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Aquaculture Resilience: Empowering Food Security through IoT Based People's Farm Robots

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Abstract.
The COVID-19 pandemic starkly revealed the vulnerability of global food systems, prompting a pressing call for sustainable and resilient practices. This conceptual paper forms an integral part of a comprehensive study aimed at investigating the pivotal role of technological and sustainable solutions in surmounting pandemic-induced challenges and attaining vital food security objectives. Specifically, this conceptual paper delves into the possibilities inherent in cloud-based management, robotics, and circular economy principles, focusing on their potential to bolster food security. To this end, the paper proposes the implementation of an 'IoT based Farm robot' to enhance aquaculture resilience in Yogyakarta, Indonesia – an apt locale renowned for its vibrant community and agricultural traditions.
Leveraging cloud technology, the paper explores the remote management and monitoring of fishponds, thereby optimizing resource utilization and elevating overall productivity. Through the integration of robotics, the automation and precision introduced to fish farming processes serve to lessen reliance on manual labor. Furthermore, the incorporation of circular economy principles underpins sustainable practices, minimizing waste and maximizing the efficiency of resources. By harnessing the synergy of cloud-based management, robotics, and circular economy principles, this conceptual paper introduces a solution that empowers local communities to both navigate the current pandemic crisis and foster enduring aquaculture resilience. The discourse presented within this paper holds valuable implications for policymakers, researchers, and practitioners invested in aquaculture and food security. Moreover, it contributes to the wider conversation concerning sustainable food systems, offering a pathway to cultivating a more secure and resilient future for aquaculture in Yogyakarta and beyond, even amidst pandemics and other disruptive occurrences.

Keywords: food security, post pandemic, fishpond, robot, cloud, IoT

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1. Introduction

In recent times, achieving food security has become increasingly challenging worldwide, driving the need for innovative solutions to address these pressing issues. The recent COVID-19 pandemic has further exacerbated the situation, causing an unprecedented global crisis with far-reaching impacts on economic, social, and health aspects. As vulnerable groups, including fishermen and fish workers, face the brunt of the pandemic's secondary effects, such as poverty and hunger, the importance of ensuring food security becomes even more apparent.

The small-scale fishing sector, which plays a crucial role in supplying fresh and locally caught fish, has been severely impacted by the pandemic. Market closures, limited storage facilities, falling wholesale fish prices, and new sanitation requirements and physical distancing measures have created significant challenges for fishermen and fish farmers. As a result, fishing and fish farming activities have been drastically reduced, leading to a decline in the availability of fish for processing and trading. Furthermore, mobility restrictions have hindered the smooth transfer of fish to the market, disrupting the fish supply chain.

Moreover, the frontline employees managing fishponds are facing additional challenges due to the lack of essential equipment and protective clothing to prevent the outbreak of COVID-19. These constraints not only endanger the health and safety of the workers but also hinder the continuity of fish cultivation practices, affecting Indonesia's overall food security, particularly in areas such as Sleman Regency, Yogyakarta Special Region (Zhu, 2010).

In this new normal era, it is imperative to embrace innovation and find sustainable solutions to ensure the resilience of aquaculture practices and maintain Indonesia's food security, especially regarding the supply of fish. This paper aims to propose the potential of cloud-based management, robotics, and circular economy principles to empower local communities in Yogyakarta, Indonesia, to overcome the challenges posed by the pandemic. By leveraging cloud technology, fishponds can be remotely managed and monitored, optimizing resource utilization and enhancing productivity. Integration of robotics brings automation and precision to the fish farming process, reducing dependency on manual labor. Furthermore, incorporating circular economy principles ensures sustainable practices, minimizing waste and maximizing resource efficiency.

1.1. The Case for Sleman Regency, Yogyakarta

Since 2014 the agricultural sector in Sleman Regency absorbed the most labor, reaching 23.56% of the population of 1,062,801 people. The agricultural sector is also the largest contributor of primary GDP in Sleman Regency which is 12.59%, this is supported by the area of agricultural land in Sleman Regency which reaches 22,233 ha, which includes a fishery area of 874.85 ha or 3.9%. The magnitude of potential in the fisheries sector of Sleman Regency can also be seen from the increase in fish seeds produced by 997,881,400 in 2014, so that Sleman is able to contribute 80% of fish seed needs in Yogyakarta special region and 55% for consumption needs in DIY. The high interest of the community in Sleman Regency to participate in the fisheries management group, can be seen from the increase that occurred, recorded to date there are 552 groups. With the increase in fisheries management groups, fisheries production in Sleman Regency also increased.

