Indonesian Journal of Electrical Engineering and Computer Science
Vol. 35, No. 3, September 2024, pp. 1426~1436
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v35.i3.pp1426-1436

Monitoring water quality parameters impacted by Indonesia's weather using internet of things

Mohammad Faisal Riftiarrasyid, Benfano Soewito
Department of Computer Science, BINUS Graduate Program, Master of Computer Science, Bina Nusantara University, Jakarta, Indonesia

Article Info

Article history:

Received Feb 7, 2024
Revised Apr 17, 2024
Accepted May 6, 2024

Keywords:

Aquaculture
Fish growth
Internet of things
Nile tilapia
Water quality parameter
Weather

ABSTRACT

Increasing need for food resources, State of Indonesia to strive to maximize the output of food production. Not only in agriculture but also aquaculture results are also trying to be improved. This is also supported by the increase of Indonesia's national fish consumption rate from 50.69 Kg per capita in 2018 to 55.37 Kg per capita in 2021. Recent aquaculture research only explored topics about monitoring the cultivation environment. But there have been no studies exploring how bad the impact of weather on the process of farming. Hence, this study aims to measure the influence of weather on freshwater aquaculture pond water quality and analyze its impact on fish growth namely *Oreochromis Sp*., using pH sensors and dissolved oxygen (DO). Then a weather simulation was carried out based on Indonesia's tropical climate, which majorly consists of sunny and rainy weather. The experimental results indicate the instability of the pH value during the rainy period. DO values tend to decrease at the end of periods of sunny weather. Moreover, fish growth analysis showed that there was a decrease in food conversion ratio (FCR) by 0.956, specific growth rate (SGR) by 2.13% and survival rate (SR) by 5.715% during rainy weather.

Corresponding Author:

Mohammad Faisal Riftiarrasyid
Department of Computer Science, BINUS Graduate Program, Master of Computer Science
Bina Nusantara University
Jakarta, Indonesia
Email: mohammad.riftiarrasyid@binus.ac.id

1. INTRODUCTION

Indonesia's population has increased in recent years. In 2023, the central statistics agency recorded a population of 278 million people. With such a large population, Indonesia faces the challenge of maintaining food availability for its entire population. With the potential of abundant natural resources, strive to utilize these resources to produce rice, crops, and other crops. But Indonesia's greatest potential lies in marine natural resources, with biodiversity of fish and other living things that can be used as a source of food. Indonesian people also like to consume fish, this is evidenced by the increase in the national fish consumption rate from 50.69 kg per capita in 2018 to 55.37 kg per capita in 2021. The increase can also be evidence that the demand for fish in Indonesia will increase every year. But unfortunately, these needs are not balanced with the current level of fish production and processing capacity [1]. To address this situation, research found that there are many factors which may impact fish production output [2]. Therefore, there is a need to determine which factors which impact the fish production sector in Indonesia.

Various studies have attempted to automate the process of fish farming [3]–[7] and examine factors which play a significant role in the growth and development of fish [2], [8], [9]. Automation of fish farming processes is useful to replace work processes that can be replaced with machines such as providing feed [10]-[12], monitor water quality [5], [13]–[15], some studies even suggest adding water quality control mechanisms [3], [7], [10], [16], [17]. Uniquely, most information technologies developed to optimize or automate the cultivation process use internet of things (IoT) technology [10], [11], [18], [19]. To take it even further some studies integrate deep learning into the systems so it can make decisions based on previously collected data [6], [10]. To measure differences between water quality parameters, this research needs to monitor water quality parameters in real time. Main water quality parameters which commonly observed in research are pH [2], [6], [7], [13], [17], [20] and dissolved oxygen (DO) [2], [7], [17], [21]. Both pH and DO parameters hold a critical role in the level of survivability [13], and growth of fish [2], [21] which greatly determines fish yield of aquaculture. So, it is in the best interest to monitor both of those parameters. Unfortunately, research in the field of aquaculture focuses more on water quality monitors based on the IoT [22]. This is not enough because there are other factors that need to be analyzed, even the influence of the amount of feed is also a crucial insight to be examined [13]. What's more, the cultivation process in the field has another factor worth considering, namely the weather. Because the weather in aquaculture has an influence on increases the likelihood of contracting a disease which affects health of growth and every being who lives inside it [23]. However, there have been no studies exploring how bad the impact of weather on the process of cultivating freshwater fish other than freshwater shrimp. And based on that insight, the main topic for this research is to measure differences in water quality parameters which are affected by weather. Furthermore, this research will provide fish growth data to give more perspective into the changes in water quality which impacted aquaculture fish yield and compare it to relevant studies which brought the best results which is [21].

Based on previous research, to observe water quality parameters, the system will need the correct sensors to measure its intended parameter. pH is measured using pH meter, specifically SEN0161 or pH4502C [6], [13]. In the other case, DO is measured using SEN0237 [17]. But on the other hand, to determine if the measured value from the sensors is tuned according to suitable environment for tilapia, Research suggests maintaining pH values in the range of 6.4-8.2, and DO values above 5 mg/L [2]. Majority of all studies with monitoring water quality topics utilize microcontrollers like Node MCU or microprocessor such as Raspberry Pi [4], [12]. Microprocessor Raspberry Pi is utilized when the system needs to handle complex algorithms or processes like machine learning. But for less complex processes such as reading data from sensors and control actuators it is more optimal to use microcontrollers. In addition to water quality parameters, fish growth and development can also be analyzed as a benchmark for the success of a cultivation process. This growth and development can be measured using the weight of fish biomass in the pond. However, there are other metrics to measure the rate of fish growth and development in more detailed manner [2], [21]. There are three metrics employed to analyze fish yield and growth, namely: food conversion ratio (FCR), specific growth rate (SGR), and survival rate (SR). To further justify the results of aquaculture, it could provide clarity in regards of weather's impact on aquaculture.

