Modeling of Upwelling Early Warning System Using Water Quality Sensor Device and Automatic Weather System Integrated with Hybrid FIS GA

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***Abstract*—It is a common fact that one of the adverse effects of upwelling in lakes is fish die-offs in floating net cages or other forms of aquaculture. A solution to prevent or reduce this unfortunate effect of upwelling is to create an upwelling early warning system that can predict the probability of upwelling events within a certain period. This research proposes such a system that can measure the parameters for upwelling prediction. The proposed system uses a sensor device that combines a water quality sensor device and an Automatic Weather System (AWS), integrated with the hybrid Tsukamoto fuzzy inference system using genetic algorithm (hybrid FIS GA) method. The sensor device used in this system has been successfully tested in laboratory and field experiments. From the test results, the water quality sensor successfully measures the water quality parameters, namely water pH, Dissolved Oxygen (DO), Oxidation-Reduction Potential (ORP), Electrical Conductivity (EC), and Resistance Temperature Detectors (RTD) or water temperature with 80% accuracy. Moreover, the AWS succeeds in measuring weather parameters, namely wind speed wind direction, rainfall, and air temperature with 100% accuracy. These measurements produce data for the hybrid FIS GA method to predict upwelling events.**

***Index Terms*—Early warning system, floating net cages, lake maninjau, upwelling, water quality sensor**

I. Introduction

Lake Maninjau is a tecto-volcanic lake, a lake created by ancient volcanic activities. Having a geographical coordinate at S:00E12'26.63"–S:00E25'02.80" and E:100E07'43.74"–E:100E16'22.48", it rests at an altitude of 461.5 meters above sea level, with a surface area covering 9,737.5 hectares [1]. Administratively, it is located in Tanjung Raya Subdistrict, Agam Regency, West Sumatra Province, Indonesia.

Lake Maninjau has for generations been a center of aquaculture activities, such as floating net-cage farming. In 2003, the number of floating net cages here reached up to approximately 4,000 units, and by 2012 has increased to 15,860 units with a fish production of 23,790 tons [2]. From the continuous aquaculture practice, a great number of wastes have settled at the bottom of the lake. Each time an upwelling occurs, negative impacts directly affect the floating net-cage farms [3], one of them being fish die-offs [4]. Therefore, a system that can predict future upwelling events is needed to reduce the possibility of fish die-offs in those floating net-cage farms.

Upwelling is associated with water quality and weather conditions [5]. The vertical water movement occurs due to the stratification of seawater or lake water density. It is caused by changes in water temperature and densities, causing energy to shift the water mass vertically [6]. Another factor that influences upwelling is weather, namely changes in sunlight intensity, surface air temperature, cloud conditions, rainfall [4], wind direction, and wind speed [7].

This research proposes a system called the upwelling early warning system, which makes use of integrated sensors and artificial intelligence to predict upwelling events in Lake Maninjau. In this research, a water quality sensor device is applied to measure the water quality parameters; the Automatic Weather System (AWS) is used to measure weather condition parameters; and the hybrid FIS GA (hybrid Tsukamoto fuzzy inference system with genetic algorithm) [3] is used to predict the probability of upwelling events. This system will be applied in Lake Maninjau, and hopefully it will able to help floating net-cage farmers prevent or reduce the adverse effects of upwelling, especially fish die-offs.

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II. Water Quality Sensor Device

A water quality sensor device is a device used to detect the predetermined parameters that indicate the quality of water [8]. The water quality parameters are pH, Dissolved Oxygen (DO), conductivity, turbidity, Dissolved Organic Carbon (DOC), dissolved metal ions, Oxidation-Reduction Potential (ORP), Electrical Conductivity (EC), Resistance Temperature Detectors (RTD), and many more [9]. Generally, the water quality sensor device uses battery for its operation. The workings of this tool start from processing information sensed by the tool's various sensors, which is converted into an electrical signal. The electrical signals then go through the signal conditioning circuit to make sure the voltage or current produced by the sensors is proportional to the actual values of the parameters being sensed. The signals will then be passed on to a microcontroller or microprocessor, which process them into values that are comprehensible by a human being [8].

