industrial needs dominate in Europe and North America (Michael and Ojha, 2013). According to the International Water Management Institute, agriculture accounts for approximately 72% of global freshwater withdrawals (IWMI, 2023). In India, per capita water availability has declined significantly, with the Ministry of Water Resources projecting a decrease from 1,486 m^3 in 2021 to 1,367 m^3 by 2031, indicating severe water stress (Reuters, 2024). This reduction poses substantial challenges to food production and overall water security.

India is an agrarian nation, with almost 70% of its population relying on agriculture either directly or indirectly. India's agricultural production faces numerous challenges, including fragmented landholdings, inadequate irrigation facilities, soil degradation, unpredictable weather patterns, insufficient credit and insurance facilities, and lack of access to modern technology and markets, leading to reduced productivity and income for farmers. Farmer suicides account for 11.2 per cent of all suicides in India (Dani and Gaur, 2016). Activists and scholars have offered a number of conflicting reasons for farmer suicides, such as monsoon failure, crop failure etc. In order to manage or solve the above mentioned problem of water scarcity, water productivity of crops should be enhanced and for the crop failure some alternative method should be incorporated to substitute the crop failure.

Traditional fish farming faces several challenges that impact its sustainability and productivity. Key issues include water quality deterioration from pollution and nutrient runoff, leading to fish health problems and environmental degradation. High dependency on external feed sources raises costs and can introduce contaminants. Waste management is another significant challenge, as fish excreta can pollute surrounding waters if not properly treated. Disease outbreaks and parasites can spread rapidly in densely stocked farms, necessitating the use of antibiotics and chemicals, which can have further environmental and health implications. Additionally, traditional fish farming often requires substantial land and water resources, which can be scarce and costly. Inconsistent regulatory frameworks and limited access to advanced technology and infrastructure further hinder the efficiency and scalability of traditional fish farming operations.

Innovative and improved farming methods can help to overcome these obstacles. These issues can be resolved with the aid of technical advancements in the production of crops and fish. Aquaponics is a new and promising agricultural technique that employs fish waste as a natural fertilizer for plants in a nutrient-rich environment. Aquaponics is any system that combines hydroponics (growing plants in water) and conventional aquaculture (rearing aquaculture creatures like snails, fish, cray fish, or prawns in tanks) in a symbiotic setting. In typical aquaculture, the water may become more poisonous as a result of the fish waste building up. Water from an aquaculture system is transferred to a hydroponic system in an aquaponics system, where nitrifying bacteria convert the byproducts into nitrites and subsequently nitrates, which the plants use as nutrition. After that, the water is recycled back into the aquaculture system (Sawkar *et al.*, 2020).

Aquaponics is a sustainable organic food production method that combines hydroponics and aquaculture in a mutually beneficial way. As a part of Integrated Farming System, aquaponics can serve as a boon for farmers to support their livelihood, as crop fails, aquaculture will come for support and if aquaculture fails, crop can come for the rescue. It serves as a tool to control the problem of water scarcity by reusing the utilized water: same water for crops as well as aquaculture. 90% less water is used in aquaponics than in soil-based farming. Compared to traditional soil-based farming, it yields two to three times as many vegetables per unit area (Somerville *et al.*, 2014). It is completely supportive of the environment, energy-efficient, and environmentally friendly. Aquaponics is often the best crop production method in remote areas that lack suitable soil or water supplies. In densely populated cities without land, people can produce fresh fruits, vegetables, and fish in little trash cans on the roof, balcony, or inside. Aquaponics can be used to turn sterile and barren regions into productive ones at a relatively cheap cost, resulting in a consistent and plentiful supply of fresh fish and greens. As the system will promise two types of marketable products using same quantity of resources, there is every possibility of “Doubling the farmers’ income” with assured market security.

In aquaponics system, water quality and water level maintenance are issues that need to be watched after and managed. Currently, farmers need to check and control water levels, pH, ammonia, dissolved oxygen (DO), temperature values of fish tank manually and regularly. The manual control method causes inconvenience and time consuming as the ammonia, pH values for plants and vegetables are varied. The Internet of Things (IoT) based automated aquaponics system helps to reduce the manual work and water quality monitoring and regulation are accomplished by using a variety of sensors and actuators, as well as microcontrollers and microprocessors throughout the device (Friha *et al.*, 2021).

The term IoT refers to a network of physical items that have sensors, software, and other technologies integrated into them in order to communicate and exchange data with other systems and devices over the internet. It aims to eliminate connectivity issues between systems. One of its key goals is to create a framework for data-driven choices to be made without the need for human intervention (Yanes *et al.*, 2020). With the use of low-cost, easy-to-install sensors and an abundance of useful data, the IoT has significantly increased the possibility of improving agricultural products (Kularbphettong *et al.*, 2019). The components of IoT are devices/sensors, connectivity, a platform and an Interface. IoT platforms can store, analyse and present data to users via a private or public web interface, as well as a mobile application (app). The web interface can be viewed anytime from a smartphone or computer over the internet, which provides a simple and easy-to-use solution (Chowdhury *et al.*, 2021). The development of IoT has allowed agriculturalists to systematize hydroponic culture (Vanipriya *et al.*, 2021). Sensors, microcontrollers and Wi-Fi module were used to automate the system for real time monitoring of the parameters remotely via laptop or mobile terminal. Real-time monitoring of the essential parameters like pH, temperature, ammonia, DO, humidity and alerting its abnormalities can be possible. The users can monitor and control this system from remote distance.

As a part of Integrated Farming System, aquaponics can serve as a boon for farmers to support their livelihood, as crop fails aquaculture will come for support and if aquaculture fails crop can come for the rescue. Additionally, aquaponics addresses water scarcity by reusing the same water for both crops and aquaculture, significantly reducing water usage. The IoT-based automated aquaponics system was chosen for its ability to provide real-time monitoring and control of key parameters remotely, ensuring optimal conditions for both fish and plants. With automated fish feeding and water quality management, the system reduces labour time and human intervention while maintaining the perfect environment for growth. This enhances productivity and ensures the production of fresh, nutritious crops. Additionally, the system requires minimal space and can be easily modified to fit varying area sizes and specific needs, making it a flexible, sustainable, and efficient option for diverse agricultural settings.

By considering all these points, the present study entitled "Development of IoT based automated aquaponics system for water quality monitoring and control" ensure sustainable and efficient food production, this study focuses on the integration of IoT technology into aquaponics systems. The research was guided by specific questions that aimed to explore how an IoT based system can be designed to automate the monitoring and control of key parameters in aquaponics. It also seeks to assess how effectively the system can regulate water quality and water level, both of which are essential for maintaining a balanced environment for plant and fish growth. Furthermore, the study examines the influence of automation on the overall productivity of the system.

Hence, this study was undertaken with the following specific objectives:

1. To design and develop an IoT based automated water monitoring and control system for aquaponics.
2. To evaluate the system based on water quality and water level parameters.
3. To evaluate the system based on growth parameters.