There are studies that have similar topics, in search of the influence of weather in aquaculture. The information found suggests that weather can even influence the behavior patterns of fish [24]. Moreover, several studies indicate the influence of weather on water quality parameters [25]. Moreover, other studies shows that weather and climate change impact fish behavior such as *Orechromis niloticus* [24]. However, details about changes in water quality parameters, and its impact on fish growth have not been explored further. Hence, this study aims to measure the influence of weather on freshwater aquaculture pond water quality, analyze its impact on fish growth, and determine which weather favors the most optimal fish growth. To do it, this research is comprised of three main focuses, design an IoTs system to monitor fishpond's water quality, record water quality parameters influenced by Indonesian weather, analyze fish growth inside the pond which is being monitored by the IoTs. Water quality parameter record can be visualized so the fluctuations in pH and DO values each day. It is possible to use that information to determine which type of weather is negatively impacting the pond's water quality. Furthermore, fish growth data can be used to determine which weather conditions are optimal for fish growth.

To provide perspective, this study will conduct trials on freshwater fish species, namely nile tilapia (*Oreochromis sp*.) in seeding growth stage, with a fish length of 3-5 cm and stocking density of 200 fish/m^3. This is because tilapia has an important role for the food needs for Indonesian with production in 2020 reaching 41,767.25-tons based on the 2020 fisheries company statistics. Moreover, there is a lot of research on water quality parameter standards that can support the growth of tilapia [2]. These quality parameters can be a baseline to consider the influence of weather on the water quality parameters of aquaculture ponds. The fish will be observed in an artificial pond made of tarpaulin that has been installed sensors and actuators of the IoT system. This study will only examine the influence of weather in the context of Indonesia's tropical climate, which is dominated by rainy and sunny weather, so the weather which is being tested to the pond is rainy and sunny.

This study is organized as follows: section 2 specifies proposed model and research methods. In section 3 presents and analyzes the results of research based on the proposed method. And section 4 distils insights and information from presented results.

2. METHOD

This section describes the proposed IoT model, how weather simulation will be conducted, and which methods utilized to evaluate the results of this research. The proposed IoT model contains narrative description of the circuit schematics, including considerations of what components to use. Weather simulations section will describe each step of how to simulate weathers based on Indonesia's climate. Lastly, evaluation methods will describe each method which is being utilized to analyze and evaluate collected data.

2.1. IoT system design

The proposed IoT model consists of two microcontrollers, two sensors, and two actuators. The two microcontrollers used are Arduino UNO and ESP8266/Node MCU. This is due to the need for analog pins to be able to read data from pH sensors and DO which needs two analog pins. In addition, to be able to store data on the internet, microcontrollers need Wi-Fi modules and flash memory large enough to store internet connection configuration program code. Both are difficult to find in a single microcontroller product, even study done by Tolentino *et al.* [7] requires a microprocessor, namely Raspberry Pi, so that the Arduino Mega microcontroller circuit can send data received from sensors to the internet. Microprocessors have great computing capabilities, but it requires a lot of power to work, so it is very wasteful to use the microprocessor only as a connecting component of the internet. There is another solution to overcome this, which is to use a combination of Arduino UNO and ESP8266/Node MCU. Microcontroller ESP8266 is equipped with a Wi-Fi module and has enough flash memory to be able to store internet connection configurations [15], unfortunately ESP8266 only has 1 analog pin. While Arduino UNO does not have a Wi-Fi module but has 5 analog pins. The 5-pin analog Arduino UNO is very suitable to be a tool that holds data obtained from pH sensors and DO, and ESP88266 will be the main component to upload sensor captured data onto the internet.

Arduino UNO will be connected to two main parts, the first is the sensor part containing the pH sensor and DO, and the second is the actuator part containing solenoid pump which control dolomite solution and relay which connected to the aeration pump. These two parts are interrelated because they function with each other to maintain the balance of water quality in the cultivation pond. Those sensors read the state of the environment and the actuator normalizes the state of the environment when there is a change. The entire schematic of the electronic circuit of the IoT can be seen in Figure 1.

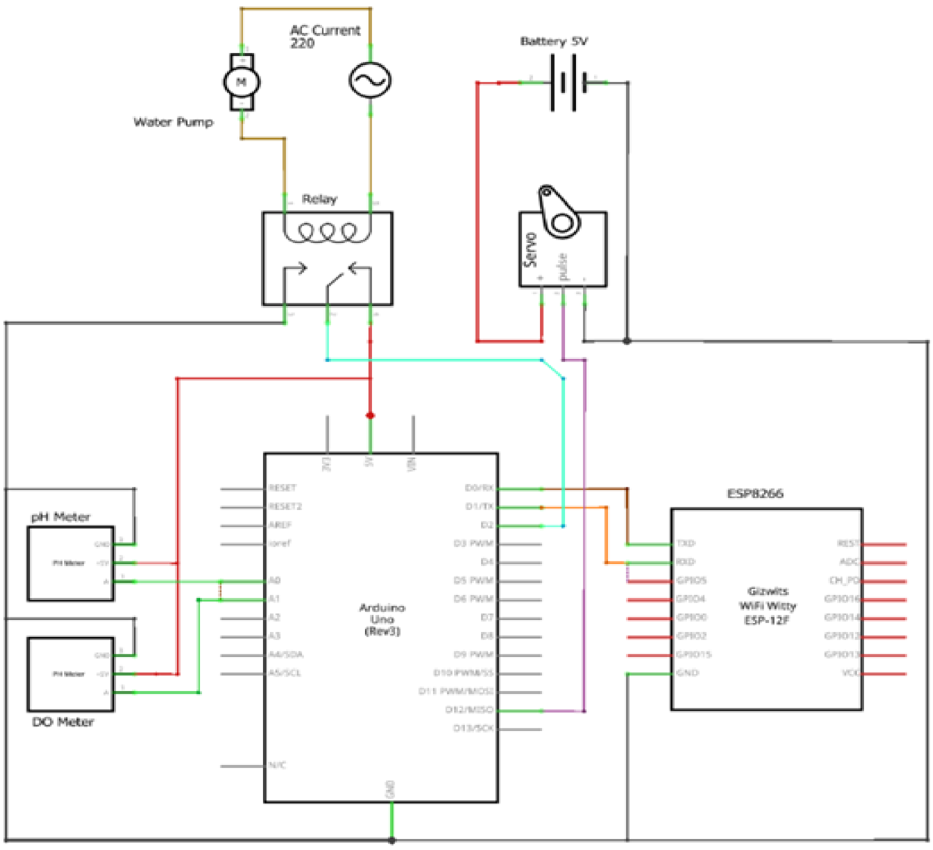
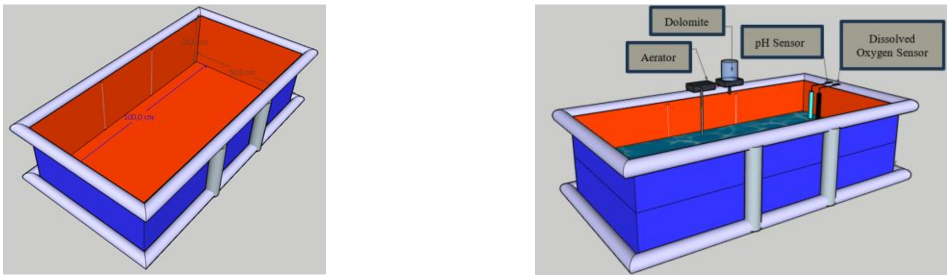