In this research, a water quality sensor device will be used to monitor the lake water quality parameters. These parameters include pH, DO, ORP, EC, and RTD or water temperature. The water quality parameters of pH, DO, and RTD will be used as input values for the artificial intelligence to predict future upwelling events in Lake Maninjau.

III. Automatic Weather Station (AWS)

A weather station is a weather gauge that can measure weather data [10]. This research uses an AWS connected to a microcontroller or microprocessor to send weather data automatically. The weather data measured are wind speed, wind direction, rainfall, air temperature, and humidity. The data can help future researches to make better predictions in their model.

The AWS uses several weather sensors, namely wind vane, anemometer, rain gauge, pressure sensor, air temperature and humidity sensor, and WeatherLink. The wind vane module is used to determine the direction of the wind. The anemometer module is used to determine wind speed. The rain gauge module is used to measure rainfall. The pressure sensor is used to measure air pressure. The DHT 11 air temperature sensor is used to measure air temperature and humidity.

IV. Hybrid Tsukamoto FIS GA

The hybrid FIS GA method was used in a previous research by Rofiq *et al*. [3] for predicting upwelling in Lake Maninjau. The genetic algorithm is used to optimize the membership function limits of Tsukamoto FIS for upwelling prediction in Lake Maninjau. This method achieved optimal membership function limits to predict upwelling with 94% accuracy, using historical data from 2001 to 2017 from the monitoring of water quality in six locations around Lake Maninjau.

The hybrid FIS GA method will use data from the water quality sensor device, namely RTD or water temperature (℃), pH, and dissolved oxygen (mg/L), to predict future upwelling events. The data will be used for the input criteria in the Tsukamoto FIS method. This method will be used in the Upwelling Early Warning System as a method for upwelling prediction.

V. Modeling of Upwelling Early Warning System

The water quality sensor device, AWS, and hybrid FIS GA method will be integrated into a single system to predict upwelling events in Lake Maninjau. The architectural design of the Upwelling Early Warning System is shown in Fig. 1, and the architectural design for the installation of the water quality sensor device and the AWS in the lake is illustrated in Fig. 2.

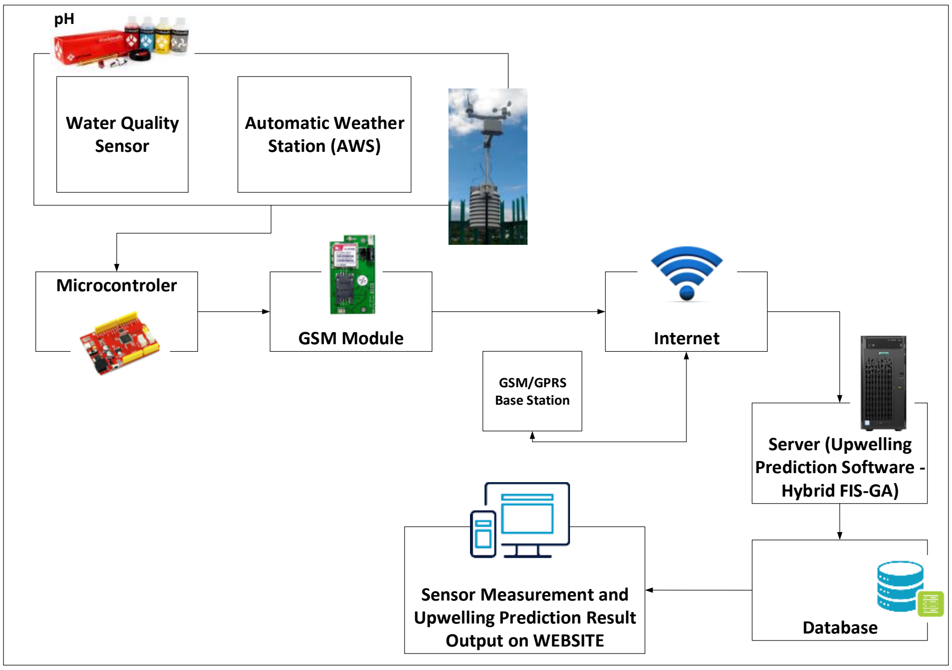

Fig. 1. Upwelling early warning system architecture.