The Yogyakarta Special Region Marine and Fisheries Office said shrimp farms spread across three districts namely Kulon Progo, Bantul and Gunung Kidul contributed quite a lot to the production of fish. At that time fish production amounted to 3,095.3 tons in the third quarter of 2014 in DIY, shrimp contributed 1,824 tons. With this significant contribution, development of shrimp ponds should be conserved, managed legally and in accordance with the rules of the Regional Spatial Plan (RTRW). The management of fisheries areas with the development of fishery cultivation and the development of fish farmers in Sleman at that time had been done with a group system. Through the system is expected to increase the productivity of red tilapia farmers. The Sleman Regency Government always strives to provide support in the implementation of shrimp fishery development and tilapia fish cultivation. Such as support in the form of budget allocation from the Sleman Regency Government, in addition, budget allocation support is also disbursed by the Central Government through the Directorate General of Aquaculture of the Ministry of Marine Affairs and Fisheries for fisheries Resource Management program, one of which is the Fish Farming Pilot with Padi / Mina Padi and Nila Aquaculture Pilot which is currently implemented. Successful farming groups at the time conducted a Farmer's Field meeting at Pokdapan Mina Murakabi Cibuk Kidul, Margoluwih, Seyegan Subdistrict on August 13, 2015 to see the pilot of tilapia rice mina and fish harvest and wiwit ceremony before rice harvest.

Mina Murakabi Timbul Prasetyo group with an area of 1,000 M^2 of agricultural land is able to produce grain of 8-9 quintal of grain and sprinkled with tilapia seeds of 6.5 kg and produces a tilapia harvest of 5 quintal. In its development to date, the agricultural sector that includes the fisheries sector is still the mainstay sector of the people of Sleman Regency, as a livelihood and source of income from the agricultural sector. In the economic context of Sleman Regency, the GDP is still dominated by the agricultural sector and the source of labor absorption. As an illustration in 2015 the contribution of the agricultural sector to the GDP was 12.6 percent. With the highest economic growth in 2015 which reached 8.26 percent growth in agricultural sector.

At this time the development of land fisheries, especially shrimp and tilapia cultivation, has been carried out in 4 districts, namely Sleman, Kulon Progo, Bantul and Gunung Kidul. The potential area of fisheries development in the regency is in Kalasan, Depok, Cangkringan, Sayegan and Minggir. Sendang Rejo village is one of the villages in Minggir Subdistrict that is a contributor and has a group of shrimp farming and tilapia fisheries. In general, shrimp commodities become export commodities that are of high economic value and shrimp supply is still insufficient market in the Special Region of Yogyakarta. However, the Sleman Regency Government still has difficulty developing shrimp galah in local fish farming groups. This condition occurs because shrimp galah must be imported from samas area of Bantul regency. Local breeders have not been able to produce their own shrimp seeds. This is because shrimp hatchery must use a mixture of seawater and is relatively difficult so that Sleman has not been able to hold it himself.

Cultivation of shrimp galah in Sleman is still done on a limited basis. The amount of production is still unable to meet the needs of local galah shrimp, so that whatever products are produced in Sleman Regency, have not been able to meet the community with the price of shrimp galah at the farmer level reaching Rp70-73 thousand per kilogram. The development of galah shrimp in Sleman is also constrained by various maintenance factors that need careful management, especially the typology of shrimp cultivation galah that requires high oxygen so that water must continue to flow so that it requires a waterwheel, maintained salinity level, controlled water ph, in addition to shrimp feed galah still depends on the factory.

At the same time shrimp entrepreneurs are faced with the choice to run shrimp farming with considerable costs and large business income or run the cultivation of red tilapia which costs less even though the income is smaller when compared to shrimp farming businesses. Especially after the eruption of Mount Merapi in 2010 which impacted the productivity of shrimp cultivation, many farmers turned to the cultivation of red tilapia business.