Figure 1. Electronical circuit schematic

The pool will be built using tarp material because the tarp is considered durable and waterproof. But unfortunately, this material is not sturdy so it must be supported by a fairly strong frame, such as the frame of a PVC pipe. The design of the frame arrangement of polyvinyl chloride (PVC) pipes so that they can support tarpaulin pools can be seen in the Figure 2. Figures 2(a) aquaculture pond size, and 2(b) sensor and actuator layout position. The pipe was chosen as the frame material because it is easy to assemble, and removed again and remains sturdy even though it bears heavy loads.



(a) (b)

Figure 2. Aquaculture pond design and layout (a) aquaculture pond size and (b) sensor and actuator layout position

Further observation on Figure 2 presents detailed specifications of the pond design. Figure 2(a) presents the size of the observation pond. It will have a length of 100 cm, a width of 50 cm, and a height of 25 cm so that the total volume of water that can be accommodated by the artificial pond is 125,000 cm^3 or 125 liters. But for this study the pond will only be filled with four-fifths of the total capacity, which is 100 liters, this is based on 2 reasons. The first is to leave enough space for rainwater entry so that the influence of incoming rainwater on water quality parameters can be observed. Figure 2(b) presents the configuration of the sensor and actuator location will be adjusted to the direction of use of each. The pH and DO sensors will be placed close to the surface of the water. But the sensor tip or probe part of both sensors, as shown in Figure 3, must be submerged with water in the observation pool. In the actuator section, a dolomite ($CaMg(CO_3)_2$) solution solenoid pump will be placed above the water surface so that the dolomite solution can flow into the pond.

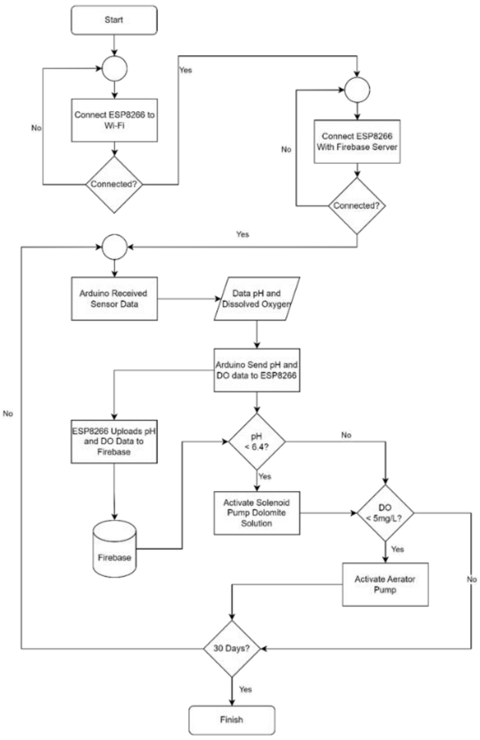


Figure 3. System workflow

The overall working process of the system is illustrated in Figure 3. pH and DO parameters were chosen based on research conducted by Mengistu *et al.* [2] concluded that the water quality parameters that have the greatest influence and correlation to fish growth, especially tilapia. Moreover, other water quality parameters were often employed to determine pollution [26], it will not be utilized because it is not compatible with this study purposes. In order to keep pH and DO stable, it is necessary to control the two water quality parameters by adding actuators that can increase or decrease the parameter values. Based on research Jubaedah *et al.* [20], the pH value can be lowered by using lime such as calcite ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$) solutions, while the DO value can be increased by using an aeration pump.

2.2. Sunny and rainy weather simulation

This study conducted data collection using two scenarios. Both scenarios are based on test conditions, namely rain and sunny. This is based on Indonesia's climate which includes a tropical climate, so it only has two seasons, namely the rainy season and the dry season. Based on data from the Indonesian Meteorology, Climatology, and Geophysics Agency (BMKG), the rainy season is dominated by rainy weather, while the dry season is dominated by sunny weather. So, it can be assumed that these two weathers have major influence on natural conditions in Indonesia.