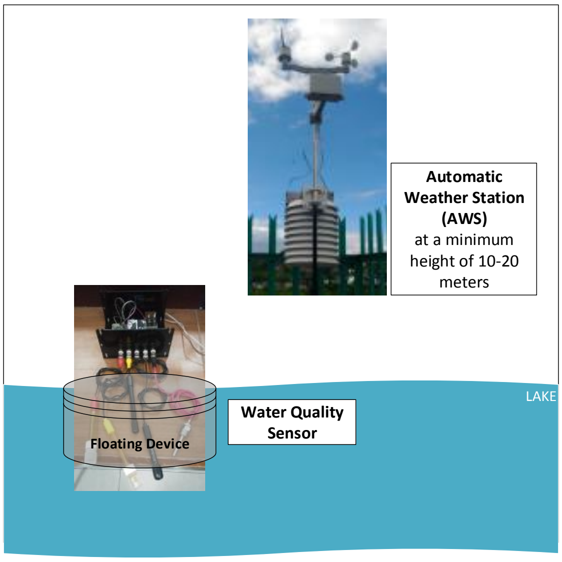

Fig. 2. Architectural design of sensor installation in the Lake.

As shown in Fig. 1, the water quality sensor device and the AWS are integrated. This device is controlled by a microcontroller which uses a global system for mobile communications (GSM) module. The GSM is used to send data from the sensor to the server through an internet connection. The sensor measurement data are then sent to the server. These will then be used as an input for the upwelling prediction method using the hybrid FIS GA.

Afterward, the results of the sensor measurements and upwelling predictions will be saved into a database. Finally, the outputs of the sensor's measurements and upwelling predictions are displayed on a website. This way, users can read the information easily.

Fig. 2 shows the AWS being mounted on a pole with a minimum height of 10 to 20 meters above the ground. In addition, the water quality sensor is placed on a device that floats on the surface of the lake.

VI. Assembly of Components

Fig. 3. Assembly results of sensors for the water quality monitoring device and the Automatic Weather Station (AWS).

There are two sensor devices used in this study, namely one for water quality monitoring and an AWS. As explained previously, the water quality monitoring device is used to monitor lake water parameters including pH, DO, ORP, EC, and RTD or water temperature. The AWS as the weather sensor device, on the other hand, is used to measure weather parameters, namely wind speed, wind direction, rainfall, temperature, and humidity. Details on the assembly of the two sensor devices can be seen in Fig. 3 to Fig. 6.

Fig. 3 shows an assembly of the water quality monitoring sensor device and the AWS, which will be used in an integrated manner for the Upwelling Early Warning System.

Fig. 4 shows the details of the water quality monitoring sensor device and its battery resources. This sensor uses a custom 3.7 volts 6600 mAH battery pack, built from combining three "Li(Ni,Co,Mn)O_2" (CGR) 2250 mAH batteries[11].

Fig. 4. Water quality monitoring sensor device (left) and details of water quality monitoring sensor device and battery resources (right).

Fig. 5. Details of water quality monitoring sensor device (left-right: pH sensor – DO sensor – ORP sensor – EC sensor RTD sensor).

Fig. 5 shows a detailed result from the assembly of the water quality monitoring sensor device, as well as the different sensors used on the device. The sensors from left to right are pH sensor, DO sensor, ORP sensor, EC sensor, and RTD sensor.

Fig. 6 shows details of the AWS. Sensor number (1) is the anemometer module used to determine wind speed. Sensor number (2) is the wind vane module used to determine the direction of the wind. Sensor number (3) is the rain gauge module used to measure rainfall. The tube in Sensor number (4) consists of two sensors, namely pressure sensor for measuring air pressure, and DHT 11 air temperature sensor for measuring air temperature and humidity. The tube also includes the microcontroller and the GSM module for the automatic delivery of measurement data to the server.