Some farming groups find strategic innovation in increasing productivity by utilizing waterwheel technology that serves to maintain water quality and provide oxygen supply.

Oxygen supply is certainly needed for the irrigation ecosystem in the crop. As an illustration Figure 1 shows the use of windmills in the cultivation of red tilapia fish.

Figure 1: Use of Waterwheels in The Cultivation of Red Tilapia Fish.

1.2. Technology as a Solution

Related to the above problems today, technology has been very developed and can be communicated with the internet or often called the Internet of Things (IoT). IoT is the latest innovation in monitoring technology because it can be accessed anywhere and anytime through websites and applications on mobile phones. In addition to monitoring, IoT main capability is the connectivity among devices. This obviously makes it easier to users as devices could be calibrated or programmed to performed individual tasks automatically based on given condition contributing to a larger system framework. The utilization of IoT has been utilized in smart homes and industrial automation.

One of the applications in industrial automation is automation in the fishing industry. Special care in shrimp cultivation does not make many things that need to be considered and require automation to be more optimal. In this paper, a farm robot is proposed which is designed to be equipped with water turbidity sensors, pH, dissolved oxygen, dissolved solids, barometric pressure, temperature, and pressure. All the data measured in these sensors will be transmitted over the internet and can be accessed by farmers remotely. In addition to being equipped with sensors, farm robots are made to communicate with other devices such as turbines. The turbine will rotate automatically when the oxygen level in the pond is less than its ideal level. The data measured by the robot will be sent in real *time* and continuously. So that farm farmers can monitor it at any time.

Based on the above exposure, to maintain its production and save many people to stay at home to break the COVID-19 distribution chain, the processing of the fisheries sector in Sleman Regency requires alternative technology to monitor ponds to produce, manage, and explore the potential of fish and help the procurement of quality mothers, and improve quality fishery human resources. Pond robots are expected to facilitate the processing of the fishery sector with all sensors that complement it in order to increase the amount of production can be carried out more efficiently.

2. Literature review

Several papers in the literature review center around how aquatic life (e.g. shrimps) could be impacted due to advances in water quality parameters (Deng, Gao, Gu, Miao, & Li, 2010). and how IoT was used to address the problem. A lot of studies was done on IoT application to deal with aquatic farming issues as IoT has recently reached a basic level with its application to farmers (Israni, Meharkure, & Yelore, 2015; Gondchawar, & Kawitkar, 2016). Previous literature focused on some type of sensors such as pH, DO, or Turbidity (Kayalvizhi, Reddy, Kumar, & Prasanth, 2015; Patil, K., Patil, S., Patil, S., & Patil, V; 2015; Simbeye, & Yang, 2014) to overcome the problem. Nonetheless, optimal fish production is completely subjected to chemical, physical and biological characteristics of water to a significant degree. Thus, effective pool management requires the realization of water quality. Water quality is determined by factors such as Dissolved Oxygen (DO), temperature, turbidity, transparency, watercolor, pH, carbon dioxide, alkalinity, hardness, conductivity, salinity, TDS, combined ammonia, nitrate, nitrite, primary productivity, plankton population, BOD, etc (Bhatnagar & Devi, 2013).

K. Raghu Sita Rama Raju and G. Harish kumar Varma (2017) conducted a study entitled "Knowledge-Based Real Time Monitoring System for Aquaculture Using IoT" which uses several sensors such as Dissolved Oxygen, Temperature, Ammonia, Salt, pH, Nitrate and Carbonate (Raju & Varma, 2017). But maintaining multiple sensors is expensive and exhausting. Then it takes a system that is cost effective and able to determine the overall water quality effectively. This is the point on which this conceptual paper is based upon. To begin with, this paper aimed to exert that not all parameters need to be monitored. Since there are some parameters, whose imbalance causes an imbalance of other parameters and from the quantity of some parameters we can assume the conditions of others. We have taken temperature, pH, conductivity, color of water as our first, second, third and fourth working parameters respectively.