The rain scenario is based on the publication of the Indonesia's central statistics agency on the number of rainfall and number of rainy days at the BMKG observation station, 2011-2015. Rainy days are the number of days of rain in a certain time, and quoting from the BMKG page, rainfall is a unit of the amount of rainwater that falls per one square meter. It was noted that the average number of rainy days in 2015 amounted to 144 days per year, 12 days per-month, so it can be assumed that there were 4 rainy days per week. For the average rainfall in 2015 has a value of 1871 ≈ mm per-year 156 mm per month so it can be assumed in one has rainfall of 5.20 mm or (0.52 cm×100 cm×100 cm) 5.2 liters of water. The number of days and rainfall serves to estimate the amount and rainfall in a period of one week. Because of the theoretical basis, this study will simulate rain on an observation pond with a frequency of rain 4 days a week and every rainy day will be added 5.2 liters of water using a sprinkler so that it is similar to rain conditions. The pond will be placed in an open space but will simulate rain with a frequency of 4 rainy days in a period of 7 days and every rainy day will be added 5.2 liters of water using a sprinkler. Even if there is natural rain during the observation period, the simulation will still be run by moving the simulation of a rainy day to the next day with the same amount of rainfall. Natural rain periods that occur during the observation period will be recorded and will be analyzed as additional data.

To achieve similar rainwater composition, the first is to prepare water with a composition resembling rainwater, and the second is the method of simulating the splashing of rainwater. In Hasan *et al.* [27] it is stated that the highest average content of material in rainwater or precipitation weight mean (PWM) is sulfate content with a range of 41.91 μEq/L to 79.71 μEq/L, then followed by ammonium with a PWM range of 30.21 μEq/L to 33.98 μEq/L. PWM in this case is a unit of weight that calculates the influence of gravity and molecular density of a solution, this quantity has a unit of milliequivalent/liter (mEq/L). So, it can be calculated that the two acid contents are SO_4 (sulfate) respectively has a content range between 2.01 mg/L to 3.82 mg/L; and NH_4 (ammonium) has a content range between 0.54 mg/L to 0.61 mg/L. To be able to achieve conditions that resemble the rainwater content, Letardi *et al.* [28], use a substance $(NH_4)_2SO_4$ (ammonium sulfate) with a density of 1.50 mg/L. So that for one rain simulation with rainfall of 5.4 liters, 8.1 mg or 0.0081 grams of ammonium sulfate are needed.

The sunny scenario will be done by exposing the pool to direct sunlight. The observation pool will be placed in an open space so that the pool is exposed to outdoor air temperature and direct sunlight. The location of the sunny scenario will be carried out in West Jakarta which based on Indonesia's BMKG has air temperatures in the range of 20.1°C-28.6°C with an average temperature of 27.8. During the observation period, rain will not be simulated or add clean water to the pool, so for 15 days it will simulate sunny weather by exposing the pool water to outside air temperature and direct day sunlight. If there is natural rain, the pool will be covered with a tarp so that water will not enter the pool.

The total observation time for both rainy and sunny weather is 30 days. So, each scenario will be implemented for 15 days. One scenario has 3 stages, namely:

- Preparatory stages. At this stage, the observation pool will be prepared to reach ideal conditions first, namely pH between the range of 6.4-8.2 and DO > 5 mg/L. Then measure the number of fish and their weight at the beginning of the observation period. This aims to get a control value so that the changes that occur in the observation period can be compared with the conditions at the beginning of the observation.
- Stages of observation. At this stage, the pool will be observed for seven days per observation scenario. Data from pH and DO sensors will be recorded every single minute a day; The data is then stored into the firebase over an internet connection. At this stage, rain simulations will also be carried out when the rain

scenario is running. The rain simulation will be conducted once a day with the simulation time being carried out at 12:00. This aims to make it easier to compare weather scenarios.

– Stages of analysis. At this stage, the number and weight of fish will be measured first, then the sensor data that has been obtained from the observation stage will be analyzed by comparing it with the ideal conditions at the beginning of observation. After one scenario has been lived for up to 15 days, it will proceed to the next scenario. Furthermore, when both scenarios have been completed, the FCR, SGR, and SR of the fish will be calculated based on the weight data and the number of fish that are still alive.

The data recorded in the observation period are fish weight data at the beginning of the observation period, fish weight data at the end of the observation period, number of fish at the beginning of the observation period, number of fish at the end of the observation period, total amount of feed weight that has been given at the end of the observation period, pH value, DO value, rain simulation time begins, rain simulation time is completed, and if there is natural rain, the data of the natural rain time from start to finish will be recorded as well. pH and DO value will be stored in the firebase database via ESP8266, so that in later stages can be easily visualized and analyzed. pH and DO data will be collected and cleaned first to make it easier to observe. Only then, the data will be visualized using Tableau. Tableau transforms the data into graphs so that patterns of pH and DO value fluctuations can be seen. Then, data such as fish weight, fish count, and feed weight will be utilized to measure fish growth and determine which weather has negative impact on it.

2.3. Fish weights data analysis

In addition to analyzing the influence of weather on water quality parameters, the data that has been collected will then be observed and analyzed to see if the impact of weather also affects the growth and development of fish in the pond. There are three multiple analytical methods that can measure fish growth and development [29], namely FCR, SR, SGR, nitrogen retention, protein efficiency ratio (PER), and much more. Nevertheless, the methodologies utilized in this study are the FCR, SGR, and SR since the study compares the effectiveness and efficiency of fish growth. Additionally, this approach is frequently employed in research of a similar nature [21].

$$FCR = \frac{F}{\Delta W} \tag{1}$$

FCR is a method to measure how much feed a fish needs to grow per gram, the calculation of FCR can be seen in (1). FCR is calculated by dividing the amount of feed given during the observation period (F) by the difference between the weight of the fish at the end and beginning of the observation period (ΔW). The value of the FCR has a range starting from the best which is close to 0 then gets worse the larger it gets.