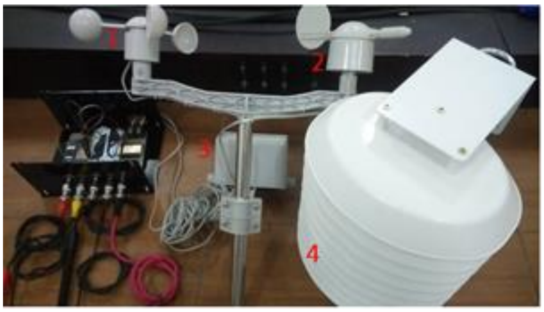

Fig. 6. Details of sensors for the automatic weather station (AWS).

VII. Testing Experiment Results

A. Testing Scenario

Testing processes are conducted to determine water quality and weather conditions. The experiments are held in a laboratory and in the field using the required instruments.

To test the water quality sensor device, pure water and a water experiment kit are used to test the ability of the sensor device to measure different water parameters. A picture of the water experiment kit can be seen in Fig. 7. The testing scenario for the water quality sensor device can be seen in Table I, whereas the testing scenario for the AWS can be seen in Table II.

Fig. 7 shows details of the water experiment kit for the testing of the water quality sensor device. The types of water from left to right are (1) 80,000 µS conductivity solution, (2) ORP calibration solution, (3 & 4) pH/ORP storage solution, (5) pH calibration solution, (6) 12,880 µS conductivity solution.

Fig. 7. Water experiment kit for testing the water quality sensor device.

Table I shows the testing scenario for the water quality sensor device, which was conducted on two types of water. The first experiment uses pure water and the second experiment uses the water experiment kit. Due to the limited number of the device, the experiment time could not be parallel. Moreover, the device needs to be re-prepared for each test. The first experiment is carried out from 17:36 to 18:25 and the second experiment is carried out from 19:31 to 20:47. Both experiments are conducted on the same date of Nov 5th, 2019, and in the same place, namely a laboratory in Malang City, East Java, Indonesia.

TABLE I: TESTING SCENARIO FOR WATER QUALITY SENSOR DEVICE

Scenario	Experiment 1	Experiment 2
Type of Water	Pure Water	Water Experiment Kit
Experiment Time	17.36 – 18.25	19.31 – 20.47
Experiment Date	Nov 5th, 2019	Nov 5th, 2019
Experiment Room	Laboratory	Laboratory
Exp Location	Malang, Indonesia	Malang, Indonesia

Table II shows the testing experiment scenario for the Automatic Weather Station (AWS). The experiment is conducted by placing the weather sensor at a height of 10 meters above the ground. The experiment is carried out from 17:32 to 19:29 on Nov 5th, 2019, in Malang City, East Java, Indonesia.

TABLE II: TESTING SCENARIO FOR AWS

Testing Material	Experiment 1
Sensor Place	A height of 10 meters above the ground
Experiment Time	17.32 – 19.29
Experiment Date	Nov 5th, 2019
Experiment Location	Malang, Indonesia

B. Testing Results

The testing results for the water quality sensor device and the AWS are shown in Table III to Table V.

Table III and Table IV show details of the testing results of experiment 1 and experiment 2 for the water quality sensor device. The actual standard value of water quality parameters on the pure water has been collected from several references [3] [12]-[13]. While the actual standard values of water quality parameters for the water experiment kit have been collected from the information provided on the water experiment kit's packaging. Based on the actual standard values, the water quality sensor device can measure the water quality parameters successfully, except for its inability to detect the ORP values for both pure water and the water experiment kit. In the future, this issue will be investigated in another experiment to find the cause of the ORP sensor's failure. All in all, the water quality sensor successfully measures four parameters and fails to measure one parameter, resulting in an approximately 80% accuracy.

Table V shows details of the experiment with the AWS. From six weather parameters, only four can be measured. This is due to the absence of actual data for pressure and humidity. Therefore, the experiment excludes both pressure and humidity parameters. The AWS sensor successfully measures the other four weather parameters, namely wind speed, wind direction, rainfall, and temperature with 100% accuracy.

The measurement results from the water quality sensor device will be used for upwelling prediction using the hybrid FIS GA method. The data used for upwelling prediction are RTD or water temperature (℃), pH, and dissolved oxygen (mg/L), all of which have been successfully measured. Therefore, the water quality sensor device is ready to be implemented in the Upwelling Early Warning System.