To elaborate further, temperature clearly affects biological and chemical procedures. Biological and chemical response rates double for every 10°C rise in temperature in general. Temperature significantly affects chemical treatments. Fish have poor resistance to sudden temperature changes. Often, rapid changes in temperature as low as 5°C will stress or even slaughter fish (Boyd, 1982). PH, DO, conductivity, salinity etc. directly depend on temperature (Adams, Whitfield, & Van Niekerk, 2020; Bhatnagar & Devi, 2013; Prapti, Mohamed Shariff, Che Man, Ramli, Perumal, & Shariff, 2022; Thu Minh, Tri, Ut, Avtar, Kumar, Dang... & Downes, 2022). So, the temperature should be within the expected range first before checking the other parameters. The general threshold range for temperature is 21°C-33°C (Raju & Varma, 2017) which can be easily maintained. For this reason, we consider temperature to be our first working parameter.

In addition, PH is the ratio of hydrogen ion concentrations and determines whether water is acidic or alkaline in a reaction. Phytoplankton and other marine plant life remove carbon dioxide from water during photosynthesis, so the pH of the body's water increases during the day and drops at night. Waters with low aggregate alkalinity regularly have an estimated pH of 6 to 7.5 before sunrise, but when phytoplankton development is large enough, at night the pH value can rise to 10 or higher significantly (Boyd, 1982). The pH of natural waters is significantly affected by the convergence of carbon dioxide which is an acidic gas (Bhatnagar & Devi, 2013). The change in pH in pond water is largely affected through carbon dioxide and ions aligned with it. PH control is needed to reduce ammonia and H2S poisoning (Prapti, Mohamed Shariff, Che Man, Ramli, Perumal, & Shariff, 2022). We see that pH is directly or indirectly related to many other parameters and controlling them is relatively easier. That's why pH is our second consideration.

Salinity is characterized as the aggregate concentration of electrically charged ions (anions - HCO -, CO-, SO-, Clations; cations - Na+, K+, Ca++, Mg++ and other constituents such as NH+, NO - and PO -). Salinity is an important driving element that influences the density and development of populations of aquatic creatures (Patil, K., Patil, S., Patil, S., & Patil, V., 2015)). In the end, one can rarely measure the concentration of all the ions in water. Conductivity sensors can be used to measure conductivity and estimate salinity estimates and there is a relationship between conductivity and TDS (Raju, & Varma, 2017). The conductivity of water depends on ionic fixation and varieties of dissolved solids. So, it is enough to measure only conductivity rather than measuring TDS and other ions individually. Salinity is our third consideration for this.

The color of the water gives a sign of what turbidity is like. If the color is greenish, it's because of plankton and if it's brown, it's often because of clay (Thu Minh, Tri, Ut, Avtar, Kumar, Dang... & Downes, 2022). If the water is clear, this indicates low biological production - not fertile enough and the fish will not develop properly in it. Muddy water is not good fish farming because fish gills can be blocked by clay particles, and this can lead to death. Concentrated green water indicates excess plankton that serve as food for fish but occur due to the utilization of more than enough compost, dirt, or supplements that sustain rich foods into ponds. Bluish green/greenish brown, green watercolor indicates a good plankton population so useful for fish welfare (Bhatnagar, & Devi, 2013)

Furthermore, DO is one of the most important factors in aquaculture. But we didn't measure this because DO decreases when temperature and salinity increase and increases when temperature and salinity decrease. Again, it also fluctuates in a similar way to the pH level (Bhatnagar & Devi, 2013; Delincé, 2013). So, we can expect that if temperature, pH and conductivity are balanced, DO will also be balanced. Then we can again assume the DO condition in the water from its color as the color of greenish water implies

That there is sufficient DO because enough DO develops phytoplankton that make the water greenish. Acceptable range and desired range are shown from the four parameters in Table 1.

Table 1: Water quality parameters.

No.	Parameters	Acceptable range	The range you want	Border
1	Temperature (°C)	15-35	20-30	<12, >35
2	Ph	7-9.5	6.5-9	<4, >11
3	Conductivity (µS/cm)	30-5,000	60-2,000	
4	Water Color	Pale to light green	Light green to light chocolate	Clear water, Dark green & Chocolate

The proposed system architecture consists of two subsections that are the introduction of required hardware and software technology and a description of architectural functions.