$$SGR = \frac{(\ln W_{end} - \ln W_{start})}{t} \times 100\% \tag{2}$$

SGR is a method to measure the presentation of fish growth per day during the observation period, the calculation of SGR can be seen in (2). SGR is obtained by calculating the difference between the natural logarithm of fish weights at the end of the observation period (ln Wakhir) with the results of the natural logarithm of fish weights at the beginning of the observation period (ln Wawal). The result of the reduction is then divided by the number of days of observation made (t) after which it is multiplied by 100%. The SGR value has a range starting from the worst 0 to reach 100%.

$$SR = \frac{N_{end}}{N_{start}} \times 100\% \tag{3}$$

SR is a method to measure fish mortality during the observation period, the calculation of SR can be seen in (3). SR is obtained by dividing the number of fish that survived at the end of the observation period (N_{end}) by the number of fish at the beginning of observation (N_{start}) then multiplying it by 100%. The SR value ranges from the worst 0 to close to 100%. After the FCR, SGR, and SR values have been obtained. It will be compared with the benchmark journal published by Wang *et al.* [21], which has a FCR value of 1.04, specific GR of 1.4%, and SR of 100%. Only then will it be considered that the proposed method is better than the existing method.

3. RESULTS AND DISCUSSION

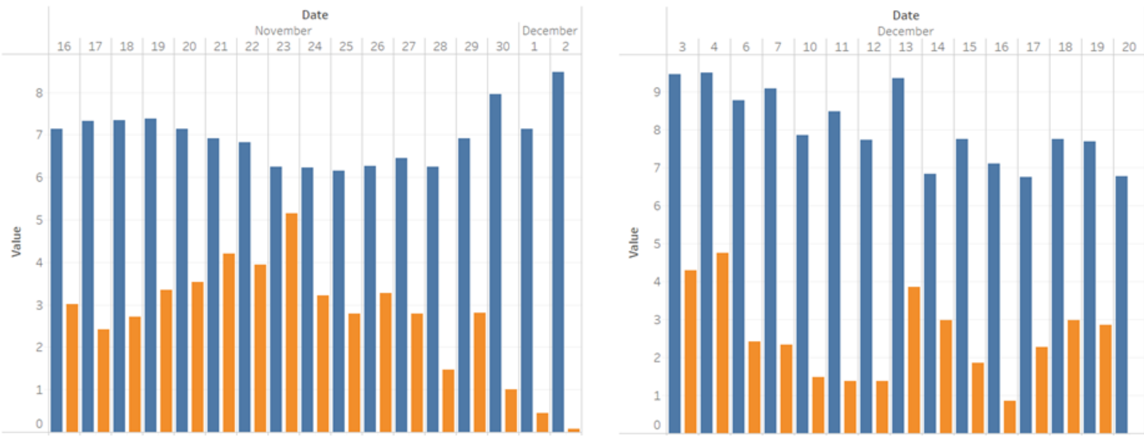
Experiment will be conducted using design which is described in section 2. Figure 4 demonstrate the application of the design which is previously shown in Figure 2, Figure 4(a) shows the applied fishpond design and Figure 4(b) shows the applied IoT system which monitor the fishpond. System will collect pH and

DO value then store it to firebase to be analyzed further. Data analysis will be divided into two, which is: Water quality parameters data analysis, and fish growth analysis. Water quality parameter data will details the weather influece on culctivation environment, and fish growth data will show weather influence on cultivation process. These two analyses will answer the formulation of this research problem regarding the influence of Indonesian weather on water quality parameters and fish growth and development. Analysis of ph and DO data was carried out using the Tableau application to produce graphics that display the movement patterns of pH and DO values during the observation period.

(a) (b)

Figure 4. Applied experiment setup (a) fishpond and (b) IoT system

Comparison of recorded pH and DO values during observation period of both sunny and rainy weather simulations can be seen in Figure 5. The first experiment was to test the pool with simulated sunny weather. This simulation is carried out for 15 days starting from November 16th, 2023, to December 2nd, 2023. Water quality parameter data in the form of pH and DO record in firebase is shown in Figure 5(a). On it, there is some information that can be drawn. First, the pH value reached its peak of 8.372 on December 2nd and its lowest of 6.158 on November 25th; on the other hand, DO had the highest value of 5,151 mg/L on November 23rd and a lowest value of 0.077 mg/L on December 2nd. The second experiment was to test the pond with simulated rainy weather. This simulation is carried out for 15 days starting from December 3rd, 2023, to December 20th, 2023. Figure 5(b) shows the fluctuation of water quality parameter values from rain simulations. The recorded water quality parameter data in the form of pH and DO can be described as follows: the average daily pH had the highest value of 9,507 on December 4th and a lowest value of 6,756 on December 17th; while DO values had the highest value of 4,761 mg/L on December 4th and a lowest value of 0.863 mg/L on December 16th.



(a) (b)

Figure 5. Recorded pH (blue) and DO (orange) in diferent weather (a) sunny weather and (b) rainy weather

Table 1 presents fish growth data during both observation period. Fish growth observed in sunny weather with the following details: The weight of fish biomass at the beginning of the observation period was 719 grams, and the weight of fish biomass at the end of the observation period was 1,165 grams. The number of fish at the beginning of the observation period was 35 fish and the number of fish at the end of the observation period was 35 fish. The amount of feed weight given during the observation period was 330 grams. Fish growth data observed in rainy weather simulation was recorded with the following details: the weight of fish biomass at the beginning of the observation period was 1,165 grams, and the weight of fish biomass at the end of the observation period was 1,293 grams. The number of fish at the beginning of the observation period was 35 fish, but the number of fish at the end of the observation period decreased to 33 fish. The amount of feed weight given during the observation period was 330 grams. Comparison between sunny and rainy weather fish growth shows a significant difference in fish growth. Even though given the same amount of food, fish in sunny weather grow 446 grams and all fish survive until the end of the observation period. However, fish in rainy weather only grow 128 grams and 2 fish died. These results provide evidence that sunny weather promotes fish growth than rainy weather.