TABLE III: TESTING RESULT FROM EXPERIMENT 1 FOR WATER QUALITY SENSOR

#	Date & Time	Experiment Result					Actual Value of Pure Water				
		RTD	EC	ORP	DO	pH	RTD (℃)	EC	ORP (mV)	DO	pH
1	2019-11-05 17:36:48	29	376	0	8	7.6	20-30	130-3000	650-950	>4	6-9
2	2019-11-05 17:41:00	28	554	0	7	7.3	20-30	130-3000	650-950	>4	6-9
3	2019-11-05 17:59:54	28	516	0	6	6.4	20-30	130-3000	650-950	>4	6-9
4	2019-11-05 18:10:19	28	454	0	6	6.1	20-30	130-3000	650-950	>4	6-9
5	2019-11-05 18:16:49	28	421	0	7	5.9	20-30	130-3000	650-950	>4	6-9
6	2019-11-05 18:25:18	28	357	0	9	5.7	20-30	130-3000	650-950	>4	6-9

TABLE IV: TESTING RESULT FROM EXPERIMENT 2 FOR WATER QUALITY SENSOR

#	Date & Time	Experiment Result					Actual Value of Water Experiment Kit				
		RTD	EC	ORP	DO	pH	RTD	EC	ORP (mV)	DO	pH
1	2019-11-05 19:31:26	26	705	0	5	7	20-30	130-3000	225	>4	4
2	2019-11-05 20:22:06	26	991	0	5	8.7	20-30	130-3000	225	>4	4
3	2019-11-05 20:34:36	26	884	0	8	7.9	20-30	130-3000	225	>4	4
4	2019-11-05 20:38:45	26	874	0	9	7.5	20-30	130-3000	225	>4	4
5	2019-11-05 20:42:54	26	813	0	9	7.1	20-30	130-3000	225	>4	4
6	2019-11-05 20:47:04	26	796	0	4	6.7	20-30	130-3000	225	>4	4

TABLE V: TESTING RESULT FOR AUTOMATIC WEATHER STATION (AWS)

#	Date & Time	Experiment Result						Actual Value of Weather Condition					
		WS	WD	R	P	T (℃)	H	WS (km/h)	WD	R (mm)	P	T (℃)	H
1	2019-11-05 17:32:38	3.5	SSW	1.66	-	15	-	7	SSW	6	-	14	-
2	2019-11-05 17:53:33	3.2	SSW	2.83	-	14	-	7	SSW	6	-	14	-
3	2019-11-05 18:10:19	3.5	SSW	0.15	-	14	-	7	SSW	6	-	14	-
4	2019-11-05 18:21:06	2.7	SSW	0.54	-	14	-	7	SSW	6	-	14	-
5	2019-11-05 18:41:26	2.6	SSW	0.12	-	14	-	7	SSW	6	-	14	-
6	2019-11-05 19:29:21	3.2	SSW	1.91	-	14	-	7	SSW	6	-	14	-

WS: wind speed, WD: wind direction, R: rainfall, P: pressure, T: temperature, H: Humidity
Actual weather condition based on averages Accu Weather data on 2019-11-05 from 17.00 – 21.00

VIII. CONCLUSION

To prevent or reduce the adverse effects of upwelling in Lake Maninjau, this research proposes the Upwelling Early Warning System which makes use of a water quality sensor device and an AWS, which is integrated with the hybrid FIS GA method to predict upwelling events. From the testing results in a laboratory, the water quality sensor device can measure the water parameters correctly with 80% accuracy. Moreover, the AWS also successfully reads the weather condition with 100% accuracy. Therefore, the data from the measurements are ready to be used for the hybrid FIS GA method as inputs for upwelling predictions. In the next research, the system will be tested in the lake directly to confirm the precision and accuracy of the sensors on the device.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Muhammad Rofiq conducts research and testing; Yogie Susdyastama Putra analyzes data; Wayan Firdaus Mahmudy and Herman Tolle supervise the research; and Ida Wahyuni writes the paper and acts as corresponding author.

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