1) Sensor: The analog pH sensor for Arduino (SEN0161) of DFRobot is used to measure the pH of water in this work. This pH sensor is specifically designed for Arduino and has convenient connections and features. A BNC connector is required to connect the sensor with Arduino. The range of this sensor is 0-14 pH. It has an accuracy of $\pm$ 0.1 pH at a standard temperature of 25°C and the operating temperature range is 0-60 °C. Only a few parts of the sensor can be put in water. The reliability of these pH sensors can last for half a year when the water is clean and one month for water with high turbidity (Saha, Rajib & Kabir, 2018).

The EC Analog Meter (Electrical Conductivity) for Arduino (DFR0300) of dfrobot is used to measure EC. This EC sensor also has a built-in simple connection and features and is also specifically aimed at Arduino. A temperature sensor (DS18B20) connected to the terminal sensor adapter adapter's connecting terminal is also required because the EC depends on the temperature and the BNC connector is required to connect the EC sensor with the Arduino. The sensor has an accuracy of <± 10% F.S. and the operating temperature range is 5-40 °C (Saha, Rajib & Kabir, 2018). We also use the Arduino Waterproofed DS18B20 (DFR0198) temperature sensor. It has an accuracy of ± 0.5 °C from -10 °C to + 85 ° C.

One of the advantages of using this sensor was that it only require one pin data communication for several sensors at once. The One Wire Library for Arduino is used to measure temperature with this sensor (Arrahman, 2022). Secondly, since the sensor we use in this work is designed specifically for Arduino, we use Arduino for sensor acquisition. Arduino Uno is a microcontroller board based on the ATmega328P. It has 6 analog input pins and 14 digital input/output pins. The operating voltage is 5V and the recommended input voltage range is 7-12V. Arduino IDE is required to program it. Arduino Uno must be connected to a computer with a USB cable to be programmed through a USB to serial converter. It can communicate data with a computer via a serial port (Arrahman, 2022). The central processing unit of this work is the Raspberry Pi3 which is at the heart of this system. The Raspberry pi3 is a small, low-cost computer board that uses Noobs, the Debian version of the Linux operating system. It has a higher speed and number of processor cores than previous versions of the Raspberry Pi. It was already built-in Wi-Fi and Bluetooth. Raspberry pi can communicate serial data with Arduino because it is a small computer.

All android smartphones with Media Transfer Protocol (MTP) can be used for this purpose. MTP allows media files to be exchanged atomically to and from portable devices. If a Dataplicity Agent is installed on our device (Raspberry pi), it will sharply set up and maintain a secure HTTPS connection with the Dataplicity IoT Router. We can access our Raspberry pi protected by Dataplicity anywhere as it has a decent internet connection (Saha, Rajib & Kabir, 2018). Python programming language, Python Imaging Library (PIL), various Linux commands, HTML, CSS, PHP, MySQL databases, Android applications etc.

2.1. Novelty and Innovation

In this technology solution proposal, the novelty lies on the ease for small farmers to control and monitor their ponds online from home, especially during pandemic crisis such as the recent Covid-19 outbreak. This paper proposed a pond robot which is equipped with water turbidity sensors, pH, dissolved oxygen, dissolved solids, barometric pressure, temperature, and pressure. All the data measured in these sensors can be transmitted over the internet and can be accessed by farmers remotely. In addition to being equipped with sensors, farm robots are made to communicate with other devices such as turbines. The turbine will rotate automatically when the oxygen level in the pond is less than its ideal level. The data measured by the robot will be sent in real time and continuously.

The above invention can facilitate farmers in cultivation and create real efficiency. With alternative technology, farm robots so that the production process, management, procurement of quality parents, and improving quality fishery human resources. Pond robots are expected to facilitate the processing of the fishery sector with all sensors that complement it to increase the amount of production can be carried out more efficiently and increase the supply of the domestic fisheries sector and export supply.

2.2. Methods and Stages of Technological Development

The methods used by the Cloud and internet of things (IoT) are wireless or control automatically without knowing distance. The development of network and Internet technology such as the presence of IPv6, 4G, and Wimax, can help implement the Internet of Things to be more optimal, and allow the distance that can be passed to be further, making it easier for us to control things. Of course, with IoT makes it easier for us to supervise and control anything without limited distance and time *(online monitoring),* therefore with the Internet of Things we can control everything through a device and make it easier to do all activities and make pond and fishery systems smart.