Table 1. Fish counts, fish weights, and given food weights observations results

Observation	Starting weight (grams)	End weight (grams)	Starting fish counts	End fish counts	Feed given (grams)
Sunny	719	1,165	35	35	330
Rainy	1,165	1,293	35	33	330

Based on the results of fish growth analysis, results can be displayed into a table that can be seen in Table 2. In these results, there are differences in the results of analysis from observations of sunny and rainy weather. The results of the FCR analysis of sunny weather are superior with a yield difference of 0.956 from rainy weather, this shows that sunny weather is more supportive of fish to change feed into fish weight optimally. This decrease in FCR levels is also associated with an increase in pH values [2]. The results of the SGR analysis also showed that the observation of sunny weather was superior to rainy weather with a difference in value of 2.13%, this shows that fish can grow faster every day in sunny weather than rainy weather. Moreover, the SR analysis shows that the sunny weather is superior with a 100% SR which means that fish can survive all while in rainy weather the SR only reaches a value of 94.285%, this shows that the sunny weather is more likely for fish to survive than in rainy weather and could represents the best result of this research.

Table 2. Comparison of sunny and rainy weather fish growth analysis

Description	FCR	SGR	SR
Sunny weather	0,74	3,217%	100%
Rainy weather	1,696	1,087%	94,285%

Previous study indicates that weather influence water quality parameters [23], [25], but no further details on how bad the impact on water quality and which weather is best suited for fish cultivation had been mentioned. To prove it, with simulated weather experiments are done and analyzed based on the proposed model in section 2. Based on the movement pattern of pH values on the Figure 5(a) shows that there is a decrease in pH value at the beginning to middle of the observation period, then followed by an increase in pH levels until the end of the observation period. On the other hand, the value of DO is seen to experience a pattern of increasing DO from begining into the half of the observation period. Then followed by a decline in value to the end of observation period. So that information can be drawn that the movement of pH values and DO in sunny weather is normal to happen in the cultivation environment studied. Figure 5(b) shows the change in pH and DO values during the rainy weather observation period. Both pH and DO parameters value fluctuates daily. Fluctuation in pH values in rainy weather experiments show instability of environmental conditions in the water. Moreover, the highest average daily pH value was at 9,507 and the lowest at 6,756. The pH value far exceeds the reasonable limit of tilapia aquaculture water quality, which is 6.4-8.2 with a difference of 1,307. An excessively high pH level may be detrimental to fish survival. Different results were obtained from sunny weather experiments, the highest average pH value was at 8,372 and the lowest value was 6,158. The range of values has a difference of 0.172 higher and 0.242 lower than the reasonable limit of tilapia aquaculture water quality, sunny weather's pH level doesn't fluctuate too much to significantly affect fish growth [2]. From collected pH and DO values from both sunny and rainy weather experiments, it can be concluded that sunny weather is more able to support the optimal growth of nile tilapia.

There are observable pH patterns which indicate a trend that tends to move downward. Downward movement of the DO value can occur due to rainy weather causing the probe's membrane of the DO sensor to often be covered by dirt or other deposits inside the pool. When rain occurs, the dirt deposits at the bottom of the pool will rise again and cause the pool to become cloudy. After some time, the dirt will settle back to the bottom of the pool, but some will stick to the tip of the DO and pH sensor probe. The dirt will block the process of exchanging oxygen that enters the sensor through the membrane probe, thereby reducing the performance of the DO sensor. Therefore, it is necessary to clean the sensor probe regularly if the probe is required to record data continuously. However, the impact of these dirt deposits on the performance of the pH sensor does not greatly change the performance of the sensor, but it should be noted that the pH sensor probe will read the environmental conditions adjacent to the sensor probe, so ideally the pH sensor probe also needs to be cleaned regularly.

When compared to other studies with similar fish weight analysis methods, the proposed system supports fish weight growth better than existing studies, this can be seen in Table 3. The data analysis of the model proposed by this research resulted in a better FCR with a difference of 0.65 from Wang et al.; the SGR of this study also resulted in better scores with a difference of 0.597% from Wang *et al.* [21]; and the SR of this study also produced better value with 100% survivability.

This study aims to measure the influence of weather on freshwater aquaculture pond water quality, analyze its impact on fish growth, and determine which weather favors the most optimal fish growth. Findings will provide insight into the best season to cultivate in order to maximize the growth and development of the fish. Based on research findings, results show that sunny weather is more suitable in fish cultivation due to more stable pH and did not overly exceed the safe limits of the parameters proposed by previous studies. Moreover, results on fish growth analysis showed significant body development, food efficiency, and survivability in sunny conditions.

Table 3. Comparison of studies with fish growth analysis

Model	FCR	SGR	SR
Proposed model	0.74	3.217%	100%
Wang *et al*. [21]	1.39	2.62%	95.73%

4. CONCLUSION

This study examines the issue of how far the impact of weather affects water quality parameters in freshwater fish farming environments using the IoT approach. This research will use the basis of weather in tropical climates, which have only two weathers: sunny and rainy weathers. The water quality parameters studied are pH and DO, to read the two water quality parameters, a pH sensor and DO are used, while to control these parameters, a solenoid pump actuator and aerator are used. Moreover, previous research also focused on the growth and development of farmed fish, therefore FCR, SGR, and SR analysis were also used. The three methods of fish growth and development analysis are used to see if there are differences in fish growth and development in different weather.