In most countries, fish are farmed in ponds but unfortunately fish farmers are not so aware of the importance of water quality management in fisheries. If they are well guided and know water quality management practices, they can get maximum fish yields in their ponds to a greater extent by applying low input costs and getting high yields from fish yields. The role of various factors such as temperature, transparency, turbidity, watercolor, carbon dioxide, pH, alkalinity, hard ness, ammonia, nitrite, nitrate, primary productivity, biochemical oxygen needs, plankton population etc. cannot be ignored to maintain a healthy aquatic environment and for the production of enough fish food organisms in ponds to increase fish production. Therefore, there is a need to ensure that, these environmental factors are well managed and regulated for good survival and optimal fish growth. The purpose of this chapter is to review and present a concise opinion regarding the optimal level of water quality characteristics required for fish production. Figure 2 shows the IoT scheme on people's farm robots.

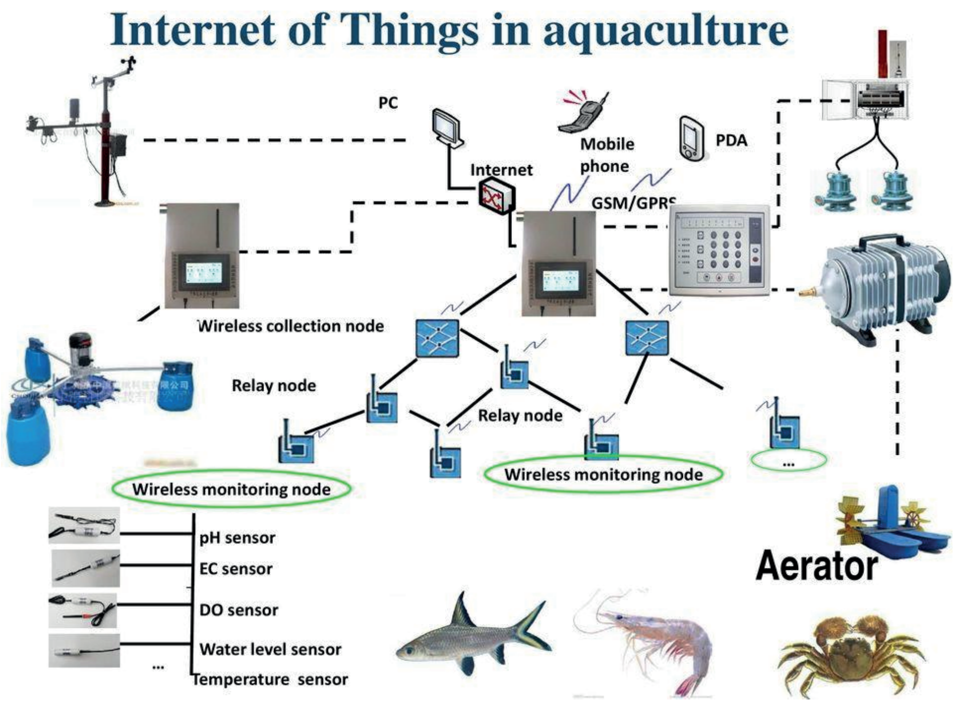

Figure 2: IoT scheme on people's farm robots.

Systematic study could be carried out with IoT-based farm robots. To make existing pond robots smarter by upgrading infrastructure such as the addition of digital sensors, online monitoring, wireless sensor networks, measuring tools, and other smart devices. The sensors used are as follows (Figure 3):

However, the existence of these tools will not necessarily make the system smarter without IoT applications. IoT will facilitate the equipment to interact and exchange data in real time so that the communication pattern becomes two ways (two ways communication) between the fishpond robot and farmers as who oversees the state of the pool based on the data sent by the robot.

3. Conclusion

In conclusion, the management and monitoring of cloud-based people's fishponds and robotics play a crucial role in strengthening food security, especially in the face of the

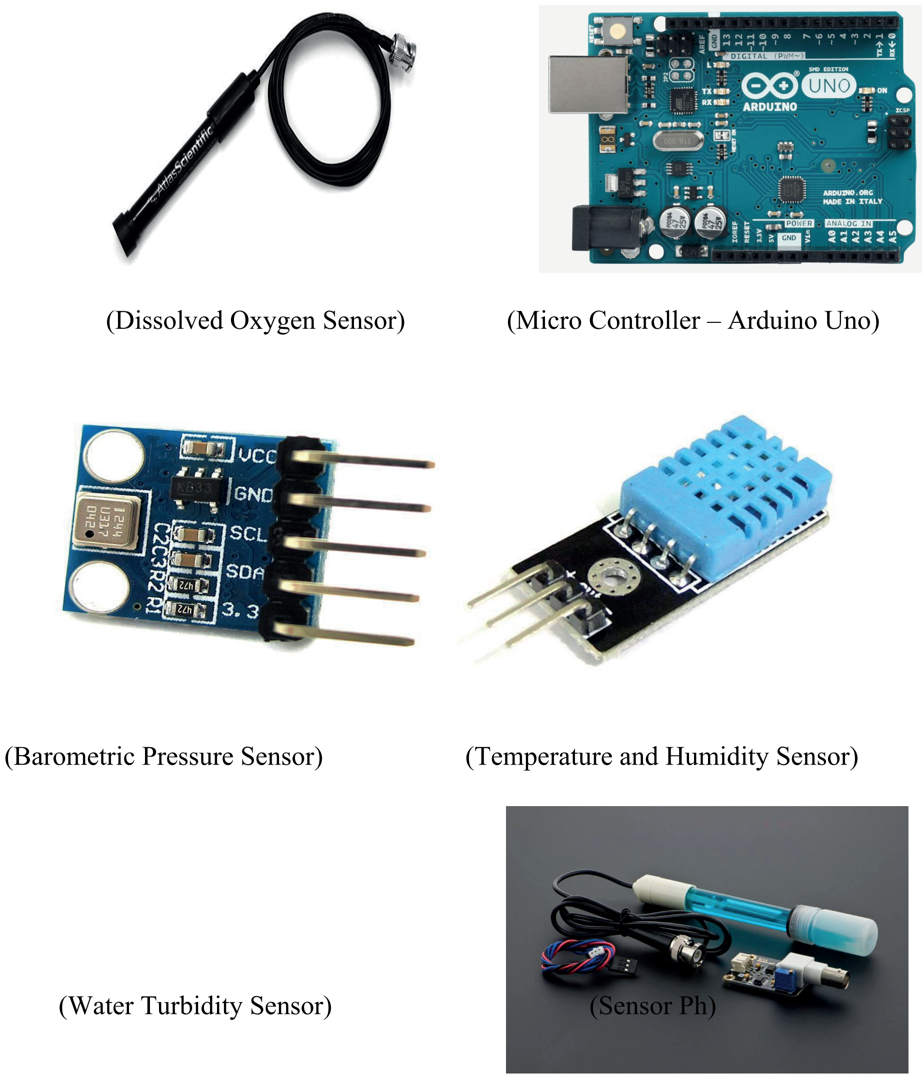

Figure 3: IoT-based farm robots digital sensors.

circular economic crisis. This innovative approach offers numerous benefits, both in terms of sustainability and efficiency. By leveraging cloud technology, fishponds can be remotely controlled, monitored, and optimized, leading to improved productivity and resource utilization. Additionally, the integration of robotics brings automation and precision to the fish farming process, further enhancing productivity and reducing dependency on manual labor. In addition, this proposal contributes to the existing body of knowledge by highlighting the potential of cloud-based management and robotics in addressing food security challenges. The findings emphasize the importance of adopting technology-driven solutions in the context of the circular economic crisis. By showcasing the benefits and opportunities offered by cloud-based people's fishponds and robotics, this technology solution proposal paves the way for future exploration and implementation of similar approaches in other regions and sectors. Furthermore, this technology solution proposal sheds light on the significance of sustainable practices in achieving food security goals. The circular economic framework, with its emphasis on reducing waste, reusing resources, and closing the loop, aligns perfectly with the objectives of food security. By integrating cloud-based management and robotics with circular economic principles, this proposal underscores the potential for achieving a more sustainable and resilient food system.

In short, the insights gained from this conceptual paper demonstrate the transformative power of technology in addressing food security issues. The combination of cloud-based management, robotics, and circular economy principles offers a promising path towards building a more secure and sustainable future for food production and consumption.

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