The results of this study show that there is a trend pattern of movement of pH and DO values in sunny weather is more stable than during rainy weather caused by the content of substances in rainwater. pH in sunny weather is more likely to rise which means it is alkaline while pH in rainy weather is more likely to drop which means it is more acidic over time. DO in sunny and rainy weather has a tendency to fall, this is caused by deposits covering the membrane of the DO sensor probe which causes sensor performance to decrease, which can also be underlined is that this tends to occur faster during rainy weather. Fish growth and development are much better during sunny weather, this can be proven by the difference in results of the sunny and rainy weather FCR by 0.956, SGR by 2.13%, and SR by 5.715% during rainy weather. Based on the results of the best analysis, sunny weather showed better results when compared to previous studies. Namely having a difference of 0.65 from the best FCR score; 0.597% from the best SGR; produce better value from the best SR value with 100% survivability. These findings should make it easier to determine which weather has the best conditions for growing fish, thereby increasing fish production. With the limitations of this study, many topics can be explored further. The author suggests research at different stages of fish growth. Other research can also be done by focusing the sensor installation position on larger pond media and with different shapes. Another focus that can be considered is to increase the number of observation days that can be done on the pool. Moreover, research on the impact of weather can be explored further using other climate bases such as: sub-tropical climate. dry climate, or even cold climate.

ACKNOWLEDGEMENTS

Author would like to express gratitude to his Family for its emotional support and Bina Nusantara University for its support towards completion of this research.

REFERENCES

[1] I. M. A. Nugraha, I. G. M. N. Desnanjaya, J. S. M. Siregar, and L. I. Boikh, "The potential of residual processing of indonesian marine and coastal areas as biogas energy," in *Proceedings of the International Conference on Tropical Agrifood, Feed and Fuel (ICTAFF 2021)*, 2022. doi: 10.2991/absr.k.220102.039.

[2] S. B. Mengistu, H. A. Mulder, J. A. H. Benzie, and H. Komen, "A systematic literature review of the major factors causing yield gap by affecting growth, feed conversion ratio and survival in Nile tilapia (*Oreochromis niloticus*)," *Reviews in Aquaculture*, vol. 12, no. 2, pp. 524–541, May 2020, doi: 10.1111/raq.12331.

[3] A. I. Arafat, T. Akter, M. F. Ahammed, M. Y. Ali, and A.-A. Nahid, "A dataset for internet of things based fish farm monitoring and notification system," *Data in Brief*, vol. 33, p. 106457, Dec. 2020, doi: 10.1016/j.dib.2020.106457.

[4] L. K. S. Tolentino *et al.*, "Weight prediction system for Nile Tilapia using image processing and predictive analysis," *International Journal of Advanced Computer Science and Applications*, vol. 11, no. 8, pp. 399–406, 2020, doi: 10.14569/IJACSA.2020.0110851.

[5] M. Amin, A. Ma'arif, and I. Suwarno, "Monitoring tools of water temperature and ph in fresh water fish pool based on the internet of things (IoT)," *Signal and Image Processing Letters*, vol. 4, no. 3, pp. 29–35, 2022.

[6] C. S. Arvind, R. Jyothi, K. Kaushal, G. Girish, R. Saurav, and G. Chetankumar, "Edge computing based smart aquaponics monitoring system using deep learning in IoT environment," in *2020 IEEE Symposium Series on Computational Intelligence (SSCI)*, IEEE, Dec. 2020, pp. 1485–1491. doi: 10.1109/SSCI47803.2020.9308395.

[7] L. K. S. Tolentino *et al.*, "Development of an IoT-based intensive aquaculture monitoring system with automatic water correction," *International Journal of Computing and Digital Systems*, vol. 10, no. 1, pp. 1355–1365, Dec. 2021, doi: 10.12785/ijcds/1001120.

[8] J. F. Neto and P. C. Giaquinto, "Environmental enrichment techniques and tryptophan supplementation used to improve the quality of life and animal welfare of Nile tilapia," *Aquaculture Reports*, vol. 17, p. 100354, Jul. 2020, doi: 10.1016/j.aqrep.2020.100354.

[9] X. Zhang *et al.*, "Evaluation and analysis of water quality of marine aquaculture area," *International Journal of Environmental Research and Public Health*, vol. 17, no. 4, p. 1446, Feb. 2020, doi: 10.3390/ijerph17041446.

[10] J. John "Automated fish feed detection in IoT based aquaponics system," in *2021 8th International Conference on Smart Computing and Communications (ICSCC)*, IEEE, Jul. 2021, pp. 286–290. doi: 10.1109/ICSCC51209.2021.9528186.

[11] A. Abu-Khadrah, G. F. Issa, S. Aslam, M. Shahzad, K. Ateeq, and M. Hussain, "IoT based smart fish-feeder and monitoring system," in *2022 International Conference on Business Analytics for Technology and Security (ICBATS)*, IEEE, Feb. 2022, pp. 1–4. doi: 10.1109/ICBATS54253.2022.9759058.

[12] K. Khairunisa, M. Mardeni, and Y. Irawan, "Smart aquarium design using Raspberry Pi and android based," *Journal of Robotics and Control (JRC)*, vol. 2, no. 5, 2021, doi: 10.18196/jrc.25109.

[13] A. K. P. M. Daud, N. A. Sulaiman, Y. W. M. Yusof, and M. Kassim, "An IoT-based smart aquarium monitoring system," in *2020 IEEE 10th Symposium on Computer Applications & Industrial Electronics (ISCAIE)*, IEEE, Apr. 2020, pp. 277–282. doi: 10.1109/ISCAIE47305.2020.9108823.

[14] D. R. Prapti, A. R. M. Shariff, H. Che Man, N. M. Ramli, T. Perumal, and M. Shariff, "Internet of Things (IoT)-based aquaculture: an overview of IoT application on water quality monitoring," *Reviews in Aquaculture*, vol. 14, no. 2, pp. 979–992, Mar. 2022, doi: 10.1111/raq.12637.

[15] M. G. B. Palconit *et al.*, "Multi-gene genetic programming of IoT water quality index monitoring from fuzzified model for *Oreochromis niloticus* recirculating aquaculture system," *Journal of Advanced Computational Intelligence and Intelligent Informatics*, vol. 26, no. 5, pp. 816–823, Sep. 2022, doi: 10.20965/jaciii.2022.p0816.

[16] T. Abinaya, J. Ishwarya, and M. Maheswari, "A novel methodology for monitoring and controlling of water quality in aquaculture using internet of things (IoT)," in *2019 International Conference on Computer Communication and Informatics (ICCCI)*, IEEE, Jan. 2019, pp. 1–4. doi: 10.1109/ICCCI.2019.8821988.

[17] G. Gao, K. Xiao, and M. Chen, "An intelligent IoT-based control and traceability system to forecast and maintain water quality in freshwater fish farms," *Computers and Electronics in Agriculture*, vol. 166, p. 105013, Nov. 2019, doi: 10.1016/j.compag.2019.105013.

[18] M. Ahmed, M. O. Rahaman, M. Rahman, and M. A. Kashem, "Analyzing the quality of water and predicting the suitability for fish farming based on IoT in the context of Bangladesh," in *2019 International Conference on Sustainable Technologies for Industry 4.0 (STI)*, IEEE, Dec. 2019, pp. 1–5. doi: 10.1109/STI47673.2019.9068050.

[19] A. Davis, P. S. Wills, J. E. Garvey, W. Fairman, M. A. Karim, and B. Ouyang, "Developing and field testing path planning for robotic aquaculture water quality monitoring," *Applied Sciences*, vol. 13, no. 5, p. 2805, Feb. 2023, doi: 10.3390/app13052805.

[20] D. Jubaedah, M. Marsi, M. Wijayanti, and S. Rahmani, "Combination cockle shells (*Anadara granosa*) and calcite lime to improve swamp water pH for catfish (*Pangasius sp.*) culture," *Omni-Akuatika*, vol. 16, no. 1, p. 48, Jul. 2020, doi: 10.20884/1.oa.2020.16.1.612.

[21] K. Wang, K. Li, L. Liu, C. Tanase, R. Mols, and M. van der Meer, "Effects of light intensity and photoperiod on the growth and stress response of juvenile Nile tilapia (*Oreochromis niloticus*) in a recirculating aquaculture system," *Aquac Fish*, vol. 8, no. 1, pp. 85–90, Jan. 2023, doi: 10.1016/j.aaf.2020.03.001.

[22] T. Adiono, A. M. Toha, S. Pamungkas, N. Sutisna and E. Sumiarsih, "Internet of things for marine aquaculture," *2021 International Symposium on Electronics and Smart Devices (ISESD)*, Bandung, Indonesia, 2021, pp. 1-5, doi: 10.1109/ISESD53023.2021.9501663.

[23] G. Reid *et al*., "Climate change and aquaculture: considering biological response and resources," *Aquac Environ Interact*, vol. 11, pp. 569–602, Nov. 2019, doi: 10.3354/aei00332.

[24] H. R. Esmaeili and Z. E. Barzoki, "Climate change may impact nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) distribution in the Southeastern Arabian peninsula through range contraction under various climate scenarios," *Fishes*, vol. 8, no. 10, p. 481, Sep. 2023, doi: 10.3390/fishes8100481.

[25] U. Nedtharnn, "The effects of climate variation on fisheries and coastal aquaculture.," *Kasetsart University Fisheries Research Bulletin*, vol. 39, no. 2, pp. 22–39, 2015.

[26] M. S. Sulaiman, M. F. A. Rahman, and A. F. M. Adam, "Variance of total dissolved solids and electrical conductivity for water quality in Sabak Bernam," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 13, no. 2, p. 2259, Apr. 2023, doi: 10.11591/ijece.v13i2.pp2259-2269.
[27] N. Y. Hasan, D. Driejana, and A. Sulaeman, "Composition of ions and trace metals in rainwater in Bandung City, Indonesia," *IPTEK Journal of Proceedings Series*, vol. 3, no. 6, Dec. 2017, doi: 10.12962/j23546026.y2017i6.3310.
[28] P. Letardi, B. R. Barat, and E. Cano, "Analysis of the influence of the electrochemical cell setup for corrosion measurements on metallic cultural heritage," 2017. [Online]. Available: https://www.researchgate.net/publication/319979704
[29] H. Hisano, P. T. L. Barbosa, L. A. Hayd, and C. C. Mattioli, "Comparative study of growth, feed efficiency, and hematological profile of nile tilapia fingerlings in biofloc technology and recirculating aquaculture system," *Trop Anim Health Prod*, vol. 53, no. 1, p. 60, Mar. 2021, doi: 10.1007/s11250-020-02523-z.

BIOGRAPHIES OF AUTHORS

Mohammad Faisal Riftiarrasyid is a master's student at Bina Nusantara University, Indonesia. He majored in computer science with experience in artificial intelligence and robotics research when pursuing his bachelor's degree. After finishing his bachelor's degree in 2018, he decided to pursue higher education to achieve a career in the educational field. His research areas are IoT, and image processing. His field of study is inspired by his interest in technological advances in robotics. He envisions to achieve an expertise in drone development and drone path automation. He can be contacted at email: mohammad.riftiarrasyid@binus.ac.id.

Prof. Benfano Soewito, M.Sc., Ph.D Benfano Soewito completed his bachelor's degree in the Faculty of Science and Technology department of Physics, Airlangga University, Surabaya, Indonesia. He completed his master's degree in the field of Computer Engineering at the Department of Electrical and Computer Engineering, Southern Illinois University, United States of America (USA) in 2004 and finished his doctoral degree in 2009 at the same faculty and university. After finished his doctoral studies, he decided to pursue a career in the education field by joining Bakrie University, Jakarta, Indonesia as a lecturer at the Faculty of Engineering and Computer Science. Since June 2013, he became full-time lecturer at the Master Graduate Programs, Master of Computer Science, Bina Nusantara University, Jakarta. He has a high interest toward researches in computer science with special interest in information technology as include internet packet processing and scanning, router development as well as security and computer network and IoT. He can be contacted at email: bsoewito@binus.edu.